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Multi-Aperture Telescopes at the Quantum Limit of Superresolution Imaging

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Size Matters!

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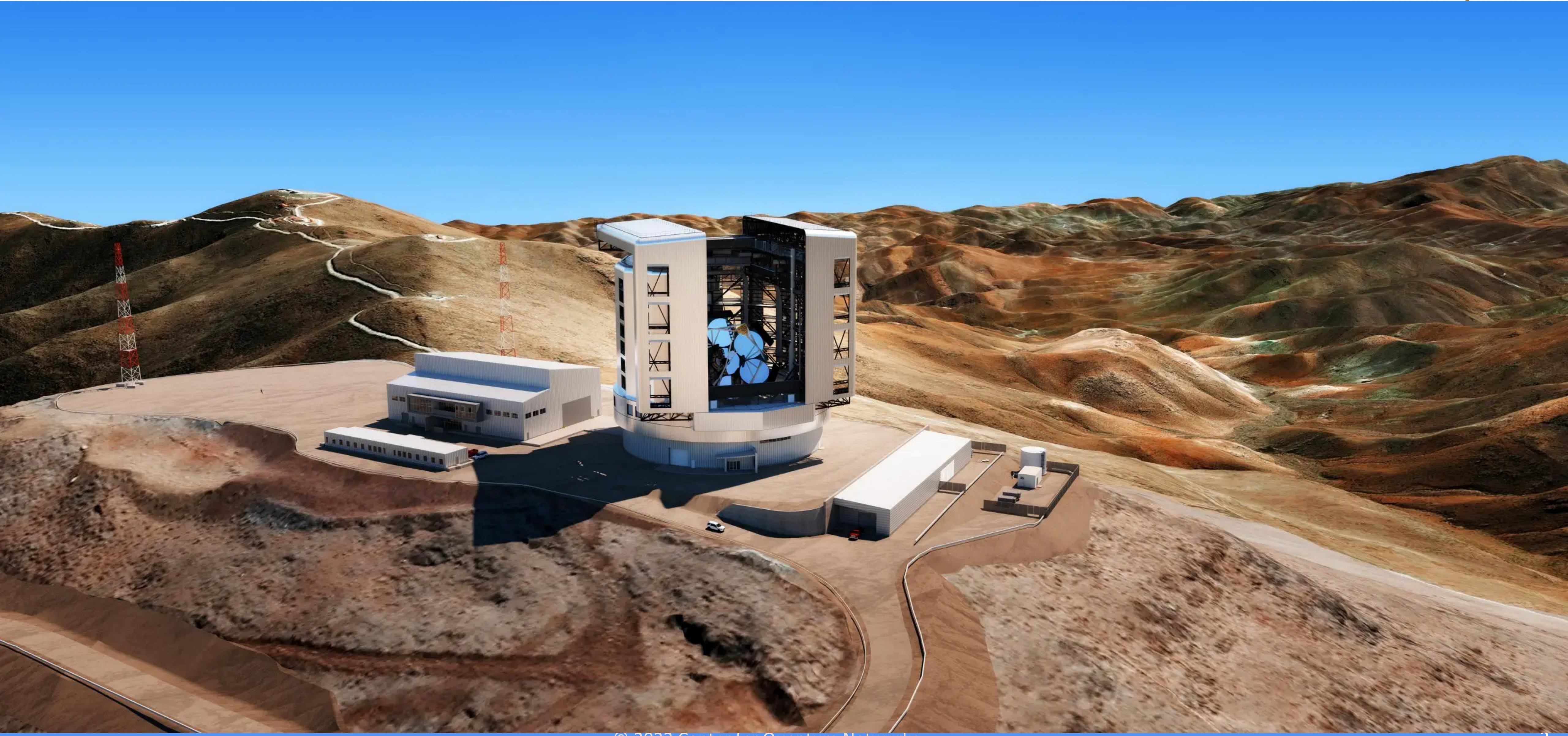
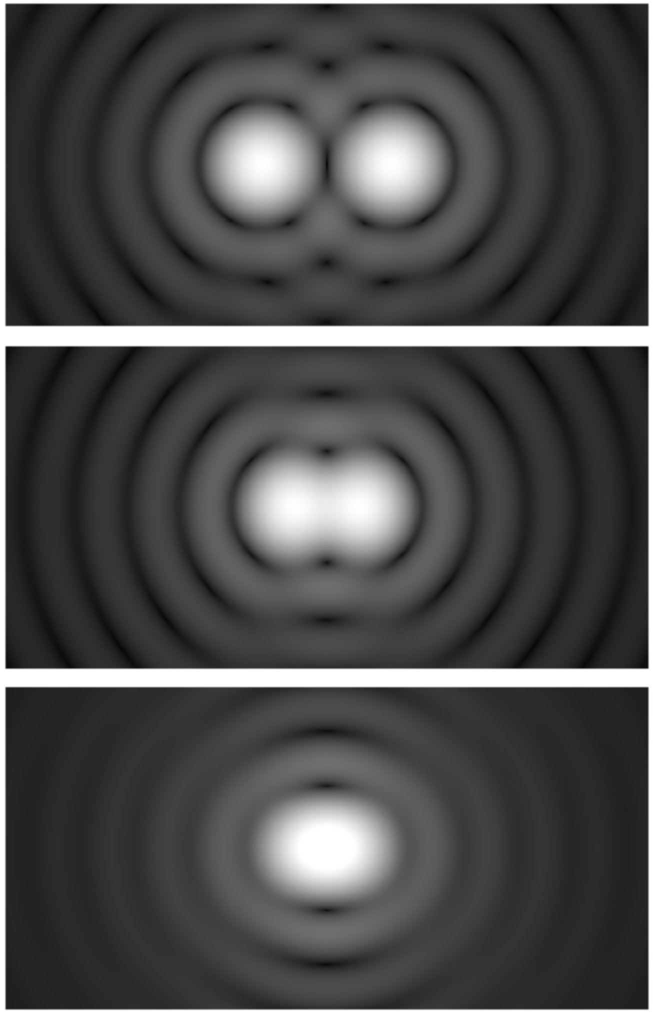
Giant Magellan Telescope



Rayleigh Limit



- Two point sources clearly distinguishable for a telescope of a given aperture
- Two sources at the Rayleigh limit
- Two sources beyond the Rayleigh limit are difficult or impossible to distinguish

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Rayleigh Limit

$$\theta \approx 1.22 \frac{\lambda}{D}$$

Angular Resolution

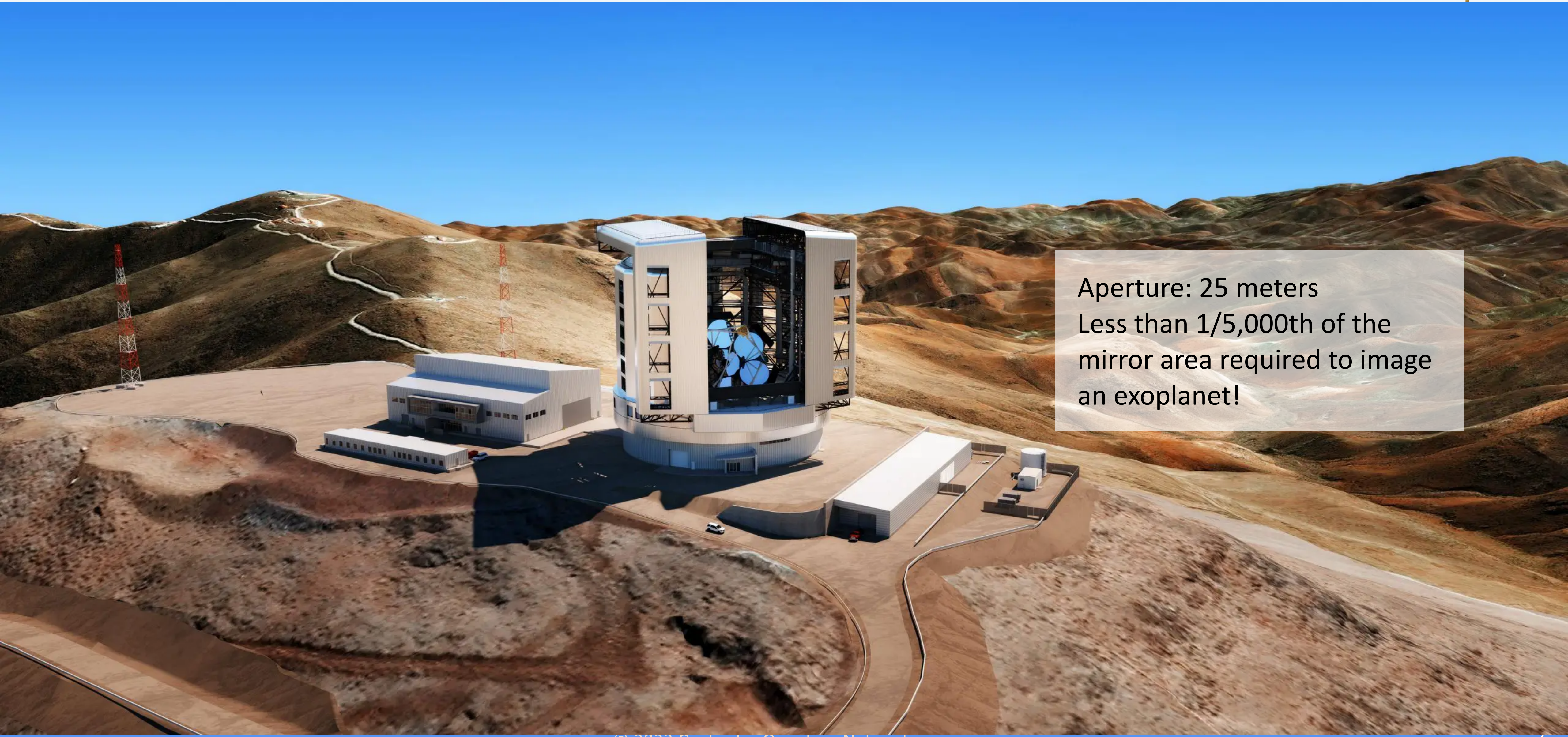
Wavelength

Diameter of mirror

The larger the telescope mirror, the more precise the resolution… *but*

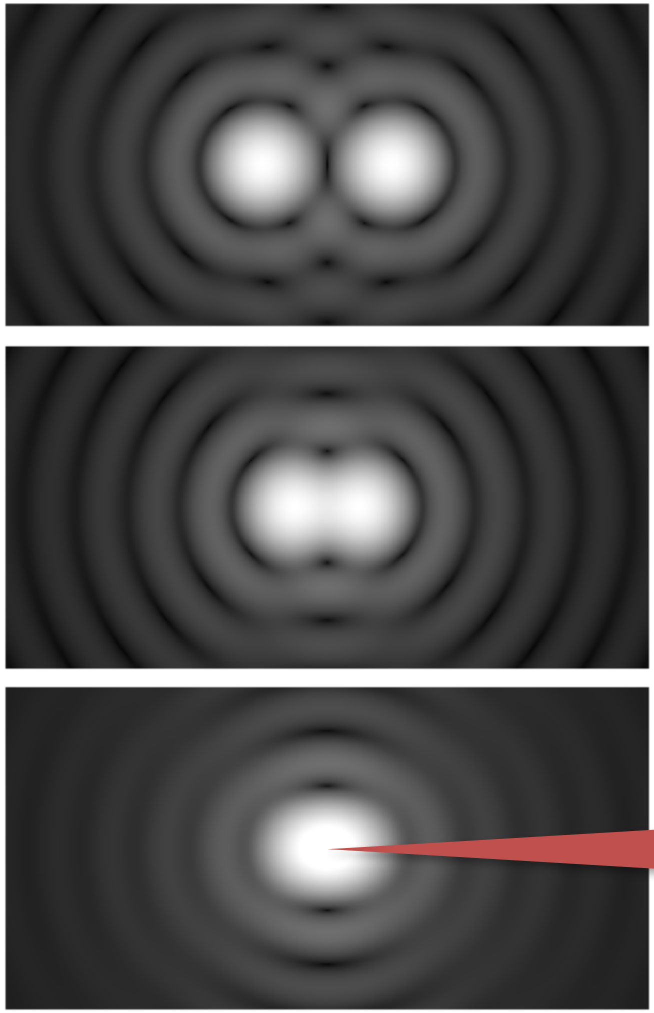
Imaging a Earth-size planet at Alpha Centauri at 40x40 pixels would require an optical telescope with a 1.8 kilometer aperture!

Giant Magellan Telescope



Aperture: 25 meters
Less than 1/5,000th of the mirror area required to image an exoplanet!

Rayleigh Limit



- Two point sources clearly distinguishable for a telescope of a given aperture
- Two sources at the Rayleigh limit
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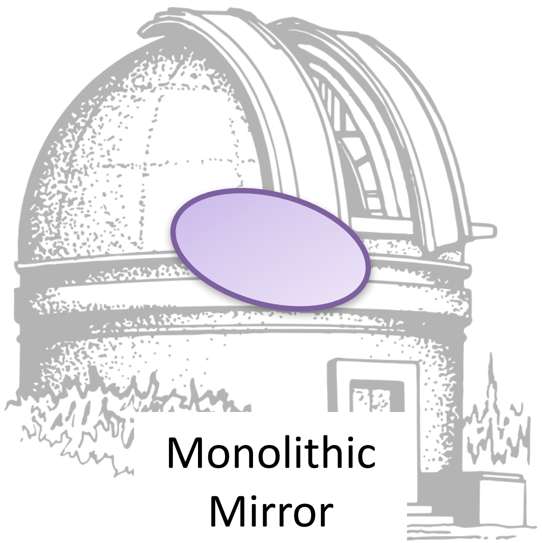
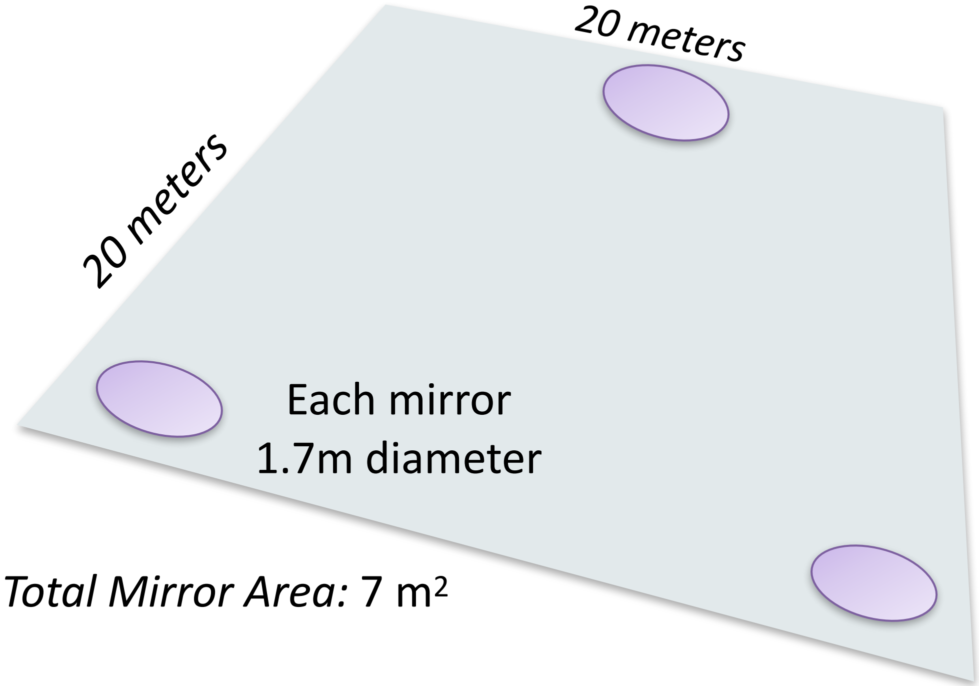
  ar … guish

Quantum techniques can beat the Rayleigh limit by unlocking all the information about amplitude and phase in the collected light

Multi-Aperture Telescopes



3m diameter
Area: 7 m²

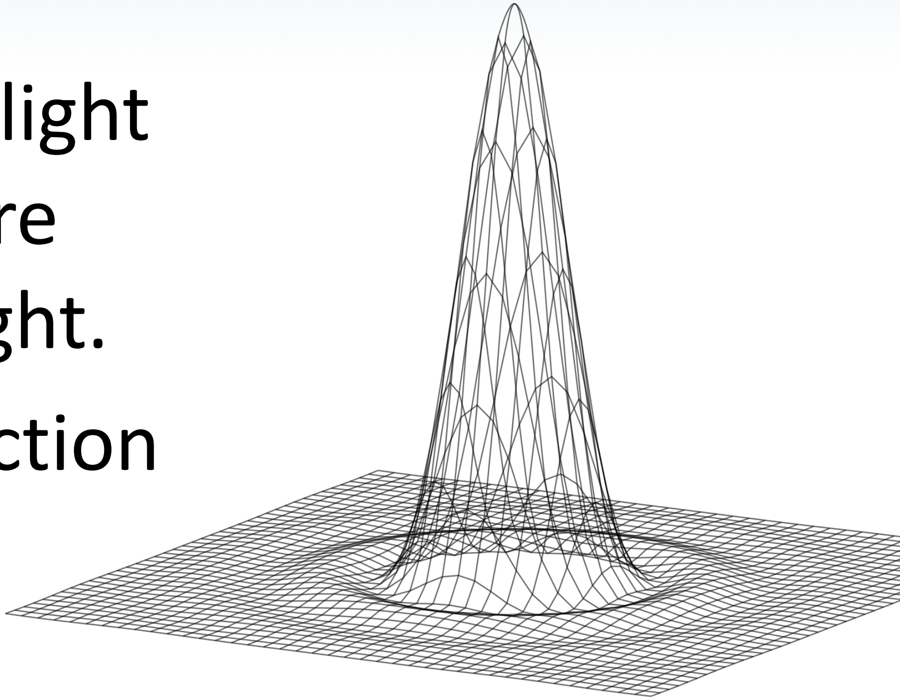


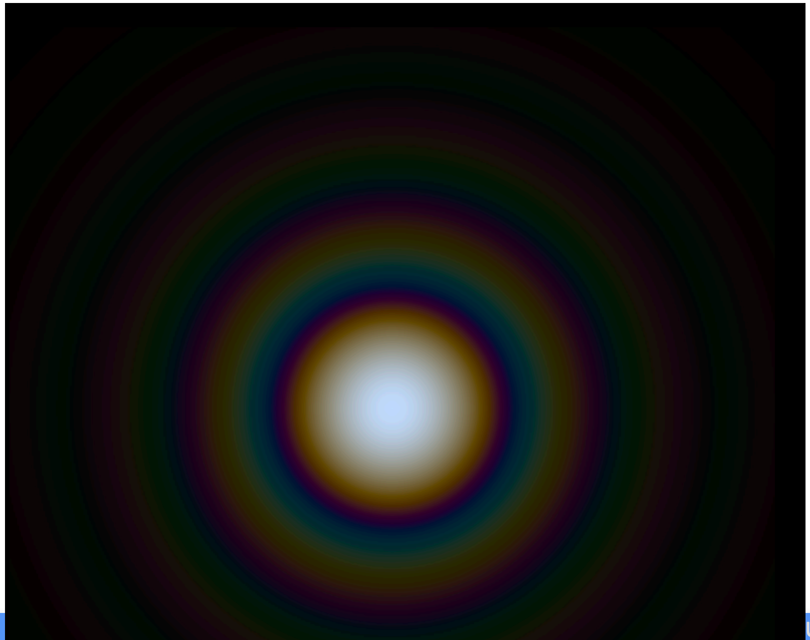
Total Mirror Area: 7 m²

Three 1.7m mirrors are much cheaper than one 3-meter mirror!

Airy Disk

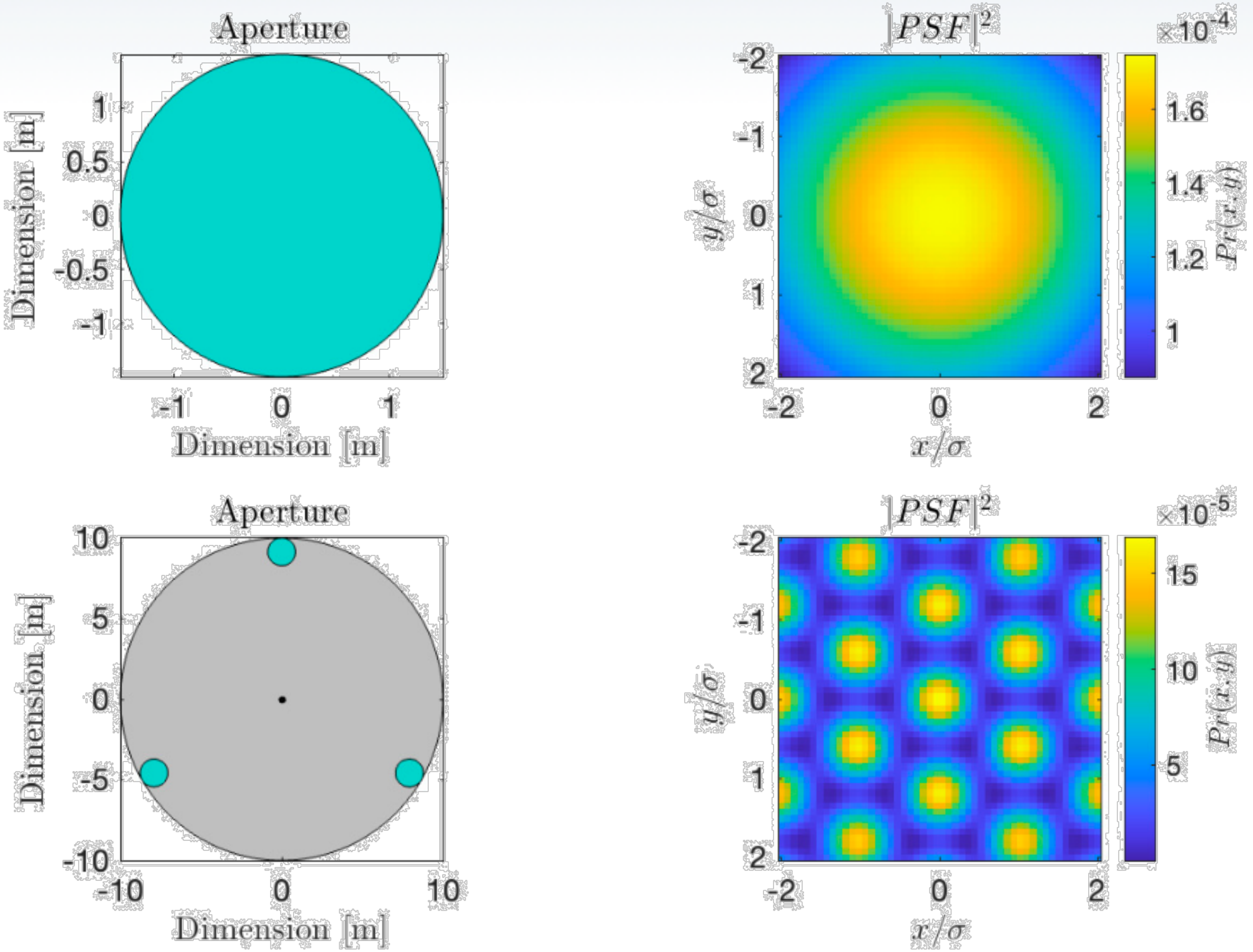
- The Airy Disk is the best-focused spot of light that a perfect lens with a circular aperture can make, limited by the diffraction of light.
- This is an example of a Point Spread Function (PSF).



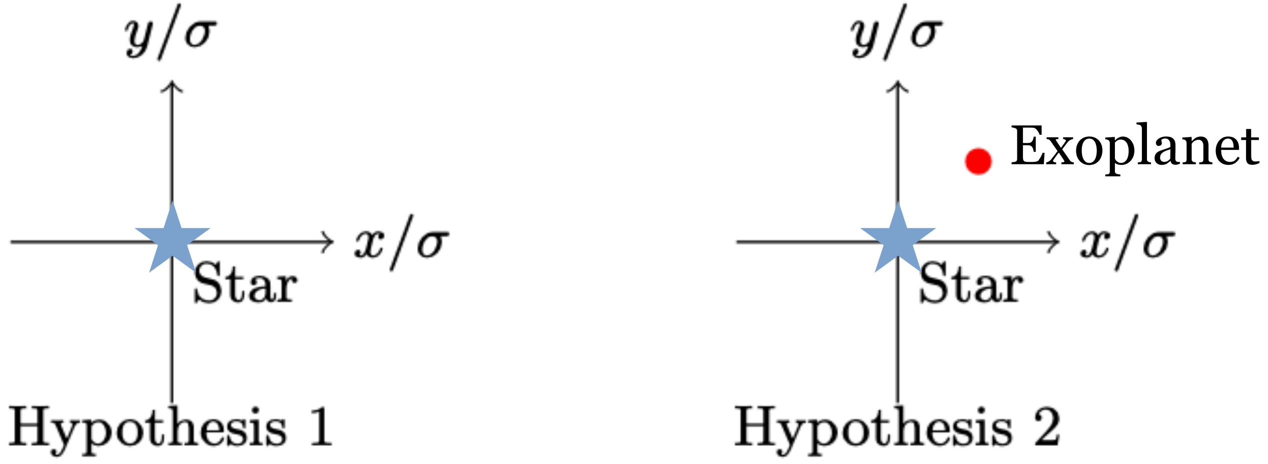


Different wavelengths will diffract differently

Point Spread Functions

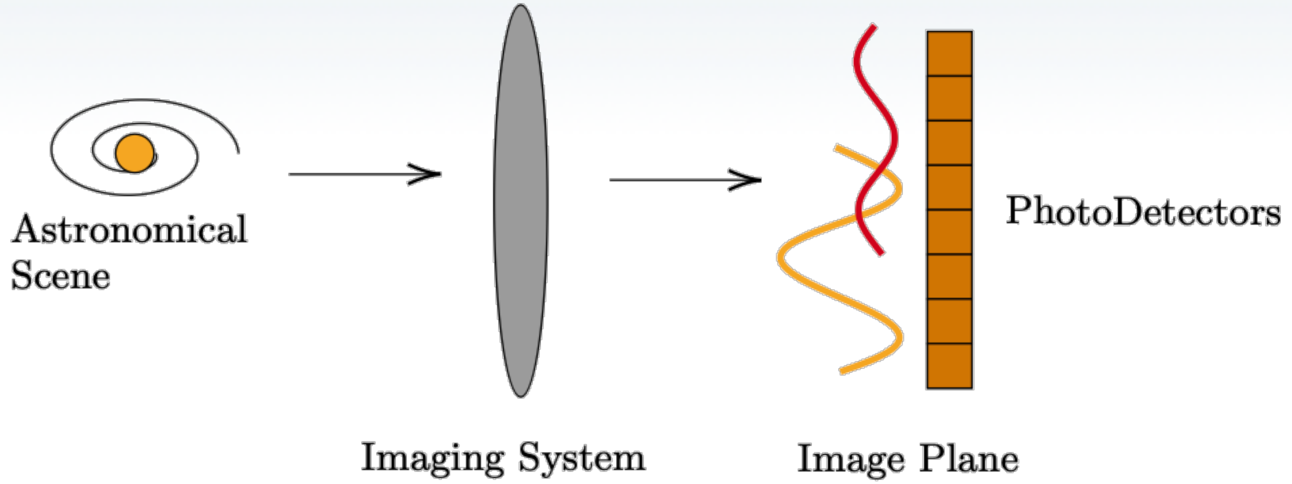


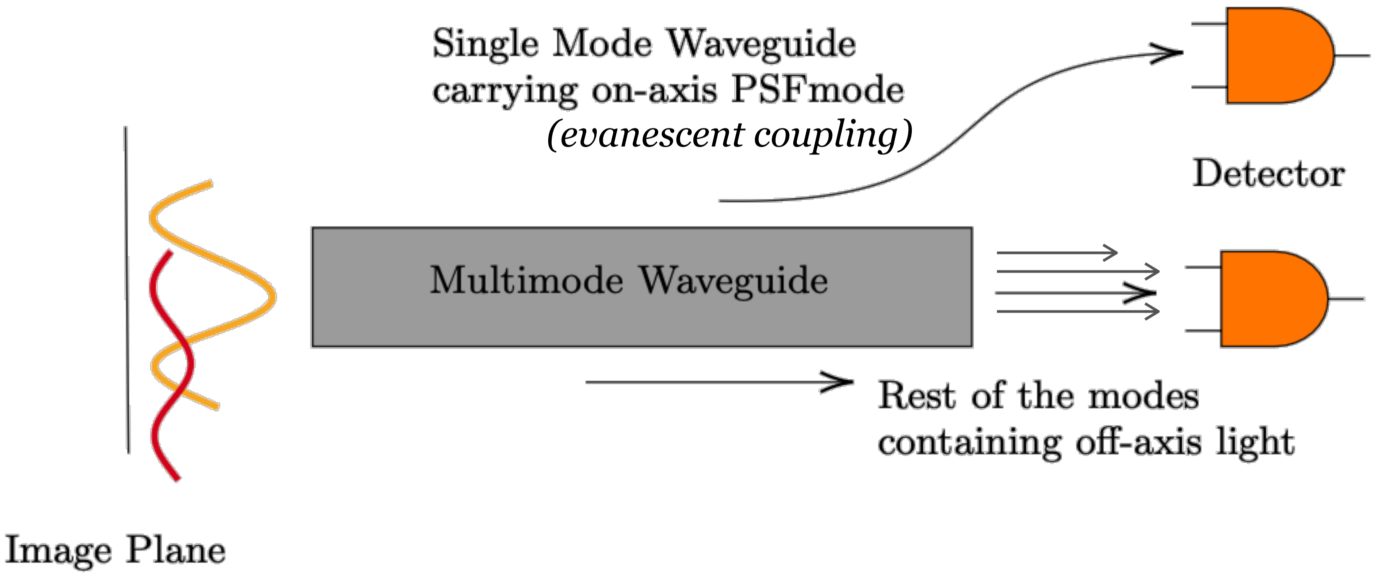
Resolving an Exoplanet



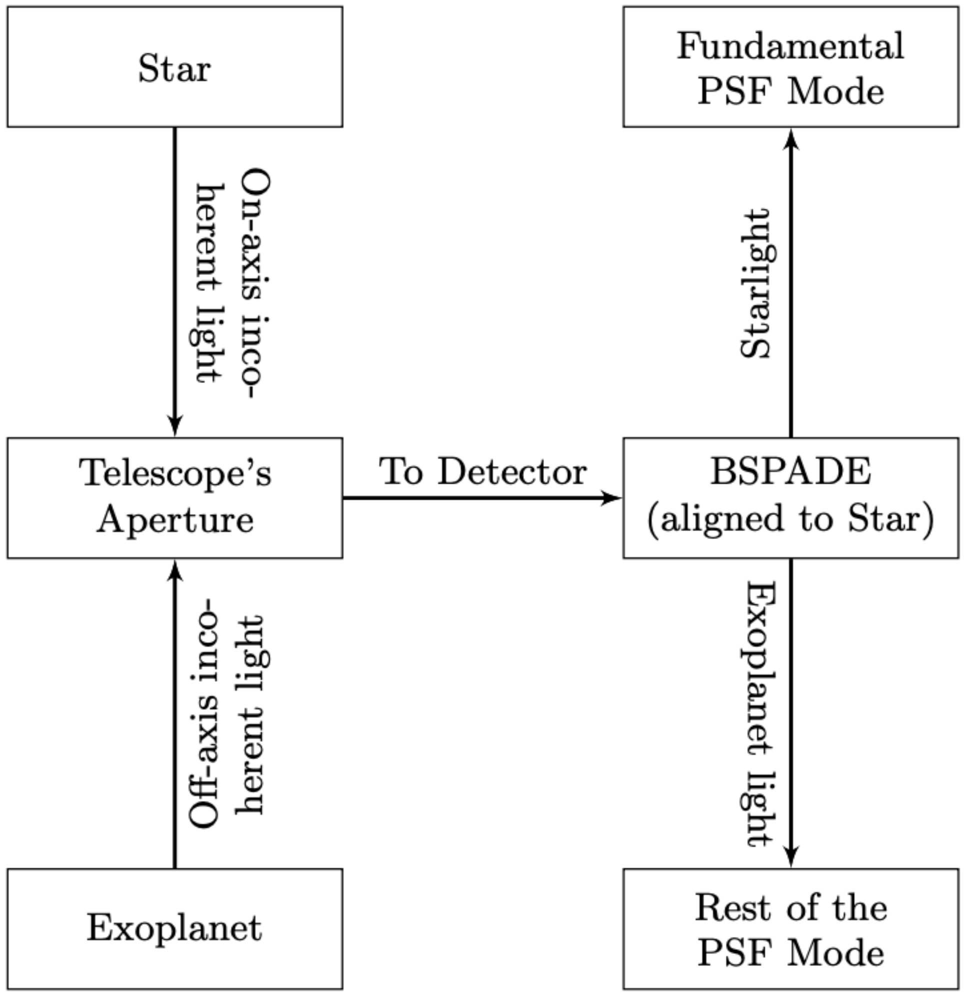
First test: Is a second source of light (exoplanet) present or not?

Direct Imaging vs. BSPADE





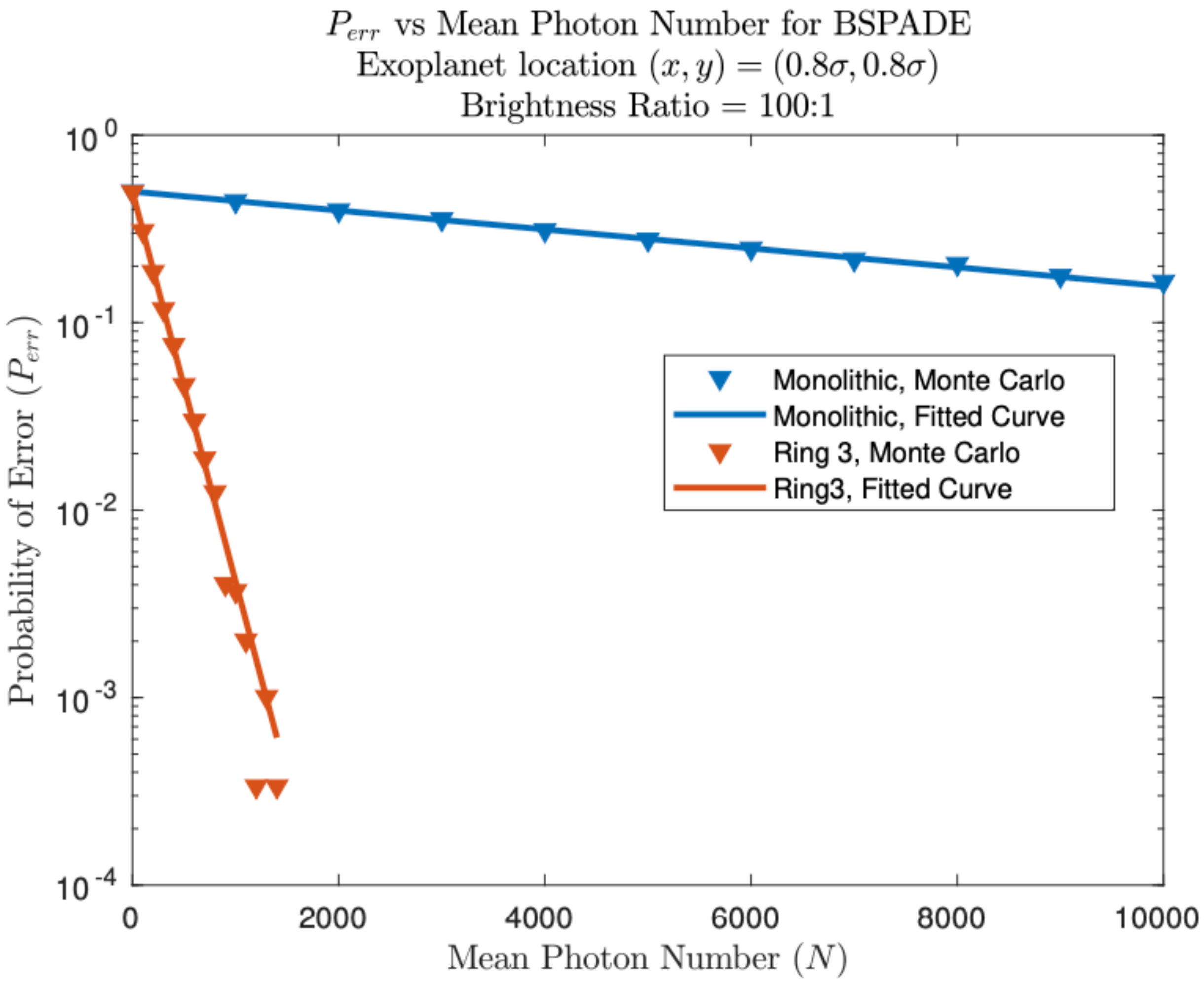
BSPADE Detection



- BSPADE: Binary Spatial Mode DEmultiplexing
- Telescope(s) are aligned with Point Spread Function (PSF) central star on-axis
- Off-axis photons are sorted into separate detector — these are (mostly) from the exoplanet(s)
- Acts as "nuller" for starlight

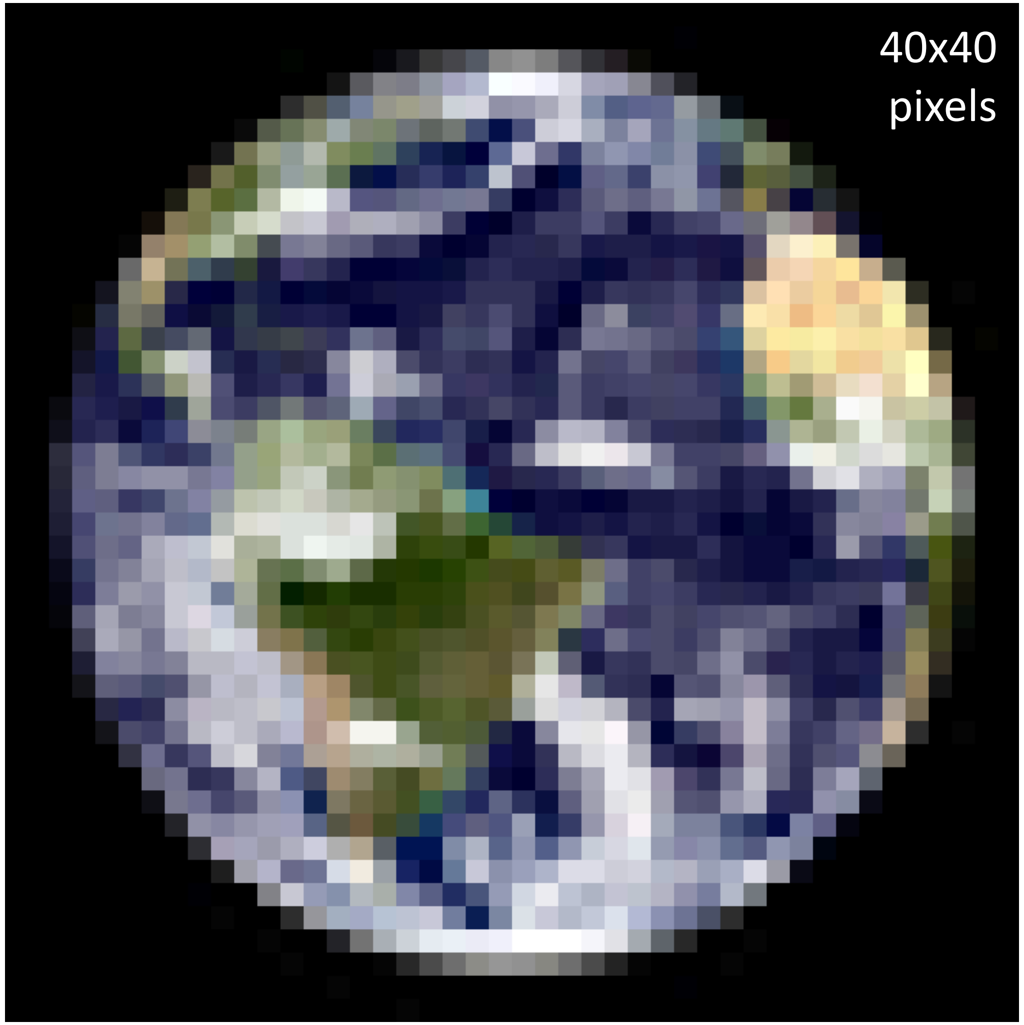
Probability of Error Simulation

- Multi-aperture arrangement (Ring3) substantially outperforms monolithic aperture
- Substantially increased probability of distinguishing exoplanet from star, even with limited photon flux



Conclusions / Future Work

- 100x increase in sensitivity for multi-aperture compared to monolithic mirrors for identical image-gathering area
- Ability to use BSPADE as starlight nuller in detecting and discriminating light from exoplanet(s)
- *Future development:* using off-axis photons to go beyond detection of exoplanets to direct imaging



Thank You!

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