An Instrument Data Simulator for MICADO

Status
October 2017

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Stable Version 0.4

Main Developments

- Imaging mode
  - 4mas, 1.5mas, sub-pixel are working
  - Improved thermal background
  - Verification with HAWK-I data proposal accepted (P100)

- Spectroscopy mode
  - Stand-alone prototype is working
  - Needs to be integrated into main package
SimCADO has more built in Source objects

- **Point Sources**
  - `cluster()`
  - `stars()`, `star()`

- **Extended Sources**
  - `elliptical()`, `sersic_profile()`
  - `spiral()`, `spiral_profile()`

- **Image support**
  - `source_from_image()`

- **Basic SIE gravitational lens**
  - `apply_grav_lens()`
Welcome to SimCADocs

The (slowly expanding) documentation base for SimCADO

Omega Cen as imaged with HST/WFC3, HST/SimCADO and MICADO/SimCADO by Maximilian Fabricius (MPE). The synthetic images of the same region of Omega Cen are based on the HST catalog by Anderson & van der Marel 2010 and augmented by all the faint stars that did not end up in the HST catalogue.

SimCADO in a nutshell

SimCADO is a python package designed to simulate the effects of the Atmosphere, E-ELT, and MICADO instrument on incoming light. The current version (v0.2) can simulate the MICADO imaging modi (4mas and 1.5mas per pixel in the wavelength range 0.7µm to 2.5µm).

iPython/Jupyter notebooks
Help desk at

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Help desk availability notice
Unfortunately for the near future** we can provide help
only on a volunteer best-effort basis

** Near future = Oliver : end of year(?), Kieran : ~March 2018
MICADO will reach K~27.5 and J~29 in 5 hours

Or $K_{AB} \sim 29.3$ and $J_{AB} \sim 29.8$ if you like AB magnitudes
Young massive clusters are useful

**Advantages**
- Young < 100 Myr
- Population intact
- No explosions
- Membership is easy

**Disadvantages**
- Too dense for current telescopes

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**Diagram Notes:**
- Arches (8.5 kpc)
- R136 (LMC)
- Star density [stars/arcsec^2]
- Cluster age [Myr]
- Limiting magnitude is K=28
- Star densities of clusters respect the magnitude limit
- Resolvability limits assume 1 star per telescope FWHM for λ=1.2 μm
- Data taken from Portegies Zwart (2010)
Extracted IMF with PSF Photometry
Don’t rely on exposure time calculators for dense regions.
SimCADO 1
Point sources and Supernovae

LSST will provide bi-weekly coverage of the sky down to i~24 mag

5 mins/day with MICADO in J-band sufficient to follow SNe for >100 days

See Wiis et al. (in prep)
Make a `Source` object and run it

```python
In [ ]:
import simcado as sim
from astropy.io import ascii

lc = ascii.read("./SN2015bn sdss_g.txt")

for i in np.arange(len(lc)):
    src_sn = sim.source.star(filter_name="J", mag=lc["mag"][i])
    sim.run(src_sn, filename=str(i)+".fits", OBS_EXPTIME=300)

make_gif(tbl=lc)
```
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for i in np.arange(len(lc)):
    src_sn = sim.source.star(filter_name="J", mag=lc["mag"][i])
    sim.run(src_sn, filename=str(i)+".fits", OBS_EXPTIME=300)

make_gif(tbl, lc)
```

Make a star object

Magic "batteries included" one-liner simulation
SimCADO 2: Extended objects and sub-structure

Model of B1938 “observed” with SimCADO

2hr runs for system H=19^m

Effects from halo sub-structures with M>1E7 M⊙ are detectable

See Vegetti & Czoske (in prep)
SimCADO 2:
The same system for H=21 mag

Model of B1938 “observed” with SimCADO

2hr runs for system H=21°
2 separate objects can be combined in a single simulation

SimCADO needs

1) Image of the lensing elliptical B1938

2) Image of the lensing elliptical B1938

3) A spectrum for each galaxy
Combine 2 Source objects and run

```python
In [1]: import simcado as sim

lam, spec = sim.source.SED("spiral",  "H",  19)
ring = sim.source.source_from_image("B1938_ring.fits", plate_scale=0.004,
                                    lam=lam, spectra=spec)
ellip = sim.source.elliptical(r_eff=0.2, plate_scale=0.004,
                               filter_name="H", mag=21, ellipticity=0.1)

src_combi = ring + ellip

sim.run(src_combi, filename="sim_B1938.fits", OBS_EXPTIME=7200)
```
Combine 2 Source objects and run

Use inbuilt model of Elliptical galaxy

Create Source from on-disk image of lensed galaxy

In [1]:
import simcido as sim

lam, spec = sim.source.SED("spiral", "H", 19)
ring = sim.source.source_from_image("B1938_ring.fits", plate_scale=0.004,
                                    lam=lam, spectra=spec)

ellip = sim.source.elliptical(r_eff=0.2, plate_scale=0.004,
                               filter_name="H", mag=21, ellipticity=0.1)

src_combi = ring + ellip

sim.run(src_combi, filename="sim_b1938.fits", OBS_EXPTIME=7200)

Combine Source objects

Make some observations
SimCADO 3: Multiply imaged quasar light curves

J=15 mag, 10 min exposure time
System diameter ~4 arcsec
Light curve from QSO J1131-1231 (Tewes+ 2013)
SimCADO 3: Multiply imaged quasar light curves

J=20 mag, 60 min exposure time
System diameter ~0.4 arcsec
Majority of effort goes into describing objects of interest

```python
In [ ]:
import simcado as sim
from astropy.io import ascii

spiral = sim.source.spiral_profile(r_eff=25, arms_width=0.3)
sp_lensed = sim.source.apply_grav_lens(spiral, y_cen=-10, eccentricity=0.3, rotation=-45)
lam, spec = sim.source.SED("spiral", "J", mag=20)
ring = sim.source.source_from_image(sp_lensed, lam=lam, spectra=spec, plate_scale=0.004)

ellip = sim.source.elliptical(0.2, plate_scale=0.004, mag=21,
              filter_name="J", ellipticity=0.7, angle=45)

tbl = ascii.read("./qso_light_curves.dat") # Tewes+ (2013)
mags = np.array([tbl[n+"_mag"] for n in "ABCD"])
xp, yp = get_dists_from_centre()

for i in range(len(t)):
    stars = sim.source.stars(mags=mags[:, i], x=xp, y=yp)

src_combi = ellip + lens + stars

sim.run(src_combi, filename=\"str(i)+".fits\", OBS_EXPTIME=3600)
```
Majority of effort goes into describing objects of interest

```python
import simcado as sim
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spiral = sim.source.spiral_profile(r_eff=25, arms_width=0.3)
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filter name="J", ellipticity=0.7, angle=45)

tbl = ascii.read("./qso_light_curves.dat") # Tewes+ (2)
mags = np.array([tbl[n+"_mag"] for n in "ABCD"])
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src_combi = ell + lens + stars

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```

Generate lensed spiral galaxy

Generate elliptical galaxy

Create variable cores

“Observe” the system
Getting started with SimCADO

Install the package

```bash
$ pip3 install --user http://www.univie.ac.at/simcado/SimCADO.tar.gz
```

Update the data

```python
>>> import simcado
>>> simcado.get_extras()
```

Make / Download a detector noise cube

```python
>>> simcado.install_noise_cube(n=25)
```
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Observational horizon for spectral types assuming an apparent magnitude limit of $K_s = 27.5''$.