BAGLE

Release 0.1

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Jan 27, 2023

CONTENTS

BAGLE allows modeling of gravitational microlensing events both photometrically and astrometrically. Supported microlensing models include:

- PSPL: point-source, point-lens with parallax
- PSBL: point-source, binary-lens
- FSPL: finite-source, point-lens (currently testing further)

All models support fitting data with single or multi-band photometry only, astrometry only, or joint fitting of photometry and astrometry (recommended).

CHAPTER

ONE

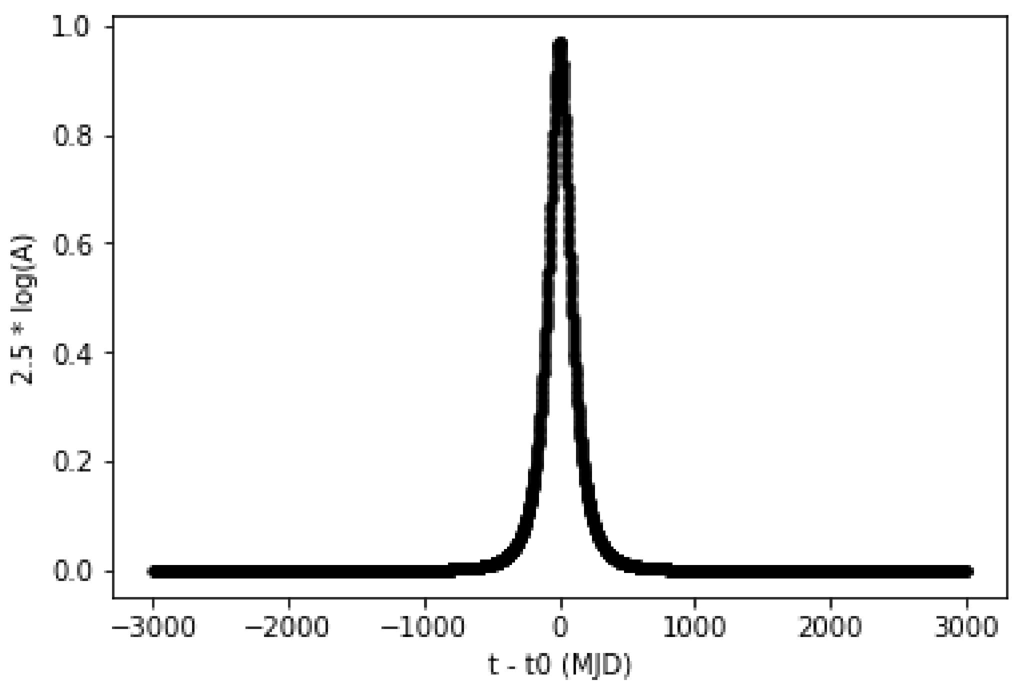
BAGLE TUTORIAL

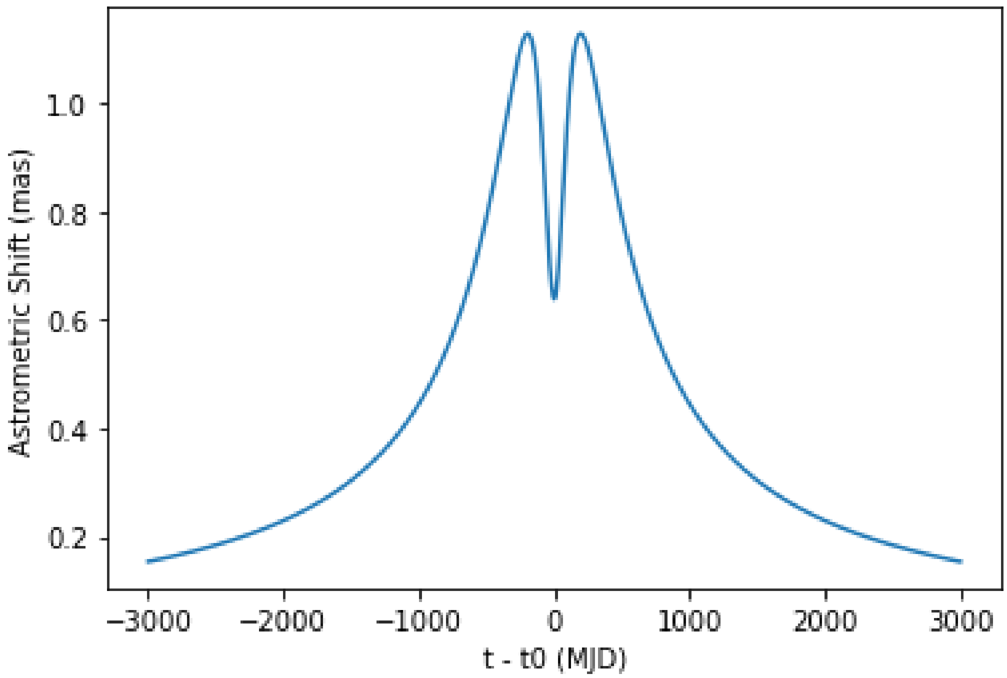
To learn to use BAGLE models, make microlensing events, and make photometric or astrometric plots, we have created a Jupyter Notebook tutorial.

1.1 PSPL Model - No Parallax

The first step in the tutorial is to generate a PSPL model with no parallax and do the following:

- Get amplification of event over time
- Plot the astrometric shift over time
- Animate the microlensing event



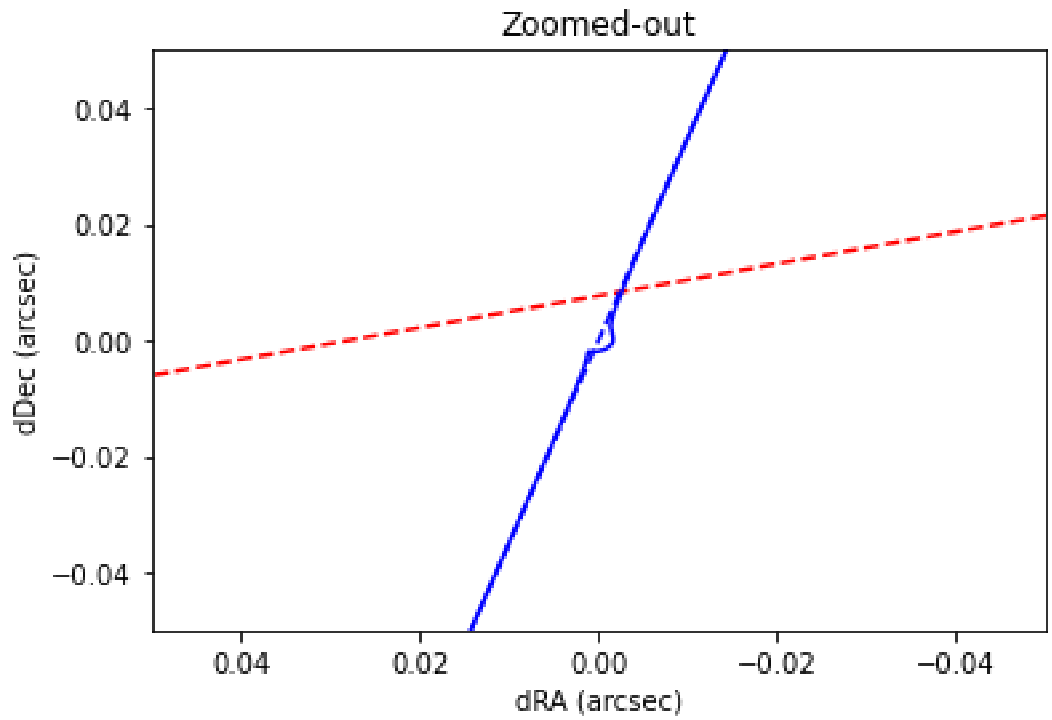


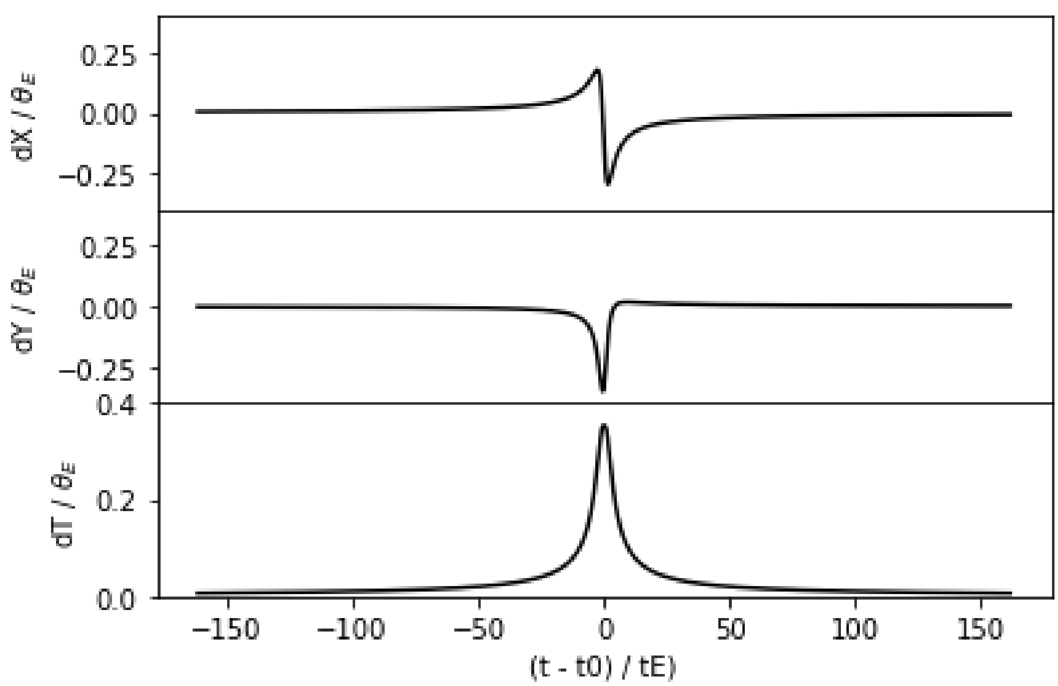
1.2 PSPL Model - With parallax

The second step is to generate a PSPL model with parallax adding the *ra* (right ascention of lens) and *dec* (declination of lens).

1.3 PSPL Model From Belokurov and Evans 2002 (Figure 1)

Then a series of plots are made of the lens, source, and image positions on the sky for a set of microlensing event parameters previously published.


Zoomed-out
0.04
0.02
0.00
−0.02
−0.04
dDec (arcsec)
0.04
0.02
0.00
−0.02
−0.04
dRA (arcsec)


0.25
0.00
−0.25
dX / θE
0.25
0.00
−0.25
dY / θE
0.4
0.2
0.0
dT / θE
−150
−100
−50
0
50
100
150
(t - t0) / tE)

CHAPTER

TWO

OVERVIEW OF BAGLE.MODEL

model.py is a module that contains a set of classes and functions that allow the user to construct microlensing models. The available classes for instantiating a microlensing event are shown in the list below. See the API documentation for each class for details.

2.1 Example

To instantiate a model:

```
from bagle import model

mL = 10.0  # msun
t0 = 57000.00
xS0 = np.array([0.000, 0.000])
beta = 1.4  # mas
muS = np.array([8.0, 0.0])
muL = np.array([0.00, 0.00])
dL = 4000.0
dS = 8000.0
b_sff = [1.0]     # one for each filter
mag_src = [19.0] # one for each filter

event1 = model.PSPL_PhotAstrom_noPar_Param1(mL,
                       t0, beta, dL, dL / dS,
                       xS0[0], xS0[1], muL[0], muL[1],
                       muS[0], muS[1],
                       b_sff, mag_src)

# Get time range for event
t = np.arange(event1.t0 - 3000,
              event1.t0 + 3000, 1)
dt = t - event1.t0

# Quanties you can print
A = event1.get_amplification(t)
shift = event1.get_centroid_shift(t)
shift_amp = np.linalg.norm(shift, axis=1)
```

Note, each model class has a name that typically has a structure of

<ModelDataType>_<Parallax>_<GP>_<Parameterization>

For example, *PSPL_Phot_noPar_Param2* has a data and model class type of PSPL_Phot, which contains a point-source, point-lens event with photometry only. The model has no parallax, no GP and uses parameterization #2.

The complete list of instantiable model classes is:

2.2 Point source, point lens, photometry only:

- PSPL_Phot_noPar_Param1
- PSPL_Phot_noPar_Param2
- PSPL_Phot_Par_Param1
- PSPL_Phot_Par_Param2
- PSPL_Phot_Par_Param1_geoproj
- PSPL_Phot_noPar_GP_Param1
- PSPL_Phot_noPar_GP_Param2
- PSPL_Phot_Par_GP_Param1
- PSPL_Phot_Par_GP_Param1_2
- PSPL_Phot_Par_GP_Param2
- PSPL_Phot_Par_GP_Param2_2

2.3 Point source, point lens, photometry and astrometry:

- PSPL_PhotAstrom_noPar_Param1
- PSPL_PhotAstrom_noPar_Param2
- PSPL_PhotAstrom_noPar_Param3
- PSPL_PhotAstrom_noPar_Param4
- PSPL_PhotAstrom_Par_Param4_geoproj
- PSPL_PhotAstrom_Par_Param1
- PSPL_PhotAstrom_Par_Param2
- PSPL_PhotAstrom_Par_Param3
- PSPL_PhotAstrom_Par_Param4
- PSPL_PhotAstrom_Par_Param5
- PSPL_PhotAstrom_LumLens_Par_Param1
- PSPL_PhotAstrom_LumLens_Par_Param2
- PSPL_PhotAstrom_LumLens_Par_Param4
- PSPL_PhotAstrom_noPar_GP_Param1
- PSPL_PhotAstrom_noPar_GP_Param2
- PSPL_PhotAstrom_Par_GP_Param1
- PSPL_PhotAstrom_Par_GP_Param2

- PSPL_PhotAstrom_Par_GP_Param3
- PSPL_PhotAstrom_Par_GP_Param4
- PSPL_PhotAstrom_Par_LumLens_GP_Param1
- PSPL_PhotAstrom_Par_LumLens_GP_Param2
- PSPL_PhotAstrom_Par_LumLens_GP_Param3
- PSPL_PhotAstrom_Par_LumLens_GP_Param4

2.4 Point source, point lens, astrometry only

- PSPL_Astrom_Par_Param4
- PSPL_Astrom_Par_Param3

2.5 Point soruce, binary lens, photometry only

- PSBL_Phot_noPar_Param1
- PSBL_Phot_Par_Param1
- PSBL_Phot_noPar_GP_Param1
- PSBL_Phot_Par_GP_Param1

2.6 Point source, binary lens, photometry and astrometry

- PSBL_PhotAstrom_noPar_Param1
- PSBL_PhotAstrom_noPar_Param2
- PSBL_PhotAstrom_noPar_Param3
- PSBL_PhotAstrom_Par_Param1
- PSBL_PhotAstrom_Par_Param2
- PSBL_PhotAstrom_Par_Param3
- PSBL_PhotAstrom_Par_Param4
- PSBL_PhotAstrom_Par_Param5
- PSBL_PhotAstrom_noPar_GP_Param1
- PSBL_PhotAstrom_noPar_GP_Param2
- PSBL_PhotAstrom_Par_GP_Param1
- PSBL_PhotAstrom_Par_GP_Param2

2.7 Binary source, point lens, photometry and only

- BSPL_Phot_noPar_Param1
- BSPL_Phot_Par_Param1
- BSPL_Phot_noPar_GP_Param1
- BSPL_Phot_Par_GP_Param1

2.8 Binary source, point lens, photometry and astrometry

- BSPL_PhotAstrom_noPar_Param1
- BSPL_PhotAstrom_noPar_Param2
- BSPL_PhotAstrom_noPar_Param3
- BSPL_PhotAstrom_Par_Param1
- BSPL_PhotAstrom_Par_Param2
- BSPL_PhotAstrom_Par_Param3
- BSPL_PhotAstrom_noPar_GP_Param1
- BSPL_PhotAstrom_noPar_GP_Param2
- BSPL_PhotAstrom_noPar_GP_Param3
- BSPL_PhotAstrom_Par_GP_Param1
- BSPL_PhotAstrom_Par_GP_Param2
- BSPL_PhotAstrom_Par_GP_Param3

2.9 Finite source, point lens, photometry and astrometry (broken)

- FSPL_PhotAstrom_Par_Param1

CHAPTER

THREE

DEVELOPERS

Each model class i built up from a menu of different features by inheriting from multiple base classes, each from a different 'family' of related classes.

Each microlensing model must contain:

1) A class from the Data Class Family:
    - *PSPL* – base class for all Data classes:
        - *PSPL_Phot*
        - *PSPL_PhotAstrom*
        - *PSPL_GP_Phot*
        - *PSPL_GP_PhotAstrom*
2) A class from the Parallax Class Family:
    - *ParallaxClassABC* – base class for all Parallax classes:
        - *PSPL_noParallax*
        - *PSPL_Parallax*
3) A class from the GP Class Family: (optional)
    - *PSPL_GP* – base class for all GP classes.
4) A class from the Parametrization Class Family:
    - *PSPL_Param* – base class for all Param classes
        - *PSPL_PhotParam1*
        - *PSPL_PhotParam2*
        - *PSPL_PhotAstromParam1*
        - *PSPL_PhotAstromParam2*
        - *PSPL_PhotAstromParam3*
        - *PSPL_PhotAstromParam4*
        - *PSPL_PhotAstromParam5*
        - *PSPL_GP_PhotParam1*
        - *PSPL_GP_PhotParam2*
        - *PSPL_GP_PhotAstromParam1*
        - *PSPL_GP_PhotAstromParam2*

   - *PSPL_GP_PhotAstromParam3*
   - *PSPL_GP_PhotAstromParam4*

There is a similar hierarchy for PSBL, etc.

For example, the *PSPL_PhotAstrom_noPar_Param1* model is declared as:

```
class PSPL_PhotAstrom_noPar_Param1(ModelClassABC,
                                   PSPL_PhotAstrom,
                                   PSPL_noParallax,
                                   PSPL_PhotAstromParam1)
```

3.1 Class Families

3.1.1 Model Class Family

These are the classes that can be instantiated by the user. The base class is ModelClassABC.

3.1.2 Data Class Family

These classes inform the model of what type of data will be used by the model. If the model will be for photometry only, then a model with the *PSPL_Phot* class must be selected. These models have the words *Phot* in their names. If the model will be using photometry and astrometry data, then a model with the *PSPL_PhotAstrom* must be selected. These models have the words *PhotAstrom* in their names.

Data containing astrometry will generate a warning that astrometry data will not be used in the model when run through a model using *PSPL_Phot*. Data that does not contain astrometry run through a model using *PSPL_PhotAstrom* will generate a RuntimeError.

The base class is PSPL.

3.1.3 Parallax Class Family

These classes set whether the model uses parallax when calculating photometry, calculating astrometry, and fitting data. There are only two options for this class family, *PSPL_noParallax* and *PSPL_Parallax*. Models that do not have parallax have the words *noPar* in their names, while models that do contain parallax have the words *Par* in their names.

The base class is ParallaxClassABC.

3.1.4 Parameterization Class Family

These classes determine which physical parameters define the model. Currently this file supports one parameterization when using only photometry (*Phot*) and three parametrizations when using photometry and astrometery (*PhotAstrom*).

The base class is PSPL_Param.

The parameters for each parameterization are:

PhotParam1 :
Point source point lens model for microlensing photometry only. This model includes the relative proper motion between the lens and the source. Parameters are reduced with the use of piRel

***Parameters*:**

t0, u0_amp, tE,
piE_E, piE_N,
b_sff, mag_src,
(ra, dec)

PhotAstromParam1 :
Point Source Point Lens model for microlensing. This model includes proper motions of both the lens and source.

***Parameters*:**

mL, t0, beta,
dL, dL_dS,
xS0_E, xS0_N,
muL_E, muL_N,
muS_E, muS_N,
b_sff, mag_src,
(ra, dec)

PhotAstromParam2 :
Point Source Point Lens model for microlensing. This model includes proper motions of the source and the source position on the sky.

***Parameters*:**

t0, u0_amp, tE, thetaE, piS,
piE_E, piE_N,
xS0_E, xS0_N,
muS_E, muS_N,
b_sff, mag_src,
(ra, dec)

PhotAstromParam3 :
Point Source Point Lens model for microlensing. This model includes proper motions of the source and the source position on the sky. Note it fits the baseline magnitude rather than the unmagnified source brightness.

***Parameters*:**

t0, u0_amp, tE, log10_thetaE, piS,
piE_E, piE_N,
xS0_E, xS0_N,
muS_E, muS_N,
b_sff, mag_base,
(ra, dec)

(ra, dec) are only required if the model is created with a parallax class. More details about each parameterization can be found in the Parameterization Class docstring.

3.1.5 Making a New Model

Each model is, as described above, constructed by combining inheriting from different parent classes that contain the desired features for the model. Each model must have one class from each class family. In addition to this, there are several rules that must be followed when creating a new class.

1) The data class must match the parameterization class. For example, if the chosen data class is *PSPL_Phot*, then the parameter class must be *PSPL_PhotParam1* (or a different PhotParam in a future version). If the data class is *PSPL_PhotAstrom*, then the parameter class must be one of the classes with a PhotAstromParam.

2) Models are built using python's multiple inheritance feature. Therefore the order in which the parent classes are listed in the model class' definition matters. Parent classes to models should always be listed in the order:

   a) ModelClassABC

   b) Data Class

   c) Parallax Class

   d) Parameterization Class

   If using the optional GP class, then the order is

   a) ModelClassABC

   b) GP Class

   c) Data Class

   d) Parallax Class

   e) Parameterization Class

3) Each class must be given the *@inheritdocstring* decorator, and include the following commands in the model's `__init__`:

   - `a.super().__init__(*args, **kwargs)`
   - `startbases(self)`
   - `checkconflicts(self)`

   Each of these performs the following function:

   - `super().__init__(*args, **kwargs)`: Inherits the `__init__` from the Parameterization Class.
   - `startbases(self)`: Runs a *start* command on each parent class, giving each parent class a chance to run a set of functions upon instantiation.
   - `checkconflicts(self)`: Checks to confirm that the combination of parent classes in the model are valid.

4) Models should be named to reflect the parents classes used to construct it, as outlined in the above sections.

CHAPTER

FOUR

INSTANTIABLE MODEL CLASSES

4.1 PSPL Model Classes

4.1.1 PSPL

class model.**PSPL_PhotAstrom_noPar_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_noParallax`, `PSPL_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
get_astrometry_unlensed(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

4.1.2 PSPL Parallax

class model.**PSPL_PhotAstrom_Par_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_Parallax`, `PSPL_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

class model.**PSPL_PhotAstrom_LumLens_Par_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_Parallax_LumLens`, `PSPL_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t_obs, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t_obs)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t_obs)`

Parallax: Get lens astrometry

`get_resolved_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

class model.**PSPL_PhotAstrom_LumLens_Par_Param2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_Parallax_LumLens`, `PSPL_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(`*t*`)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(`*t_obs*, *ast_filt_idx=0*`)`

Parallax: Get astrometry

`get_astrometry_unlensed(`*t_obs*`)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(`*t*, *ast_filt_idx=0*`)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(`*t_obs*`)`

Parallax: Get lens astrometry

`get_resolved_amplification(`*t*`)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(`*t_obs*`)`

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

class model.**PSPL_PhotAstrom_LumLens_Par_Param4**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_Parallax_LumLens`, `PSPL_PhotAstromParam4`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t_obs, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t_obs)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t_obs)`

Parallax: Get lens astrometry

`get_resolved_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t_obs)`

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.

- xS_minus is the vector position of the plus image.

4.1.3 PSPL_parallax2 / PSPL_multiphot_parallax

class model.**PSPL_PhotAstrom_Par_Param2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_Parallax`, `PSPL_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot

e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t_obs, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t_obs)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t_obs)`

Parallax: Get lens astrometry

`get_resolved_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t_obs)`

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.

- xS_minus is the vector position of the plus image.

class model.**PSPL_PhotAstrom_noPar_Param2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_noParallax`, `PSPL_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
get_astrometry_unlensed(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

`class model.PSPL_PhotAstrom_Par_Param3`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_Parallax`, `PSPL_PhotAstromParam3`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t_obs, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t_obs)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t_obs)`

Parallax: Get lens astrometry

`get_resolved_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t_obs)`

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`class model.PSPL_PhotAstrom_Par_Param4(*args, **kwargs)`

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_Parallax`, `PSPL_PhotAstromParam4`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t_obs, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t_obs)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t_obs)`

Parallax: Get lens astrometry

`get_resolved_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t_obs)`

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`class model.PSPL_PhotAstrom_noPar_Param4(*args, **kwargs)`

Bases: `ModelClassABC`, `PSPL_PhotAstrom`, `PSPL_noParallax`, `PSPL_PhotAstromParam4`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
get_astrometry_unlensed(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

`class model.PSPL_Astrom_Par_Param4`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_Astrom`, `PSPL_Parallax`, `PSPL_AstromParam4`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`class model.PSPL_Astrom_Par_Param3`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_Astrom`, `PSPL_Parallax`, `PSPL_AstromParam3`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
`calc_piE_ecliptic`()	Parallax: Get piE_ecliptic
`get_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, ast_filt_idx])	Parallax: Get astrometry
`get_astrometry_unlensed`(t_obs)	Get the astrometry of the source if the lens didn't exist.
`get_centroid_shift`(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	
`get_lens_astrometry`(t_obs)	Parallax: Get lens astrometry
`get_resolved_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm’s

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t_obs, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t_obs)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t_obs)`

Parallax: Get lens astrometry

`get_resolved_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t_obs)`

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

4.1.4 PSPL_phot

class model.**PSPL_Phot_noPar_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_Phot`, `PSPL_noParallax`, `PSPL_PhotParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.

calc_piE_ecliptic	
get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification(t)`

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t, ast_filt_idx=0)`

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed(t)`

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t)`

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_amplification(t)`

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t)`

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

`class model.PSPL_Phot_noPar_Param2(*args, **kwargs)`

Bases: `ModelClassABC`, `PSPL_Phot`, `PSPL_noParallax`, `PSPL_PhotParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.

calc_piE_ecliptic	
get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

get_amplification(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

4.1.5 PSPL_phot_parallax / PSPL_phot_multiphot_parallax

class `model.PSPL_Phot_Par_Param1`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_Phot`, `PSPL_Parallax`, `PSPL_PhotParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	

get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t*)

Parallax: Get lens astrometry

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

class `model.PSPL_Phot_Par_Param2`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_Phot`, `PSPL_Parallax`, `PSPL_PhotParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	

get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t)`

Parallax: Get lens astrometry

`get_resolved_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t)`

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

4.1.6 PSPL Phot parallax with GP

`class model.PSPL_Phot_Par_GP_Param1(*args, **kwargs)`

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_Phot`, `PSPL_Parallax`, `PSPL_GP_PhotParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
`calc_piE_ecliptic`()	Parallax: Get piE_ecliptic
`get_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t.
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	
`get_log_det_covariance`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`get_photometry_with_gp`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`log_likely_photometry`(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t)`

Parallax: Get lens astrometry

`get_log_det_covariance(t_obs, mag_obs, mag_err_obs, filt_index=0, t_pred=None)`

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp(t_obs, mag_obs, mag_err_obs, filt_index=0, t_pred=None)`

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t)`

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class model.**PSPL_Phot_Par_GP_Param2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_Phot`, `PSPL_Parallax`, `PSPL_GP_PhotParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot

e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t)`

Parallax: Get lens astrometry

`get_log_det_covariance(t_obs, mag_obs, mag_err_obs, filt_index=0, t_pred=None)`

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp(t_obs, mag_obs, mag_err_obs, filt_index=0, t_pred=None)`

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

get_resolved_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class model.**PSPL_Phot_Par_GP_Param1_2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_Phot`, `PSPL_Parallax`, `PSPL_GP_PhotParam1_2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_astrometry(*t*, *ast_filt_idx=0*)

Parallax: Get astrometry

get_astrometry_unlensed(*t*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t*)

Parallax: Get lens astrometry

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

---

class `model.PSPL_Phot_Par_GP_Param2_2`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_Phot`, `PSPL_Parallax`, `PSPL_GP_PhotParam2_2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
`calc_piE_ecliptic`()	Parallax: Get piE_ecliptic
`get_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t.
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	
`get_log_det_covariance`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`get_photometry_with_gp`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`log_likely_photometry`(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`
Parallax: Get piE_ecliptic

`get_amplification(t)`
Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t, ast_filt_idx=0)`
Parallax: Get astrometry

`get_astrometry_unlensed(t)`
Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(t, ast_filt_idx=0)`
Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t)`
Parallax: Get lens astrometry

`get_log_det_covariance(t_obs, mag_obs, mag_err_obs, filt_index=0, t_pred=None)`
Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp(t_obs, mag_obs, mag_err_obs, filt_index=0, t_pred=None)`
Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification(t)`
Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry(t)`
Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

4.1.7 PSPL Phot, no parallax with GP

class model.**PSPL_Phot_noPar_GP_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_Phot`, `PSPL_noParallax`, `PSPL_GP_PhotParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

calc_piE_ecliptic	
get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`class model.PSPL_Phot_noPar_GP_Param2`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_Phot`, `PSPL_noParallax`, `PSPL_GP_PhotParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
`get_amplification`(t)	noParallax: Get the photometric amplification term at a set of times, t.
`get_log_det_covariance`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`get_photometry_with_gp`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`log_likely_photometry`(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

calc_piE_ecliptic	
get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry_each	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

get_photometry_with_gp(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

get_resolved_amplification(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

4.1.8 PSPL PhotAstrom, parallax with GP

class model.**PSPL_PhotAstrom_Par_GP_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_Parallax`, `PSPL_GP_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(`*t*`)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(`*t_obs*, *ast_filt_idx=0*`)`

Parallax: Get astrometry

`get_astrometry_unlensed(`*t_obs*`)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(`*t*, *ast_filt_idx=0*`)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(`*t_obs*`)`

Parallax: Get lens astrometry

`get_log_det_covariance(`*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*`)`

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp(`*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*`)`

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification(`*t*`)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class model.**PSPL_PhotAstrom_Par_GP_Param2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_Parallax`, `PSPL_GP_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`class model.PSPL_PhotAstrom_Par_GP_Param3`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_Parallax`, `PSPL_GP_PhotAstromParam3`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(`*t*`)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(`*t_obs*, *ast_filt_idx=0*`)`

Parallax: Get astrometry

`get_astrometry_unlensed(`*t_obs*`)`

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift(`*t*, *ast_filt_idx=0*`)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(`*t_obs*`)`

Parallax: Get lens astrometry

`get_log_det_covariance(`*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*`)`

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp(`*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*`)`

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification(`*t*`)`

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`class model.PSPL_PhotAstrom_Par_GP_Param4`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_Parallax`, `PSPL_GP_PhotAstromParam4`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class `model.PSPL_PhotAstrom_Par_LumLens_GP_Param1`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_Parallax_LumLens`, `PSPL_GP_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class model.**PSPL_PhotAstrom_Par_LumLens_GP_Param2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_Parallax_LumLens`, `PSPL_GP_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class `model.PSPL_PhotAstrom_Par_LumLens_GP_Param3`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_Parallax_LumLens`, `PSPL_GP_PhotAstromParam3`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class model.**PSPL_PhotAstrom_Par_LumLens_GP_Param4**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_Parallax_LumLens`, `PSPL_GP_PhotAstromParam4`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

`get_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

4.1.9 PSPL PhotAstrom, no parallax with GP

`class model.PSPL_PhotAstrom_noPar_GP_Param1`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_noParallax`, `PSPL_GP_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
get_astrometry_unlensed(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens.
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm’s

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class model.**PSPL_PhotAstrom_noPar_GP_Param2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSPL_PhotAstrom`, `PSPL_noParallax`, `PSPL_GP_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
get_astrometry_unlensed(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens.
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

4.2 PSBL User Classes

4.2.1 PSBL

class model.**PSBL_PhotAstrom_noPar_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSBL_PhotAstrom`, `PSBL_noParallax`, `PSBL_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
`get_all_arrays`(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
`get_amp_arr`(z_arr, z1, z2)	Calculations amplification array
`get_amplification`(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
`get_astrometry_unlensed`(t_obs)	Get the astrometry of the source if the lens didn't exist.
`get_centroid`(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_centroid_shift`(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_complex_pos`(t_obs)	Get the positions of the lenses and source as complex numbers.
`get_image_pos_arr`(w, z1, z2, m1, m2[, ...])	Gets image positions.
`get_image_pos_arr_old`(w, z1, z2[, check_sols])	Gets image positions.
`get_lens_astrometry`(t_obs)	Equation of motion for just the foreground lens system.
`get_photometry`(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
`get_resolved_amplification`(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
`get_resolved_lens_astrometry`(t_obs)	Equation of motion for just the foreground lenses, individually.
`get_resolved_photometry`(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
`rescale_complex_pos`(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot

e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

rescale_complex_pos(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

class model.**PSBL_PhotAstrom_noPar_Param2**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSBL_PhotAstrom`, `PSBL_noParallax`, `PSBL_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_centroid_shift(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens system.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)
noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)
Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)
Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)
PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*)
noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)
Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)
Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)
Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_resolved_amplification`(*t*)
Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)
Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)
Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

get_resolved_photometry(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

rescale_complex_pos(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

4.2.2 PSBL Parallax

class model.**PSBL_PhotAstrom_Par_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSBL_PhotAstrom`, `PSBL_Parallax`, `PSBL_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens system.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

get_lens_astrometry(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

get_photometry(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

get_resolved_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

get_resolved_lens_astrometry(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

`class model.PSBL_PhotAstrom_Par_Param2`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSBL_PhotAstrom`, `PSBL_Parallax`, `PSBL_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens system.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

`class model.PSBL_PhotAstrom_Par_Param3`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSBL_PhotAstrom`, `PSBL_Parallax`, `PSBL_PhotAstromParam3`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens system.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_all_arrays(`*t_obs*, *check_sols=True*, *rescale=True*`)`

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr(`*z_arr*, *z1*, *z2*`)`

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

class `model.PSBL_PhotAstrom_Par_Param4`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSBL_PhotAstrom`, `PSBL_Parallax`, `PSBL_PhotAstromParam4`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens system.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_all_arrays(`*t_obs*, *check_sols=True*, *rescale=True*`)`

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr(`*z_arr*, *z1*, *z2*`)`

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

get_resolved_photometry(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

rescale_complex_pos(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

4.2.3 PSBL_Phot

class model.**PSBL_Phot_noPar_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSBL_Phot`, `PSBL_noParallax`, `PSBL_PhotParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in Einstein radii.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in Einstein radii.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

calc_piE_ecliptic	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_resolved_amplification	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]` – note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in Einstein radii.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist. Note, this is a photometry only model, so units are in Einstein radii.

Returns

xS_unlensed
[numpy array, dtype=float, `shape = len(t_obs) x 2`] The unlensed positions of the source in Einstein radii.

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers.

This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in Einstein radii.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

4.2.4 PSBL_phot_parallax

class `model.PSBL_Phot_Par_Param1`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSBL_Phot`, `PSBL_Parallax`, `PSBL_PhotParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in Einstein radii.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in Einstein radii.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_resolved_amplification	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]` – note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in Einstein radii.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist. Note, this is a photometry only model, so units are in Einstein radii.

Returns

xS_unlensed
[numpy array, dtype=float, `shape = len(t_obs) x 2`] The unlensed positions of the source in Einstein radii.

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers.

This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t*)

Parallax: Get lens astrometry

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in Einstein radii.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

4.2.5 PSBL PhotAstrom, no parallax with GP

class model.**PSBL_PhotAstrom_noPar_GP_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSBL_PhotAstrom`, `PSBL_noParallax`, `PSBL_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
`get_all_arrays`(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
`get_amp_arr`(z_arr, z1, z2)	Calculations amplification array
`get_amplification`(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
`get_astrometry_unlensed`(t_obs)	Get the astrometry of the source if the lens didn't exist.
`get_centroid`(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_centroid_shift`(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_complex_pos`(t_obs)	Get the positions of the lenses and source as complex numbers.
`get_image_pos_arr`(w, z1, z2, m1, m2[, ...])	Gets image positions.
`get_image_pos_arr_old`(w, z1, z2[, check_sols])	Gets image positions.
`get_lens_astrometry`(t_obs)	Equation of motion for just the foreground lens system.
`get_log_det_covariance`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`get_photometry`(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
`get_photometry_with_gp`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`get_resolved_amplification`(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
`get_resolved_lens_astrometry`(t_obs)	Equation of motion for just the foreground lenses, individually.
`get_resolved_photometry`(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
`log_likely_photometry`(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.
`rescale_complex_pos`(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]` – note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

class `model.PSBL_PhotAstrom_noPar_GP_Param2`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSBL_PhotAstrom`, `PSBL_noParallax`, `PSBL_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
`get_all_arrays`(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
`get_amp_arr`(z_arr, z1, z2)	Calculations amplification array
`get_amplification`(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
`get_astrometry_unlensed`(t_obs)	Get the astrometry of the source if the lens didn't exist.
`get_centroid`(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_centroid_shift`(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_complex_pos`(t_obs)	Get the positions of the lenses and source as complex numbers.
`get_image_pos_arr`(w, z1, z2, m1, m2[, ...])	Gets image positions.
`get_image_pos_arr_old`(w, z1, z2[, check_sols])	Gets image positions.
`get_lens_astrometry`(t_obs)	Equation of motion for just the foreground lens system.
`get_log_det_covariance`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`get_photometry`(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
`get_photometry_with_gp`(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
`get_resolved_amplification`(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
`get_resolved_lens_astrometry`(t_obs)	Equation of motion for just the foreground lenses, individually.
`get_resolved_photometry`(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
`log_likely_photometry`(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.
`rescale_complex_pos`(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

calc_piE_ecliptic	
get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

4.2.6 PSBL PhotAstrom, parallax with GP

`class model.PSBL_PhotAstrom_Par_GP_Param1`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSBL_PhotAstrom`, `PSBL_Parallax`, `PSBL_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens system.
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

get_all_arrays(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

get_amp_arr(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.
See PSBL writeup for full equations.
All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

`class model.PSBL_PhotAstrom_Par_GP_Param2`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSBL_PhotAstrom`, `PSBL_Parallax`, `PSBL_PhotAstromParam2`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens system.
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry_each	
start	

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

get_complex_pos(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

get_image_pos_arr(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.

See PSBL writeup for full equations.

All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

get_image_pos_arr_old(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

4.2.7 PSBL Phot, no parallax with GP

`class model.PSBL_Phot_noPar_GP_Param1`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSBL_Phot`, `PSBL_noParallax`, `PSBL_PhotParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in Einstein radii.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in Einstein radii.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

calc_piE_ecliptic	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_resolved_amplification	
log_likely_astrometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this

value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_amplification`(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in Einstein radii.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist. Note, this is a photometry only model, so units are in Einstein radii.

Returns

xS_unlensed
[numpy array, dtype=float, `shape = len(t_obs) x 2`] The unlensed positions of the source in Einstein radii.

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_complex_pos`(*t_obs*)

Get the positions of the lenses and source as complex numbers.

This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.
See PSBL writeup for full equations.
All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in Einstein radii.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

4.2.8 PSBL Phot, parallax with GP

`class model.PSBL_Phot_Par_GP_Param1`(**args*, ***kwargs*)

Bases: `ModelClassABC`, `PSPL_GP`, `PSBL_Phot`, `PSBL_Parallax`, `PSBL_PhotParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_amplification(t_obs[, amp_arr])	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in Einstein radii.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in Einstein radii.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_resolved_amplification	
log_likely_astrometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_all_arrays(`*t_obs*, *check_sols=True*, *rescale=True*`)`

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr(`*z_arr*, *z1*, *z2*`)`

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

get_amplification(*t_obs*, *amp_arr=None*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_astrometry(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in Einstein radii.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

get_astrometry_unlensed(*t_obs*)

Get the astrometry of the source if the lens didn't exist. Note, this is a photometry only model, so units are in Einstein radii.

Returns

xS_unlensed
[numpy array, dtype=float, `shape = len(t_obs) x 2`] The unlensed positions of the source in Einstein radii.

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

get_centroid_shift(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

get_complex_pos(*t_obs*)

Get the positions of the lenses and source as complex numbers.

This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.
See PSBL writeup for full equations.
All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_lens_astrometry`(*t*)

Parallax: Get lens astrometry

`get_log_det_covariance`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_photometry_with_gp`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in Einstein radii.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`log_likely_photometry`(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

4.3 FSPL User Class

4.3.1 FSPL_parallax

class model.**FSPL_PhotAstrom_Par_Param1**(**args*, ***kwargs*)

Bases: `ModelClassABC`, `FSPL_PhotAstrom`, `FSPL_Parallax`, `FSPL_PhotAstromParam1`

Helper class that provides a standard way to create an ABC using inheritance.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t)	Outputs position of source unlensed.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_source_outline_astrometry(r, n, center)	Return astrometric points that outline the outer circumference of the source star.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	
start	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`calc_piE_ecliptic()`

Parallax: Get piE_ecliptic

`get_amplification(t)`

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry(t_obs, ast_filt_idx=0)`

Parallax: Get astrometry

`get_astrometry_unlensed(t)`

Outputs position of source unlensed.

Input a list of times and it will output the position of the source had it not been lensed at each of the times in the list

e.g if `n = 4`, and say `v = [1,0]` & the times are `[0,1,2]` in years.
This will return
`((( (1,0),(0,1),(-1,0),(0,-1) ), ( (2,0),(1,1),(0,0),(1,-1) ), ( (3,0),(2,1),(1,0),(2,-1) ))...`
= (positions at t=0), (positions at t=1), (positions at t=2)

so `np.array(positions)` is an array which contains an array for each time step with the positions of all the points on the boundary of the source.

`get_centroid_shift(t, ast_filt_idx=0)`

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry(t_obs)`

Parallax: Get lens astrometry

`get_photometry(t_obs, filt_idx=0, amp_arr=None, print_warning=True)`

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Other Parameters

———-

amp_arr
[array_like] Amplifications of each individual image at each time, i.e. amp_arr.shape = (len(t_obs), number of images at each t_obs).

This will over-ride t_obs; but is more efficient when calculating both photometry and astrometry. If None, then just use t_obs.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`get_source_outline_astrometry`(*r*, *n*, *center*)

Return astrometric points that outline the outer circumference of the source star.

The outline is described as a circle of radius self.radius and is evaluated at self.n_outline number of points.

takes in the radius of the circle, centre position and number of points we are approximating the circle by and returns a numpy array of positions

e.g: `( ((1,0), (0,1), (-1,0), (0,-1)) )` if n = 4 and radius = 1

Returns

source_points
[numpy array] Returns an array of `shape = [2, self.n_outline, len(time)]`

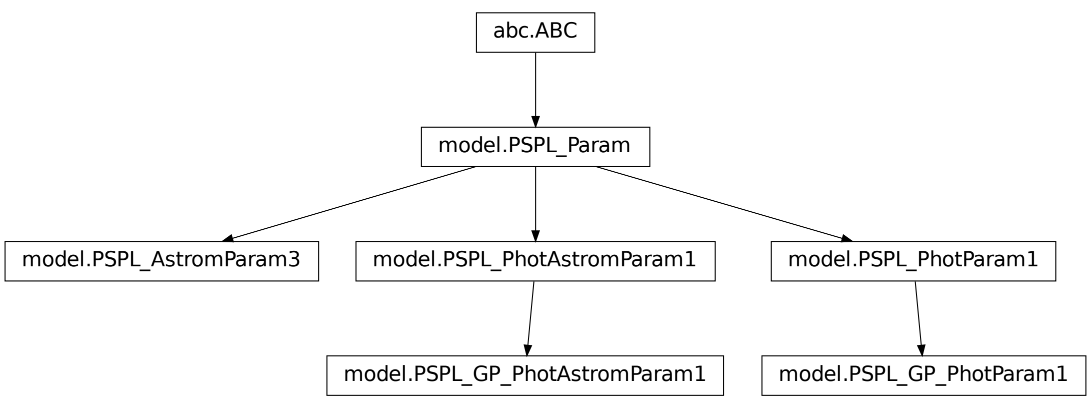
CHAPTER

FIVE

POINT SOURCE POINT LENS (PSPL) CLASSES

5.1 Parameterization Class Family

Here is a subsection of the inheritance diagram for the PSPL Parametrization classes showing the AstromParam, PhotParam, and PhotAstromParam structures.



5.1.1 PSPL Models

class `model.`**`PSPL_Param`**(**args*, ***kwargs*)

Bases: `ABC`

An abstract class that all Param classes should sub-class. This serves as a reminder for the class variables that MUST be set.

class `model.`**`PSPL_AstromParam4`**(*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

Point Source Point Lens model for microlensing. This model includes proper motions of the source and the source position on the sky. It is the same as PSPL_PhotAstromParam2 except it fits for baseline instead of source magnitude.

Notes

Note: Required parameters if calculating with parallax

- raL: Right ascension of the lens in decimal degrees.
- decL: Declination of the lens in decimal degrees.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time (days).

thetaE: float
The size of the Einstein radius in (mas).

piS: float
Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E: float
RA Source proper motion (mas/yr)

muS_N: float
Dec Source proper motion (mas/yr)

`class model.PSPL_AstromParam3`(*t0*, *u0_amp*, *tE*, *log10_thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

DESCRIPTION: Point Source Point Lens model for microlensing. This model includes proper motions of the source and the source position on the sky. It is the same as PSPL_PhotAstromParam3 except it fits only astrometry, no photometry.

Notes

Note: Required parameters if calculating with parallax

- raL: Right ascension of the lens in decimal degrees.
- decL: Declination of the lens in decimal degrees.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time (days).

log10_thetaE: float
The log of the Einstein radius log10(thetaE/mas).

piS: float
Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E: float
RA Source proper motion (mas/yr)

muS_N: float
Dec Source proper motion (mas/yr)

`class model.PSPL_PhotParam1`(*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *b_sff*, *mag_src*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

PSPL model for photometry only.

Point source point lens model for microlensing photometry only. This model includes the relative proper motion between the lens and the source. Parameters are reduced with the use of piRel (rather than dL and dS) and muRel (rather than muL and muS).

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. It can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time in days.

piE_E: float
The microlensing parallax in the East direction in units of thetaE.

piE_N: float
The microlensing parallax in the North direction in units of thetaE

b_sff: numpy array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = f_S/(f_S + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src: numpy array or list
Photometric magnitude of the source. This must be passed in as a list or array, with one entry for each photometric filter.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

`class model.PSPL_PhotParam2`(*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *b_sff*, *mag_base*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

DESCRIPTION: Point source point lens model for microlensing photometry only. This model includes the relative proper motion between the lens and the source. Parameters are reduced with the use of piRel (rather than dL and dS) and muRel (rather than muL and muS). Same as PSPL_PhotParam1, except fits for mag_base instead of mag_src.

Notes

Note: Required parameters if calculating with parallax

- raL: Right ascension of the lens in decimal degrees.
- decL: Declination of the lens in decimal degrees.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. It can be positive (u0_amp > 0 when u0_hat[0] > 0) or negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time in days.

piE_E: float
The microlensing parallax in the East direction in units of thetaE.

piE_N: float
The microlensing parallax in the North direction in units of thetaE

b_sff: numpy array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_s ff = f_S/(f_S + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

mag_base: numpy array or list
Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter.

`class model.PSPL_PhotAstromParam1`(*mL*, *t0*, *beta*, *dL*, *dL_dS*, *xS0_E*, *xS0_N*, *muL_E*, *muL_N*, *muS_E*, *muS_N*, *b_sff*, *mag_src*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

PSPL model for astrometry and photometry - physical parameterization.

A Point Source Point Lens model for microlensing. This model uses a parameterization that depends on only physical quantities such as the lens mass and positions and proper motions of both the lens and source.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Attributes

mL: float
Mass of the lens (Msun)

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

beta: float
Angular distance between the lens and source on the plane of the sky (mas). Can be

- positive (u0_amp > 0 when u0_hat[0] < 0) or
- negative (u0_amp < 0 when u0_hat[0] > 0).

dL: float
Distance from the observer to the lens (pc)

dL_dS: float
Ratio of Distance from the obersver to the lens to Distance from the observer to the source

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muL_E: float
RA Lens proper motion (mas/yr)

muL_N: float
Dec Lens proper motion (mas/yr)

muS_E: float
RA Source proper motion (mas/yr)

muS_N: float
Dec Source proper motion (mas/yr)

b_sff: numpy array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_s ff = f_S/(f_S + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src: numpy array or list
Photometric magnitude of the source. This must be passed in as a list or array, with one entry for each photometric filter.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

`class model.PSPL_PhotAstromParam2`(*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *b_sff*, *mag_src*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

PSPL model for photometry and astrometry – photom-like parameterization

Point Source Point Lens model for microlensing. This model includes proper motions of the source and the source position on the sky.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time (days).

thetaE: float
The size of the Einstein radius in (mas).

piS: float
Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E: float
RA Source proper motion (mas/yr)

muS_N: float
Source proper motion (mas/yr)

b_sff: numpy array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = f_S/(f_S + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src: numpy array or list
Photometric magnitude of the source. This must be passed in as a list or array, with one entry for each photometric filter.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

`class model.PSPL_PhotAstromParam3`(*t0*, *u0_amp*, *tE*, *log10_thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *b_sff*, *mag_base*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

Point Source Point Lens model for microlensing. This model includes proper motions of the source and the source position on the sky. It is the same as PSPL_PhotAstromParam4 except it fits for log10(thetaE) instead of thetaE.

Notes

Note: Required parameters if calculating with parallax

- raL: Right ascension of the lens in decimal degrees.
- decL: Declination of the lens in decimal degrees.

Attributes

t0
[float] Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE
[float] Einstein crossing time (days).

log10_thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr)

muS_N
[float] Dec Source proper motion (mas/yr)

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

$$b_s ff = f_S/(f_S + f_L + f_N).$$

This must be passed in as a list or array, with one entry for each photometric filter.

mag_base
[numpy array or list] Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter.

`class model.`**`PSPL_PhotAstromParam4`**(*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *b_sff*, *mag_base*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

DESCRIPTION: Point Source Point Lens model for microlensing. This model includes proper motions of the source and the source position on the sky. It is the same as PSPL_PhotAstromParam2 except it fits for baseline instead of source magnitude.

Parameters

t0
[float] Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE
[float] Einstein crossing time (days).

thetaE:
The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr)

muS_N
[float] Dec Source proper motion (mas/yr)

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

$b_s ff = f_S/(f_S + f_L + f_N)$.

This must be passed in as a list or array, with one entry for each photometric filter.

mag_base
[numpy array or list] Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter.

Notes

Note: Required parameters if calculating with parallax

- raL: Right ascension of the lens in decimal degrees.
- decL: Declination of the lens in decimal degrees.

`class model.PSPL_PhotAstromParam5`(*t0*, *u0_amp*, *tE*, *log10_thetaE*, *piS*, *piE_E*, *piEN_piEE*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *b_sff*, *mag_base*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

DESCRIPTION: Point Source Point Lens model for microlensing. This model includes proper motions of the source and the source position on the sky. It fits for piEN/piEE and piEE, instead of piEE and piEN.

Notes

Note: Required parameters if calculating with parallax

- raL: Right ascension of the lens in decimal degrees.
- decL: Declination of the lens in decimal degrees.

Attributes

t0
[float] Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp
[float] Angular distance between the source and the lens on the plane of the sky at closest approach in units of thetaE. Can

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE
[float] Einstein crossing time (days).

log10_thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piEN_piEE
[float] Ratio of piE_N to piE_E.

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr)

muS_N
[float] Dec Source proper motion (mas/yr)

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

$b_sff = f_S/(f_S + f_L + f_N)$.

This must be passed in as a list or array, with one entry for each photometric filter.

mag_base
[numpy array or list] Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter.

5.1.2 GP Models

`class model.`**`PSPL_GP_PhotParam1`**`(`*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *b_sff*, *mag_src*, *gp_log_sigma*, *gp_log_rho*, *gp_log_S0*, *gp_log_omega0*, *raL=None*, *decL=None*`)`

Bases: `PSPL_PhotParam1`

`class model.`**`PSPL_GP_PhotParam1_2`**`(`*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *b_sff*, *mag_src*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*`)`

Bases: `PSPL_PhotParam1`

Figuring out the new prior parametrization.

`class model.`**`PSPL_GP_PhotParam2`**`(`*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *b_sff*, *mag_base*, *gp_log_sigma*, *gp_log_rho*, *gp_log_S0*, *gp_log_omega0*, *raL=None*, *decL=None*`)`

Bases: `PSPL_PhotParam2`

class model.**PSPL_GP_PhotParam2_2**(*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *b_sff*, *mag_base*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: PSPL_PhotParam2

class model.**PSPL_GP_PhotAstromParam1**(*mL*, *t0*, *beta*, *dL*, *dL_dS*, *xS0_E*, *xS0_N*, *muL_E*, *muL_N*, *muS_E*, *muS_N*, *b_sff*, *mag_src*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: PSPL_PhotAstromParam1

class model.**PSPL_GP_PhotAstromParam2**(*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *b_sff*, *mag_src*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: PSPL_PhotAstromParam2

class model.**PSPL_GP_PhotAstromParam2**(*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *b_sff*, *mag_src*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: PSPL_PhotAstromParam2

class model.**PSPL_GP_PhotAstromParam3**(*t0*, *u0_amp*, *tE*, *log10_thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *b_sff*, *mag_base*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: PSPL_PhotAstromParam3

Point Source Point Lens with GP model for microlensing. This model includes proper motions of the source and the source position on the sky. It is the same as PSPL_PhotAstromParam4 except it fits for log10(thetaE) instead of thetaE.

Notes

Note: *raL* and *decL* are required parameters if calculating with parallax

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time (days).

log10_thetaE: float
log10 of the size of the Einstein radius in (mas).

piS: float
Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E: float
RA Source proper motion (mas/yr)

muS_N: float
Dec Source proper motion (mas/yr)

b_sff: numpy array or list of floats
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = f_S/(f_S + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

mag_base: numpy array or list of floats
Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter.

gp_log_sigma: float
Guassian process $log(\sigma)$ for the Matern 3/2 kernel.

gp_rho: float
Guassian process ρ for the Matern 3/2 kernel.

gp_log_omega04_S0: float
Guassian process $log(\omega_0^4 * S_0)$ from the SHO kernel.

gp_log_omega0: float
Guassian process $log(\omega_0)$ from the SHO kernel.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

class model.**PSPL_GP_PhotAstromParam4**(*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *b_sff*, *mag_base*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: `PSPL_PhotAstromParam4`

Point Source Point Lens with GP model for microlensing. This model includes proper motions of the source and the source position on the sky. It is the same as PSPL_PhotAstromParam2 except it fits for baseline instead of source magnitude.

Notes

Note:

raL and *decL* are required parameters if calculating with parallax

For an explanation of the Guassian process parameters, see Golovich et al. 2019()

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time (days).

thetaE: float
The size of the Einstein radius in (mas).

piS: float
Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E: float
RA Source proper motion (mas/yr)

muS_N: float
Dec Source proper motion (mas/yr)

b_sff: float
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = f_S/(f_S + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

mag_base: float
Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter.

gp_log_sigma: float
Guassian process $log(\sigma)$ for the Matern 3/2 kernel.

gp_rho: float
Guassian process ρ for the Matern 3/2 kernel.

gp_log_omega04_S0: float
Guassian process $log(\omega_0^4 * S_0)$ from the SHO kernel.

gp_log_omega0: float
Guassian process $log(\omega_0)$ from the SHO kernel.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

5.2 Data Class Family

class `model.PSPL`

Bases: `ABC`

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.

get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_photometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

class model.**PSPL_Phot**

Bases: PSPL

Contains methods for model a PSPL photometry only. This is a Data-type class in our hierarchy. It is abstract and should not be instantiated.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.

get_astrometry	
get_astrometry_unlensed	
get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
get_resolved_amplification	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

class model.**PSPL_PhotAstrom**

Bases: PSPL

Contains methods for model a PSPL photometry + astrometry. This is a Data-type class in our hierarchy. It is abstract and should not be instantiated.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot

e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

class model.**PSPL_Astrom**

Bases: PSPL

Contains methods for model a PSPL photometry + astrometry. This is a Data-type class in our hierarchy. It is abstract and should not be instantiated.

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

animate(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot

e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

5.3 GP Class Family

class model.**Celerite_GP_Model**(*pspl_model*, *filter_index*)

Bases: `Model`

This is nedeed for the GP. Just a wrapper over our model so it is a celerite model.

Attributes

full_size
The total number of parameters (including frozen parameters)

parameter_vector
An array of all parameters (including frozen parameters)

vector_size
The number of active (or unfrozen) parameters

Methods

compute_gradient(*args, **kwargs)	Compute the "gradient" of the model for the current parameters
freeze_all_parameters()	Freeze all parameters of the model
freeze_parameter(name)	Freeze a parameter by name
get_parameter(name)	Get a parameter value by name
get_parameter_bounds([include_frozen])	Get a list of the parameter bounds
get_parameter_dict([include_frozen])	Get an ordered dictionary of the parameters
get_parameter_names([include_frozen])	Get a list of the parameter names
get_parameter_vector([include_frozen])	Get an array of the parameter values in the correct order
get_value(t_obs)	Compute the "value" of the model for the current parameters
log_prior()	Compute the log prior probability of the current parameters
set_parameter(name, value)	Set a parameter value by name
set_parameter_vector(vector[, include_frozen])	Set the parameter values to the given vector
thaw_all_parameters()	Thaw all parameters of the model
thaw_parameter(name)	Thaw a parameter by name

get_gradient	

get_value(*t_obs*)
Compute the "value" of the model for the current parameters

This method should be overloaded by subclasses to implement the actual functionality of the model.

compute_gradient(**args*, ***kwargs*)
Compute the "gradient" of the model for the current parameters

This method should be overloaded by subclasses to implement the actual functionality of the model. The output of this function should be an array where the first dimension is `full_size`.

freeze_all_parameters()
Freeze all parameters of the model

freeze_parameter(*name*)
Freeze a parameter by name

Args:
name: The name of the parameter

property full_size
The total number of parameters (including frozen parameters)

get_parameter(*name*)
Get a parameter value by name

Args:
name: The name of the parameter

`get_parameter_bounds`(*include_frozen=False*)

Get a list of the parameter bounds

Args:

include_frozen (Optional[bool]): Should the frozen parameters be
included in the returned value? (default: `False`)

`get_parameter_dict`(*include_frozen=False*)

Get an ordered dictionary of the parameters

Args:

include_frozen (Optional[bool]): Should the frozen parameters be
included in the returned value? (default: `False`)

`get_parameter_names`(*include_frozen=False*)

Get a list of the parameter names

Args:

include_frozen (Optional[bool]): Should the frozen parameters be
included in the returned value? (default: `False`)

`get_parameter_vector`(*include_frozen=False*)

Get an array of the parameter values in the correct order

Args:

include_frozen (Optional[bool]): Should the frozen parameters be
included in the returned value? (default: `False`)

`log_prior()`

Compute the log prior probability of the current parameters

`property parameter_vector`

An array of all parameters (including frozen parameters)

`set_parameter`(*name*, *value*)

Set a parameter value by name

Args:
name: The name of the parameter value (float): The new value for the parameter

`set_parameter_vector`(*vector*, *include_frozen=False*)

Set the parameter values to the given vector

Args:

vector (array[vector_size] or array[full_size]): The target
parameter vector. This must be in the same order as `parameter_names` and it should only include frozen parameters if `include_frozen` is `True`.

include_frozen (Optional[bool]): Should the frozen parameters be
included in the returned value? (default: `False`)

`thaw_all_parameters()`

Thaw all parameters of the model

`thaw_parameter`(*name*)

Thaw a parameter by name

Args:
name: The name of the parameter

property vector_size

The number of active (or unfrozen) parameters

class model.PSPL_GP

Bases: ABC

PSPL object that has optional support for gaussian process on each photometric filter.

Methods

get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_photometry_with_gp(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

get_log_det_covariance(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

class model.PSPL_GP

Bases: ABC

PSPL object that has optional support for gaussian process on each photometric filter.

Methods

get_log_det_covariance(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
get_photometry_with_gp(t_obs, mag_obs, ...)	Returns photometry with GP noise added in.
log_likely_photometry(t_obs, mag_obs, ...[, ...])	Calculate the log-likelihood for the PSPL + GP model and photometric data.

get_photometry_with_gp(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

get_log_det_covariance(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*, *t_pred=None*)

Returns photometry with GP noise added in.

Note: This will throw an error if this is a filter with *use_gp_phot[filt_index] = False*.

log_likely_photometry(*t_obs*, *mag_obs*, *mag_err_obs*, *filt_index=0*)

Calculate the log-likelihood for the PSPL + GP model and photometric data.

Note: The GP will only be used for filters where *use_gp_phot[filt_index] = True*.

5.4 Parallax Class Family

class model.**PSPL_noParallax**

Bases: `ParallaxClassABC`

Methods

`get_amplification`(t)	noParallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
`get_astrometry_unlensed`(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
`get_centroid_shift`(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_lens_astrometry`(t_obs)	Equation of motion for just the foreground lens.
`get_resolved_amplification`(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	

get_amplification(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_astrometry_unlensed`(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

`class model.PSPL_Parallax`

Bases: `ParallaxClassABC`

Methods

`calc_piE_ecliptic`()	Parallax: Get piE_ecliptic
`get_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, ast_filt_idx])	Parallax: Get astrometry
`get_astrometry_unlensed`(t_obs)	Get the astrometry of the source if the lens didn't exist.
`get_centroid_shift`(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	
`get_lens_astrometry`(t_obs)	Parallax: Get lens astrometry
`get_resolved_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

start	

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_lens_astrometry(*t_obs*)

Parallax: Get lens astrometry

get_astrometry(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

get_centroid_shift(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

get_astrometry_unlensed(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

get_resolved_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

class model.**PSPL_Parallax**

Bases: `ParallaxClassABC`

Methods

`calc_piE_ecliptic`()	Parallax: Get piE_ecliptic
`get_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, ast_filt_idx])	Parallax: Get astrometry
`get_astrometry_unlensed`(t_obs)	Get the astrometry of the source if the lens didn't exist.
`get_centroid_shift`(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	
`get_lens_astrometry`(t_obs)	Parallax: Get lens astrometry
`get_resolved_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

start	

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_lens_astrometry(*t_obs*)

Parallax: Get lens astrometry

get_astrometry(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

get_centroid_shift(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

get_astrometry_unlensed(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

get_resolved_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

class model.**PSPL_noParallax_LumLens**

Bases: `PSPL_noParallax`

Methods

get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
get_astrometry_unlensed(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_amplification`(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_astrometry_unlensed`(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

class `model.PSPL_Parallax_LumLens`

Bases: `PSPL_Parallax`

Methods

`calc_piE_ecliptic()`	Parallax: Get piE_ecliptic
`get_amplification(t)`	Parallax: Get the photometric amplification term at a set of times, t.
`get_astrometry(t_obs[, ast_filt_idx])`	Parallax: Get astrometry
`get_astrometry_unlensed(t_obs)`	Get the astrometry of the source if the lens didn't exist.
`get_centroid_shift(t[, ast_filt_idx])`	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_geoproj_ast_params(t0par)`	
`get_geoproj_params(t0par)`	
`get_lens_astrometry(t_obs)`	Parallax: Get lens astrometry
`get_resolved_amplification(t)`	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry(t_obs)`	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

start	

get_astrometry(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

get_centroid_shift(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_astrometry_unlensed(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

get_lens_astrometry(*t_obs*)

Parallax: Get lens astrometry

get_resolved_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

class model.**PSPL_Parallax**

Bases: `ParallaxClassABC`

Methods

`calc_piE_ecliptic`()	Parallax: Get piE_ecliptic
`get_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, ast_filt_idx])	Parallax: Get astrometry
`get_astrometry_unlensed`(t_obs)	Get the astrometry of the source if the lens didn't exist.
`get_centroid_shift`(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_geoproj_ast_params`(t0par)	
`get_geoproj_params`(t0par)	
`get_lens_astrometry`(t_obs)	Parallax: Get lens astrometry
`get_resolved_amplification`(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

start	

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_lens_astrometry(*t_obs*)

Parallax: Get lens astrometry

get_astrometry(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

`calc_piE_ecliptic`()

Parallax: Get piE_ecliptic

CHAPTER

SIX

POINT SOURCE BINARY LENS (PSBL) CLASSES

6.1 Data Class Family

class model.**PSBL**

Bases: PSPL

Contains methods for model a PSBL photometry + astrometry. This is a Data-type class in our hierarchy. It is abstract and should not be instantiated.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_chi2_photometry	
get_lnL_constant	
log_likely_photometry	
log_likely_photometry_each	

get_amp_arr(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr

[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]` – note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`rescale_complex_pos`(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.
See PSBL writeup for full equations.
All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_resolved_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

class model.**PSBL_Phot**

Bases: PSBL, PSPL_Phot

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in Einstein radii.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in Einstein radii.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_resolved_amplification	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	

get_complex_pos(*t_obs*)

Get the positions of the lenses and source as complex numbers.

This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w
[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1
[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2
[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist. Note, this is a photometry only model, so units are in Einstein radii.

Returns

xS_unlensed
[numpy array, dtype=float, `shape = len(t_obs) x 2`] The unlensed positions of the source in Einstein radii.

Notes

Note: Note, this is a photometry only model, so units are in Einstein radii.

`get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in Einstein radii.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in Einstein radii.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.
See PSBL writeup for full equations.
All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

get_photometry(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

get_resolved_photometry(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

rescale_complex_pos(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

class model.**PSBL_PhotAstrom**

Bases: `PSBL`, `PSPL_PhotAstrom`

Contains methods for model a PSPL photometry + astrometry. This is a Data-type class in our hierarchy. It is abstract and should not be instantiated.

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_all_arrays(t_obs[, check_sols, rescale])	Obtain the image and amplitude arrays for each t_obs.
get_amp_arr(z_arr, z1, z2)	Calculations amplification array
get_astrometry(t_obs[, image_arr, amp_arr, ...])	Position of the observed (unresolved) source position in arcsec.
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid(t_obs[, ast_filt_idx, ...])	PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_complex_pos(t_obs)	Get the positions of the lenses and source as complex numbers.
get_image_pos_arr(w, z1, z2, m1, m2[, ...])	Gets image positions.
get_image_pos_arr_old(w, z1, z2[, check_sols])	Gets image positions.
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens system.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_resolved_astrometry(t_obs[, image_arr, ...])	Position of the observed source position in arcsec.
get_resolved_lens_astrometry(t_obs)	Equation of motion for just the foreground lenses, individually.
get_resolved_photometry(t_obs[, filt_idx, ...])	Get the photometry for each of the lensed source images.
rescale_complex_pos(w, z1, z2)	Make sure everything is roughly centered on the origin in a 1 x 1 box.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

get_complex_pos(*t_obs*)

Get the positions of the lenses and source as complex numbers. This is needed for further calculations. Note that all units are still the same as before, this is just rewriting vectors $z = (x, y)$ as $z = x + iy$.

Returns

w

[complex array] Source position as an array of complex numbers with real = east component, imaginary = north component

z1

[complex array] Lens primary component position as an array of complex numbers with real = east component, imaginary = north component

z2

[complex array] Lens secondary component position as an array of complex numbers with real = east component, imaginary = north component `get_resolved_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*)

Position of the observed source position in arcsec.

Parameters

t_obs
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_astrometry`(*t_obs*, *image_arr=None*, *amp_arr=None*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in arcsec.

Parameters

t_obs
[array_like] Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lens system.

Parameters

t_obs
[array_like] Time (in MJD).

`get_resolved_lens_astrometry`(*t_obs*)

Equation of motion for just the foreground lenses, individually.

Parameters

t_obs
[array_like] Time (in MJD).

`get_centroid`(*t_obs*, *ast_filt_idx=0*, *image_arr=None*, *amp_arr=None*)

PSPL: Get the centroid shift (in mas) for a list of observation times (in MJD).

Parameters

t_obs
[array or float]

Returns

Centroid offset on the plane of the sky in milli-arcseoncds.

Other Parameters

ast_filt_idx
[int] Index into the photometry parameter lists for the photometry that corresponds to this astrometry data set.

image_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

amp_arr
[list] List returned from PSPL get_all_arrays() used to improve efficiency.

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_all_arrays`(*t_obs*, *check_sols=True*, *rescale=True*)

Obtain the image and amplitude arrays for each t_obs.

Parameters

t_obs
[array_like] Array of times to model.

Returns

images
[array_like] Array/tuple of complex positions of each images at each t_obs.

amp_arr
[array_like] Array/tuple of amplification of each images at each t_obs.

`get_amp_arr`(*z_arr*, *z1*, *z2*)

Calculations amplification array

Calculates the amplification A from the Jacobian J, $A = 1/|J|$

Parameters

z_arr
[array_like]

Complex position of images. `Shape = [N_times, N_solutions, 1]`
– note this could be jagged.

z1
[array_like] Complex position(s) of lens 1 (primary). `Shape = [N_times, 1]`

z2
[array_like] Complex position(s) of lens 2 (secondary). `Shape = [N_times, 1]`

Returns

amp_arr
[array_like] BLEH

`get_image_pos_arr`(*w*, *z1*, *z2*, *m1*, *m2*, *check_sols=True*)

Gets image positions.

Solve the fifth-order polynomial and get the image positions.
See PSBL writeup for full equations.
All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

`get_image_pos_arr_old`(*w*, *z1*, *z2*, *check_sols=True*)

Gets image positions. | Solve the fifth-order polynomial and get the image positions. | See PSBL writeup for full equations. | All angular distances are in arcsec.

Parameters

w
[array_like] Complex position(s) of the source. Shape = [N_times, 1]

z1
[array_like] Complex position(s) of lens 1 (primary). Shape = [N_times, 1]

z2
[array_like] Complex position(s) of lens 2 (secondary). Shape = [N_times, 1]

check_sols
[bool, optional] If True, calculated roots are checked against the lens equation, and output will only contain those within self.root_tol. If False, all calculated roots are returned.

Returns

z_arr
[array_like] Position of the lensed source images. Rank-1 array of polynomial roots, possibly complex. If check_sols = True, only roots solving the lens equation are returned.

get_photometry(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

get_resolved_photometry(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images. Implement with no blending (since we don't support different blendings for the different images).

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of each lensed image centroid at t_obs. Shape = [5, len(t_obs)]

rescale_complex_pos(*w*, *z1*, *z2*)

Make sure everything is roughly centered on the origin in a 1 x 1 box.

6.2 Parallax Class Family - PSBL

class model.**PSPL_Parallax**

Bases: `ParallaxClassABC`

Methods

calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

start	

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_lens_astrometry(*t_obs*)

Parallax: Get lens astrometry

get_astrometry(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

get_centroid_shift(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

get_astrometry_unlensed(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

get_resolved_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

class model.**PSPL_noParallax**

Bases: `ParallaxClassABC`

Methods

`get_amplification`(t)	noParallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
`get_astrometry_unlensed`(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
`get_centroid_shift`(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_lens_astrometry`(t_obs)	Equation of motion for just the foreground lens.
`get_resolved_amplification`(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	

get_amplification(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_lens_astrometry(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

get_astrometry(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

`get_centroid_shift`(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_astrometry_unlensed`(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_resolved_amplification`(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

6.3 Parameterization Class Family - PSBL

6.3.1 PSBL Models

`class model.PSBL_PhotAstromParam1`(*mLp*, *mLs*, *t0*, *xS0_E*, *xS0_N*, *beta*, *muL_E*, *muL_N*, *muS_E*, *muS_N*, *dL*, *dS*, *sep*, *alpha*, *b_sff*, *mag_src*, *raL=None*, *decL=None*, *root_tol=1e-08*)

Bases: `PSPL_Param`

Point source binary lens. It has 3 more parameters than PSPL (additional mass term, separation, and angle of approach). Note that this is a STATIC binary lens, i.e. there is no orbital motion.

Attributes

mLp, mLs
[float] Masses of the lenses (Msun)

t0
[float] Time of photometric peak, as seen from Earth (MJD.DDD)

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

beta
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky (mas). Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

muL_E
[float] Lens system proper motion in the RA direction (mas/yr)

muL_N
[float] Lens system proper motion in the Dec. direction (mas/yr)

muS_E
[float] Source proper motion in the RA direction (mas/yr)

muS_N
[float] Source proper motion in the Dec. direction (mas/yr)

dL
[float] Distance from the observer to the lens system (pc)

dS
[float] Distance from the observer to the source (pc)

sep
[float] Angular separation of the two lenses (mas)

alpha
[float] Angle made between the binary axis and North; measured in degrees East of North.

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

mag_src
[numpy array or list] Source magnitude, unlensed. One in each filter.

root_tol
[float] Tolerance in comparing the polynomial roots to the physical solutions. Default = 1e-8

`class model.PSBL_PhotAstromParam2`(*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *q*, *sep*, *alpha*, *b_sff*, *mag_src*, *raL=None*, *decL=None*, *root_tol=1e-08*)

Bases: `PSPL_Param`

Point source binary lens. It has 3 more parameters than PSPL (additional mass term, separation, and angle of approach). Note that this is a STATIC binary lens, i.e. there is no orbital motion.

Attributes

t0
[float] Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE
[float] Einstein crossing time (days).

thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr)

muS_N
[float] Dec Source proper motion (mas/yr)

q
[float] Mass ratio (M2 / M1)

sep
[float] Angular separation of the two lenses (mas)

alpha
[float] Angle made between the binary axis and North; measured in degrees East of North.

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

mag_src
[numpy array or list] Source magnitude, unlensed. One in each filter.

root_tol
[float] Tolerance in comparing the polynomial roots to the physical solutions. Default = 1e-8

`class model.PSBL_PhotAstromParam3`(*t0*, *u0_amp*, *tE*, *log10_thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *q*, *sep*, *alpha*, *b_sff*, *mag_base*, *raL=None*, *decL=None*, *root_tol=1e-08*)

Bases: `PSPL_Param`

Point source binary lens. It has 3 more parameters than PSPL (additional mass term, separation, and angle of approach). Note that this is a STATIC binary lens, i.e. there is no orbital motion.

Attributes

t0
[float] Time of photometric peak, as seen from Earth (MJD.DDD) FIXME: THIS IS NOT RIGHT

u0_amp
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky at closest approach in units of thetaE. Can

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE
[float] Einstein crossing time (days).

log10_thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr)

muS_N
[float] Dec Source proper motion (mas/yr)

q
[float] Mass ratio (M2 / M1)

sep
[float] Angular separation of the two lenses (mas)

alpha
[float] Angle made between the binary axis and North; measured in degrees East of North.

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

$b_s ff = f_S/(f_S + f_L + f_N)$.

This must be passed in as a list or array, with one entry for each photometric filter.

mag_base
[numpy array or list] Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter.

root_tol
[float] Tolerance in comparing the polynomial roots to the physical solutions. Default = 1e-8

`class model.`**`PSBL_PhotAstromParam4`**`(`*t0_com*, *u0_amp_com*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *q*, *sep*, *alpha*, *b_sff*, *mag_src*, *raL=None*, *decL=None*, *root_tol=1e-08*`)`

Bases: `PSPL_Param`

Point source binary lens. It has 3 more parameters than PSPL (additional mass term, separation, and angle of approach). Note that this is a STATIC binary lens, i.e. there is no orbital motion.

Attributes

t0_com
[float] Time of photometric peak, as seen from Earth (MJD.DDD) FIXME: THIS IS NOT RIGHT

u0_amp_com
[float] Angular distance between the source and the binary lens COM on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE
[float] Einstein crossing time (days).

thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr)

muS_N
[float] Dec Source proper motion (mas/yr)

beta
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky (mas).

q
[float] Mass ratio (M2 / M1)

sep
[float] Angular separation of the two lenses (mas)

alpha
[float] Angle made between the binary axis and North; measured in degrees East of North.

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

mag_src
[numpy array or list] Source magnitude, unlensed. One in each filter.

root_tol
[float] Tolerance in comparing the polynomial roots to the physical solutions. Default = 1e-8

`class model.`**`PSBL_PhotAstromParam5`**(*t0_prim*, *u0_amp_prim*, *tE*, *thetaE*, *piS*, *piE_E*, *piEN_piEE*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *q*, *sep*, *alpha*, *b_sff*, *mag_base*, *raL=None*, *decL=None*, *root_tol=1e-08*)

Bases: `PSPL_Param`

Point source binary lens. It has 3 more parameters than PSPL (additional mass term, separation, and angle of approach). Note that this is a STATIC binary lens, i.e. there is no orbital motion.

Attributes

t0_prim
[float] Time of photometric peak, as seen from Earth (MJD.DDD) FIXME: THIS IS NOT RIGHT

u0_amp_prim
[float] Angular distance between the source and the PRIMARY lens on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE
[float] Einstein crossing time (days).

thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr)

muS_N
[float] Dec Source proper motion (mas/yr)

beta
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky (mas).

q
[float] Mass ratio (M2 / M1)

sep
[float] Angular separation of the two lenses (mas)

alpha
[float] Angle made between the binary axis and North; measured in degrees East of North.

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

mag_src
[numpy array or list] Source magnitude, unlensed. One in each filter.

root_tol
[float] Tolerance in comparing the polynomial roots to the physical solutions. Default = 1e-8

`class model.PSBL_PhotAstromParam6`(*t0_prim*, *u0_amp_prim*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *q*, *sep*, *alpha*, *b_sff*, *mag_src*, *raL=None*, *decL=None*, *root_tol=1e-08*)

Bases: `PSPL_Param`

Point source binary lens. It has 3 more parameters than PSPL (additional mass term, separation, and angle of approach). Note that this is a STATIC binary lens, i.e. there is no orbital motion.

Attributes

t0_prim
[float] Time of photometric peak, as seen from Earth (MJD.DDD) FIXME: THIS IS NOT RIGHT

u0_amp_prim
[float] Angular distance between the source and the PRIMARY lens on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE
[float] Einstein crossing time (days).

thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr)

muS_N
[float] Dec Source proper motion (mas/yr)

beta
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky (mas).

q
[float] Mass ratio (M2 / M1)

sep
[float] Angular separation of the two lenses (mas)

alpha
[float] Angle made between the binary axis and North; measured in degrees East of North.

b_sff
[numpy array or list] The ratio of the source flux to the total (source + neighbors + lenses). One for each filter.

mag_src
[numpy array or list] Source magnitude, unlensed. One in each filter.

root_tol
[float] Tolerance in comparing the polynomial roots to the physical solutions. Default = 1e-8

`class model.PSBL_PhotParam1`(*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *q*, *sep*, *phi*, *b_sff*, *mag_src*, *raL=None*, *decL=None*, *root_tol=1e-08*)

Bases: `PSPL_Param`

Point source binary lens, photometry only.

It has 3 more parameters than PSPL_PhotParam1:

- mass ratio
- separation – in units of thetaE
- angle of approach

Note that this is a STATIC binary lens, i.e. there is no orbital motion.

Attributes

t0: float
Time of photometric peak, as seen from Earth [MJD]

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. It can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time. [MJD]

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

q: float
Mass ratio (low-mass / high-mass)

sep: float
Angular separation of the two lenses in units of thetaE where thetaE is defined with the total binary mass.

phi: float
Angle made between the binary axis and the relative proper motion vector, measured in degrees.

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = f_S/(f_S + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src: array or list
Photometric magnitude of the source. This must be passed in as a list or array, with one entry for each photometric filter.

Other Parameters

raL: float
Right ascension of the lens in decimal degrees. Required if calculating with parallax

decL: float
Declination of the lens in decimal degrees. Required if calculating with parallax

root_tol: float

Tolerance in comparing the polynomial roots to the physical solutions.
Default = 0.0

6.3.2 GP Models

class model.**PSBL_GP_PhotParam1**(*t0, u0_amp, tE, piE_E, piE_N, q, sep, phi, b_sff, mag_src, gp_log_sigma, gp_log_rho, gp_log_S0, gp_log_omega0, raL=None, decL=None, root_tol=1e-08*)

Bases: `PSBL_PhotParam1`

class model.**PSBL_GP_PhotAstromParam1**(*mLp, mLs, t0, xS0_E, xS0_N, beta, muL_E, muL_N, muS_E, muS_N, dL, dS, sep, alpha, b_sff, mag_src, gp_log_sigma, gp_log_rho, gp_log_S0, gp_log_omega0, raL=None, decL=None, root_tol=1e-08*)

Bases: `PSBL_PhotAstromParam1`

class model.**PSBL_GP_PhotAstromParam2**(*t0, u0_amp, tE, thetaE, piS, piE_E, piE_N, xS0_E, xS0_N, muS_E, muS_N, q, sep, alpha, b_sff, mag_src, gp_log_sigma, gp_log_rho, gp_log_S0, gp_log_omega0, raL=None, decL=None, root_tol=1e-08*)

Bases: `PSBL_PhotAstromParam2`

CHAPTER

SEVEN

BINARY SOURCE POINT LENS (BSPL) CLASSES

7.1 Parameterization Class Family - BSPL

7.1.1 BSPL Models

`class model.BSPL_PhotParam1`(*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *sep*, *phi*, *mag_src_pri*, *mag_src_sec*, *b_sff*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

BSPL model for photometry only

A Binary point Source Point Lens model for microlensing.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. It can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

Note, since this is a binary source, we are expressing the nominal source position as that of the primary star in the source binary system.

tE: float
Einstein crossing time. [MJD]

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

sep: float
Angular separation of the source scondary from the source primary (in units of thetaE).

phi: float
Angle made between the binary axis and the relative proper motion vector, measured in degrees.

mag_src_pri: array or list
Photometric magnitude of the first (primary) source. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src_sec: array or list
Photometric magnitude of the second (secondary) source. This must be passed in as a list or array, with one entry for each photometric filter.

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_s f f = (f_S 1 + f_S 2)/(f_S 1 + f_s 2 + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

`class model.BSPL_PhotAstromParam1`(*mL*, *t0*, *beta*, *dL*, *dL_dS*, *xS0_E*, *xS0_N*, *muL_E*, *muL_N*, *muS_E*, *muS_N*, *sep*, *alpha*, *mag_src_pri*, *mag_src_sec*, *b_sff*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

BSPL model for astrometry and photometry - physical parameterization.

A Binary point Source Point Lens model for microlensing. This model uses a parameterization that depends on only physical quantities such as the lens mass and positions and proper motions of both the lens and source.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Attributes

mL: float
Mass of the lens (Msun)

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

beta: float
Angular distance between the lens and primary source on the plane of the sky (mas). Can be

- positive (u0_amp > 0 when u0_hat[0] < 0) or
- negative (u0_amp < 0 when u0_hat[0] > 0).

Note, since this is a binary source, we are expressing the nominal source position as that of the primary star in the source binary system.

dL: float
Distance from the observer to the lens (pc)

dL_dS: float
Ratio of Distance from the obersver to the lens to Distance from the observer to the source

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame. This should be the position of the source primary.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame. This should be the position of the source primary.

muL_E: float
RA Lens proper motion (mas/yr)

muL_N: float
Dec Lens proper motion (mas/yr)

muS_E: float
RA Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

muS_N: float
Dec Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

sep: float
Angular separation of the source scondary from the source primary (mas).

alpha: float
Angle made between the binary source axis and North; measured in degrees East of North.

mag_src_pri: array or list
Photometric magnitude of the first (primary) source. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src_sec: array or list
Photometric magnitude of the second (secondary) source. This must be passed in as a list or array, with one entry for each photometric filter.

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_s ff = (f_S 1 + f_S 2)/(f_S 1 + f_s 2 + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

`class model.BSPL_PhotAstromParam2`(*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *sep*, *alpha*, *fratio_bin*, *mag_base*, *b_sff*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

BSPL model for astrometry and photometry - physical parameterization.

A Binary point Source Point Lens model for microlensing. This model uses a parameterization that depends on only physical quantities such as the lens mass and positions and proper motions of both the lens and source.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky at closest approach in units of thetaE. Can

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

Note, since this is a binary source, we are expressing the nominal source position as that of the primary star in the source binary system.

tE
[float] Einstein crossing time (days).

thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame. This should be the position of the source primary.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

muS_N
[float] Dec Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

sep: float
Angular separation of the source scondary from the source primary (mas).

alpha: float
Angle made between the binary source axis and North; measured in degrees East of North.

fratio_bin: float
Flux ratio of secondary flux / primary flux.

mag_base
[array or list] Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter. Note that

$$flux_{base} = f_{src1} + f_{src2} + f_{blend}$$

such that
$b_sff = (f_{src1} + f_{src2})/(f_{src1} + f_{src2} + f_{blend})$

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = (f_{S1} + f_{S2})/(f_{S1} + f_{s2} + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

`class model.`**`BSPL_PhotAstromParam3`**(*t0*, *u0_amp*, *tE*, *log10_thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *sep*, *alpha*, *fratio_bin*, *mag_base*, *b_sff*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

BSPL model for astrometry and photometry - physical parameterization.

A Binary point Source Point Lens model for microlensing. This model uses a parameterization that depends on only physical quantities such as the lens mass and positions and proper motions of both the lens and source.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky at closest approach in units of thetaE. Can

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

Note, since this is a binary source, we are expressing the nominal source position as that of the primary star in the source binary system.

tE
[float] Einstein crossing time (days).

log10_thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame. This should be the position of the source primary.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

muS_N
[float] Dec Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

sep: float
Angular separation of the source scondary from the source primary (mas).

alpha: float
Angle made between the binary source axis and North; measured in degrees East of North.

fratio_bin: float
Flux ratio of secondary flux / primary flux.

mag_base
[array or list] Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter. Note that

$$flux_base = f_{src1+f_{src2+f_{blend}}}$$

such that
$b_sff = (f_{src1} + f_{src2})/(f_{src1} + f_{src2} + f_{blend})$

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = (f_{S1} + f_{S2})/(f_{S1} + f_{s2} + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

7.1.2 GP Models

class model.**BSPL_GP_PhotParam1**(*t0*, *u0_amp*, *tE*, *piE_E*, *piE_N*, *sep*, *phi*, *mag_src_pri*, *mag_src_sec*, *b_sff*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: *BSPL_PhotParam1*

BSPL model for photometry only, with GP.

A Binary point Source Point Lens model for microlensing.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Parameters

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. It can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

Note, since this is a binary source, we are expressing the nominal source position as that of the primary star in the source binary system.

tE: float
Einstein crossing time. [MJD]

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

sep: float
Angular separation of the source scondary from the source primary (in units of thetaE).

phi: float
Angle made between the binary axis and the relative proper motion vector, measured in degrees.

mag_src_pri: array or list
Photometric magnitude of the first (primary) source. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src_sec: array or list
Photometric magnitude of the second (secondary) source. This must be passed in as a list or array, with one entry for each photometric filter.

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = (f_{S1} + f_{S2})/(f_{S1} + f_{s2} + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

gp_log_sigma: float
Guassian process $log(\sigma)$ for the Matern 3/2 kernel.

gp_rho: float
Guassian process ρ for the Matern 3/2 kernel.

gp_log_omega04_S0: float
Guassian process $log(\omega_0^4 * S_0)$ from the SHO kernel.

gp_log_omega0: float
Guassian process $log(\omega_0)$ from the SHO kernel.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

class model.**BSPL_GP_PhotAstromParam1**(*mL*, *t0*, *beta*, *dL*, *dL_dS*, *xS0_E*, *xS0_N*, *muL_E*, *muL_N*, *muS_E*, *muS_N*, *sep*, *alpha*, *mag_src_pri*, *mag_src_sec*, *b_sff*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: *BSPL_PhotAstromParam1*

BSPL model for astrometry and photometry with GP - physical parameterization.

A Binary point Source Point Lens model for microlensing. This model uses a parameterization that depends on only physical quantities such as the lens mass and positions and proper motions of both the lens and source.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Attributes

mL: float
Mass of the lens (Msun)

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

beta: float
Angular distance between the lens and primary source on the plane of the sky (mas). Can be

- positive (u0_amp > 0 when u0_hat[0] < 0) or
- negative (u0_amp < 0 when u0_hat[0] > 0).

Note, since this is a binary source, we are expressing the nominal source position as that of the primary star in the source binary system.

dL: float
Distance from the observer to the lens (pc)

dL_dS: float
Ratio of Distance from the obersver to the lens to Distance from the observer to the source

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame. This should be the position of the source primary.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame. This should be the position of the source primary.

muL_E: float
RA Lens proper motion (mas/yr)

muL_N: float
Dec Lens proper motion (mas/yr)

muS_E: float
RA Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

muS_N: float
Dec Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

sep: float
Angular separation of the source scondary from the source primary (mas).

alpha: float
Angle made between the binary source axis and North; measured in degrees East of North.

mag_src_pri: array or list
Photometric magnitude of the first (primary) source. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src_sec: array or list
Photometric magnitude of the second (secondary) source. This must be passed in as a list or array, with one entry for each photometric filter.

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) $b_sff = (f_{S1} + f_{S2})/(f_{S1} + f_{s2} + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

gp_log_sigma: float
Guassian process $log(\sigma)$ for the Matern 3/2 kernel.

gp_rho: float
Guassian process ρ for the Matern 3/2 kernel.

gp_log_omega04_S0: float
Guassian process $log(\omega_0^4 * S_0)$ from the SHO kernel.

gp_log_omega0: float
Guassian process $log(\omega_0)$ from the SHO kernel.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

`class model.BSPL_GP_PhotAstromParam2(`*t0*, *u0_amp*, *tE*, *thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *sep*, *alpha*, *fratio_bin*, *mag_base*, *b_sff*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*`)`

Bases: *BSPL_PhotAstromParam2*

BSPL model for astrometry and photometry with GP - physical parameterization.

A Binary point Source Point Lens model for microlensing. This model uses a parameterization that depends on only physical quantities such as the lens mass and positions and proper motions of both the lens and source.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp
[float] Angular distance between the source and the GEOMETRIC center of the lenses on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or
- negative (u0_amp < 0 when u0_hat[0] < 0).

Note, since this is a binary source, we are expressing the nominal source position as that of the primary star in the source binary system.

tE
[float] Einstein crossing time (days).

thetaE
[float] The size of the Einstein radius in (mas).

piS
[float] Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E
[float] The microlensing parallax in the East direction in units of thetaE

piE_N
[float] The microlensing parallax in the North direction in units of thetaE

xS0_E
[float] R.A. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame. This should be the position of the source primary.

xS0_N
[float] Dec. of source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E
[float] RA Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

muS_N
[float] Dec Source proper motion (mas/yr) Identical proper motions are assumed for the source primary and secondary.

sep: float
Angular separation of the source scondary from the source primary (mas).

alpha: float
Angle made between the binary source axis and North; measured in degrees East of North.

fratio_bin: float
Flux ratio of secondary flux / primary flux.

mag_base
[array or list] Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter. Note that

$$flux_{base} = f_{src1} + f_{src2} + f_{blend}$$

such that
$$b_{sff} = (f_{src1} + f_{src2})/(f_{src1} + f_{src2} + f_{blend})$$

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) :math:` b_{sff} = (f_{S1} + f_{S2}) / (f_{S1} + f_{s2} + f_L + f_N)`. This must be passed in as a list or array, with one entry for each photometric filter.

gp_log_sigma: float
Guassian process $log(\sigma)$ for the Matern 3/2 kernel.

gp_rho: float
Guassian process ρ for the Matern 3/2 kernel.

gp_log_omega04_S0: float
Guassian process $log(\omega_0^4 * S_0)$ from the SHO kernel.

gp_log_omega0: float
Guassian process $log(\omega_0)$ from the SHO kernel.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

class model.**BSPL_GP_PhotAstromParam3**(*t0*, *u0_amp*, *tE*, *log10_thetaE*, *piS*, *piE_E*, *piE_N*, *xS0_E*, *xS0_N*, *muS_E*, *muS_N*, *sep*, *alpha*, *fratio_bin*, *mag_base*, *b_sff*, *gp_log_sigma*, *gp_rho*, *gp_log_omega04_S0*, *gp_log_omega0*, *raL=None*, *decL=None*)

Bases: *BSPL_PhotAstromParam3*

Point Source Point Lens with GP model for microlensing. This model includes proper motions of the source and the source position on the sky. It is the same as PSPL_PhotAstromParam4 except it fits for log10(thetaE) instead of thetaE.

Attributes

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

u0_amp: float
Angular distance between the lens and source on the plane of the sky at closest approach in units of thetaE. Can be

- positive (u0_amp > 0 when u0_hat[0] > 0) or

- negative (u0_amp < 0 when u0_hat[0] < 0).

tE: float
Einstein crossing time (days).

log10_thetaE: float
log10 of the size of the Einstein radius in (mas).

piS: float
Amplitude of the parallax (1AU/dS) of the source. (mas)

piE_E: float
The microlensing parallax in the East direction in units of thetaE

piE_N: float
The microlensing parallax in the North direction in units of thetaE

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muS_E: float
RA Source proper motion (mas/yr)

muS_N: float
Dec Source proper motion (mas/yr)

sep: float
Angular separation of the source scondary from the source primary (mas).

alpha: float
Angle made between the binary source axis and North; measured in degrees East of North.

fratio_bin: float
Flux ratio of secondary flux / primary flux.

mag_base
[array or list] Photometric magnitude of the base. This must be passed in as a list or array, with one entry for each photometric filter. Note that

$$flux_{base} = f_{src1} + f_{src2} + f_{blend}$$

such that
$$b_{sff} = (f_{src1} + f_{src2})/(f_{src1} + f_{src2} + f_{blend})$$

b_sff: array or list
The ratio of the source flux to the total (source + neighbors + lens) :math:` b_{sff} = (f_{S1} + f_{S2}) / (f_{S1} + f_{s2} + f_L + f_N)`. This must be passed in as a list or array, with one entry for each photometric filter.

gp_log_sigma: float
Guassian process $log(\sigma)$ for the Matern 3/2 kernel.

gp_rho: float
Guassian process ρ for the Matern 3/2 kernel.

gp_log_omega04_S0: float
Guassian process $log(\omega_0^4 * S_0)$ from the SHO kernel.

gp_log_omega0: float
Guassian process $log(\omega_0)$ from the SHO kernel.

7.2 Data Class Family

class model.**BSPL**

Bases: PSPL

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t[, filt_idx])	Parallax: Get the photometric amplification term at a set of times, t.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_u(t)	**Parameters**

get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_photometry	
log_likely_photometry_each	

get_u(*t*)

Parameters

t
[numpy array] Times at which to evaluate the source-lens separation.

Returns

u
[numpy array] Shape = *[len(t), 2 sources, 2 directions on sky]*

get_resolved_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t: Array of times in MJD.DDD

Returns

A_resolved
[numpy array] [shape = len(t), len(sources), 2]

Notes

For each time t and each source, we have:

- A_plus is the amplification for the plus image.
- A_minus is the amplification for the minus image.

In other words,
xS[0, 0, 0] returns the amplification of the first source's "plus" image at the first time.

Similarly,
xS[0, 0, 1] returns the amplification of the first source's "minus" image at the first time.

`get_amplification`(*t*, *filt_idx=0*)

Parallax: Get the photometric amplification term at a set of times, t.

Note that this is a convenience function that combines amplifications from multiple sources. The returned amplification is

..math:

```
A = (f1 * A1 + f2 * A2) / (f1 + f2)
```

where the fluxes are the intrinsic source flux in the specified filter.

Parameters

t: Array of times in MJD.DDD

Returns

A
[numpy array]

Array of combined amplifications in the specified filter.
Shape = [len(t)]

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

class model.**BSPL_Phot**

Bases: *BSPL*, PSPL_Phot

Contains methods for model a BSPL photometry only. This is a Data-type class in our hierarchy. It is abstract and should not be instantiated.

Attributes

t0
tE
u0_amp
u0_E
u0_N
piE_E:
valid only if parallax model

piE_N:
valid only if parallax model

piE_amp
b_sff[#]
mag_src[#]:
add in

mag_base[#]:
add in

raL:
if parallax model

decL:
if parallax model

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t[, filt_idx])	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t[, ast_filt_idx])	Position of the observed (unresolved) source position in Einstein radii.
get_astrometry_unlensed(t[, ast_filt_idx])	Get the astrometry of the source if the lens didn't exist.
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t)	Position of the observed source position in Einstein radii.
get_resolved_astrometry_unlensed(t)	Get the astrometry of the source if the lens didn't exist.
get_u(t)	**Parameters**

get_centroid_shift	
get_chi2_photometry	
get_lens_astrometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_photometry	
log_likely_photometry_each	

`get_resolved_astrometry_unlensed`(*t*)

Get the astrometry of the source if the lens didn't exist. Note, this is a photometry only model, so units are in Einstein radii.

Returns

xS_resolved_unlensed
[numpy array, [shape = len(t_obs), N_sources, 2]] The unlensed positions of the sources in Einstein radii.

In other words,
xS[0, 0, :] returns the 2D sky position of the first source at the first time.

Similarly,
xS[0, 1, :] returns the 2D sky position of the second source at the first time.

`get_astrometry_unlensed`(*t*, *ast_filt_idx=0*)

Get the astrometry of the source if the lens didn't exist. Note, this is a photometry only model, so units are in Einstein radii.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in Einstein radii.

`get_resolved_astrometry`(*t*)

Position of the observed source position in Einstein radii.

Parameters

t
[array_like, shape = [N_times]] Array of times to model.

Returns

model_pos
[array_like. shape = [N_times, N_images, 2]] Array of vector positions of the centroid at each t_obs.

`get_astrometry`(*t*, *ast_filt_idx=0*)

Position of the observed (unresolved) source position in Einstein radii.

Parameters

t: array_like
Array of times to model.

Returns

model_pos
[array_like] Array of vector positions of the centroid at each t_obs.

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*, *filt_idx=0*)

Parallax: Get the photometric amplification term at a set of times, t.

Note that this is a convenience function that combines amplifications from multiple sources. The returned amplification is

..math:

```
A = (f1 * A1 + f2 * A2) / (f1 + f2)
```

where the fluxes are the intrinsic source flux in the specified filter.

Parameters

t: Array of times in MJD.DDD

Returns

A
[numpy array]

Array of combined amplifications in the specified filter.
Shape = [len(t)]

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t: Array of times in MJD.DDD

Returns

A_resolved
[numpy array] [shape = len(t), len(sources), 2]

Notes

For each time t and each source, we have:

- A_plus is the amplification for the plus image.
- A_minus is the amplification for the minus image.

In other words,
xS[0, 0, 0] returns the amplification of the first source's "plus" image at the first time.

Similarly,
xS[0, 0, 1] returns the amplification of the first source's "minus" image at the first time.

`get_u(t)`

Parameters

t
[numpy array] Times at which to evaluate the source-lens separation.

Returns

u
[numpy array] Shape = *[len(t), 2 sources, 2 directions on sky]*

`class model.BSPL_PhotAstrom`

Bases: *BSPL*, `PSPL_PhotAstrom`

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_amplification(t[, filt_idx])	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t[, ast_filt_idx])	Parallax: Get unresolved astrometry for binary source, point lens.
get_astrometry_unlensed(t[, ast_filt_idx])	Get the astrometry of the sources if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t)	Parallax: For each source, get the x, y astrometry for the two lensed source images.
get_resolved_astrometry_unlensed(t)	Get the astrometry of the source if the lens didn't exist.
get_u(t)	**Parameters**

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_photometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

`get_resolved_astrometry_unlensed`(*t*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_resolved_unlensed
[numpy array, [shape = len(t_obs), N_sources, 2]] The unlensed positions of the sources in arcseconds.

In other words,
xS[0, 0, :] returns the 2D sky position of the first source at the first time.

Similarly,
xS[0, 1, :] returns the 2D sky position of the second source at the first time.

`get_astrometry_unlensed`(*t*, *ast_filt_idx=0*)

Get the astrometry of the sources if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2 directions]

The unlensed positions of the combined sources in arcseconds.
Shape = [len(t), 2 directions]

`get_resolved_astrometry`(*t*)

Parallax: For each source, get the x, y astrometry for the two lensed source images. For each source, we label the two images as plus and minus.

Returns

xS_resolved
[numpy array] [shape = len(t), len(sources), 2, 2]

Notes

For each time t and each source, we have:

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the minus image.

In other words,
xS[0, 0, 0, :] returns the 2D sky position of the first source's "plus" image at the first time.

Similarly,
xS[0, 0, 1, :] returns the 2D sky position of the first source's "minus" image at the first time.

`get_astrometry`(*t*, *ast_filt_idx=0*)

Parallax: Get unresolved astrometry for binary source, point lens.

Parameters

t:
Array of times in MJD.DDD

Returns

xS_lensed
Returns flux-weighted average of lensed source positions.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

Returns the flux-weighted centroid of all the sources lensed images.

Parameters

t:
Array of times in MJD.DDD

Returns

centroid_shift
[numpy array] [shape = len(t), 2]

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_amplification`(*t*, *filt_idx=0*)

Parallax: Get the photometric amplification term at a set of times, t.

Note that this is a convenience function that combines amplifications from multiple sources. The returned amplification is

..math:

```
A = (f1 * A1 + f2 * A2) / (f1 + f2)
```

where the fluxes are the intrinsic source flux in the specified filter.

Parameters

t: Array of times in MJD.DDD

Returns

A
[numpy array]

Array of combined amplifications in the specified filter.
Shape = [len(t)]

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t: Array of times in MJD.DDD

Returns

A_resolved
[numpy array] [shape = len(t), len(sources), 2]

Notes

For each time t and each source, we have:

- A_plus is the amplification for the plus image.
- A_minus is the amplification for the minus image.

In other words,
xS[0, 0, 0] returns the amplification of the first source's "plus" image at the first time.

Similarly,
xS[0, 0, 1] returns the amplification of the first source's "minus" image at the first time.

`get_u`(*t*)

Parameters

t
[numpy array] Times at which to evaluate the source-lens separation.

Returns

u
[numpy array] Shape = *[len(t), 2 sources, 2 directions on sky]*

7.3 Parallax Class Family

class model.**BSPL_noParallax**

Bases: PSPL_noParallax

Methods

get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
get_astrometry_unlensed(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	

get_amplification(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_astrometry(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

get_astrometry_unlensed(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

get_centroid_shift(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

get_lens_astrometry(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

get_resolved_amplification(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

class model.**BSPL_Parallax**

Bases: PSPL_Parallax

Methods

calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

start	

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

`get_astrometry`(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

`get_astrometry_unlensed`(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)

Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)

Parallax: Get lens astrometry

`get_resolved_amplification`(*t*)

Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)

Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

CHAPTER

EIGHT

FSPL(FINITE-SOURCE POINT LENS) MODELS - NOT DONE YET... PLACE HOLDERS

8.1 FSPL Classes

class model.**FSPL**

Bases: PSPL

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_source_outline_astrometry(r, n, center)	Return astrometric points that outline the outer circumference of the source star.

get_chi2_photometry	
get_lnL_constant	
log_likely_photometry	
log_likely_photometry_each	

get_source_outline_astrometry(*r*, *n*, *center*)

Return astrometric points that outline the outer circumference of the source star.

The outline is described as a circle of radius self.radius and is evaluated at self.n_outline number of points.

takes in the radius of the circle, centre position and number of points we are approximating the circle by and returns a numpy array of positions

e.g: `( ((1,0), (0,1), (-1,0), (0,-1)) )` if n = 4 and radius = 1

Returns

source_points

[numpy array] Returns an array of `shape = [2, self.n_outline, len(time)]`

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Other Parameters

——–-

amp_arr
[array_like] Amplifications of each individual image at each time, i.e. amp_arr.shape = (len(t_obs), number of images at each t_obs).

This will over-ride t_obs; but is more efficient when calculating both photometry and astrometry. If None, then just use t_obs.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

class model.**FSPL_PhotAstrom**

Bases: `FSPL`, `PSPL_PhotAstrom`

Contains methods for model a PSPL photometry + astrometry. This is a Data-type class in our hierarchy. It is abstract and should not be instantiated.

Attributes

Available class variables that should be defined.
t0
tE
u0_amp
u0_E
u0_N
beta
piE_E:
valid only if parallax model

piE_N:
valid only if parallax model

piE_amp
mL
thetaE_amp
thetaE_E
thetaE_N
xS0_E
xS0_N
xL0_E
xL0_N
muS_E
muS_N
muL_E
muL_N
muRel_E
muRel_N
muRel_amp
piS
piL
dL
dS
dL_dS (dL over dS)
radius
n
b_sff[#]
mag_src[#] – add in
mag_base[#] – add in
raL:
if parallax model

decL:
if parallax model

Methods

animate(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
get_astrometry_unlensed(t)	Outputs position of source unlensed.
get_lens_astrometry(t_obs)	
get_photometry(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_source_outline_astrometry(r, n, center)	Return astrometric points that outline the outer circumference of the source star.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Other Parameters

——-

amp_arr
[array_like] Amplifications of each individual image at each time, i.e. amp_arr.shape = (len(t_obs), number of images at each t_obs).

This will over-ride t_obs; but is more efficient when calculating both photometry and astrometry. If None, then just use t_obs.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_astrometry_unlensed(t)`

Outputs position of source unlensed.

Input a list of times and it will output the position of the source had it not been lensed at each of the times in the list

e.g if `n = 4`, and say `v = [1,0]` & the times are `[0,1,2]` in years.
This will return
`((( (1,0),(0,1),(-1,0),(0,-1) ), ( (2,0),(1,1),(0,0),(1,-1) ), ( (3,0),(2,1),(1,0),(2,-1) ))...`
= (positions at t=0), (positions at t=1), (positions at t=2)

so `np.array(positions)` is an array which contains an array for each time step with the positions of all the points on the boundary of the source.

`get_source_outline_astrometry(r, n, center)`

Return astrometric points that outline the outer circumference of the source star.

The outline is described as a circle of radius self.radius and is evaluated at self.n_outline number of points.

takes in the radius of the circle, centre position and number of points we are approximating the circle by and returns a numpy array of positions

e.g: `( ((1,0), (0,1), (-1,0), (0,-1)) )` if n = 4 and radius = 1

Returns

source_points
[numpy array] Returns an array of `shape = [2, self.n_outline, len(time)]`

`class model.FSPL_noParallax`

Bases: `PSPL_noParallax`

Methods

get_amplification(t)	noParallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
get_astrometry_unlensed(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_lens_astrometry(t_obs)	Equation of motion for just the foreground lens.
get_resolved_amplification(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	

get_amplification(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_astrometry(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

get_astrometry_unlensed(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

get_centroid_shift(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

get_lens_astrometry(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

get_resolved_amplification(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

class model.FSPL_Parallax

Bases: `PSPL_Parallax`

Methods

calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

start	

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_astrometry(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

get_astrometry_unlensed(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)
Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)
Parallax: Get lens astrometry

`get_resolved_amplification`(*t*)
Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)
Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

class `model.FSPL_PhotAstromParam1`(*mL*, *t0*, *beta*, *dL*, *dS*, *xS0_E*, *xS0_N*, *muL_E*, *muL_N*, *muS_E*, *muS_N*, *radius*, *b_sff*, *mag_src*, *n_outline=10*, *raL=None*, *decL=None*)

Bases: `PSPL_Param`

PSPL model for astrometry and photometry - physical parameterization.

A Point Source Point Lens model for microlensing. This model uses a parameterization that depends on only physical quantities such as the lens mass and positions and proper motions of both the lens and source.

Note the attributes, RA (raL) and Dec (decL) are required if you are calculating a model with parallax.

Parameters

mL: float
Mass of the lens (Msun)

t0: float
Time of photometric peak, as seen from Earth (MJD.DDD)

beta: float
Angular distance between the lens and source on the plane of the sky (mas). Can be

- positive (u0_amp > 0 when u0_hat[0] (East component) < 0) or
- negative (u0_amp < 0 when u0_hat[0] (East component) > 0).

dL: float
Distance from the observer to the lens (pc)

dL_dS: float
Ratio of Distance from the obersver to the lens to Distance from the observer to the source

xS0_E: float
RA Source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

xS0_N: float
Dec source position on sky at t = t0 (arcsec) in an arbitrary ref. frame.

muL_E: float
RA Lens proper motion (mas/yr)

muL_N: float
Dec Lens proper motion (mas/yr)

muS_E: float
RA Source proper motion (mas/yr)

muS_N: float
Dec Source proper motion (mas/yr)

radius: float
Projected radius of the star in arcsec on the sky plane.

b_sff: float
The ratio of the source flux to the total (source + neighbors + lens) $b_s ff = f_S/(f_S + f_L + f_N)$. This must be passed in as a list or array, with one entry for each photometric filter.

mag_src: float
Photometric magnitude of the source. This must be passed in as a list or array, with one entry for each photometric filter.

n_outline: int
Number of boundary points to use when approximating the source outline. Calculation time scales approximately linearly with 'n_outline'.

raL: float, optional
Right ascension of the lens in decimal degrees.

decL: float, optional
Declination of the lens in decimal degrees.

`class model.FSPL_PhotAstrom`

Bases: `FSPL`, `PSPL_PhotAstrom`

Contains methods for model a PSPL photometry + astrometry. This is a Data-type class in our hierarchy. It is abstract and should not be instantiated.

Attributes

Available class variables that should be defined.
t0
tE
u0_amp
u0_E
u0_N
beta
piE_E:
valid only if parallax model

piE_N:
valid only if parallax model

piE_amp
mL
thetaE_amp
thetaE_E
thetaE_N
xS0_E
xS0_N
xL0_E
xL0_N
muS_E
muS_N
muL_E
muL_N
muRel_E
muRel_N
muRel_amp
piS
piL
dL
dS
dL_dS (dL over dS)
radius
n
b_sff[#]
mag_src[#] – add in
mag_base[#] – add in
raL:
if parallax model

decL:
if parallax model

Methods

`animate`(tE, time_steps, frame_time, name, ...)	Produces animation of microlensing event.
`get_astrometry_unlensed`(t)	Outputs position of source unlensed.
`get_lens_astrometry`(t_obs)	
`get_photometry`(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
`get_source_outline_astrometry`(r, n, center)	Return astrometric points that outline the outer circumference of the source star.

get_chi2_astrometry	
get_chi2_photometry	
get_lnL_constant	
get_resolved_astrometry	
log_likely_astrometry	
log_likely_astrometry_each	
log_likely_photometry	
log_likely_photometry_each	

`get_photometry`(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Other Parameters

———-

amp_arr
[array_like] Amplifications of each individual image at each time, i.e. amp_arr.shape = (len(t_obs), number of images at each t_obs).

This will over-ride t_obs; but is more efficient when calculating both photometry and astrometry. If None, then just use t_obs.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`animate`(*tE*, *time_steps*, *frame_time*, *name*, *size*, *zoom*, *astrometry*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_astrometry_unlensed`(*t*)

Outputs position of source unlensed.

Input a list of times and it will output the position of the source had it not been lensed at each of the times in the list

e.g if `n = 4`, and say `v = [1,0]` & the times are `[0,1,2]` in years.
This will return

```
((( (1,0),(0,1),(-1,0),(0,-1) ), ( (2,0),(1,1),(0,0),(1,-1) ), (
(3,0),(2,1),(1,0),(2,-1) ))...
```

= (positions at t=0), (positions at t=1), (positions at t=2)

so `np.array(positions)` is an array which contains an array for each time step with the positions of all the points on the boundary of the source.

get_source_outline_astrometry(*r*, *n*, *center*)

Return astrometric points that outline the outer circumference of the source star.

The outline is described as a circle of radius self.radius and is evaluated at self.n_outline number of points.

takes in the radius of the circle, centre position and number of points we are approximating the circle by and returns a numpy array of positions

e.g: `( ((1,0), (0,1), (-1,0), (0,-1)) )` if n = 4 and radius = 1

Returns

source_points
[numpy array] Returns an array of `shape = [2, self.n_outline, len(time)]`

8.2 FSPL Limb Classes

class model.**FSPL_Limb**

Bases: FSPL

Methods

`animate`(crossings, time_steps, frame_time, ...)	Produces animation of microlensing event.
`get_photometry`(t_obs[, filt_idx, amp_arr, ...])	Get the photometry for each of the lensed source images.
get_source_outline_astrometry(r, n, center)	Return astrometric points that outline the outer circumference of the source star.

F	
get_amplification	
get_chi2_photometry	
get_lnL_constant	
log_likely_photometry	
log_likely_photometry_each	

get_photometry(*t_obs*, *filt_idx=0*, *amp_arr=None*, *print_warning=True*)

Get the photometry for each of the lensed source images.

Parameters

t_obs
[array_like] Array of times to model.

Returns

mag_model
[array_like] Magnitude of the centroid at t_obs.

`animate`(*crossings*, *time_steps*, *frame_time*, *name*, *size*, *zoom*)

Produces animation of microlensing event. This function takes the PSPL and makes an animation, the input variables are as follows

Parameters

tE:

number of einstein crossings times before/after the peak you want the animation to plot
e.g tE = 2 => graph will go from -2 tE to 2 tE

time_steps:
number of time steps before/after peak, so total number of time steps will be 2 times this value

frame_time:
times in ms of each frame in the animation

name: string
the animation will be saved as name.html

size: list
[horizontal, vertical] cm's

zoom:
# of einstein radii plotted in vertical direction

`get_source_outline_astrometry`(*r*, *n*, *center*)

Return astrometric points that outline the outer circumference of the source star.

The outline is described as a circle of radius self.radius and is evaluated at self.n_outline number of points.

takes in the radius of the circle, centre position and number of points we are approximating the circle by and returns a numpy array of positions

e.g: `( ((1,0), (0,1), (-1,0), (0,-1)) )` if n = 4 and radius = 1

Returns

source_points
[numpy array] Returns an array of `shape = [2, self.n_outline, len(time)]`

class model.**FSPL_Limb_noParallax**

Bases: `FSPL_noParallax`

Methods

`get_amplification`(t)	noParallax: Get the photometric amplification term at a set of times, t.
`get_astrometry`(t_obs[, ast_filt_idx])	noParallax: Position of the observed source position in arcsec.
`get_astrometry_unlensed`(t_obs)	noParallax: Get the astrometry of the source if the lens didn't exist.
`get_centroid_shift`(t)	noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
`get_lens_astrometry`(t_obs)	Equation of motion for just the foreground lens.
`get_resolved_amplification`(t)	Get the photometric amplification term at a set of times, t for both the plus and minus images.
`get_resolved_astrometry`(t_obs)	Get the x, y astrometry for each of the two source images, which we label plus and minus.

calc_piE_ecliptic	

get_amplification(*t*)

noParallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_astrometry(*t_obs*, *ast_filt_idx=0*)

noParallax: Position of the observed source position in arcsec.

get_astrometry_unlensed(*t_obs*)

noParallax: Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

get_centroid_shift(*t*)

noParallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

get_lens_astrometry(*t_obs*)

Equation of motion for just the foreground lens.

Parameters

t_obs
[array_like] Time (in MJD).

get_resolved_amplification(*t*)

Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

get_resolved_astrometry(*t_obs*)

Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image in arcsec
- xS_minus is the vector position of the plus image in arcsec

class model.**FSPL_Limb_Parallax**

Bases: FSPL_Parallax

Methods

calc_piE_ecliptic()	Parallax: Get piE_ecliptic
get_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t.
get_astrometry(t_obs[, ast_filt_idx])	Parallax: Get astrometry
get_astrometry_unlensed(t_obs)	Get the astrometry of the source if the lens didn't exist.
get_centroid_shift(t[, ast_filt_idx])	Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).
get_geoproj_ast_params(t0par)	
get_geoproj_params(t0par)	
get_lens_astrometry(t_obs)	Parallax: Get lens astrometry
get_resolved_amplification(t)	Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.
get_resolved_astrometry(t_obs)	Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

start	

calc_piE_ecliptic()

Parallax: Get piE_ecliptic

get_amplification(*t*)

Parallax: Get the photometric amplification term at a set of times, t.

Parameters

t:
Array of times in MJD.DDD

get_astrometry(*t_obs*, *ast_filt_idx=0*)

Parallax: Get astrometry

get_astrometry_unlensed(*t_obs*)

Get the astrometry of the source if the lens didn't exist.

Returns

xS_unlensed
[numpy array, dtype=float, shape = len(t_obs) x 2] The unlensed positions of the source in arcseconds.

`get_centroid_shift`(*t*, *ast_filt_idx=0*)
Parallax: Get the centroid shift (in mas) for a list of observation times (in MJD).

`get_lens_astrometry`(*t_obs*)
Parallax: Get lens astrometry

`get_resolved_amplification`(*t*)
Parallax: Get the photometric amplification term at a set of times, t for both the plus and minus images.

Parameters

t:
Array of times in MJD.DDD

`get_resolved_astrometry`(*t_obs*)
Parallax: Get the x, y astrometry for each of the two source images, which we label plus and minus.

Returns

[xS_plus, xS_minus]
[list of numpy arrays]

- xS_plus is the vector position of the plus image.
- xS_minus is the vector position of the plus image.

class model.**FSPL_Limb_PhotAstromParam1**(*lens_mass*, *t0*, *xS0*, *beta*, *muL*, *muS*, *dL*, *dS*, *n*, *radius*, *utilde*, *nr*, *mag_src*)

Bases: `PSPL_Param`

CHAPTER NINE

GENERAL USE AND SHARED FUNCTIONS

9.1 Shared Functions

`model.`**`u0_hat_from_thetaE_hat`**(*thetaE_hat*, *beta*)

Calculate the closest approach vector direction. Define the beta sign convention as Andy Gould does with

- beta > 0 means u0_E > 0
- u0_amp > 0 mean u0_E > 0

See *Gould 2004, pg 320, bottom right*

u0 > 0 –> lens passes to the right side of the source as seen from Earth

$thetaX0 = xS0 - xL0 = u0 * thetaE$

which implies that:

- u0_E > 0 for u0 > 0
- u0_E < 0 for u0 < 0

which is what we use.

`model.`**`parallax_in_direction`**(*RA*, *Dec*, *mjd*)

Memoized version of parallax_in_direction(RA, Dec, mjd)

R.A. in degrees. (J2000)
Dec. in degrees. (J2000)
MJD

Equations following MulensModel.

`model.`**`dparallax_dt_in_direction`**(*RA*, *Dec*, *mjd*)

R.A. in degrees. (J2000) Dec. in degrees. (J2000) MJD

Equations following MulensModel. Time derivative –> units are yr^-1

`model.`**`sun_position`**(*mjd*, *radians=False*)

NAME:
SUNPOS

PURPOSE:
To compute the RA and Dec of the Sun at a given date.

INPUTS:
mjd - The modified Julian date of the day (and time), scalar or vector

OUTPUTS:

ra:

The right ascension of the sun at that date in DEGREES

double precision, same number of elements as jd

dec:
The declination of the sun at that date in DEGREES

elong:
Ecliptic longitude of the sun at that date in DEGREES.

obliquity:
the obliquity of the ecliptic, in DEGREES

OPTIONAL INPUT KEYWORD:
RADIAN [def=False] - If this keyword is set to True, then all output variables are given in Radians rather than Degrees

NOTES:
Patrick Wallace (Rutherford Appleton Laboratory, UK) has tested the accuracy of a C adaptation of the sunpos.pro code and found the following results. From 1900-2100 SUNPOS gave 7.3 arcsec maximum error, 2.6 arcsec RMS. Over the shorter interval 1950-2050 the figures were 6.4 arcsec max, 2.2 arcsec RMS.

The returned RA and Dec are in the given date's equinox.

Procedure was extensively revised in May 1996, and the new calling sequence is incompatible with the old one.

METHOD:
Uses a truncated version of Newcomb's Sun. Adapted from the IDL routine SUN_POS by CD Pike, which was adapted from a FORTRAN routine by B. Emerson (RGO).

EXAMPLE:

(1) Find the apparent RA and Dec of the Sun on May 1, 1982

IDL> jdcnv, 1982, 5, 1,0 ,jd ;Find Julian date jd = 2445090.5

IDL> sunpos, jd, ra, dec

IDL> print,adstring(ra,dec,2)

02 31 32.61 +14 54 34.9

The Astronomical Almanac gives 02 31 32.58 +14 54 34.9 so the error in SUNPOS for this case is < 0.5".

(2) Find the apparent RA and Dec of the Sun for every day in 1997

IDL> jdcnv, 1997,1,1,0, jd ;Julian date on Jan 1, 1997

IDL> sunpos, jd+ dindgen(365), ra, dec ;RA and Dec for each day

MODIFICATION HISTORY:

- Written by Michael R. Greason, STX, 28 October 1988.
- Accept vector arguments, W. Landsman - April,1989
- Eliminated negative right ascensions - MRG, Hughes STX, 6 May 1992.
- Rewritten using the 1993 Almanac. Keywords added. MRG, HSTX, 10 February 1994.
- Major rewrite, improved accuracy, always return values in degrees - W. Landsman May, 1996
- Added /RADIAN keyword; W. Landsman; August, 1997
- Converted to IDL V5.0; W. Landsman; September 1997
- Converted to python; J. R. Lu; August 2016

model.**get_angular_einstein_radius**(*m*, *d1*, *d2*)

model.**get_unit_vector**(*x*)

model.**get_u0**(*thetaE_hat*, *beta*, *thetaE_amp*)

model.**get_uhat**(*thetaE_hat*, *beta*)

model.**get_einstein_time**(*theta*, *v*, *days*)

model.**get_thetas**(*source*, *lens*)

model.**get_amplitudes**(*vectors*)

model.**get_unit_vectors**(*vectors*)

model.**get_plus**(*amps*, *hats*, *pos*, *lens*, *radius*)

model.**get_minus**(*amps*, *hats*, *pos*, *lens*, *radius*)

model.**oned_int**(*centre*, *function1*, *function2*, *ymax*, *ymin*, *n*, *x*, *middle*, *centres*)

model.**twod_int**(*centre*, *function1*, *function2*, *xmax*, *xmin*, *ymax*, *ymin*, *nx*, *ny*, *middle*, *centres*)

model.**twod_cent_x_int**(*centre*, *function1*, *function2*, *xmax*, *xmin*, *ymax*, *ymin*, *nx*, *ny*, *middle*, *centres*)

model.**oned_x_int**(*centre*, *function1*, *function2*, *ymax*, *ymin*, *n*, *x*, *middle*, *centres*)

model.**twod_cent_y_int**(*centre*, *function1*, *function2*, *xmax*, *xmin*, *ymax*, *ymin*, *nx*, *ny*, *middle*, *centres*)

model.**oned_y_int**(*centre*, *function1*, *function2*, *ymax*, *ymin*, *n*, *x*, *middle*, *centres*)

model.**get_image**(*y0*, *m1*, *d*, *R*)

Function to find the images of the star

Parameters

y0:
position of the cente of the source star, in units of anguler Einstein radius

m1:
Mass of rightmost lens divided by the total mass

d:
separation of the lenses in angular Einstein radii

R:
angular radius of the source in angular Einstein radii

CHAPTER

TEN

MODEL FITTER

10.1 PSPL_Solver

class model_fitter.**PSPL_Solver**(*data*, *model_class*, *custom_additional_param_names=None*, *add_error_on_photometry=False*, *multiply_error_on_photometry=False*, *use_phot_optional_params=True*, *use_ast_optional_params=True*, *wrapped_params=None*, *importance_nested_sampling=False*, *multimodal=True*, *const_efficiency_mode=False*, *n_live_points=300*, *evidence_tolerance=0.5*, *sampling_efficiency=0.8*, *n_iter_before_update=100*, *null_log_evidence=-1e+90*, *max_modes=100*, *mode_tolerance=-1e+90*, *outputfiles_basename='chains/1-'*, *seed=-1*, *verbose=False*, *resume=False*, *context=0*, *write_output=True*, *log_zero=-1e+100*, *max_iter=0*, *init_MPI=False*, *dump_callback='default'*)

Bases: `Solver`

A PyMultiNest solver to find the optimal PSPL parameters, given data and a microlensing model from model.py. DESPITE THE NAME YOU CAN ALSO USE IT TO FIT PSBL!

Examples

Assuming that a data dictionary has been instantiated with the above keys, and that a model has been loaded in from model.py, PSPL_Solver can be run with the following commands: .. code:

```
fitter = PSPL_Solver(data,
                     PSPL_PhotAstrom_Par_Param1,
                     add_error_on_photometry=True,
                     custom_additional_param_names=['dS', 'tE'],
                     outputfiles_basename='./model_output/test_')
fitter.solve()
```

Attributes

data

[dictionary] Observational data used to fit a microlensing model. What the data must contain depends on what type of microlensing model you are solving for.

The data dictionary must always photometry information of at least one filter. This data must contain the times, magnitudes, and magnitude errors of the observations. The keys to these arrays are:

- *t_phot1* (MJD)

- *mag1* (magnitudes)
- *mag_err1* (magnitudes)

PSPL_Solver supports multiple photometric filters. For each additional filter, increments the extension of the above keys by one. For example, a second filter would be:

- *t_phot2* (MJD)
- *mag2* (magnitudes)
- *mag_err2* (magnitudes)

PSPL_Solver supports solving microlensing models that calculate with parallax. These models must be accompanied with data that contains the right ascenscion and declination of the target. These keys are:

- *raL* (decimal degrees)
- *decL* (decimal degrees)

PSPL_Solver supports solving microlensing models that fit astrometry. These models must be accompanied with data that contains astrometric observations in the following keys:

- *t_ast* (MJD)
- *xpos* (arcsec along East-West increasing to the East)
- *ypos* (arcsec along the North-South increasing to the North)
- *xpos_err* (arcsec)
- *ypos_err* (arcsec)

model_class
PSPL_Solver must be provided with the microlensing model that you are trying to fit to your data. These models are written out in model.py, along with extensive documentation as to their content and construction in the file's docstring. The model can support either

1. photometric data or photometric and astrometric data,
2. parallax or no parallax, and
3. different parameterizations of the model.

For example, a model with accepts both astrometric and photometric data, uses parallax, and uses a parameterization that includes the distance to the source and the lens is: *PSPL_PhotAstrom_Par_Param1*.

custom_additional_param_names
[list, optional] If provided, the fitter will override the default *additional_param_names* of the model_class. These are the parameters, besides those that are being fitted for, that are written out to disk for posterior plotting after the fit has completed. To see the default additional_param_names run:

print(model_class.additional _param_names)

add_error_on_photometry
[boolean, optional] If set to True, the fitter will fit for an additive error to the photometric magnitudes in the fitting process. This error will have the name *add_errN*, with an *N* equal to the filter number.

multiply_error_on_photometry
[boolean, optional] If set to True, the fitter will fit for a multiplicative error to the photometric

magnitudes in the fitting process. This error will have the name *mult_errN*, with an *N* equal to the filter number.

All other parameters

See pymultinest.run() for a description of all other parameters.

Methods

`LogLikelihood`(cube[, ndim, n_params])	This is just a wrapper because PyMultinest requires passing in the ndim and nparams.
`Prior`(cube[, ndim, nparams])	
`Prior_from_post`(cube[, ndim, nparams])	Get the bin midpoints
`calc_best_fit`(tab, smy[, s_idx, def_best])	Returns best-fit parameters, where best-fit can be median, maxl, or MAP.
`calc_chi2`([params, verbose])	**Parameters**
`calc_chi2_manual`([params, verbose])	**Parameters**
`get_best_fit`([def_best])	Returns best-fit parameters, where best-fit can be median, maxl, or MAP.
`get_best_fit_model`([def_best])	Identify best-fit model
`get_best_fit_modes`([def_best])	Returns a list of best-fit parameters, where best-fit can be median, maxl, or MAP.
`load_mnest_modes`([remake_fits])	Load up the separate modes results into an astropy table.
`load_mnest_modes_results_for_dynesty`([...])	Make a Dynesty-style results object that can be used in the nicer plotting codes.
`load_mnest_results`([remake_fits])	Load up the MultiNest results into an astropy table.
`load_mnest_results_for_dynesty`([remake_fits])	Make a Dynesty-style results object that can be used in the nicer plotting codes.
`load_mnest_summary`([remake_fits])	Load up the MultiNest results into an astropy table.
`log_likely`(cube[, verbose])	**Parameters**
`make_default_priors`()	Setup our prior distributions (i.e.
`plot_dynesty_style`([sim_vals, fit_vals, ...])	**Parameters**
`plot_model_and_data`(model[, input_model, ...])	Make and save the model and data plots.
`plot_model_and_data_modes`([def_best])	Plots photometry data, along with n random draws from the posterior.
`print_likelihood`([params, verbose])	**Parameters**
`sample_post`(binmids, cdf, bininds)	Randomly sample from a multinest posterior distribution.
`separate_modes`()	Reads in the fits for the different modes (post_separate.dat) and splits it into a .dat file per mode.
`solve`()	Run a MultiNest fit to find the optimal parameters (and their posteriors) given the data.
`write_params_yaml`()	Write a YAML file that contains the parameters to re-initialize this object, if desired.

Prior_copy	
callback_plotter	
check_data	
dyn_log_likely	
dyn_prior	
get_best_fit_modes_model	
get_model	
get_modified_mag_err	
log_likely_astrometry	
log_likely_photometry	
setup_params	
summarize_results	
summarize_results_modes	
write_summary_maxL	

`make_default_priors()`

Setup our prior distributions (i.e. random samplers). We will draw from these in the Prior() function. We set them up in advance because they depend on properties of the data. Also, they can be over-written by custom priors as desired.

To make your own custom priors, use the make_gen() functions with different limits.

`Prior_from_post`(*cube*, *ndim=None*, *nparams=None*)

Get the bin midpoints

`sample_post`(*binmids*, *cdf*, *bininds*)

Randomly sample from a multinest posterior distribution.

Parameters

Nparams:
number of parameters

Nbins:
number of histogram bins per dimension

Nnzero:
number of histogram bins with non-zero probability

binmids
[list of length N, each list entry is an array of shape (M,)] The centers of the bins for each parameter

cdf
[(Nnzero,) array] CDF of the distribution. Only the non-zero probability entries.

bininds
[(Nnzero, Nparams) array] Histogram indices of the non-zero probability entries.

`LogLikelihood`(*cube*, *ndim=None*, *n_params=None*)

This is just a wrapper because PyMultinest requires passing in the ndim and nparams.

`log_likely`(*cube*, *verbose=False*)

Parameters

cube
[list or dict] The dictionary or cube of the model parameters.

`write_params_yaml()`

Write a YAML file that contains the parameters to re-initialize this object, if desired.

`solve()`

Run a MultiNest fit to find the optimal parameters (and their posteriors) given the data.

Note we will ALWAYS tell multinest to be verbose.

`separate_modes()`

Reads in the fits for the different modes (post_separate.dat) and splits it into a .dat file per mode.

Is there a more intelligent way to deal with all the indices??? Write better later, but it seems to work for now...

`calc_best_fit`(*tab*, *smy*, *s_idx=0*, *def_best='maxl'*)

Returns best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If best-fit is median, then also return +/- 1 sigma uncertainties.

If best-fit is MAP, then also need to indicate which row of summary table to use. Default is *s_idx = 0* (global solution). *s_idx = 1, 2, ... , n* for the n different modes.

tab = self.load_mnest_results() smy = self.load_mnest_summary()

`get_best_fit`(*def_best='maxl'*)

Returns best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If def_best is median, then also return +/- 1 sigma uncertainties.

Returns

Either a dicitonary or a tuple of length=2 holding
two dictionaries, one for values and one for uncertainty ranges.
See calc_best_fit() for details.

`get_best_fit_modes`(*def_best='maxl'*)

Returns a list of best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If def_best is median, then also return +/- 1 sigma uncertainties.

Returns

Either a list of dicitonaries or a list where each entry is
a tuple of length=2 holding two dictionaries, one for values
and one for uncertainty ranges.
See calc_best_fit() for details.

`get_best_fit_model`(*def_best='maxl'*)

Identify best-fit model

Parameters

def_best
[str] Choices are 'map' (maximum a posteriori), 'median', or 'maxl' (maximum likelihood)

`load_mnest_results`(*remake_fits=False*)

Load up the MultiNest results into an astropy table.

`load_mnest_summary`(*remake_fits=False*)

Load up the MultiNest results into an astropy table.

`load_mnest_modes`(*remake_fits=False*)

Load up the separate modes results into an astropy table.

`load_mnest_results_for_dynesty`(*remake_fits=False*)

Make a Dynesty-style results object that can be used in the nicer plotting codes.

`load_mnest_modes_results_for_dynesty`(*remake_fits=False*)

Make a Dynesty-style results object that can be used in the nicer plotting codes.

`plot_dynesty_style`(*sim_vals=None*, *fit_vals=None*, *remake_fits=False*, *dims=None*, *traceplot=True*, *cornerplot=True*, *kde=True*)

Parameters

sim_vals
[dict] Dictionary of simulated input or comparison values to overplot on posteriors.

fit_vals
[str] Choices are 'map' (maximum a posteriori), 'mean', or 'maxl' (maximum likelihood)

`plot_model_and_data`(*model*, *input_model=None*, *mnest_results=None*, *suffix=''*, *zoomx=None*, *zoomy=None*, *zoomy_res=None*, *fitter=None*, *N_traces=50*)

Make and save the model and data plots.

zoomx, xoomy, zoomy_res : list the same length as *self.n_phot_sets* Each entry of the list is a list *[a, b]* cooresponding to the plot limits

`plot_model_and_data_modes`(*def_best='maxl'*)

Plots photometry data, along with n random draws from the posterior.

`print_likelihood`(*params='best'*, *verbose=True*)

Parameters

model_params
[str or dict, optional]

model_params = 'best' will load up the best solution and calculate
the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

`calc_chi2`(*params='best'*, *verbose=False*)

Parameters

params
[str or dict, optional] model_params = 'best' will load up the best solution and calculate the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

`calc_chi2_manual`(*params='best'*, *verbose=False*)

Parameters

params
[str or dict, optional] model_params = 'best' will load up the best solution and calculate the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

class model_fitter.**PSPL_Solver_weighted**(*data*, *model_class*, *custom_additional_param_names=None*, *add_error_on_photometry=False*, *multiply_error_on_photometry=False*, *use_phot_optional_params=True*, *use_ast_optional_params=True*, *wrapped_params=None*, *importance_nested_sampling=False*, *multimodal=True*, *const_efficiency_mode=False*, *n_live_points=300*, *evidence_tolerance=0.5*, *sampling_efficiency=0.8*, *n_iter_before_update=100*, *null_log_evidence=-1e+90*, *max_modes=100*, *mode_tolerance=-1e+90*, *outputfiles_basename='chains/1-'*, *seed=-1*, *verbose=False*, *resume=False*, *context=0*, *write_output=True*, *log_zero=-1e+100*, *max_iter=0*, *init_MPI=False*, *dump_callback=None*, *weights='phot_ast_equal'*)

Bases: `PSPL_Solver`

Soliver where the likelihood function has each data set weigthed equally (i.e. not the natural weighting by the number of points; but rather each contributes 1/n_k where n is the number of data points and k is the data set.

Methods

LogLikelihood(cube[, ndim, n_params])	This is just a wrapper because PyMultinest requires passing in the ndim and nparams.
Prior(cube[, ndim, nparams])	
Prior_from_post(cube[, ndim, nparams])	Get the bin midpoints
calc_best_fit(tab, smy[, s_idx, def_best])	Returns best-fit parameters, where best-fit can be median, maxl, or MAP.
calc_chi2([params, verbose])	**Parameters**
calc_chi2_manual([params, verbose])	**Parameters**
calc_weights(weights)	order of weight_arr is `[phot_1, phot_2, .
get_best_fit([def_best])	Returns best-fit parameters, where best-fit can be median, maxl, or MAP.
get_best_fit_model([def_best])	Identify best-fit model
get_best_fit_modes([def_best])	Returns a list of best-fit parameters, where best-fit can be median, maxl, or MAP.
load_mnest_modes([remake_fits])	Load up the separate modes results into an astropy table.
load_mnest_modes_results_for_dynesty([...])	Make a Dynesty-style results object that can be used in the nicer plotting codes.
load_mnest_results([remake_fits])	Load up the MultiNest results into an astropy table.
load_mnest_results_for_dynesty([remake_fits])	Make a Dynesty-style results object that can be used in the nicer plotting codes.
load_mnest_summary([remake_fits])	Load up the MultiNest results into an astropy table.
log_likely(cube[, verbose])	**Parameters**
make_default_priors()	Setup our prior distributions (i.e.
plot_dynesty_style([sim_vals, fit_vals, ...])	**Parameters**
plot_model_and_data(model[, input_model, ...])	Make and save the model and data plots.
plot_model_and_data_modes([def_best])	Plots photometry data, along with n random draws from the posterior.
print_likelihood([params, verbose])	**Parameters**
sample_post(binmids, cdf, bininds)	Randomly sample from a multinest posterior distribution.
separate_modes()	Reads in the fits for the different modes (post_separate.dat) and splits it into a .dat file per mode.
solve()	Run a MultiNest fit to find the optimal parameters (and their posteriors) given the data.
write_params_yaml()	Write a YAML file that contains the parameters to re-initialize this object, if desired.

Prior_copy	
callback_plotter	
check_data	
dyn_log_likely	
dyn_prior	
get_best_fit_modes_model	
get_model	
get_modified_mag_err	
log_likely_astrometry	
log_likely_photometry	
setup_params	
summarize_results	
summarize_results_modes	
write_summary_maxL	

`calc_weights`(*weights*)

order of weight_arr is *[phot_1, phot_2, … phot_n, ast_1, ast_2, … ast_n]*

`LogLikelihood`(*cube*, *ndim=None*, *n_params=None*)

This is just a wrapper because PyMultinest requires passing in the ndim and nparams.

`Prior_from_post`(*cube*, *ndim=None*, *nparams=None*)

Get the bin midpoints

`calc_best_fit`(*tab*, *smy*, *s_idx=0*, *def_best='maxl'*)

Returns best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If best-fit is median, then also return +/- 1 sigma uncertainties.

If best-fit is MAP, then also need to indicate which row of summary table to use. Default is *s_idx = 0* (global solution). *s_idx = 1, 2, … , n* for the n different modes.

tab = self.load_mnest_results() smy = self.load_mnest_summary()

`calc_chi2`(*params='best'*, *verbose=False*)

Parameters

params
[str or dict, optional] model_params = 'best' will load up the best solution and calculate the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

`calc_chi2_manual`(*params='best'*, *verbose=False*)

Parameters

params
[str or dict, optional] model_params = 'best' will load up the best solution and calculate the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

`get_best_fit`(*def_best='maxl'*)

Returns best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If def_best is median, then also return +/- 1 sigma uncertainties.

Returns

Either a dicitonary or a tuple of length=2 holding
two dictionaries, one for values and one for uncertainty ranges.
See calc_best_fit() for details.

`get_best_fit_model`(*def_best='maxl'*)

Identify best-fit model

Parameters

def_best
[str] Choices are 'map' (maximum a posteriori), 'median', or 'maxl' (maximum likelihood)

`get_best_fit_modes`(*def_best='maxl'*)

Returns a list of best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If def_best is median, then also return +/- 1 sigma uncertainties.

Returns

Either a list of dicitonaries or a list where each entry is
a tuple of length=2 holding two dictionaries, one for values
and one for uncertainty ranges.
See calc_best_fit() for details.

`load_mnest_modes`(*remake_fits=False*)

Load up the separate modes results into an astropy table.

`load_mnest_modes_results_for_dynesty`(*remake_fits=False*)

Make a Dynesty-style results object that can be used in the nicer plotting codes.

`load_mnest_results`(*remake_fits=False*)

Load up the MultiNest results into an astropy table.

`load_mnest_results_for_dynesty`(*remake_fits=False*)

Make a Dynesty-style results object that can be used in the nicer plotting codes.

`load_mnest_summary`(*remake_fits=False*)

Load up the MultiNest results into an astropy table.

`log_likely`(*cube*, *verbose=False*)

Parameters

cube
[list or dict] The dictionary or cube of the model parameters.

`make_default_priors`()

Setup our prior distributions (i.e. random samplers). We will draw from these in the Prior() function. We set them up in advance because they depend on properties of the data. Also, they can be over-written by custom priors as desired.

To make your own custom priors, use the make_gen() functions with different limits.

`plot_dynesty_style`(*sim_vals=None*, *fit_vals=None*, *remake_fits=False*, *dims=None*, *traceplot=True*, *cornerplot=True*, *kde=True*)

Parameters

sim_vals
[dict] Dictionary of simulated input or comparison values to overplot on posteriors.

fit_vals
[str] Choices are 'map' (maximum a posteriori), 'mean', or 'maxl' (maximum likelihood)

`plot_model_and_data`(*model*, *input_model=None*, *mnest_results=None*, *suffix=''*, *zoomx=None*, *zoomy=None*, *zoomy_res=None*, *fitter=None*, *N_traces=50*)

Make and save the model and data plots.

zoomx, xoomy, zoomy_res : list the same length as *self.n_phot_sets* Each entry of the list is a list *[a, b]* cooresponding to the plot limits

`plot_model_and_data_modes`(*def_best='maxl'*)

Plots photometry data, along with n random draws from the posterior.

`print_likelihood`(*params='best'*, *verbose=True*)

Parameters

model_params
[str or dict, optional]

model_params = 'best' will load up the best solution and calculate
the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

`sample_post`(*binmids*, *cdf*, *bininds*)

Randomly sample from a multinest posterior distribution.

Parameters

Nparams:
number of parameters

Nbins:
number of histogram bins per dimension

Nnzero:
number of histogram bins with non-zero probability

binmids
[list of length N, each list entry is an array of shape (M,)] The centers of the bins for each parameter

cdf
[(Nnzero,) array] CDF of the distribution. Only the non-zero probability entries.

bininds
[(Nnzero, Nparams) array] Histogram indices of the non-zero probability entries.

`separate_modes`()

Reads in the fits for the different modes (post_separate.dat) and splits it into a .dat file per mode.

Is there a more intelligent way to deal with all the indices??? Write better later, but it seems to work for now…

`solve`()

Run a MultiNest fit to find the optimal parameters (and their posteriors) given the data.

Note we will ALWAYS tell multinest to be verbose.

`write_params_yaml`()

Write a YAML file that contains the parameters to re-initialize this object, if desired.

class model_fitter.**PSPL_Solver_Hobson_Weighted**(*data*, *model_class*, *custom_additional_param_names=None*, *add_error_on_photometry=False*, *multiply_error_on_photometry=False*, *use_phot_optional_params=True*, *use_ast_optional_params=True*, *wrapped_params=None*, *importance_nested_sampling=False*, *multimodal=True*, *const_efficiency_mode=False*, *n_live_points=300*, *evidence_tolerance=0.5*, *sampling_efficiency=0.8*, *n_iter_before_update=100*, *null_log_evidence=-1e+90*, *max_modes=100*, *mode_tolerance=-1e+90*, *outputfiles_basename='chains/1-'*, *seed=-1*, *verbose=False*, *resume=False*, *context=0*, *write_output=True*, *log_zero=-1e+100*, *max_iter=0*, *init_MPI=False*, *dump_callback='default'*)

Bases: `PSPL_Solver`

Methods

LogLikelihood(cube[, ndim, n_params])	This is just a wrapper because PyMultinest requires passing in the ndim and nparams.
Prior(cube[, ndim, nparams])	
Prior_from_post(cube[, ndim, nparams])	Get the bin midpoints
calc_best_fit(tab, smy[, s_idx, def_best])	Returns best-fit parameters, where best-fit can be median, maxl, or MAP.
calc_chi2([params, verbose])	**Parameters**
calc_chi2_manual([params, verbose])	**Parameters**
get_best_fit([def_best])	Returns best-fit parameters, where best-fit can be median, maxl, or MAP.
get_best_fit_model([def_best])	Identify best-fit model
get_best_fit_modes([def_best])	Returns a list of best-fit parameters, where best-fit can be median, maxl, or MAP.
get_hobson_effective_weights(cube)	Return the effective weights, alpha_k, for each data set.
hobson_weight_log_likely(ln_prob_dk_giv_ak_1)	Implement a data-set-specific weighting scheme by using a hyperparameter, alpha_k, for the kth data set as described in Hobson et al. 2002.
load_mnest_modes([remake_fits])	Load up the separate modes results into an astropy table.
load_mnest_modes_results_for_dynesty([...])	Make a Dynesty-style results object that can be used in the nicer plotting codes.
load_mnest_results([remake_fits])	Load up the MultiNest results into an astropy table.
load_mnest_results_for_dynesty([remake_fits])	Make a Dynesty-style results object that can be used in the nicer plotting codes.
load_mnest_summary([remake_fits])	Load up the MultiNest results into an astropy table.
log_likely(cube[, verbose])	Compute a log-likelihood where there is a hyperparameter, alpha_k, that controls the weighting between each data k set.
make_default_priors()	Setup our prior distributions (i.e.
plot_dynesty_style([sim_vals, fit_vals, ...])	**Parameters**
plot_model_and_data(model[, input_model, ...])	Make and save the model and data plots.
plot_model_and_data_modes([def_best])	Plots photometry data, along with n random draws from the posterior.
print_likelihood([params, verbose])	**Parameters**
sample_post(binmids, cdf, bininds)	Randomly sample from a multinest posterior distribution.
separate_modes()	Reads in the fits for the different modes (post_separate.dat) and splits it into a .dat file per mode.
solve()	Run a MultiNest fit to find the optimal parameters (and their posteriors) given the data.
write_params_yaml()	Write a YAML file that contains the parameters to re-initialize this object, if desired.

Prior_copy	
callback_plotter	
check_data	
dyn_log_likely	
dyn_prior	
get_best_fit_modes_model	
get_model	
get_modified_mag_err	
log_likely_astrometry	
log_likely_photometry	
setup_params	
summarize_results	
summarize_results_modes	
write_summary_maxL	

`log_likely`(*cube*, *verbose=False*)

Compute a log-likelihood where there is a hyperparameter, alpha_k, that controls the weighting between each data k set. This algorithm is described in Hobson et al. 2002.

Specifically, we are implementing Eq. 35.

Parameters

cube
[list or dict] The dictionary or cube of the model parameters.

`hobson_weight_log_likely`(*ln_prob_dk_giv_ak_1*)

Implement a data-set-specific weighting scheme by using a hyperparameter, alpha_k, for the kth data set as described in Hobson et al. 2002.

Specifically, we are implementing Eq. 16 and 23-27, with the prior described in Eq. 21.

We are not using the simplifications in Section 5 for now.

`get_hobson_effective_weights`(*cube*)

Return the effective weights, alpha_k, for each data set. Photometry first, then astrometry.

`LogLikelihood`(*cube*, *ndim=None*, *n_params=None*)

This is just a wrapper because PyMultinest requires passing in the ndim and nparams.

`Prior_from_post`(*cube*, *ndim=None*, *nparams=None*)

Get the bin midpoints

`calc_best_fit`(*tab*, *smy*, *s_idx=0*, *def_best='maxl'*)

Returns best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If best-fit is median, then also return +/- 1 sigma uncertainties.

If best-fit is MAP, then also need to indicate which row of summary table to use. Default is *s_idx = 0* (global solution). *s_idx = 1, 2, … , n* for the n different modes.

tab = self.load_mnest_results() smy = self.load_mnest_summary()

`calc_chi2`(*params='best'*, *verbose=False*)

Parameters

params
[str or dict, optional] model_params = 'best' will load up the best solution and calculate the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

`calc_chi2_manual`(*params='best'*, *verbose=False*)

Parameters

params
[str or dict, optional] model_params = 'best' will load up the best solution and calculate the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

`get_best_fit`(*def_best='maxl'*)

Returns best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If def_best is median, then also return +/- 1 sigma uncertainties.

Returns

Either a dicitonary or a tuple of length=2 holding
two dictionaries, one for values and one for uncertainty ranges.
See calc_best_fit() for details.

`get_best_fit_model`(*def_best='maxl'*)

Identify best-fit model

Parameters

def_best
[str] Choices are 'map' (maximum a posteriori), 'median', or 'maxl' (maximum likelihood)

`get_best_fit_modes`(*def_best='maxl'*)

Returns a list of best-fit parameters, where best-fit can be median, maxl, or MAP. Default is maxl.

If def_best is median, then also return +/- 1 sigma uncertainties.

Returns

Either a list of dicitonaries or a list where each entry is
a tuple of length=2 holding two dictionaries, one for values
and one for uncertainty ranges.
See calc_best_fit() for details.

`load_mnest_modes`(*remake_fits=False*)

Load up the separate modes results into an astropy table.

`load_mnest_modes_results_for_dynesty`(*remake_fits=False*)

Make a Dynesty-style results object that can be used in the nicer plotting codes.

`load_mnest_results`(*remake_fits=False*)

Load up the MultiNest results into an astropy table.

`load_mnest_results_for_dynesty`(*remake_fits=False*)

Make a Dynesty-style results object that can be used in the nicer plotting codes.

`load_mnest_summary`(*remake_fits=False*)

Load up the MultiNest results into an astropy table.

`make_default_priors()`

Setup our prior distributions (i.e. random samplers). We will draw from these in the Prior() function. We set them up in advance because they depend on properties of the data. Also, they can be over-written by custom priors as desired.

To make your own custom priors, use the make_gen() functions with different limits.

`plot_dynesty_style`(*sim_vals=None*, *fit_vals=None*, *remake_fits=False*, *dims=None*, *traceplot=True*, *cornerplot=True*, *kde=True*)

Parameters

sim_vals
[dict] Dictionary of simulated input or comparison values to overplot on posteriors.

fit_vals
[str] Choices are ‘map’ (maximum a posteriori), ‘mean’, or ‘maxl’ (maximum likelihood)

`plot_model_and_data`(*model*, *input_model=None*, *mnest_results=None*, *suffix=''*, *zoomx=None*, *zoomy=None*, *zoomy_res=None*, *fitter=None*, *N_traces=50*)

Make and save the model and data plots.

zoomx, xoomy, zoomy_res : list the same length as *self.n_phot_sets* Each entry of the list is a list *[a, b]* cooresponding to the plot limits

`plot_model_and_data_modes`(*def_best='maxl'*)

Plots photometry data, along with n random draws from the posterior.

`print_likelihood`(*params='best'*, *verbose=True*)

Parameters

model_params
[str or dict, optional]

model_params = ‘best’ will load up the best solution and calculate
the chi^2 based on those values. Alternatively, pass in a dictionary with the model parameters to use.

`sample_post`(*binmids*, *cdf*, *bininds*)

Randomly sample from a multinest posterior distribution.

Parameters

Nparams:
number of parameters

Nbins:
number of histogram bins per dimension

Nnzero:
number of histogram bins with non-zero probability

binmids
[list of length N, each list entry is an array of shape (M,)] The centers of the bins for each parameter

cdf
[(Nnzero,) array] CDF of the distribution. Only the non-zero probability entries.

bininds
[(Nnzero, Nparams) array] Histogram indices of the non-zero probability entries.

separate_modes()

Reads in the fits for the different modes (post_separate.dat) and splits it into a .dat file per mode.

Is there a more intelligent way to deal with all the indices??? Write better later, but it seems to work for now…

solve()

Run a MultiNest fit to find the optimal parameters (and their posteriors) given the data.

Note we will ALWAYS tell multinest to be verbose.

write_params_yaml()

Write a YAML file that contains the parameters to re-initialize this object, if desired.

10.2 Prior Generators

model_fitter.**make_gen**(*min*, *max*)

model_fitter.**make_norm_gen**(*mean*, *std*)

model_fitter.**make_lognorm_gen**(*mean*, *std*)

Make a natural-log normal distribution for a variable. The specified mean and std should be in the ln() space.

model_fitter.**make_log10norm_gen**(*mean_in_log10*, *std_in_log10*)

Scale scipy lognorm from natural log to base 10. Note the mean and std should be in the log10() space already.

Parameters

mean:
mean of the underlying log10 gaussian (i.e. a log10 quantity)

std:
variance of underlying log10 gaussian

model_fitter.**make_truncnorm_gen**(*mean*, *std*, *lo_cut*, *hi_cut*)

lo_cut and hi_cut are in the units of sigma

model_fitter.**make_truncnorm_gen_with_bounds**(*mean*, *std*, *low_bound*, *hi_bound*)

low_bound and hi_bound are in the same units as mean and std

model_fitter.**make_t0_gen**(*t*, *mag*)

Get an approximate t0 search range by finding the brightest point and then searching days where flux is higher than 80% of this peak.

model_fitter.**make_mag_base_gen**(*mag*)

Make a prior for baseline magnitude using the data.

model_fitter.**make_mag_src_gen**(*mag*)

Make a prior for source magnitude using the data. Allow negative blending.

model_fitter.**make_xS0_gen**(*pos*)

model_fitter.**make_xS0_norm_gen**(*pos*) `model_fitter.`**`make_muS_EN_gen`**(*t*, *pos*, *scale_factor=100.0*)

Get an approximate muS search range by looking at the best fit straight line to the astrometry. Then allows lots of free space.

Returns

gen:
uniform generator for velocity in mas/yr

`model_fitter.`**`make_muS_EN_norm_gen`**(*t*, *pos*, *n_use=None*, *scale_factor=10.0*)

Get an approximate muS search range by looking at the best fit straight line to the astrometry. Then allows lots of free space.

Parameters

t:
array of times in days

pos:
array of positions in arcsec

Returns

gen:
uniform generator for velocity in mas/yr

`model_fitter.`**`make_invgamma_gen`**(*t_arr*)

ADD DESCRIPTION

Parameters

t_arr:
time array

`model_fitter.`**`compute_invgamma_params`**(*t_arr*)

Based on function of same name from

Fran Bartolic's `caustic` package: https://github.com/fbartolic/caustic | Returns parameters of an inverse gamma distribution s.t.

- 1% of total prob. mass is assigned to values of $t < t_{min}$ and
- 1% of total prob. masss to values greater than t_{tmax}.

t_{min} is defined to be the median spacing between consecutive data points in the time series and t_{max} is the total duration of the time series.

Parameters

t_arr
[array] Array of times

Returns

invgamma_a, invgamma_b
[float (?)] The parameters a,b of the inverse gamma function.

`model_fitter.`**`make_piS`**()

`model_fitter.`**`make_fdfdt`**()

`model_fitter.`**`random_prob`**(*generator*, *x*) `model_fitter.weighted_quantile`(*values*, *quantiles*, *sample_weight=None*, *values_sorted=False*, *old_style=False*)

Very close to numplt.percentile, but supports weights.

10.2.1 Parameters

values:
numplt.array with data

quantiles:
array-like with many quantiles needed

sample_weight:
array-like of the same length as *array*

values_sorted: bool,
if True, then will avoid sorting of initial array

old_style:
if True, will correct output to be consistent with numplt.percentile.

Returns

arr:
numplt.array with computed quantiles.

Notes

Note: quantiles should be in [0, 1]!

`model_fitter.split_param_filter_index1`(*s*)

Split a parameter name into the <string><number> components where <string> is the parameter name and <number> is the filter index (1-based). If there is no number at the end for a filter index, then return None for the second argument.

Returns

param_name
[str] The name of the parameter.

filt_index
[int (or None)] The 1-based filter index.

`model_fitter.generate_params_dict`(*params*, *fitter_param_names*)

Take a list, dictionary, or astropy Row of fit parameters and extra parameters and convert it into a well-formed dictionary that can be fed straight into a model object.

The output object will only contain parameters specified by name in fitter_param_names. Multi-filter photometry parameters are treated specially and grouped together into an array such as [‘mag_src’] = [mag_src1, mag_src2].

Parameters

params
[list, dict, Row] Contains values of parameters. Note that if the params are in a list, they need to be in the same order as fitter_param_names. If the params are in a dict or Row, then order is irrelevant.

fitter_param_names
[list] The names of the parameters that will be delivered, in order, in the output.

Returns

params_dict
[dict] Dictionary of the parameter names and values.

10.3 GENERAL USE AND SHARED FUNCTIONS

10.3.1 Shared Functions

`model_fitter.`**`pointwise_likelihood`**(*data*, *model*, *filt_index=0*)

Makes some plots to diagnose weirdness in GP fits.

`model_fitter.`**`debug_gp_nan`**(*data*, *model*, *filt_index=0*)

Makes some plots to diagnose weirdness in GP fits.

`model_fitter.`**`plot_params`**(*model*)

Print parameters

`model_fitter.`**`plot_photometry`**(*data*, *model*, *input_model=None*, *dense_time=True*, *residuals=True*, *filt_index=0*, *zoomx=None*, *zoomy=None*, *zoomy_res=None*, *mnest_results=None*, *N_traces=50*, *gp=False*, *fitter=None*)

Get the data out.

`model_fitter.`**`plot_photometry_gp`**(*data*, *model*, *input_model=None*, *dense_time=True*, *residuals=True*, *filt_index=0*, *zoomx=None*, *zoomy=None*, *zoomy_res=None*, *mnest_results=None*, *N_traces=50*, *gp=False*)

`model_fitter.`**`plot_astrometry`**(*data*, *model*, *input_model=None*, *dense_time=True*, *residuals=True*, *n_phot_sets=0*, *filt_index=0*, *ast_filt_index=0*, *mnest_results=None*, *N_traces=50*, *fitter=None*)

Astrometry on the sky

`model_fitter.`**`plot_astrometry_on_sky`**(*data*, *model*, *ast_filt_index=0*)

`model_fitter.`**`plot_astrometry_proper_motion_removed`**(*data*, *model*, *ast_filt_index=0*)

Proper Motion Subtracted

`model_fitter.`**`quantiles`**(*mnest_results*, *sigma=1*)

Calculate the median and N sigma credicble interval.

Parameters

mnest_results
[astropy table] The table that comes out of load_mnest_results.

sigma
[int, optional] 1, 2, or 3 sigma to determine which credible interval to return.

`model_fitter.`**`get_mnest_results`**(*root_name*, *parameters*)

Parameters

root_name
[str] The directory and base name of the MultiNest output.

parameters
[list or array] A list of strings with the parameter names to be displayed. There should be one name for each parameter in MultiNest and in the order that they appeared in the hyper-cube.

`model_fitter.calc_AIC(`*k*, *maxlogL*`)`

Calculate Akaike Information Criterion.

k = number of parameters

maxlogL = maximum log likelihood

`model_fitter.calc_BIC(`*n*, *k*, *maxlogL*`)`

Calculate Bayesian Information Criterion.

n = sample size

k = number of parameters

maxlogL = maximum log likelihood

`model_fitter.postplot(`*results*, *span=None*, *quantiles=[0.025, 0.5, 0.975]*, *q_color='gray'*, *smooth=0.02*, *post_color='blue'*, *post_kwargs=None*, *kde=True*, *nkde=1000*, *max_n_ticks=5*, *use_math_text=False*, *labels=None*, *label_kwargs=None*, *show_titles=False*, *title_fmt='.2f'*, *title_kwargs=None*, *truths1=None*, *truths2=None*, *truth_color1='red'*, *truth_color2='blue'*, *truth_kwargs1=None*, *truth_kwargs2=None*, *verbose=False*, *fig=None*`)`

Plot marginalized posteriors for each parameter. Basically copied half of traceplot.

Parameters

results
[`Results` instance] A `Results` instance from a nested sampling run. **Compatible with results derived from** nestle.

span
[iterable with shape (ndim,), optional] A list where each element is either a length-2 tuple containing lower and upper bounds or a float from *(0., 1.]* giving the fraction of (weighted) samples to include. If a fraction is provided, the bounds are chosen to be equal-tailed. An example would be:

```
span = [(0., 10.), 0.95, (5., 6.)]
```

Default is *0.999999426697* (5-sigma credible interval) for each parameter.

quantiles
[iterable, optional] A list of fractional quantiles to overplot on the 1-D marginalized posteriors as vertical dashed lines. Default is *[0.025, 0.5, 0.975]* (the 95%/2-sigma credible interval).

smooth
[float or iterable with shape (ndim,), optional] The standard deviation (either a single value or a different value for each subplot) for the Gaussian kernel used to smooth the 1-D marginalized posteriors, expressed as a fraction of the span. Default is *0.02* (2% smoothing). If an integer is provided instead, this will instead default to a simple (weighted) histogram with *bins=smooth*.

post_color
[str or iterable with shape (ndim,), optional] A *~matplotlib*-style color (either a single color or a different value for each subplot) used when plotting the histograms. Default is *'blue'*.

post_kwargs
[dict, optional] Extra keyword arguments that will be used for plotting the marginalized 1-D posteriors.

kde
[bool, optional] Whether to use kernel density estimation to estimate and plot the PDF of the importance weights as a function of log-volume (as opposed to the importance weights themselves). Default is *True*.

nkde
[int, optional] The number of grid points used when plotting the kernel density estimate. Default is *1000*.

max_n_ticks
[int, optional] Maximum number of ticks allowed. Default is *5*.

use_math_text
[bool, optional] Whether the axis tick labels for very large/small exponents should be displayed as powers of 10 rather than using *e*. Default is *False*.

labels
[iterable with shape (ndim,), optional] A list of names for each parameter. If not provided, the default name used when plotting will follow x_i style.

label_kwargs
[dict, optional] Extra keyword arguments that will be sent to the *~matplotlib.axes.Axes.set_xlabel* and *~matplotlib.axes.Axes.set_ylabel* methods.

show_titles
[bool, optional] Whether to display a title above each 1-D marginalized posterior showing the 0.5 quantile along with the upper/lower bounds associated with the 0.025 and 0.975 (95%/2-sigma credible interval) quantiles. Default is *True*.

title_fmt
[str, optional] The format string for the quantiles provided in the title. Default is *'.2f'*.

title_kwargs
[dict, optional] Extra keyword arguments that will be sent to the *~matplotlib.axes.Axes.set_title* command.

truths
[iterable with shape (ndim,), optional] A list of reference values that will be overplotted on the traces and marginalized 1-D posteriors as solid horizontal/vertical lines. Individual values can be exempt using *None*. Default is *None*.

truth_color
[str or iterable with shape (ndim,), optional] A *~matplotlib*-style color (either a single color or a different value for each subplot) used when plotting *truths*. Default is *'red'*.

truth_kwargs
[dict, optional] Extra keyword arguments that will be used for plotting the vertical and horizontal lines with *truths*.

verbose
[bool, optional] Whether to print the values of the computed quantiles associated with each parameter. Default is *False*.

fig
[(*~matplotlib.figure.Figure*, *~matplotlib.axes.Axes*), optional] If provided, overplot the traces and marginalized 1-D posteriors onto the provided figure. Otherwise, by default an internal figure is generated.

Returns

traceplot
[(*~matplotlib.figure.Figure*, *~matplotlib.axes.Axes*)] Output trace plot.

`model_fitter.cornerplot_2truth`(*results*, *dims=None*, *span=None*, *quantiles=[0.025, 0.5, 0.975]*, *color='black'*, *smooth=0.02*, *quantiles_2d=None*, *hist_kwargs=None*, *hist2d_kwargs=None*, *labels=None*, *label_kwargs=None*, *show_titles=False*, *title_fmt='.2f'*, *title_kwargs=None*, *truths1=None*, *truth_color1='red'*, *truth_kwargs1=None*, *truths2=None*, *truth_color2='blue'*, *truth_kwargs2=None*, *max_n_ticks=5*, *top_ticks=False*, *use_math_text=False*, *verbose=False*, *fig=None*)

Generate a corner plot of the 1-D and 2-D marginalized posteriors.

Parameters

results
[`Results` instance] A `Results` instance from a nested sampling run. **Compatible with results derived from** nestle.

dims
[iterable of shape (ndim,), optional] The subset of dimensions that should be plotted. If not provided, all dimensions will be shown.

span
[iterable with shape (ndim,), optional] A list where each element is either a length-2 tuple containing lower and upper bounds or a float from *(0., 1.]* giving the fraction of (weighted) samples to include. If a fraction is provided, the bounds are chosen to be equal-tailed. An example would be:

```
.. code::
```

span = [(0., 10.), 0.95, (5., 6.)]

Default is *0.999999426697* (5-sigma credible interval).

quantiles
[iterable, optional] A list of fractional quantiles to overplot on the 1-D marginalized posteriors as vertical dashed lines. Default is *[0.025, 0.5, 0.975]* (spanning the 95%/2-sigma credible interval).

color
[str or iterable with shape (ndim,), optional] A *~matplotlib*-style color (either a single color or a different value for each subplot) used when plotting the histograms. Default is *'black'*.

smooth
[float or iterable with shape (ndim,), optional] The standard deviation (either a single value or a different value for each subplot) for the Gaussian kernel used to smooth the 1-D and 2-D marginalized posteriors, expressed as a fraction of the span. Default is *0.02* (2% smoothing). If an integer is provided instead, this will instead default to a simple (weighted) histogram with *bins=smooth*.

quantiles_2d
[iterable with shape (nquant,), optional] The quantiles used for plotting the smoothed 2-D distributions. If not provided, these default to 0.5, 1, 1.5, and 2-sigma contours roughly corresponding to quantiles of *[0.1, 0.4, 0.65, 0.85]*.

hist_kwargs
[dict, optional] Extra keyword arguments to send to the 1-D (smoothed) histograms.

hist2d_kwargs
: [dict, optional] Extra keyword arguments to send to the 2-D (smoothed) histograms.

labels
: [iterable with shape (ndim,), optional] A list of names for each parameter. If not provided, the default name used when plotting will follow x_i style.

label_kwargs
: [dict, optional] Extra keyword arguments that will be sent to the *~matplotlib.axes.Axes.set_xlabel* and *~matplotlib.axes.Axes.set_ylabel* methods.

show_titles
: [bool, optional] Whether to display a title above each 1-D marginalized posterior showing the 0.5 quantile along with the upper/lower bounds associated with the 0.025 and 0.975 (95%/2-sigma credible interval) quantiles. Default is *True*.

title_fmt
: [str, optional] The format string for the quantiles provided in the title. Default is *'.2f'*.

title_kwargs
: [dict, optional] Extra keyword arguments that will be sent to the *~matplotlib.axes.Axes.set_title* command.

truths
: [iterable with shape (ndim,), optional] A list of reference values that will be overplotted on the traces and marginalized 1-D posteriors as solid horizontal/vertical lines. Individual values can be exempt using *None*. Default is *None*.

truth_color
: [str or iterable with shape (ndim,), optional] A *~matplotlib*-style color (either a single color or a different value for each subplot) used when plotting *truths*. Default is *'red'*.

truth_kwargs
: [dict, optional] Extra keyword arguments that will be used for plotting the vertical and horizontal lines with *truths*.

max_n_ticks
: [int, optional] Maximum number of ticks allowed. Default is *5*.

top_ticks
: [bool, optional] Whether to label the top (rather than bottom) ticks. Default is *False*.

use_math_text
: [bool, optional] Whether the axis tick labels for very large/small exponents should be displayed as powers of 10 rather than using *e*. Default is *False*.

verbose
: [bool, optional] Whether to print the values of the computed quantiles associated with each parameter. Default is *False*.

fig
: [(*~matplotlib.figure.Figure*, *~matplotlib.axes.Axes*), optional] If provided, overplot the traces and marginalized 1-D posteriors onto the provided figure. Otherwise, by default an internal figure is generated.

Returns

cornerplot
: [(*~matplotlib.figure.Figure*, *~matplotlib.axes.Axes*)] Output corner plot.

`model_fitter.`**`contour2d_alpha`**(*x*, *y*, *smooth=0.02*, *span=None*, *weights=None*, *sigma_levels=[1, 2, 3]*, *ax=None*, *color='gray'*, *plot_density=True*, *plot_contours=True*, *contour_kwargs=None*, ***kwargs*)

Simplified/modified from dynesty's plotting._hist2d function. Plots non-filled 2D contours, where the contours are the 0.5, 1, 1.5, 2 sigma contours (note this)

Parameters

x
[interable with shape (nsamps,)] Sample positions in the first dimension.

y
[iterable with shape (nsamps,)] Sample positions in the second dimension.

span
[iterable with shape (ndim,), optional] A list where each element is either a length-2 tuple containing lower and upper bounds or a float from *(0., 1.]* giving the fraction of (weighted) samples to include. If a fraction is provided, the bounds are chosen to be equal-tailed. An example would be:

```
`span = [(0., 10.), 0.95, (5., 6.)]`
```

Default is *0.999999426697* (5-sigma credible interval).

weights
[iterable with shape (nsamps,)] Weights associated with the samples. Default is *None* (no weights).

sigma_levels
[iterable, optional] The contour levels to draw. Default are *[1, 2, 3]*-sigma. UNITS ARE IN SIGMA

ax
[*~matplotlib.axes.Axes*, optional] An *~matplotlib.axes.axes* instance on which to add the 2-D histogram. If not provided, a figure will be generated.

color
[str, optional] The *~matplotlib*-style color used to draw lines and color cells and contours. Default is *'gray'*.

plot_density
[bool, optional] Whether to draw the density colormap. Default is *True*.

plot_contours
[bool, optional] Whether to draw the contours. Default is *True*.

contour_kwargs
[dict] Any additional keyword arguments to pass to the *contour* method.

data_kwargs
[dict] Any additional keyword arguments to pass to the *plot* method when adding the individual data points.

model_fitter.**traceplot_custom**(*results_list*, *quantiles=[0.025, 0.5, 0.975]*, *smooth=0.02*, *thin=1*, *dims=None*, *contour_labels_list=None*, *post_color_list=['blue']*, *post_kwargs=None*, *kde=True*, *nkde=1000*, *trace_cmap='plasma'*, *trace_color=None*, *trace_kwargs=None*, *connect=False*, *connect_highlight=10*, *connect_color='red'*, *connect_kwargs=None*, *max_n_ticks=5*, *use_math_text=False*, *labels=None*, *label_kwargs=None*, *show_titles=False*, *title_fmt='.2f'*, *title_kwargs=None*, *truths=None*, *truth_color='red'*, *truth_kwargs=None*, *verbose=False*, *fig=None*)

Plot traces and marginalized posteriors for each parameter. Allows you to plot multiple trace plots on top of each other. The keywords are mostly the same as the dynesty default, only listing the new keywords here.

Parameters

results_list
[list of `Results` instance] A `Results` instance from a nested sampling run. **Compatible with results derived from** nestle.

color_list
[list of length the same as results_list] List of ~*matplotlib*-style colors.

contour_labels_list
[list of length the same as results_list] List of strings for labelling each contour.

Returns

traceplot
[(~*matplotlib.figure.Figure*, ~*matplotlib.axes.Axes*)] Output trace plot.

`model_fitter.cornerplot_custom`(*results_list*, *dims=None*, *quantiles=[0.025, 0.5, 0.975]*, *color_list=['blue']*, *smooth=0.02*, *quantiles_2d=None*, *hist_kwargs=None*, *hist2d_kwargs=None*, *labels=None*, *label_kwargs=None*, *contour_labels_list=None*, *show_titles=False*, *title_fmt='.2f'*, *title_kwargs=None*, *truths=None*, *truth_color='red'*, *truth_kwargs=None*, *max_n_ticks=5*, *top_ticks=False*, *use_math_text=False*, *verbose=False*, *fig=None*)

Generate a corner plot of the 1-D and 2-D marginalized posteriors. Allows you to plot multiple corner plots on top of each other. The keywords are mostly the same as dynesty default, only listing the new keywords here.

Parameters

results_list
[list of `Results` instance] A `Results` instance from a nested sampling run. **Compatible with results derived from** nestle.

color_list
[list of length the same as results_list] List of ~*matplotlib*-style colors.

contour_labels_list
[list of length the same as results_list] List of strings for labelling each contour.

Returns

cornerplot
[(~*matplotlib.figure.Figure*, ~*matplotlib.axes.Axes*)] Output corner plot.

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