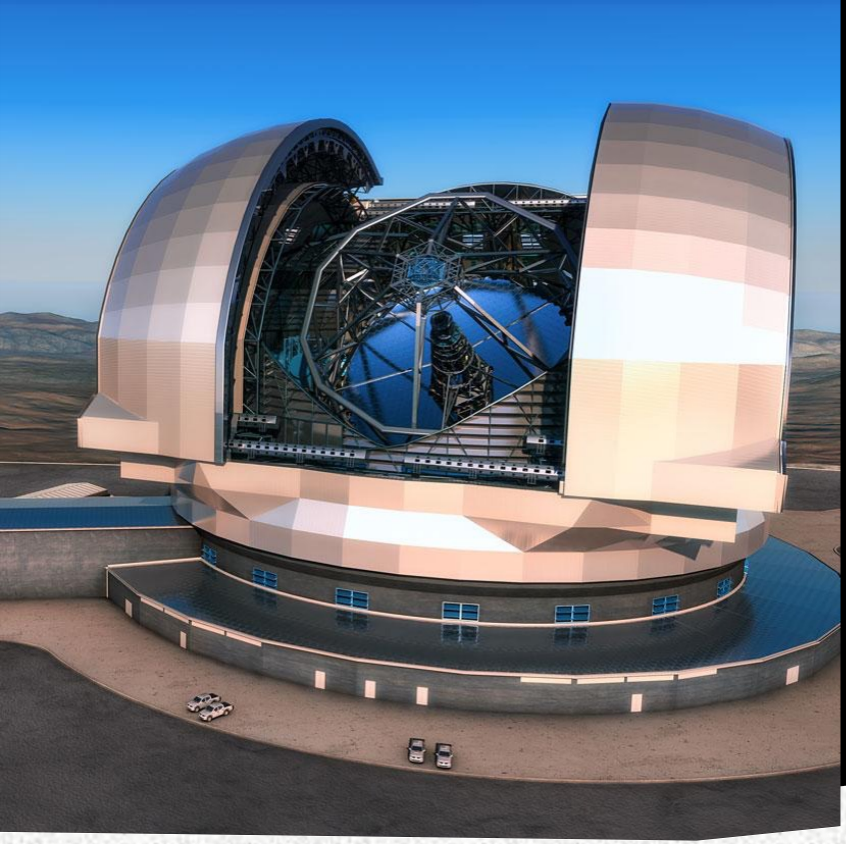
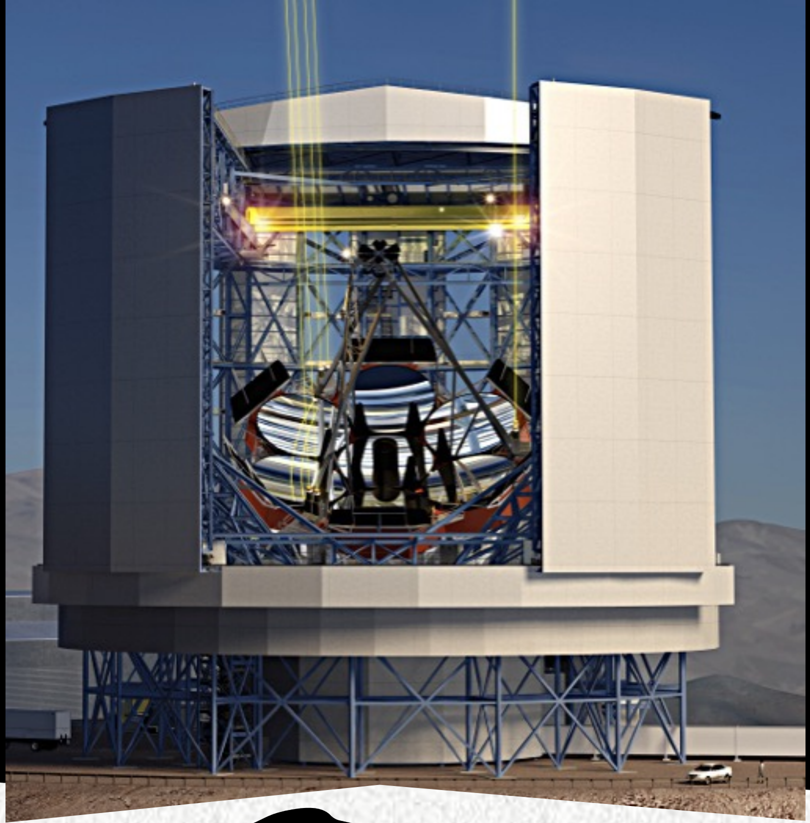
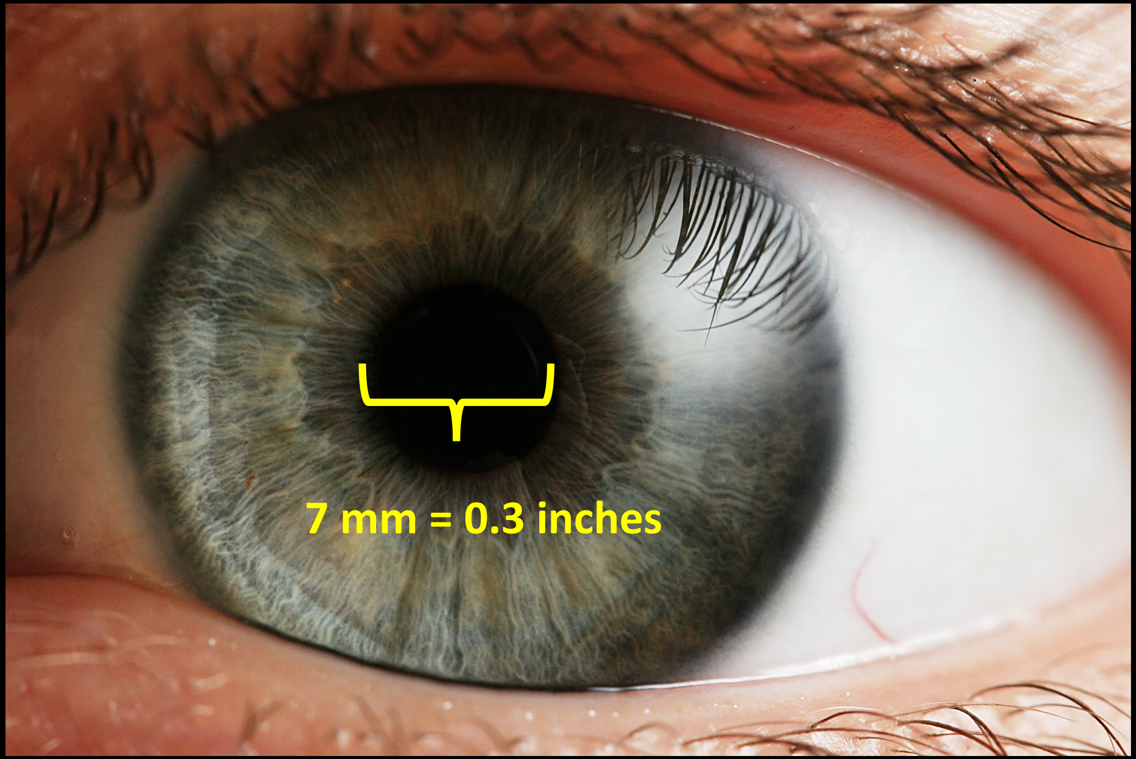




# Future Facilities: ELTs

Quinn Konopacky
UC San Diego
2023 Sagan Summer Workshop

The construction of new telescope technology has always led to unexpected discoveries in astrophysics.




In planetary science, the discovery of the moons of Jupiter revolutionized our understanding of the Solar System (and the Universe).

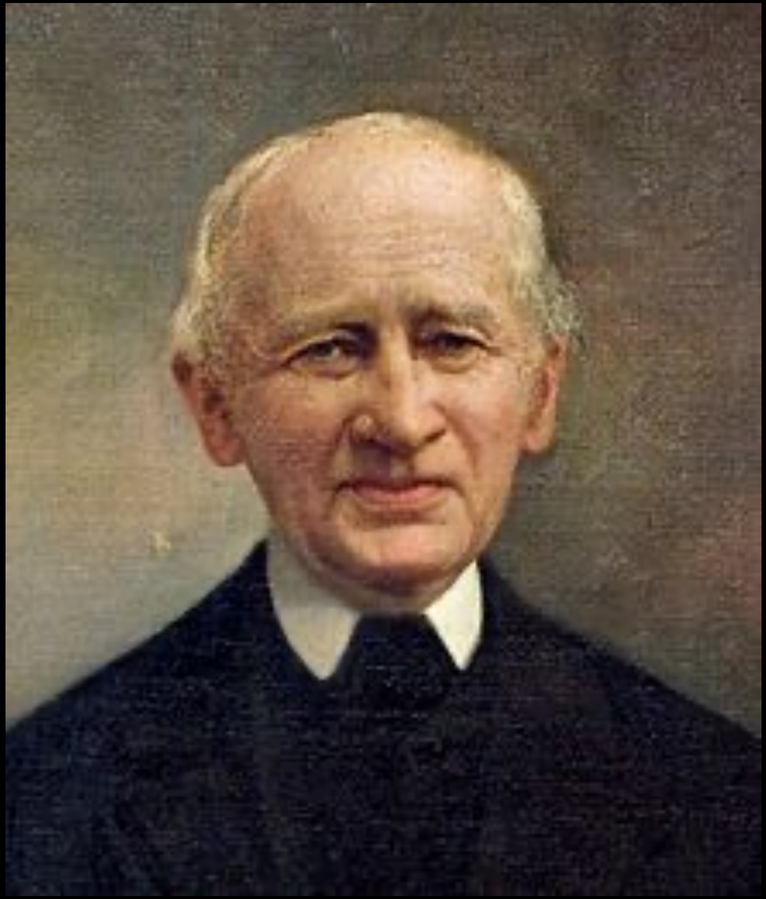

Ernie Wright, etwright.org

# Larger telescopes enabled the discovery of the ice giants.

Sir William Herschel


**Discovered Uranus:**
**13 March 1781**

# Larger telescopes enabled the discovery of the ice giants.



Johann Gottfried Galle

24 cm = 9 inches

Discovered Neptune:
23 September 1846

# In the modern era, combinations of larger telescopes and technology have led to breakthroughs in exoplanet science.

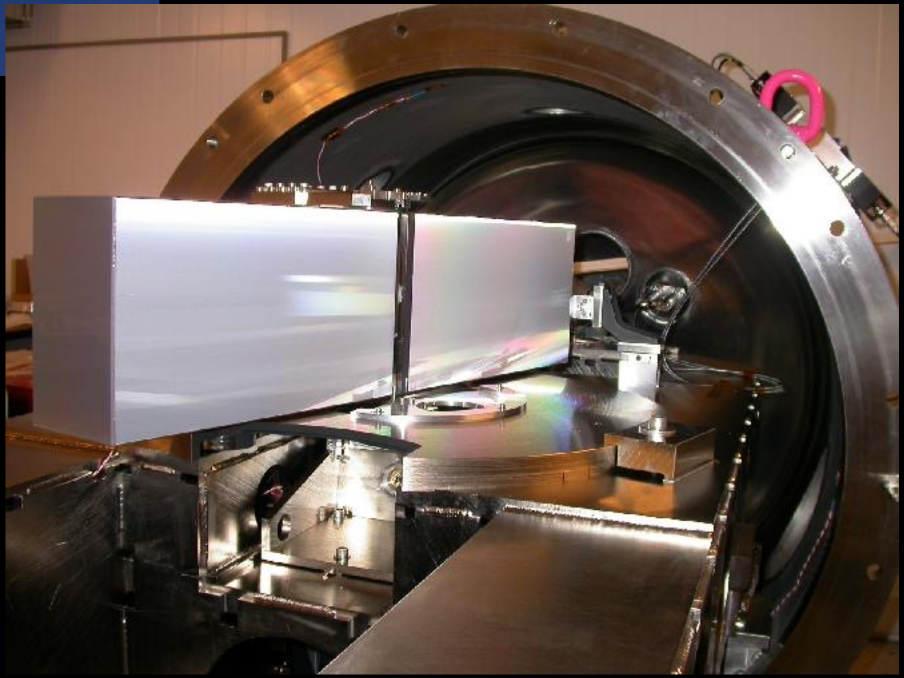
Haute-Provence 1.93 meter = 76 inches
France, 1958

Discovered 51 Pegasi b:
Mayor & Queloz, 1994-1995

ELODIE Spectrograph

# In the modern era, combinations of larger telescopes and technology have led to breakthroughs in exoplanet science.

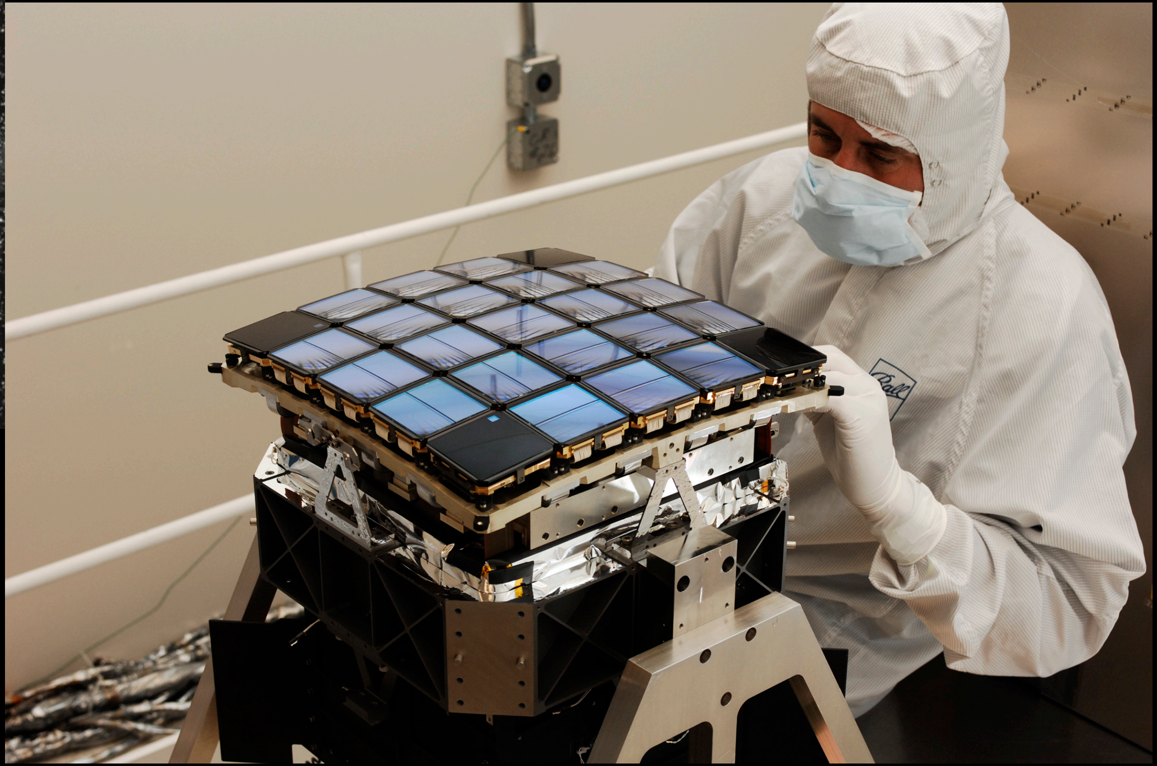
ESO 3.6 meter = 141 inches
La Silla, Chile, 1977



HARPS Spectrograph

# In the modern era, combinations of larger telescopes and technology have led to breakthroughs in exoplanet science.

Kepler 1.4 meter = 55 inches
2009-2018 (PI Borucki)



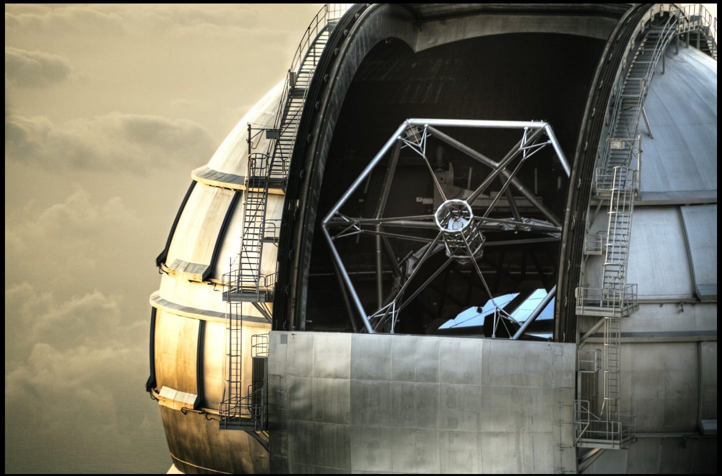
Kepler Focal Plane (1 square foot)

Exoplanets Discovered > 2600

# The largest optical telescopes currently are 8-10 meters (315-394 inches) in diameter.






If we are discovering amazing things with <10 meter sized telescopes, why try to go even bigger?

Bigger telescopes have great sensitivity and great spatial resolution.

# Notionally, telescope sensitivity goes as the area of the primary mirror.

Sensitivity $\propto D^2$

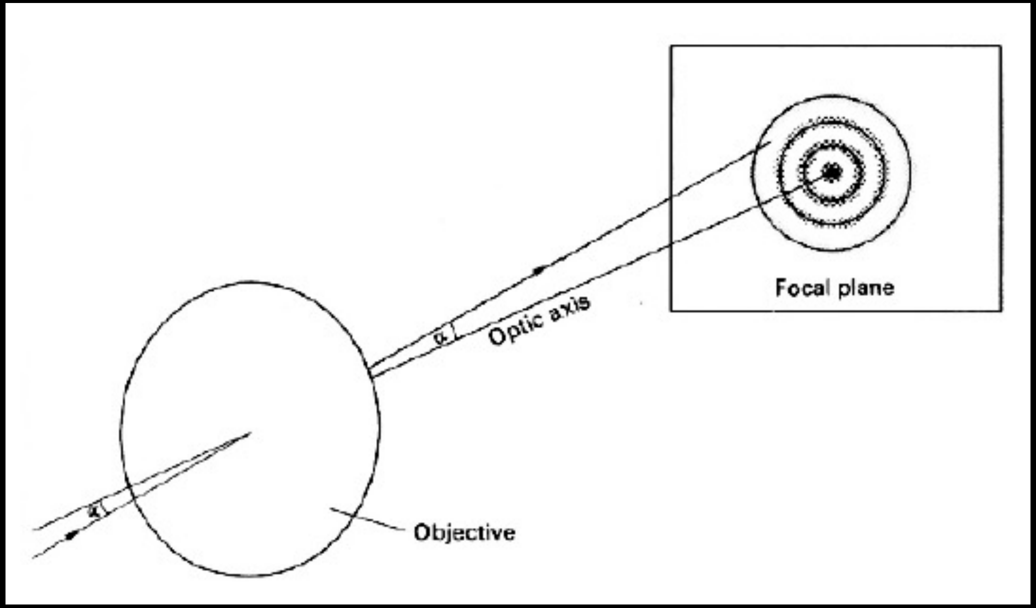
# Telescope resolution also improves (gets smaller) with larger telescope mirrors.

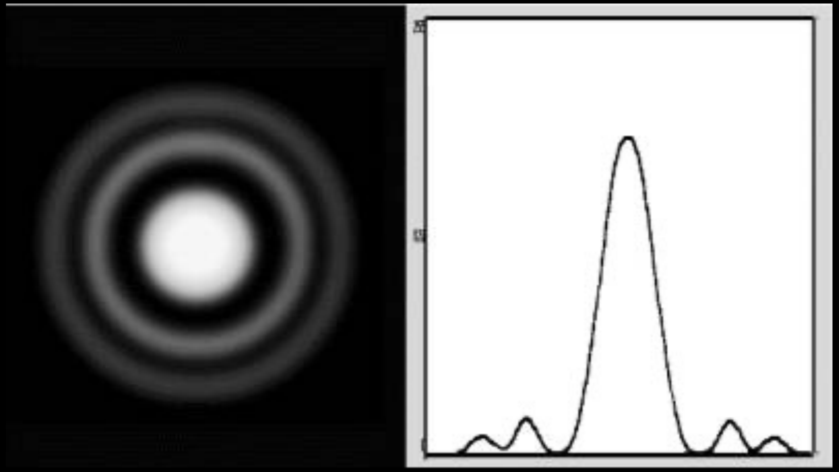
- The diffraction pattern is given by the Airy function

$$Ai\,(x) = \frac{1}{\pi}\int_0^{\infty} \cos\left(\frac{t^3}{3} + xt\right) dt$$

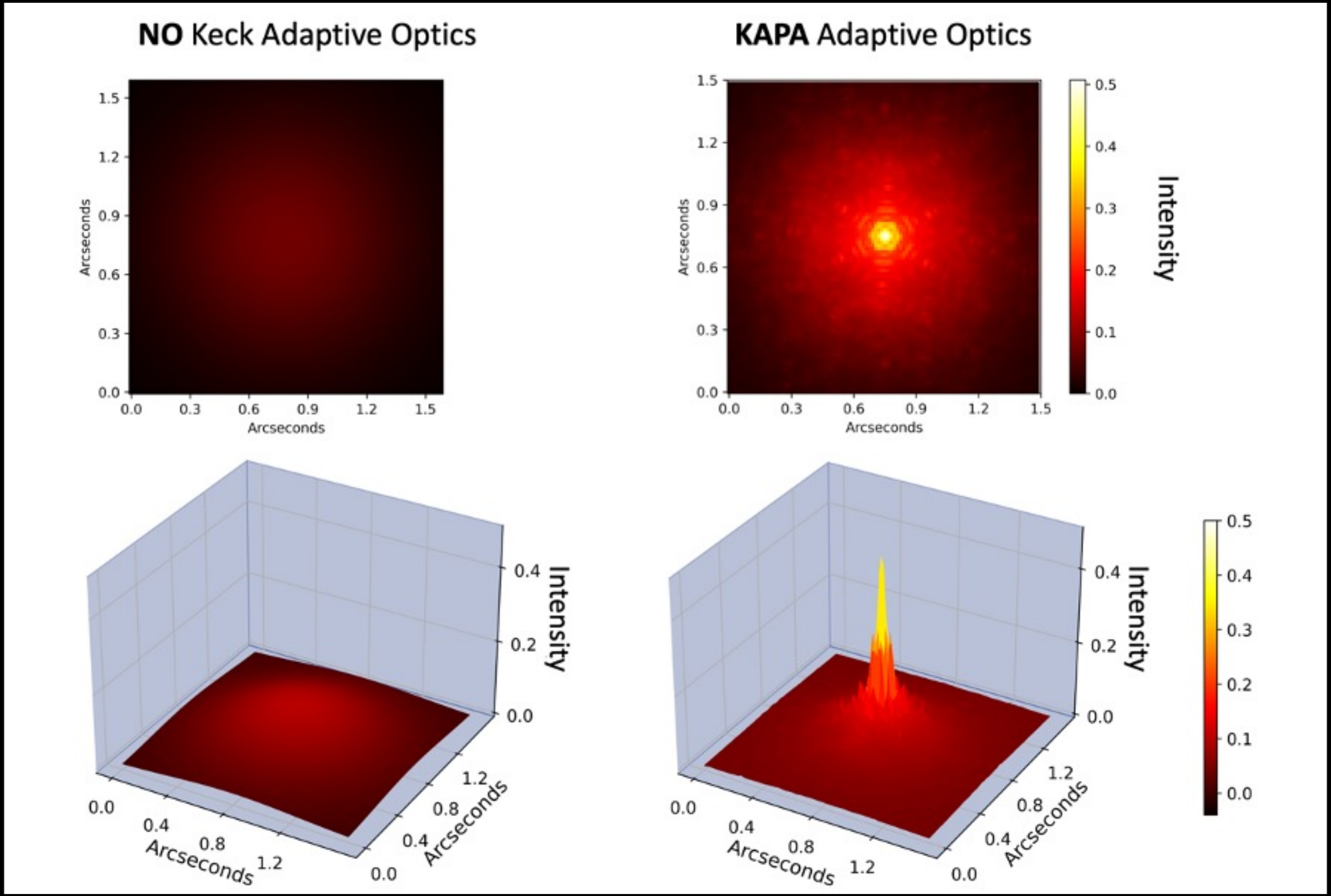
- The first minimum of the Airy function is at,

$$\sin\theta = 1.22\frac{\lambda}{D}$$



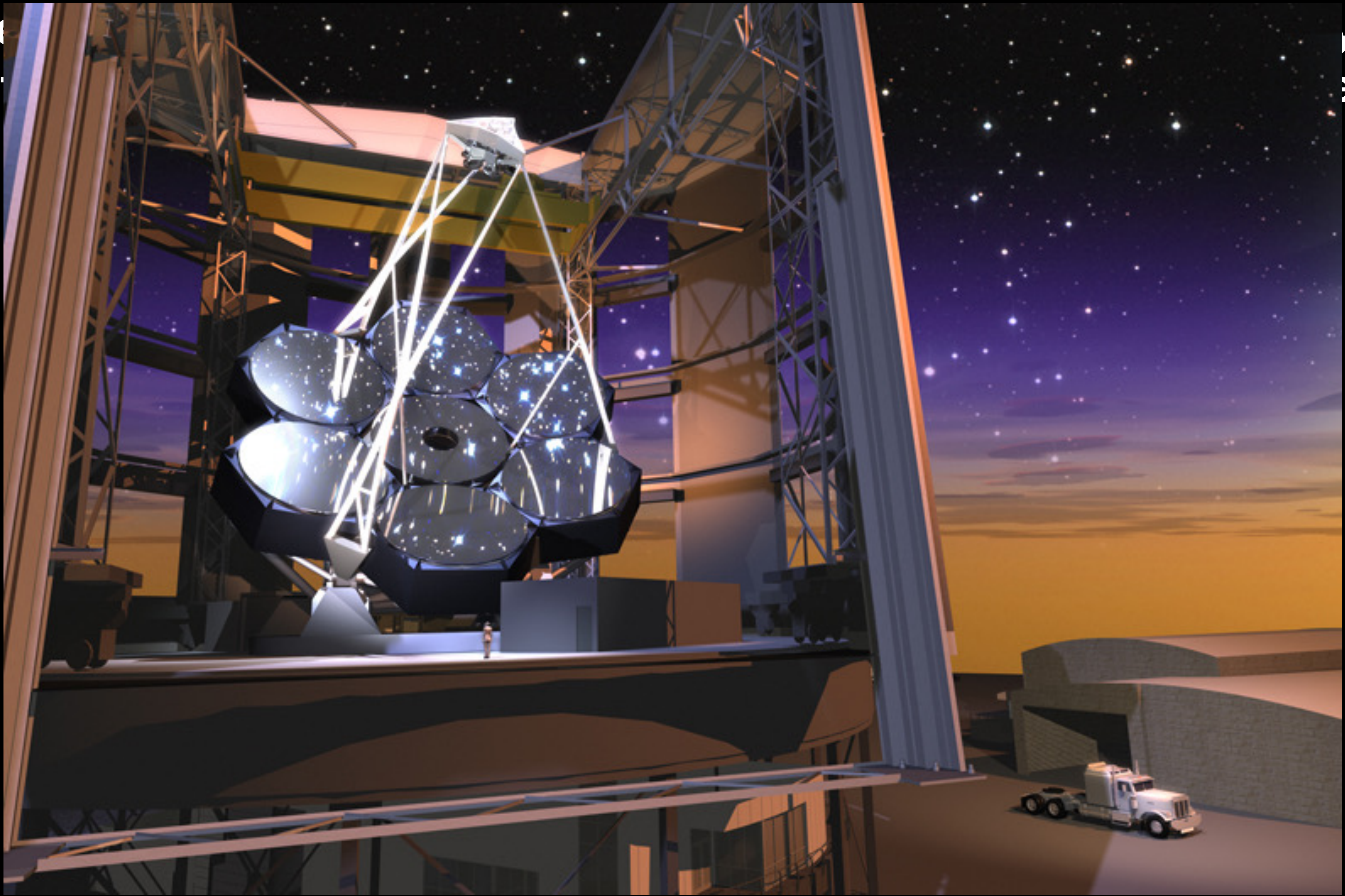



# If you can operate at the diffraction limit of a telescope, the sensitivity goes as $D^4$ rather than $D^2$.



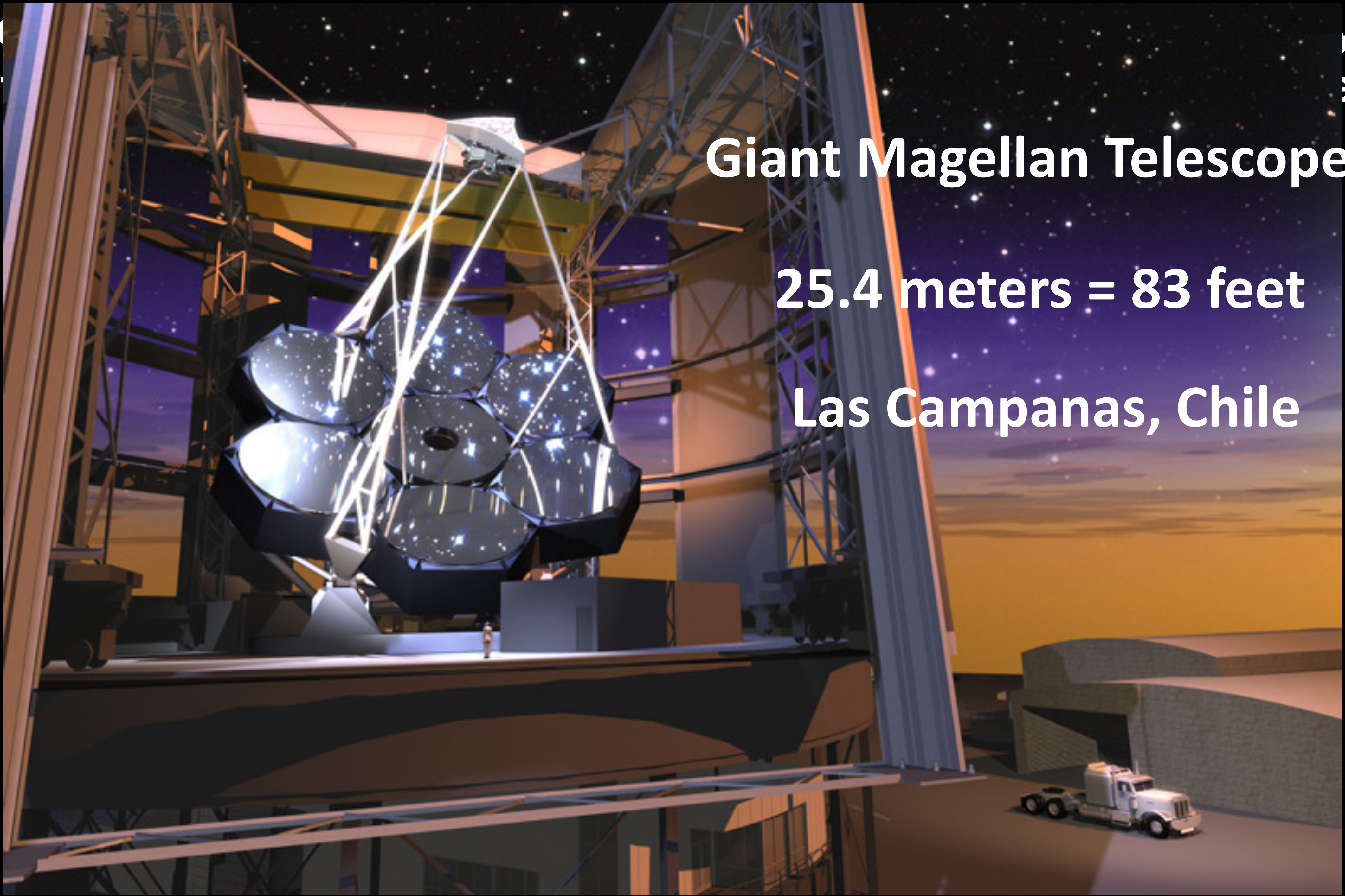

The source signal is "smeared" over a smaller area, meaning less background noise is impacting the signal-to-noise ration

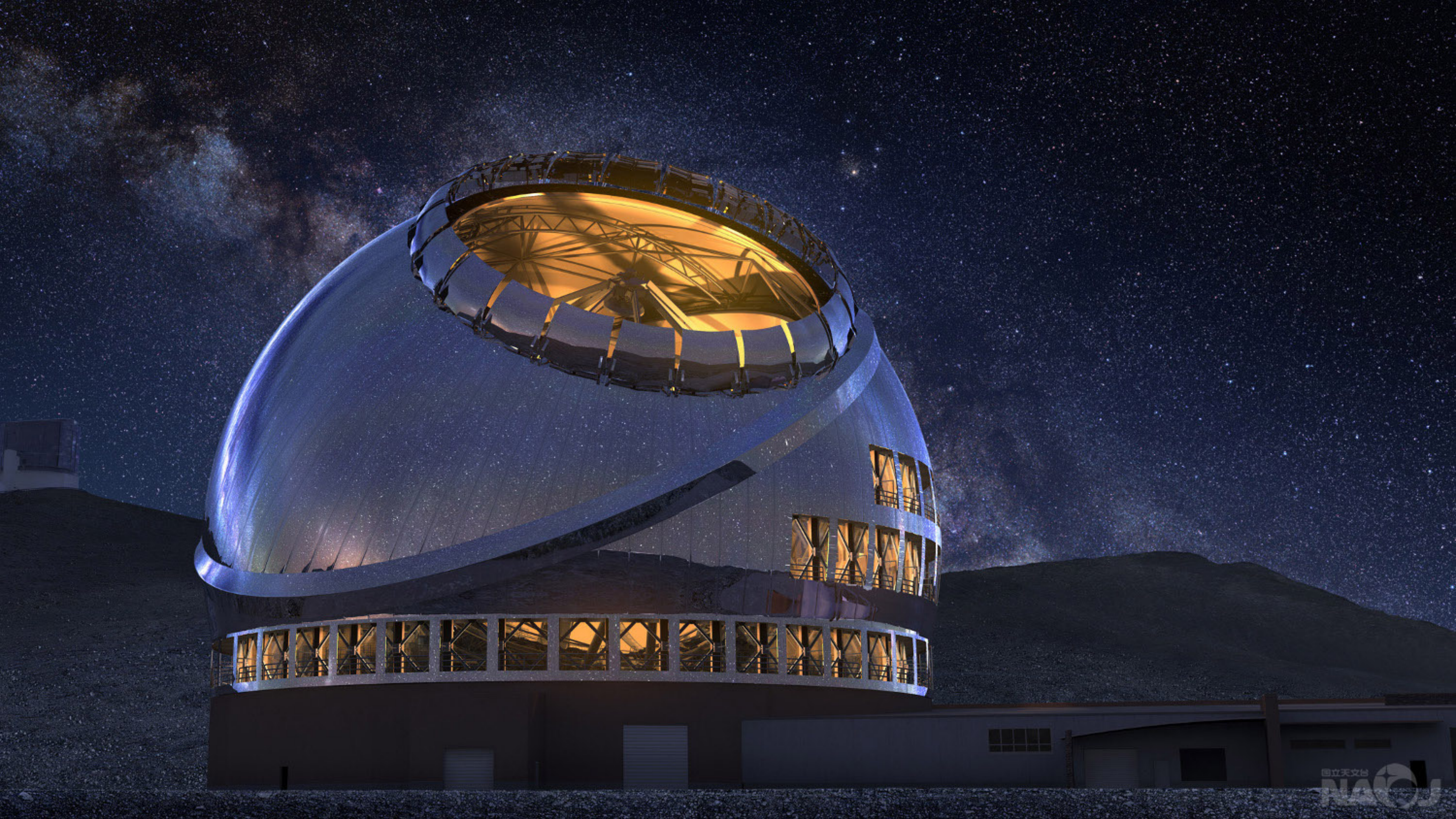
Altoge y
large es.



Altoge y

large es.

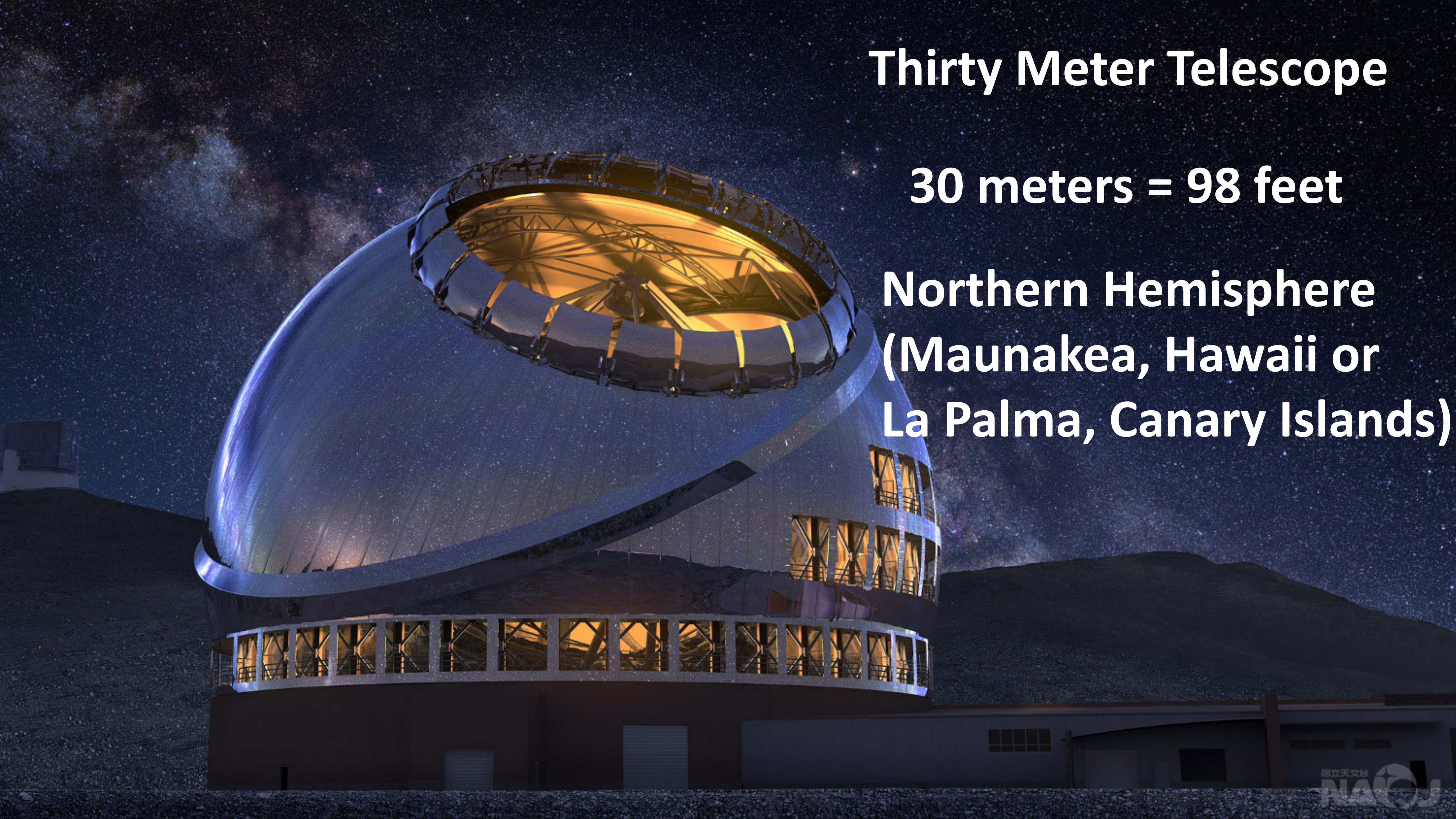


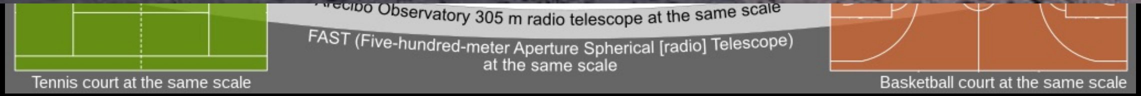


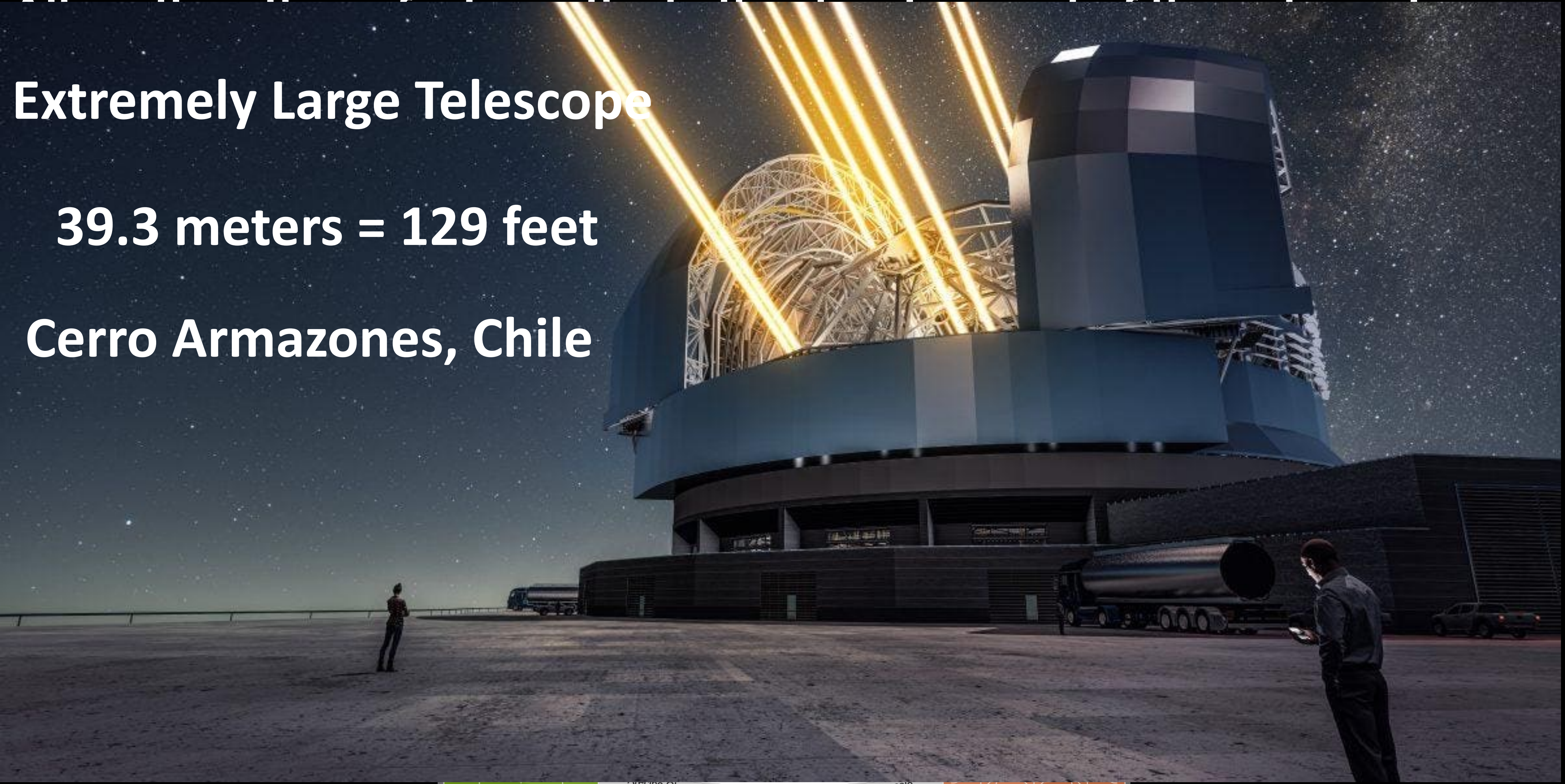
# Thirty Meter Telescope

30 meters = 98 feet

Northern Hemisphere
(Maunakea, Hawaii or
La Palma, Canary Islands)



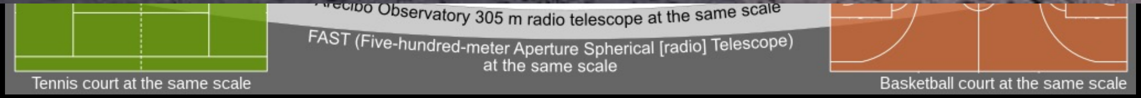

Observatory 305 m radio telescope at the same scale
FAST (Five-hundred-meter Aperture Spherical [radio] Telescope)
at the same scale
Tennis court at the same scale
Basketball court at the same scale



# Extremely Large Telescope

## 39.3 meters = 129 feet

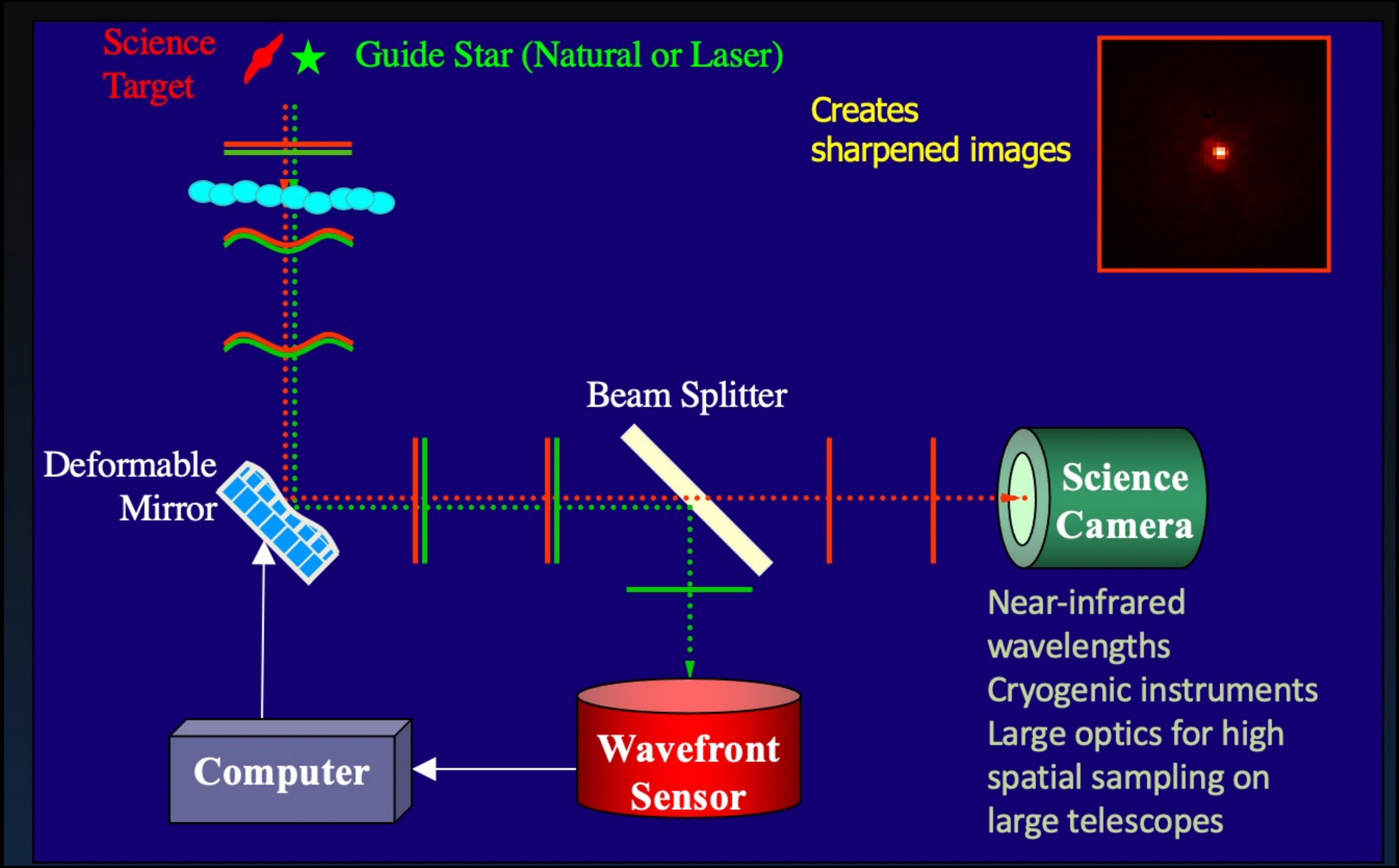
## Cerro Armazones, Chile



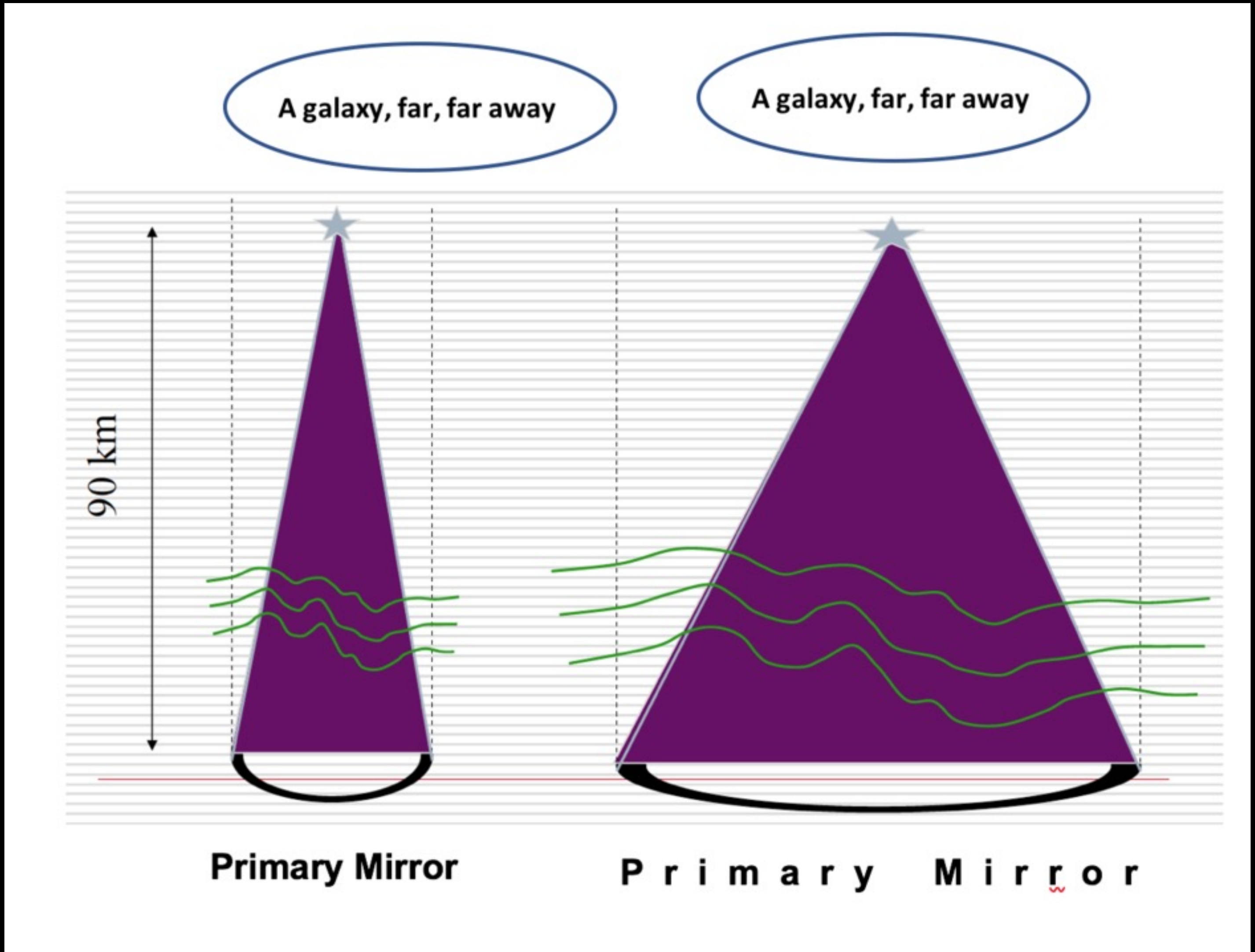
# Adaptive optics is required to get to the diffraction limit (and the $D^4$ advantage).

ESO

# Adaptive optics is required to get to the diffraction limit (and the $D^4$ advantage).

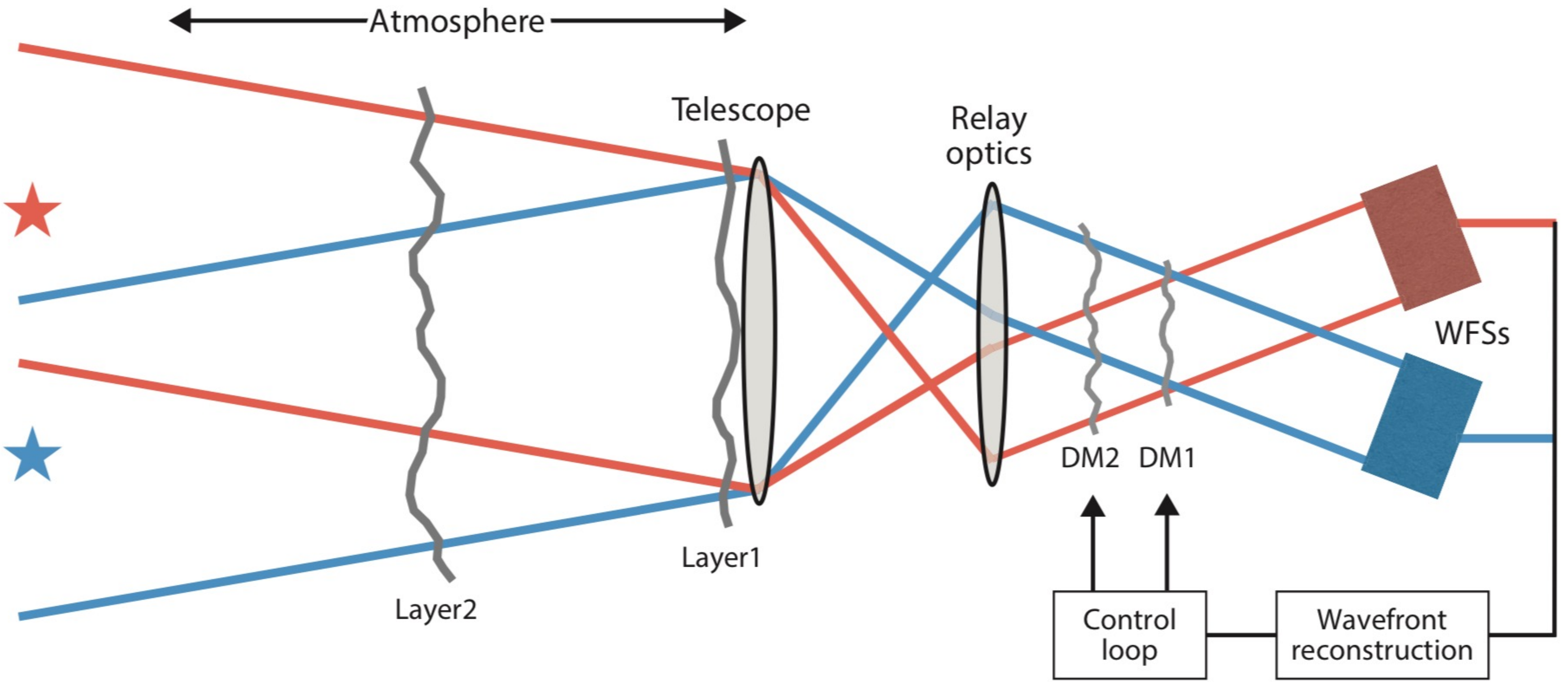


# Traditional adaptive optics systems will not work for these telescopes.




The Cone Effect, Don Gavel

# All of the GSMTs will have multiconjugate adaptive optics (MCAO) systems to mitigate this issue.




Rigaut & Neichel 2020

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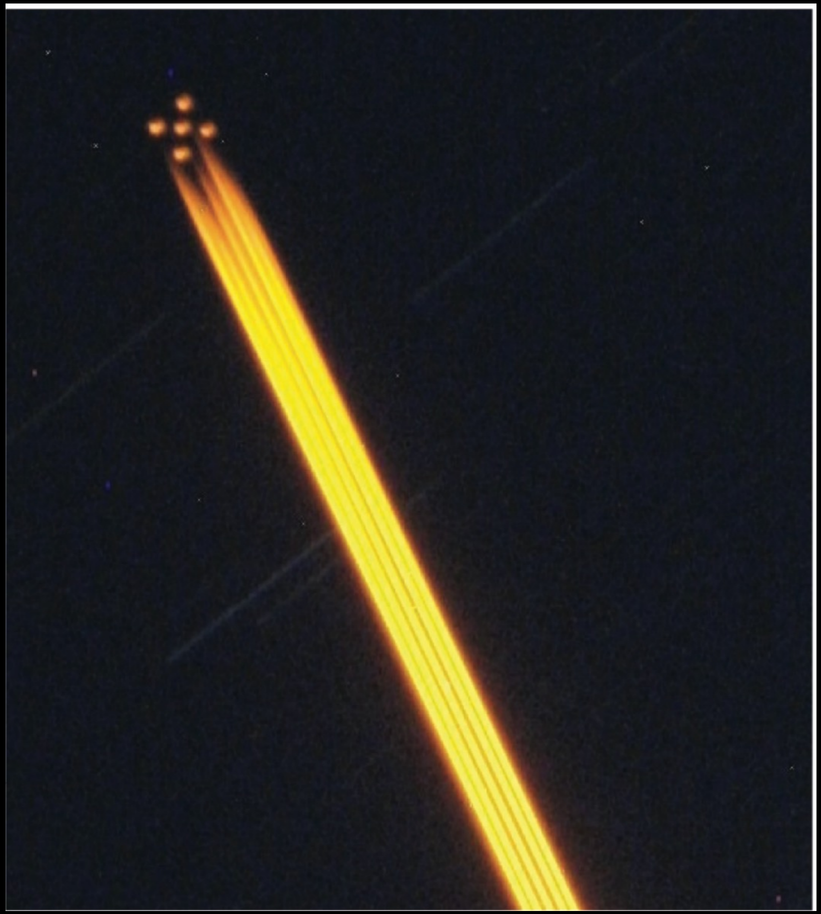
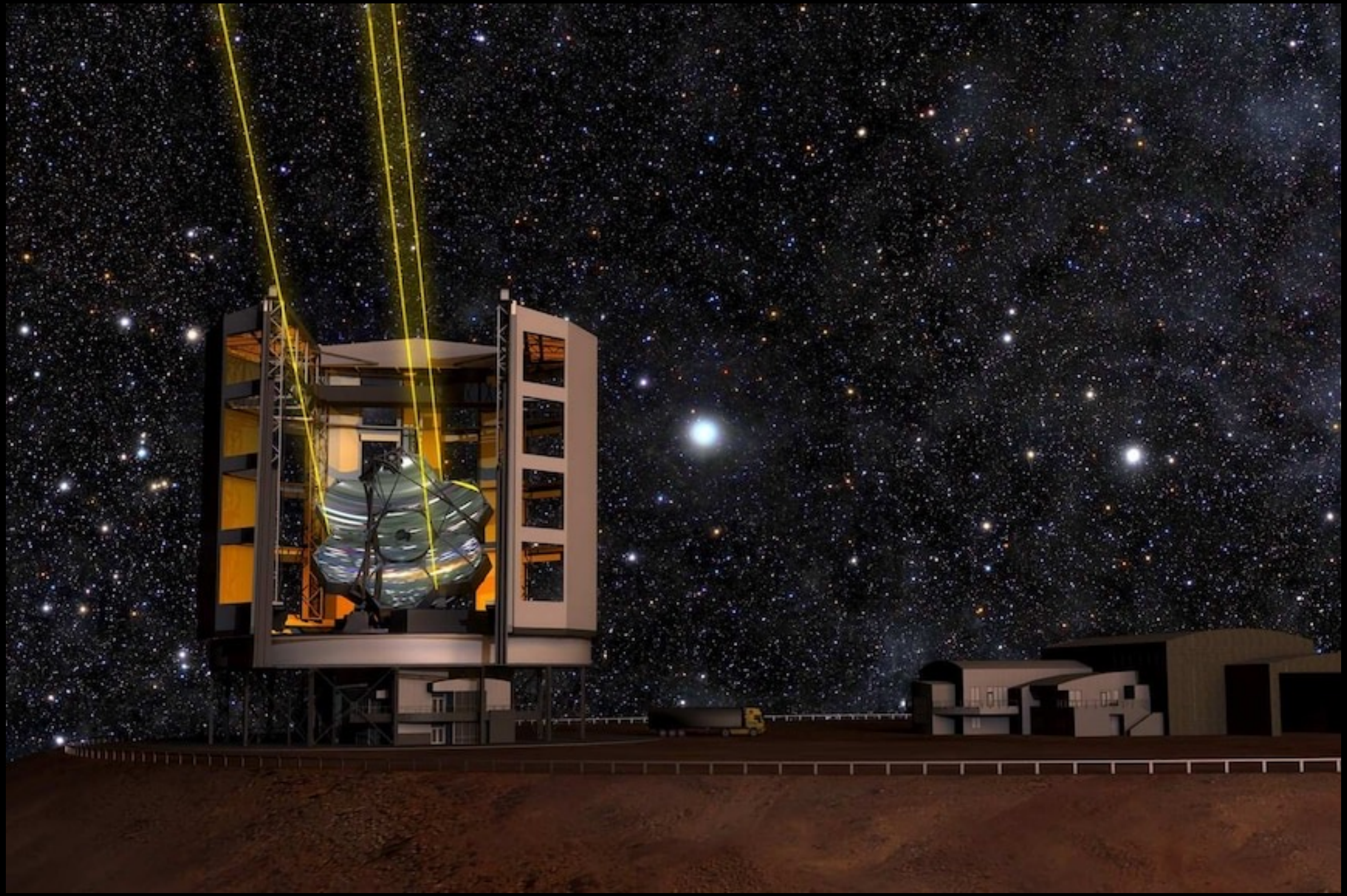
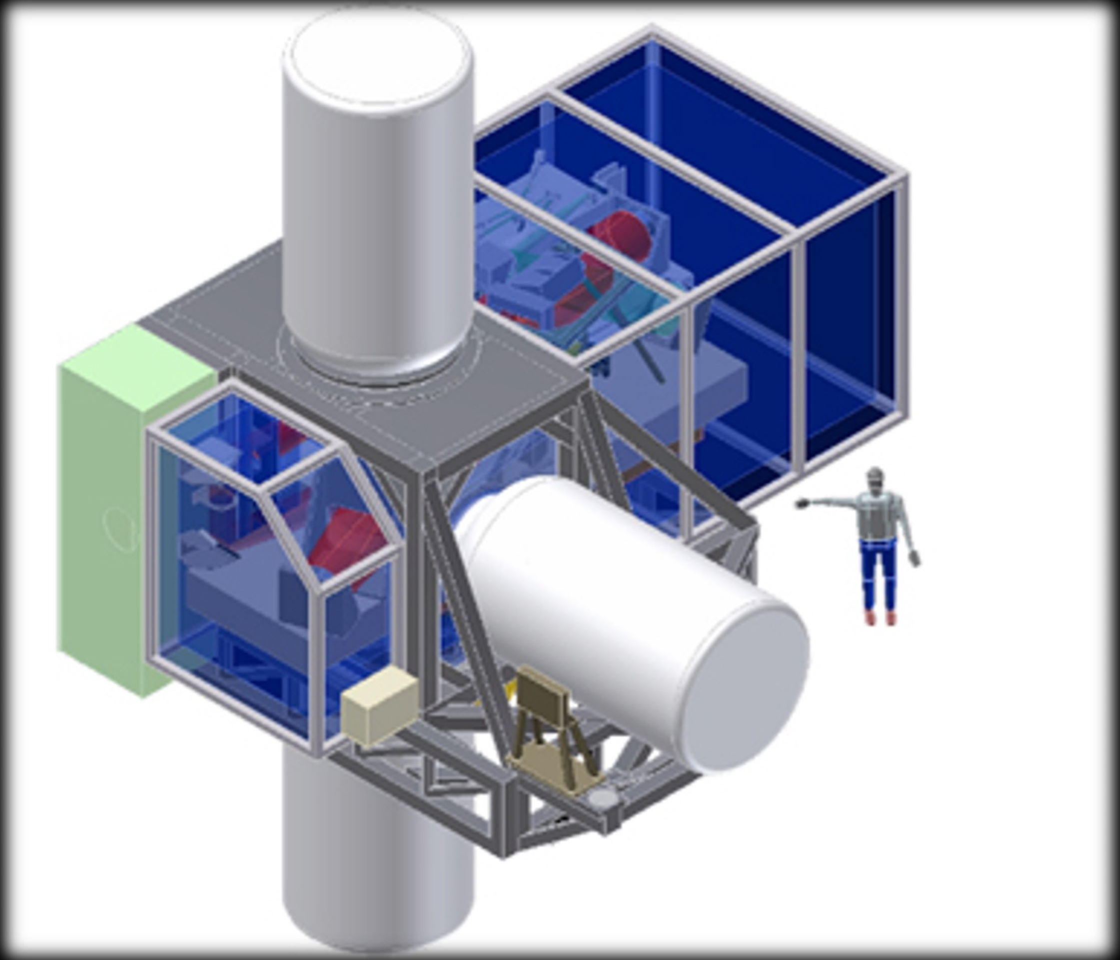


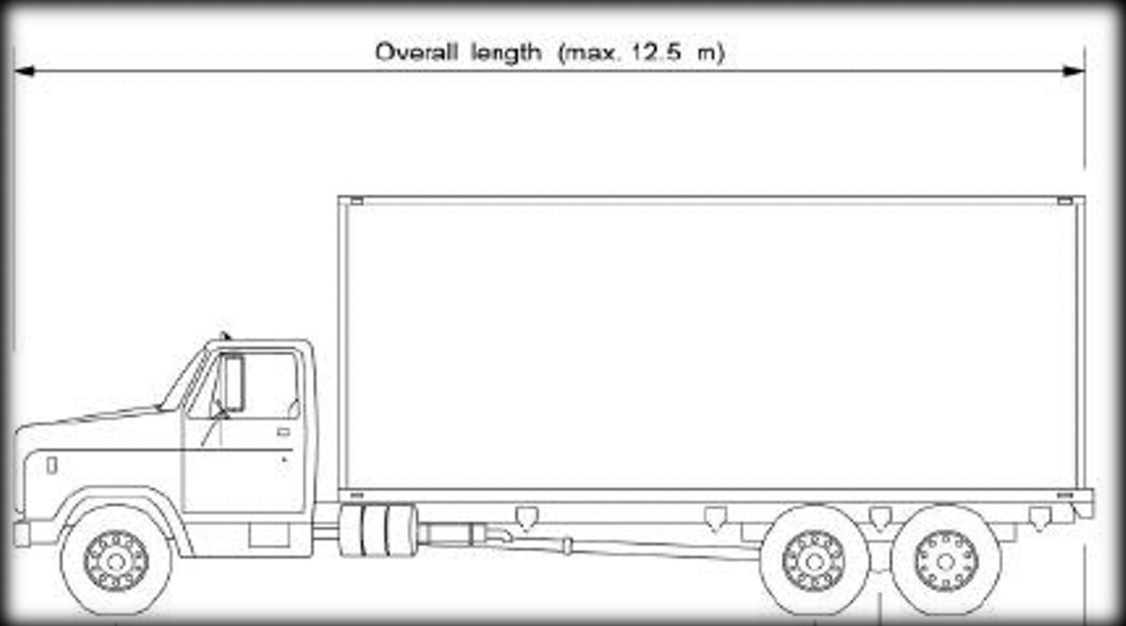
Gemini GeMS MCAO Laser Constellation



Artist's Depiction of the GMT LGS Constellation

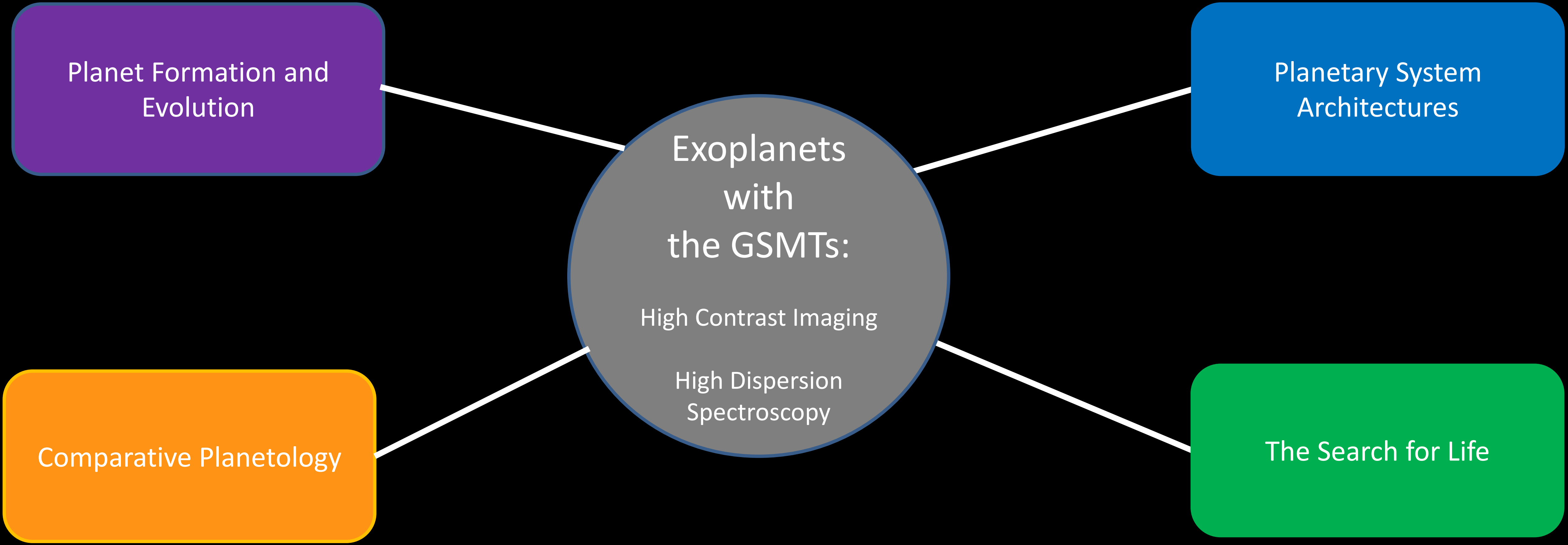
# All of the GSMTs will have multiconjugate adaptive optics (MCAO) systems to mitigate this issue.



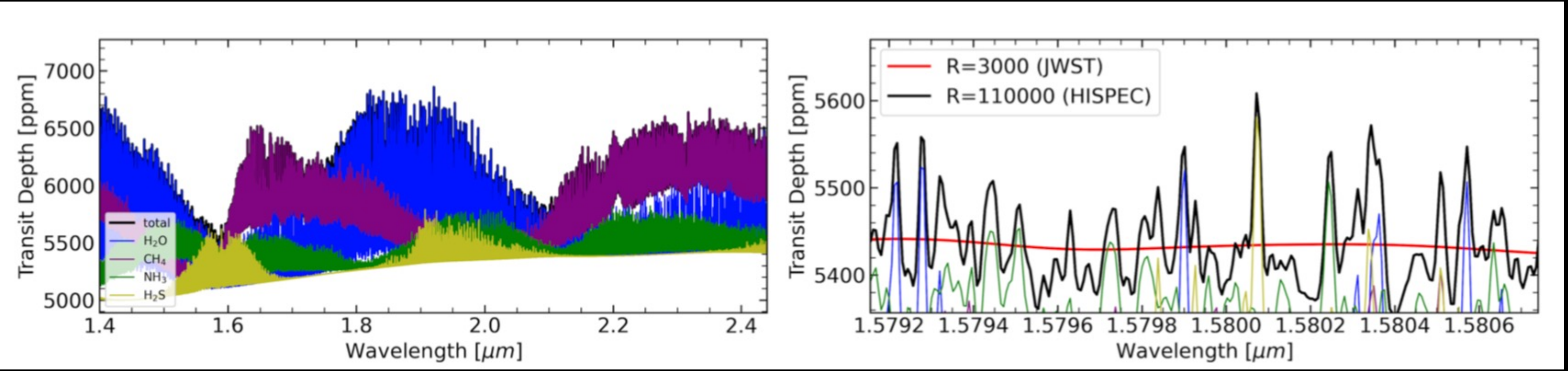



TMT NFIRAOS

# Exoplanet (atmosphere) Science with the 20-40 meter telescopes (GSMTs)

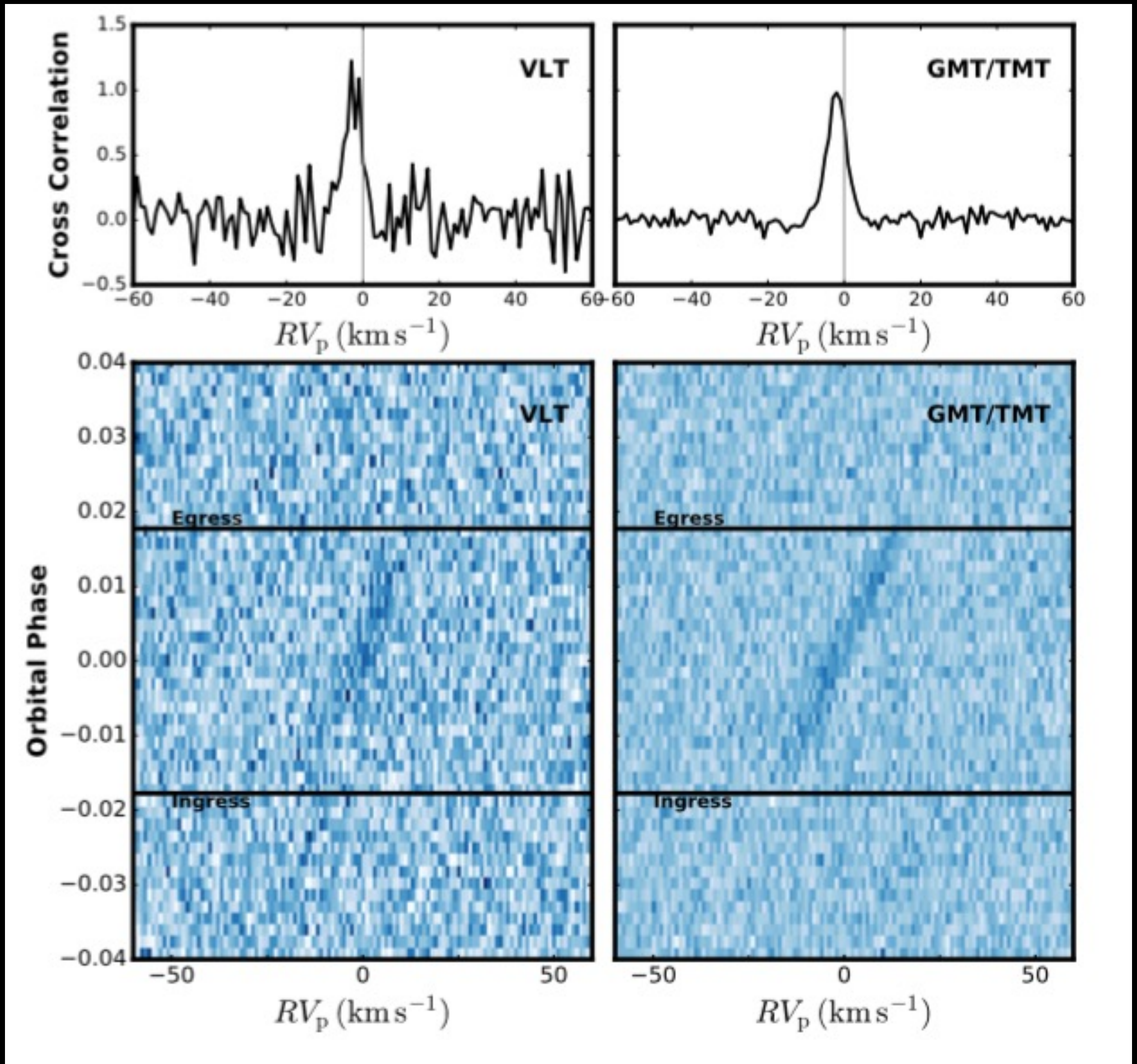

Exoplanets
with
the GSMTs:
High Contrast Imaging
High Dispersion
Spectroscopy
Planet Formation and
Evolution
Planetary System
Architectures
Comparative Planetology
The Search for Life

# For unresolved planets, there are many advantages to very high-resolution spectroscopy.




B. Benneke

# High-resolution spectroscopy on the GSMTs enables atmospheric characterization of close-in planets down into the terrestrial planet regime.




HD 209458B

Dragomir et al. 2019

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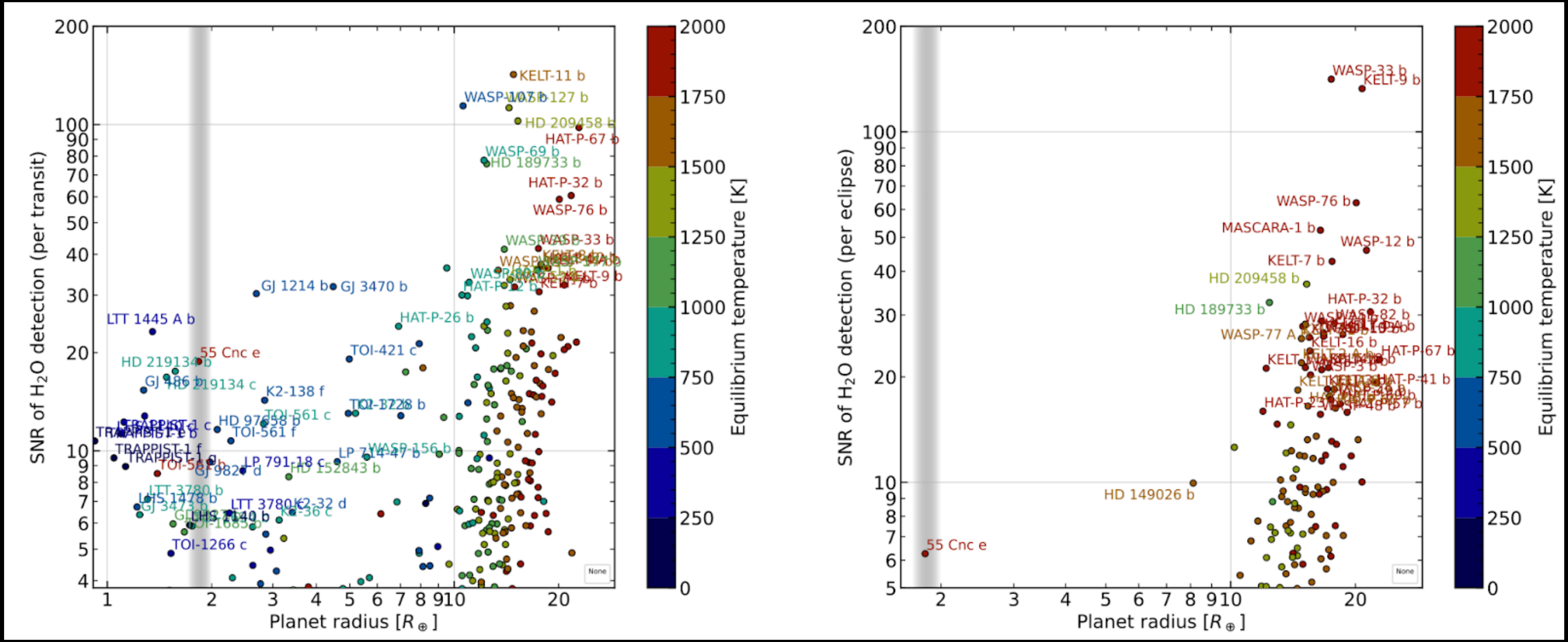
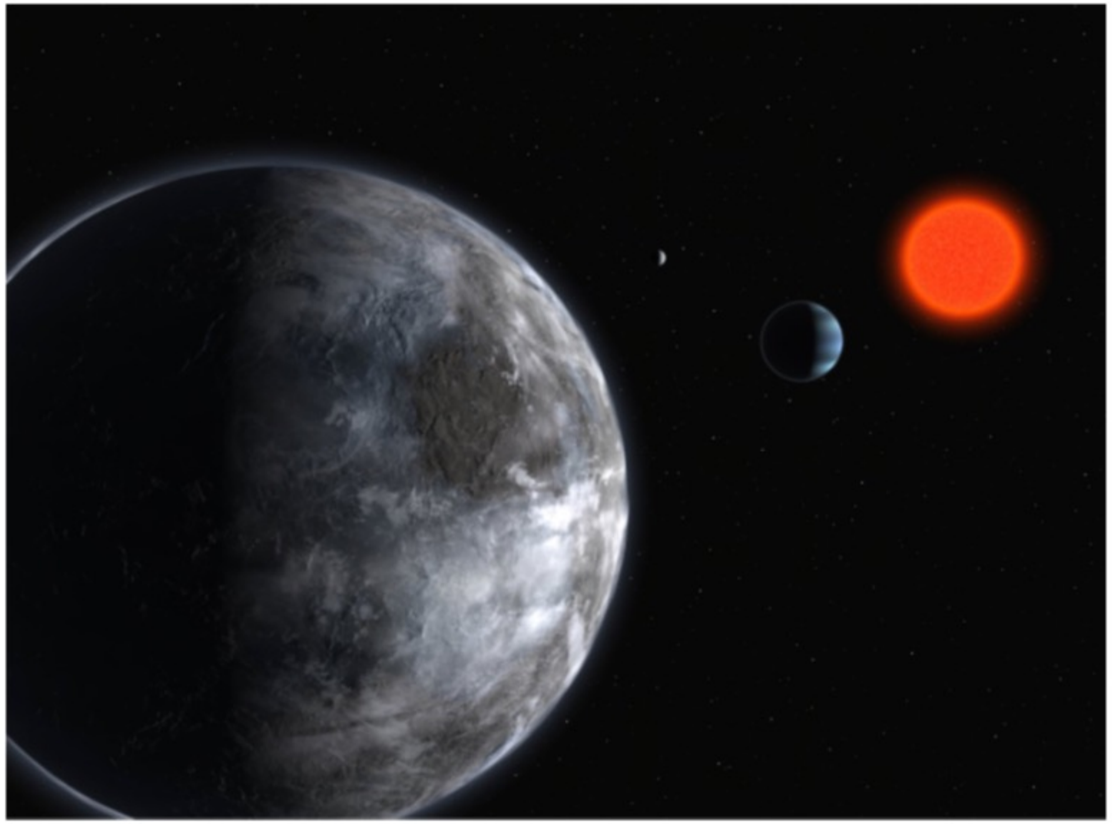
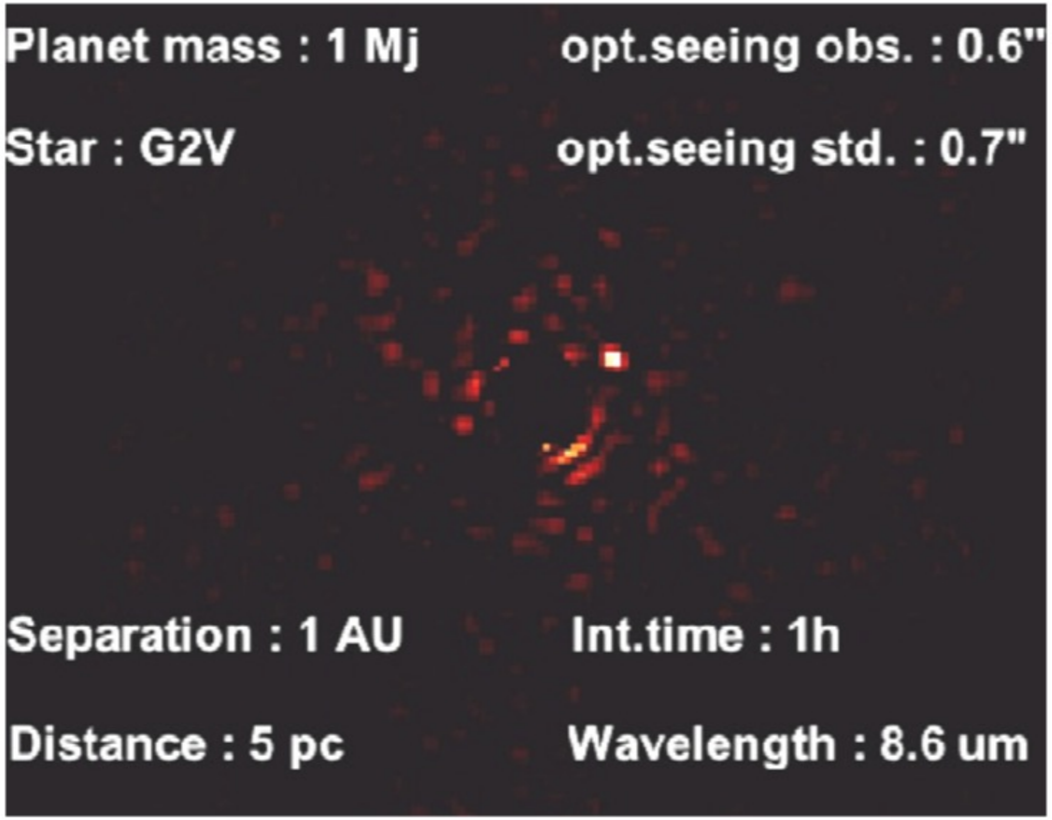



B. Benneke

# With unprecedented spatial resolution, the GSMTs will image hundreds of exoplanets.






Simulation for ELT METIS, Brandl et al. 2010

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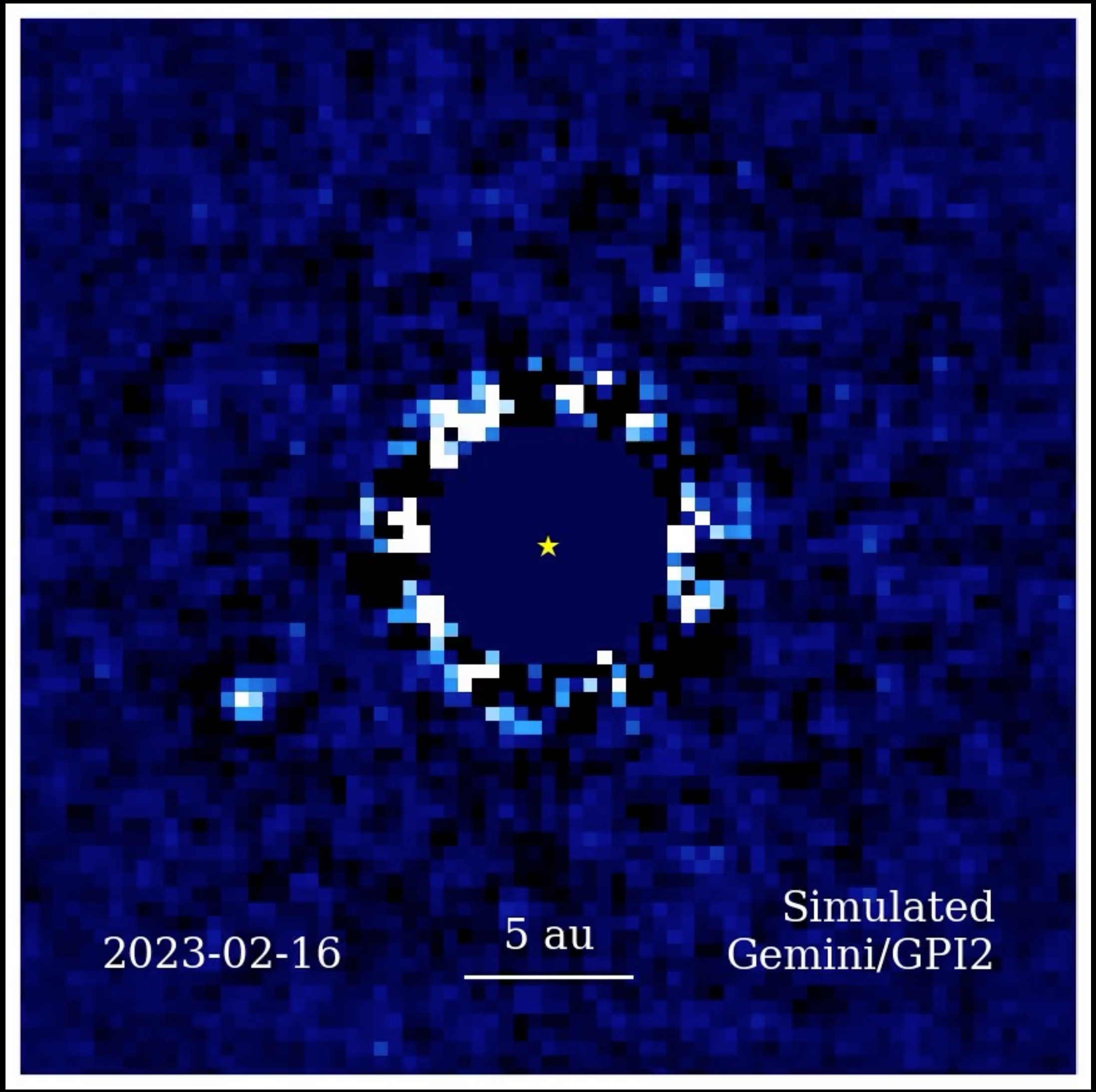


**TMT NFIRAOS**
**J. Wang & NFIRAOS/IRIS Team**

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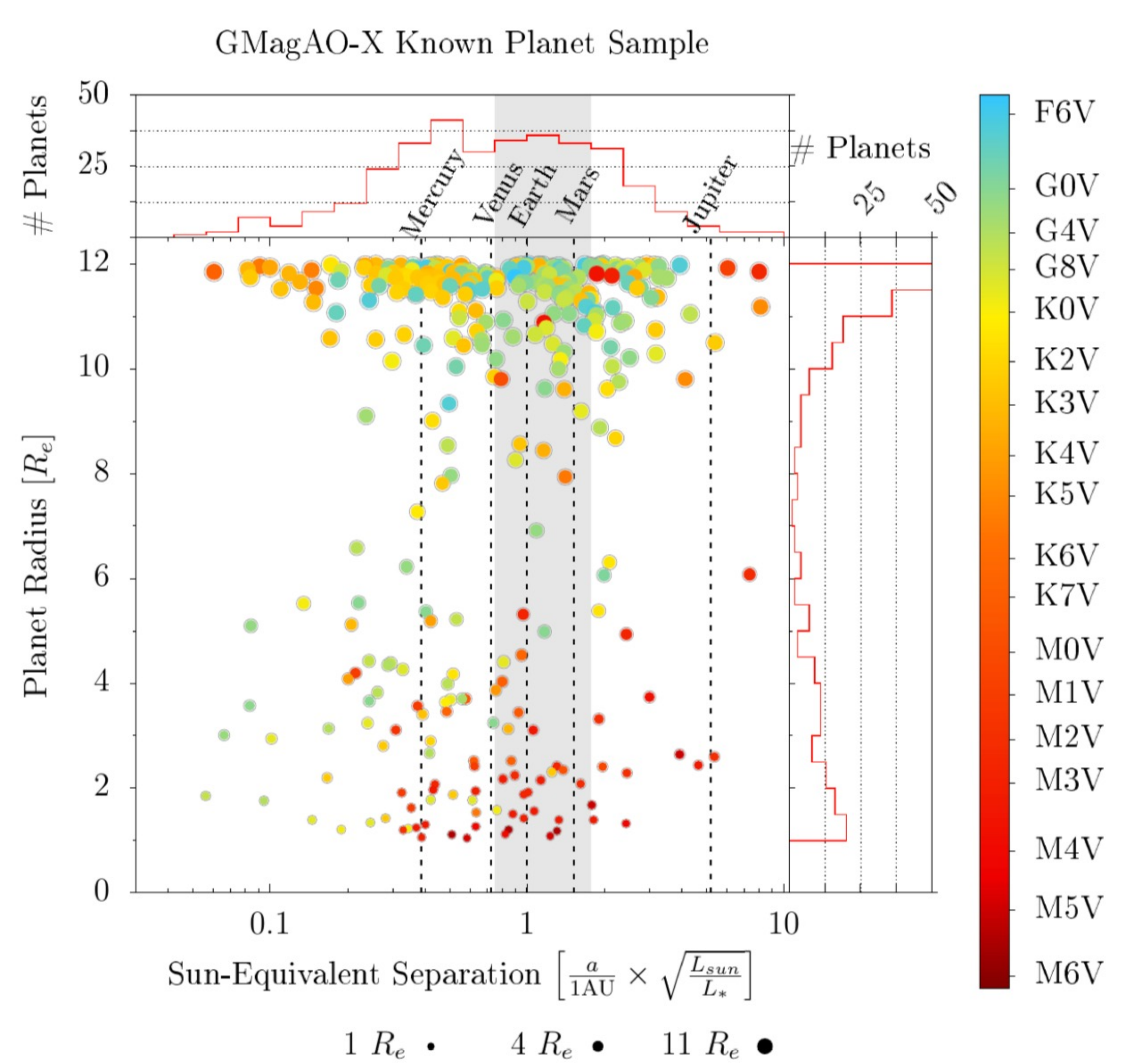
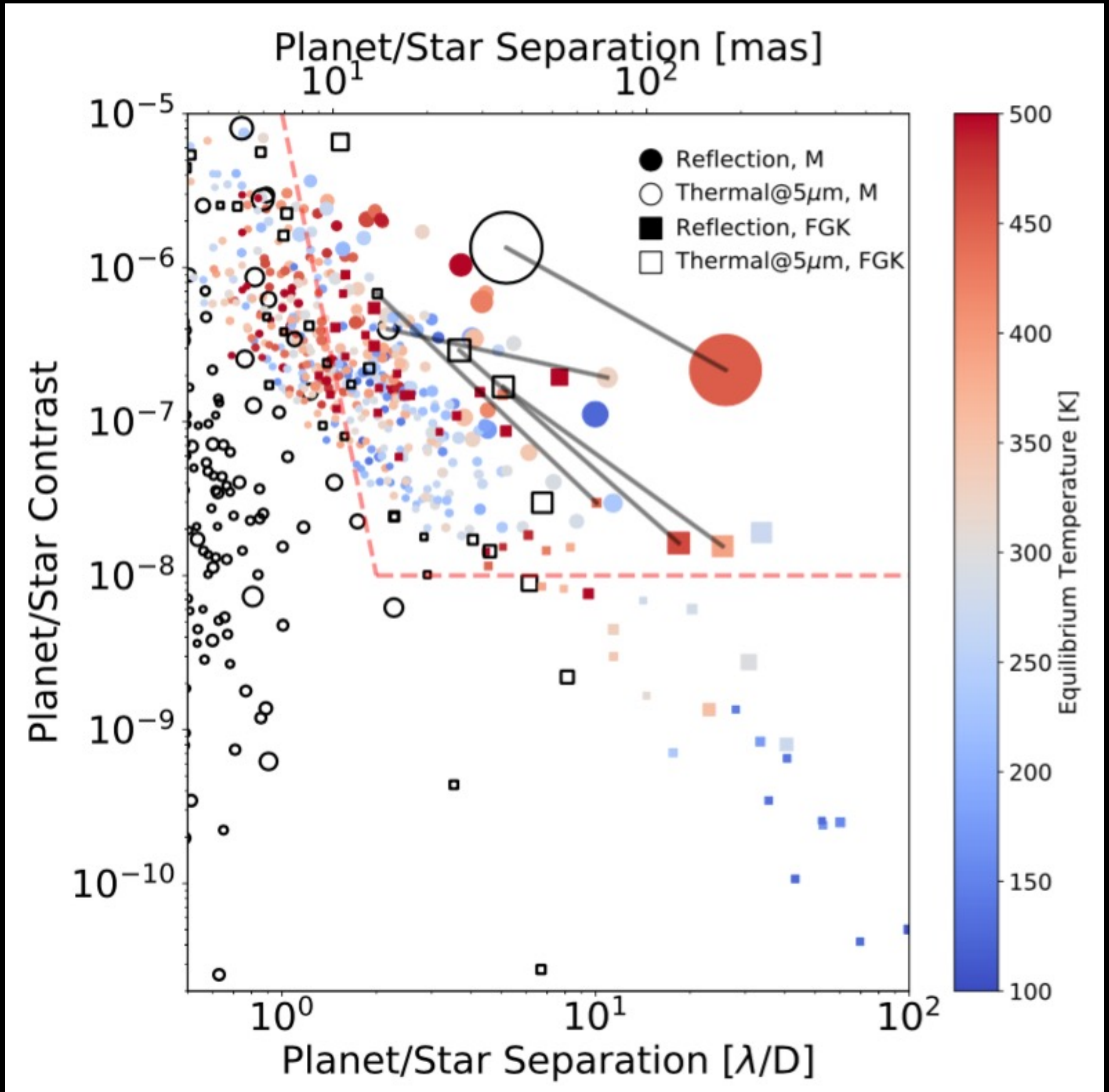


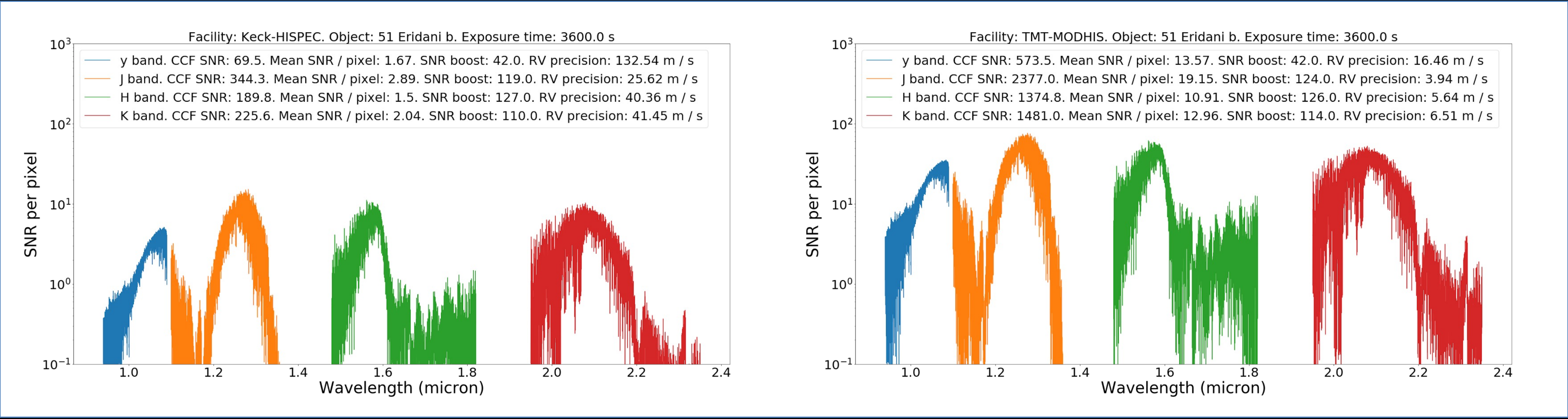

GMagAO-X
Males et al. 2022

# With unprecedented spatial resolution, the GSMTs will image hundreds of exoplanets.



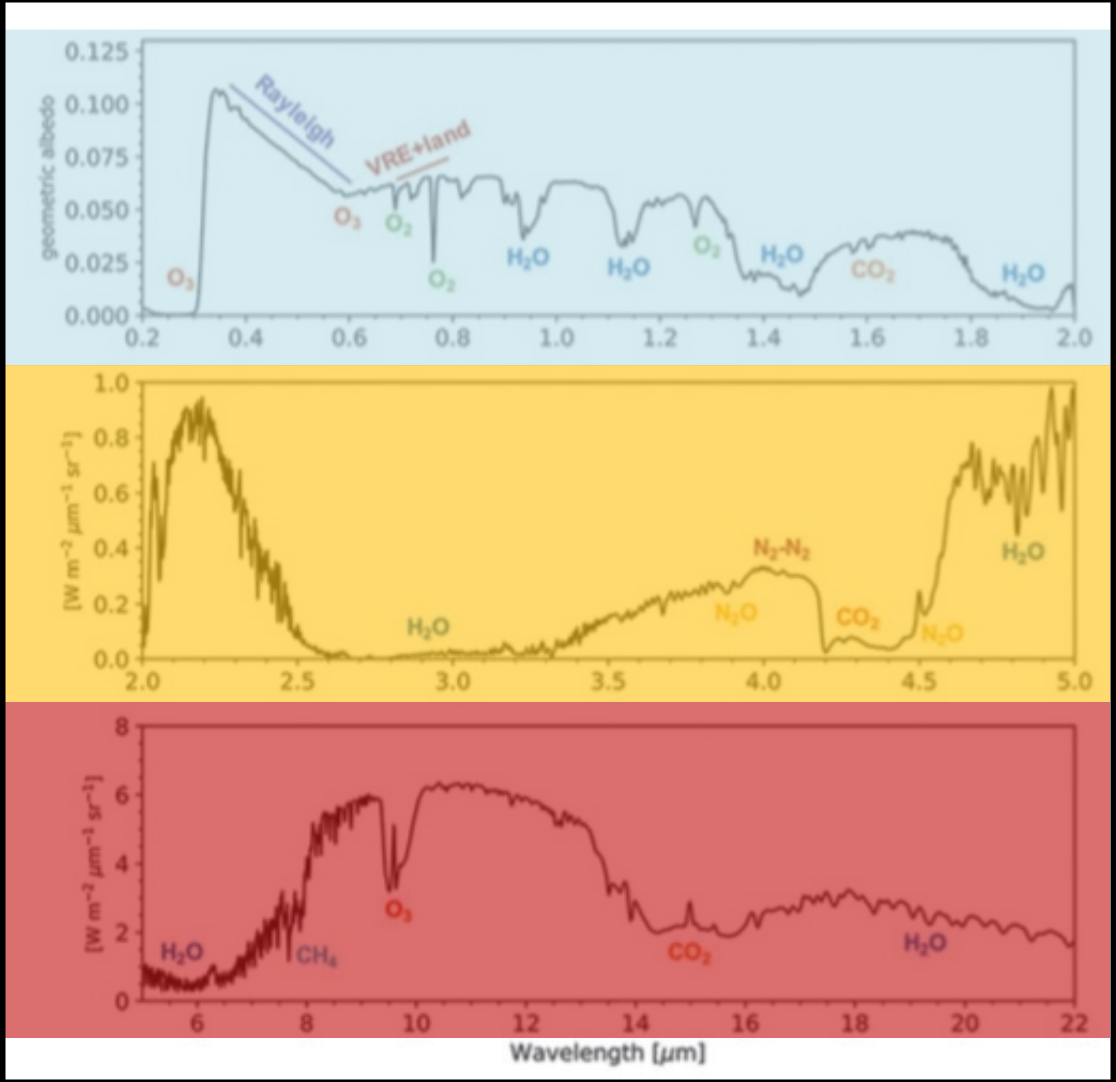

Wang, Meyer et al. 2019

# The combination of high spatial and high spectral resolution will enable unique atmosphere sciences.




D. Mawet

# There has been significant exploration of potential biosignature detection on the GSMTs using high spectral and/or high spatial resolution.



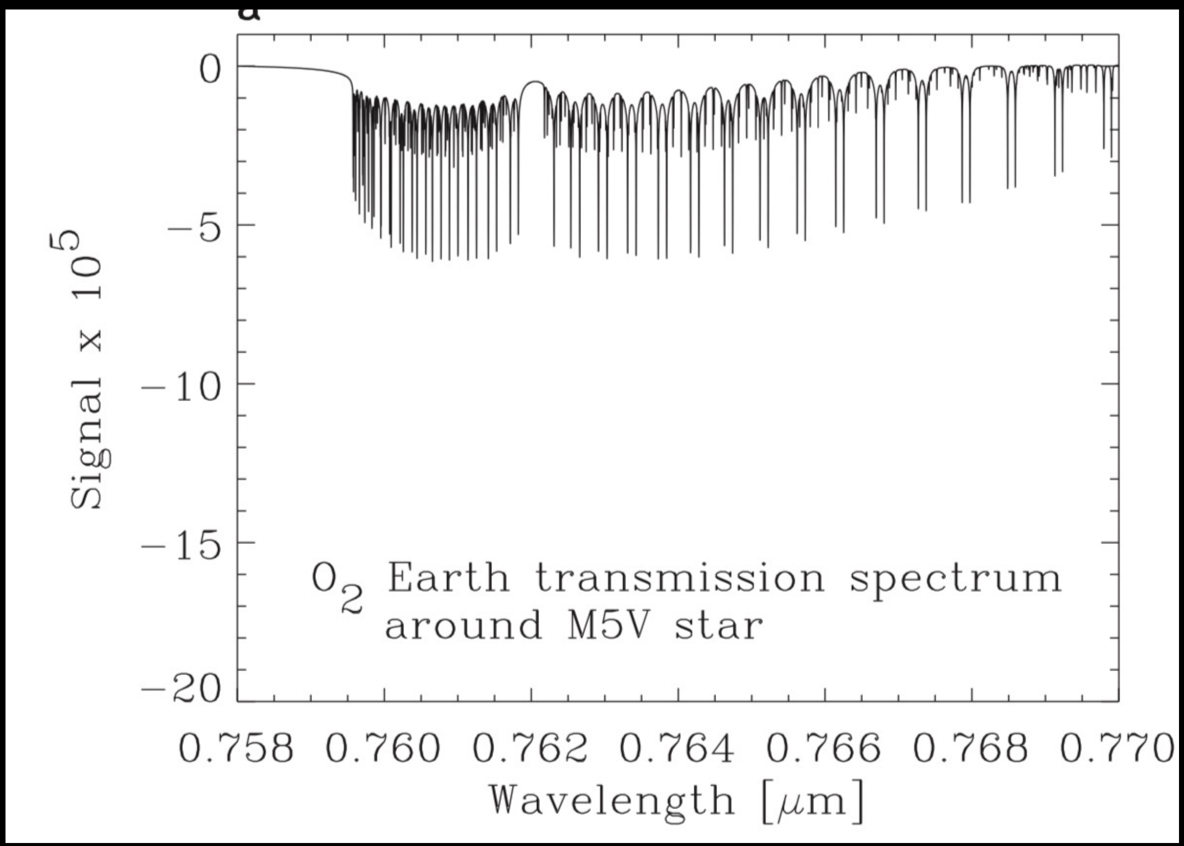

Optical Transmission spectroscopy

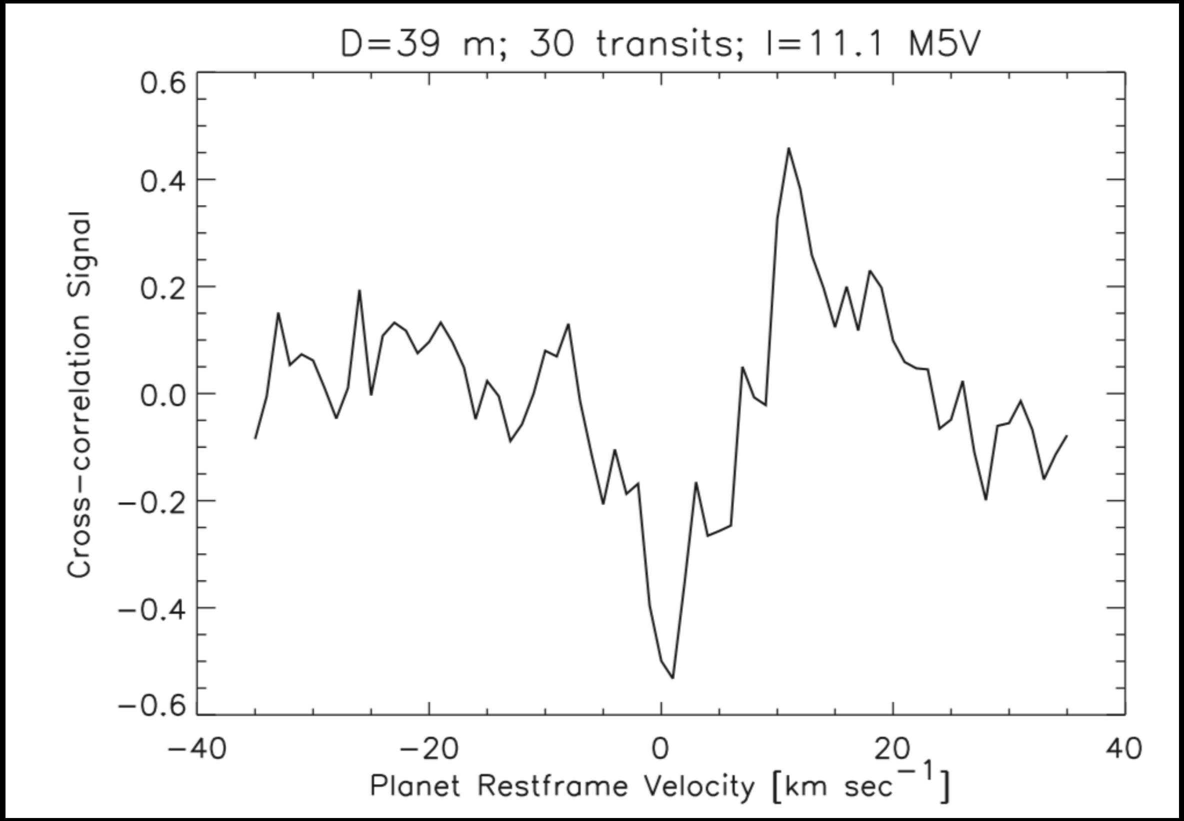
NIR Transmission spectroscopy + direct imaging in reflected light

Direct imaging in thermal emission

Lopez Morales et al. 2019

# There has been significant exploration of potential biosignature detection on the GSMTs using high spectral and/or high spatial resolution.




Snellen et al. 2013

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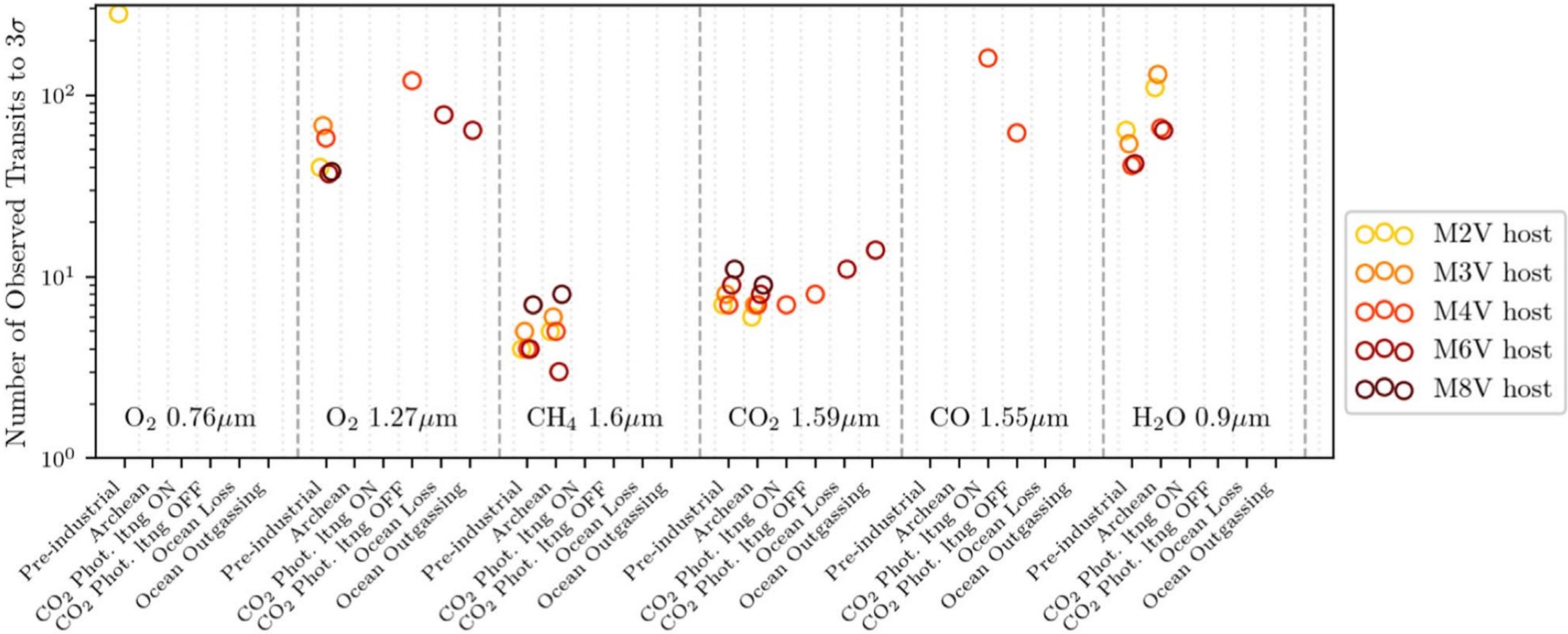


Currie, Meadows, & Rasmussen 2023

# All GSMTs will offer the capability of high contrasting and high resolution spectroscopy.

ANDES

METIS
Mid-infrared
E-ELT Imager and


MODHIS

# Expect really exciting results from these telescopes to start happening by the end of the decade!