



Humanity's next big Journey: Exploring Proxima Cen b and Habitable Planets around Nearby Stars

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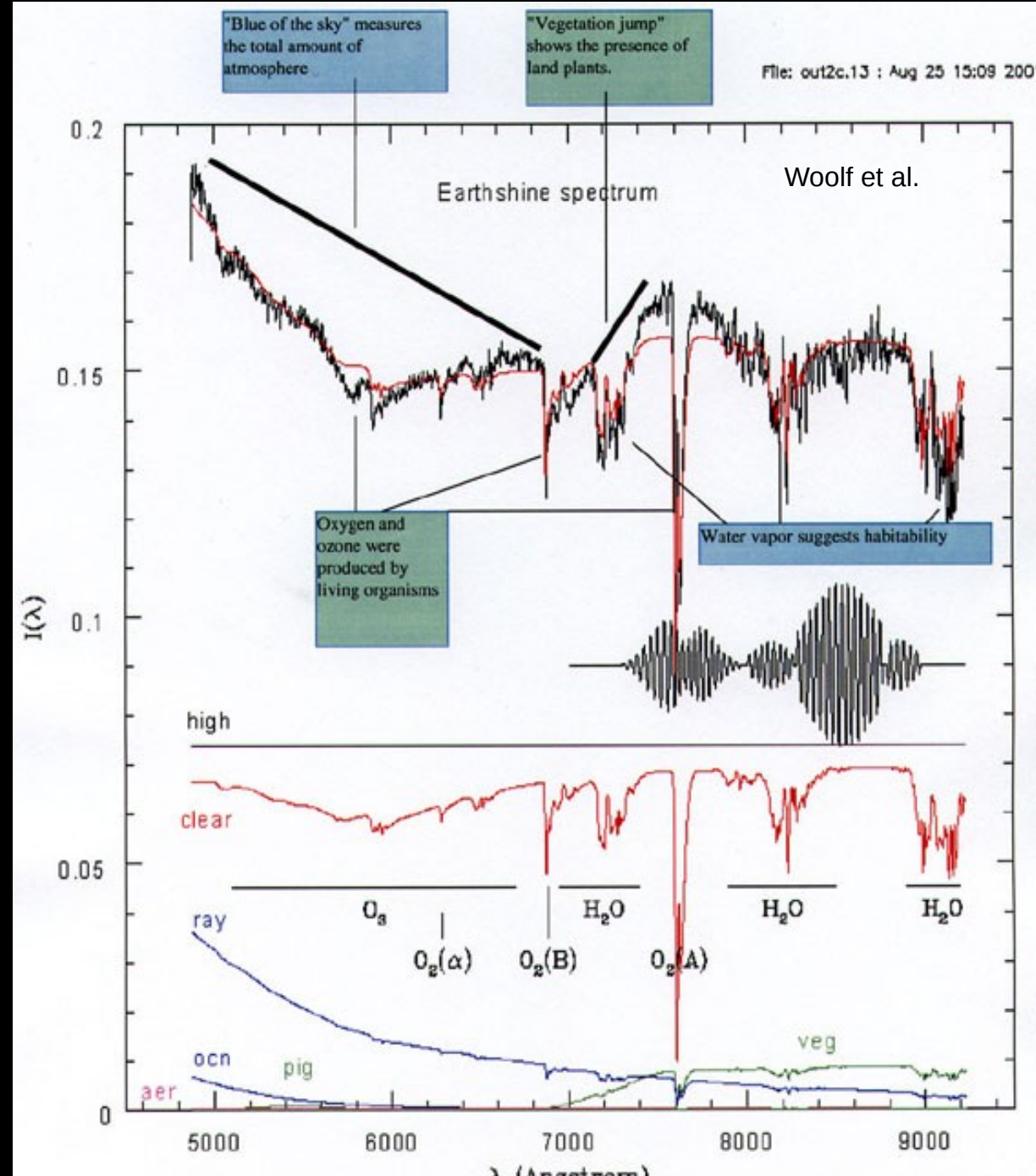
Astrobiology Center, National Institutes for Natural Sciences (NINS)

Breakthrough Initiatives team member (Starshot and Watch)

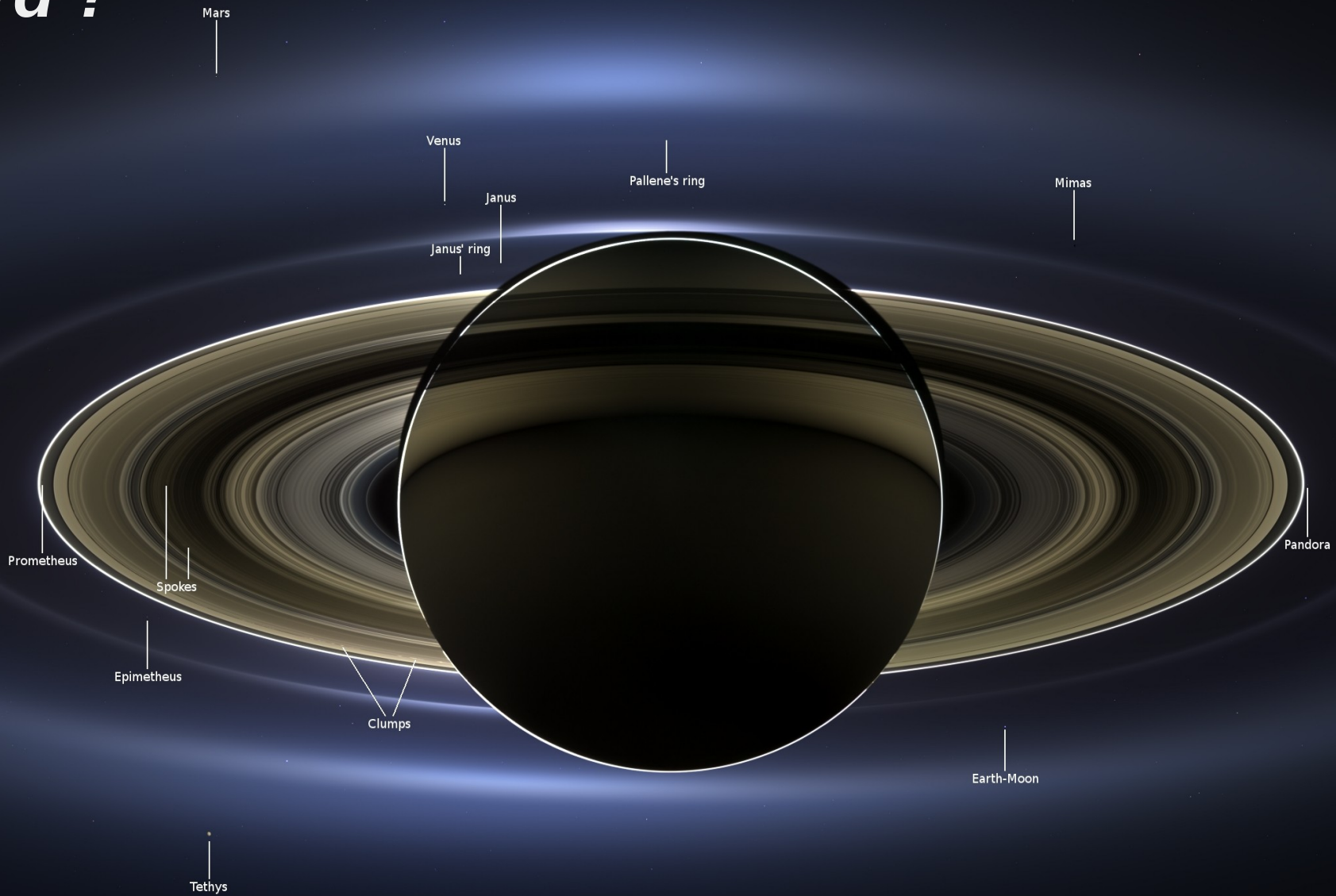
May 3, Seattle

Why directly imaging ?

Spectrum of Earth (taken by looking at Earthshine) shows evidence for life and plants



Taking images of habitable exoplanets: Why is it hard ?



A photograph taken from space showing the planet Saturn in the upper left corner, with its characteristic yellowish-brown rings and atmosphere. A bright, glowing white arc of light, likely the Sun or a reflection, curves across the top of the frame. The background is a deep, dark blue space. In the lower right, a small, distant point of light is labeled 'Earth' with a small white arrow pointing directly at it.

Saturn

↑
Earth

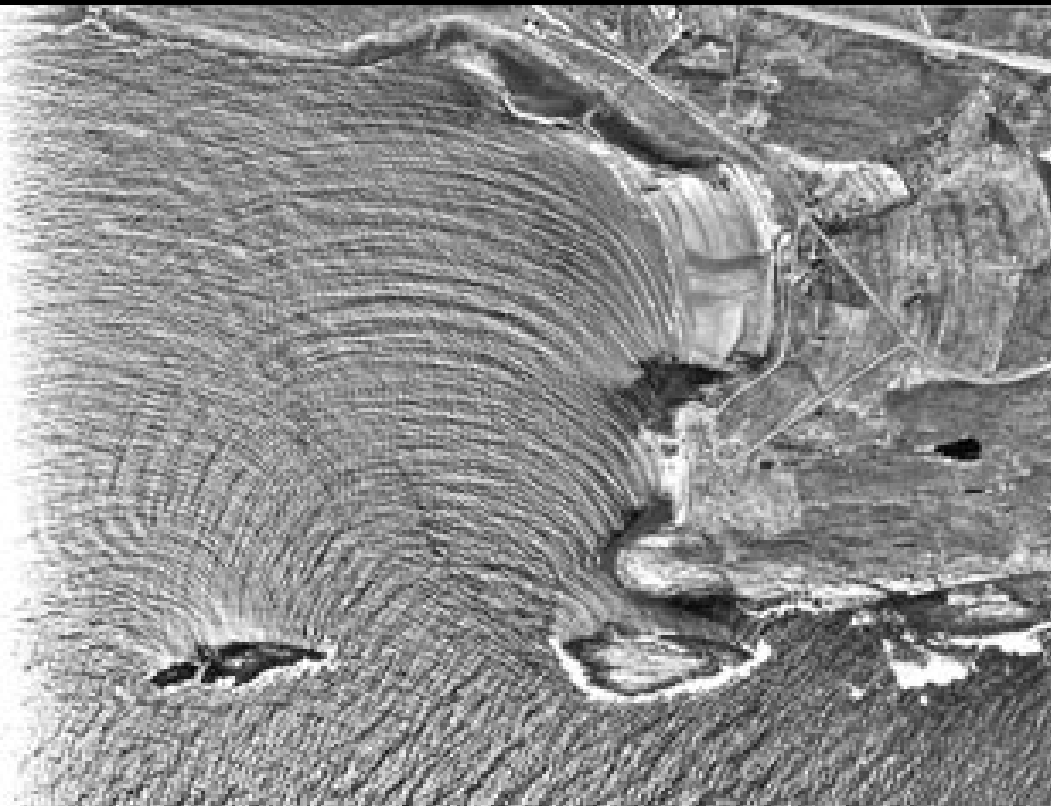
Coronagraphy ... Using optics tricks to remove starlight (without removing planet light)



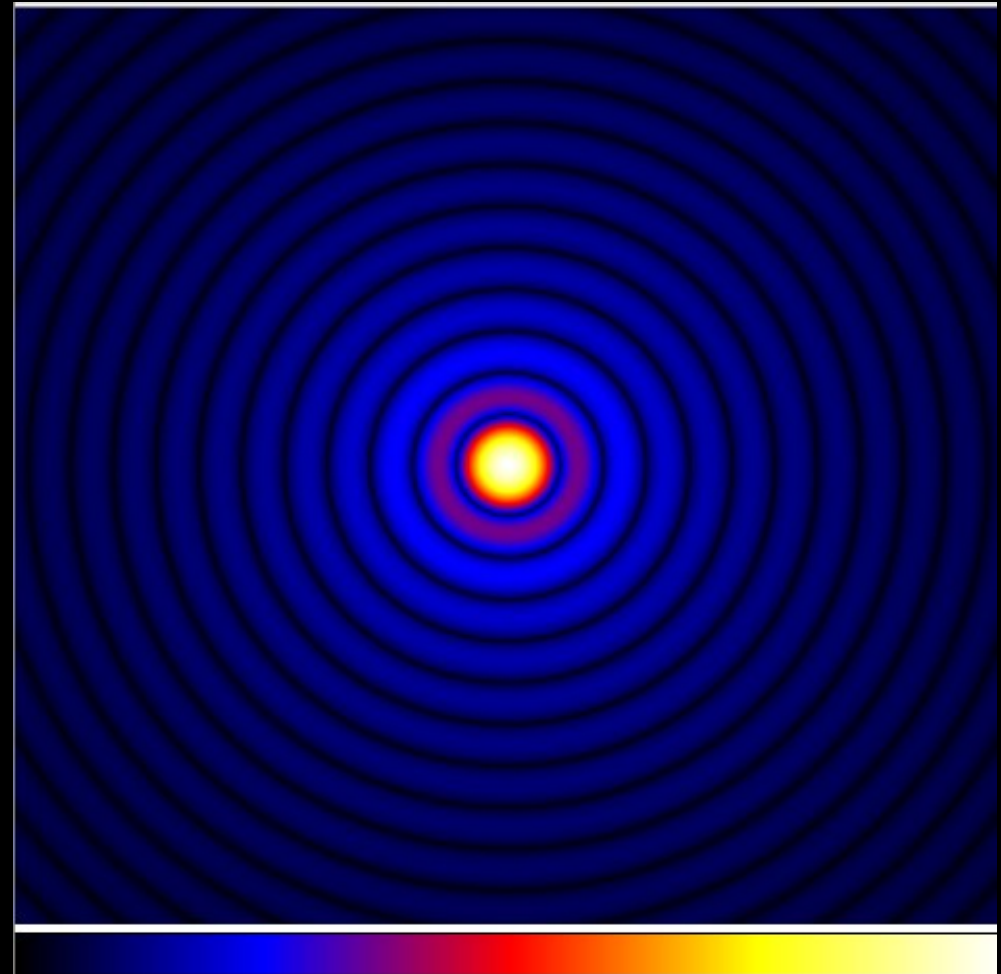
← Olivier's thumb...
the easiest coronagraph
Doesn't work well enough to
see planets around other stars

We need a better coronagraph... and a larger eye (telescope)

Water waves diffract around obstacles, edges, and so does light

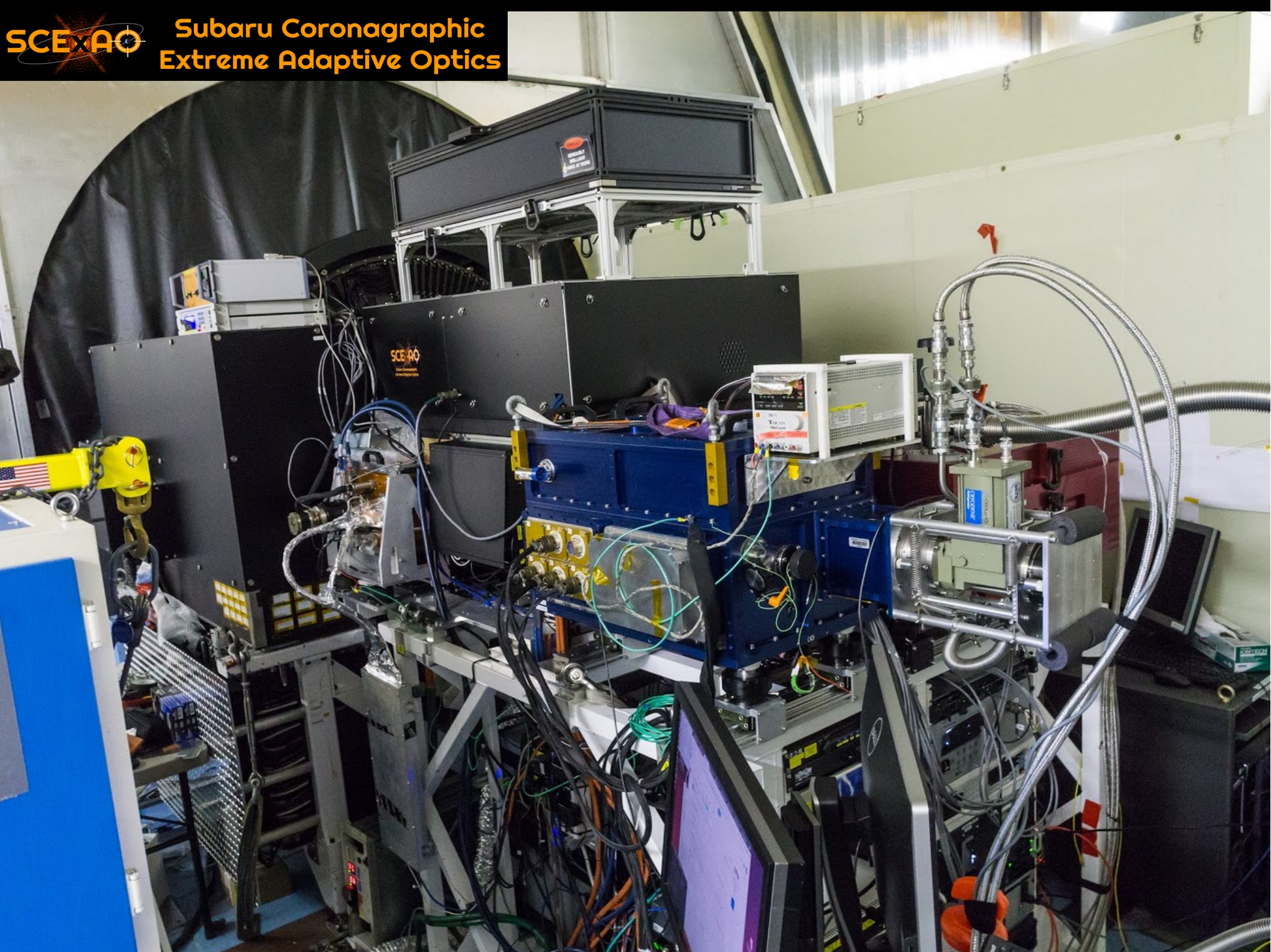


Waves diffracted by coastline and islands



Ideal image of a distant star by a telescope
Diffraction rings around the image core

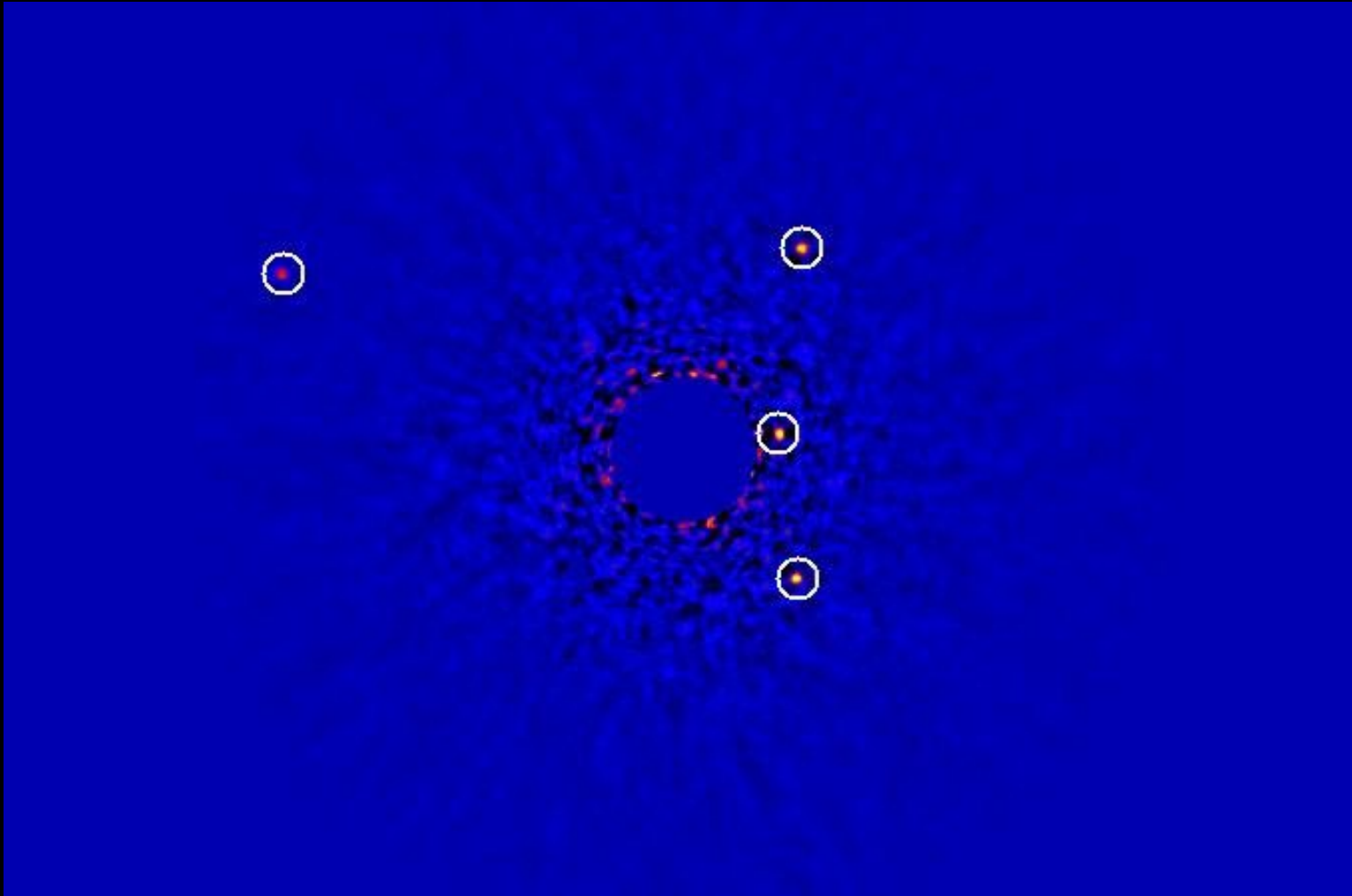
Subaru Coronagraphic Extreme Adaptive Optics



HR8799

Four planets, orbital periods on the order of 100yr
Each planet 5 to 7 Jupiter Mass

Subaru Telescope/ SCExAO (Currie et. al 2017)



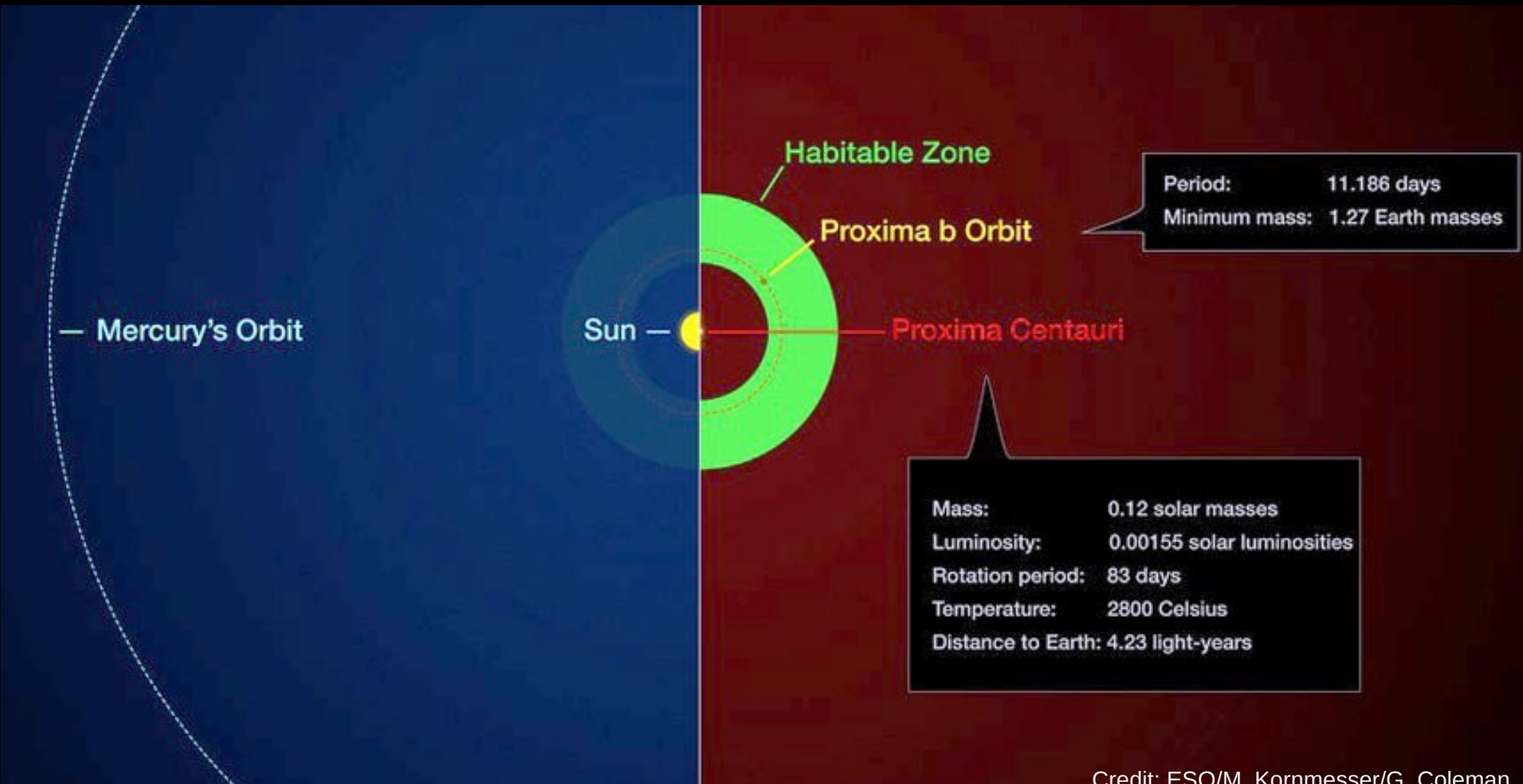
M-type stars (low mass)

Habitable zone is close to star

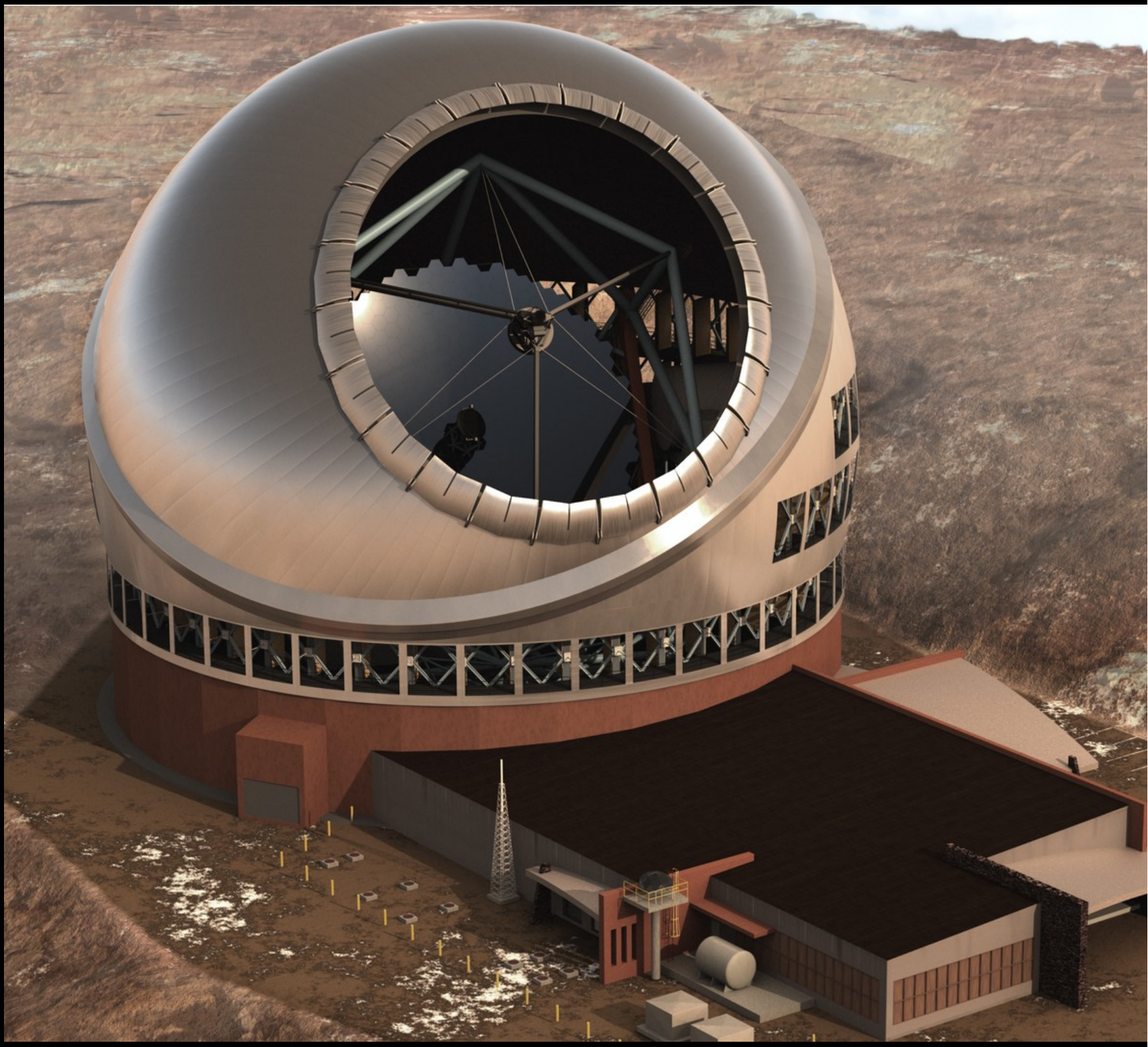
→ **big telescope needed to resolve it**

Star is fainter, so Star/Planet contrast is easier

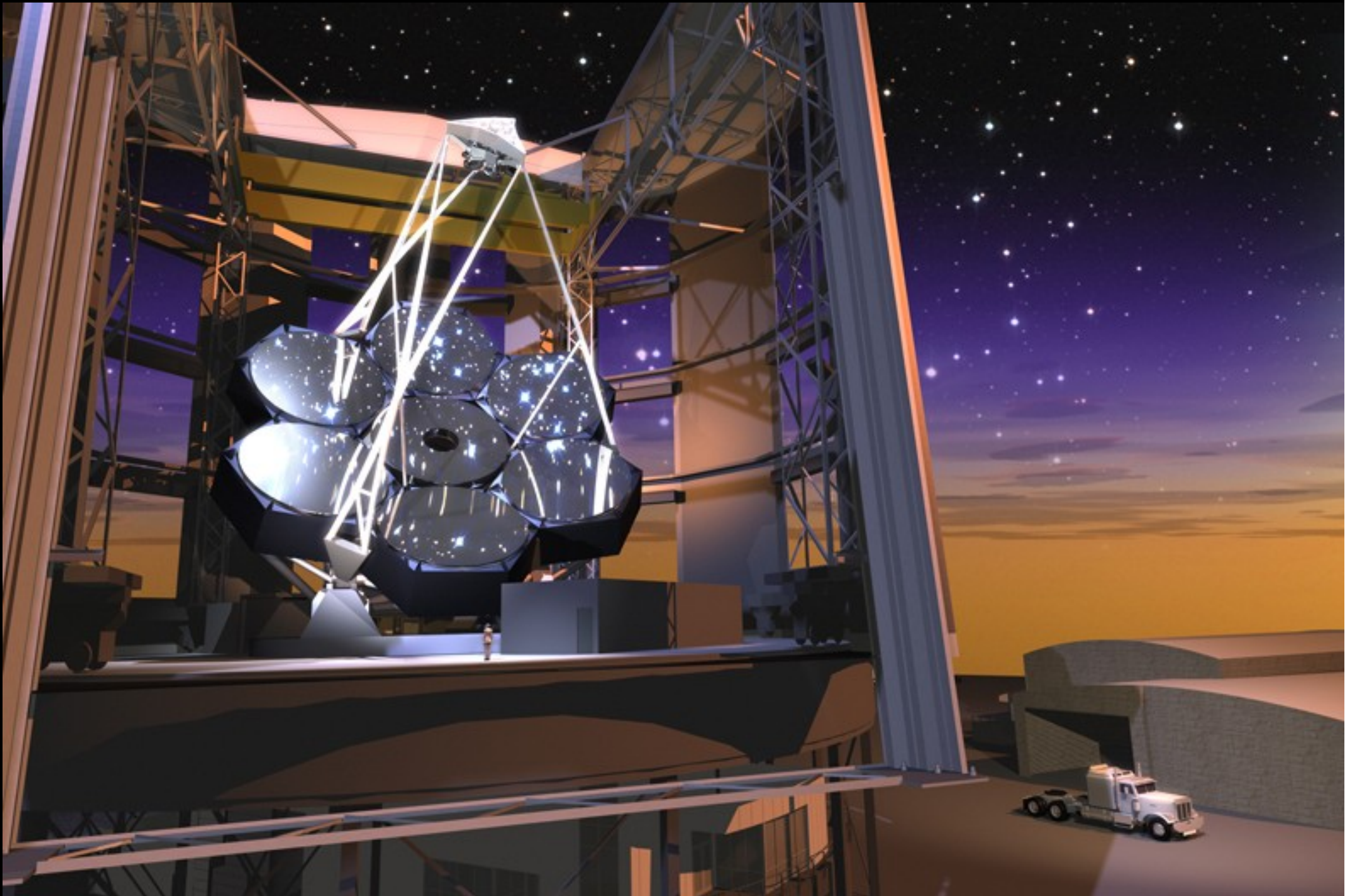
→ **can be done from ground** (no need to be in space)



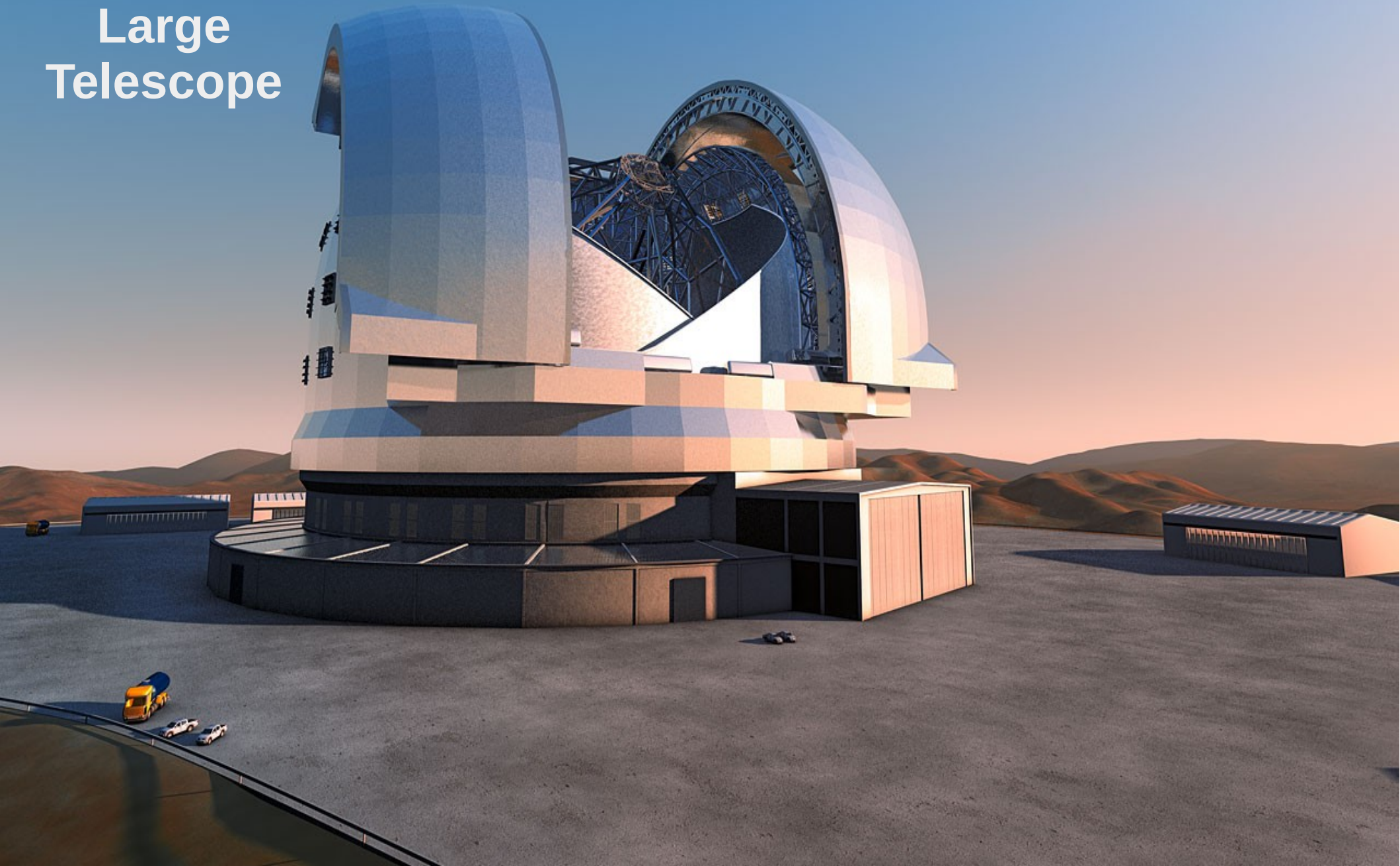
Thirty Meter Telescope



Giant Magellan Telescope



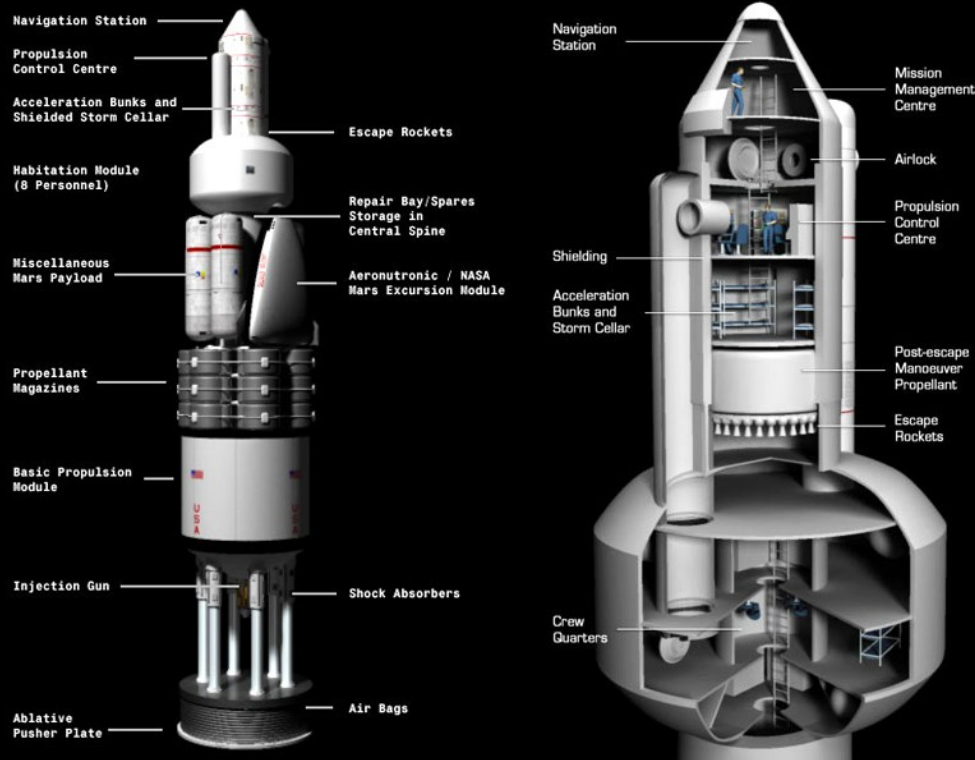
European Extremely Large Telescope



Interstellar travel: pre-2000 studies

Several serious studies (Longshot, Orion, Deadalus)

Propulsion challenge is significant



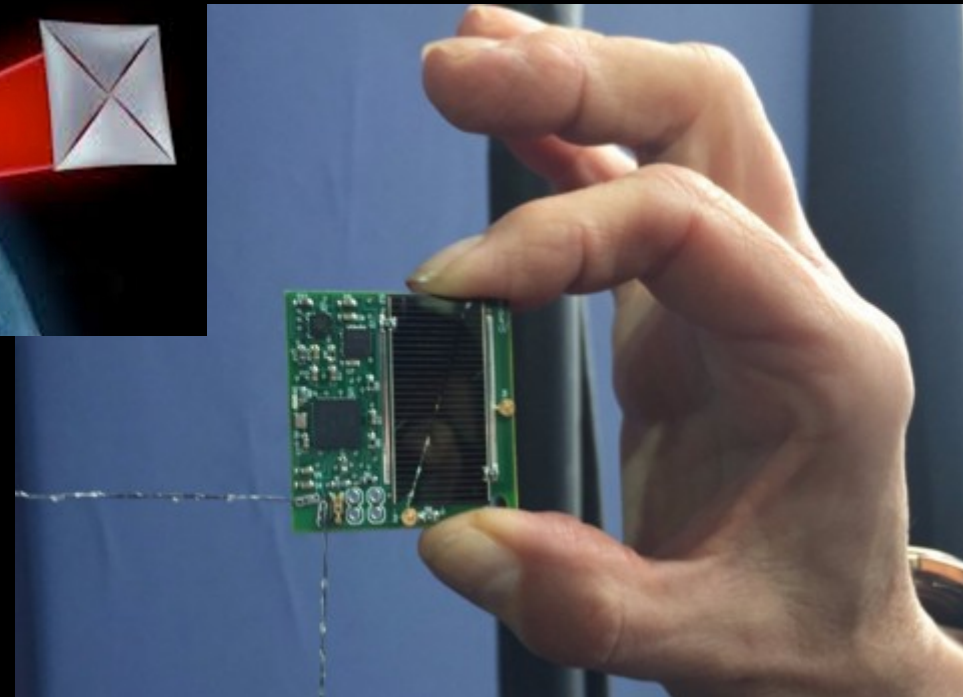
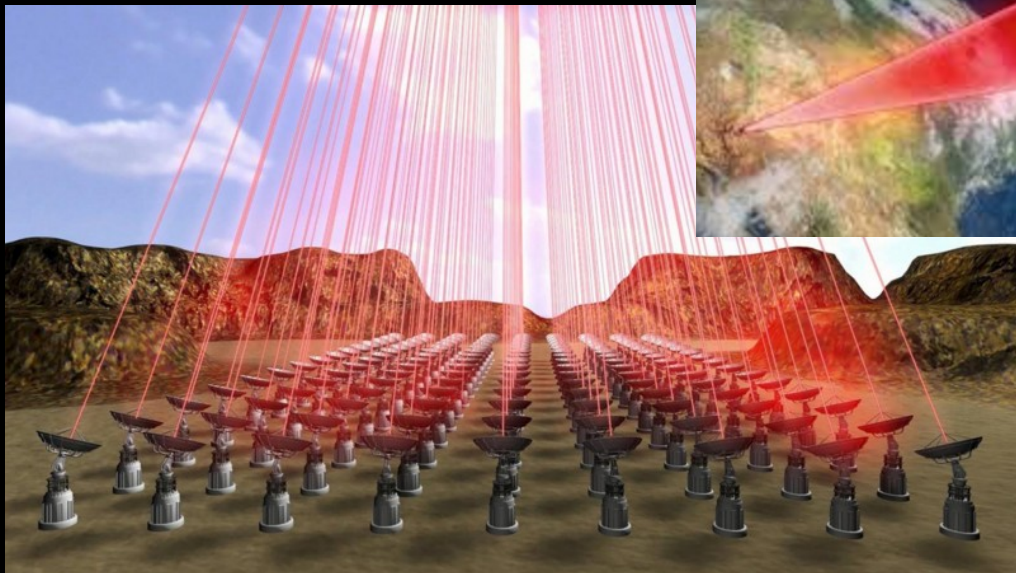
Project Orion – using nuclear propulsion, massive spacecraft

Starshot project: Laser propulsion, robotic spacecraft (no human)

Leverages current/future technology developments:

- Small spacecraft (~gram)
- Ground-based laser propulsion (“don't carry your fuel”)

breakthroughinitiatives.org



~300 billion stars in our galaxy



~300 billion stars in our galaxy

~30 billion habitable planets ?

If 100 explorers were sent to visit each habitable for 10 seconds (only 300 million planets/explorer)...

... it would take 95 yrs to complete the habitable exoplanets tour ... in our galaxy alone

A deep-field astronomical image showing a vast field of galaxies and stars against a black background. The image is filled with numerous galaxies of various shapes and sizes, including spiral, elliptical, and irregular forms. Some galaxies are bright and clear, while others are faint and distant. The stars appear as small, bright points of light, some with diffraction spikes. The overall scene conveys the immense scale and diversity of the universe.

**200 billion galaxies
in the observable
universe**