SimCADO

An Instrument Data Simulator for MICADO

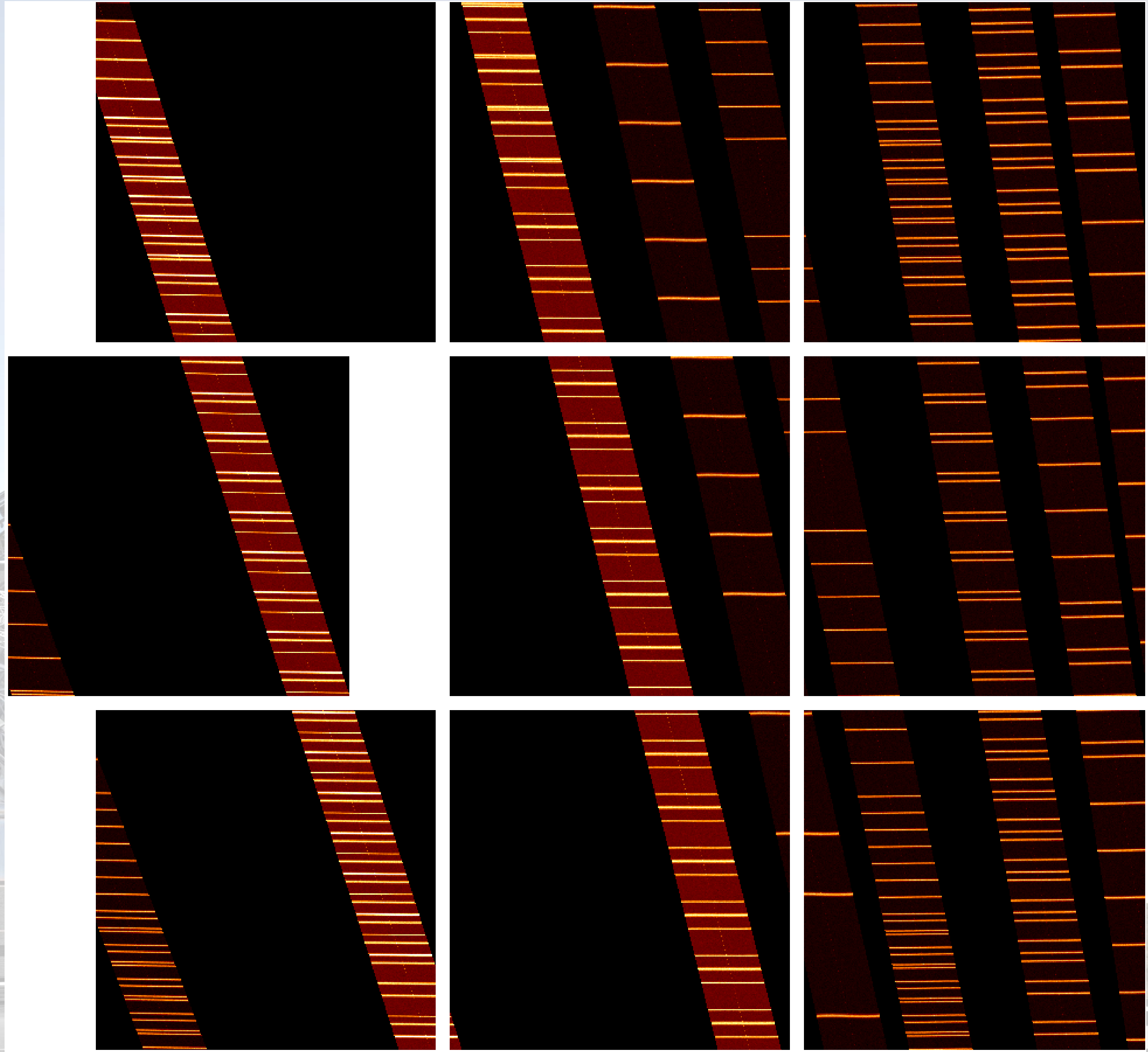
Status

October 2017

Kieran Leschinski

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 integtrated 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()`

Documentation available at

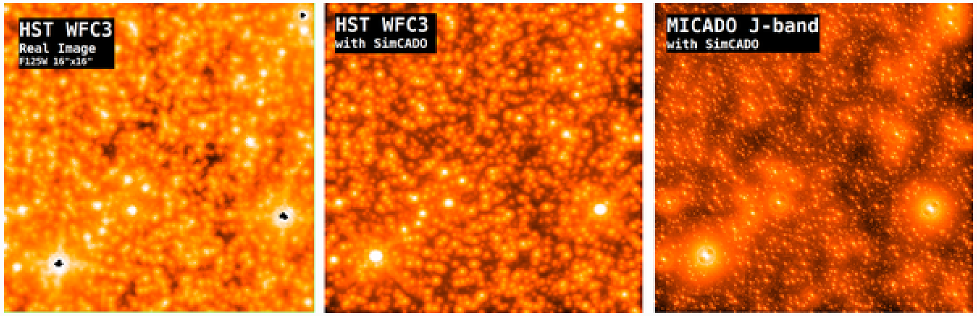
www.univie.ac.at/simcado/

SimCADocs - Documentation for SimCADO

Search docs

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

oliver.czoske@univie.ac.at

kieran.leschinski@univie.ac.at

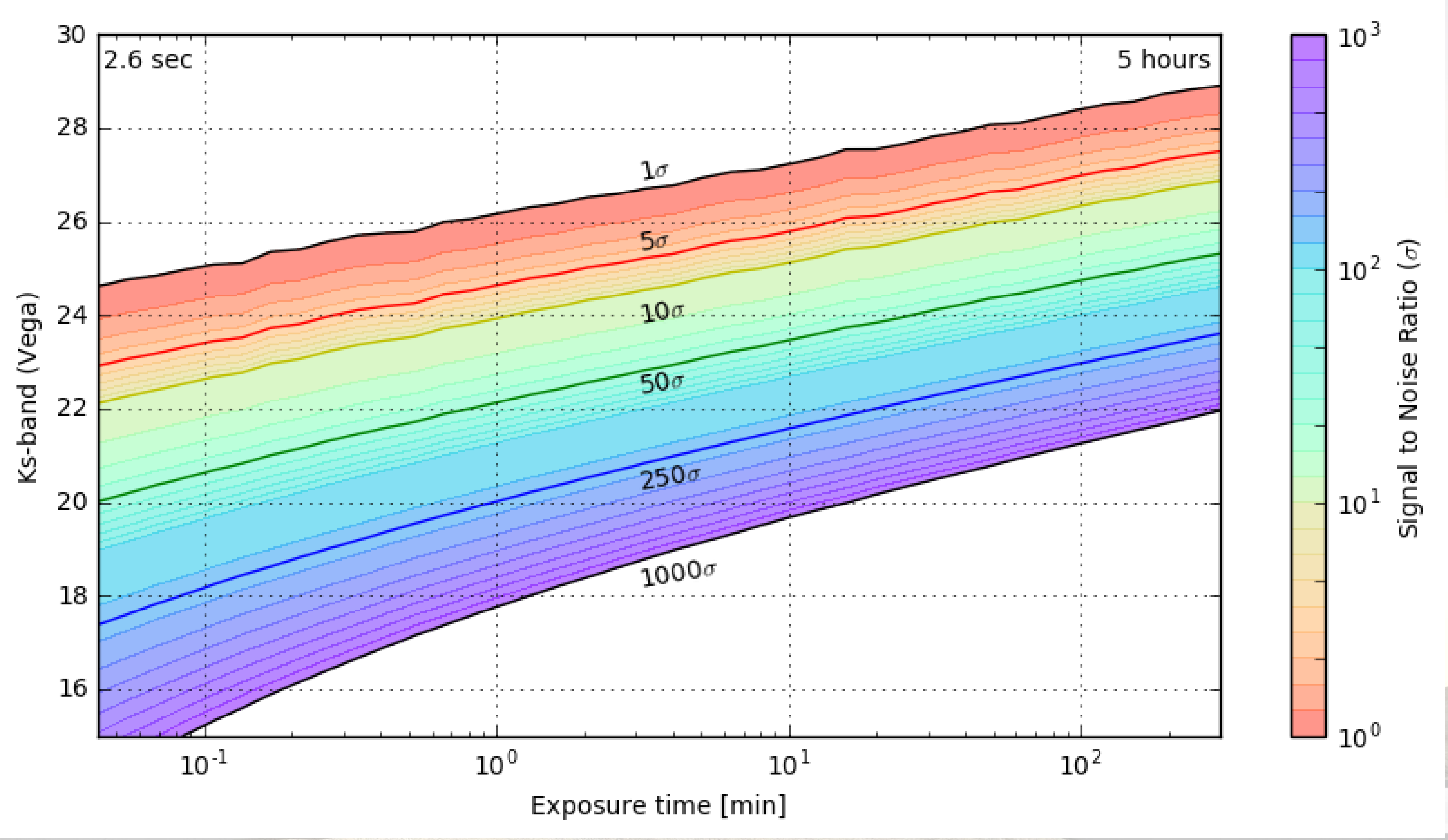
Help desk availability notice

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}~29.3 and J_{AB}~29.8 if you like AB magnitudes



Young massive clusters are useful

Advantages

Young <100 Myr

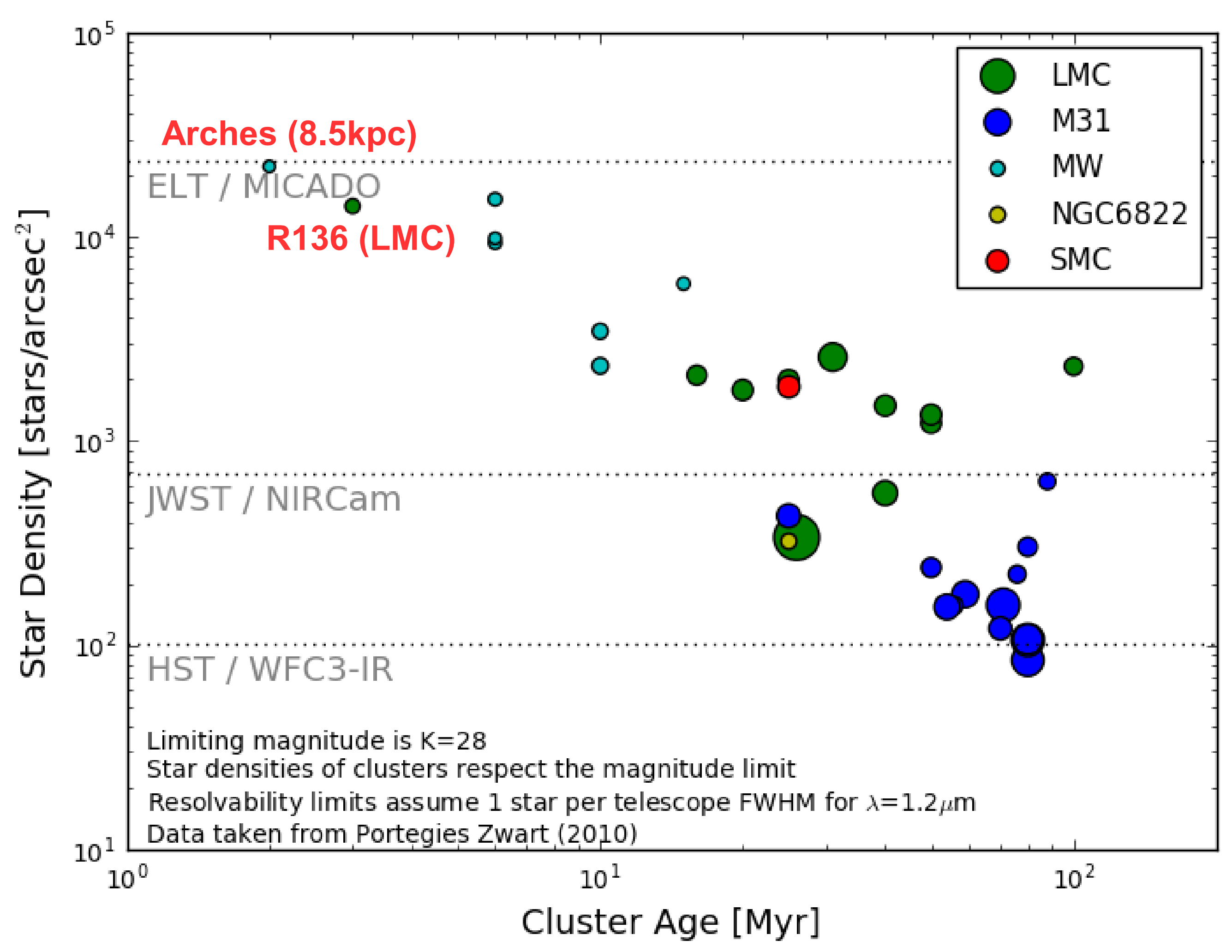
Population intact

No explosions

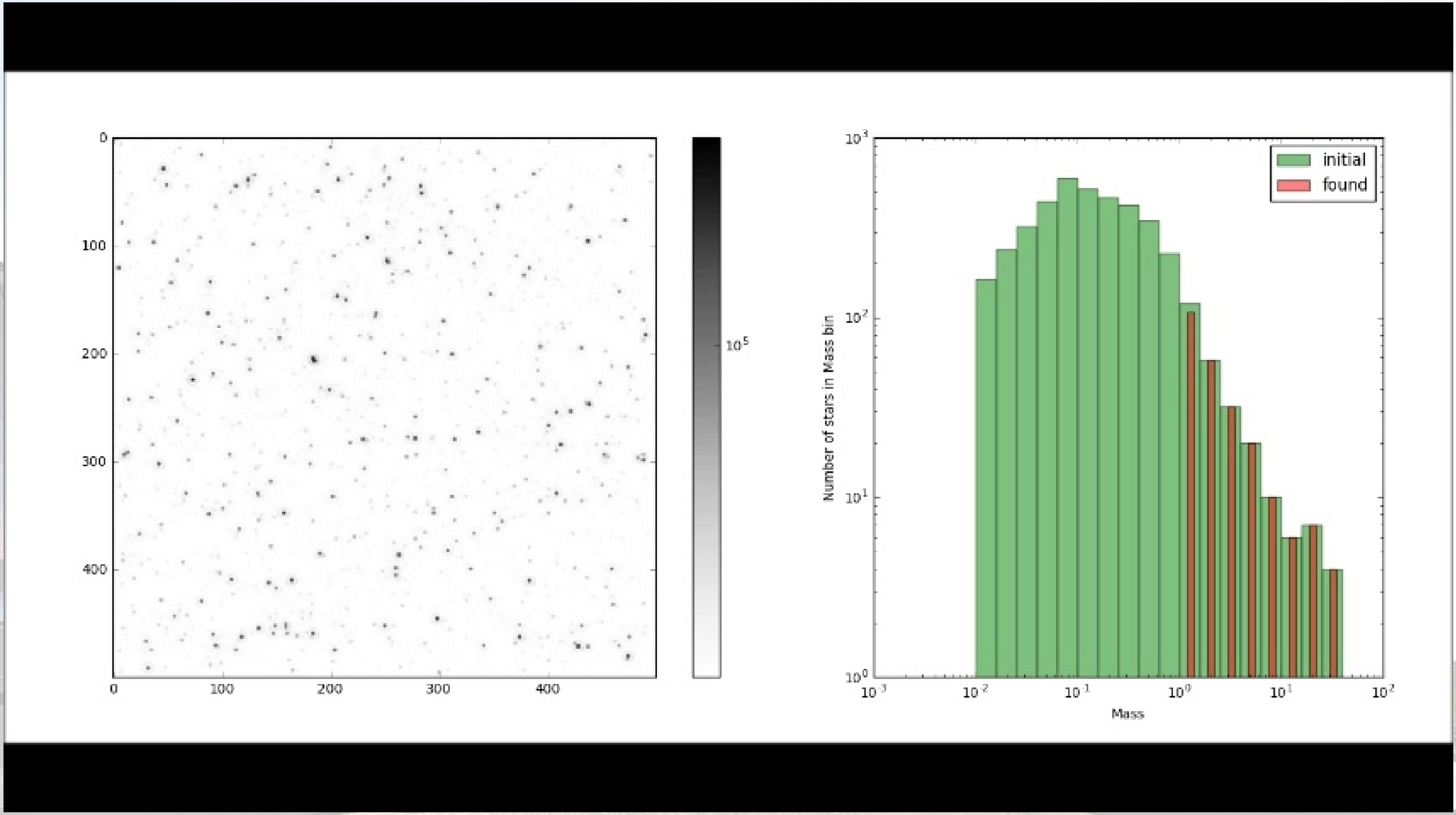
Membership is easy

Disadvantages

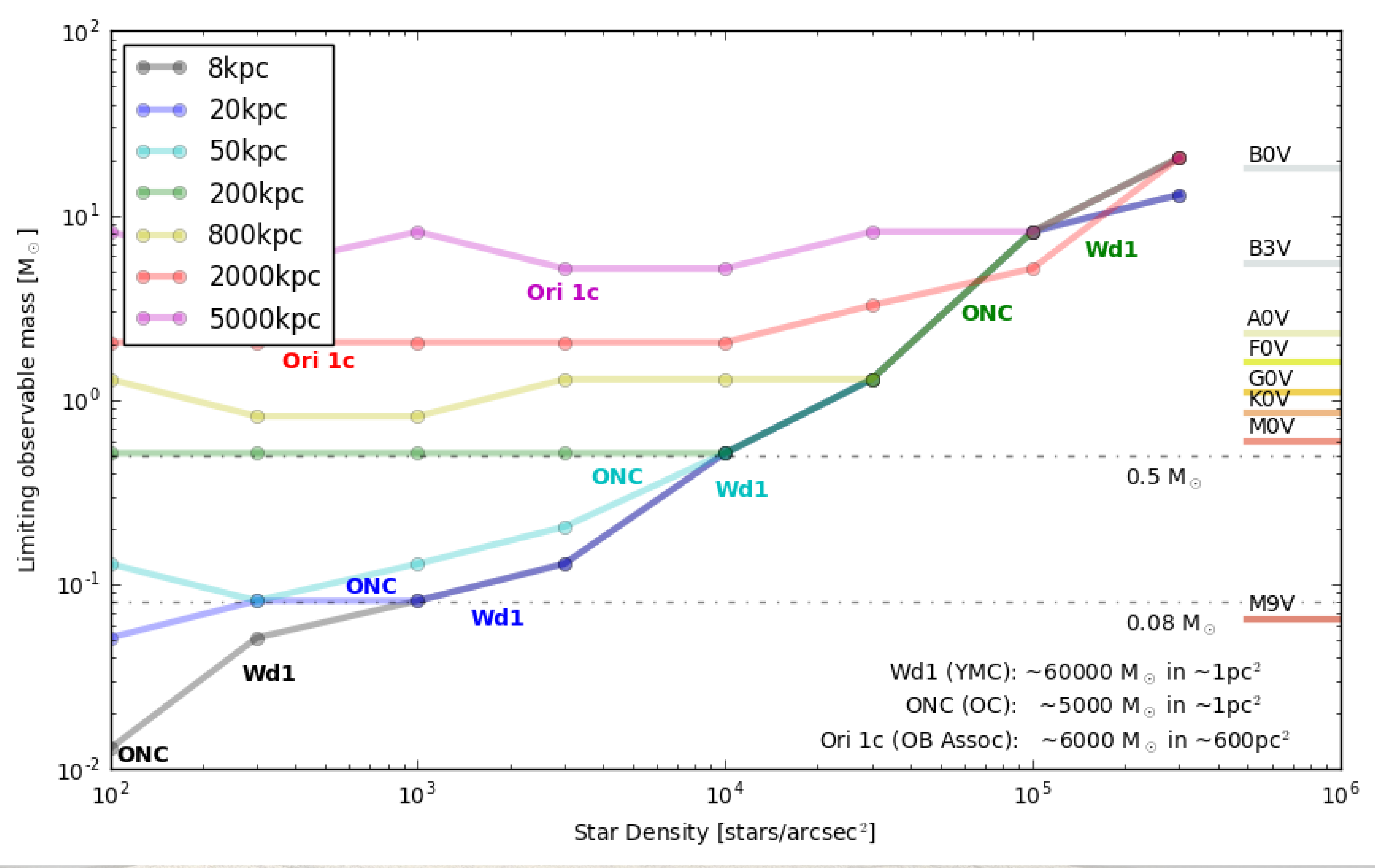
Too dense for current telescopes



Extracted IMF with PSF Photometry



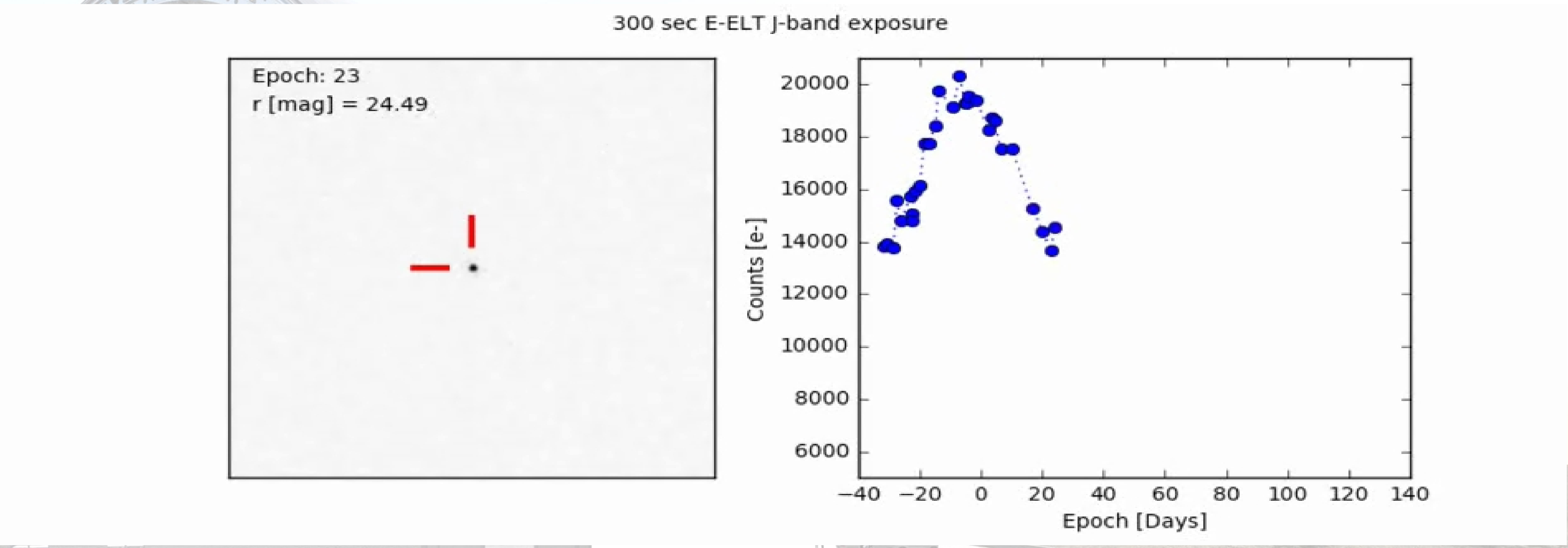
Don‘t rely on exposure time calculators for dense regions



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

```
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)
```

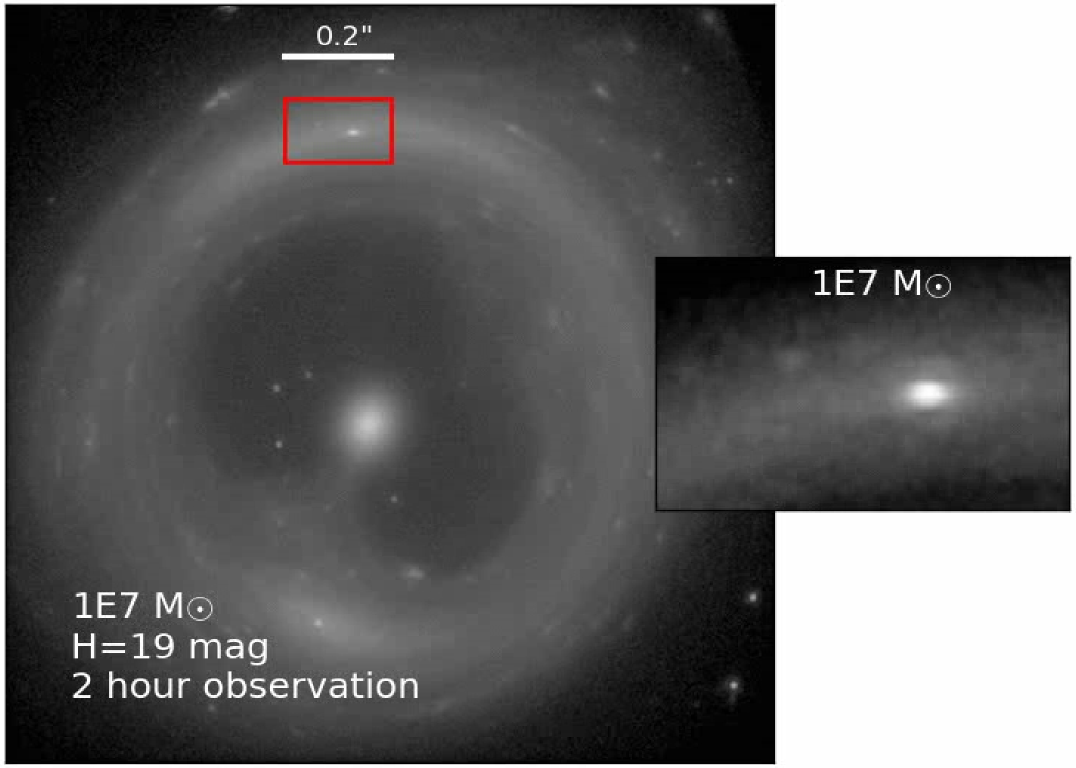
Make a `Source` object and `run` it

Make a star object

```
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)
```

Magic “batteries included“
one-liner simulation

SimCADO 2: Extended objects and sub-structure



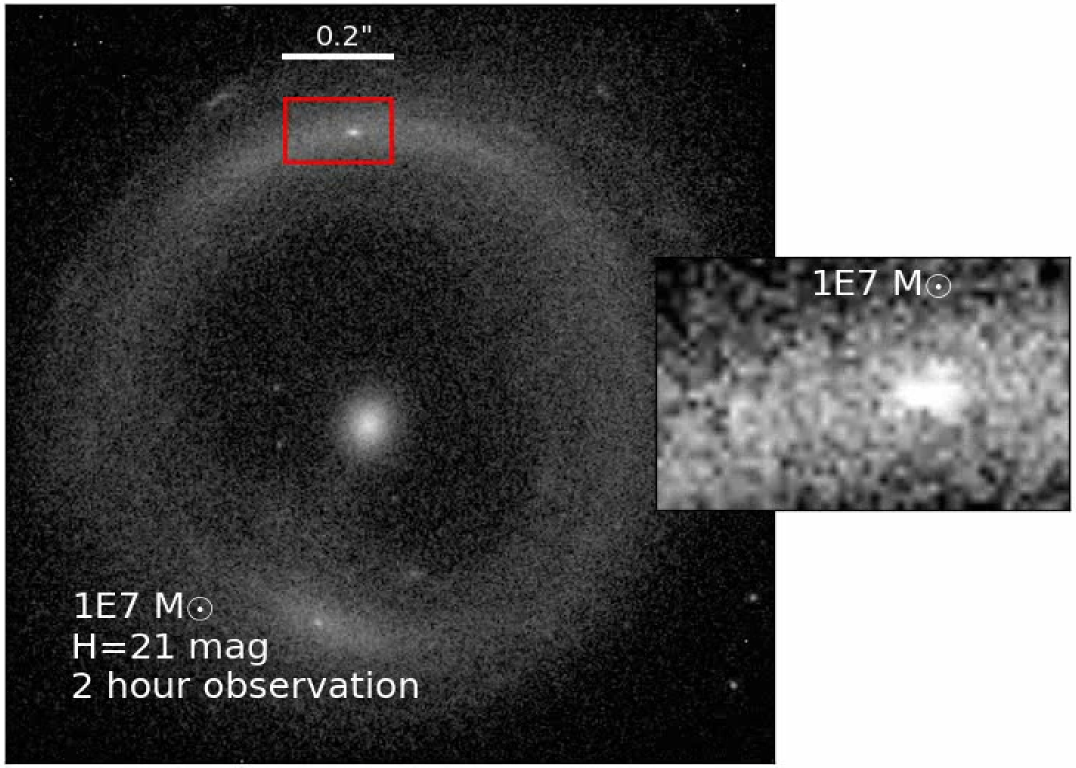
Model of B1938 “observed“ with SimCADO

2hr runs for system H=19^m

See Vegetti & Czoske (in prep)

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

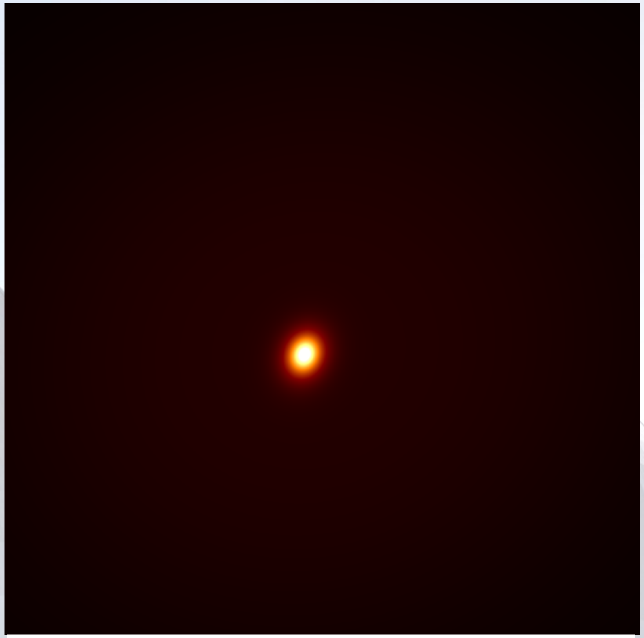
SimCADO 2:
The same system for H=21 mag

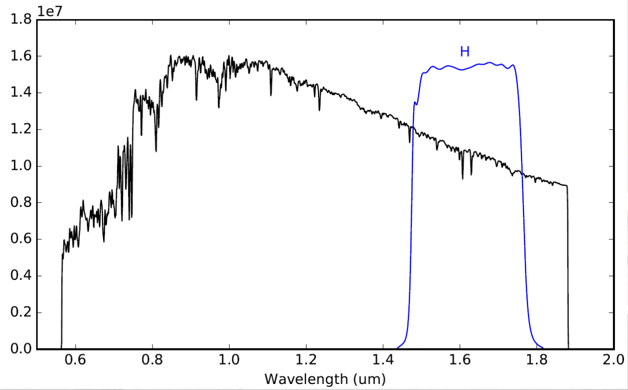


Model of B1938 “observed“ with SimCADO

2hr runs for system $H=21^m$

2 seperate objects can be combined in a single simulation



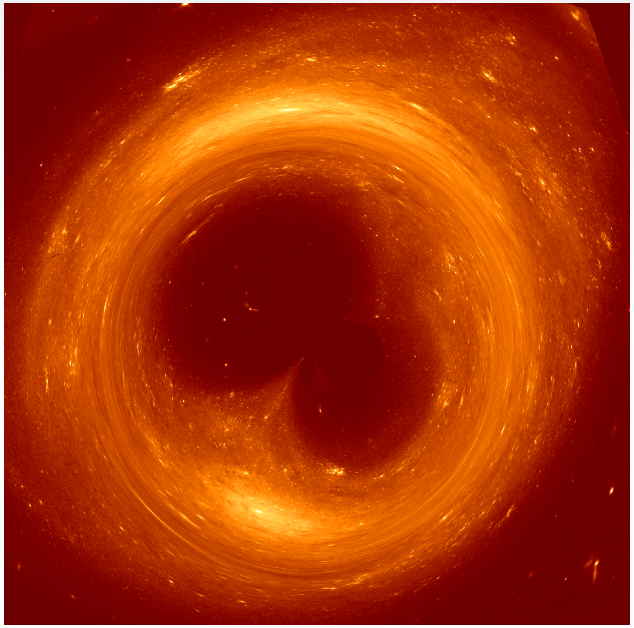


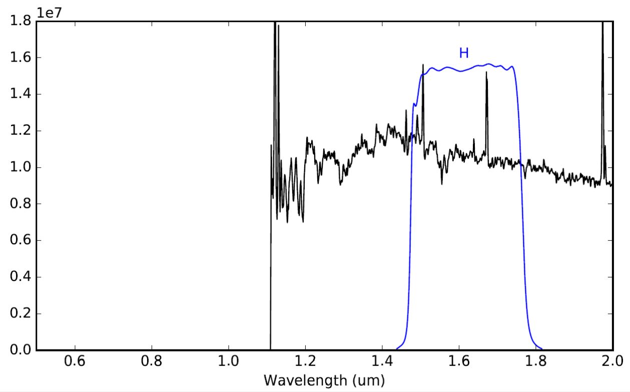
SimCADO needs

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

```
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 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 `Source` objects

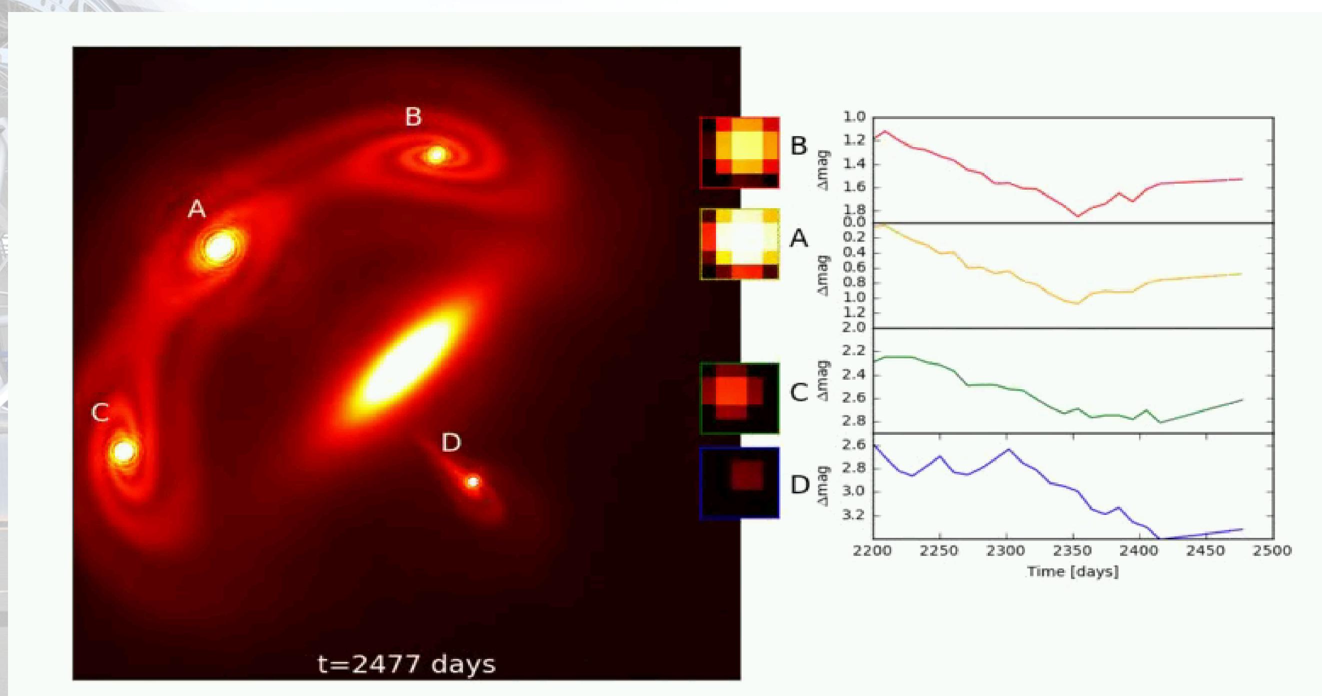
Make some observations

SimCADO 3:
Multiply imaged quasar light curves

J=15 mag, 10 min exposure time

System diameter ~4 arcsec

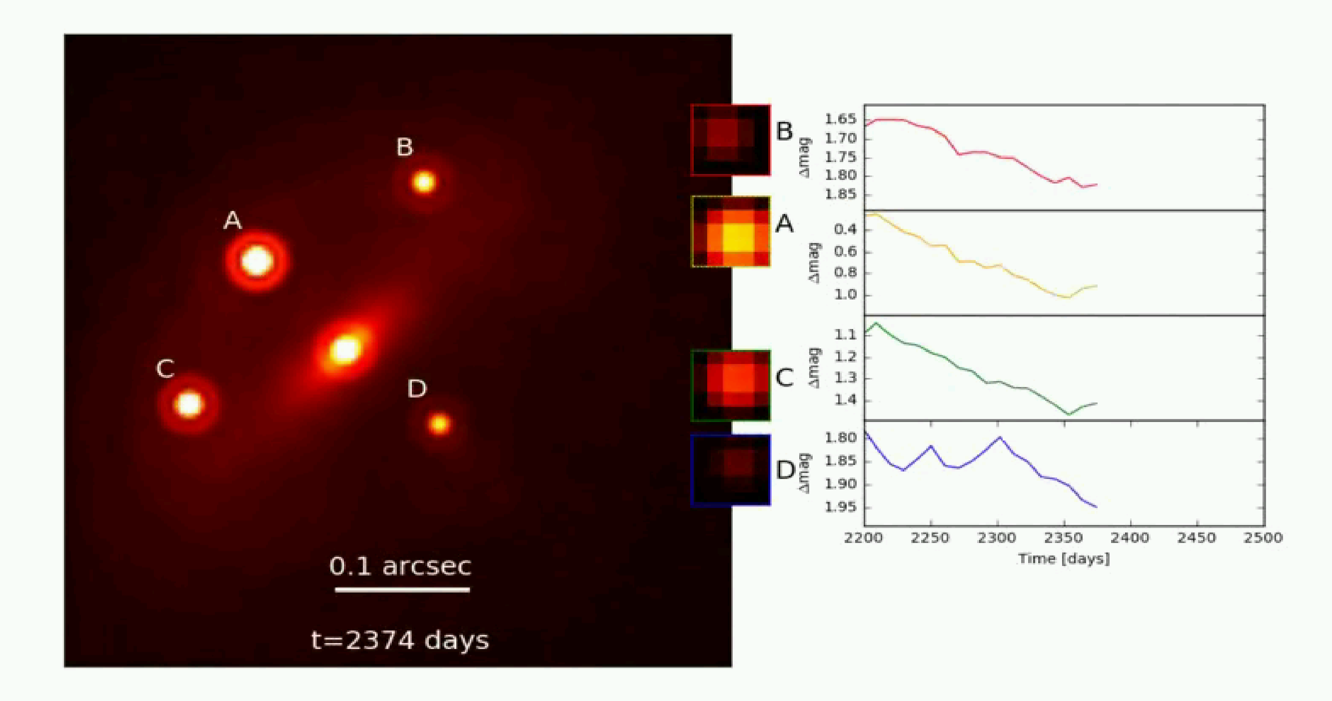
Light curve from QSO J1131-1231 (Tewes+ 2013)



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

```
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 = ell + lens + stars

            sim.run(src_combi, filename=str(i)+".fits", OBS_EXPTIME=3600)
```

Majority of effort goes into describing objects of interest

```
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+ (2
        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 = ell + lens + stars

            sim.run(src_combi, filename=str(i)+".fits", OBS_EXPTIME=3600)
```

Generate lensed spiral galaxy

Generate elliptical galaxy

Create variable cores

“Observe“ the system

Getting started with SimCADO

Install the package

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

Update the data

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

Make / Download a detector noise cube

```
>>> simcado.install_noise_cube(n=25)
```

Documentation available at

www.univie.ac.at/simcado/

SimCADocs - Documentation for SimCADO

Search docs

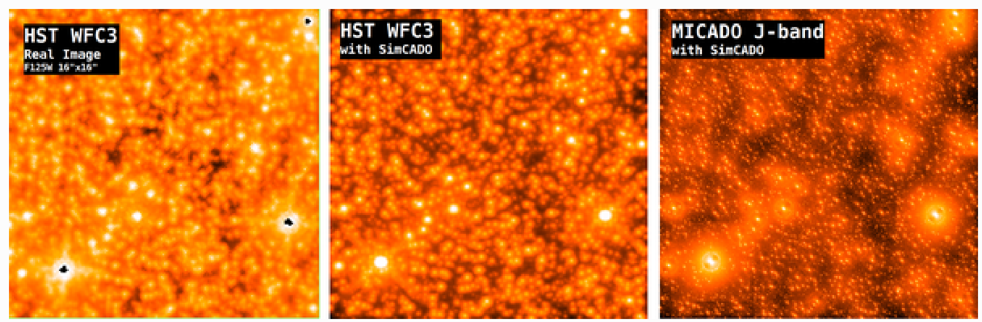
- **Home**
  - Welcome to SimCADocs
  - SimCADO in a nutshell
  - Downloading and Installing
  - Running a simulation in 3 lines
  - Bugs and Issues
  - Contact
- Getting Started
- Examples
  - Notebooks
  - Creating Sources
  - Controlling SimCADO
  - Manipulating the Optical Train
  - Reading out the Detector
- Download
- Updates
- Features
- SimCADO in depth
  - How SimCADO works

Next »

Docs » Home

Welcome to SimCADocs

The (slowly expanding) documentation base for SimCADO

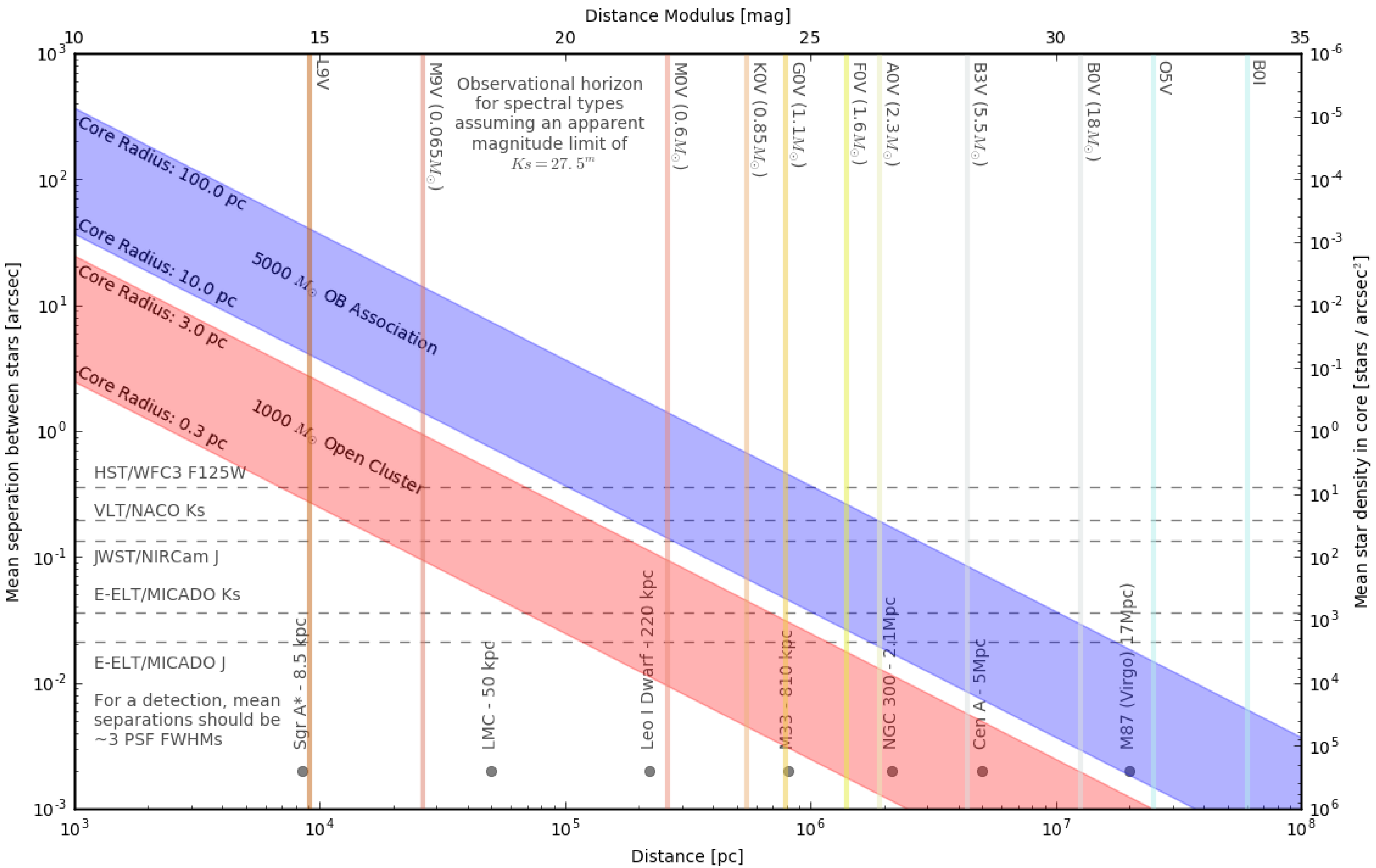


Omega Cen as imaged with HST/WFC3, HST/SimCADO and MICADO/SimCADO by Maximilian Fabricius (MPE). The synthetic images of the same region of Omega Cen are based on the HST catalog by Anderson & van der Marel 2010 and augmented by all the faint stars that did not end up in the HST catalogue.

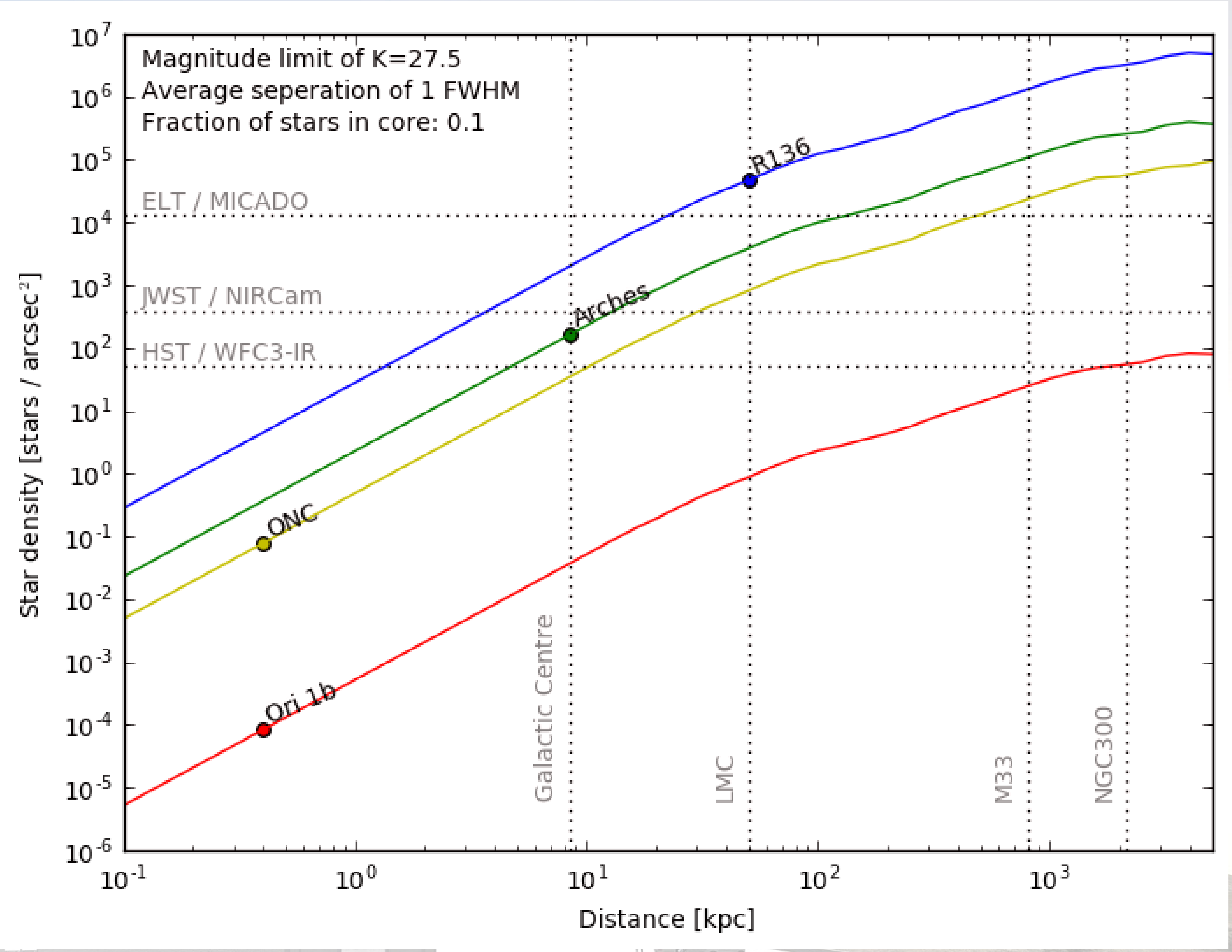
SimCADO in a nutshell

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



Distance Modulus [mag]
Observational horizon for spectral types assuming an apparent magnitude limit of $Ks = 27.5^m$
L9V
M9V ($0.065 M_\odot$)
M0V ($0.6 M_\odot$)
K0V ($0.85 M_\odot$)
G0V ($1.1 M_\odot$)
F0V ($1.6 M_\odot$)
A0V ($2.3 M_\odot$)
B3V ($5.5 M_\odot$)
B0V ($18 M_\odot$)
O5V
B0I
Core Radius: 100.0 pc
Core Radius: 10.0 pc
$5000\ M_\odot$ OB Association
Core Radius: 3.0 pc
Core Radius: 0.3 pc
$1000\ M_\odot$ Open Cluster
HST/WFC3 F125W
VLT/NACO Ks
JWST/NIRCam J
E-ELT/MICADO Ks
E-ELT/MICADO J
For a detection, mean separations should be ~3 PSF FWHMs
Sgr A* - 8.5 kpc
LMC - 50 kpc
Leo I Dwarf - 220 kpc
M33 - 810 kpc
NGC 300 - 2.1Mpc
Cen A - 5Mpc
M87 (Virgo) 17Mpc
Mean seperation between stars [arcsec]
Mean star density in core [stars / arcsec^2]
Distance [pc]



Magnitude limit of K=27.5
Average seperation of 1 FWHM
Fraction of stars in core: 0.1
ELT / MICADO
JWST / NIRCam
HST / WFC3-IR
R136
Arches
ONC
Ori 1b
Galactic Centre
LMC
M33
NGC300
Star density [stars / arcsec^2]
Distance [kpc]
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}