PopSyCLE with Galaxia v3

- PopSyCLE Pipeline with run.py
- Running Galaxia versions

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Moving Universe Lab - Group Meeting
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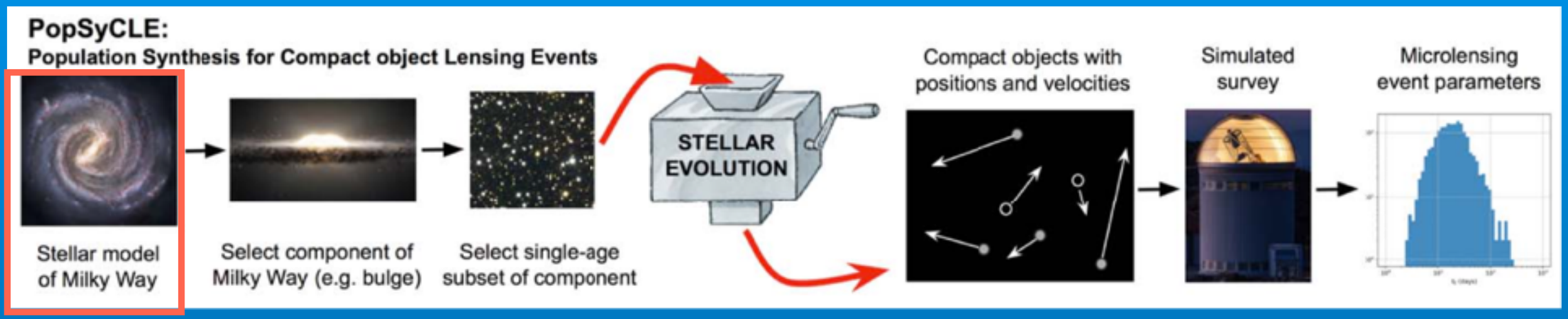
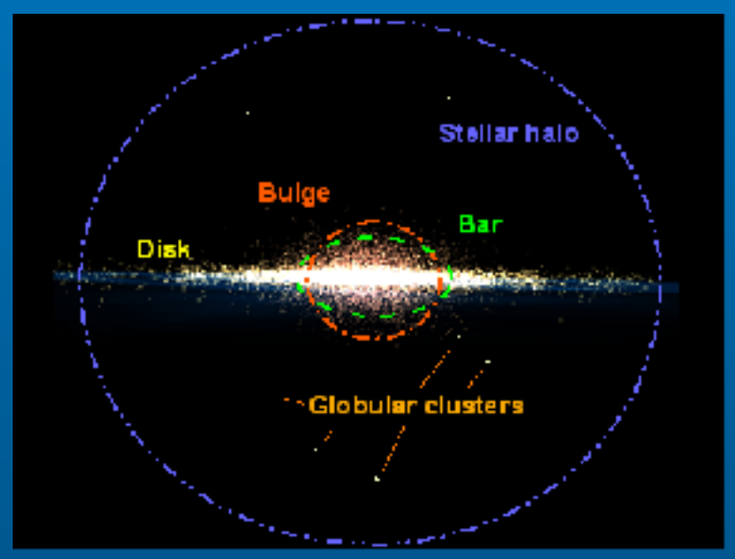
PopSyCLE

Population **Sy**nthesis for **C**ompact object **L**ensing **E**vents

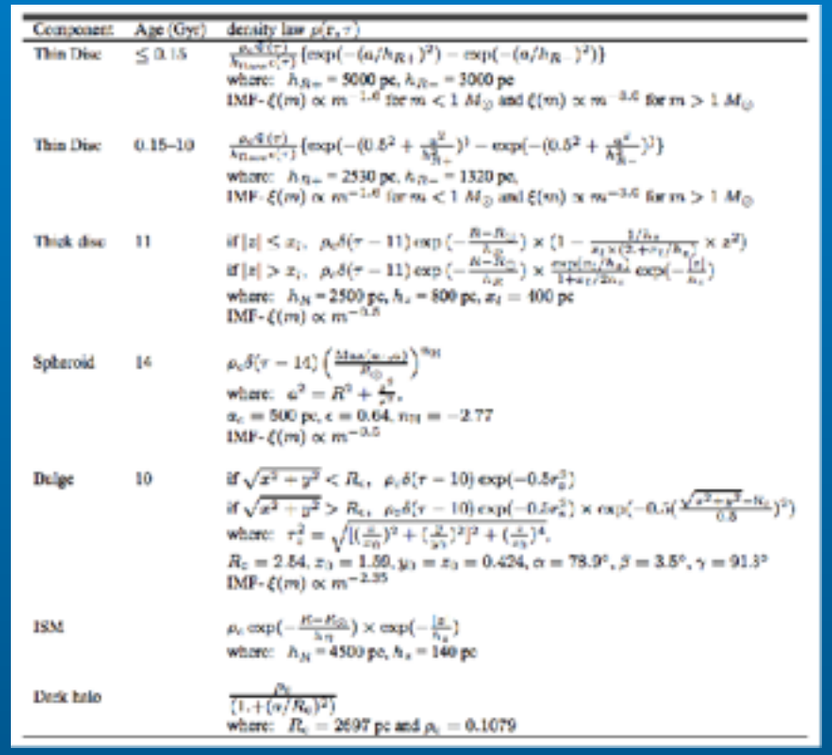
Lam et al. 2020



Galaxia



https://kof.zcu.cz/st/dis/schwarzmeier/galaxy_models.html



Component	Age (Gyr)	density law $\rho(r,z)$
Thin Disc	$\lesssim 0.15$	$\frac{\rho_0 \delta(r)}{N_{norm}(r)} \{\exp(-(a/h_{R1})^2) - \exp(-(a/h_{R2})^2)\}$ where: $h_{R-} = 5000$ pc, $h_{R+} = 3000$ pc IMF-$\xi(m) \propto m^{-1.6}$ for $m < 1\ M_\odot$ and $\xi(m) \propto m^{-3.6}$ for $m > 1\ M_\odot$
Thin Disc	0.15–10	$\frac{\rho_0 \delta(r)}{N_{norm}(r)} \{\exp(-((0.5^2 + \frac{z^2}{h_{z+}^2})^1 - \exp(-(0.5^2 + \frac{z^2}{h_{z-}^2})^1)\}$ where: $h_{z+} = 2530$ pc, $h_{z-} = 1320$ pc, IMF-$\xi(m) \propto m^{-1.6}$ for $m < 1\ M_\odot$ and $\xi(m) \propto m^{-3.6}$ for $m > 1\ M_\odot$
Thick disc	11	if $\lvert z\rvert < z_1$, $\rho_0 \delta(\tau - 11) \exp(-\frac{R - R_\odot}{h_R}) \times (1 - \frac{1/h_z}{z_1 \times (2 + \tau_1/h_{z_1})} \times z^2)$ if $\lvert z\rvert > z_1$, $\rho_0 \delta(\tau - 11) \exp(-\frac{R - R_\odot}{h_R}) \times \frac{\exp(\lvert z_1\rvert/h_{z1})}{1 + z_1/2h_{z_1}} \exp(-\frac{\lvert z\rvert}{h_z})$ where: $h_R = 2500$ pc, $h_z = 800$ pc, $z_1 = 400$ pc IMF-$\xi(m) \propto m^{-3.5}$
Spheroid	14	$\rho_0 \delta(\tau - 14) \left(\frac{3.5 \sin(\omega - \omega_1)}{R_\odot}\right)^{n_{SH}}$ where: $\omega^2 = R^2 + \frac{z^2}{\epsilon^2}$, $a_c = 500$ pc, $\epsilon = 0.64$, $n_{SH} = -2.77$ IMF-$\xi(m) \propto m^{-3.5}$
Bulge	10	if $\sqrt{x^2 + y^2} < R_c$, $\rho_c \delta(\tau - 10) \exp(-0.5 r_s^2)$ if $\sqrt{x^2 + y^2} > R_c$, $\rho_0 \delta(\tau - 10) \exp(-0.5 r_s^2) \times \exp(-0.5((\frac{\sqrt{x^2 + y^2} - N_c}{0.5})^2)$ where: $r_s^2 = \sqrt{[(\frac{x}{x_0})^2 + (\frac{y}{y_0})^2]^2 + (\frac{z}{z_0})^4}$, $R_c = 2.54$, $x_0 = 1.59$, $y_0 = z_0 = 0.424$, $\alpha = 78.9°$, $\beta = 3.5°$, $\gamma = 91.3°$ IMF-$\xi(m) \propto m^{-2.35}$
ISM		$\rho_c \exp(-\frac{R - R_\odot}{h_R}) \times \exp(-\frac{\lvert z\rvert}{h_z})$ where: $h_R = 4500$ pc, $h_z = 140$ pc
Dark halo		$\frac{\rho_0}{(1 + (a/R_c)^2)}$ where: $R_c = 2697$ pc and $\rho_c = 0.1079$

Sharma et al. 2011

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PopSyCLE - synthetic.py

```
from popsycle import synthetic

synthetic.run_galaxia(output_root = 'example',
                      longitude = 1.25,
                      latitude = -2.65,
                      area = 0.001)

synthetic.perform_pop_syn(ebf_file = 'example.ebf',
                          output_root = 'example',
                          iso_dir = '/path/to/isochrones/',
                          bin_edges_number = 20,
                          BH_kick_speed_mean = 100,
                          NS_kick_speed_mean = 350)

synthetic.calc_events(hdf5_file = 'example.h5',
                      output_root2 = 'example',
                      radius_cut = 2,
                      obs_time = 1000,
                      n_obs = 11,
                      theta_frac = 2,
                      blend_rad = 0.65,
                      overwrite = False,
                      n_proc = 1)

synthetic.refine_events(input_root = 'example',
                        filter_name = 'I',
                        photometric_system = 'ubv',
                        red_law = 'Damineli16',
                        overwrite = False,
                        output_file = 'default')
```

- generate galaxia parameter file
- execute galaxia, creating galaxy model

- inject compact objects (WD, NS, BH)
- sort objects into bins

- search for microlensing events
- bins can be parallelized across multiple cores

- calculate microlensing parameters for events in a specific observing filter

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PopSyCLE - run.py

Run once from ipython or jupyter notebook

```
from popsycle import run

run.generate_field_config_file(longitude = 1.25,
                               latitude = -2.65,
                               area = 0.001)

run.generate_popsycle_config_file(radius_cut = 2,
                                  obs_time = 1000,
                                  n_obs = 101,
                                  theta_frac = 2,
                                  blend_rad = 0.75,
                                  isochrones_dir = '/Users/myself/popsycle_isochrones',
                                  galaxia_galaxy_model_filename = '/Users/myself/galaxia_galaxy_model_filename',
                                  bin_edges_number = 20,
                                  BH_kick_speed_mean = 50,
                                  NS_kick_speed_mean = 400,
                                  photometric_system = 'ubv',
                                  filter_name = 'R', red_law = 'Damineli16',
                                  config_filename = 'popsycle_config.yaml')
```

Run from terminal

```
python ~/PycharmProjects/PopSyCLE/popsycle/run.py --output-root=base0 --field-config-filename=field_config.yaml
--popsycle-config-filename=popsycle_config.yaml
--n-cores-calc-events=4 --seed=0
```

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PopSyCLE - run.py

```
(base) ~$ python ~/PycharmProjects/PopSyCLE/popsycle/run.py -h
/Users/michael/miniconda3/lib/python3.6/site-packages/pysynphot/locations.py:346: UserWarning: Extinction files not found in /Users/m
  warnings.warn('Extinction files not found in %s' % (extdir, ))
usage: run.py [-h] [--output-root OUTPUT_ROOT]
              [--field-config-filename FIELD_CONFIG_FILENAME]
              [--popsycle-config-filename POPSYCLE_CONFIG_FILENAME]
              [--n-cores-calc-events N_CORES_CALC_EVENTS] [--seed SEED]
              [--overwrite] [--skip-galaxia] [--skip-perform-pop-syn]
              [--skip-calc-events] [--skip-refine-events]

    Run the PopSyCLE pipeline. This executable can be either
    run by slurm scripts generated by `generate_slurm_scripts` or from the
    command line.

    Script must be executed in a folder containing a field_config file and
    point to a popsycle_config file both generated by
    `popsycle.slurm.generate_config_file`.


optional arguments:
  -h, --help            show this help message and exit

Required:
  --output-root OUTPUT_ROOT
                        Base filename of the output files. Default: root0
  --field-config-filename FIELD_CONFIG_FILENAME
                        Name of configuration file containing the field parameters. Default: field_config.yaml
  --popsycle-config-filename POPSYCLE_CONFIG_FILENAME
                        Name of configuration file containing the PopSyCLE parameters. Default: popsycle_config.yaml
  --n-cores-calc-events N_CORES_CALC_EVENTS
                        Number of cores to use in the calc_events function (the only piece of the PopSyCLE pipeline that uses multipr

Optional:
  --seed SEED           Set a seed for all PopSyCLE functions with randomness, which are running Galaxia and PyPopStar. Setting this
  --overwrite           Overwrite all output files.
  --skip-galaxia        Skip running galaxia.
  --skip-perform-pop-syn
                        Skip running perform_pop_syn.
  --skip-calc-events    Skip running calc_events.
  --skip-refine-events  Skip running refine_events.
```

Galaxia Bulge Parameter Versions

Version 1

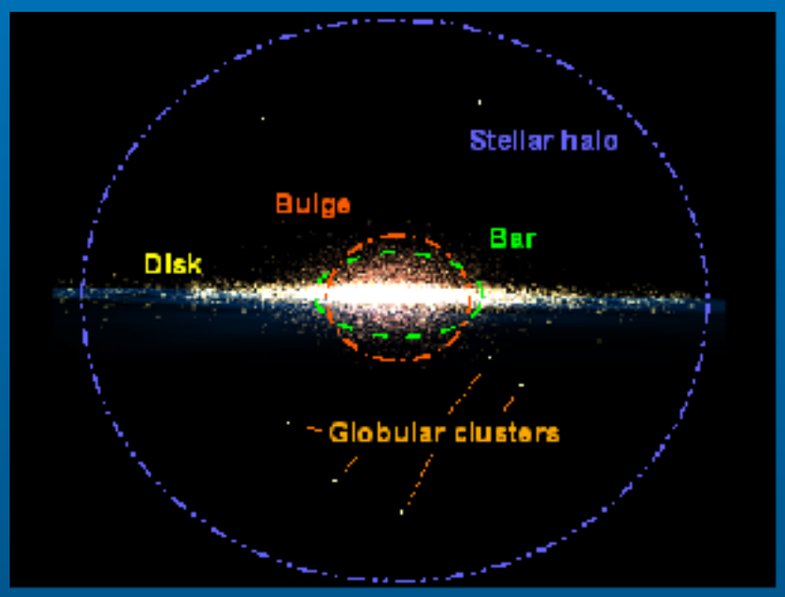
```
bulge_Rc 2.54
bulge_x0 1.59
bulge_y0 0.424
bulge_z0 0.424
bulge_alpha 78.9
bulge_beta 3.5
bulge_gamma 91.3
bulge_sigma_r 110
bulge_sigma_phi 110
bulge_sigma_z 100
bulge_patternspeed 71.62
```

Version 2

```
bulge_Rc 2.54
bulge_x0 1.59
bulge_y0 0.424
bulge_z0 0.424
bulge_alpha 78.9
bulge_beta 3.5
bulge_gamma 91.3
bulge_sigma_r 100
bulge_sigma_phi 100
bulge_sigma_z 100
bulge_patternspeed 40.00
```

Version 3

```
bulge_Rc 2.54
bulge_x0 0.70
bulge_y0 0.424
bulge_z0 0.424
bulge_alpha 62.0
bulge_beta 3.5
bulge_gamma 91.3
bulge_sigma_r 100
bulge_sigma_phi 100
bulge_sigma_z 100
bulge_patternspeed 40.00
```



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Galaxia Bulge Parameter Versions

Installed from https://github.com/jluastro/galaxia

```
(base) ~$ galaxia -h

NAME:
        galaxia-0.7.2.1 - a code to generate a synthetic galaxy survey
        Modified to ingest galaxy model parameter files.
        Source: https://github.com/jluastro/galaxia

USAGE:
        galaxia         -s [warp or nowarp] galaxymodelfile
        galaxia         -r parameterfile galaxymodelfile
        galaxia         -a --psys=photometricSystem filename galaxymodelfile
        galaxia         -r --nfile=haloname [--hdim=3 or 6] parameterfile galaxymodelfile
        galaxia         --copyright
        galaxia         --help
DESCRIPTION:
        -s          initial setup to generate BHTREE files
        -r          run the code to generate stellar data
        -a          append catalog file with magnitudes in an alternate photometric system
        --nfile     halo02,halo05 etc to sample Bullock Johnston stellar halos
        --fieldfile to generate specific fields
        --hdim      dimensionality of smoothing lengths, for N-body models only
                    6 for with kinematics and 3 for without
        --copyright print the copyright and warranty
CONTACT:
Report bugs to <bugsanjib@gmail.com>.
```

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Galaxia Galaxy Model File

Generated and edited in a text editor

```
(base) ~/PycharmProjects/galaxia/docs$ cat galaxyModelParams_PopSyCLEv3.txt
GalaxiaData /path/to/GalaxiaData
bulge_Rc 2.54
bulge_x0 0.70
bulge_y0 0.424
bulge_z0 0.424
bulge_alpha 62.0
bulge_beta 3.5
bulge_gamma 91.3
bulge_sigma_r 100
bulge_sigma_phi 100
bulge_sigma_z 100
bulge_patternspeed 40.00
```

Run from ipython or jupyter notebook

```
from popsycle import synthetic

synthetic.run_galaxia(output_root = 'example',
                      longitude = 1.25,
                      latitude = -2.65,
                      area = 0.001,
                      galaxia_galaxy_model_filename='galaxyModelParams_PopSyCLEv3.txt')
```

Or to be used in `run.py`, include as an argument in `synthetic.generate_popsycle_config()`

```
run.generate_popsycle_config_file(galaxia_galaxy_model_filename = '/Users/myself/galaxia_galaxy_model_filename')
```

GalaxiaData Folder

Each galxay_model_file must point to a unique GalaxiaData folder
due to the generation of binary search trees
(automatically generated the first time a new GalaxiaData folder is run)

```
(base) ~/PycharmProjects/galaxia/docs$ cat galaxyModelParams_PopSyCLEv3.txt
GalaxiaData /path/to/GalaxiaData
bulge_Rc 2.54
bulge_x0 0.70
bulge_y0 0.424
bulge_z0 0.424
```

Installation and running examples at https://github.com/jluastro/galaxia

Running galaxia

The functions and features of galaxia are outlined on the galaxia documentation page. We provide an example of the required galaxia parameter file at example_galaxiaParams.txt.

Our version requires an additional parameter file that states the location of the GalaxiaData directory and the galaxy model parameters. An example galaxyModel parameter file is located at example_galaxyModelParams.txt.

To run galaxia with this parameter file, place it as the next argument after the regular galaxia parameter file.

```
galaxia -r example_galaxiaParams.txt example_galaxyModelParams.txt
```

Make sure that the GalaxiaData directory specified in your galaxyModel parameter file points to a unique directory for each different set of galaxy model parameters.

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In Conclusion

- If convenient to your workflow, consider using `run.py` to simulate many PopSyCLE runs with different sky locations (`run.generate_field_config`), microlensing parameters (`run.generate_popsycle_config`), or random seeds (`—seed`)

- Different galaxy models can be simulated in Galaxia with the github.com/jluastro/galaxia installation and a galaxy_model_file

- See a walkthrough of this implementation at https://github.com/jluastro/PopSyCLE/blob/master/docs/PopSyCLE_example_run.ipynb and more details about run.py by running `PATH/TO/PopSyCLE/popsycle/run.py -h`