Overview of the Imaging Simulator

Geoff Bryden

Goal: a tool for the exoplanet community to evaluate the science capability of different telescope architectures.

Key technical characteristics:
- easily accessible (website interface with simple I/O)
- easily adaptable (tunable parameters; highly compartmentalized)

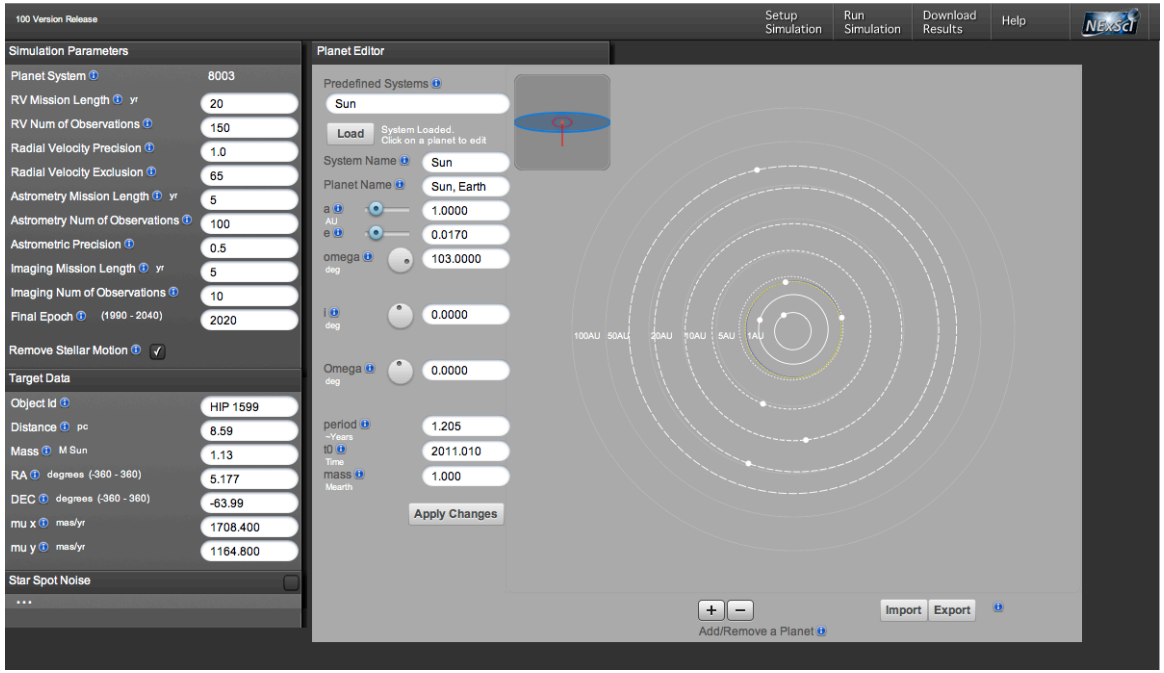
Key physical inputs:
- (this talk)

Heritage Capability

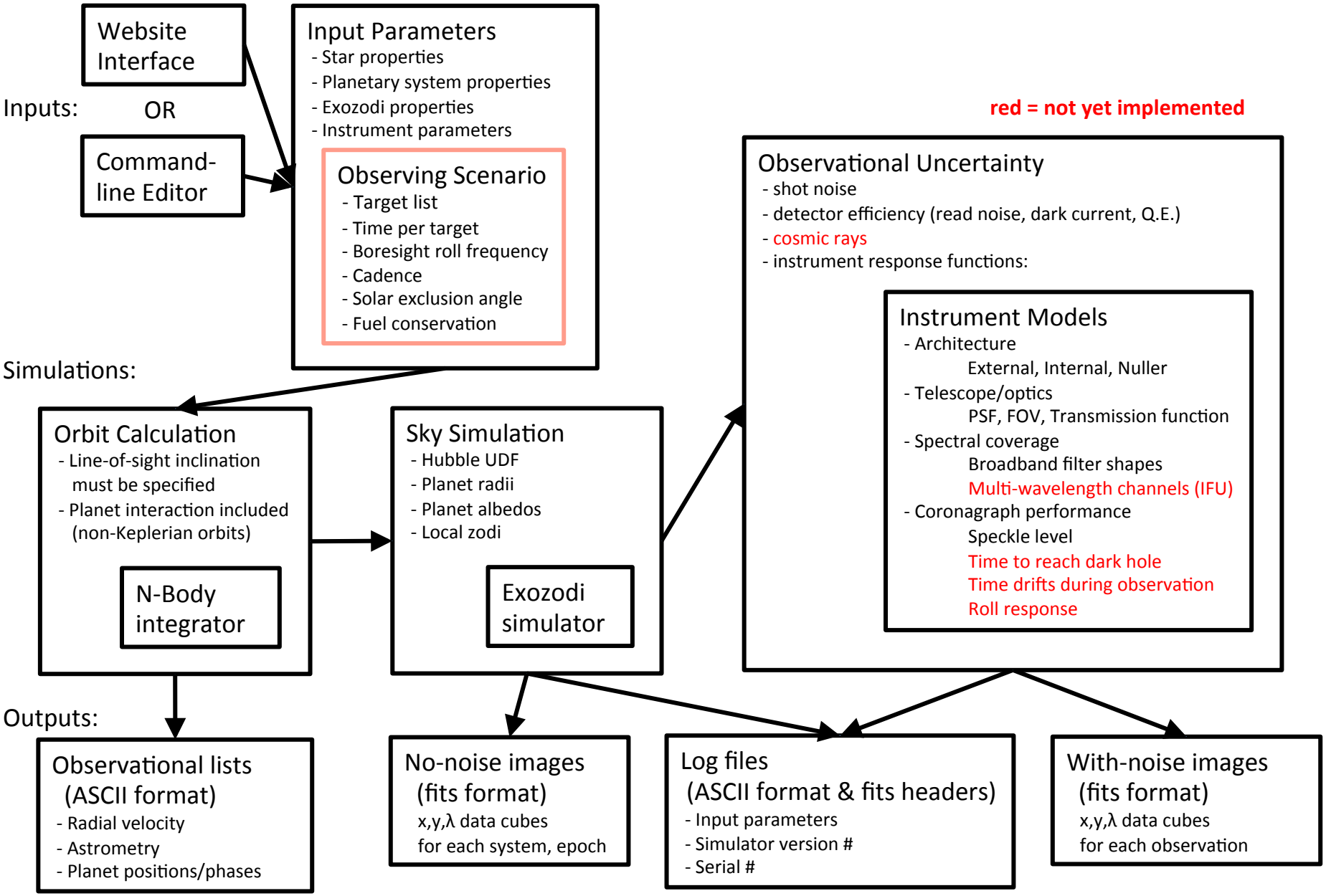
The foundation of the imaging simulator is a pre-existing tool developed as part of NASA's SIM double-blind study.

- website interface to enter parameters
- observed planet and star characteristics from NStED
- N-body integrator to calculate planet orbits
- observing platform in Earth or L2 orbit
- visual output and/or download results
- user set-up can be saved for future restart

Screen shot:



IPS Architecture

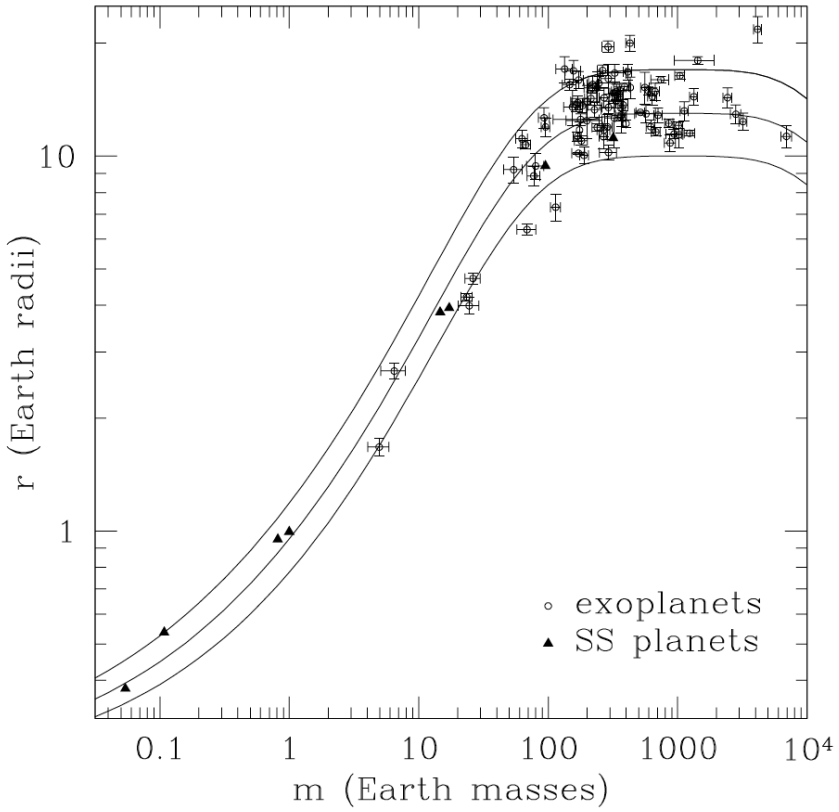


Planet Parameters

Planetary system options:
- known systems
- create your own
- theoretical systems calculated by 5 teams for the SIM double-blind study
- random selection from a power-law distribution extrapolated from RV/Kepler observations

Albedo options:
- grey, isotropic
- analytic scattering function (Hong)
- wavelength and time dependence could also be included, using Earth as fiducial

Radius options:
- constant density
- Traub relation (see figure)



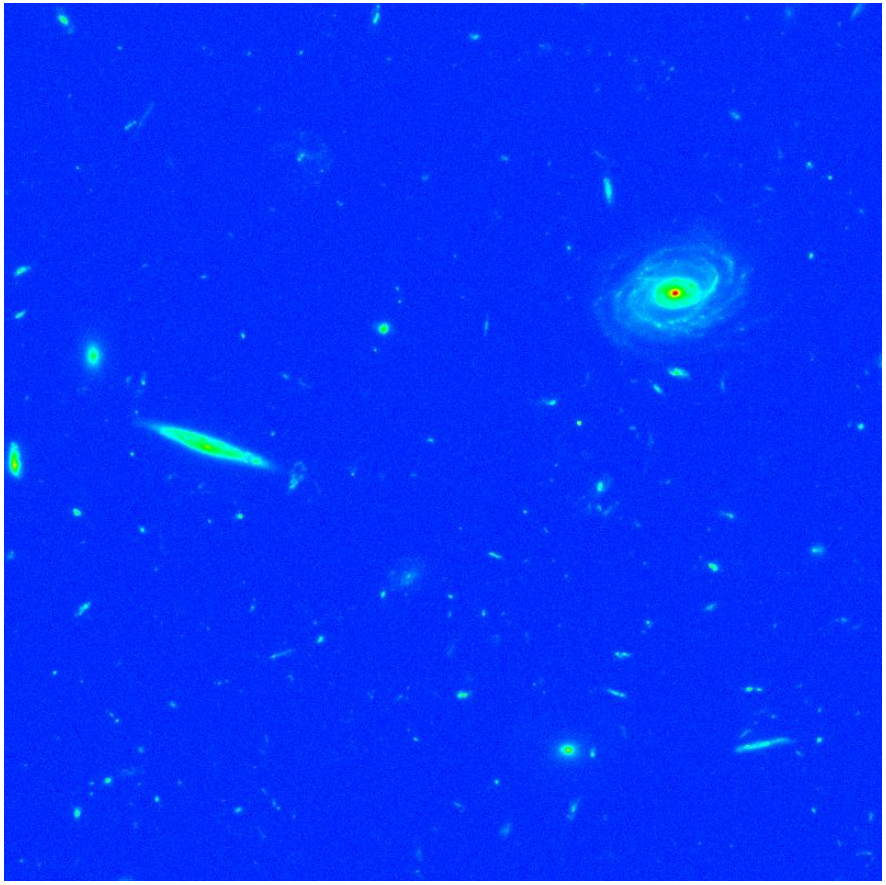
Planet radius relation from Traub (2011) based on fit to SS/transiting planets.

Sky Background

The Hubble Ultra Deep Field provides deep images over four optical wavelengths at the resolution of a 2.4-m telescope.

For now, we are using these images directly (no deconvolution/reconvolution), interpolating between the wavelength bands.

Due to stellar proper motion, this sky background shifts between each observing epoch.



Local Zodi

A local zodiacal dust distribution is included based on COBE/DIRBE observations of the Solar System (Kelsall et al. 1998)

Line-of-sight brightness is integrated as a function of target star's ecliptic latitude (currently assuming observation at opposition).

Exozodi

The main component of the target's debris disk is scaled from the Solar System's. (The scaling factor is currently set to 1, i.e. same as the local zodi.)

Currently assuming grey opacity & smooth distribution.
Color can be included by prescribing the dust composition/emissivity.

Exozodi structure is important; it can mimic planets.
Will be included in a parameterized form based on detailed models.
(see Roberge/Stark talk at this meeting)

Spectral Coverage

SEDs interpolated from Pickles (1998) library of stellar spectral fluxes.
(The library is scaled to V band, covering 0.1–2.5 μm.)

Four broad bands (20% width) are considered –
B, V, R, and H at 0.44, 0.55, 0.70, and 1.65 μm

Note that the wavelength resolution within the simulations is higher, such that the capability of an integral field spectrograph can easily be included.

S/N

CCD detectors with nominal:
- Quantum efficiency
- Read noise
- Dark current

Shot noise is included as random sampling from a Poisson distribution.

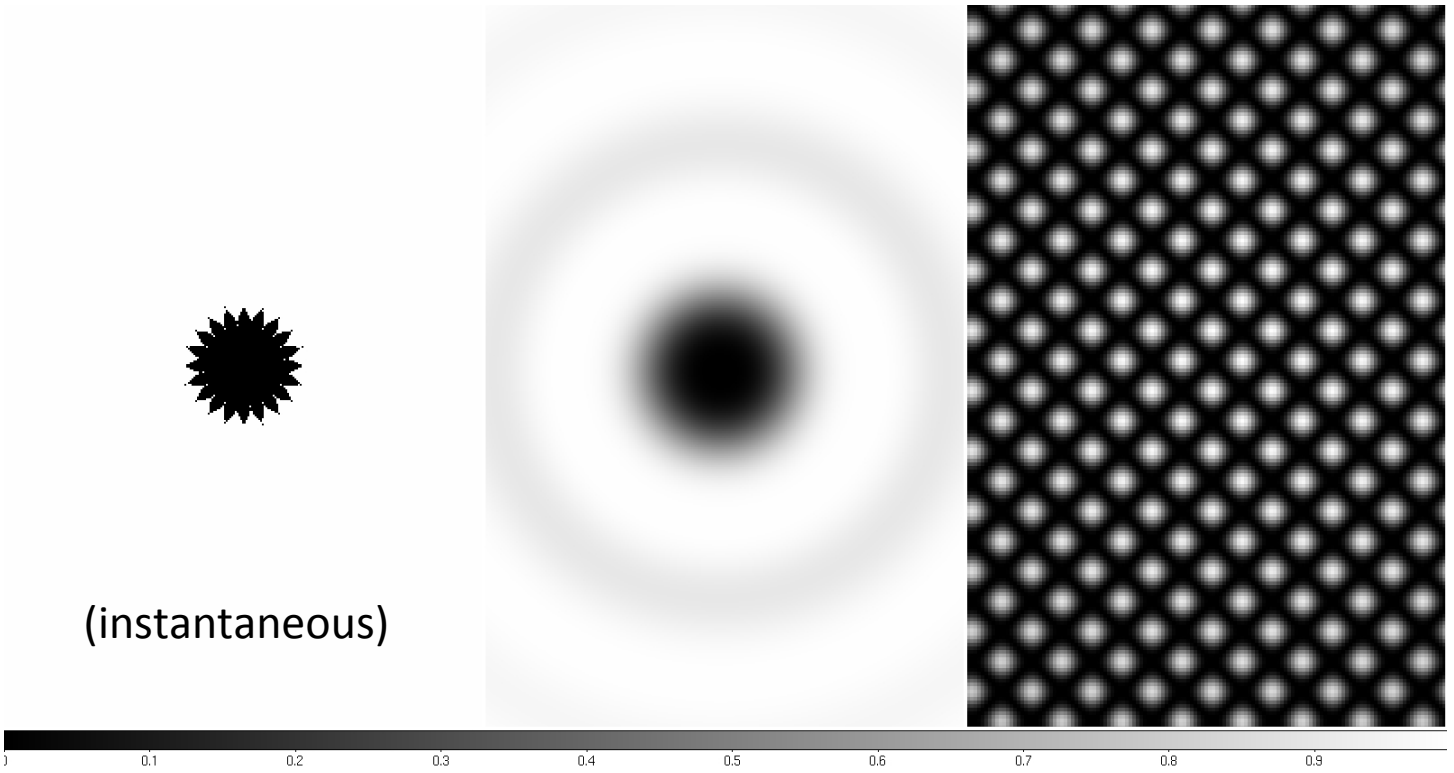
Instrument Throughput

Instrument throughput is reduced by each reflection along the optical path, by losses from the Lyot stop (if there is one), and by the instrument occulter. The occultation pattern varies considerably between architectures:

External occulter

Internal coronagraph

Visible nuller



(instantaneous)

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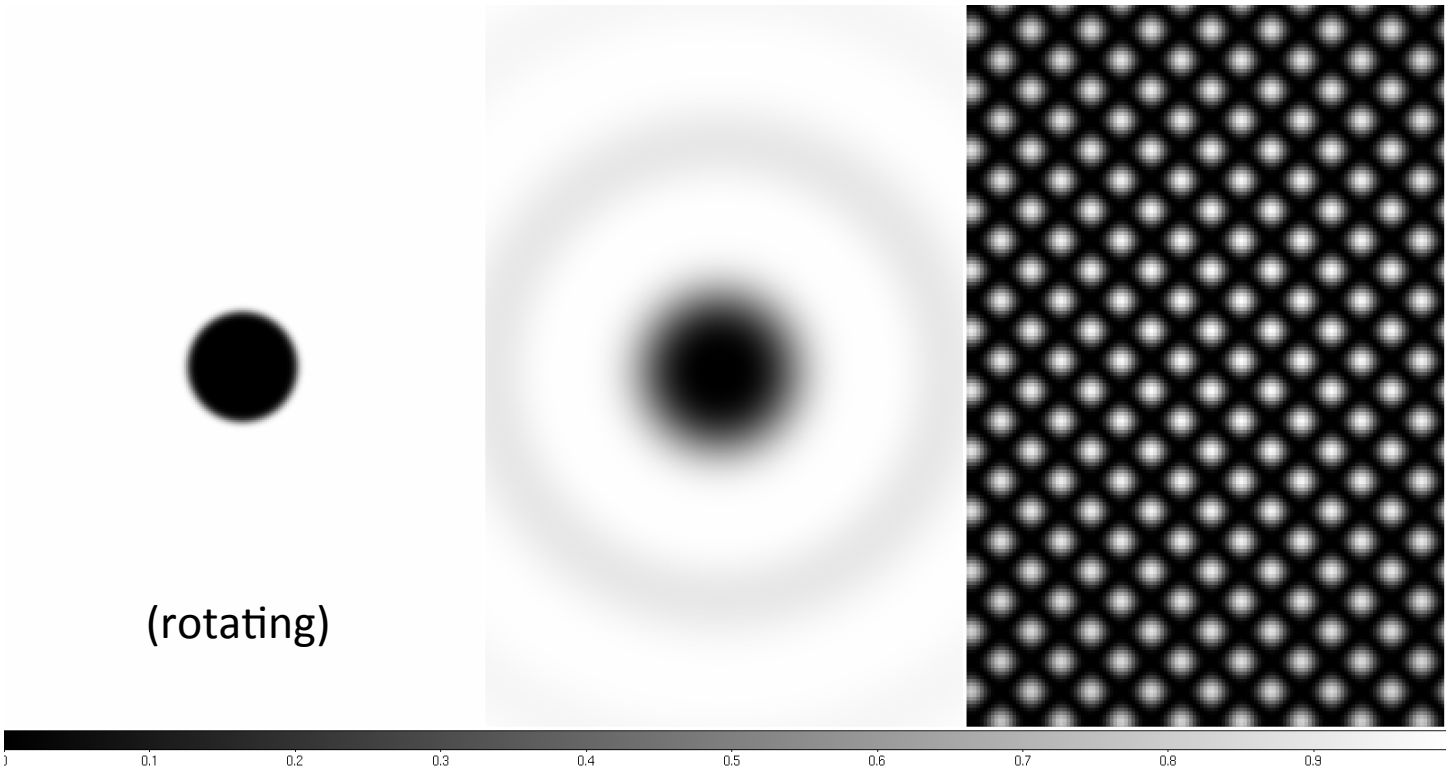

Residual Speckles

A large fraction of the effort put into the imaging simulator has been devoted to calculating the flux remaining after stellar subtraction. As with the occultation pattern, the residual speckles vary considerably between architectures:

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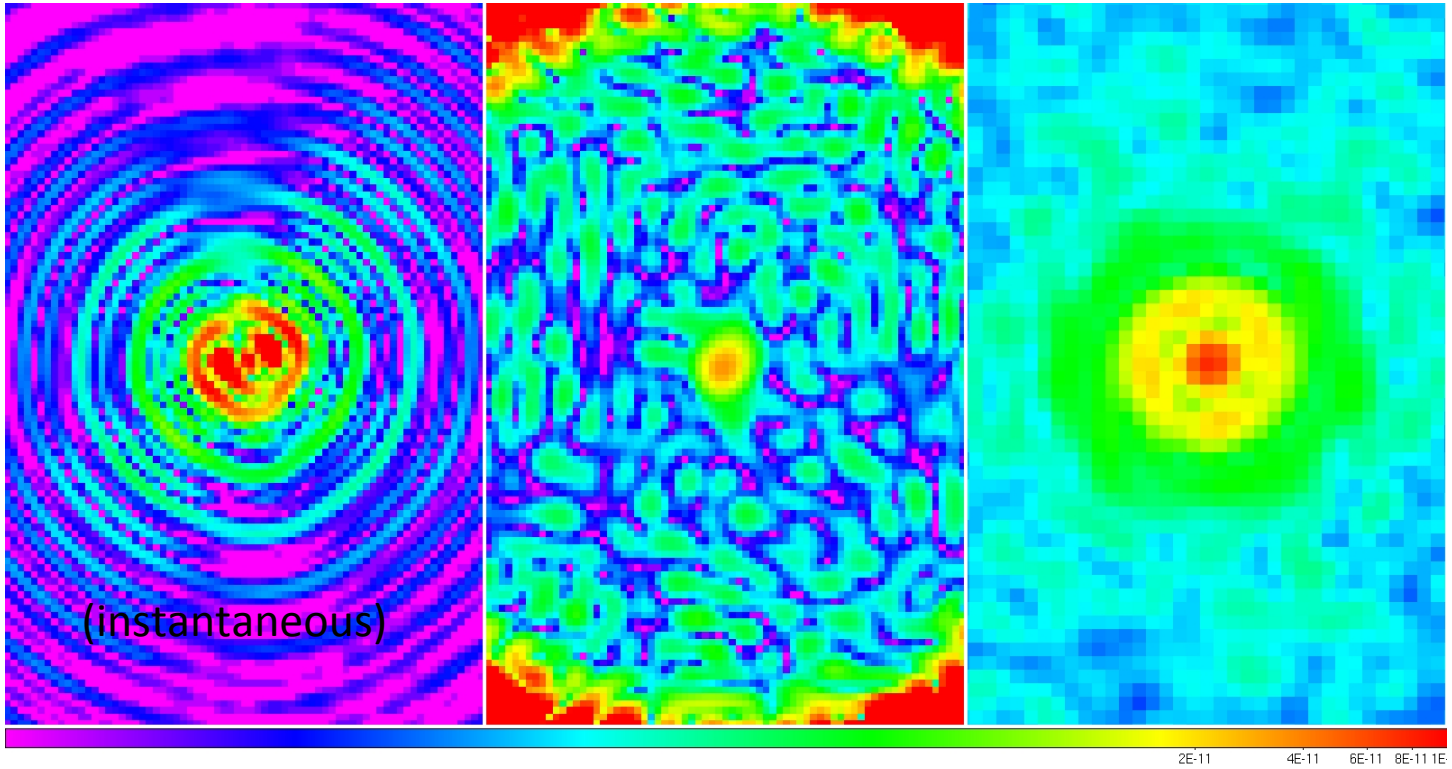

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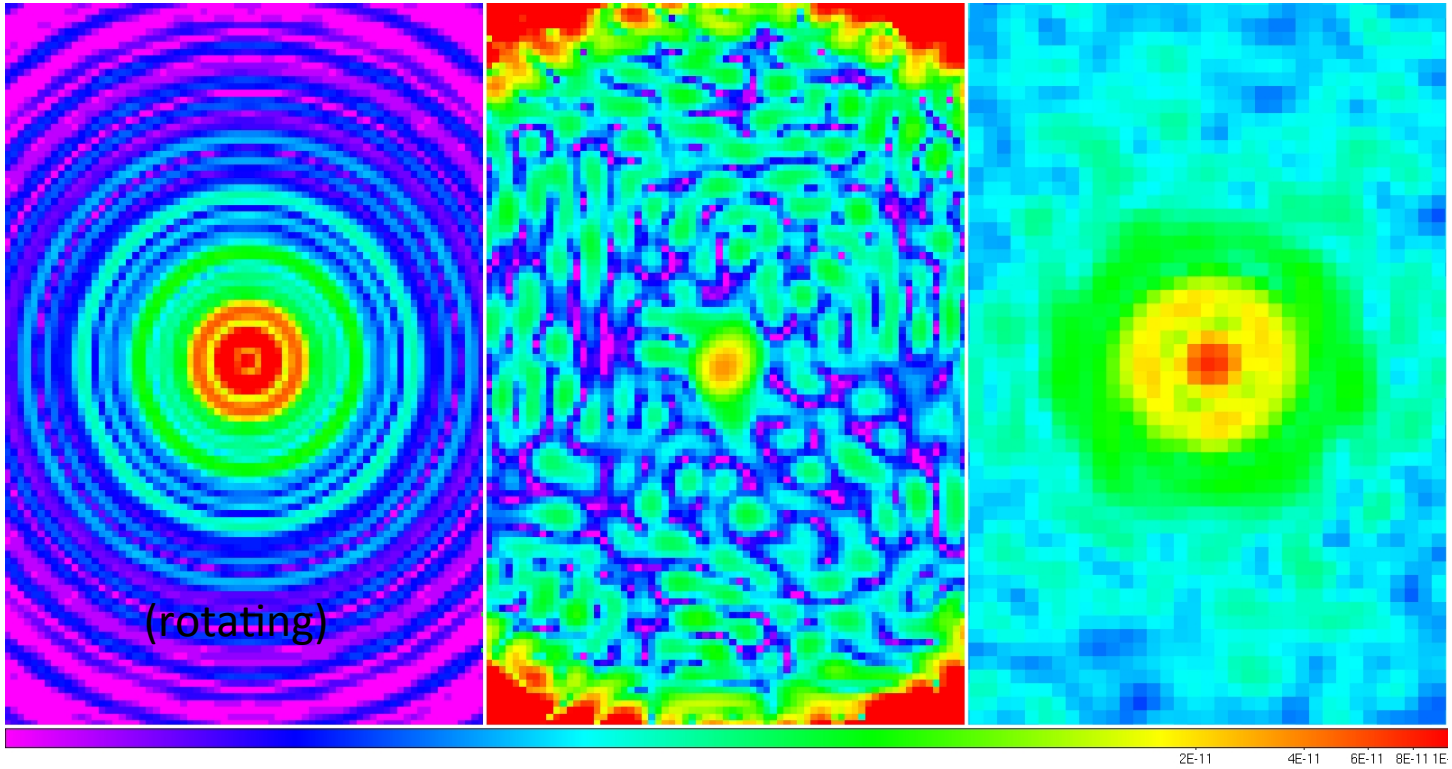
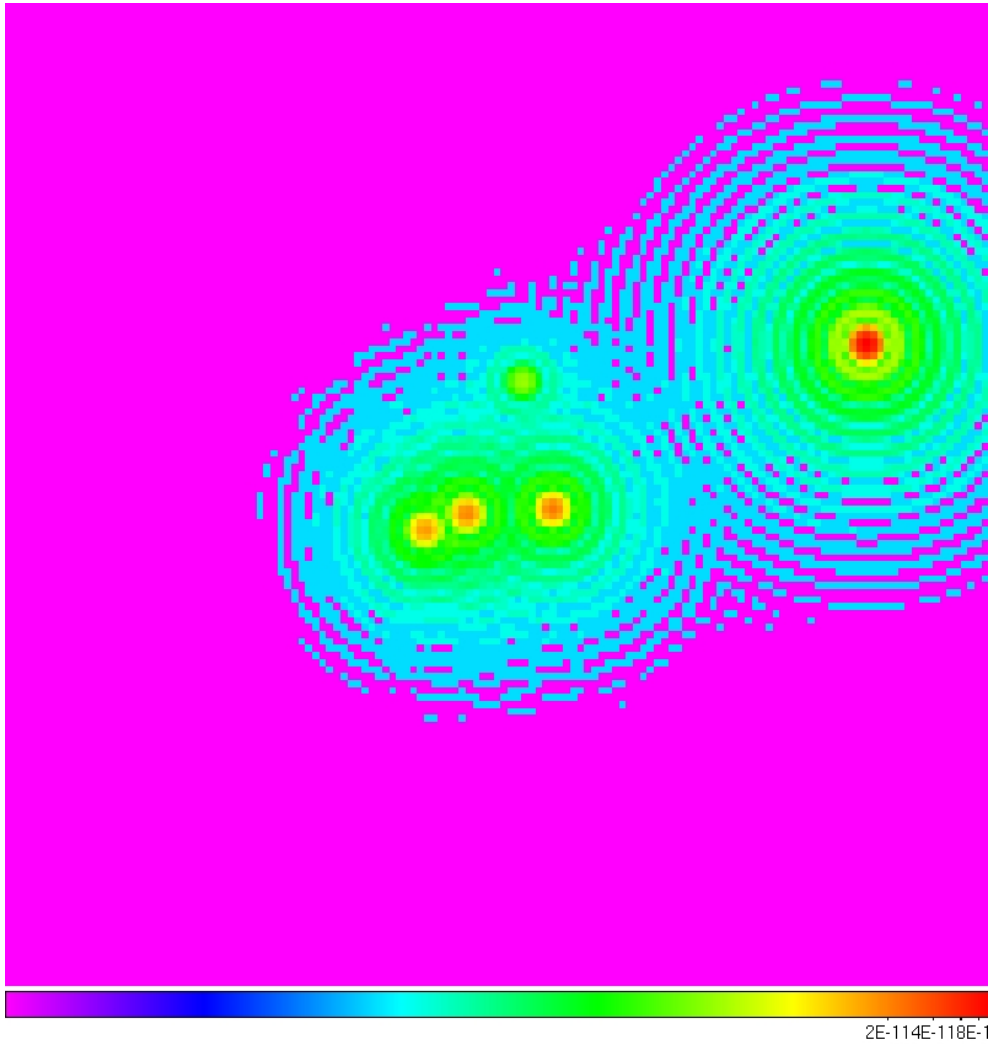


Example Images

Consider the Solar System,
face-on at 10 pc.

Planets, monochromatic ←
Planets, broadband
HUDF background
Exozodi
Local Zodi
Transmission function
Residual speckles
Detector noise

(All images are for external occulter. Equivalent images for Lyot coronagraph and for visible nuller are appended as backup slides.)



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Wavelength range is 0.5-0.6 μm.

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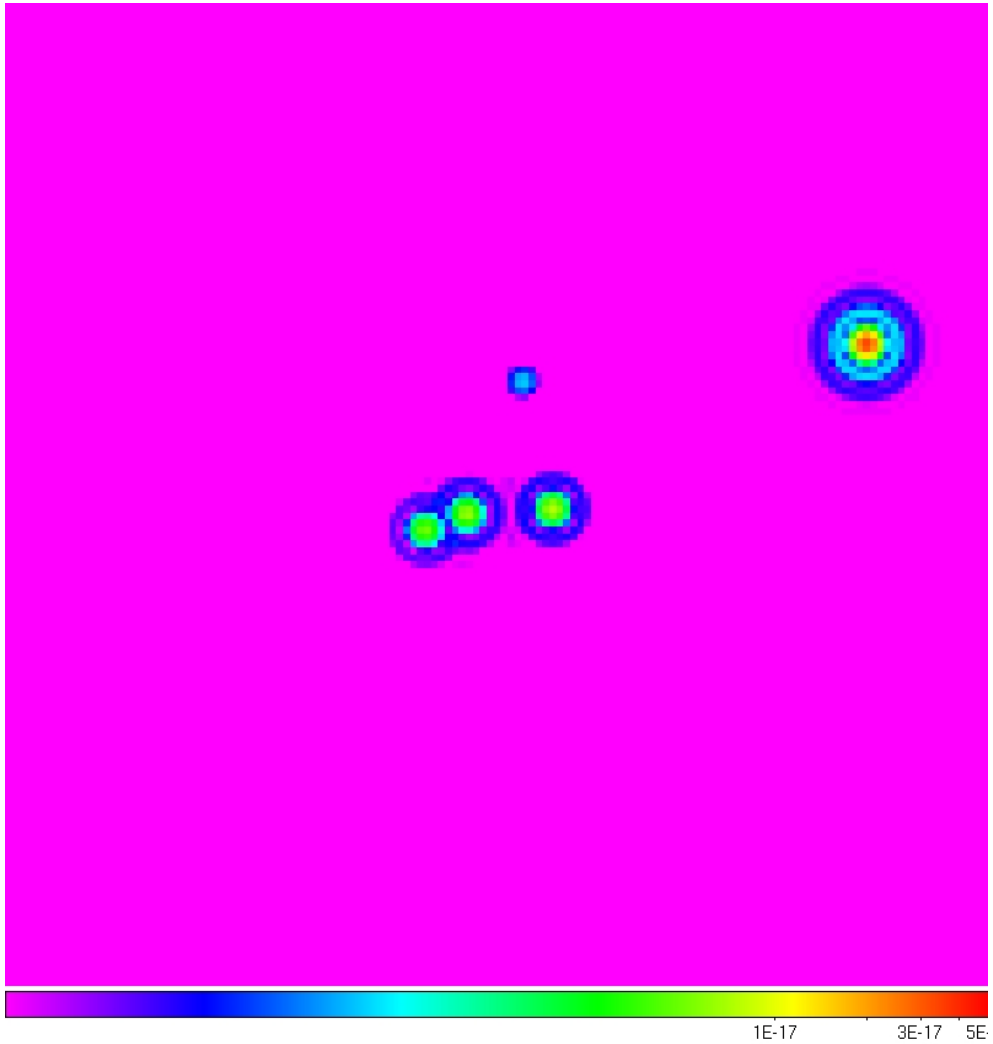

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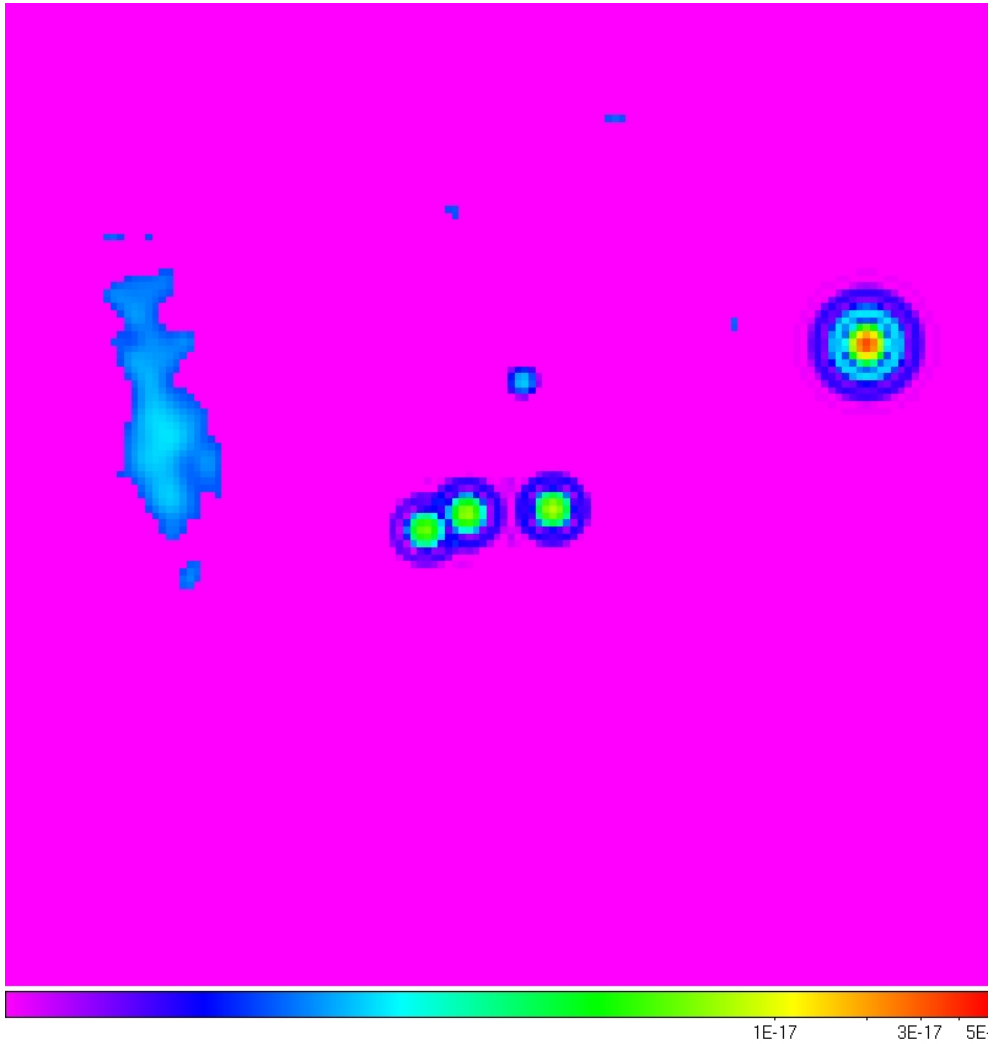

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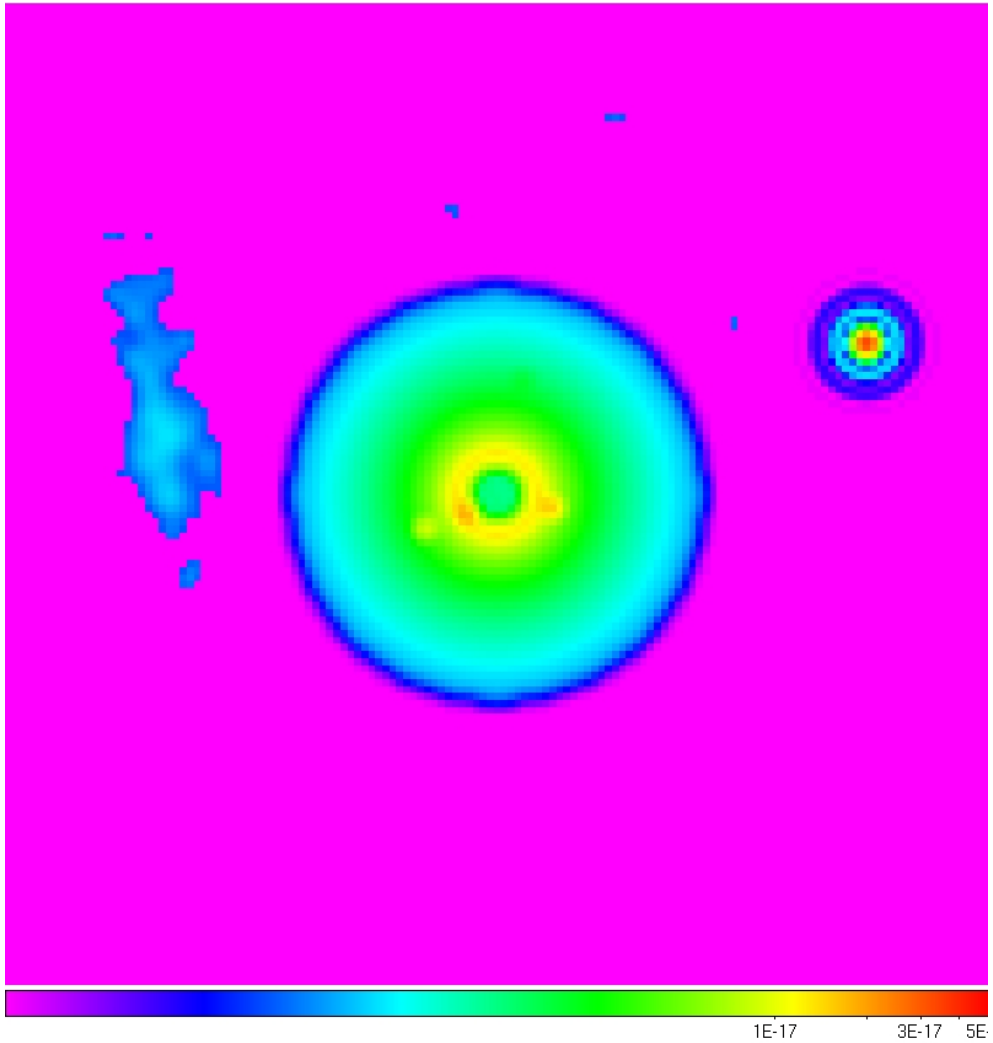

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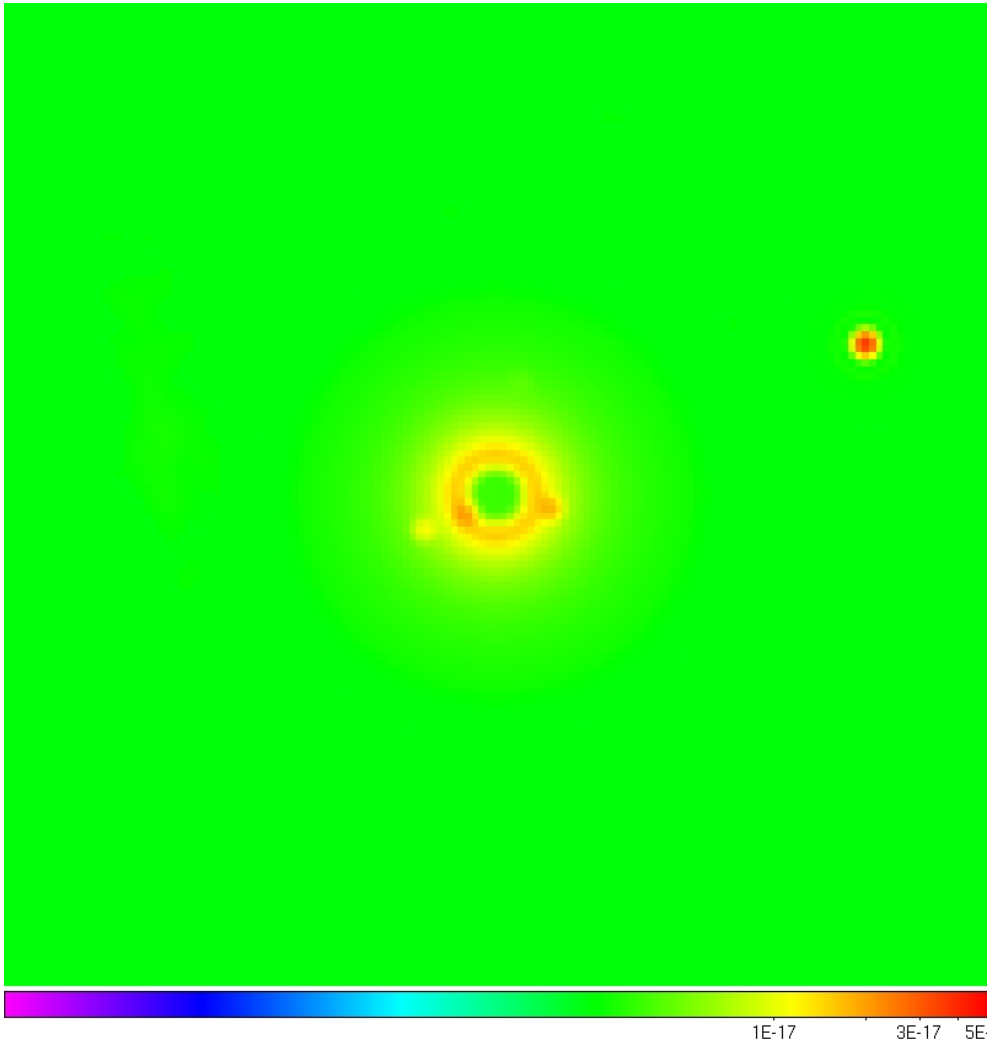

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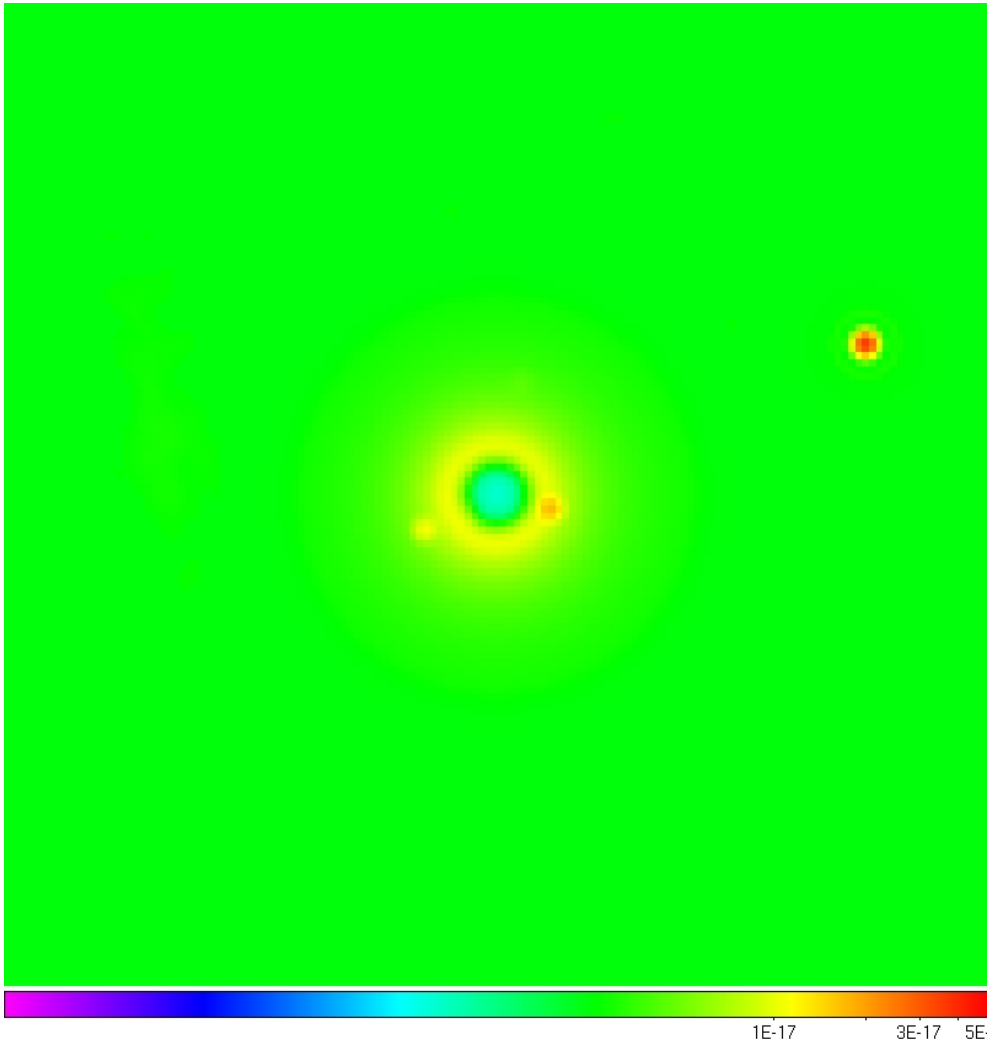

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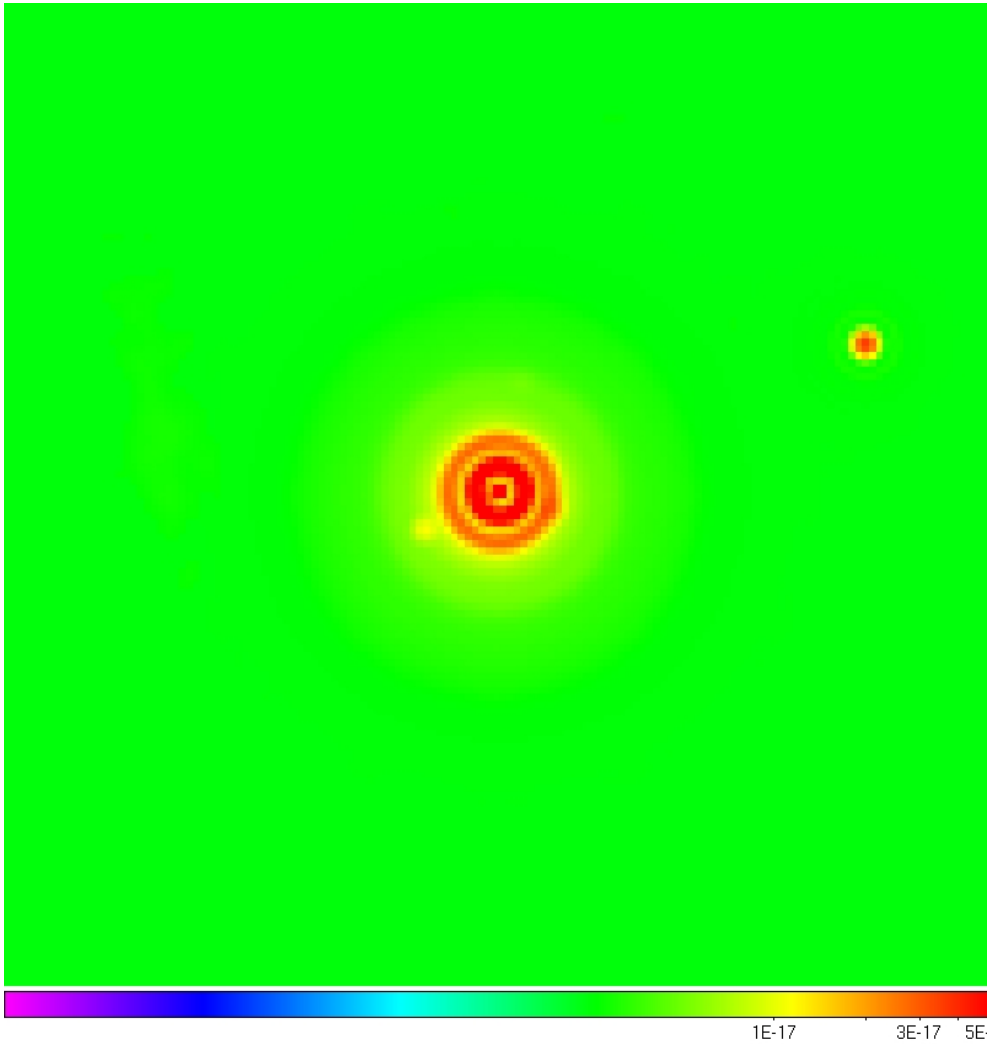

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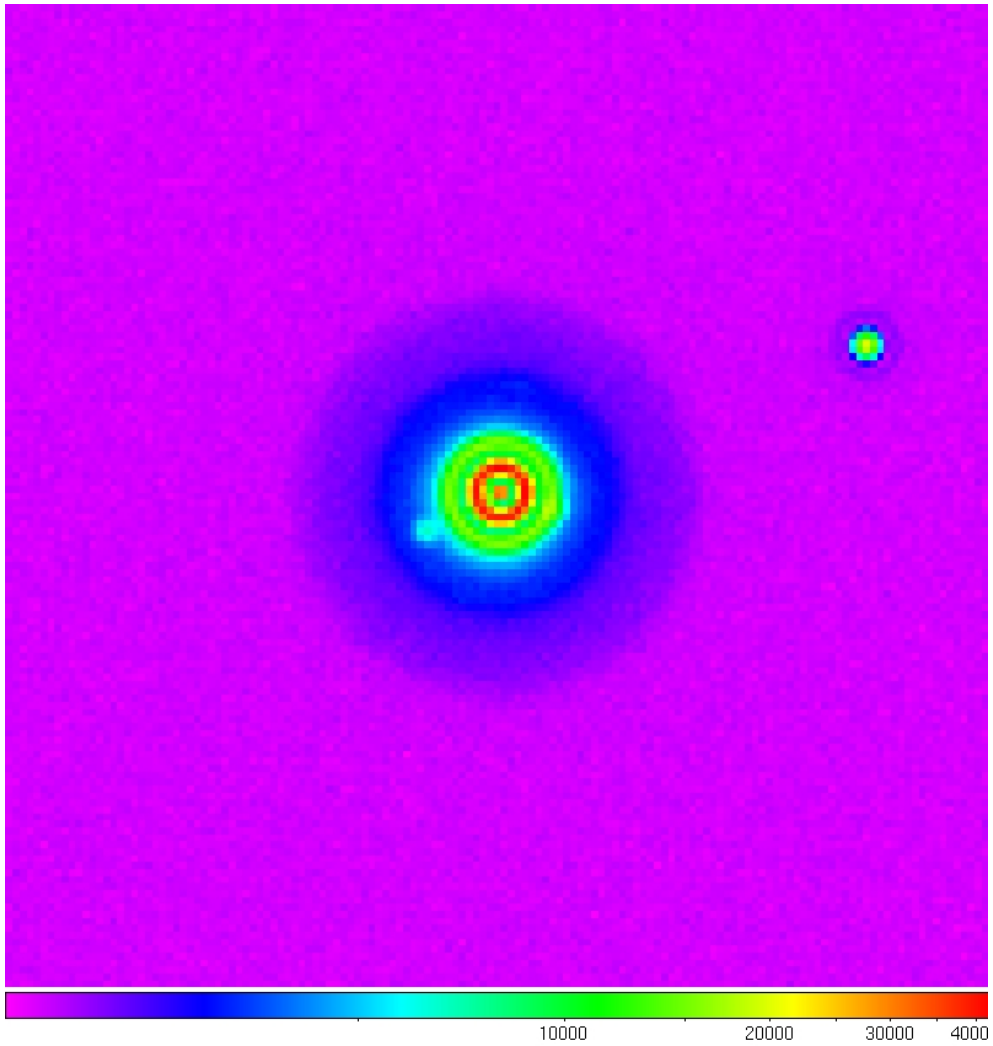

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Summary

- Most capabilities of the imaging simulator will soon be accessible to the exoplanet community via the web.
- The compartmentalized structure is easy to modify – change parameters, turn parts on/off, add new instruments… – such that the simulator can be used to test the science output for any supplied technical design.

- The current framework for the simulator contains a minimum set of physics needed to evaluate the science performance of various telescope designs.
- Community input to further define the input physics is welcome.
- In particular, the fidelity of the exozodi component can be improved with detailed simulations (see later talk by Roberge/Stark).

- The majority of the effort so far has been for the instrumentation (following 3 talks by Cady, Krist, Mennesson).
- Again, community input is crucial.

Backup Slides

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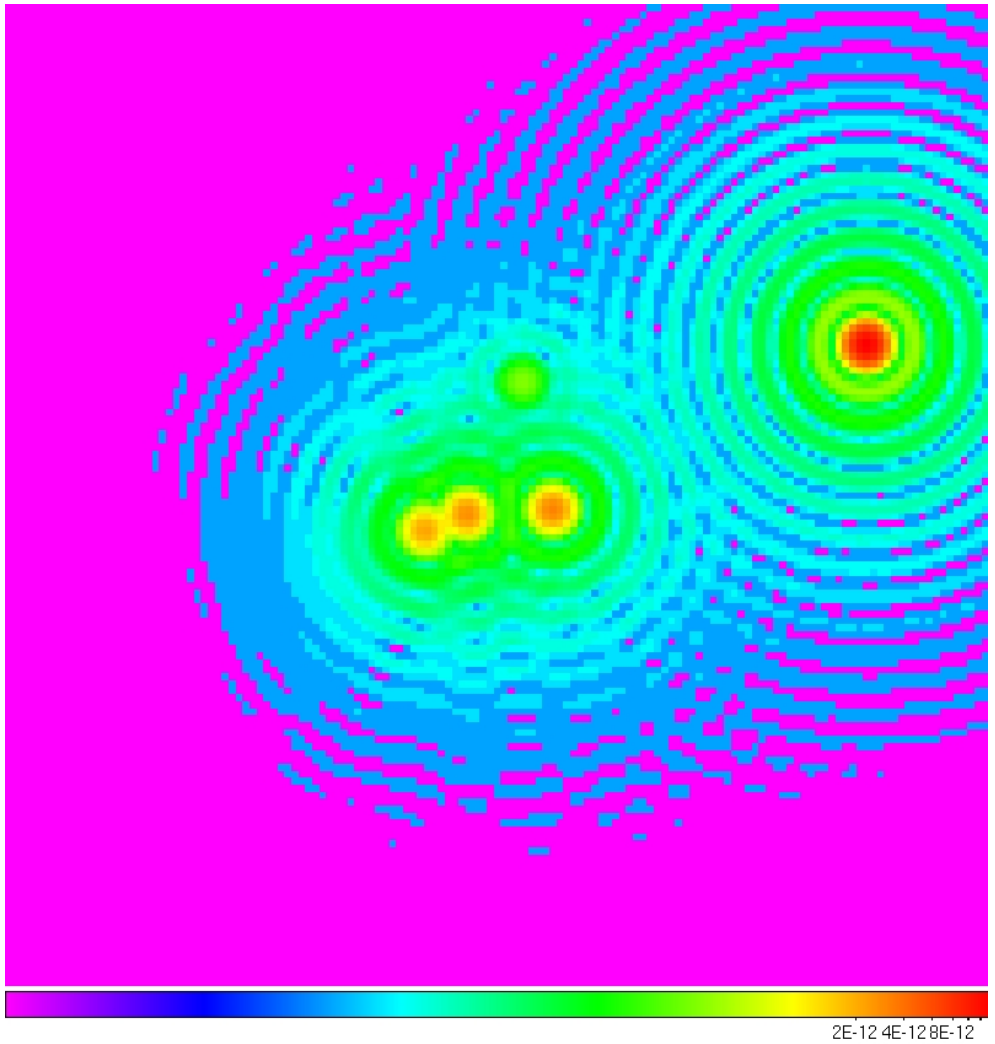

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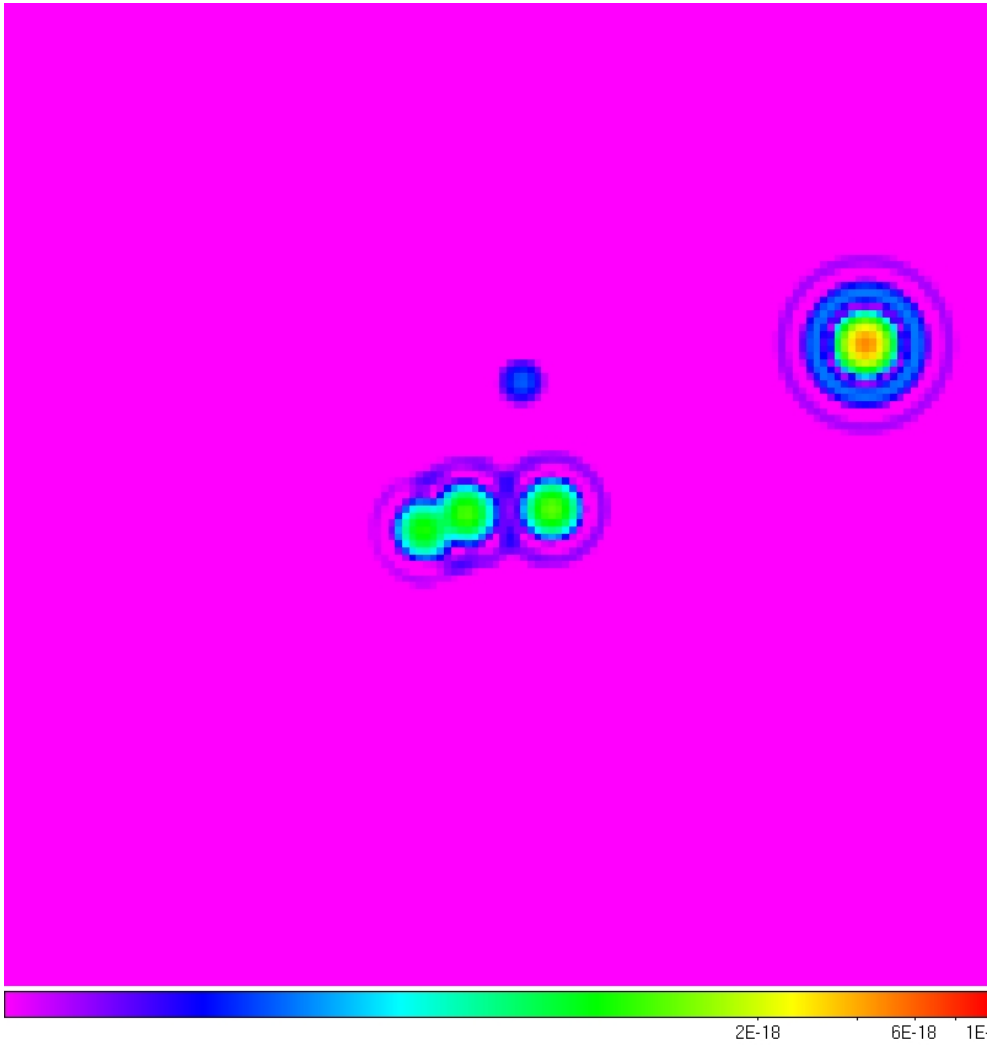

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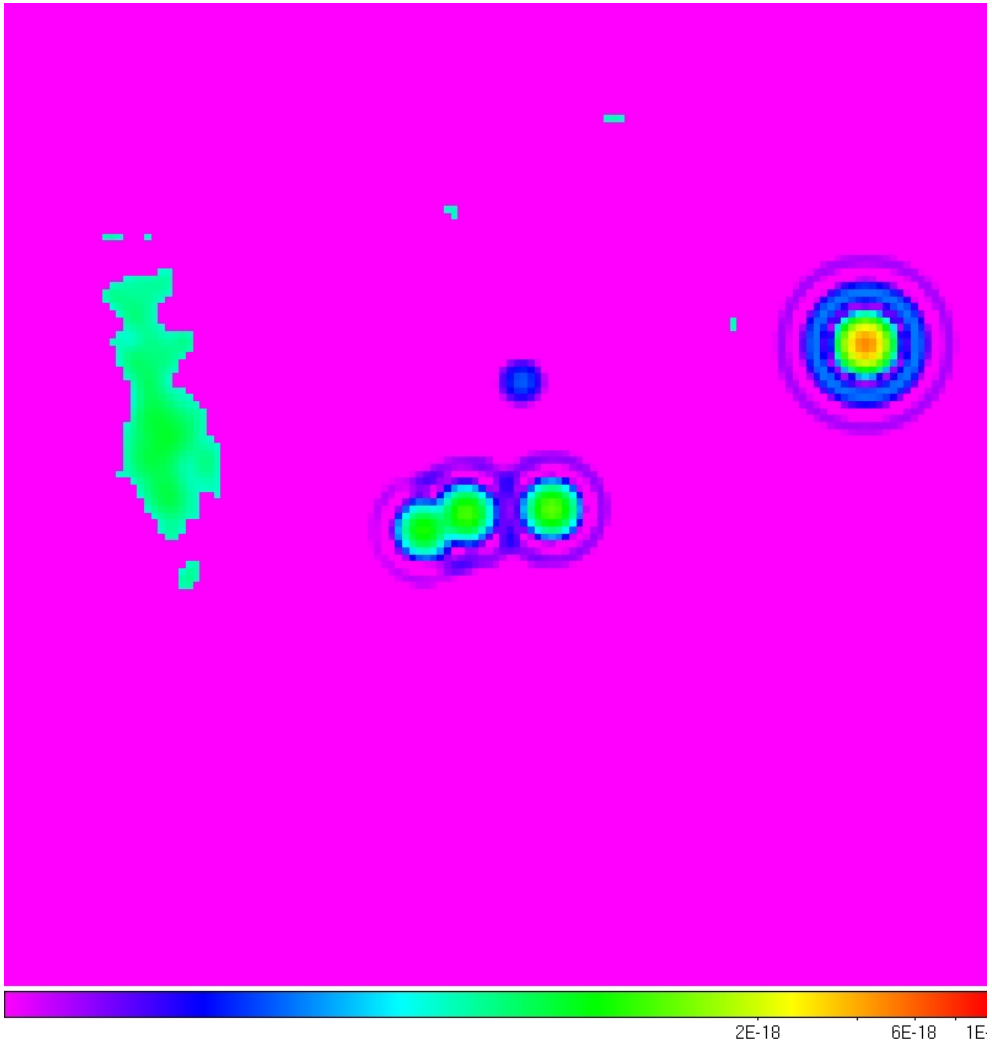

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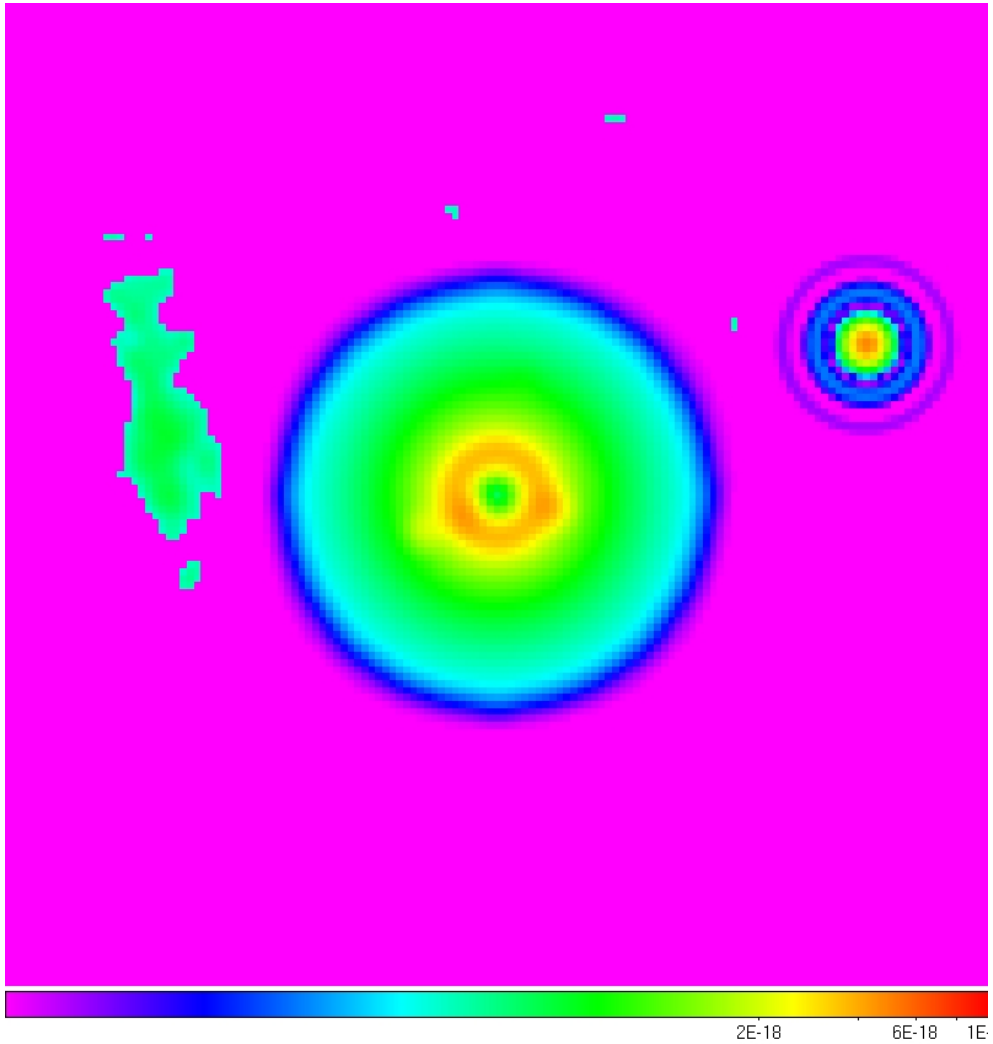

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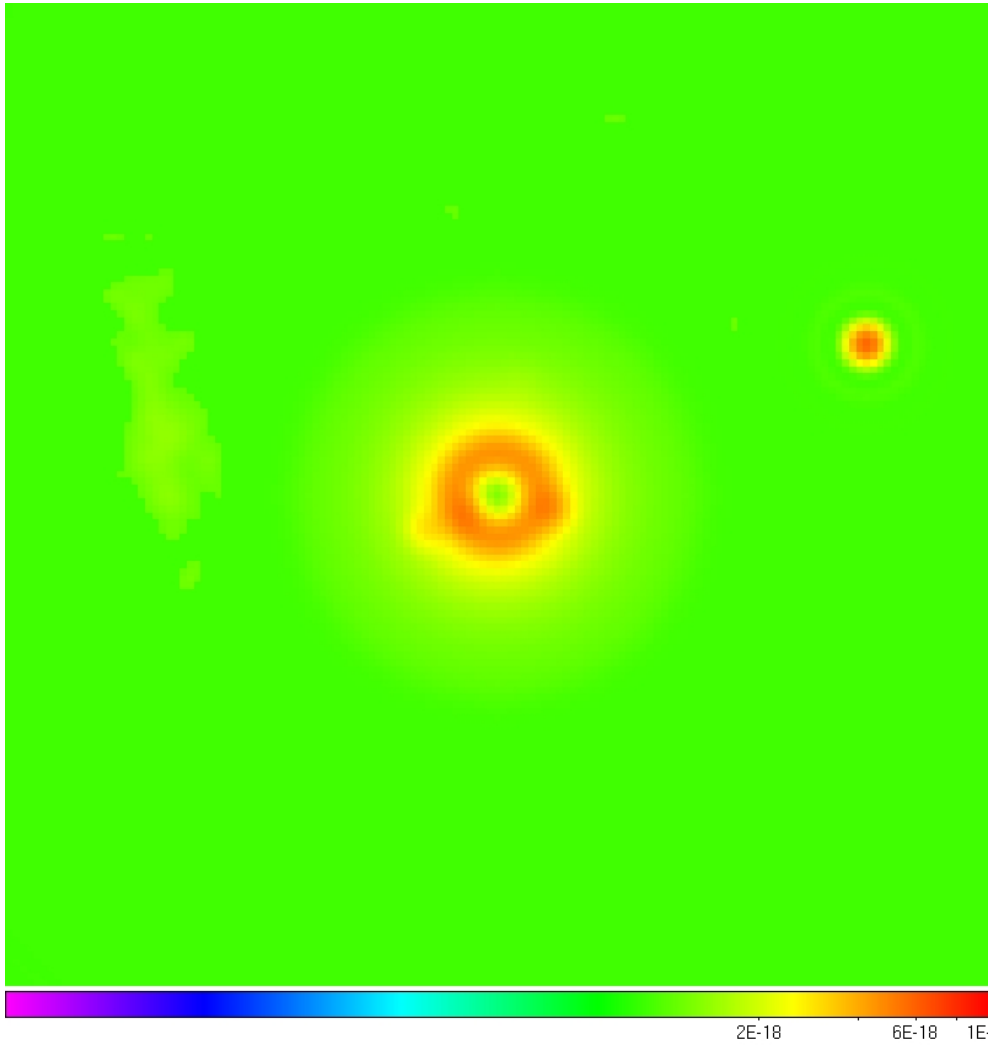

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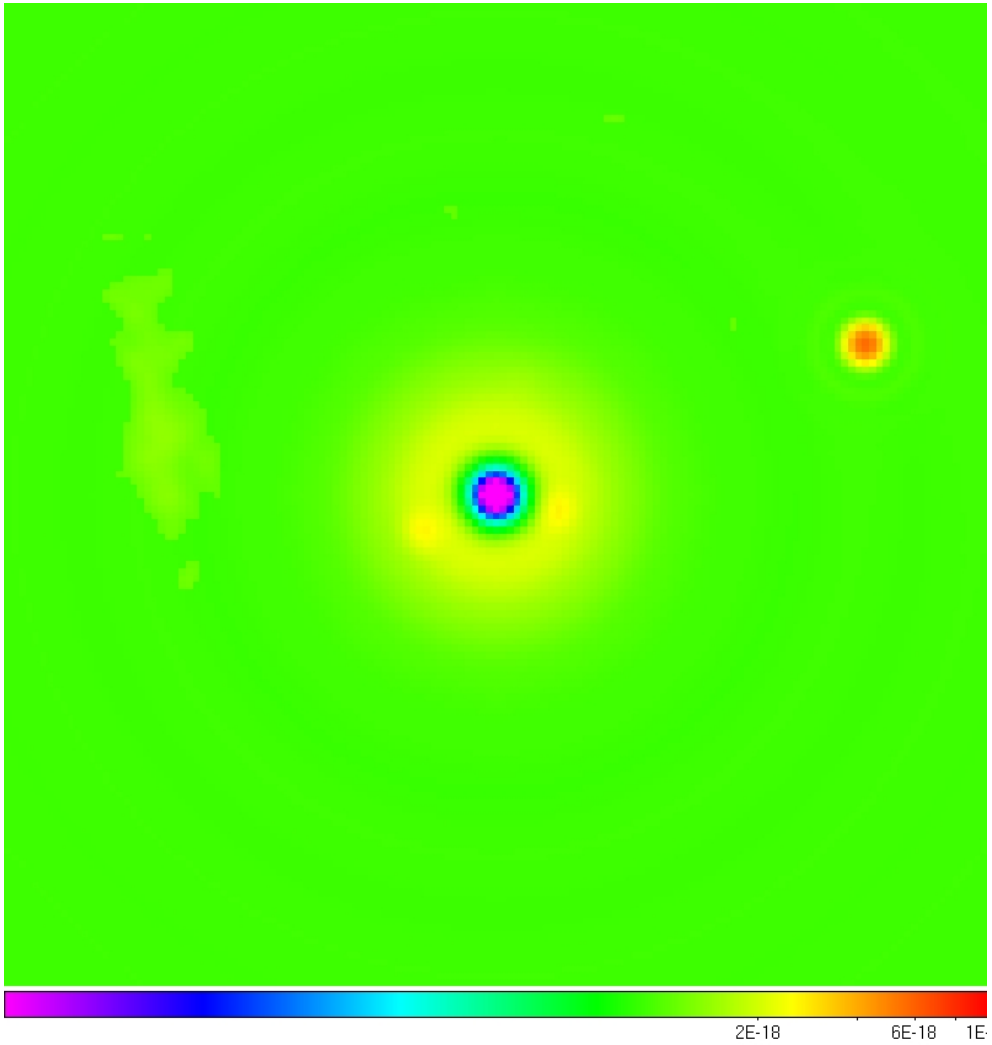

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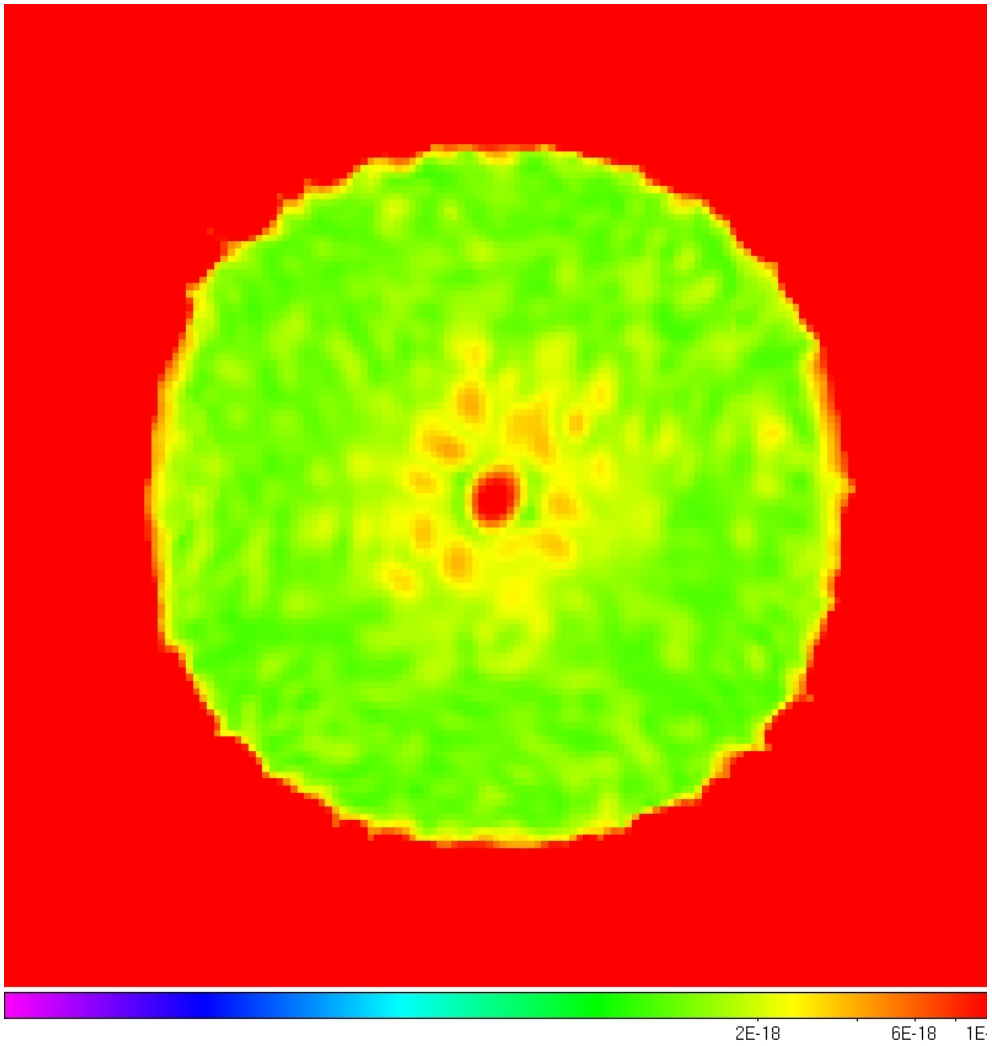

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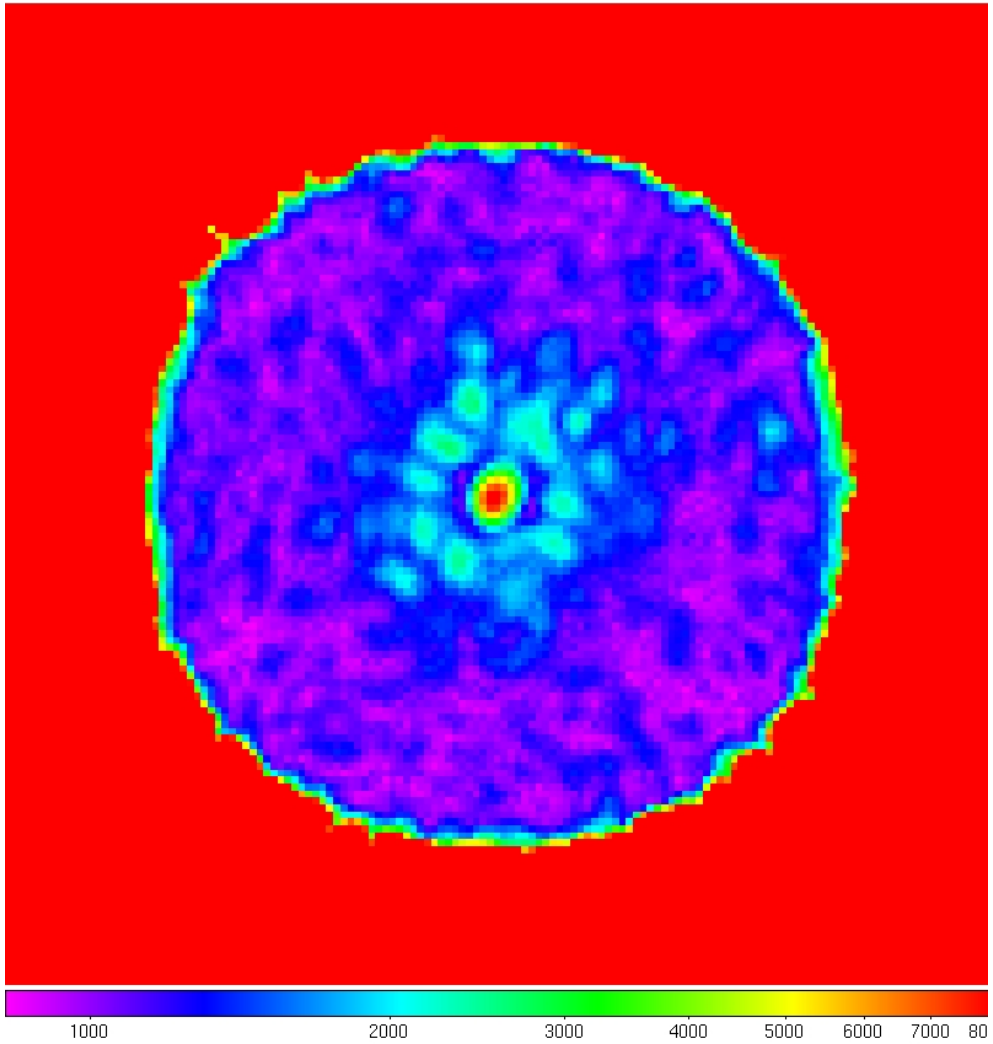

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