AETC

advanced exposure time calculator

A web tool to simulate astronomical imaging instruments

M.Uslenghi – astrosiesta 8 Ottobre 2015

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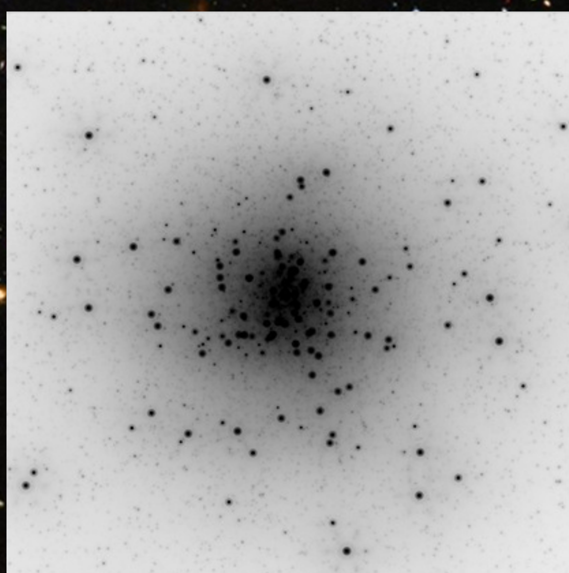
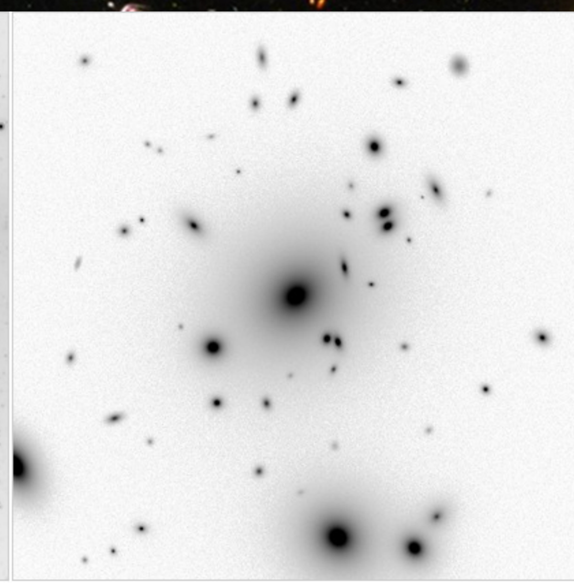
AETC

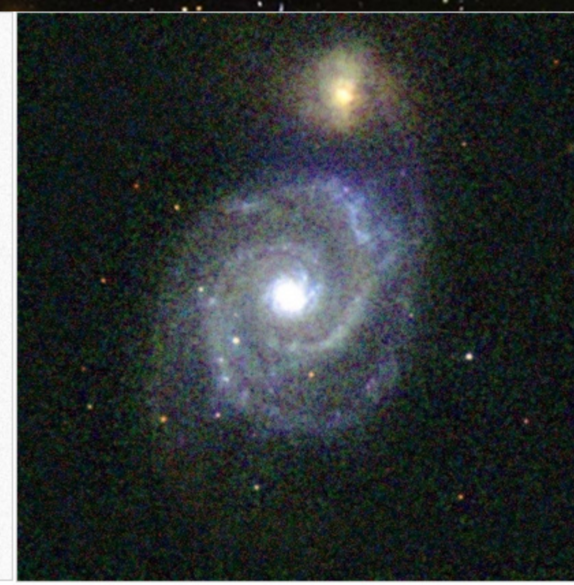
- [web]tool to simulate images of astrophysical objects obtained with any combination of telescope, instrument and filter
- ⇒ count rates and photon distribution over the focal plane
- ⇒ detailed simulation of the observed fields including stars, galaxies and any kind of astronomical object



Nuclear star cluster. MICADO@E-ELT



Nearby galaxy cluster. WFC@INT



M51-like galaxy @z=2.4. MICADO@E-ELT

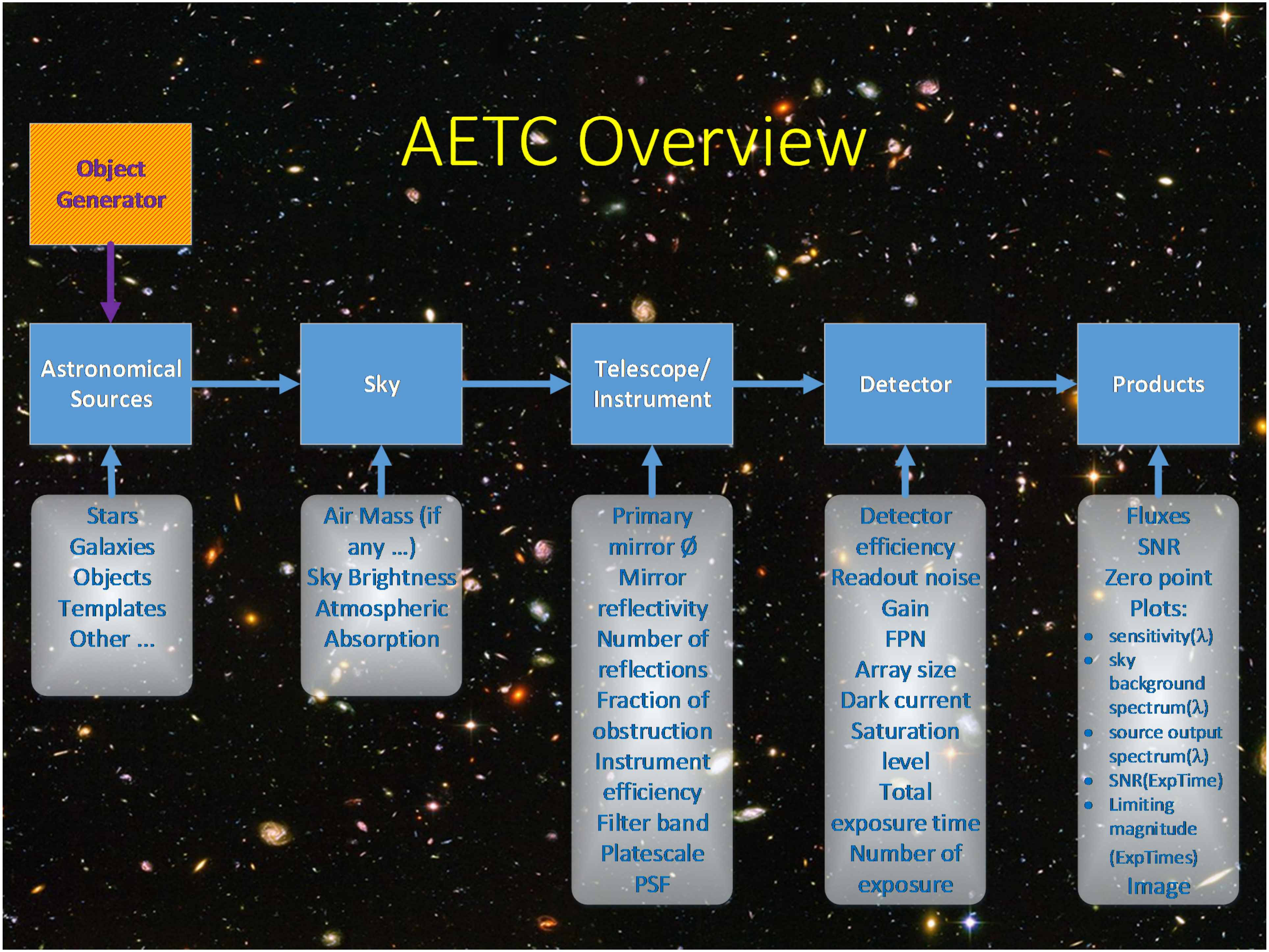
Why AETC?

- ETCs are crucial both in planning observations and in developing new instruments

- Possibility to change the parameters of the adopted instrumentation and/or the conditions of the observation $\rightarrow$ important !!!

- The main trigger has been the study of science cases for ELT/MAORY+MICADO $\rightarrow$ focus on realistic[(*)] simulations of the field images

[(*)] "Realistic":
- PSF variable in the FoV
- Large variety of targets (stars, galaxies modeled by sersic law, but also more complex obj…)
- …


AETC Overview
Object Generator
Astronomical Sources
Sky
Telescope/ Instrument
Detector
Products
Stars
Galaxies
Objects
Templates
Other …
Air Mass (if any …)
Sky Brightness
Atmospheric Absorption
Primary mirror Ø
Mirror reflectivity
Number of reflections
Fraction of obstruction
Instrument efficiency
Filter band
Platescale
PSF
Detector efficiency
Readout noise
Gain
FPN
Array size
Dark current
Saturation level
Total exposure time
Number of exposure
Fluxes
SNR
Zero point
Plots:
• sensitivity(λ)
• sky background spectrum(λ)
• source output spectrum(λ)
• SNR(ExpTime)
• Limiting magnitude (ExpTimes)
Image

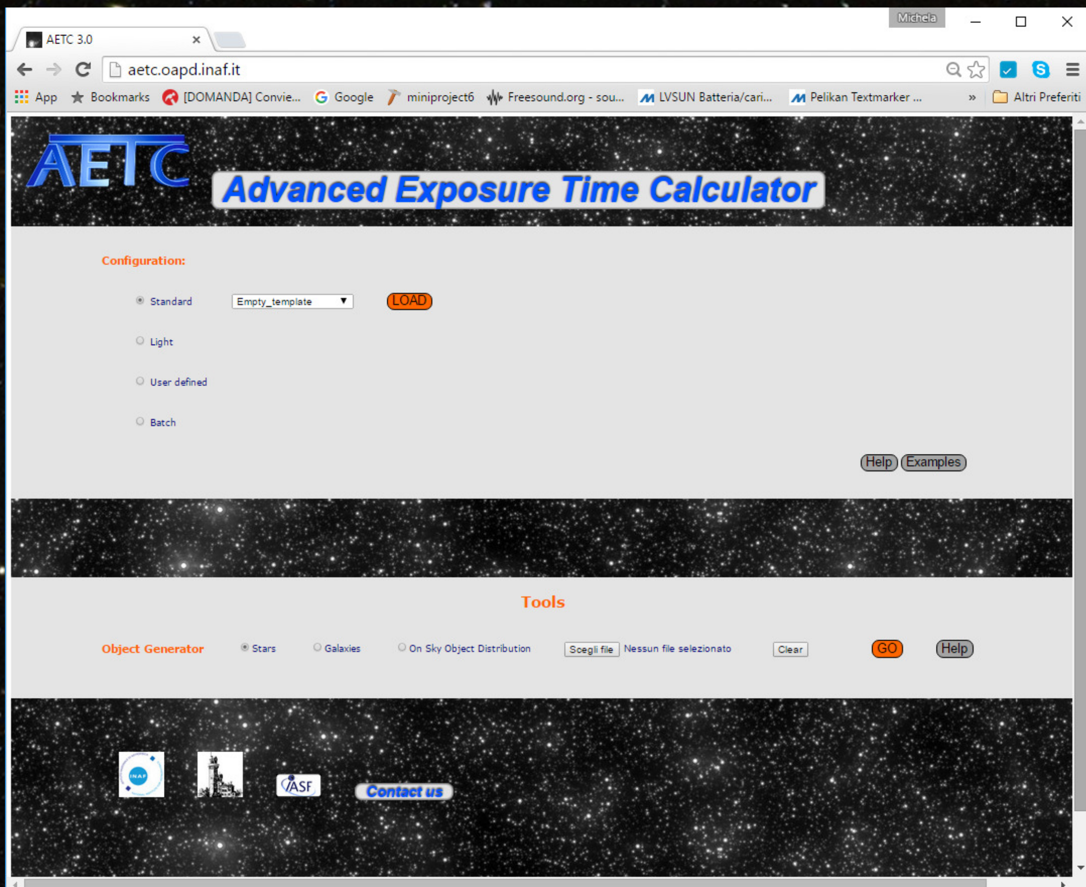
Pre-configured instruments

(currently available)

Telescope	Instrument
HST	WFPC2
JWST	NIRcam
VLT	FORS
ELT	MICADO
TNG	NICS
	DOLORES
REM	ROSS
	REMIR
LBT	LBC

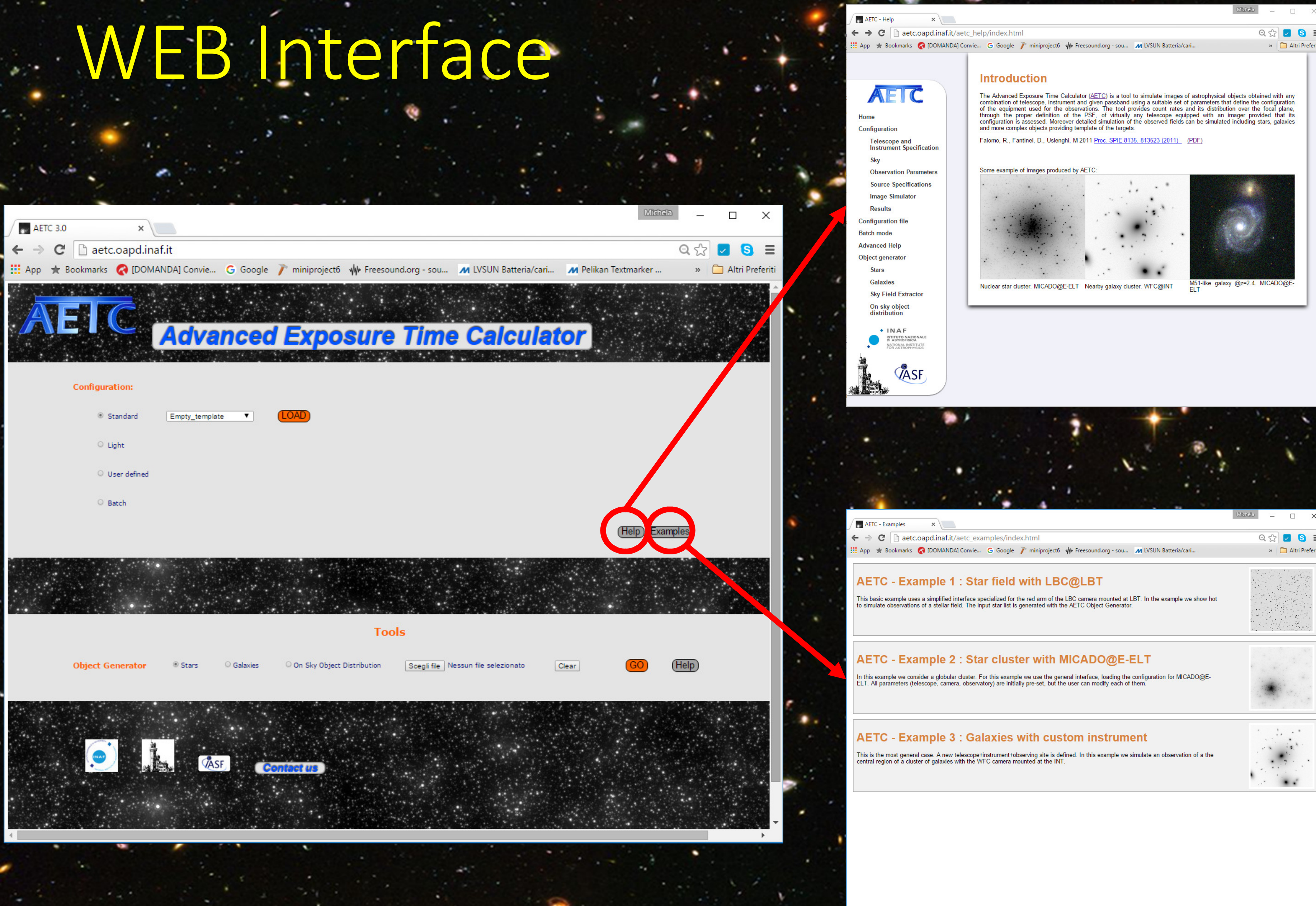
The templates can be also used as starting point for a new configuration (all the parameters can be changed by the user)

WEB Interface

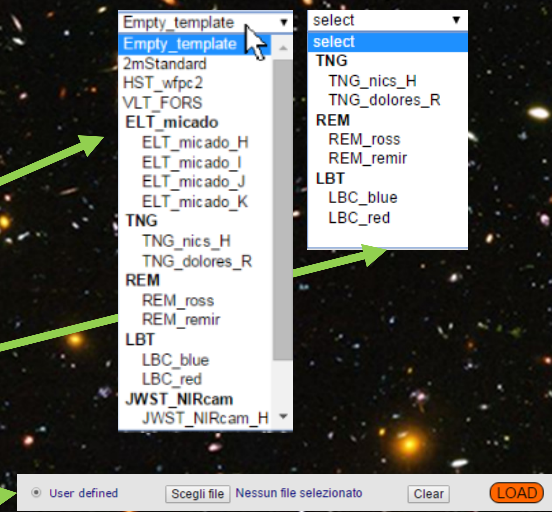


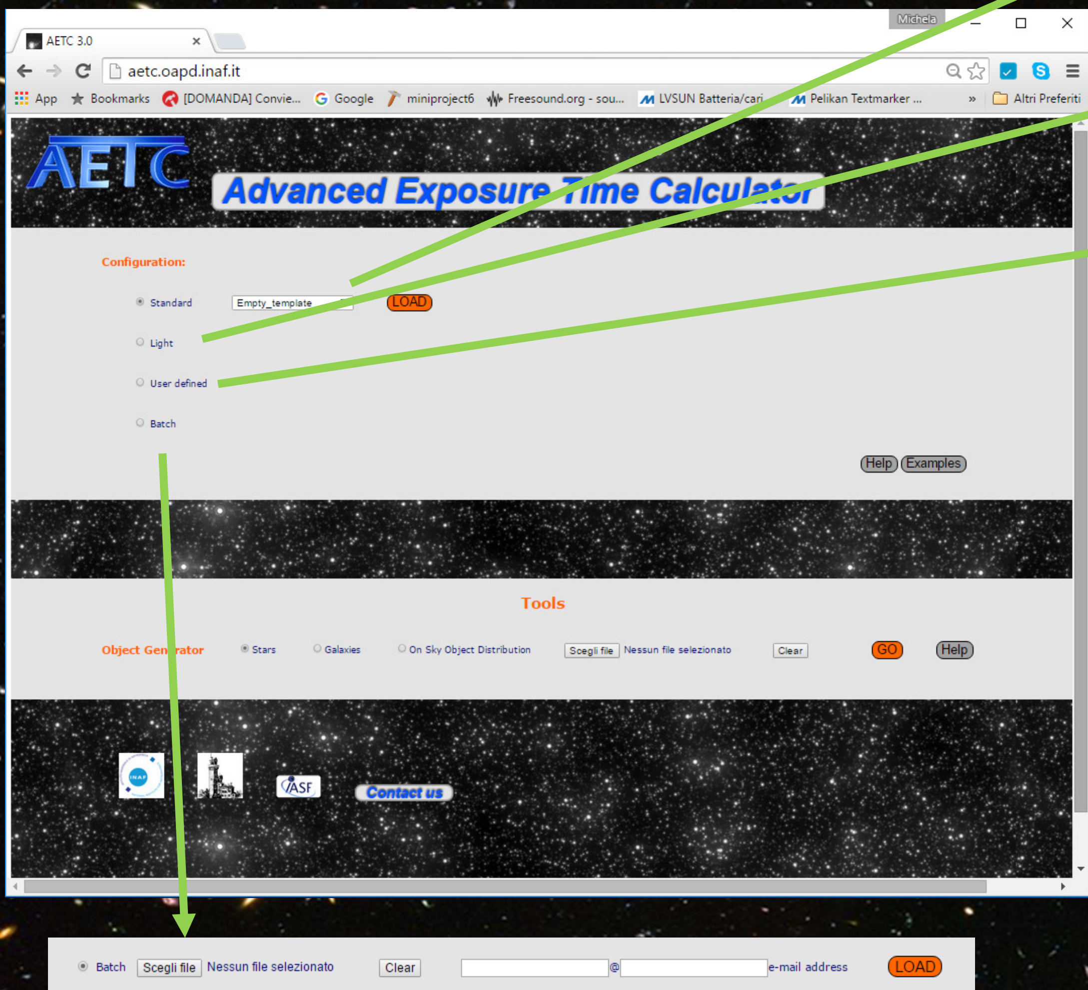
- GUI to set all the parameters
- Batch mode to perform multiple simulations

WEB Interface

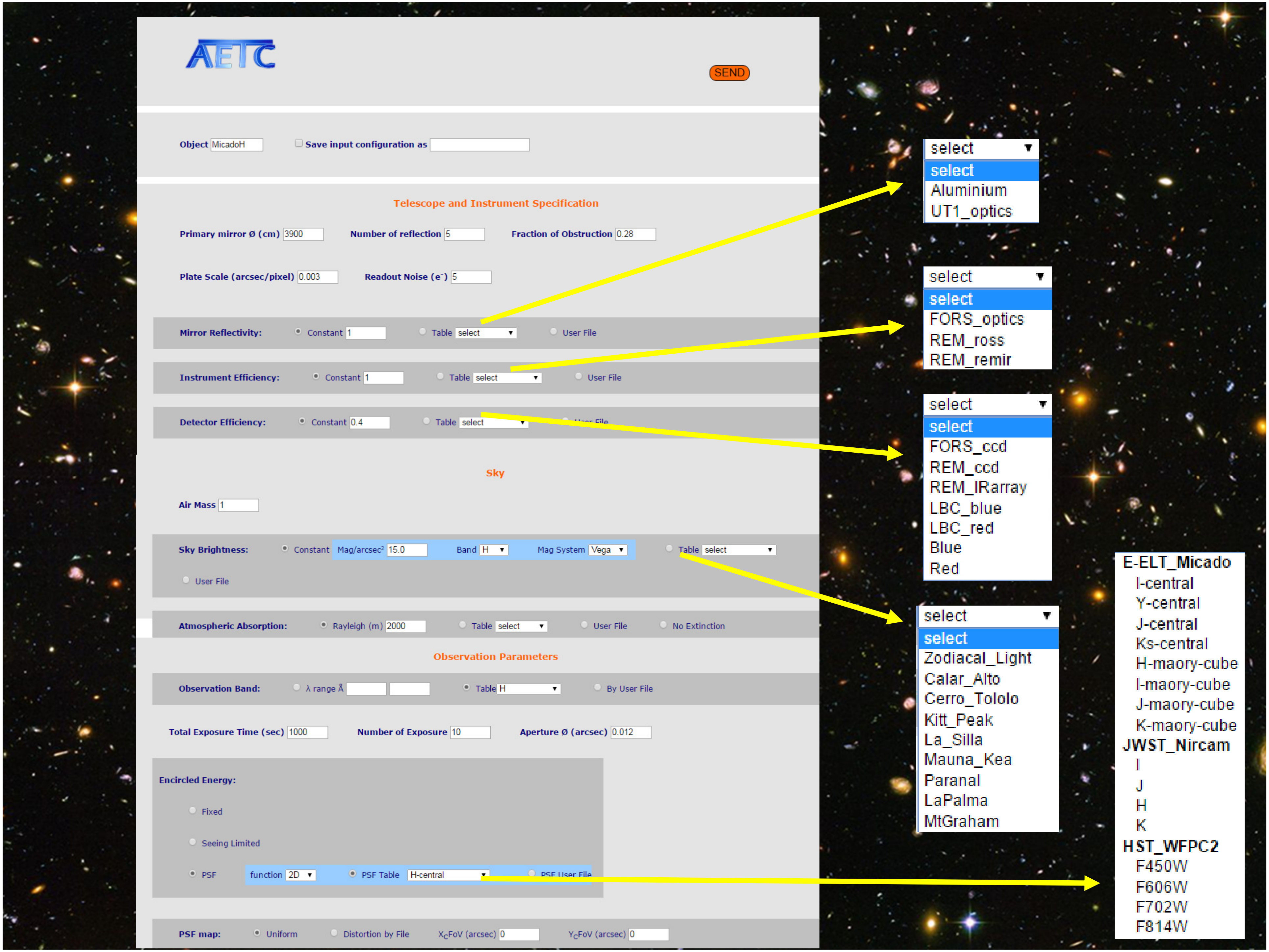


WEB Interface

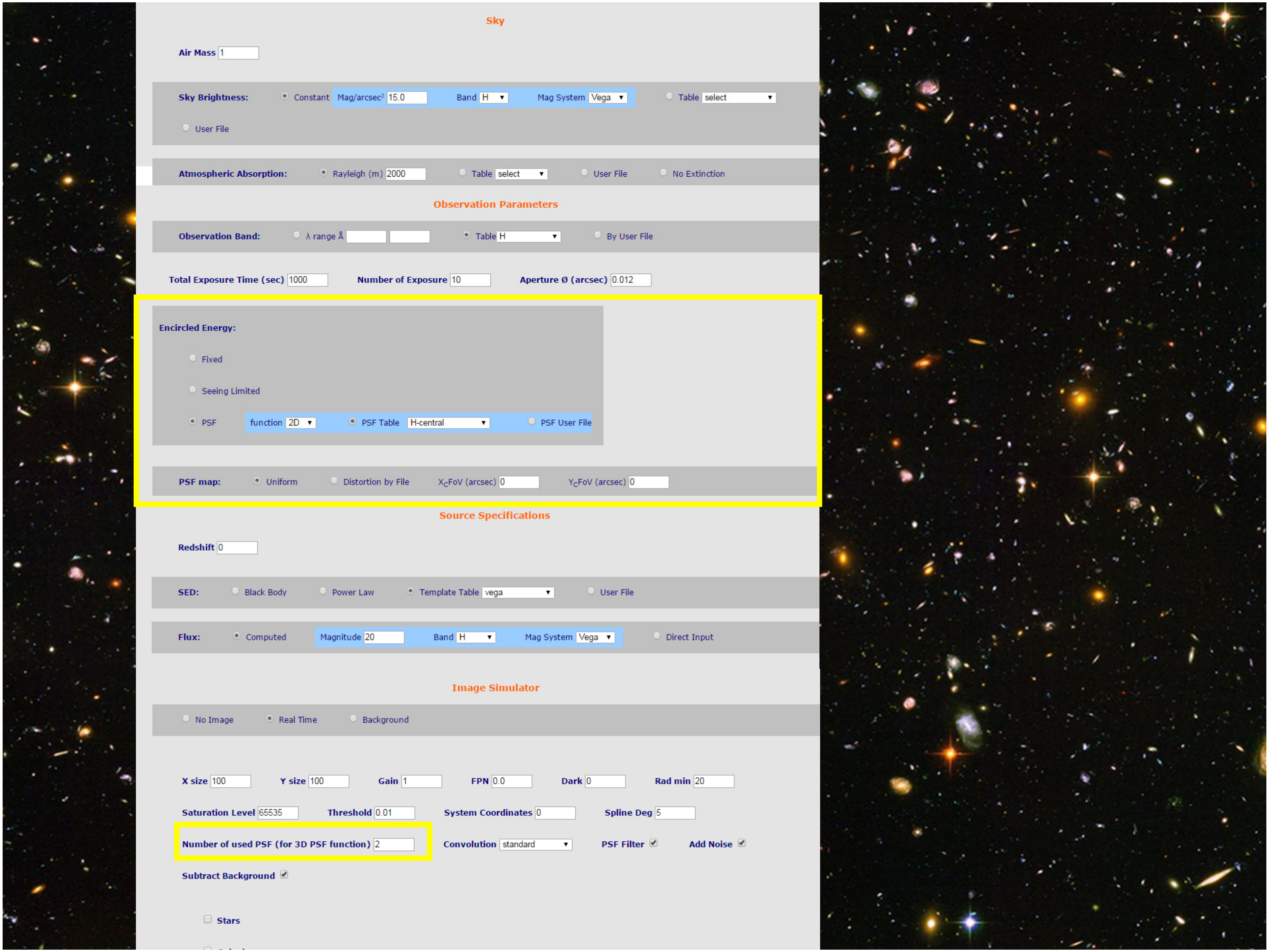




- GUI to set all the parameters
- Batch mode to perform multiple simulations

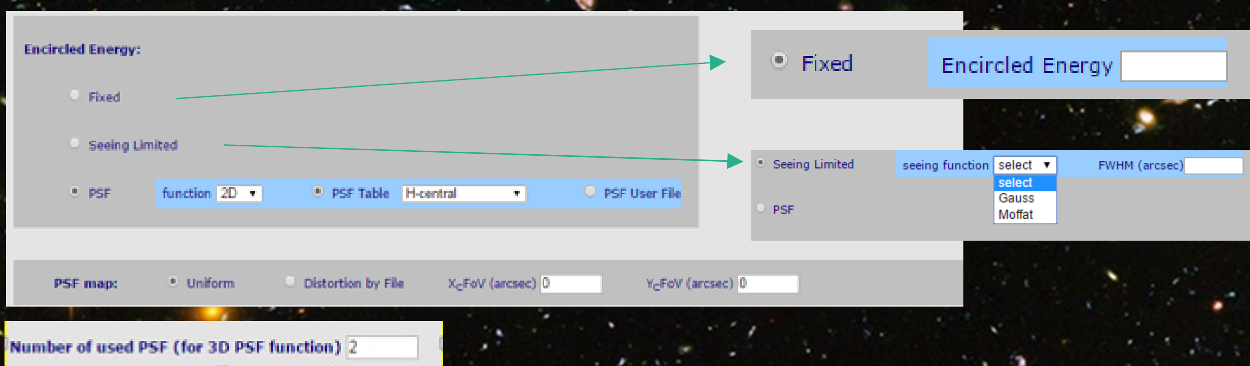


AETC
SEND
Object MicadoH
Save input configuration as
Telescope and Instrument Specification
Primary mirror ø (cm) 3900
Number of reflection 5
Fraction of Obstruction 0.28
Plate Scale (arcsec/pixel) 0.003
Readout Noise (e⁻) 5
Mirror Reflectivity: Constant 1 Table select User File
Instrument Efficiency: Constant 1 Table select User File
Detector Efficiency: Constant 0.4 Table select User File
Sky
Air Mass 1
Sky Brightness: Constant Mag/arcsec² 15.0 Band H Mag System Vega Table select
User File
Atmospheric Absorption: Rayleigh (m) 2000 Table select User File No Extinction
Observation Parameters
Observation Band: λ range Å Table H By User File
Total Exposure Time (sec) 1000
Number of Exposure 10
Aperture ø (arcsec) 0.012
Encircled Energy:
Fixed
Seeing Limited
PSF function 2D PSF Table H-central PSF User File
PSF map: Uniform Distortion by File XcFoV (arcsec) 0 YcFoV (arcsec) 0
select
select
Aluminium
UT1_optics
select
select
FORS_optics
REM_ross
REM_remir
select
select
FORS_ccd
REM_ccd
REM_IRarray
LBC_blue
LBC_red
Blue
Red
select
select
Zodiacal_Light
Calar_Alto
Cerro_Tololo
Kitt_Peak
La_Silla
Mauna_Kea
Paranal
LaPalma
MtGraham
E-ELT_Micado
I-central
Y-central
J-central
Ks-central
H-maory-cube
I-maory-cube
J-maory-cube
K-maory-cube
JWST_Nircam
I
J
H
K
HST_WFPC2
F450W
F606W
F702W
F814W



Sky
Air Mass 1
Sky Brightness: Constant Mag/arcsec² 15.0 Band H Mag System Vega Table select
User File
Atmospheric Absorption: Rayleigh (m) 2000 Table select User File No Extinction
Observation Parameters
Observation Band: λ range Å Table H By User File
Total Exposure Time (sec) 1000 Number of Exposure 10 Aperture Ø (arcsec) 0.012
Encircled Energy:
Fixed
Seeing Limited
PSF function 2D PSF Table H-central PSF User File
PSF map: Uniform Distortion by File X_cFoV (arcsec) 0 Y_cFoV (arcsec) 0
Source Specifications
Redshift 0
SED: Black Body Power Law Template Table vega User File
Flux: Computed Magnitude 20 Band H Mag System Vega Direct Input
Image Simulator
No Image Real Time Background
X size 100 Y size 100 Gain 1 FPN 0.0 Dark 0 Rad min 20
Saturation Level 65535 Threshold 0.01 System Coordinates 0 Spline Deg 5
Number of used PSF (for 3D PSF function) 2 Convolution standard PSF Filter Add Noise
Subtract Background
Stars

PSF



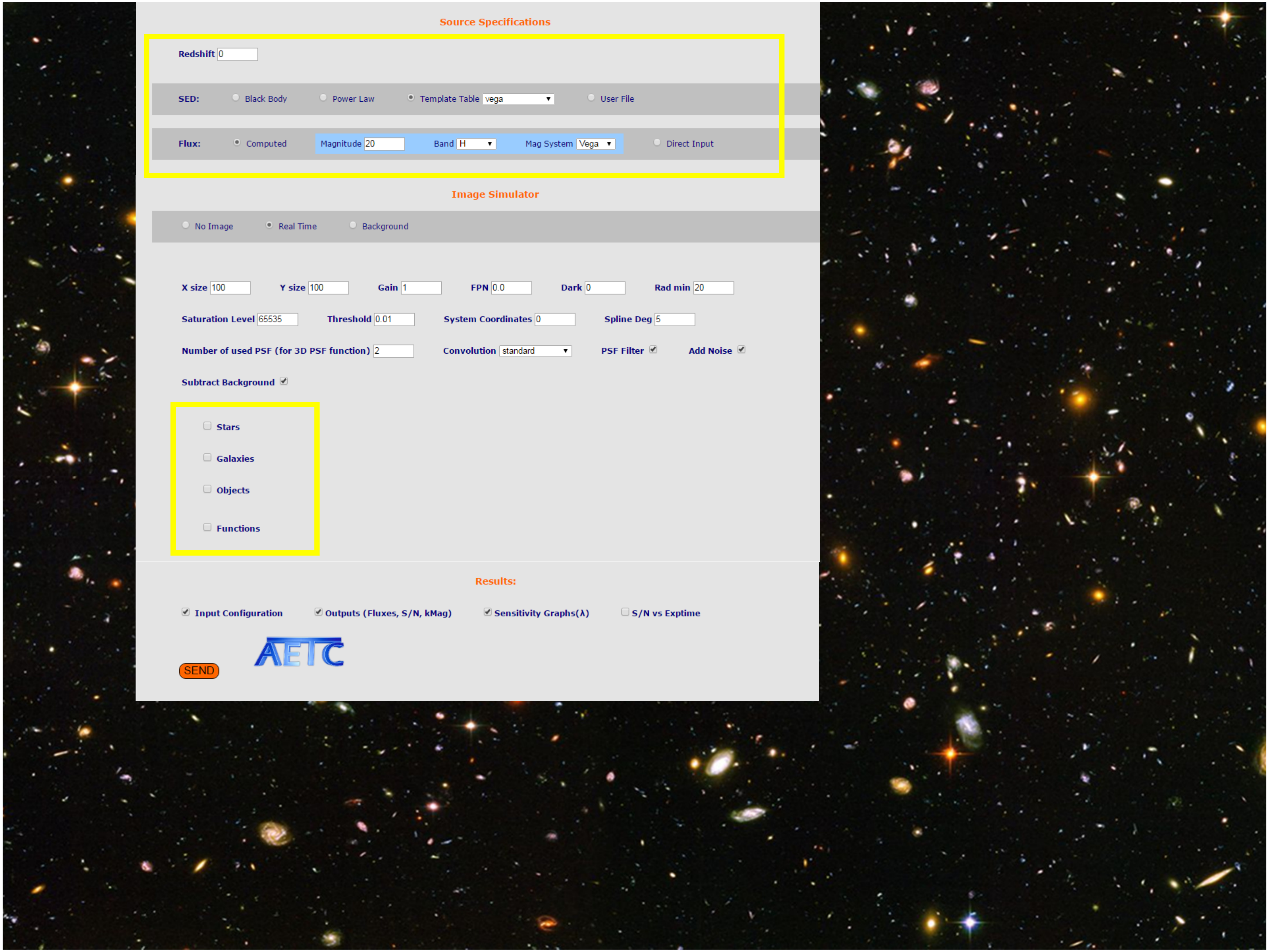
Seeing limited: Gauss or Moffat function of a given FWHM
1D radial intensity profile selecting one of the available PSF tables or a user file
2D fits image
3D fits data cube (PSF(x,y))

How to model a PSF variable in the FOV?

```
# Example of PSF distortion map :
#   X        Y     FWHM(ratio)   Ellipticity    Position_Angle
  500      700     1.00             0.00                  0
  600      700     1.07             0.08                 20
  700      700     1.14             0.16                 40
  800      700     1.21             0.24                 60
  900      700     1.28             0.32                 80
```

1) Reference PSF at given position + distortion file/distortion map → Existing instruments

2) PSF on a grid -> interpolate the PSF at the x,y position → Instruments in development


Source Specifications
Redshift 0
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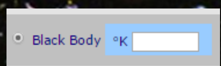
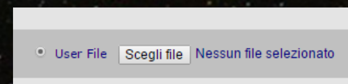
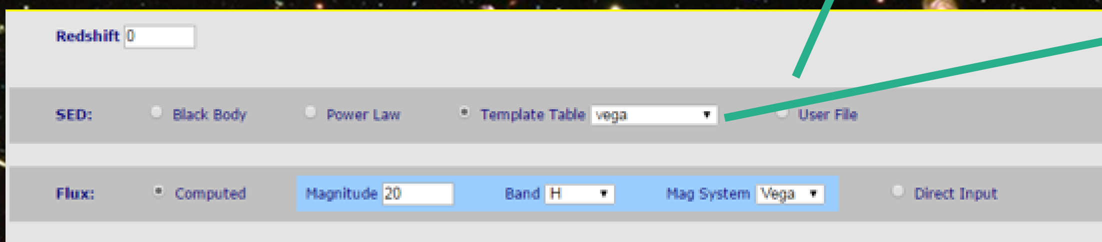
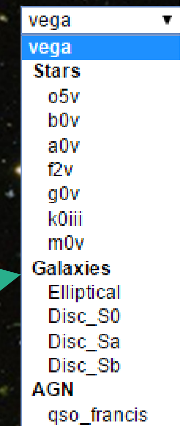
Flux: Computed Magnitude 20 Band H Mag System Vega Direct Input
Image Simulator
No Image Real Time Background
X size 100 Y size 100 Gain 1 FPN 0.0 Dark 0 Rad min 20
Saturation Level 65535 Threshold 0.01 System Coordinates 0 Spline Deg 5
Number of used PSF (for 3D PSF function) 2 Convolution standard PSF Filter Add Noise
Subtract Background
Stars
Galaxies
Objects
Functions
Results:
Input Configuration Outputs (Fluxes, S/N, kMag) Sensitivity Graphs(λ) S/N vs Exptime
SEND
AETC

Input Sources



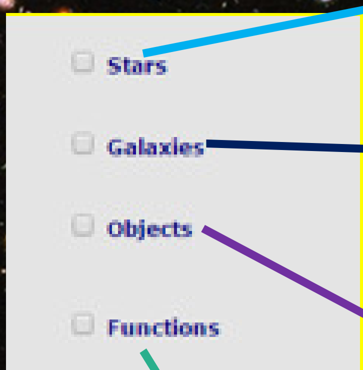






- Reference source:
  - Rest frame SED
  - Flux/magnitude
  - z

```
#   Xpix    Ypix Magnitude
#
321.30 213.91 17.22
125.38 299.83 16.71
```



Sources to be included in the image

```
# Re is in arcsec
# position angle PA in degrees
#
# Xpix   Ypix    mag SersicIndex     Re  ellipticity   PA
 100.1 100.1   15.8         4.0    3.0          0 0    0.
 200.8 200.4   19.5         2.5    5.8          0.2   90.
 300.3 300.2   20.0         1.4   12.7          0.3   45.
 400.6 400.7   17.1         2.1   0.85          0.1    0.
 500.5 500.9   18.0         5.8   15.9          0.1  180.
```

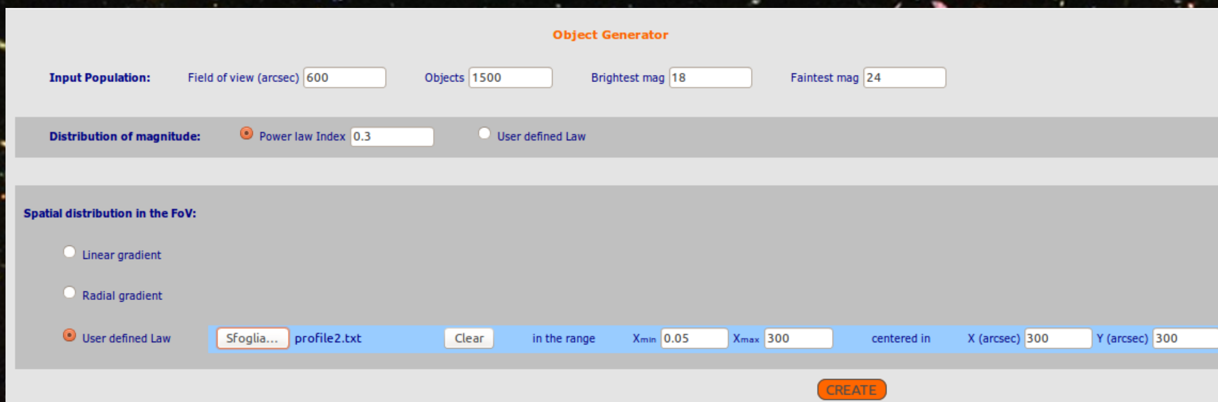
```
STAR = starlist.dat
STAR = starlist2.dat
GALAXY = gallist.dat
GAUSS = spots.dat
```

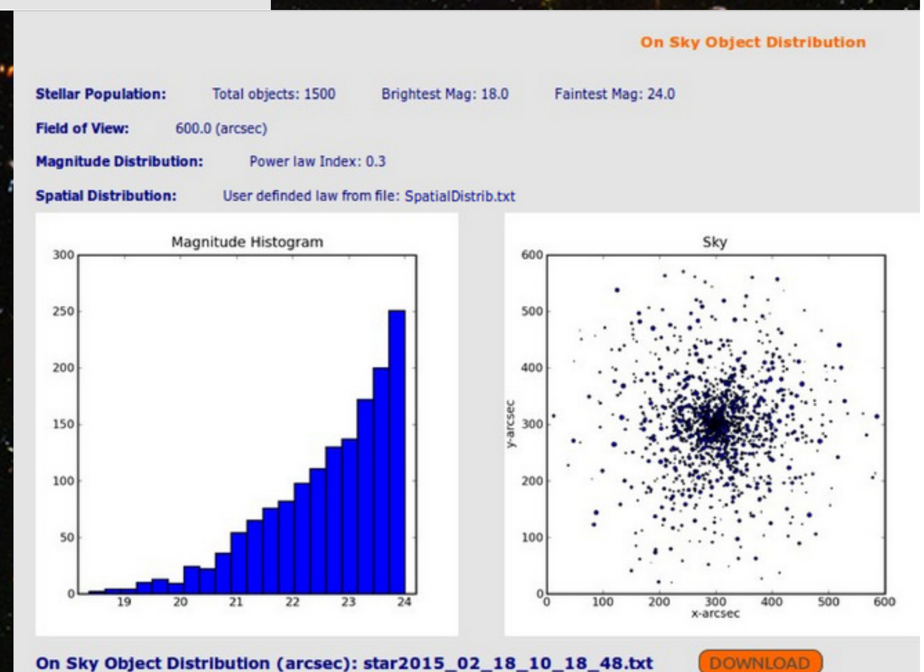
```
# Xpix     Ypix    mag        template_file      Δ"
 320.7     450.3   17.0    objtemplate1.fits    1.0
 620.0     650.3   18.7    objtemplate2.fits    2.5
 652.7     654.2   19.3    objtemplate3.fits    5.1
1300.1    1450.0   12.5    objtemplate4.fits   10.7
```

Object generator

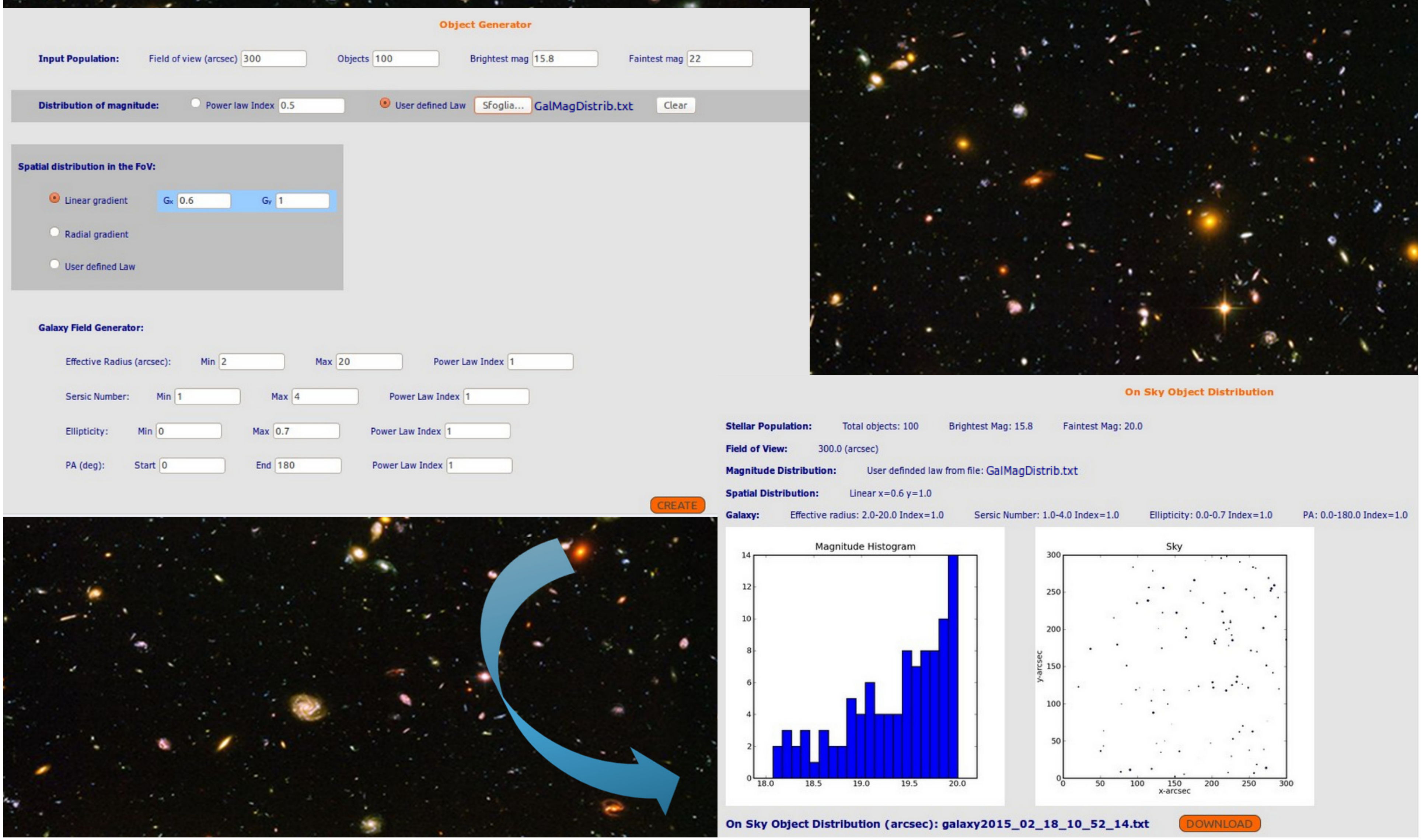
- tool for creating lists of astronomical objects ($\rightarrow$AETC input):
    - Build a list of objects with given input population parameters, distribution of magnitude, spatial distribution in the FoV:
        - Stars
        - Galaxies
    - Extract a sub-list from a user-provided list

Object generator: stars



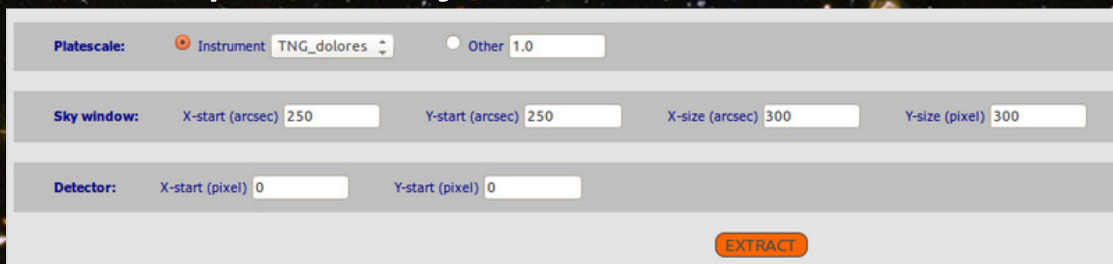


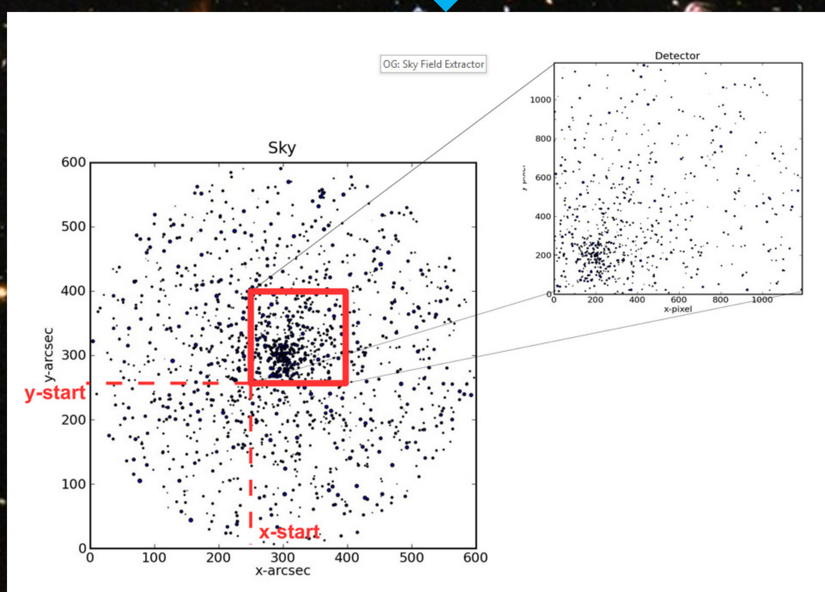
Object generator: galaxies

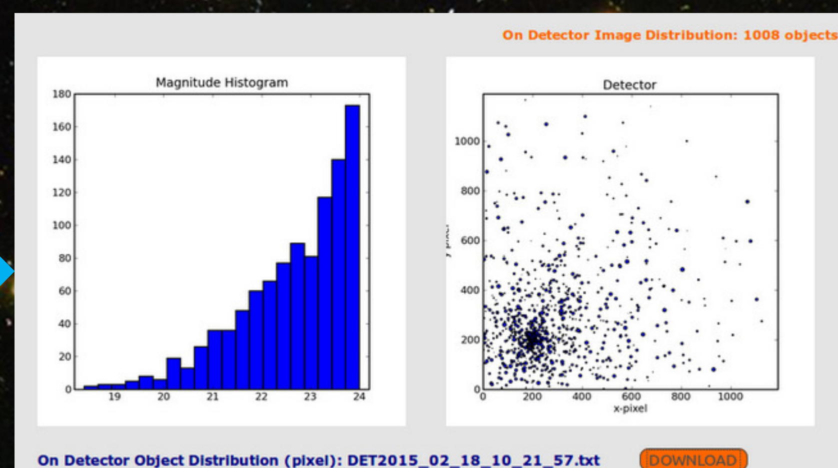


OG: Sky Field Extractor

- Map the object list on the detector







Output

Results:

Input Configuration | Outputs (Fluxes, S/N, kMag) | Sensitivity Graphs(λ) | S/N vs Exptime

- Input configuration: summary of all input parameters
- Output (Fluxes,S/N,..): output counts and the expected Signal-to-Noise ratio

AETC version: 4.0 **Date:** 2015-10-07 18:10:00 **Simulator:** aetc_15_06_15.pro

AETC

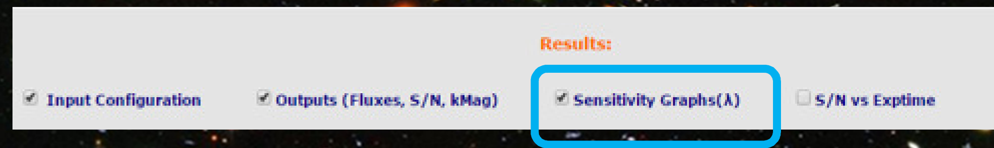
Input configuration

Air Mass: 1
Exposure time: 1000 sec
Number of exposure: 10
Aperture Ø: 0.012 arcsec
Number of reflections: 5
Input: mag: 20, band: H, mag system: Vega
Object: MicadoH
Instrument efficiency: 1
Photometric system: UBVRI_Bessel
Observation band: BX 3700.0 - 5500.0 Å
Function file: No Function file
Detector efficiency: 0.4
Primary mirror diameter: 3900 cm
Fraction of obstruction: 0.28
Plate scale: 0.003 arcsec/pixel
Mirror reflectivity: 1
Atmospheric Absorption: Rayleigh: at 2000m
Star file: No Star file
Galaxy file: No Galaxy file
Encircled Energy: 0.32 (psf function: 2D, psf file: E-ELT_Micado H-central)
Single Object - SED: Stars vega (900.0 - 100000.0) Å
Sky Brightness: mag: 15.0, band: H, mag system: Vega
Redshift: 0
Readout noise: 5 e-
Object file: No Object file

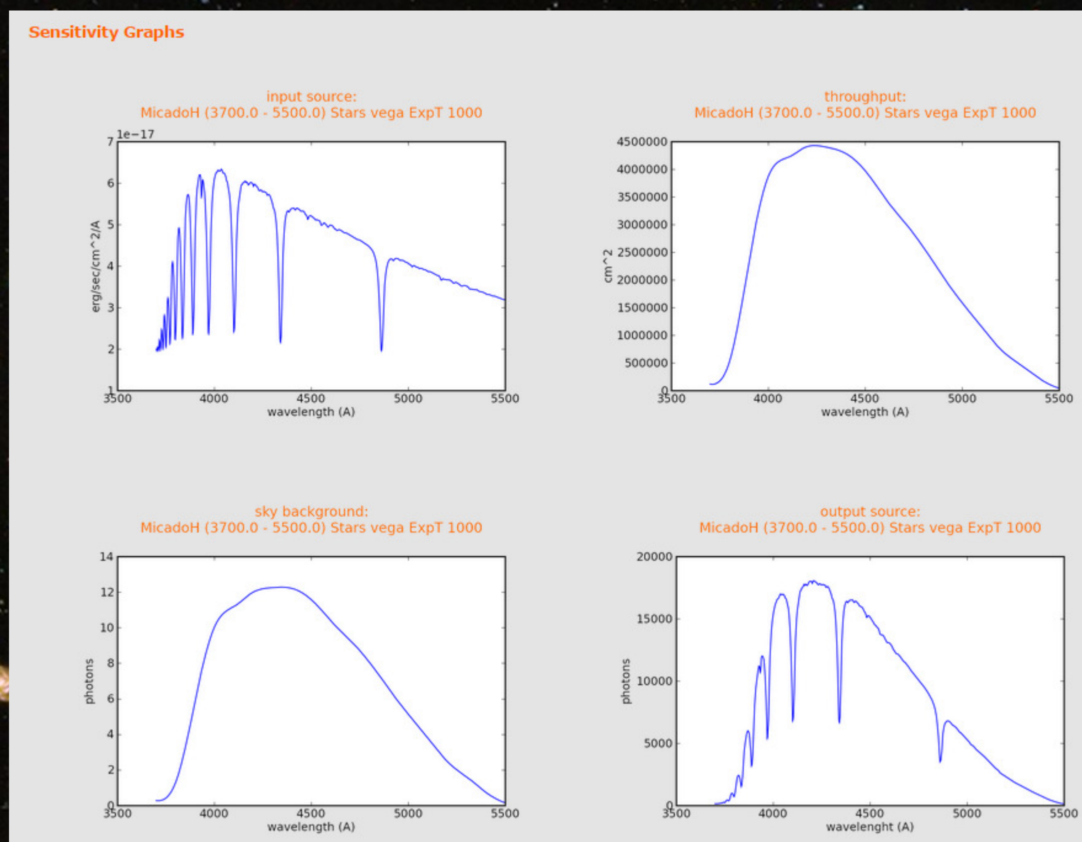
Aperture Output Signals:

S/N area: 12.6 px
Collecting area: 11009347.0298 cm²
Zero Point: 31.69
Source: 1.531018e+07 ph/aper/expT
StoN: 3911.19
Background: 1.246547e+04 ph/aper/expT (0.99 ph/sec/px)
Effective wavelenght: 4434.0 Å
Extinction at λeff: 0.17

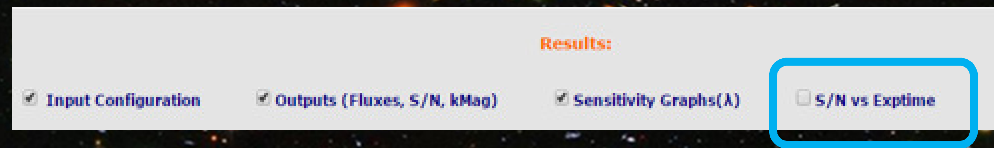
Output



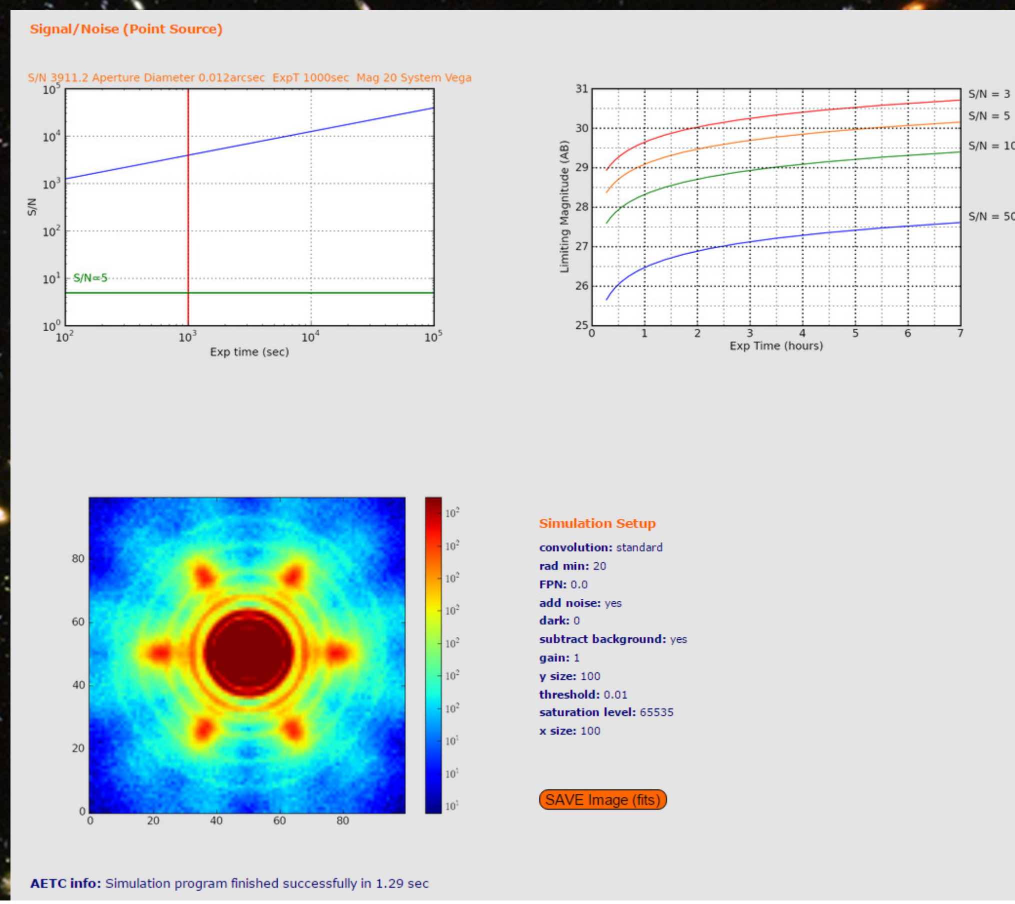
- Sensitivity Graphs: plots of the input source, passband and the troughput



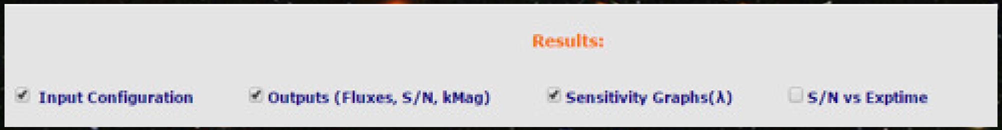
Output



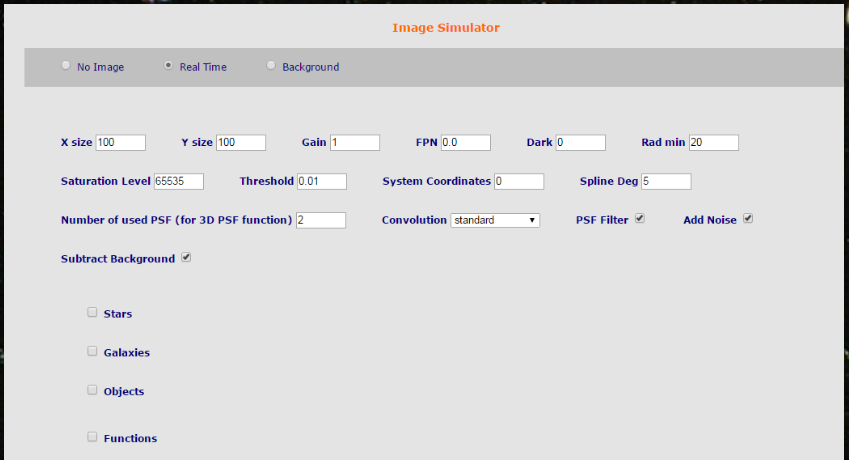
- S/N vs Exptime: plot on the trend of the S/N against the exposure time



Output



- Input configuration: summary of all input parameters
- Output (Fluxes,S/N,..): output counts and the expected Signal-to-Noise ratio
- Sensitivity Graphs: plots of the input source, passband and the troughput
- S/N vs Exptime: plot on the trend of the S/N against the exposure time
- **Images !!!!**

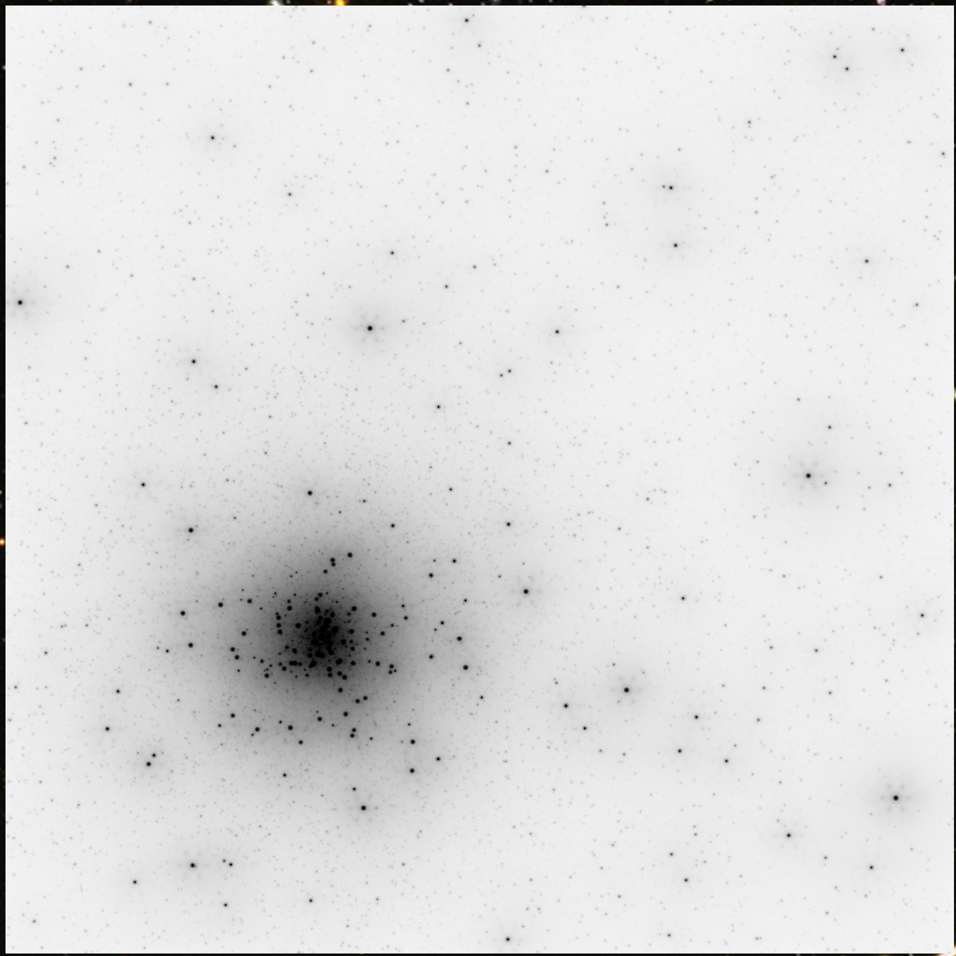


Example: star cluster

J-band observations of a star cluster in a nearby galaxy with MICADO@E-ELT.

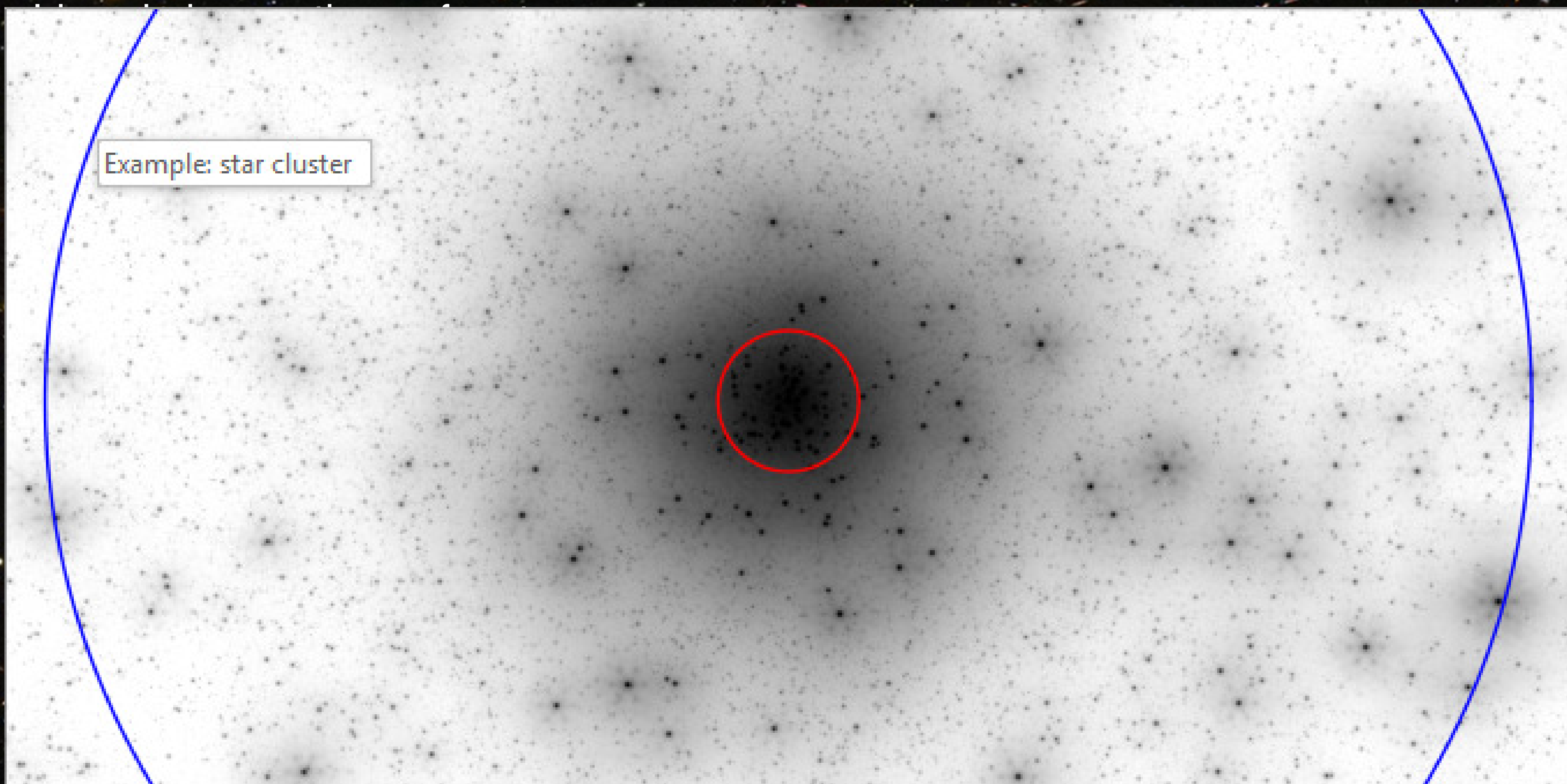
Total exposure time: 3h
input star list (**465567 stars**):

- host galaxy body: spatially uniform distribution of stars, magnitudes calculated assuming a constant star formation rate over the last 12 Gyr,
- star cluster: stars distributed according to a King-like profile. Magnitudes taken along theoretical isocrones



Probing the nuclear star cluster of galaxies with extremely large telescopes
Gullieuszik et al. (2014, A&A Vol.568,11)

Example: star cluster



Probing the nuclear star cluster of galaxies with extremely large telescopes
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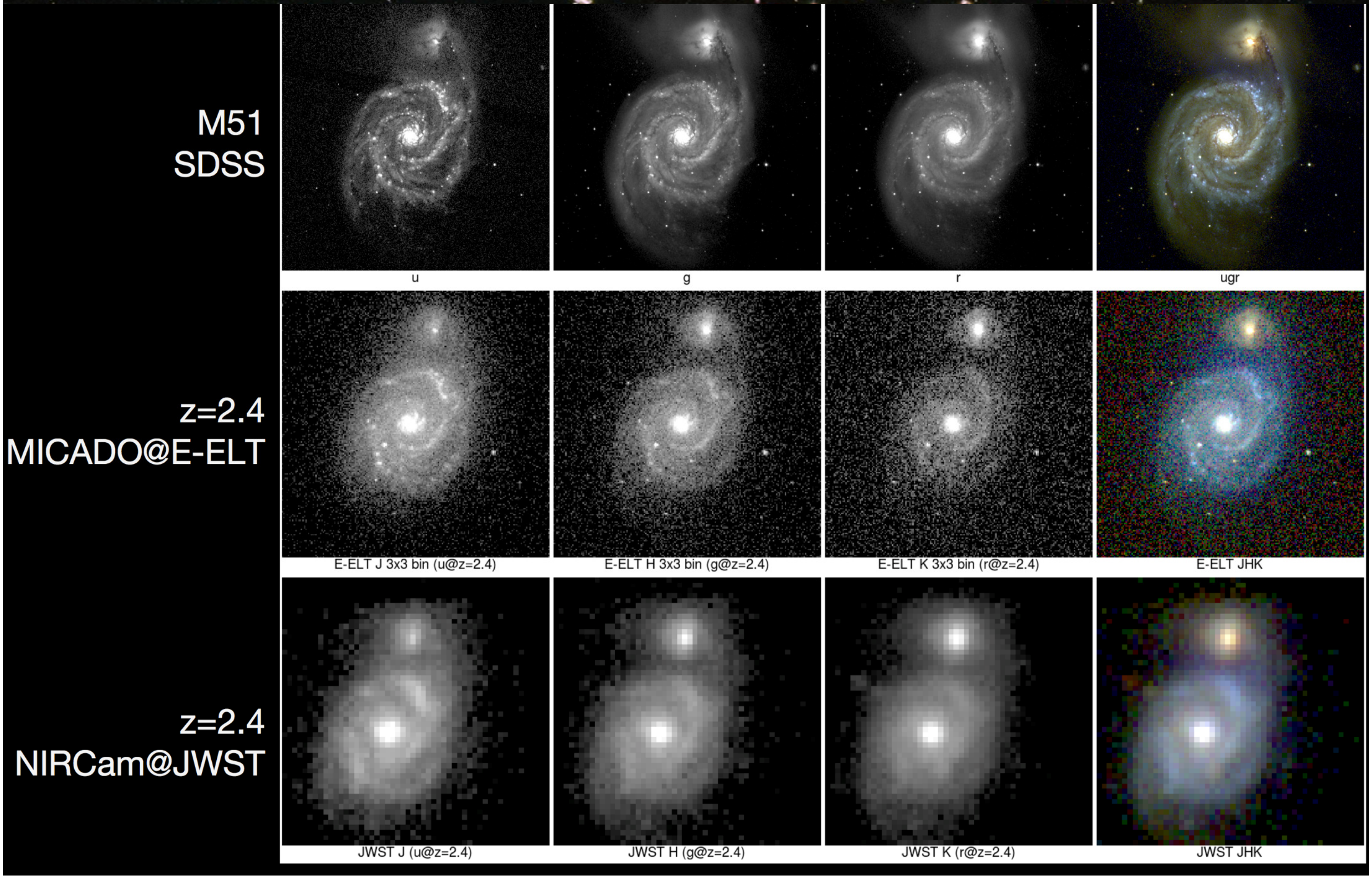
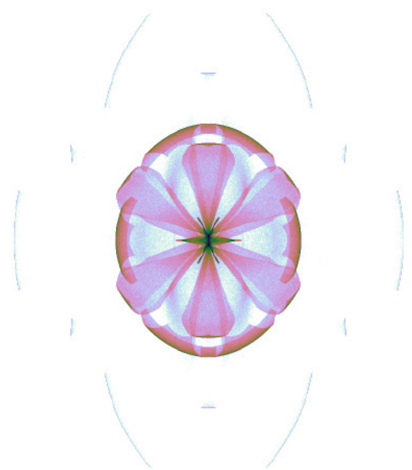
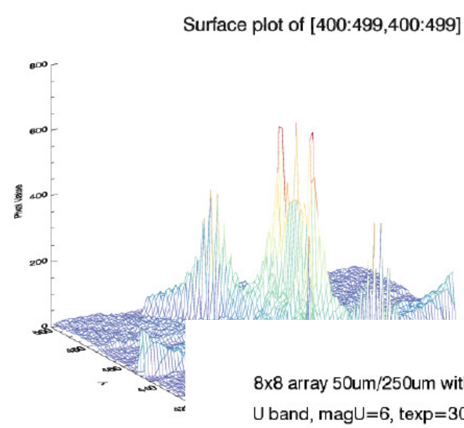
Example of galaxy simulations

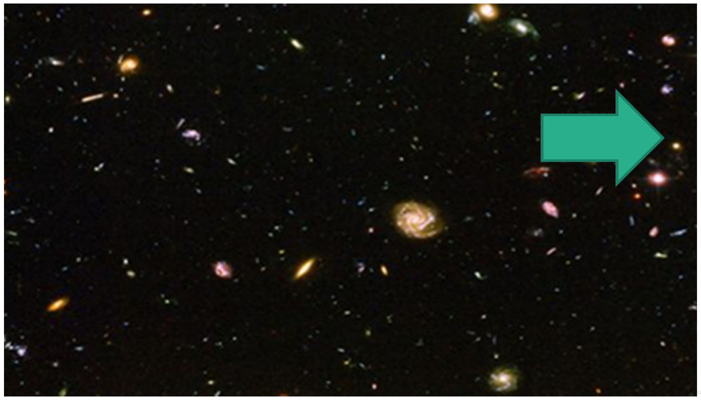


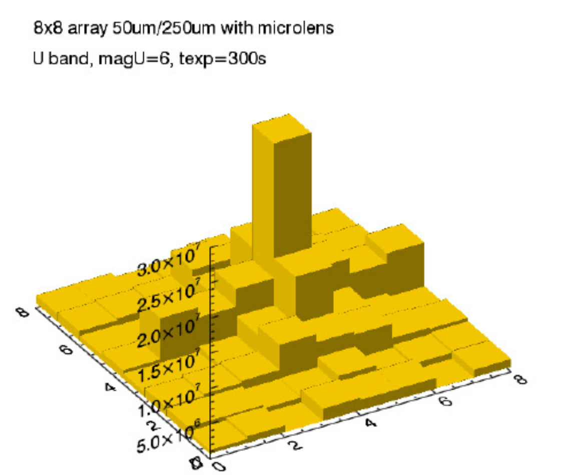
OT: simulation of spad array+ASTRI

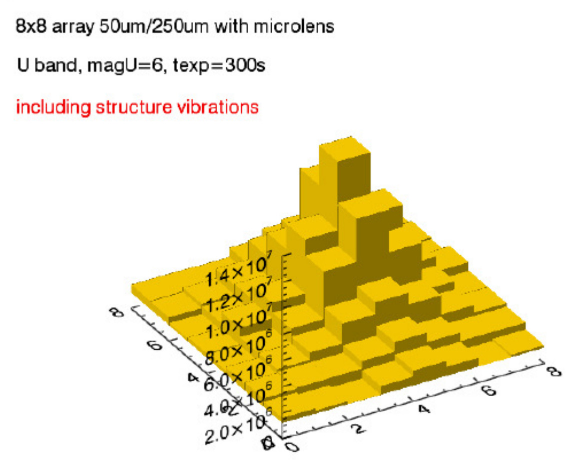
- Non standard detector: AETC has been used to produce the distribution of the photons on the focal plane but the detector has been simulated with a module developed in IDL



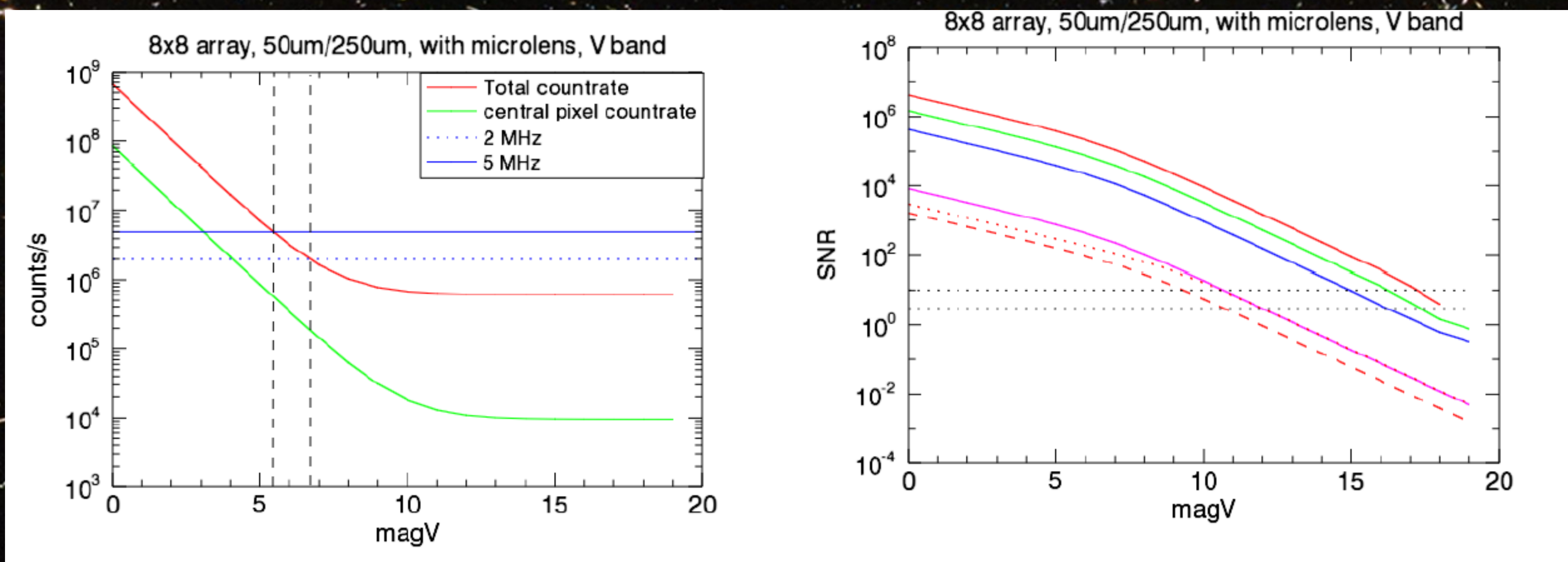








OT: simulation of spad array+ASTRI




http://aetc.oapd.inaf.it

ELTCam science cases with AETC

- L. Greggio et al. *Properties of High Redshift Galaxies in the ELTs Era,* IAU General Assembly, Meeting #29,2015
- L.Greggio et al. *Studying Stellar Halos with Future Facilities,* IAU General Assembly, Meeting #29,2015
- L. Schreiber et al. *Studying the metallicity gradient in Virgo ellipticals with European-Extremely Large Telescope photometry of resolved stars, MNRAS 437, issue 3, p.2966, 2014*
- *M. Gullieuszik et al. Probing the nuclear star cluster of galaxies with extremely large telescopes*, A&A 568, 2014
- *L.Greggio et al. Resolved Stellar Population of Distant Galaxies in the ELT Era, PASP 124, issue 917, p.653, 2012*