BYOSED Documentation

Release 0.0.2

Justin Pierel

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Contents

CHAPTER 1

Overview

BYOSED enables flexible testing of possible effects on Type Ia distance measure-ments using any baseline SED model in an open source Python framework.

1.1 Installation

1.1.1 Install using GitHub

Currently, the software can be installed via GitHub:

```
git clone https://github.com/jpierel14/BYOSED.git
```

In your local directory:

```
python setup.py test
python setup.py install
```

Or via Pip:: pip install byosed

1.2 SNANA Integration

BYOSED is integrated into the public version of SNANA at this time. Details can be found in Section 9 of the SNANA manual. The code will look for the byosed.params file in your specified directory, which is described below.

1.3 Simulating with BYOSED

The BYOSED framework allows any spectrophotometric model to be used as the underlying template to generate simulated Type Ia light curve data with SNANA. By default, this model is the Hsiao+07 model (initfiles/Hsiao07.dat). This can be replaced by any model.

1.3.1 Param File Basics

The only file to set up is the BYOSED.params file. This contains the general aspects of the simulated SN you want to create using BYOSED, and any warping perturbers you want to add in. This file is separated into the following required and optional sections:

[MAIN]

(Required)

This section contains **SED_FILE** (name of SED file), as well as **MAGSMEAR** (magnitude smearing) and **MAGOFF** (magnitude offsets) definitions to be applied to the base SED defined by sed_file. You may also define **CLOBBER** and **VERBOSE** flags here as well. This section may look like the following:

```
[MAIN]

SED_FILE: Hsiao07.dat
MAGSMEAR: 0.0
MAGOFF: 0.0
```

[FLAGS]

(Optional)

This section allows you to simply turn warping perturbers defined in the next section(s) on and off. If this section exists, then it supersedes later sections and defines the warping perturbers to be used. If it does not exist, all defined warping perturbers are used. Adding this onto the **[MAIN]** section, the params file might now look like the following:

```
[MAIN]

SED_FILE: Hsiao07.dat
MAGSMEAR: 0.1
MAGOFF: 0.0

[FLAGS]

COLOR: False
STRETCH: True
HOST_MASS: True
```

In this case, a magnitude smearing of 0.1 would be applied to the Hsiao model at all wavelengths, and some host mass and stretch perturbers are applied as well based on functions you will define in the next sections.

1.3.2 Warping Perturbers

The following sections contain all of the various wavelength/phase dependent perturbers that you want to apply to your SED. In this case, based on the **[FLAGS]** section, you must have a "HOST_MASS" section and a "STRETCH" section. You can name perturbers whatever you want, as long as the name of your section and the corresponding name in the **[FLAGS]** section are identical. Perturbers are either **"HOST"** perturbers, or they are **"SN"** perturbers. They both require the same basic variables, but have different names. In all cases, you will have the following variables defined:

1. **SCALE_DIST_PEAK**
    - The PEAK of an (a)symmetric Gaussian that will define the distribution for the scale parameter

2. **SCALE_DIST_SIGMA**
    - The "low" and "high" standard deviations of the same distribution
3. **SCALE_DIST_LIMITS**
    - The lower and upper cutoff you would like for the same distribution

1.3.3 HOST Perturbers

Creating a HOST warping perturber section requires the following variable:

HOST_FUNCTION

- A file name to be read that contains a gridded list parameters and values like the following:

```
#phase wavelength host_mass value
-20     1000    9.0             25.75805
-20     1010    9.0             25.64852
-20     1020    9.0             25.53899
-20     1030    9.0             25.42946
-20     1040    9.0             25.31993
-20     1050    9.0             25.2104
                ...
```

You may pass relevant host galaxy parameters (e.g. host mass, redshift, etc.) to the warpSED function, or you may create a distribution here to randomize the relevant parameter. You can do this by defining another (a)symmetric Gaussian:

1. **HOST_PARAM_DIST_PEAK**
    - The PEAK of an (a)symmetric Gaussian that will define the distribution for the host galaxy parameter
2. **HOST_PARAM_DIST_SIGMA**
    - The "low" and "high" standard deviations of the same distribution
3. **HOST_PARAM_DIST_LIMITS**
    - The lower and upper cutoff you would like for the same distribution

OR by passing a filename that contains a distribution of the relevant host parameter:

HOST_PARAM_DIST_FILE: host_mass_distribution.txt

1.3.4 SN Perturbers

These are exactly the same as host perturbers, with different labels. To create a SN perturber, follow the same directions listed for the HOST perturber, but replace "HOST" with "SN" in each variable name.

1.3.5 Creating Perturbers in the Params File

You must now define a section for each warping perturber, with these variables. For our current example, where I have defined host_mass and stretch perturbers in my **[FLAGS]** section, I must define these two sections. If I do not define a **[FLAGS]** section, then whatever sections that exist apart from the **[MAIN]** section are assumed to be warping perturbers. One such section might look like the following:

```
[STRETCH]

SN_FUNCTION: color_func.dat
SCALE_DIST_PEAK: 0.5
SCALE_DIST_SIGMA: 1.0 0.7
SCALE_DIST_LIMITS: -2.5 2.5
```

All together, after adding in the HOST_MASS section as well, a **BYOSED.params** file might look something like this:

```
[MAIN]

SED_FILE: Hsiao07.dat
MAGSMEAR: 0.0
MAGOFF: 0.0

[FLAGS]

COLOR: False
STRETCH: True
VELOCITY: False
SFR: False
METALLICITY: False
HOST_MASS: True

[HOST_MASS]

HOST_FUNCTION: host_mass_func.dat

SCALE_DIST_PEAK: 1
SCALE_DIST_SIGMA: 0 0
SCALE_DIST_LIMITS: 1 1

HOST_PARAM_DIST_PEAK: 10
HOST_PARAM_DIST_SIGMA: 2 2
HOST_PARAM_DIST_LIMITS: 5 20

[STRETCH]

SN_FUNCTION: stretch_func.dat

SCALE_DIST_PEAK: 0.5
SCALE_DIST_SIGMA: 1.0 0.7
SCALE_DIST_LIMITS: -2.5 2.5
```

Or, if you do not define a flags section, host_mass and stretch will automatically be used as warping perturbers with the following **BYOSED.params** file:

```
[MAIN]

SED_FILE: Hsiao07.dat
MAGSMEAR: 0.0
MAGOFF: 0.0

[HOST_MASS]

HOST_FUNCTION: host_mass_func.dat
```

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```
SCALE_DIST_PEAK: 1
SCALE_DIST_SIGMA: 0 0
SCALE_DIST_LIMITS: 1 1

HOST_PARAM_DIST_PEAK: 10
HOST_PARAM_DIST_SIGMA: 2 2
HOST_PARAM_DIST_LIMITS: 5 20


[STRETCH]

SN_FUNCTION: stretch_func.dat

SCALE_DIST_PEAK: 0.5
SCALE_DIST_SIGMA: 1.0 0.7
SCALE_DIST_LIMITS: -2.5 2.5
```

1.3.6 Final Notes

Now you can replace the Hsiao template with your own template SED, and start adding in warping perturbers. This warping process is designed so that as many perturbers as you would like can be included. Each perturber is applied multiplicatively to the baseline model. For the example file above, the final flux would look like this

$$F(\lambda,\phi) = A \times H(\lambda,\phi)\Big[1 + S(\lambda,\phi)s + M(\lambda,\phi,M)m\Big]$$

Where here F is the final flux, H is the Hsiao template, S is the defined stretch function, M is the defined host mass function, s is the scale parameter pulled from the distribution defined for the stretch function, m is the scale parameter pulled from the distribution defined for the host mass function, and M is the host mass itself, pulled from the parameter distribution defined for the host mass perturber. In principle this could look like the following if you had N such perturbers:

$$F(\lambda,\phi) = A \times H(\lambda,\phi)\Big[1 + X_1(\lambda,\phi)x_1 + X_2(\lambda,\phi)x_2 + ... + X_N(\lambda,\phi)x_N\Big]$$

1.3.7 Combining HOST and SN Perturbers

You can also define an perturber that involves both HOST and SN parameters. Perhaps you want an perturber that combines host mass and velocity. You might then have a params file that looks like this (the entire perturber still only gets one scale parameter):

```
[MAIN]

SED_FILE: Hsiao07.dat
MAGSMEAR: 0.0
MAGOFF: 0.0

[HOST_MASS_VELOCITY]

HOST_FUNCTION: host_mass_func.dat

SCALE_DIST_PEAK: 1
SCALE_DIST_SIGMA: 0 0
```

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```
SCALE_DIST_LIMITS: 1 1

HOST_PARAM_DIST_PEAK: 10
HOST_PARAM_DIST_SIGMA: 2 2
HOST_PARAM_DIST_LIMITS: 5 20

SN_FUNCTION: gridded_velocity.dat

SN_PARAM_DIST_FILE: velocity_hist_data.txt
```

In this case, the final flux would be calculated in the following way:

$$F(\lambda,\phi) = A \times H(\lambda,\phi)\Big[1 + V(\lambda,\phi,v)sM(\lambda,\phi,M)\Big]$$

Where here F is the final flux, H is the Hsiao template, V is the velocity component of the HOST_MASS_VELOCITY perturber, s is the scale factor, and M is the host mass component of the HOST_MASS_VELOCITY perturber. This generalizes to N such perturbers in the following way:

$$F(\lambda,\phi) = A \times H(\lambda,\phi)\Big[1 + SN_1(\theta_{SN})s_1G_1(\theta_{SN},\theta_{HOST}) + SN_2(\theta_{SN})s_2G_2(\theta_{SN},\theta_{HOST}) + ... \\ + SN_N(\theta_{SN})s_NG_N(\theta_{SN},\theta_{HOST})\Big]$$

1.3.8 Example Files

These are example files that can be used for your `sed_file` and `BYOSED.params`. The host mass and stretch functions are defined by accompanying `host mass` and `stretch` files.

1.4 Publications with BYOSED

1. Understanding Type Ia Supernova Distance Biases by Simulating Spectral Variations: Pierel, J. D. R.; Jones, D. O.; Dai, M.; Adams, D. Q.; Kessler, R.; Rodney, S.; Siebert, M. R.; Foley, R. J.; Kenworthy, W. D.; Scolnic, D.

1.5 Primary Contributors

Fig. 1: Justin Pierel

CHAPTER 2

Indices and tables

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