

The logo for AETC (Advanced Exposure Time Calculator) is rendered in a blue, 3D-style font. The letters 'A', 'E', and 'T' are connected at the top, and the 'C' is a simple curve. The background of the slide is a deep space image filled with numerous galaxies and stars of various colors and sizes.

advanced exposure time calculator

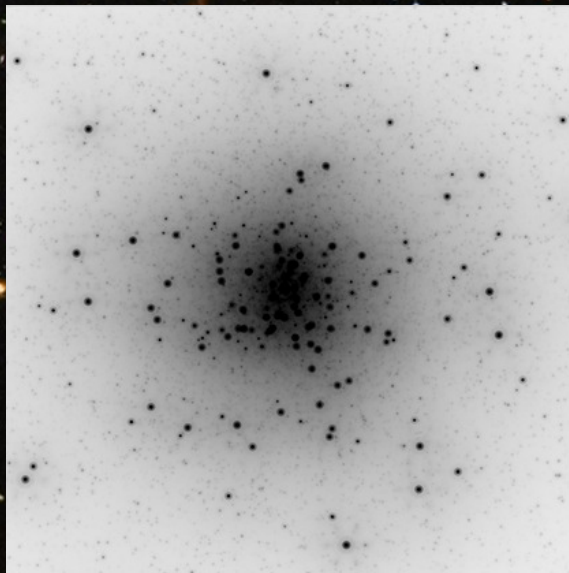
A web tool to simulate astronomical
imaging instruments

M. Usienghi – astrosiesta 8 Ottobre 2015

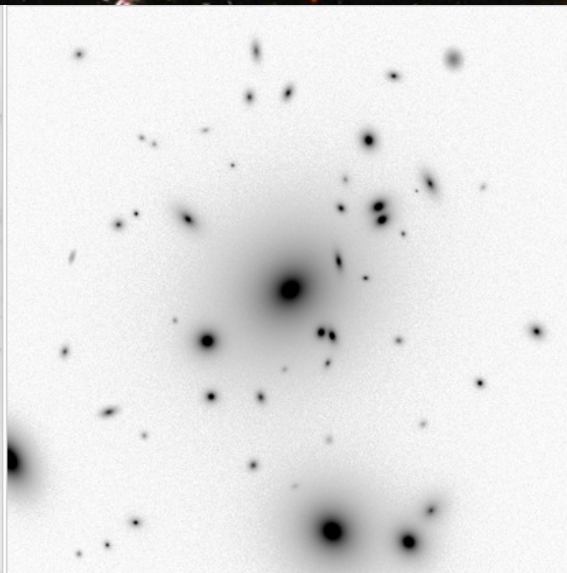
D. Fantinel, R. Falomo (OAPd)

AETC

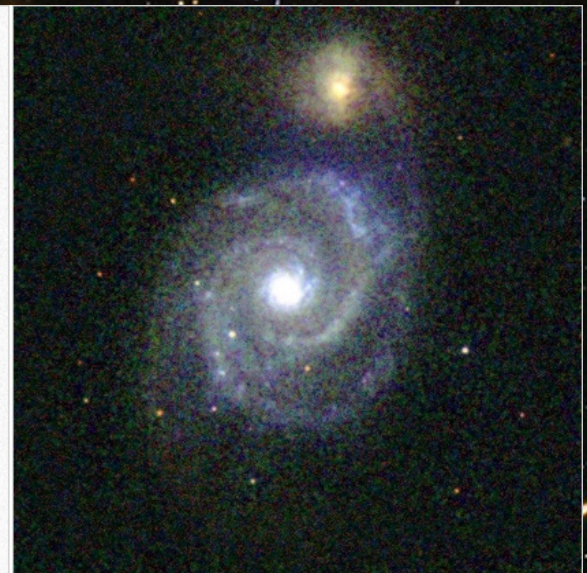
- [web]tool to simulate images of astrophysical objects obtained with any combination of telescope, instrument and filter
- \Rightarrow **count rates** and **photon distribution** over the focal plane
- \Rightarrow **detailed simulation of the observed fields** including stars, galaxies and any kind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



Nuclear star cluster. MICADO@E-ELT



Nearby galaxy cluster. WFC@INT



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

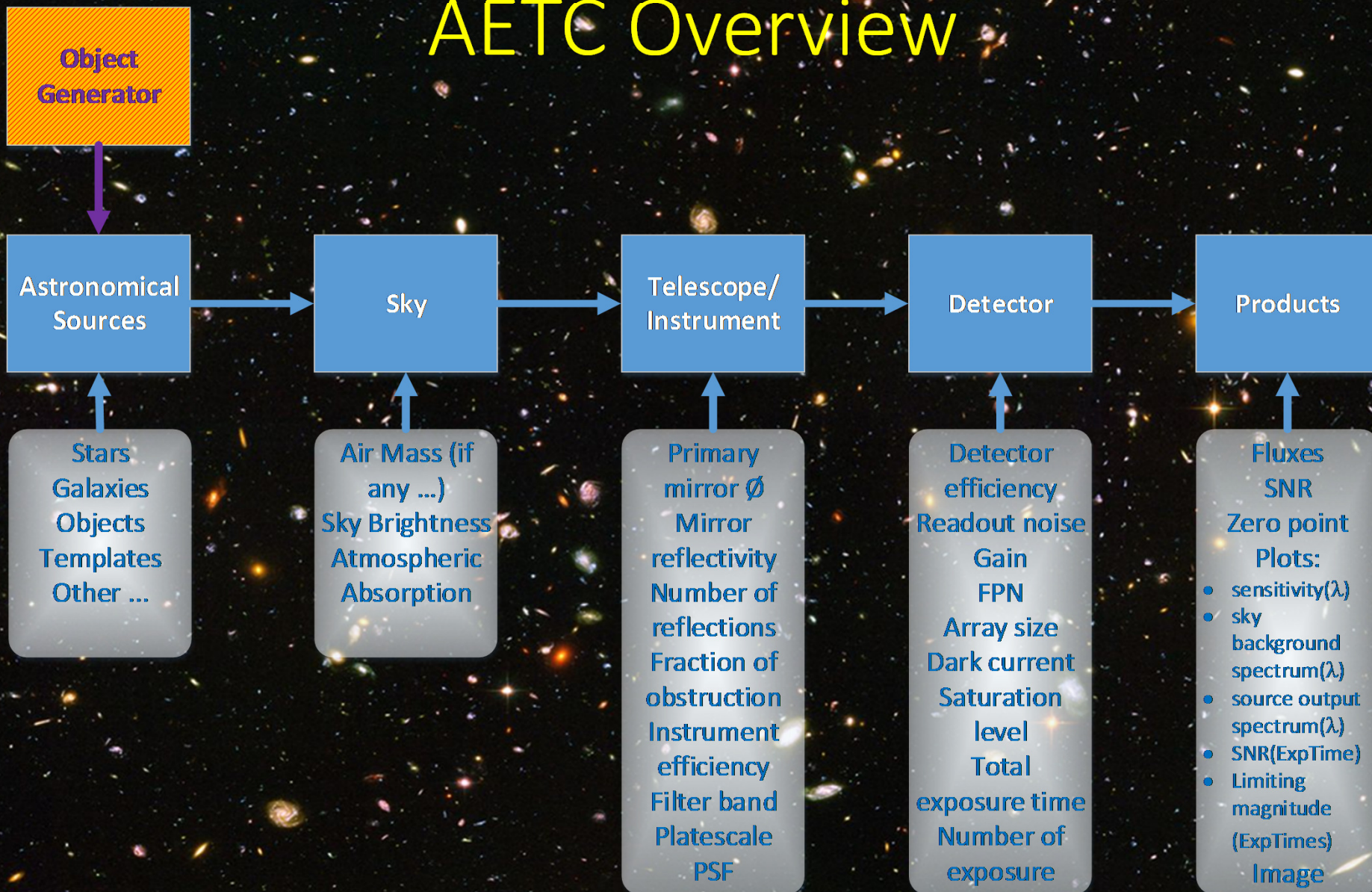
Why AETC?

- 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** → **important !!!**
- The main trigger has been the study of science cases for **ELT/MAORY+MICADO** → 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



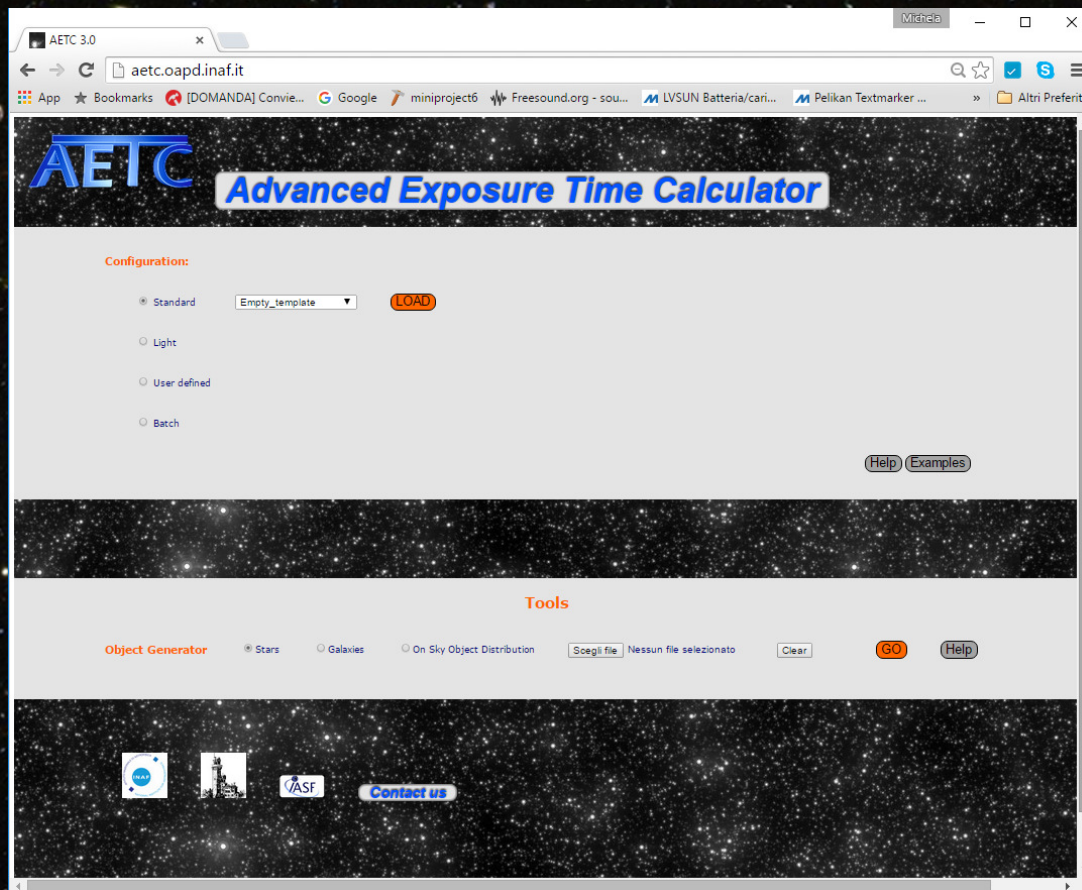
Pre-configured instruments

(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

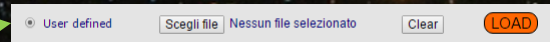
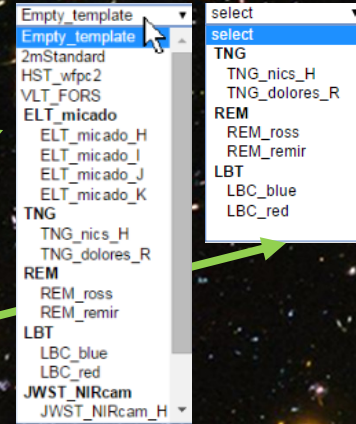
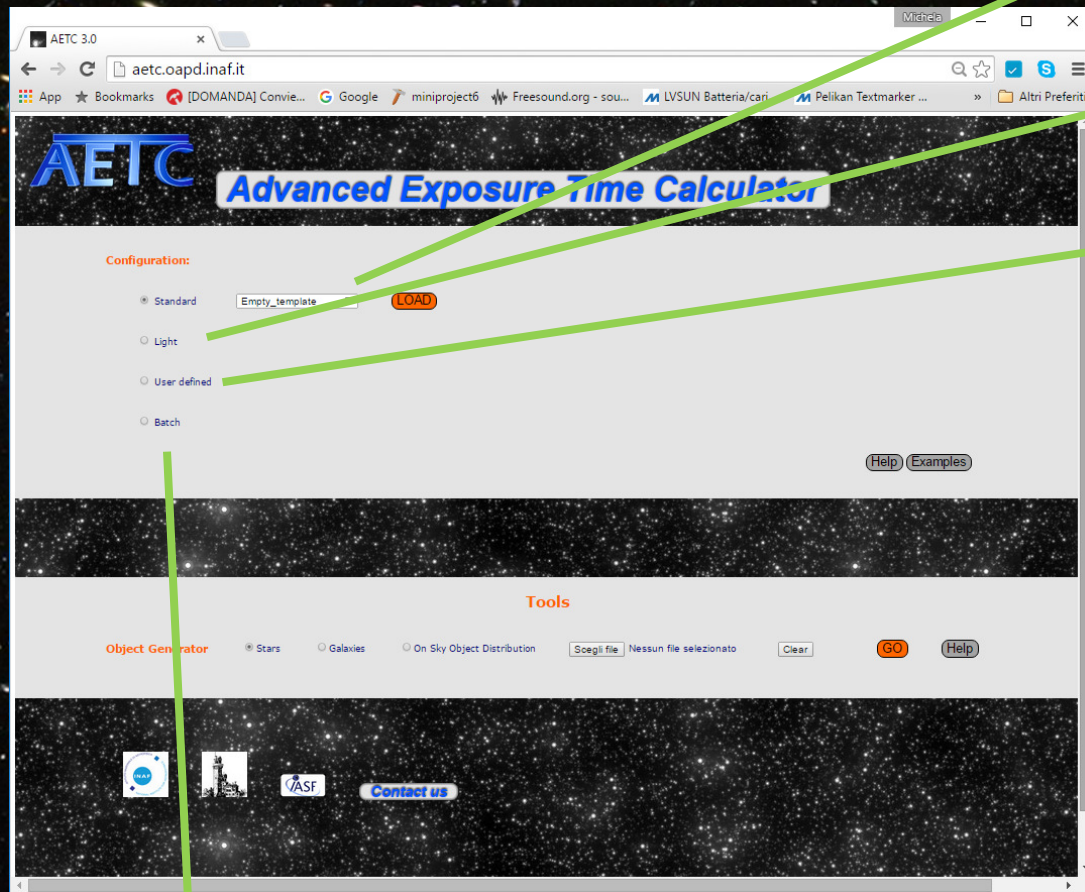
WEB Interface

The screenshot shows the AETC 3.0 web interface. The main heading is "AETC Advanced Exposure Time Calculator". Under the "Configuration:" section, there are radio buttons for "Standard", "Light", "User defined", and "Batch". The "Standard" option is selected, and a dropdown menu shows "Empty_template" with a "LOAD" button next to it. Below this is a "Tools" section with "Object Generator" and radio buttons for "Stars", "Galaxies", and "On Sky Object Distribution". There is a "Scogli file" input field, a "Nessun file selezionato" label, a "Clear" button, a "GO" button, and a "Help" button. The "Help" and "Examples" buttons are circled in red. At the bottom, there are logos for INAF and ASF, and a "Contact us" button.

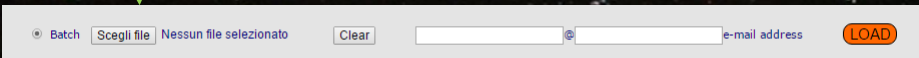
The screenshot shows the AETC Help page. The title is "Introduction". The text describes the AETC tool: "The Advanced Exposure Time Calculator (AETC) is a tool to simulate images of astrophysical objects obtained with any combination of telescope, instrument and given passband using a suitable set of parameters that define the configuration of the equipment used for the observations. The tool provides count rates and its distribution over the focal plane, through the proper definition of the PSF of virtually any telescope equipped with an imager provided that its configuration is assessed. Moreover detailed simulation of the observed fields can be simulated including stars, galaxies and more complex objects providing template of the targets." Below the text, there are three simulated images: "Nuclear star cluster: MICADO@E-ELT", "Nearby galaxy cluster: WFC@INT", and "M51-like galaxy @z=2.4: MICADO@E-ELT". The page also includes a navigation menu on the left with items like Home, Configuration, Telescope and Instrument Specification, Sky, Observation Parameters, Source Specifications, Image Simulator, Results, Configuration file, Batch mode, Advanced Help, Object generator, Stars, Galaxies, Sky Field Extractor, and On sky object distribution. Logos for INAF and ASF are at the bottom.

The screenshot shows the AETC Examples page. It features three example simulations, each with a title, a description, and a small image of the simulated field.
1. "AETC - Example 1 : Star field with LBC@LBT" - Description: "This basic example uses a simplified interface specialized for the red arm of the LBC camera mounted at LBT. In the example we show hot to simulate observations of a stellar field. The input star list is generated with the AETC Object Generator."
2. "AETC - Example 2 : Star cluster with MICADO@E-ELT" - Description: "In this example we consider a globular cluster. For this example we use the general interface, loading the configuration for MICADO@E-ELT. All parameters (telescope, camera, observatory) are initially pre-set, but the user can modify each of them."
3. "AETC - Example 3 : Galaxies with custom instrument" - Description: "This is the most general case. A new telescope+instrument+observing site is defined. In this example we simulate an observation of a the central region of a cluster of galaxies with the WFC camera mounted at the INT."
The page also includes a navigation menu on the left with items like Home, Configuration, Telescope and Instrument Specification, Sky, Observation Parameters, Source Specifications, Image Simulator, Results, Configuration file, Batch mode, Advanced Help, Object generator, Stars, Galaxies, Sky Field Extractor, and On sky object distribution. Logos for INAF and ASF are at the bottom.

WEB Interface



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



Object Save input configuration as

Telescope and Instrument Specification

Primary mirror Ø (cm) Number of reflection Fraction of Obstruction

Plate Scale (arcsec/pixel) Readout Noise (e⁻)

Mirror Reflectivity: Constant Table User File

Instrument Efficiency: Constant Table User File

Detector Efficiency: Constant Table User File

Sky

Air Mass

Sky Brightness: Constant Mag/arcsec² Band Mag System Table

User File

Atmospheric Absorption: Rayleigh (m) Table User File No Extinction

Observation Parameters

Observation Band: λ range Å Table By User File

Total Exposure Time (sec) Number of Exposure Aperture Ø (arcsec)

Encircled Energy:

Fixed

Seeing Limited

PSF function PSF Table PSF User File

PSF map: Uniform Distortion by File X_cFoV (arcsec) Y_cFoV (arcsec)

- 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

Sky Brightness: Constant Mag/arcsec² Band Mag System Table

User File

Atmospheric Absorption: Rayleigh (m) Table User File No Extinction

Observation Parameters

Observation Band: λ range \AA Table By User File

Total Exposure Time (sec) Number of Exposure Aperture θ (arcsec)

Encircled Energy:

Fixed

Seeing Limited

PSF function PSF Table PSF User File

PSF map: Uniform Distortion by File X_c FoV (arcsec) Y_c FoV (arcsec)

Source Specifications

Redshift

SED: Black Body Power Law Template Table User File

Flux: Computed Magnitude Band Mag System Direct Input

Image Simulator

No Image Real Time Background

X size Y size Gain FPN Dark Rad min

Saturation Level Threshold System Coordinates Spline Deg

Number of used PSF (for 3D PSF function) Convolution PSF Filter Add Noise

Subtract Background

Stars

PSF

Encircled Energy:

Fixed Seeing Limited PSF

function: 2D PSF Table: H-central PSF User File

seeing function: select FWHM (arcsec)

select
Gauss
Moffat

PSF map: Uniform Distortion by File XcFoV (arcsec) 0 YcFoV (arcsec) 0

Number of used PSF (for 3D PSF function) 2

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))

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

How to model a PSF variable in the FOV?

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

SED: Black Body Power Law Template Table User File

Flux: Computed Magnitude Band Mag System Direct Input

Image Simulator

No Image Real Time Background

X size Y size Gain FPN Dark Rad min

Saturation Level Threshold System Coordinates Spline Deg

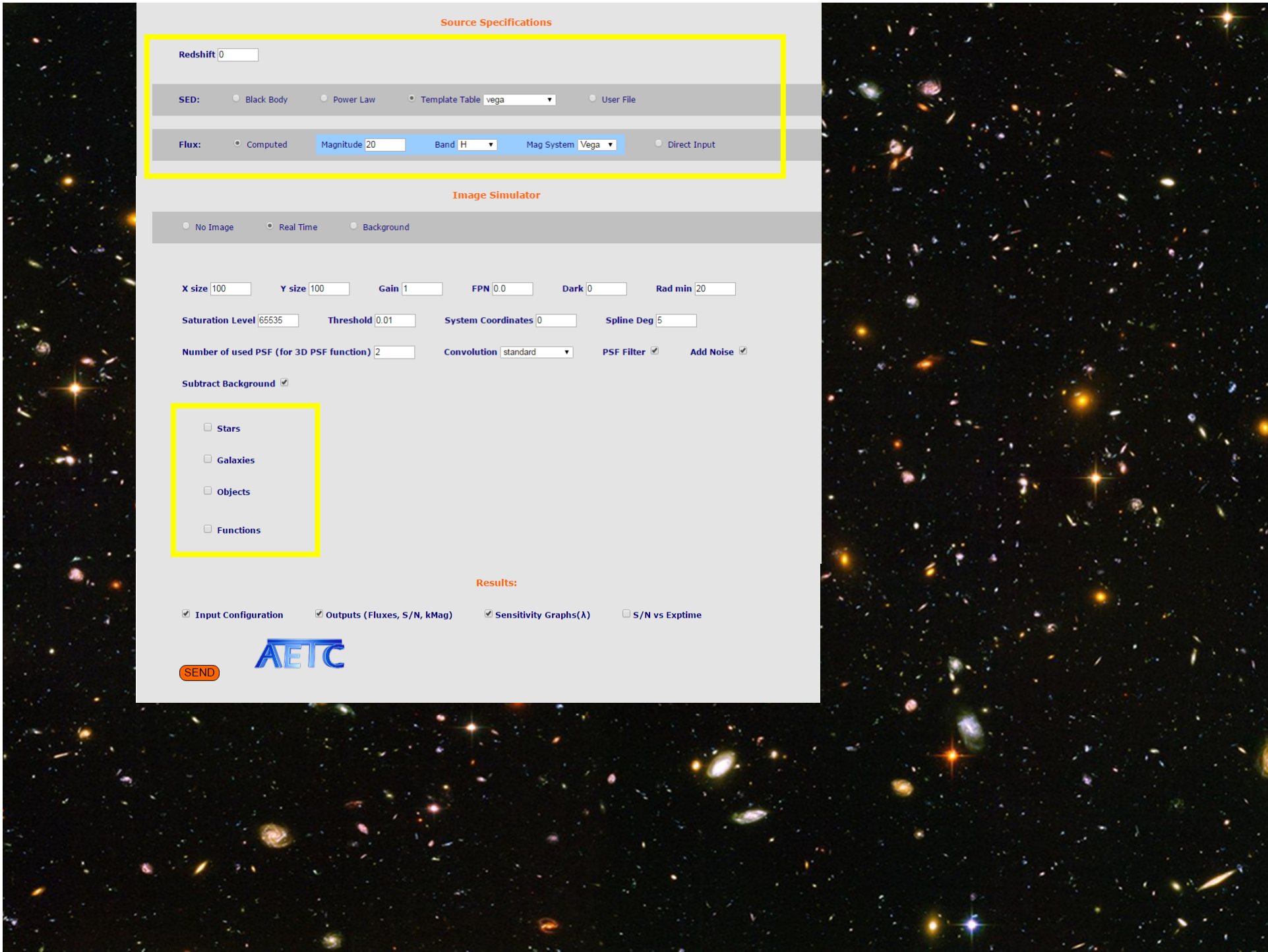
Number of used PSF (for 3D PSF function) Convolution PSF Filter Add Noise

Subtract Background

- Stars
- Galaxies
- Objects
- Functions

Results:

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



Input Sources

- vega
- vega
- Stars
 - o5v
 - b0v
 - a0v
 - f2v
 - g0v
 - k0iii
 - m0v
- Galaxies
 - Elliptical
 - Disc_S0
 - Disc_Sa
 - Disc_Sb
- AGN
 - qso_francis

Black Body

User File Nessun file selezionato

Redshift

SED: Black Body Power Law Template Table User File

Flux: Computed Direct Input

- 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

- Stars
- Galaxies
- Objects
- Functions

```
# 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 (→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

Input Population: Field of view (arcsec) Objects Brightest mag Faintest mag

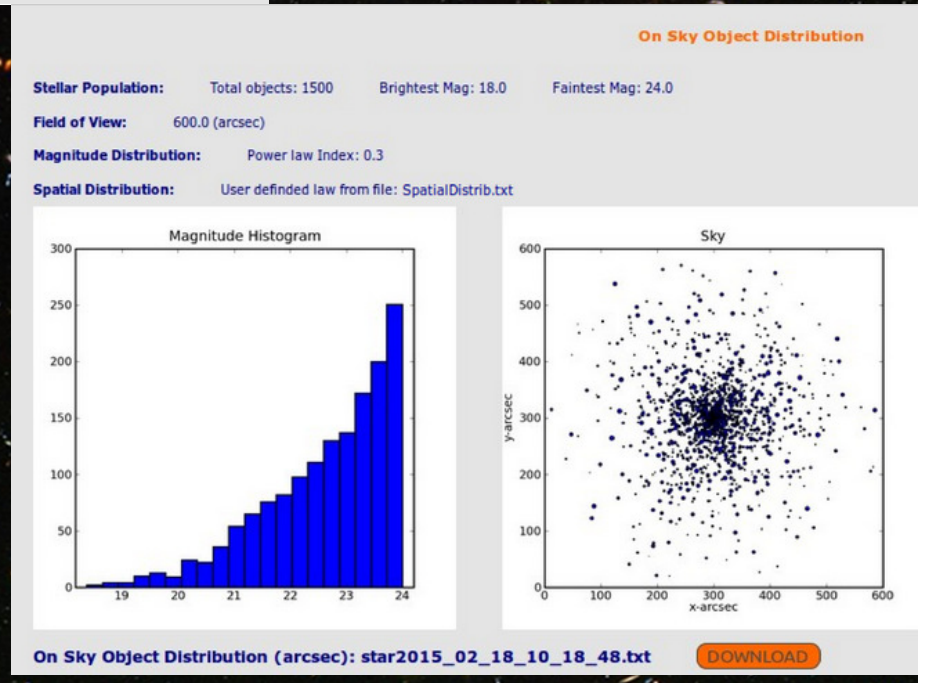
Distribution of magnitude: Power law Index User defined Law

Spatial distribution in the FoV:

Linear gradient

Radial gradient

User defined Law profile2.txt in the range X_{min} X_{max} centered in X (arcsec) Y (arcsec)



Object generator: galaxies

Object Generator

Input Population: Field of view (arcsec) Objects Brightest mag Faintest mag

Distribution of magnitude: Power law Index User defined Law

Spatial distribution in the FoV:

Linear gradient

Radial gradient

User defined Law

Galaxy Field Generator:

Effective Radius (arcsec): Min Max Power Law Index

Sersic Number: Min Max Power Law Index

Ellipticity: Min Max Power Law Index

PA (deg): Start End Power Law Index



On Sky Object Distribution



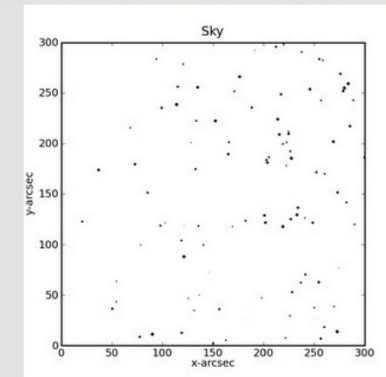
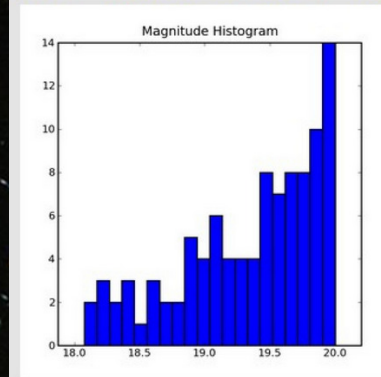
Stellar Population: Total objects: 100 Brightest Mag: 15.8 Faintest Mag: 20.0

Field of View: 300.0 (arcsec)

Magnitude Distribution: User defined law from file: GalMagDistrib.txt

Spatial Distribution: Linear $x=0.6$ $y=1.0$

Galaxy: Effective radius: 2.0-20.0 Index=1.0 Sersic Number: 1.0-4.0 Index=1.0 Ellipticity: 0.0-0.7 Index=1.0 PA: 0.0-180.0 Index=1.0



On Sky Object Distribution (arcsec): galaxy2015_02_18_10_52_14.txt

OG: Sky Field Extractor

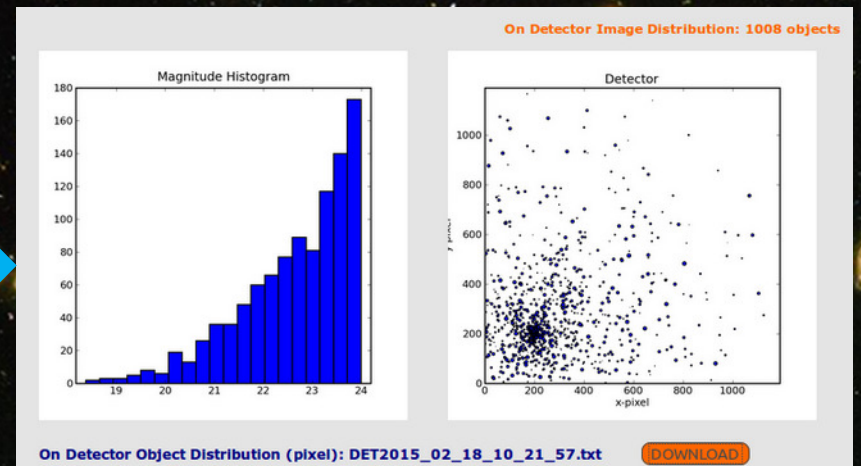
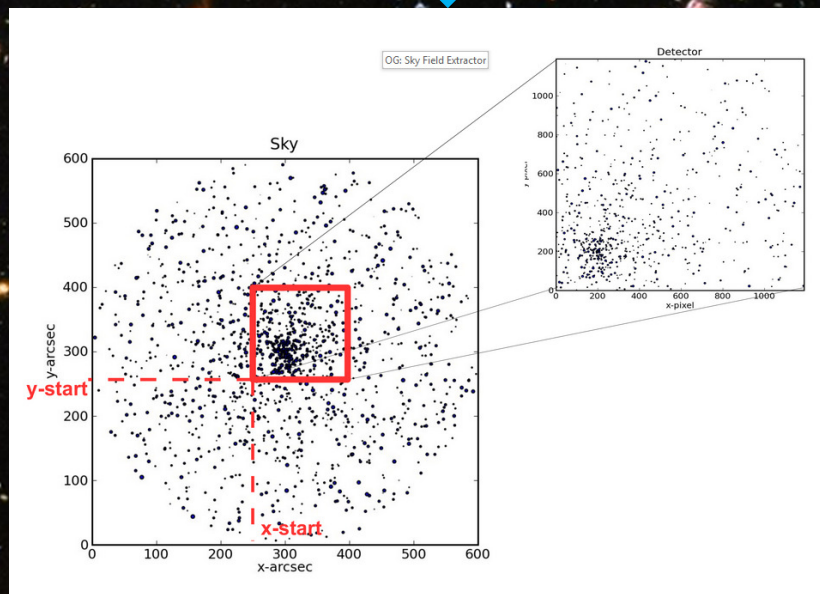
- Map the object list on the detector

Platescale: Instrument TNG_dolores Other 1.0

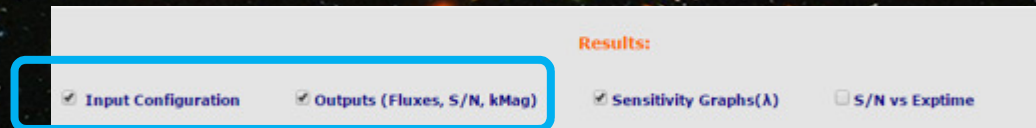
Sky window: X-start (arcsec) 250 Y-start (arcsec) 250 X-size (arcsec) 300 Y-size (pixel) 300

Detector: X-start (pixel) 0 Y-start (pixel) 0

EXTRACT



Output



- 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

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 wavelength: 4434.0 Å
Extinction at λ_{eff}: 0.17

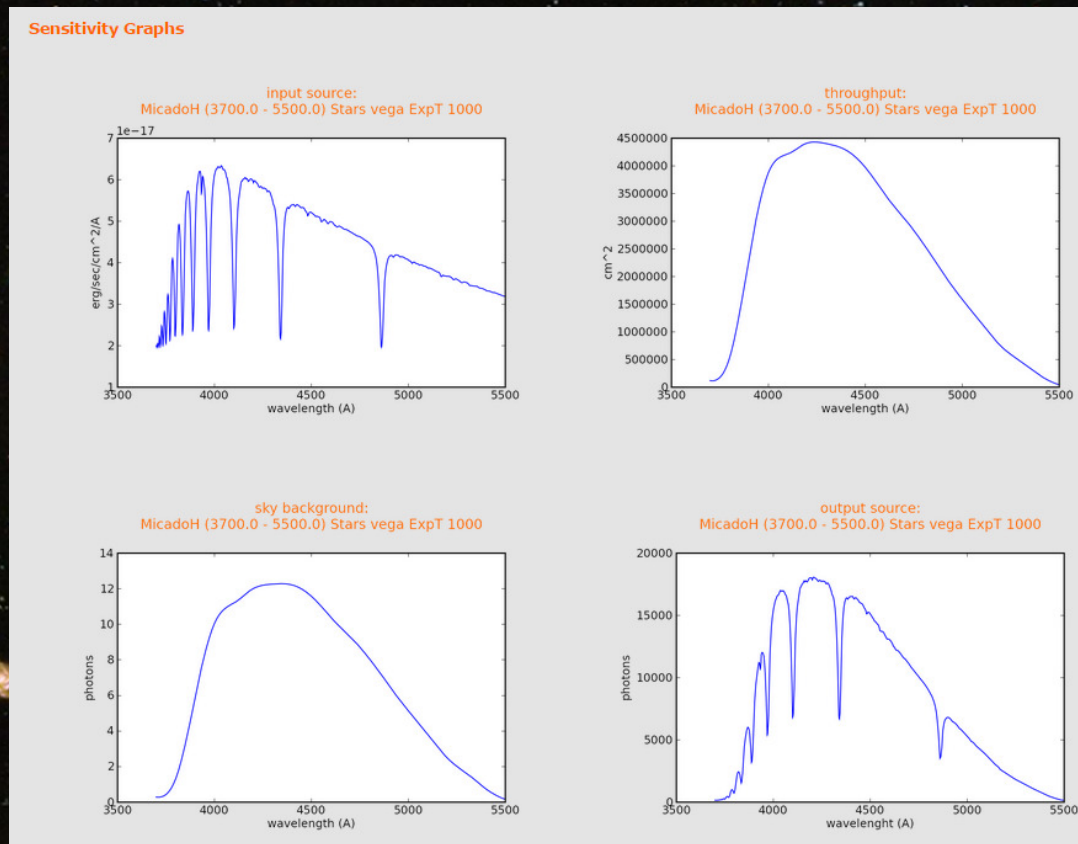


Output

Results:

- Input Configuration
- Outputs (Fluxes, S/N, kMag)
- Sensitivity Graphs(A)
- S/N vs Exptime

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

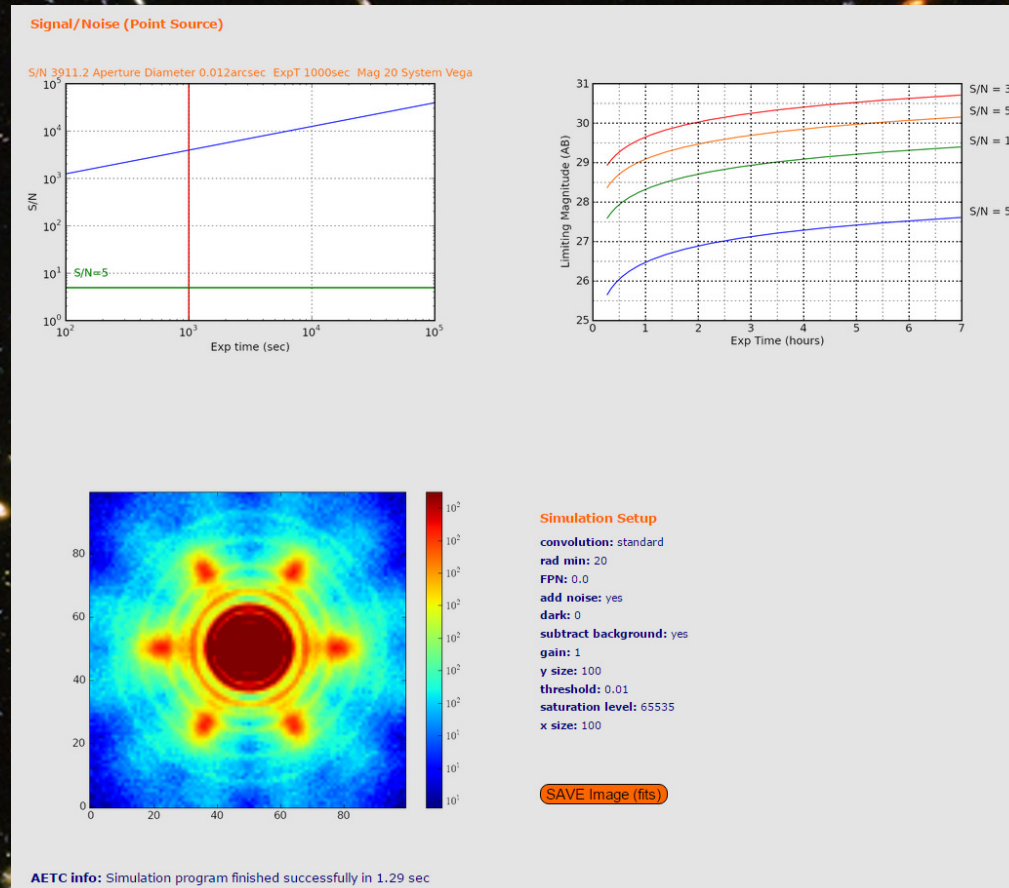


Output

Results:

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

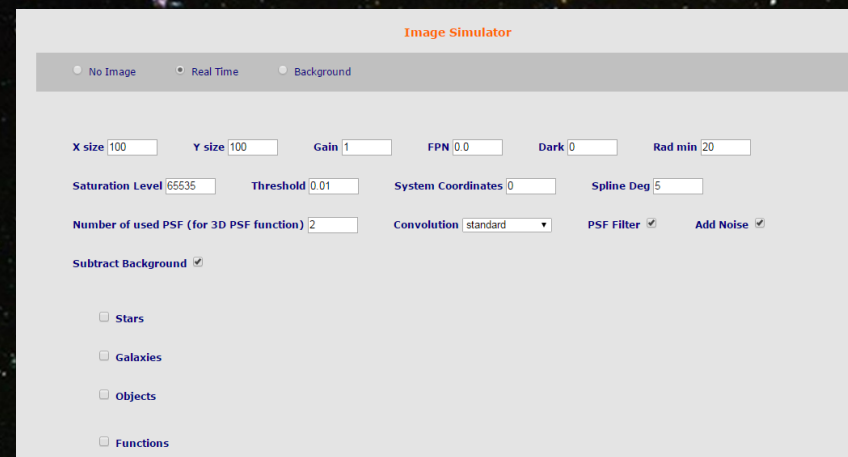
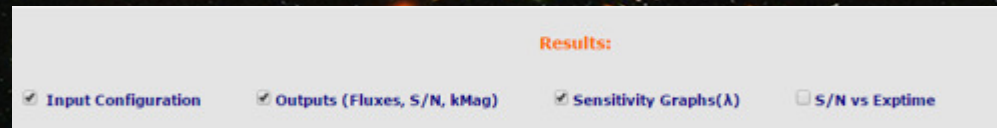
- S/N vs Exptime: plot on the trend of the S/N against the exposure time



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

• **Images !!!!**

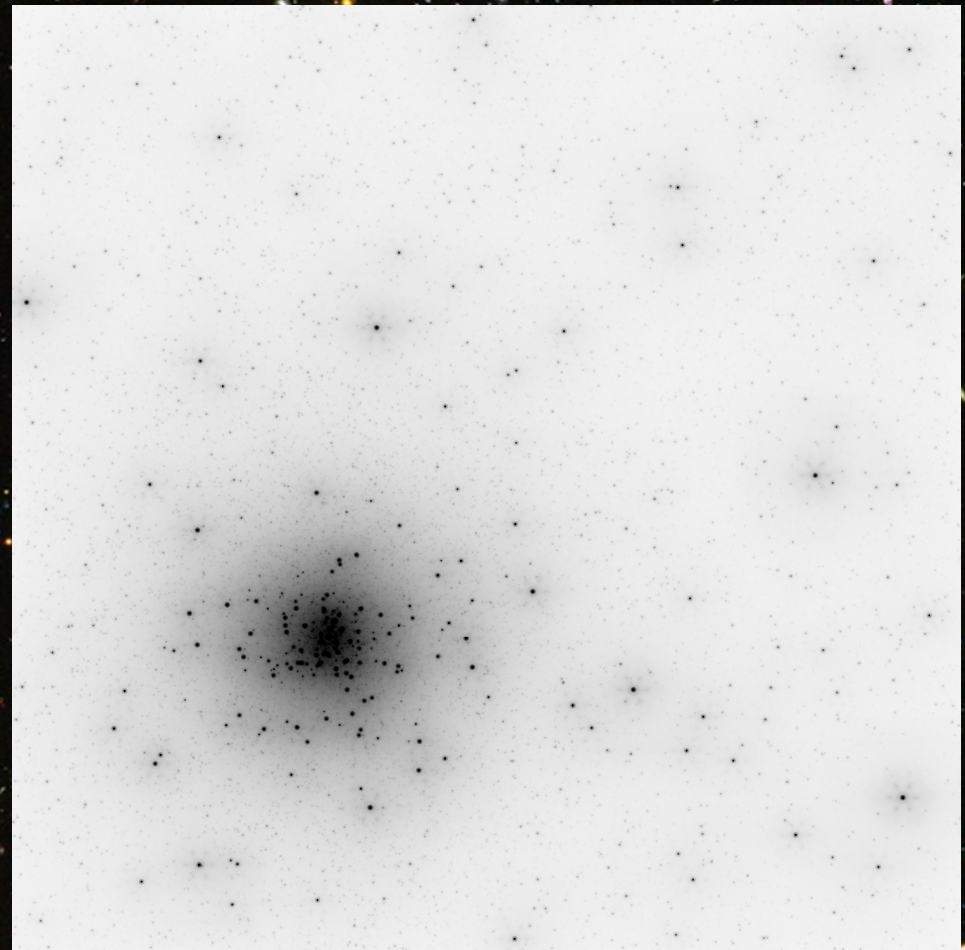


Example: star cluster

J-band observations of a star cluster in a nearby galaxy with [MICADO@E-ELT](#).

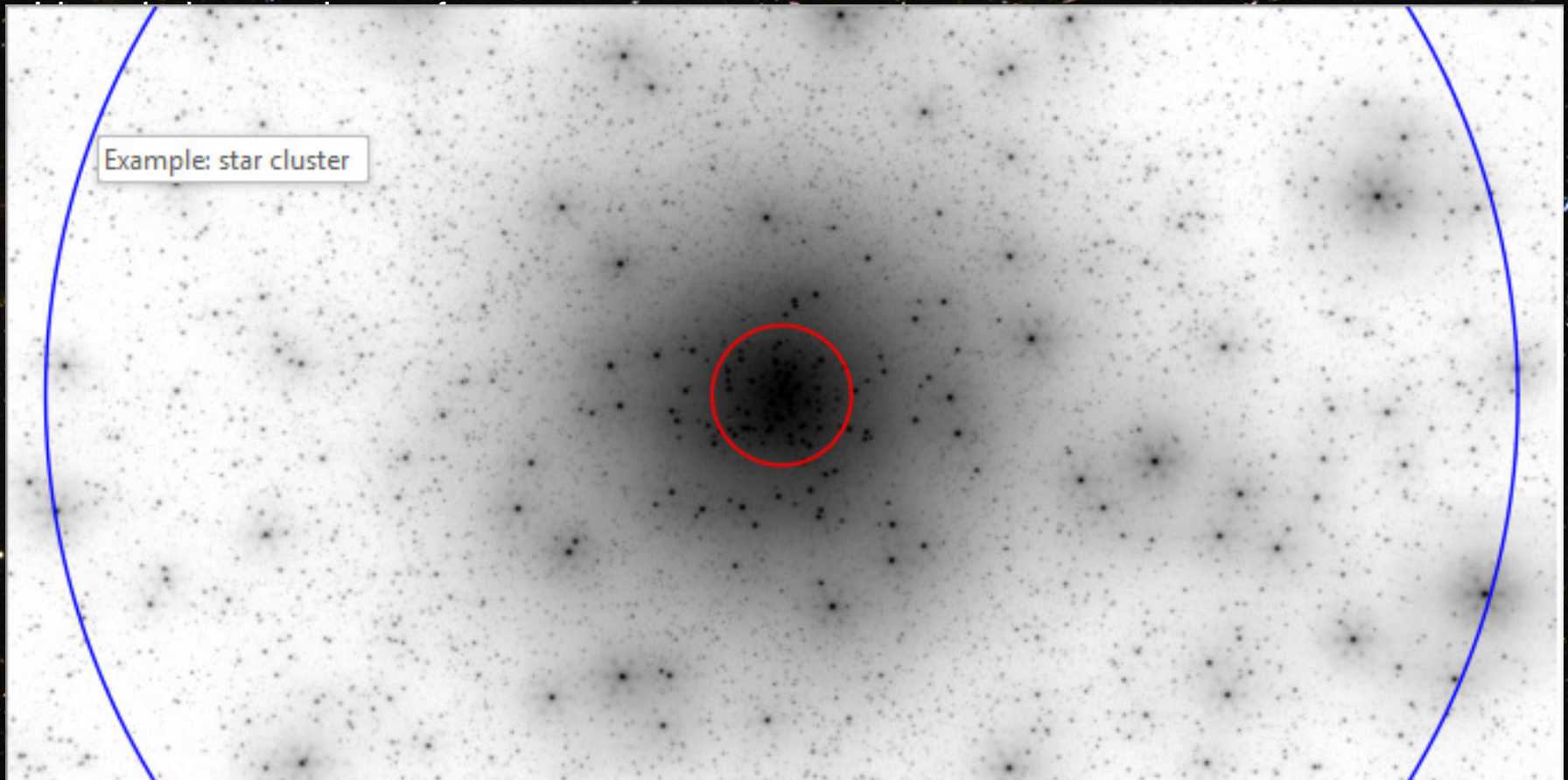
Total exposure time: 3h
input star list (**465567 stars**):

- 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.
Gullieuszik et al. (2014, A&A Vol.568,11)

Example of galaxy simulations

M51
SDSS



u



g

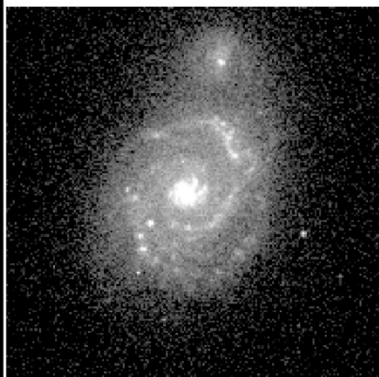


r



ugr

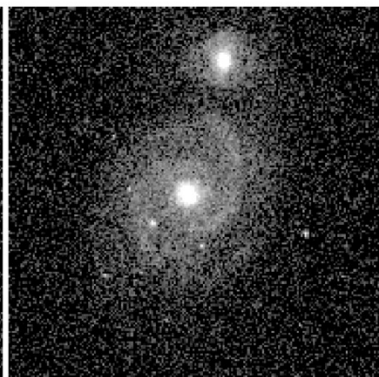
z=2.4
MICADO@E-ELT



E-ELT J 3x3 bin (u@z=2.4)



E-ELT H 3x3 bin (g@z=2.4)

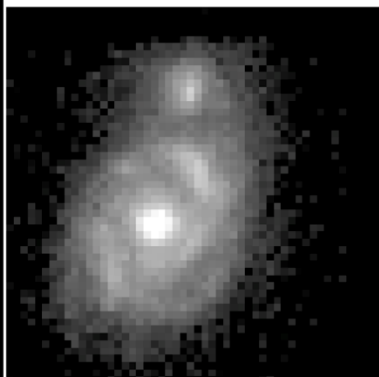


E-ELT K 3x3 bin (r@z=2.4)

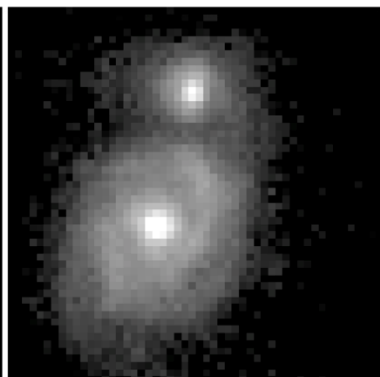


E-ELT JHK

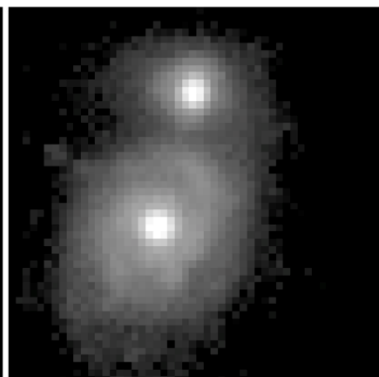
z=2.4
NIRCam@JWST



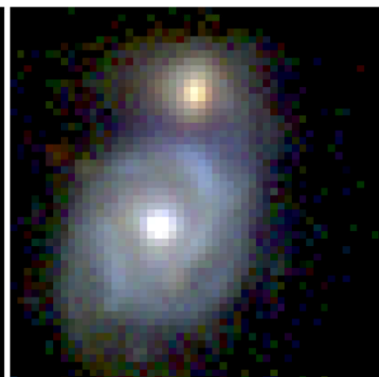
JWST J (u@z=2.4)



JWST H (g@z=2.4)



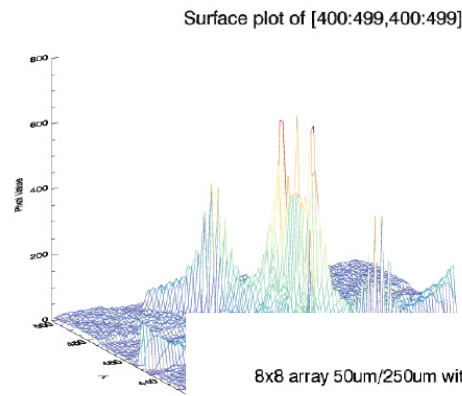
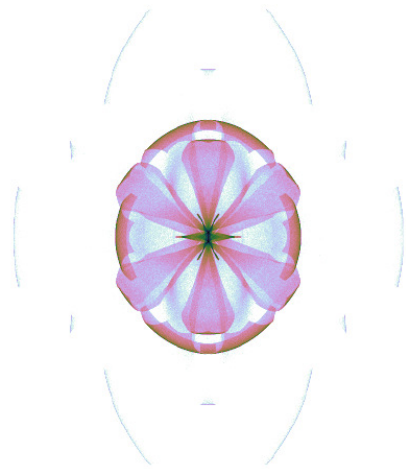
JWST K (r@z=2.4)



JWST JHK

OT: simulation of spad array+ASTRI

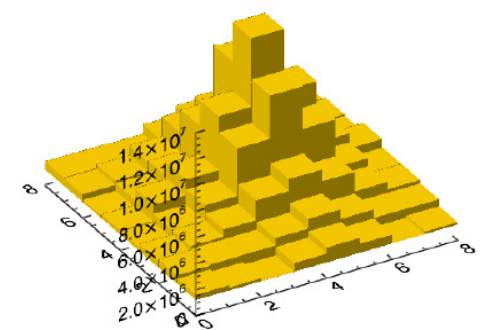
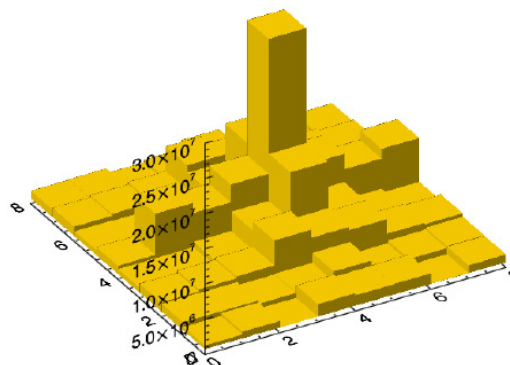
- Non standard detector: AETC has been used to produce the distribution of the photons on the focal plane but the detector has been simulated with a module developed in IDL



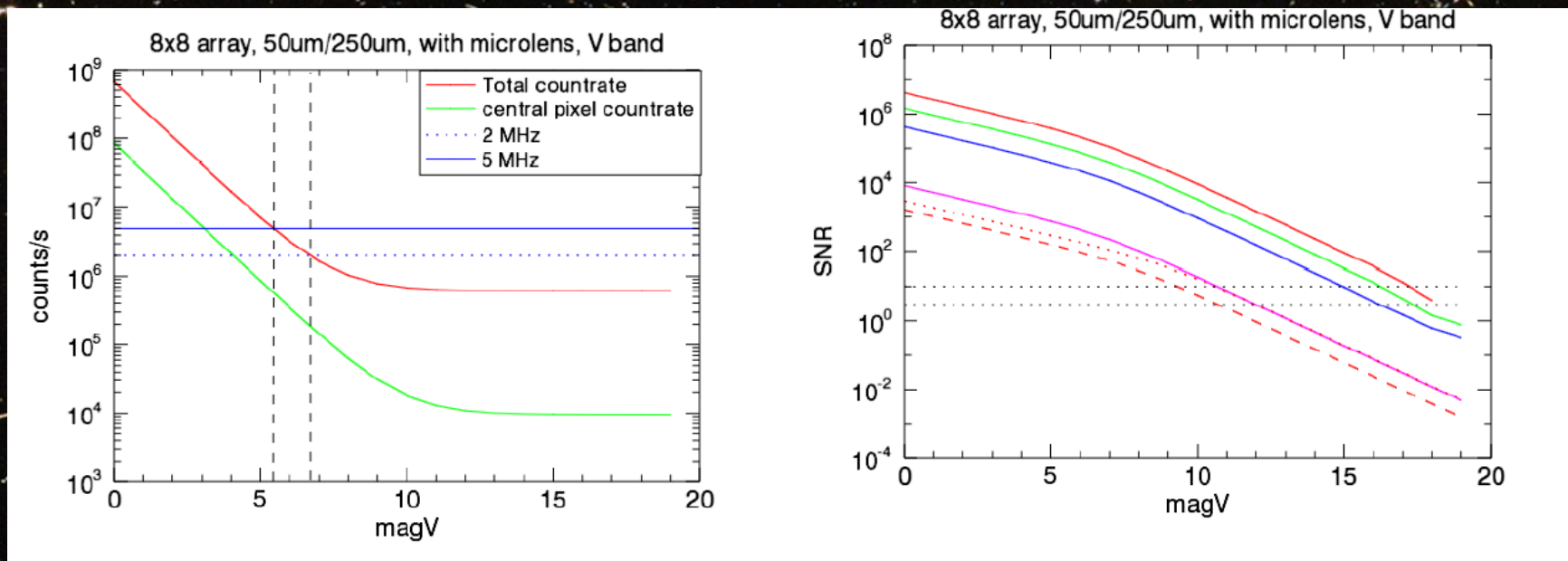
8x8 array 50um/250um with microlens
U band, magU=6, texp=300s

8x8 array 50um/250um with microlens
U band, magU=6, texp=300s

including structure vibrations



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