UCI School of Physical Sciences

Imaging Planet Formation
with Professor Steph Sallum

Welcome, we will begin shortly

For questions, please utilize the Q&A feature at the bottom of your screen

Text PSBLS to 41444 to give!

Imaging Planet Formation

UCI SoPS Virtual Lecture Series

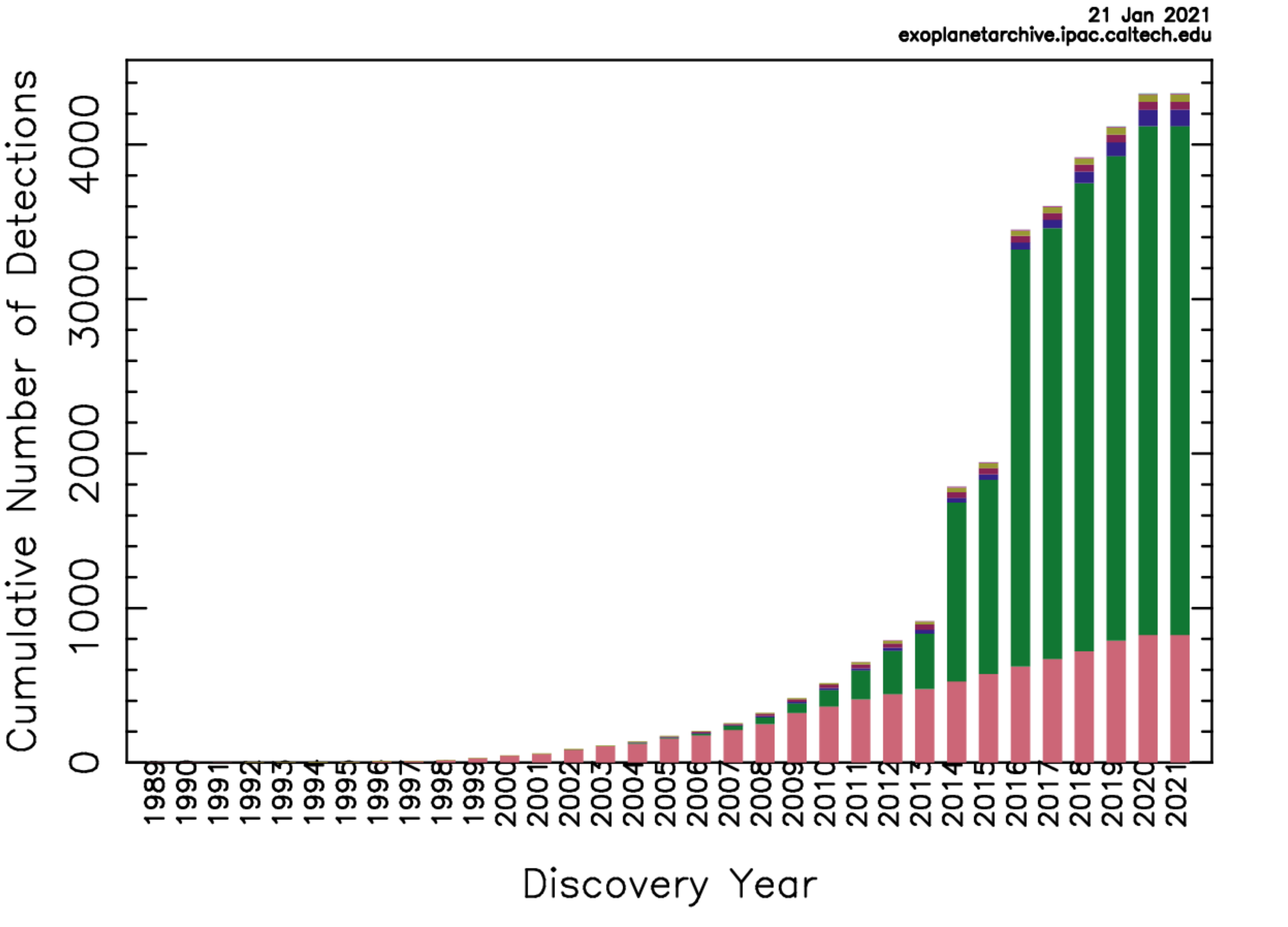
Prof. Steph Sallum

UCI School of Physical Sciences

UCI Department of Physics & Astronomy

Why study planet formation?

Total Number of Discovered Exoplanets



Exoplanet Diversity

Martin Vargic

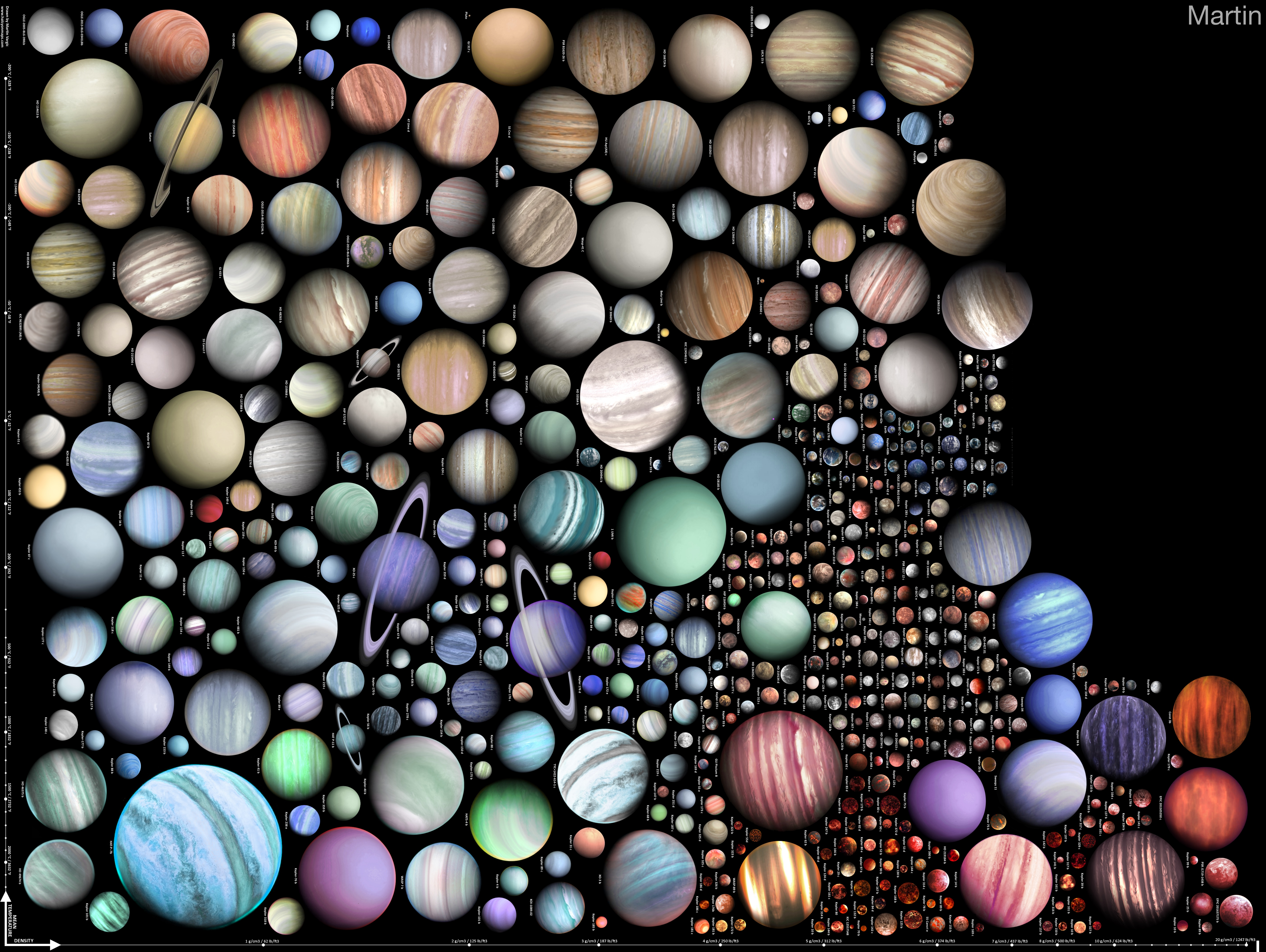
-330 F

-60 F

212 F

2700 F

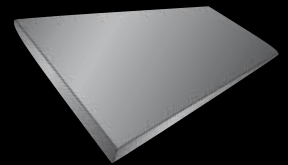
3600 F



1 g/cm3

2.75 g/cm3

8 g/cm3



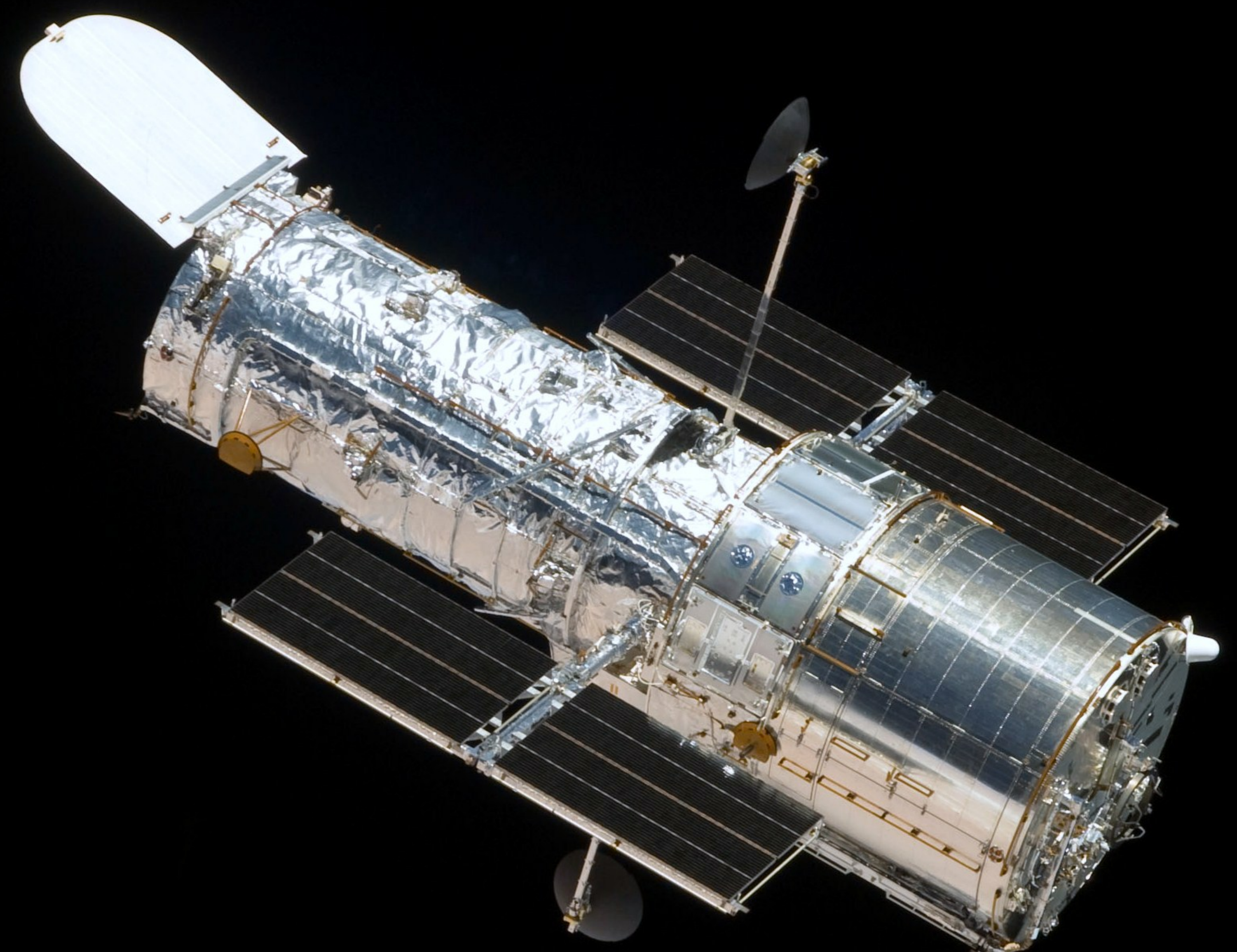
20 g/cm3

Planet Formation


NASA APOD October 23, 2010


Rigel
Bellatrix
Lambda
Orionis
(SH2 264)
Mintaka
Orion nebula (M42)
Meissa
Alnilam
Alnitak
Horsehead nebula
M78
Saiph
Betelgeuse
vdb62/63
Barnard's Loop
NASA APOD October 23, 2010

Protoplanetary Disks: The Sites of Planet Formation



Mark McCaughrean (Max-Planck-Institute for Astronomy), C. Robert O'Dell (Rice University), and NASA

Protoplanetary Disks: The Sites of Planet Formation

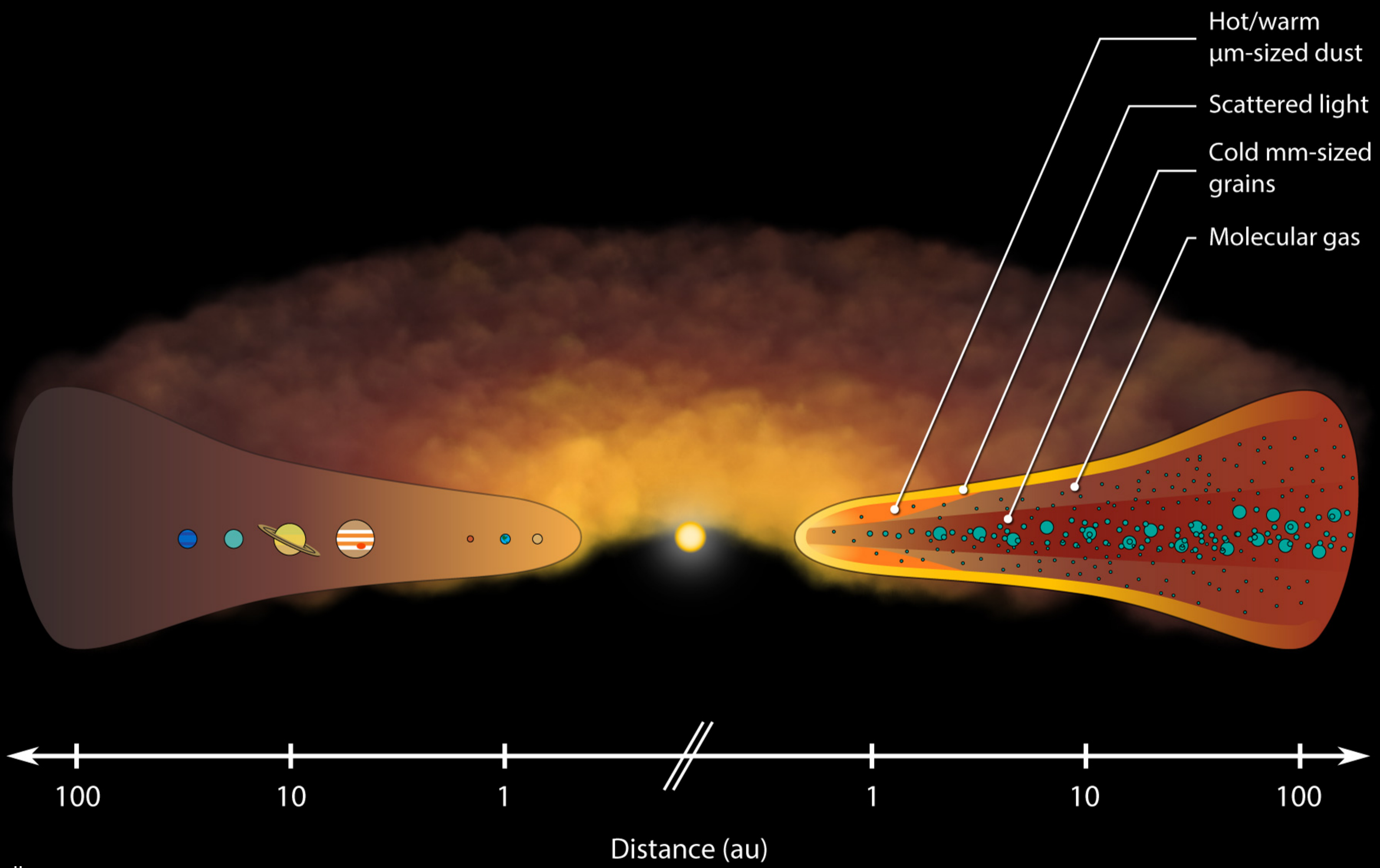


Image credit: Annie Mejia

Protoplanetary Disks: The Sites of Planet Formation

DSHARP; e.g. Andrews+2018

Planet Formation

m

mm - cm

10^3 km

Planet Formation

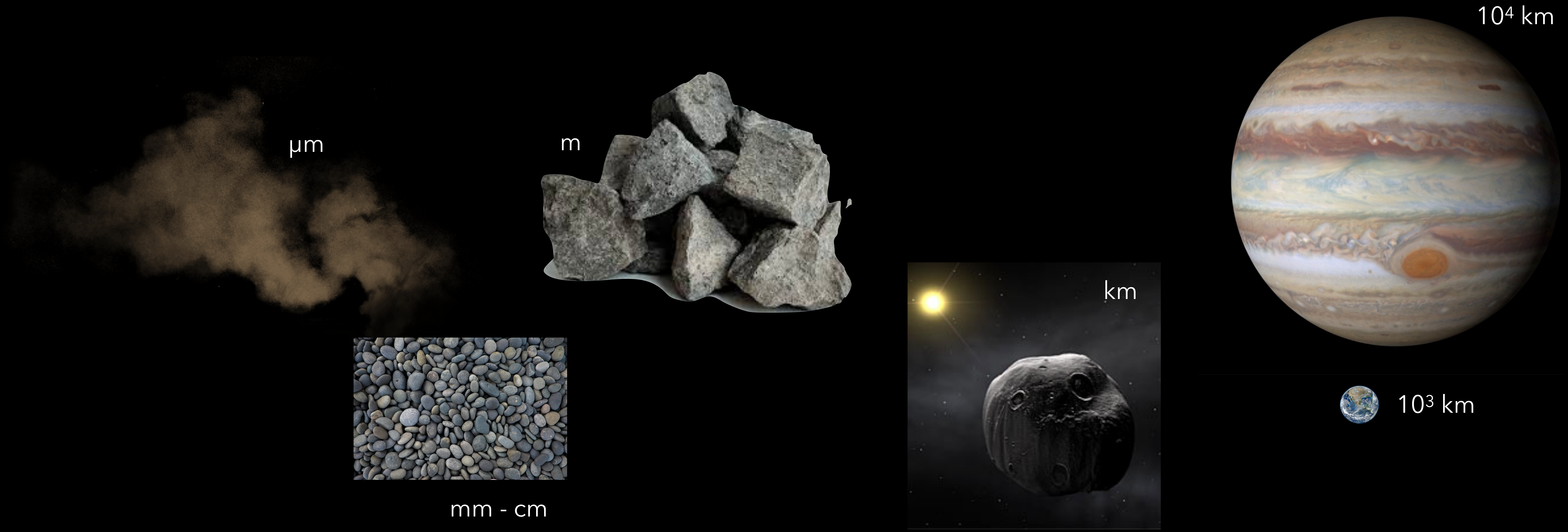
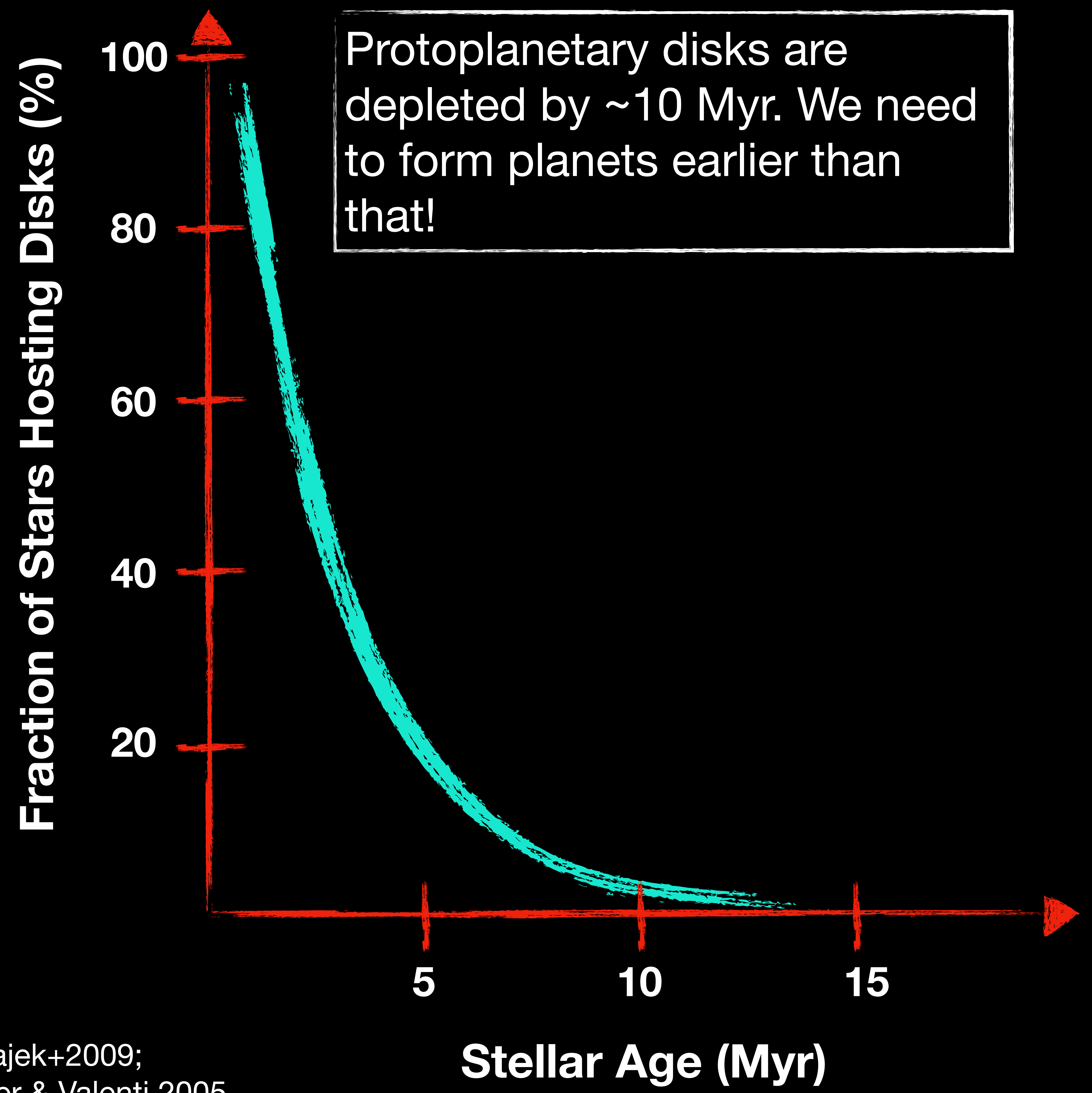
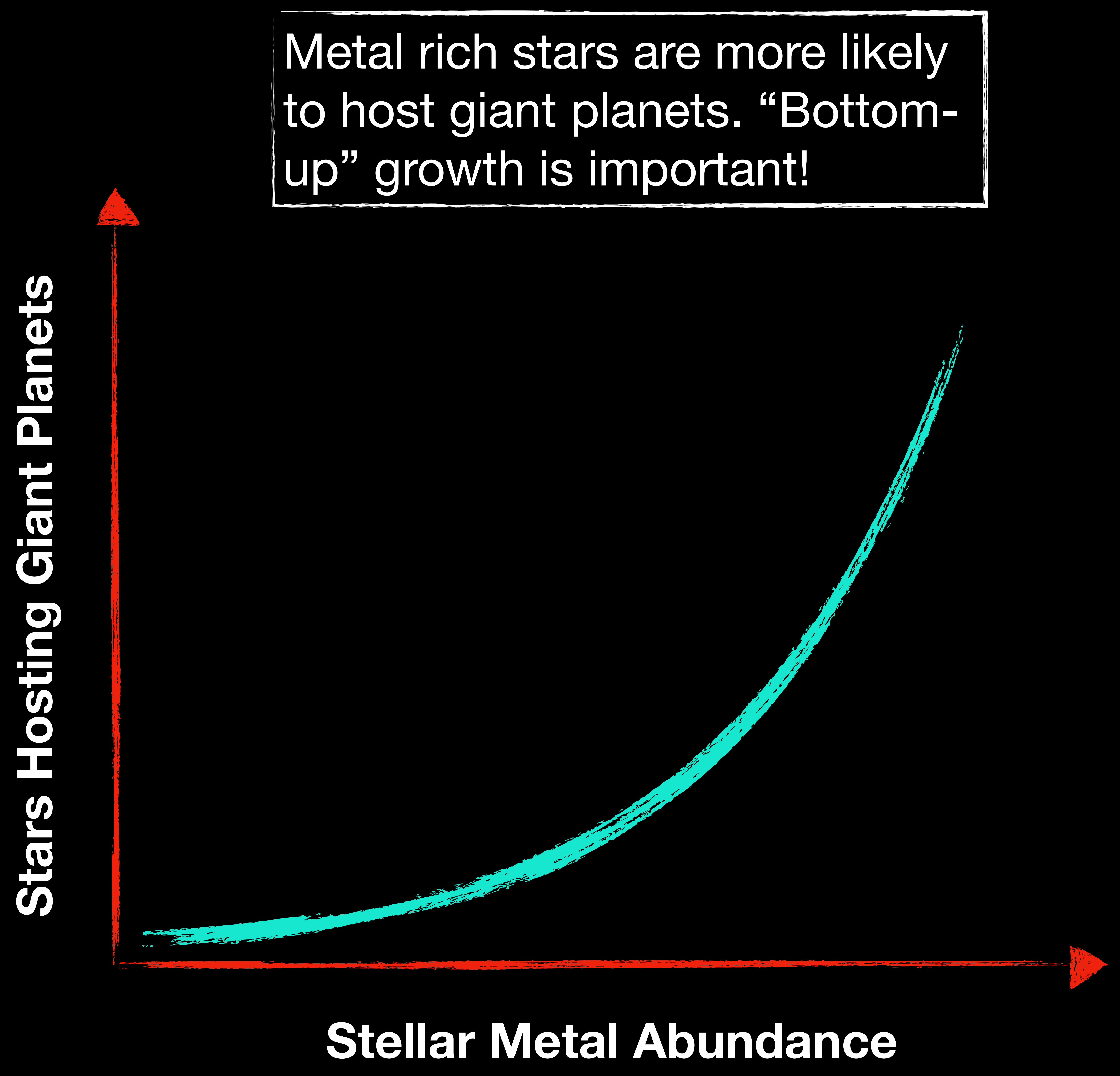


Image credits: Daria Dall`Olio

Planet Formation: Some Things We Know

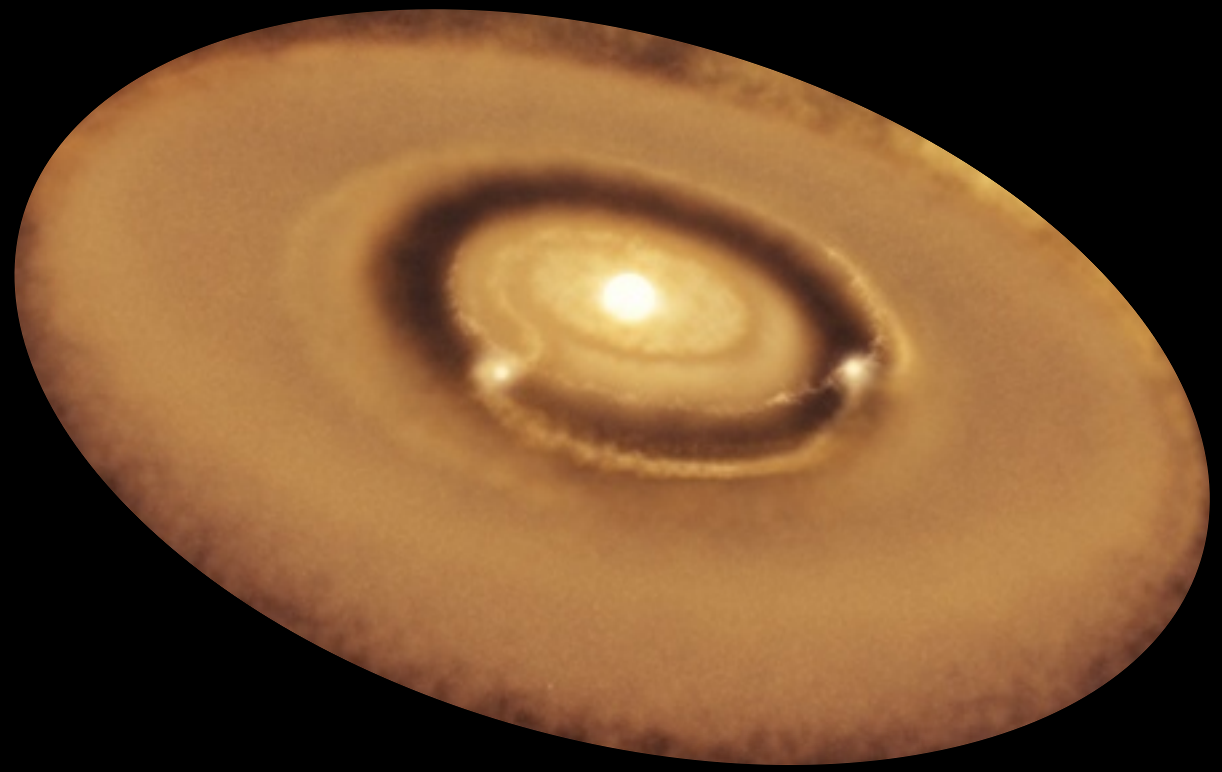




Mamajek+2009;
Fischer & Valenti 2005

Planet Formation

Some Things We Don't Know



- How fast does material fall onto a forming planet?

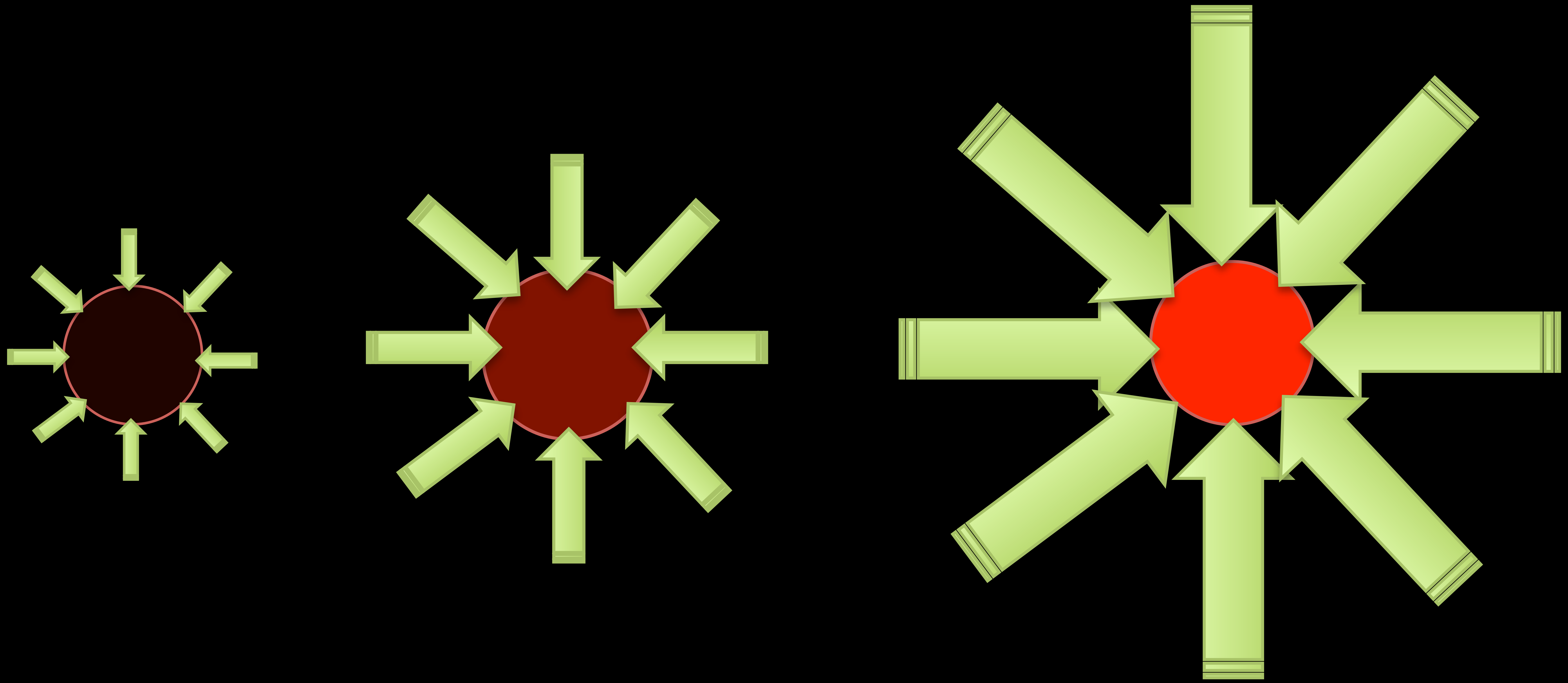
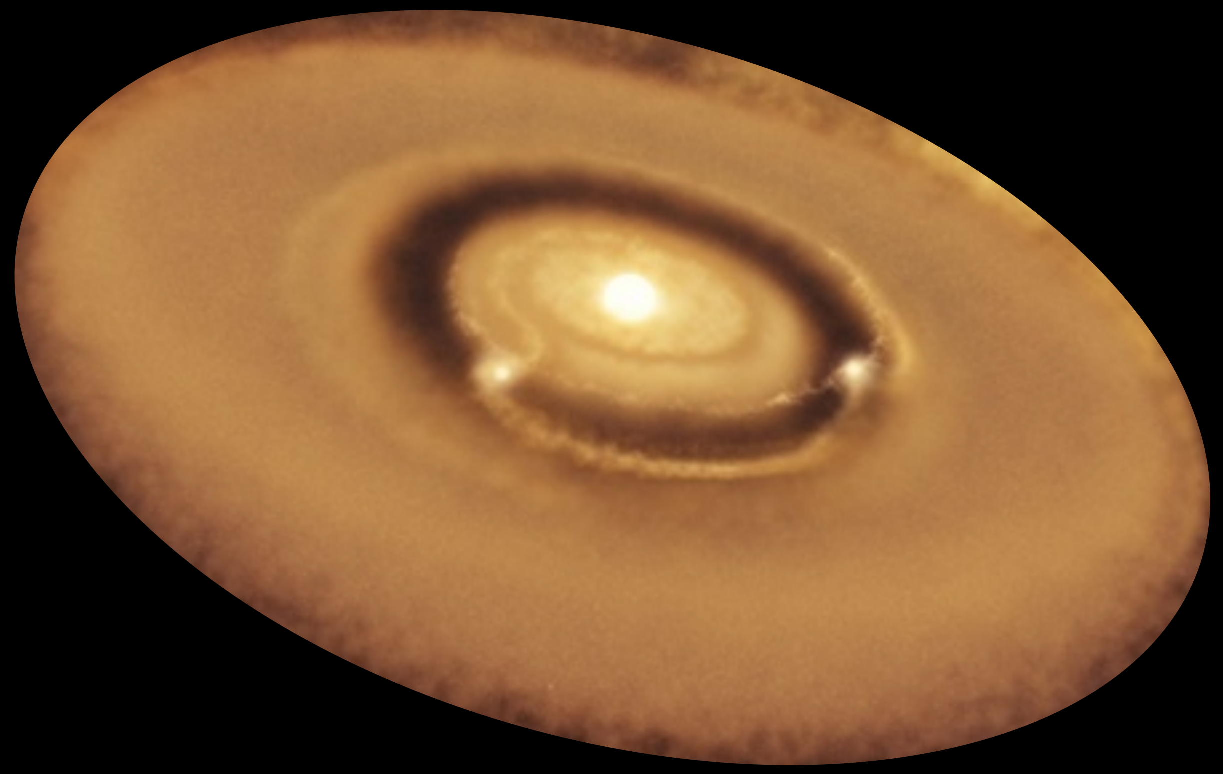


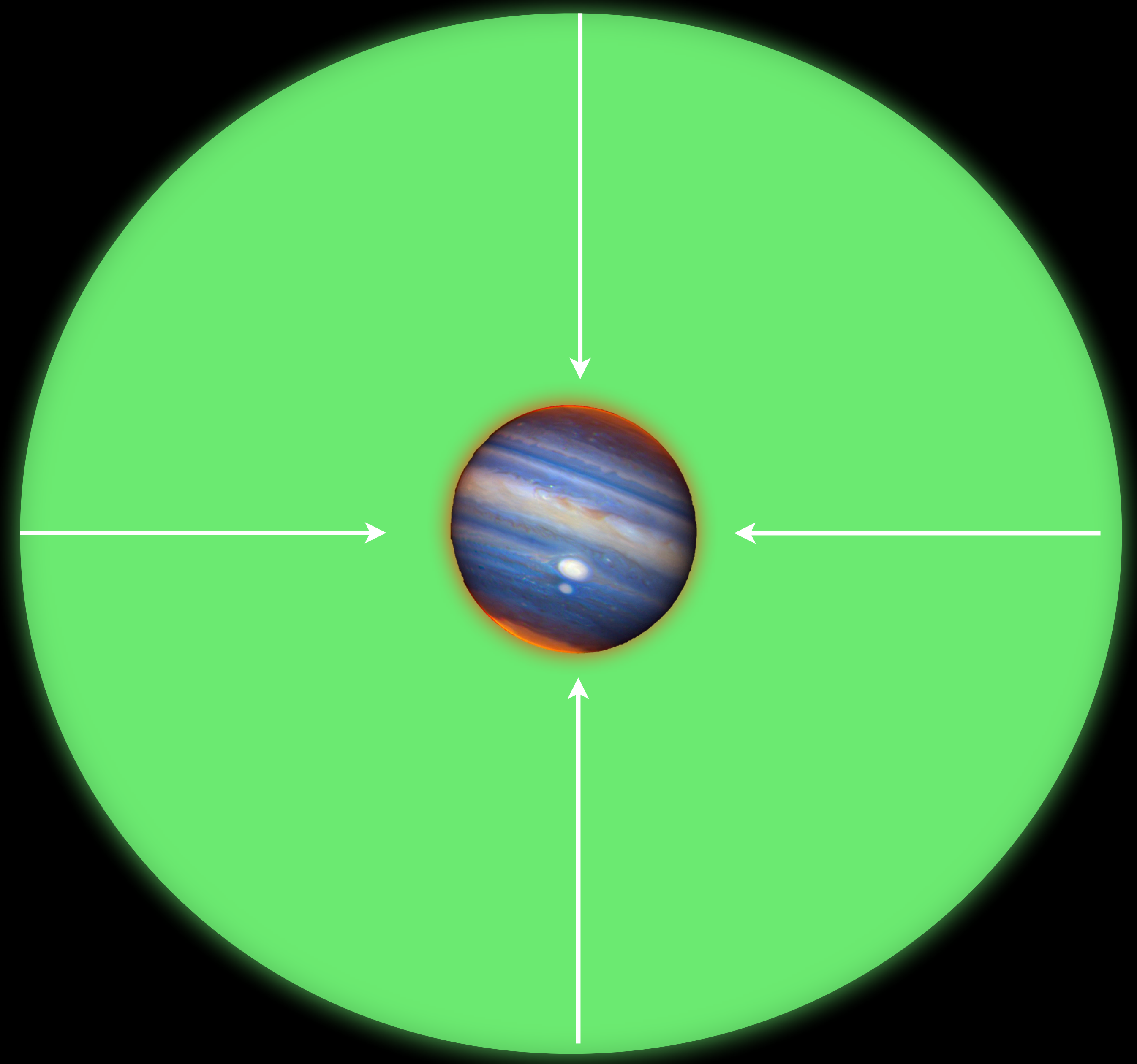
Image credits: Universe Today

Planet Formation

Some Things We Don't Know



- How fast does material fall onto a forming planet?
- What path does the infalling material take?



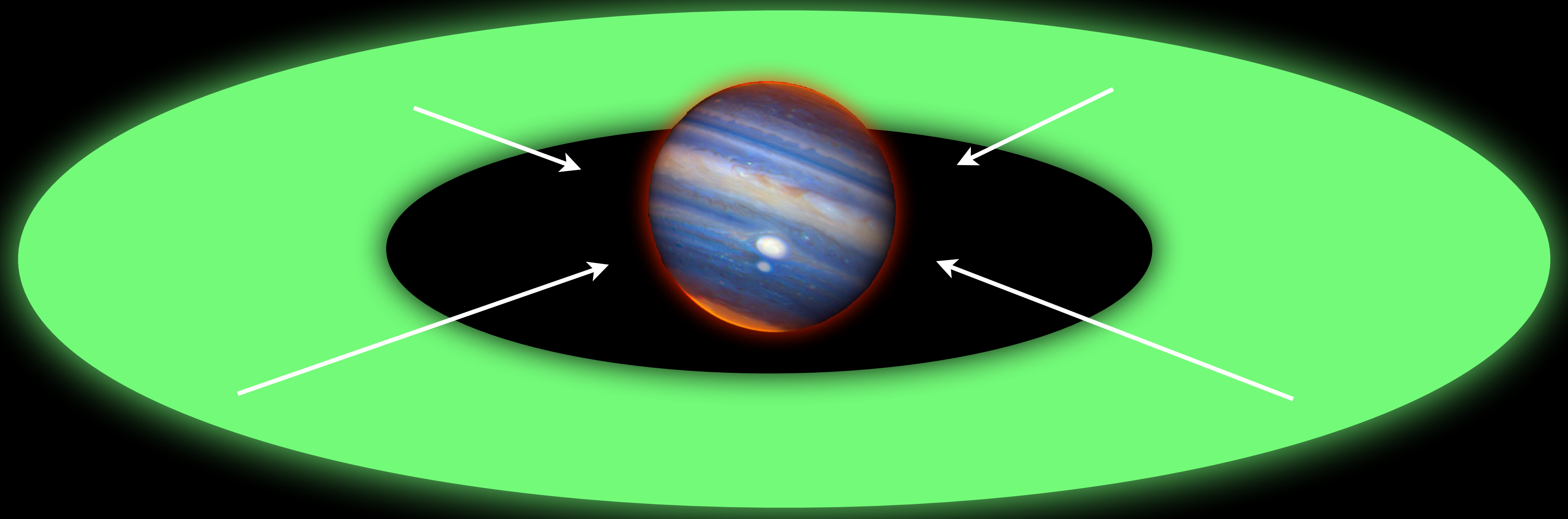
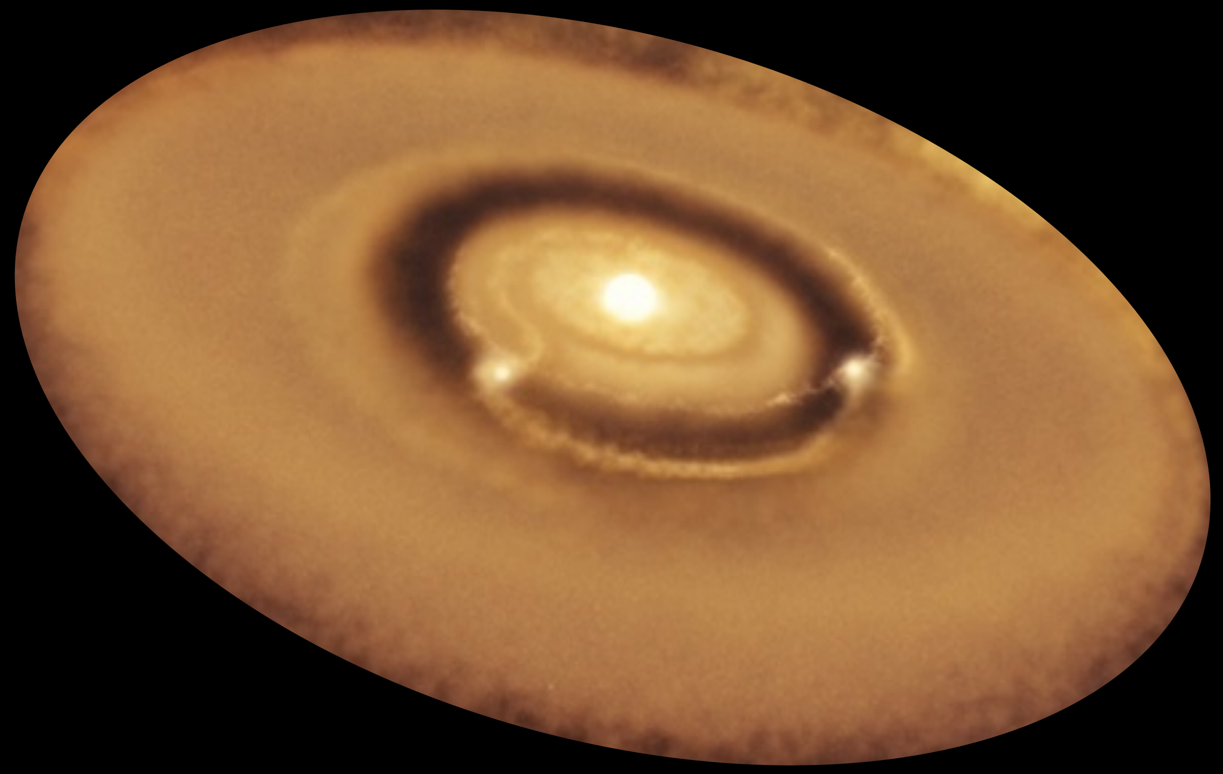


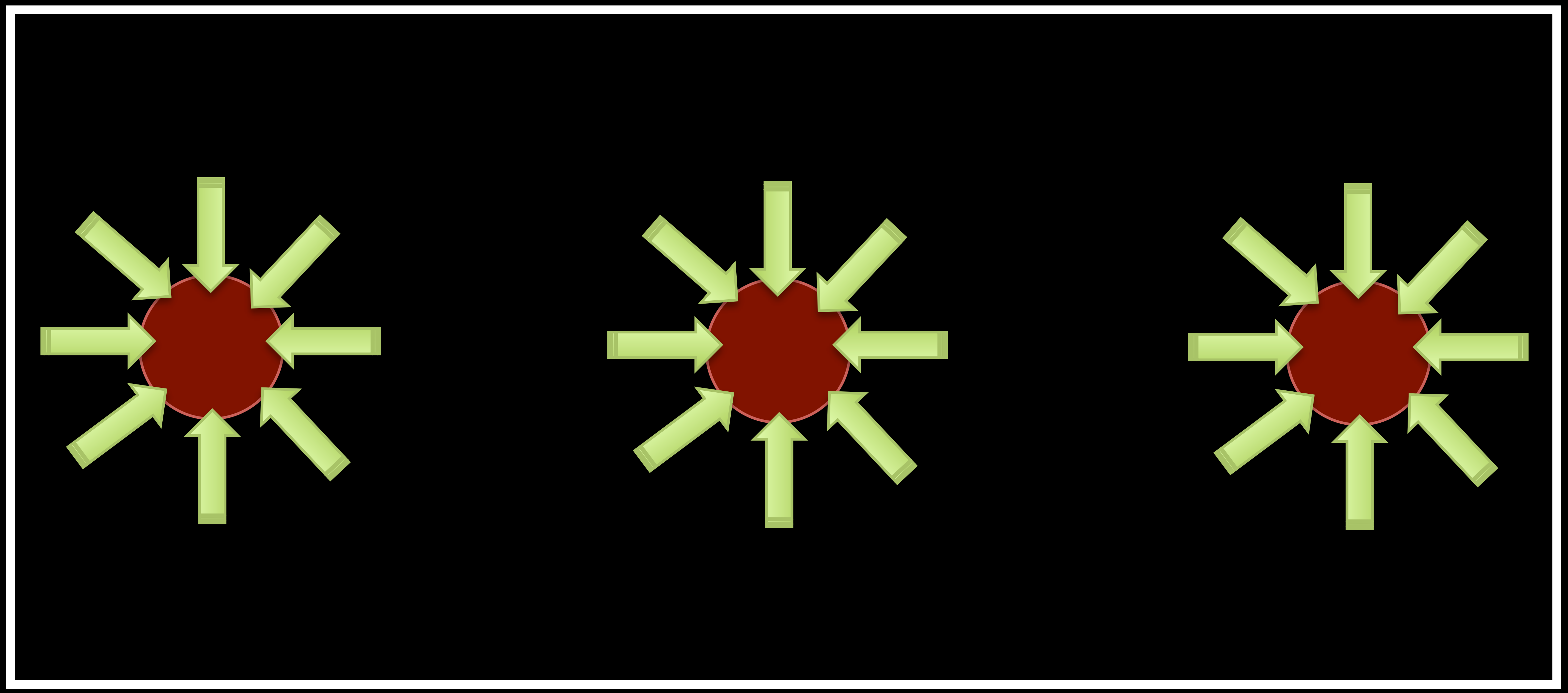
Image credits: Universe Today

Planet Formation

Some Things We Don’t Know



- How fast does material fall onto a forming planet?
- What path does the infalling material take?
- How steadily do planets accumulate mass?



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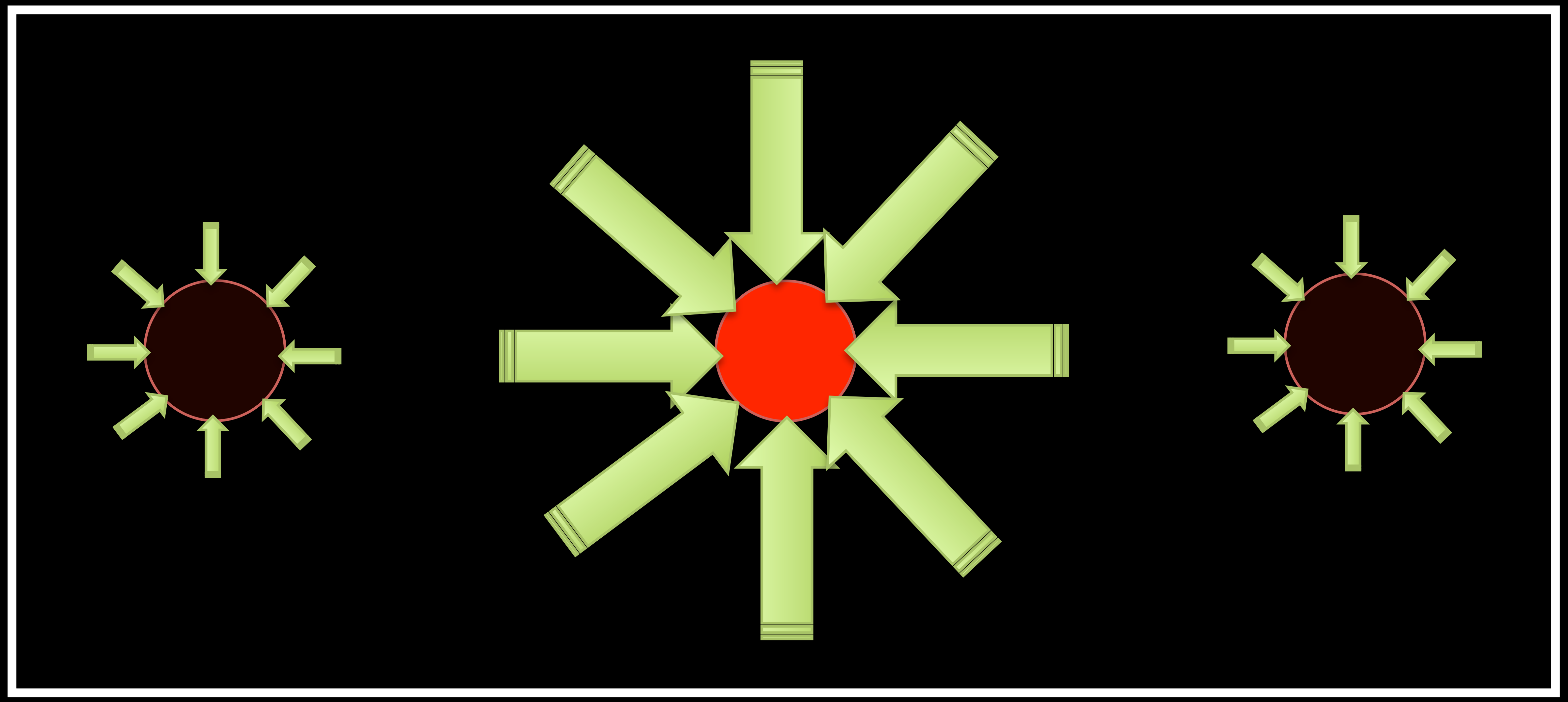
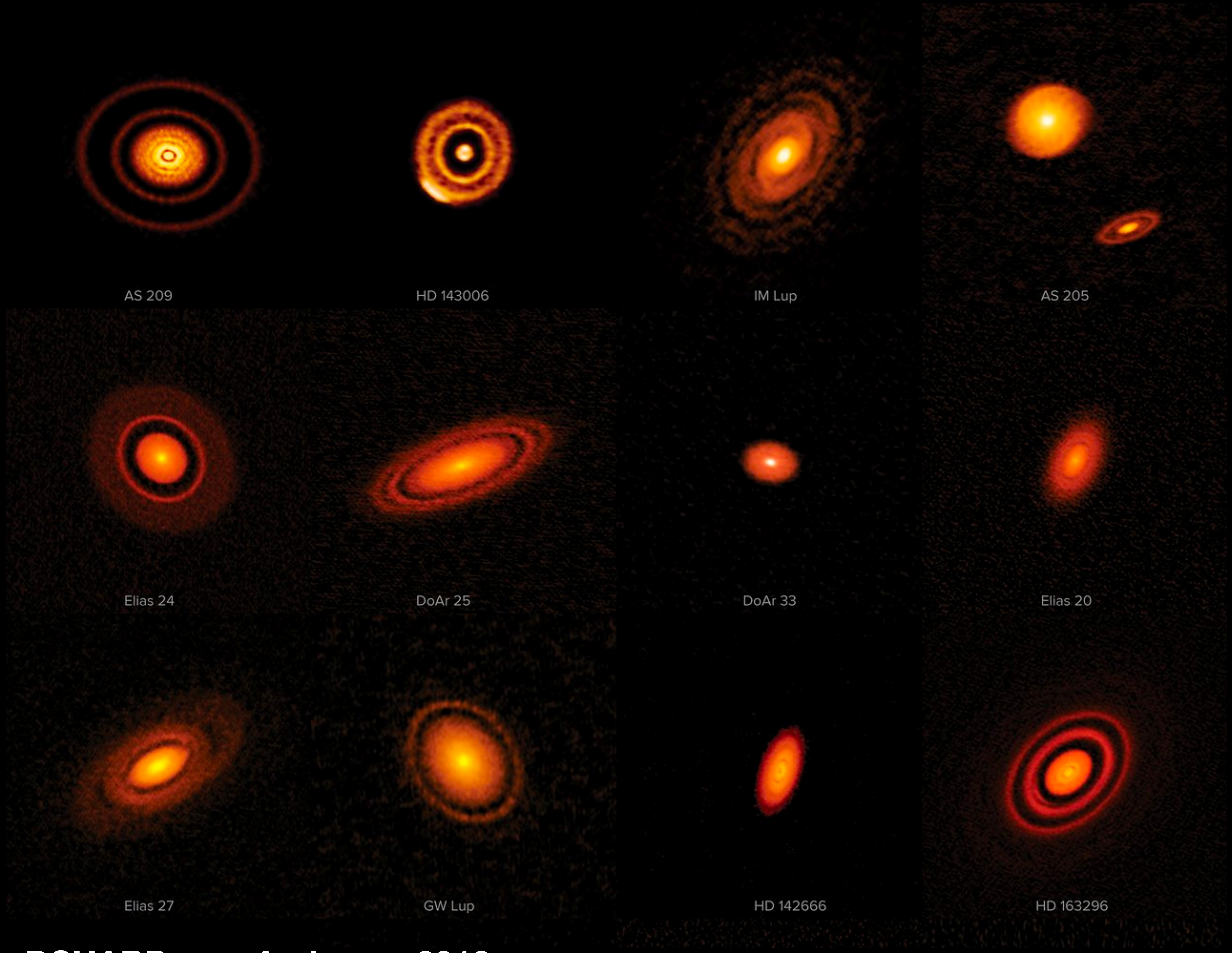
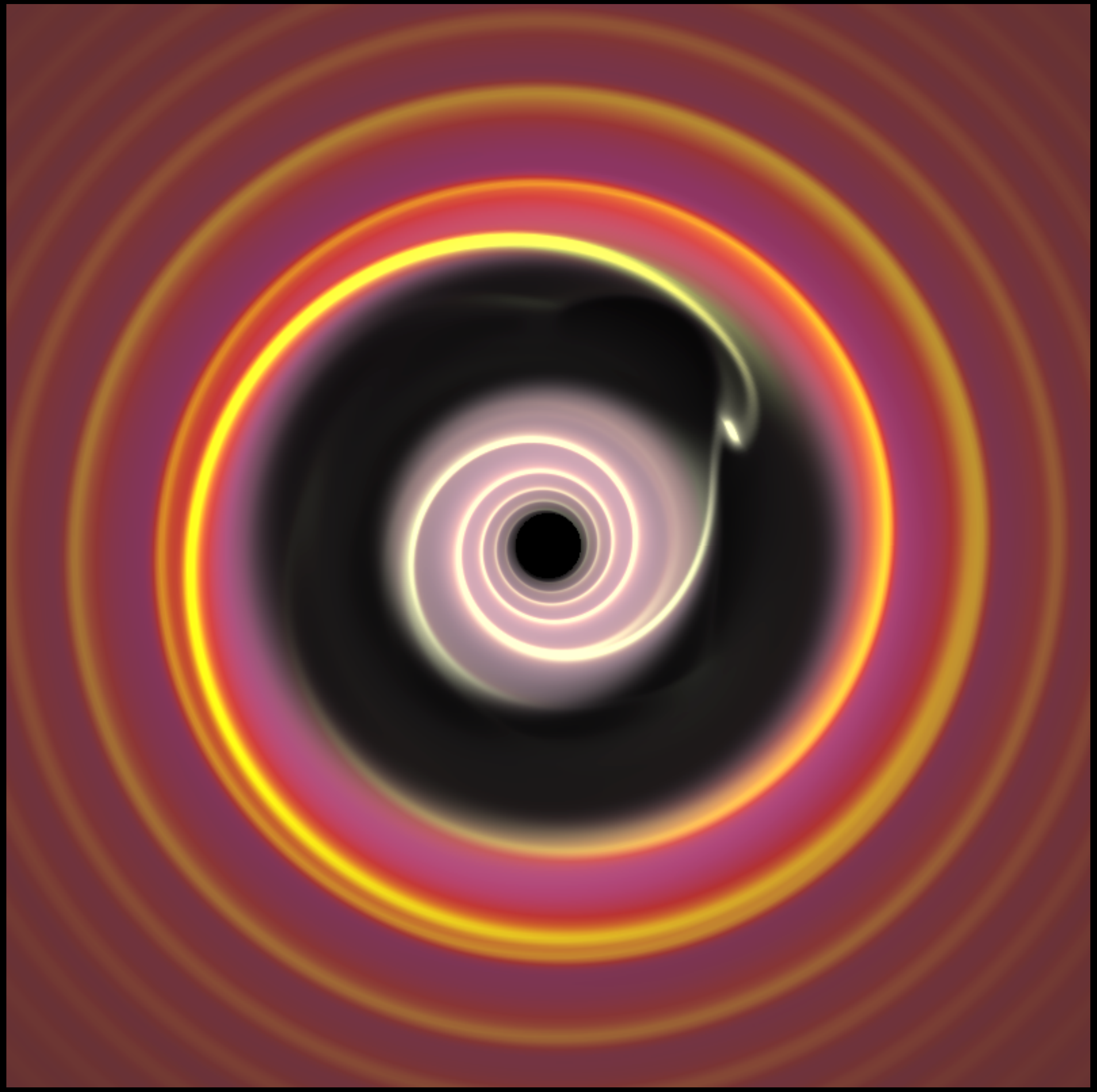


Image credits: Universe Today

Imaging Planet Formation

Imaging protoplanets: where to search

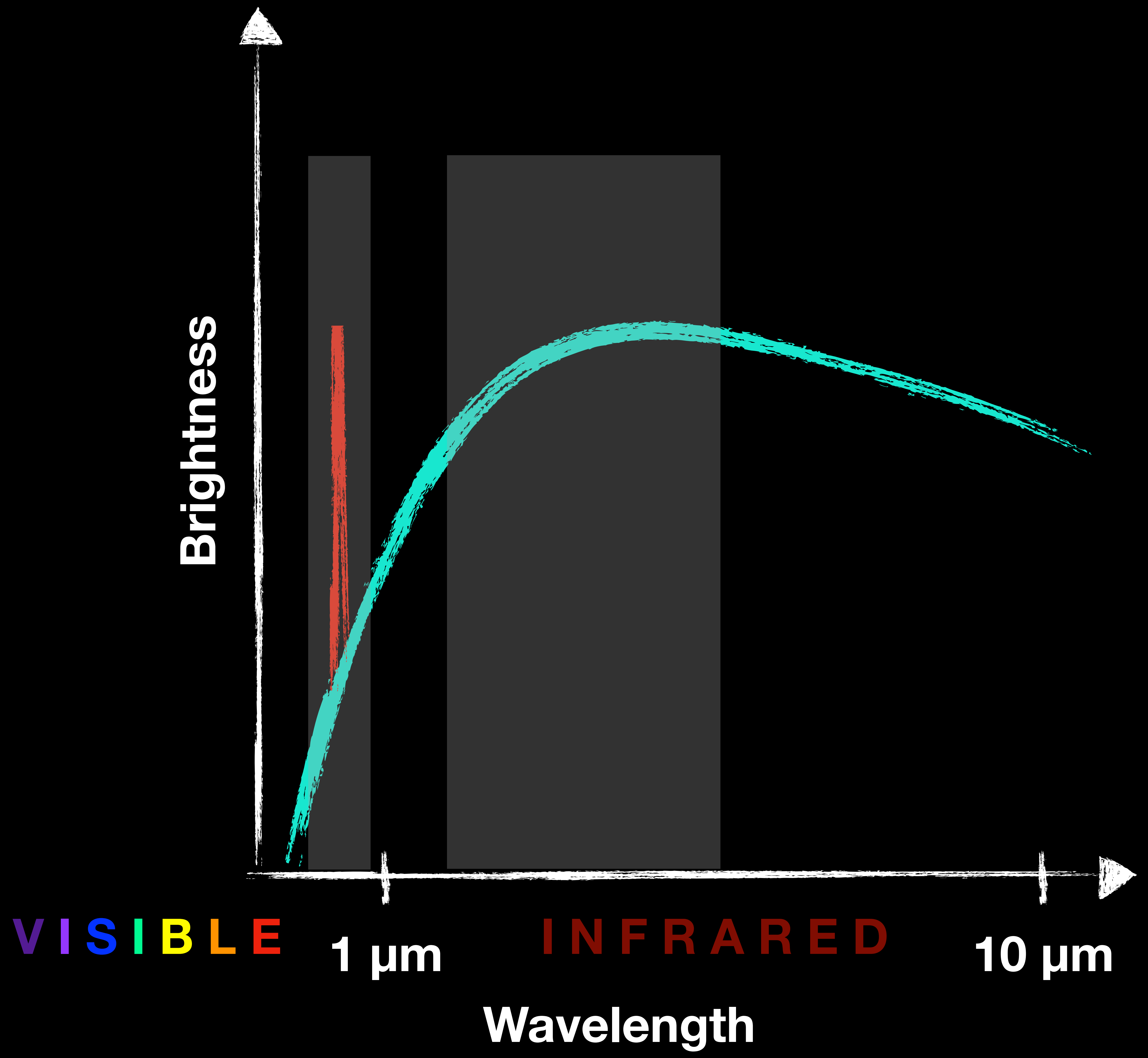


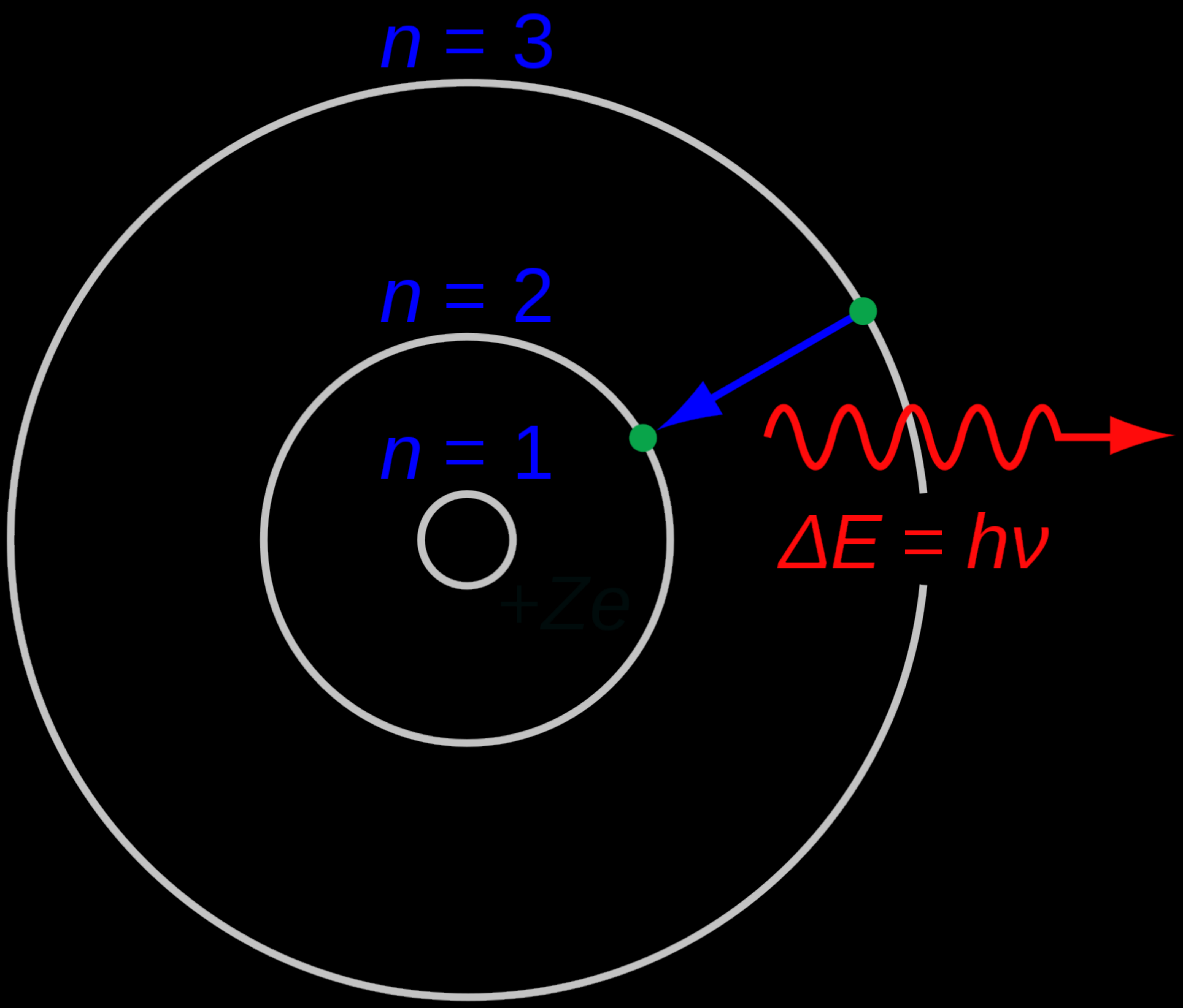


Phil Armitage

DSHARP; e.g. Andrews+2018

Imaging protoplanets: what wavelengths to use





Wikipedia: H-alpha

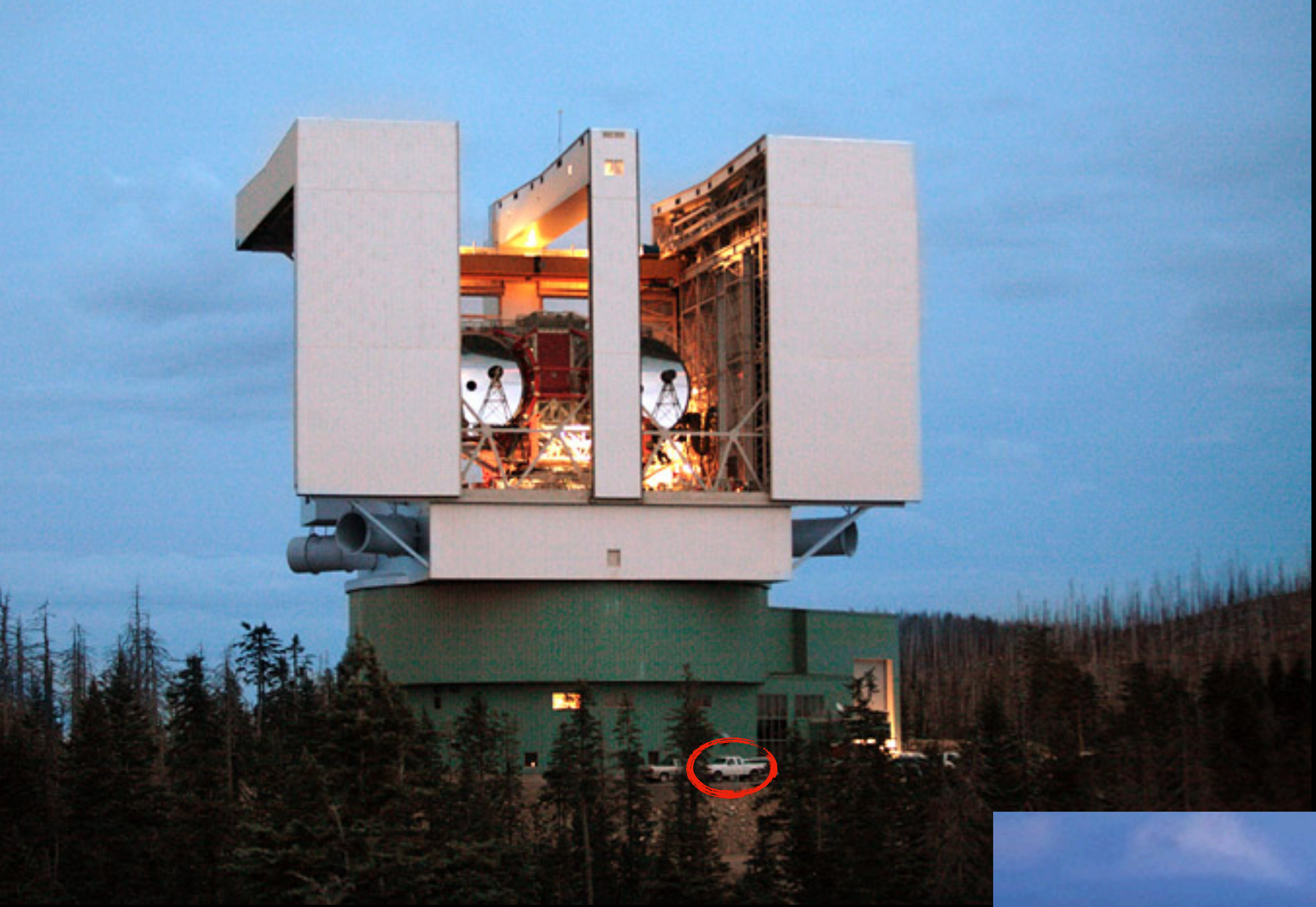
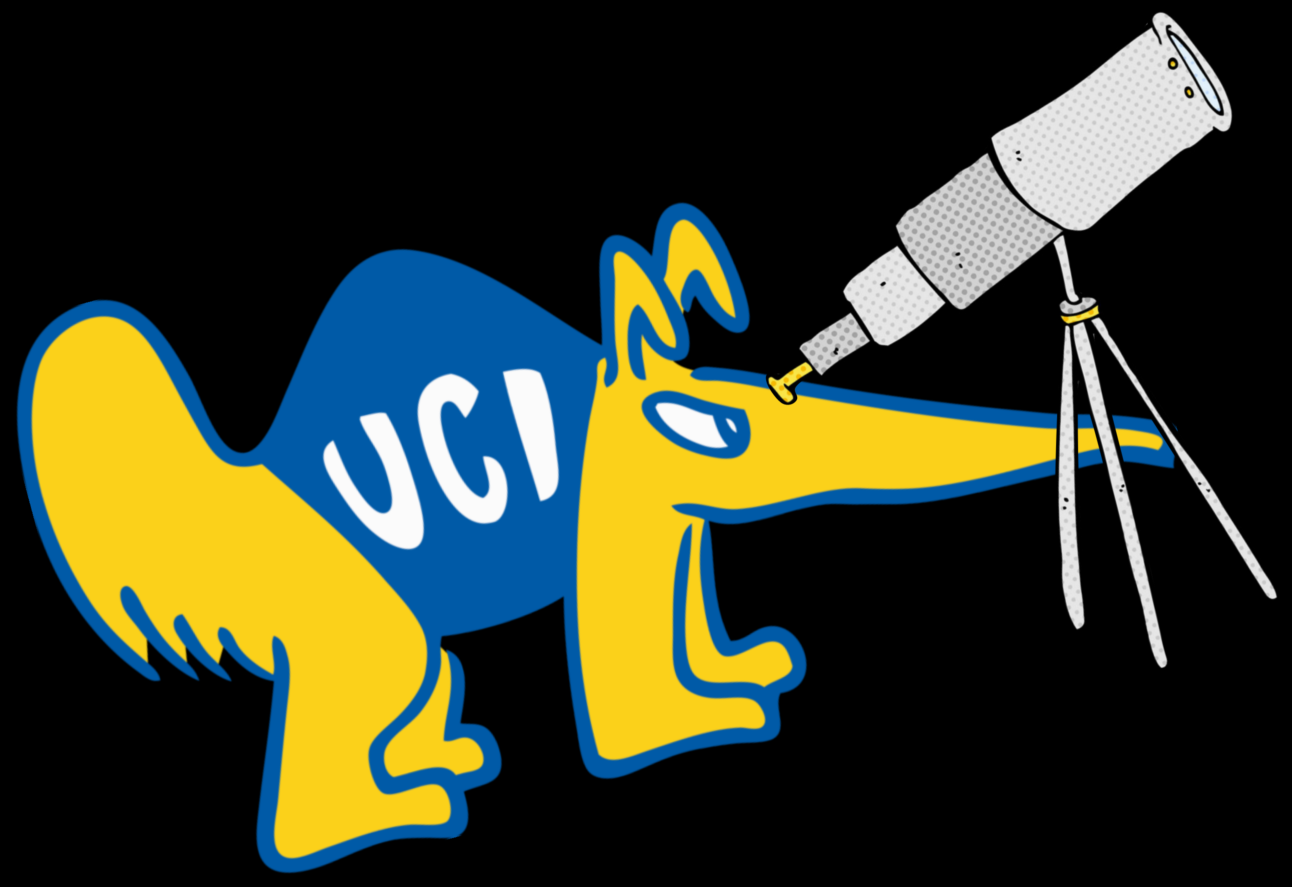
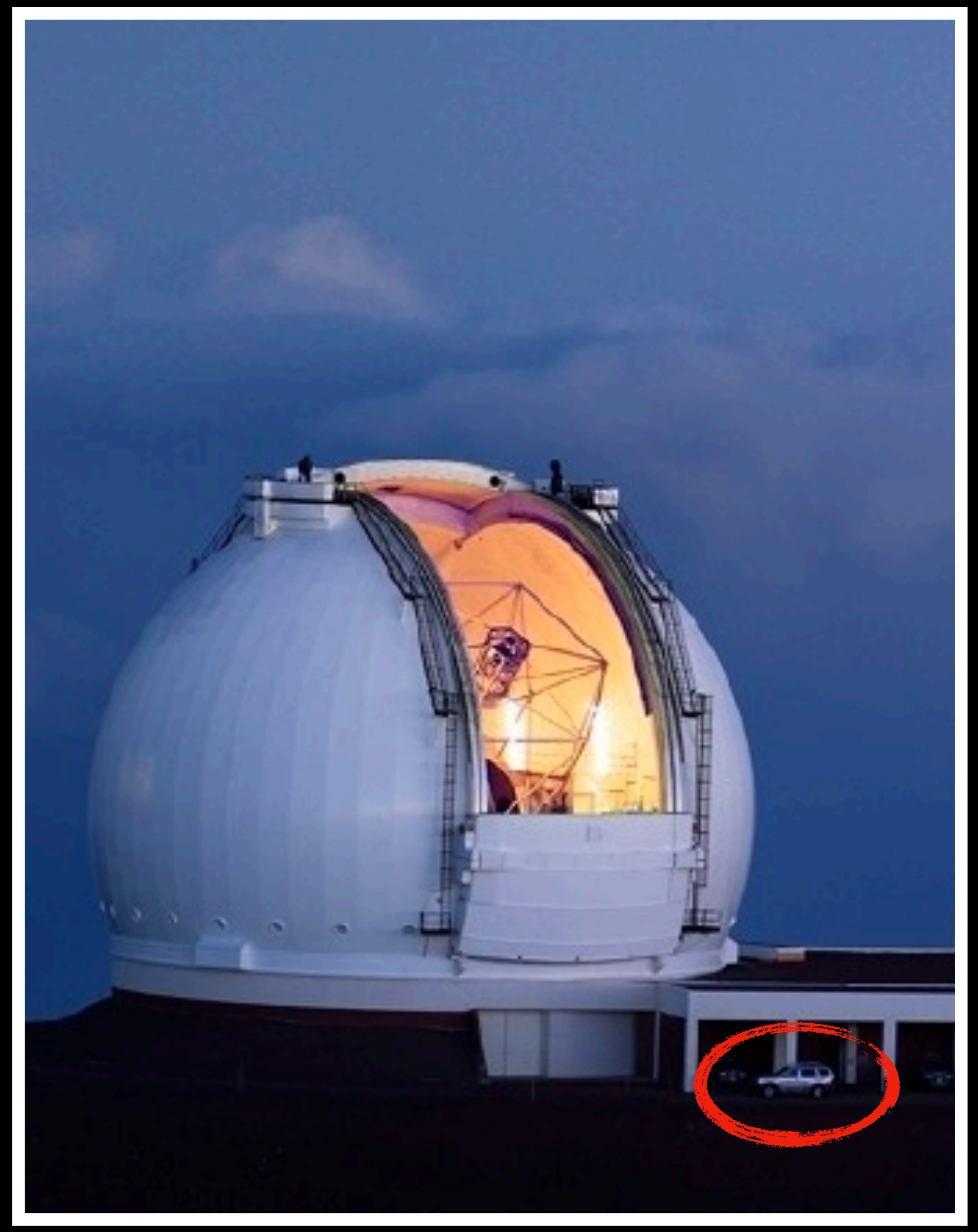


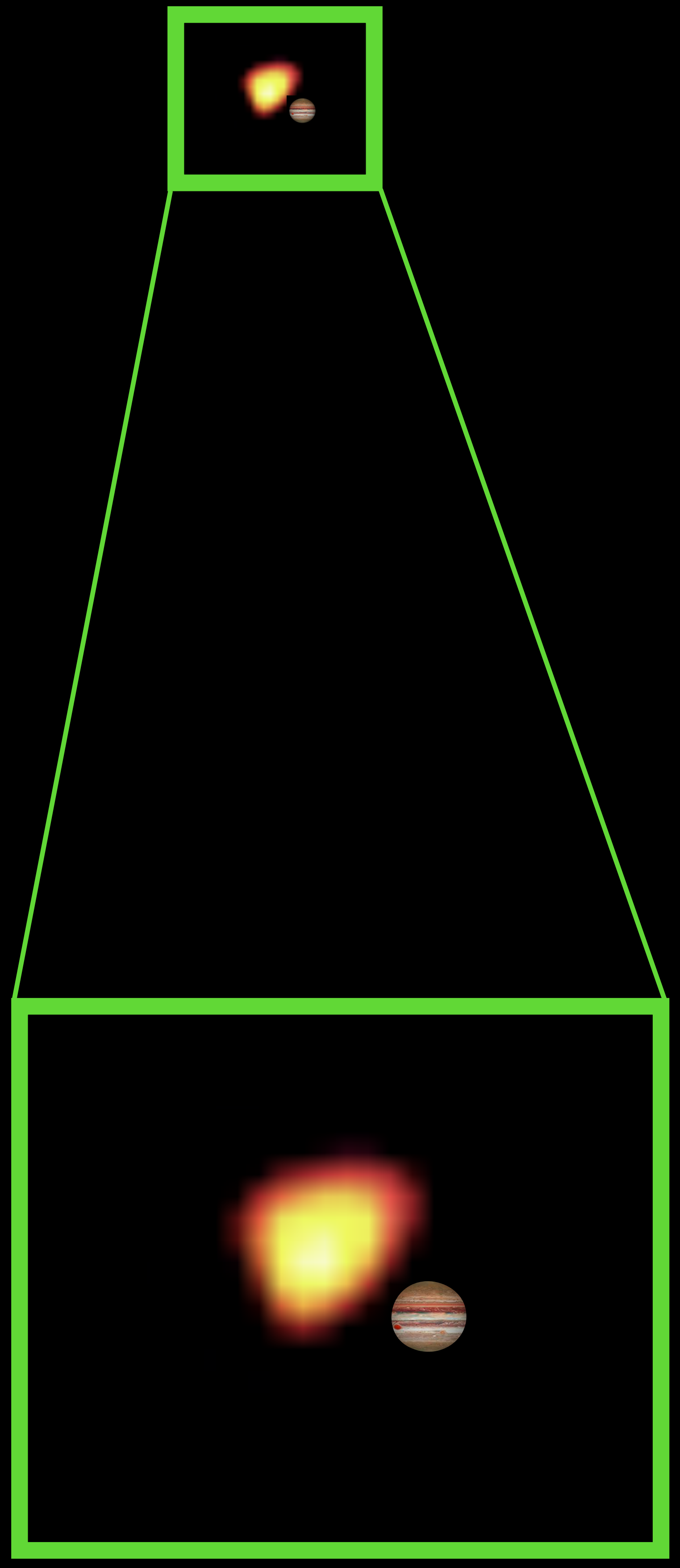
Image credit: Leibniz Institute for Astrophysics

Image credit: Keck Observatory

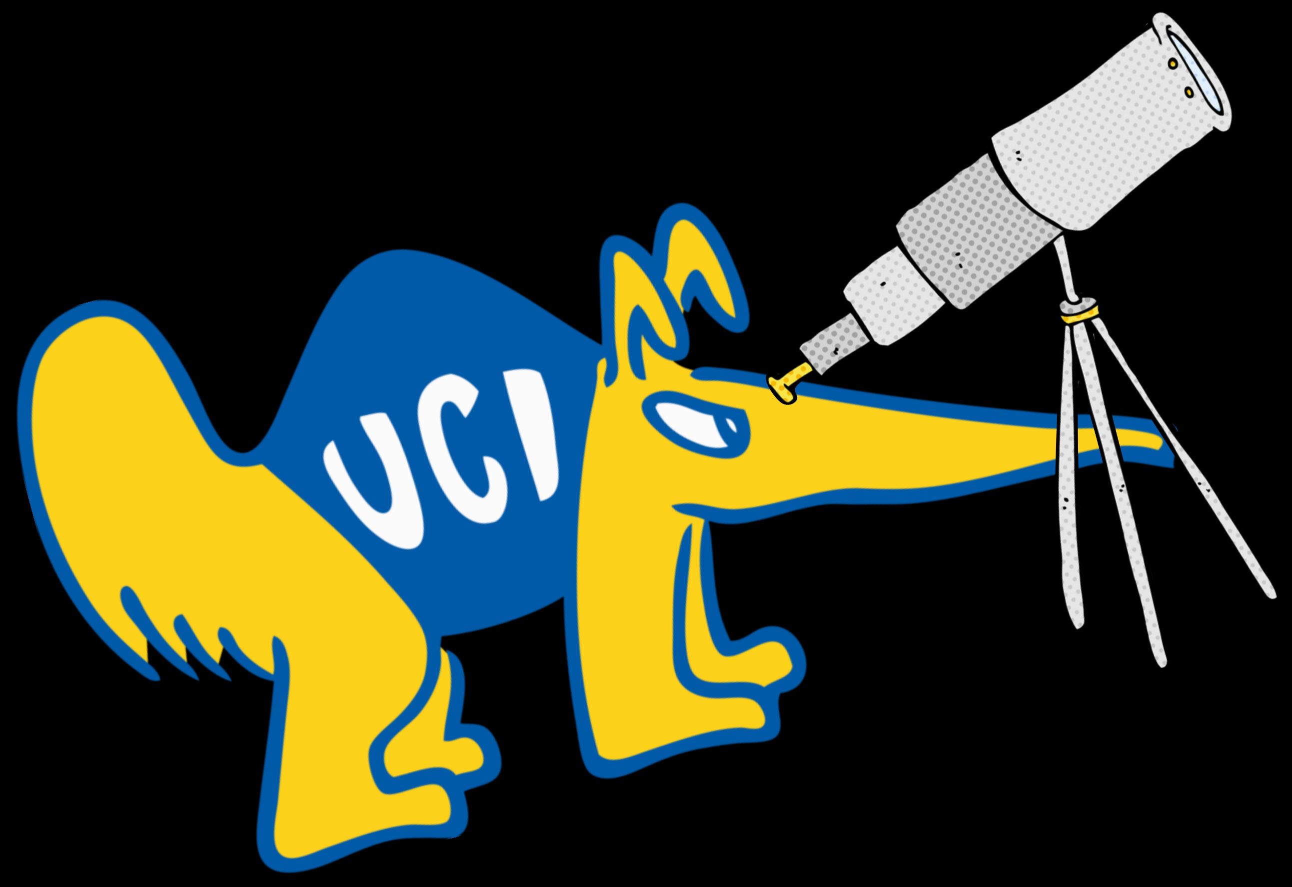
A bigger telescope means a better view…

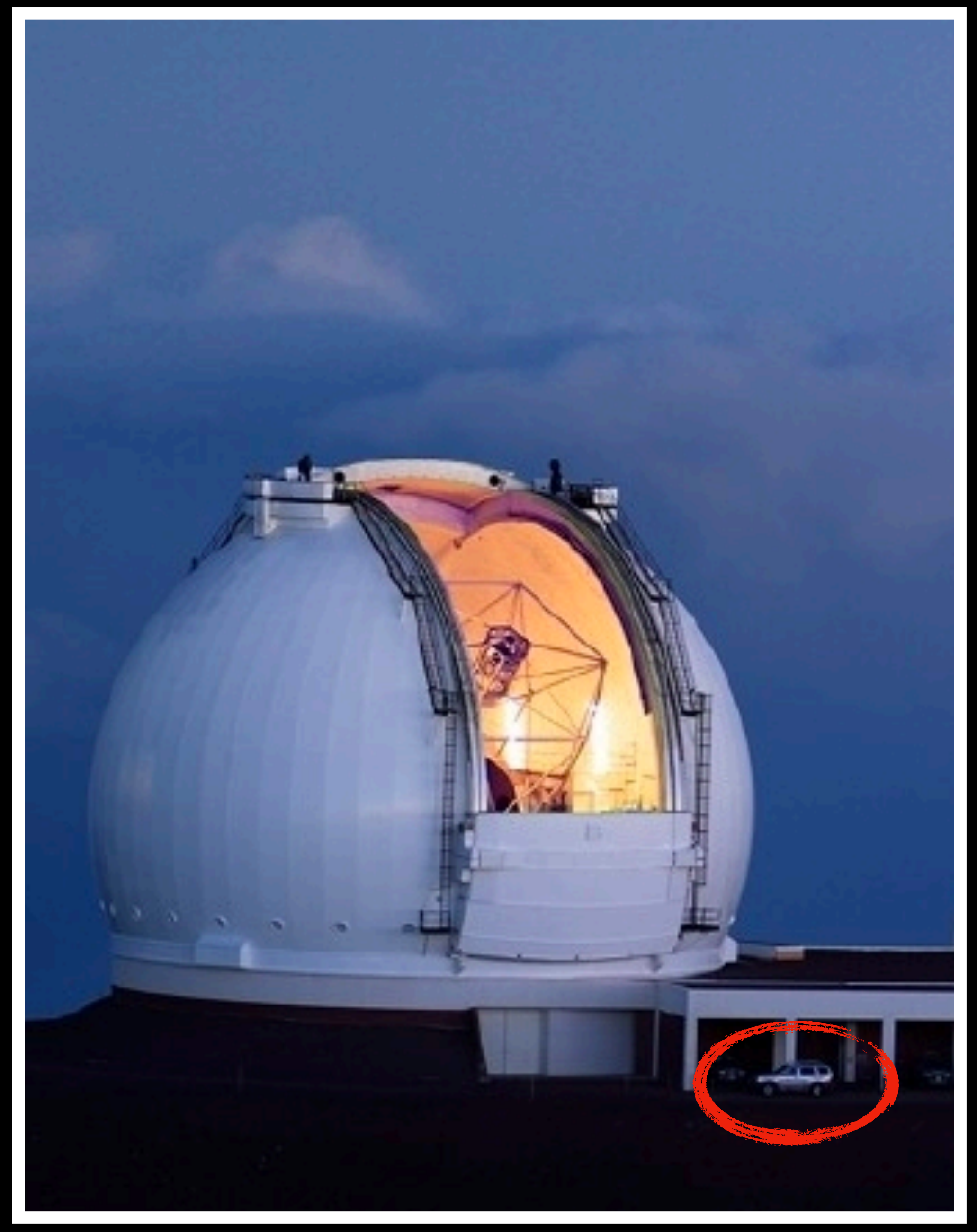


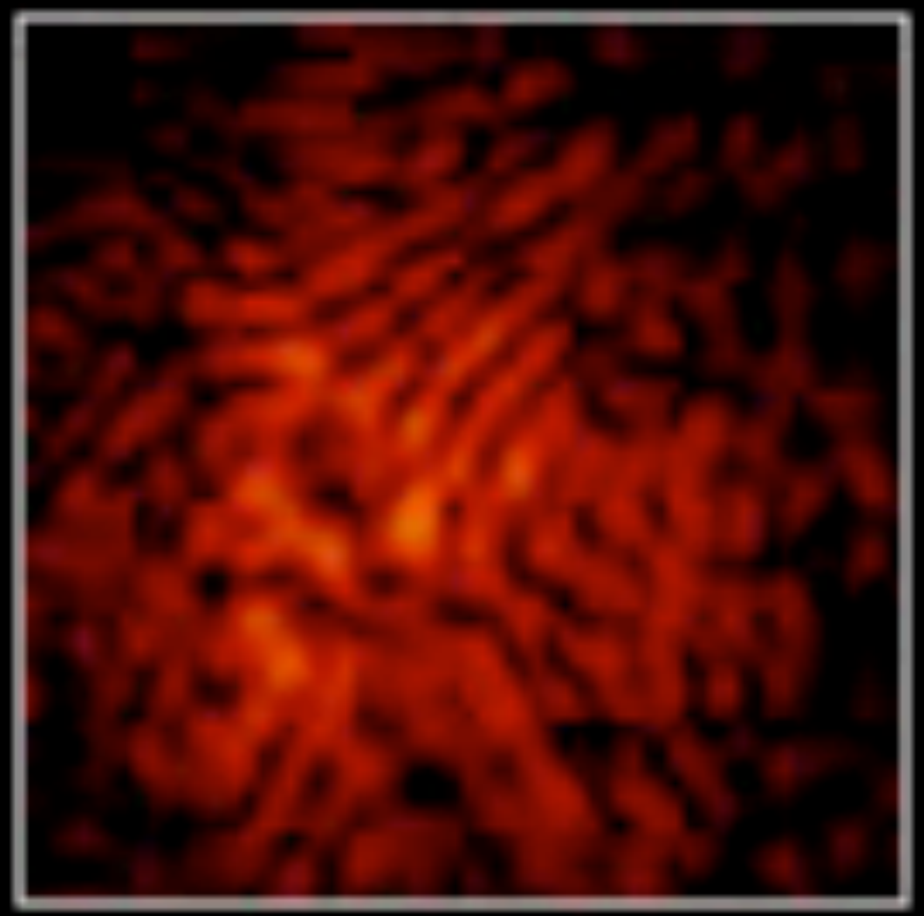




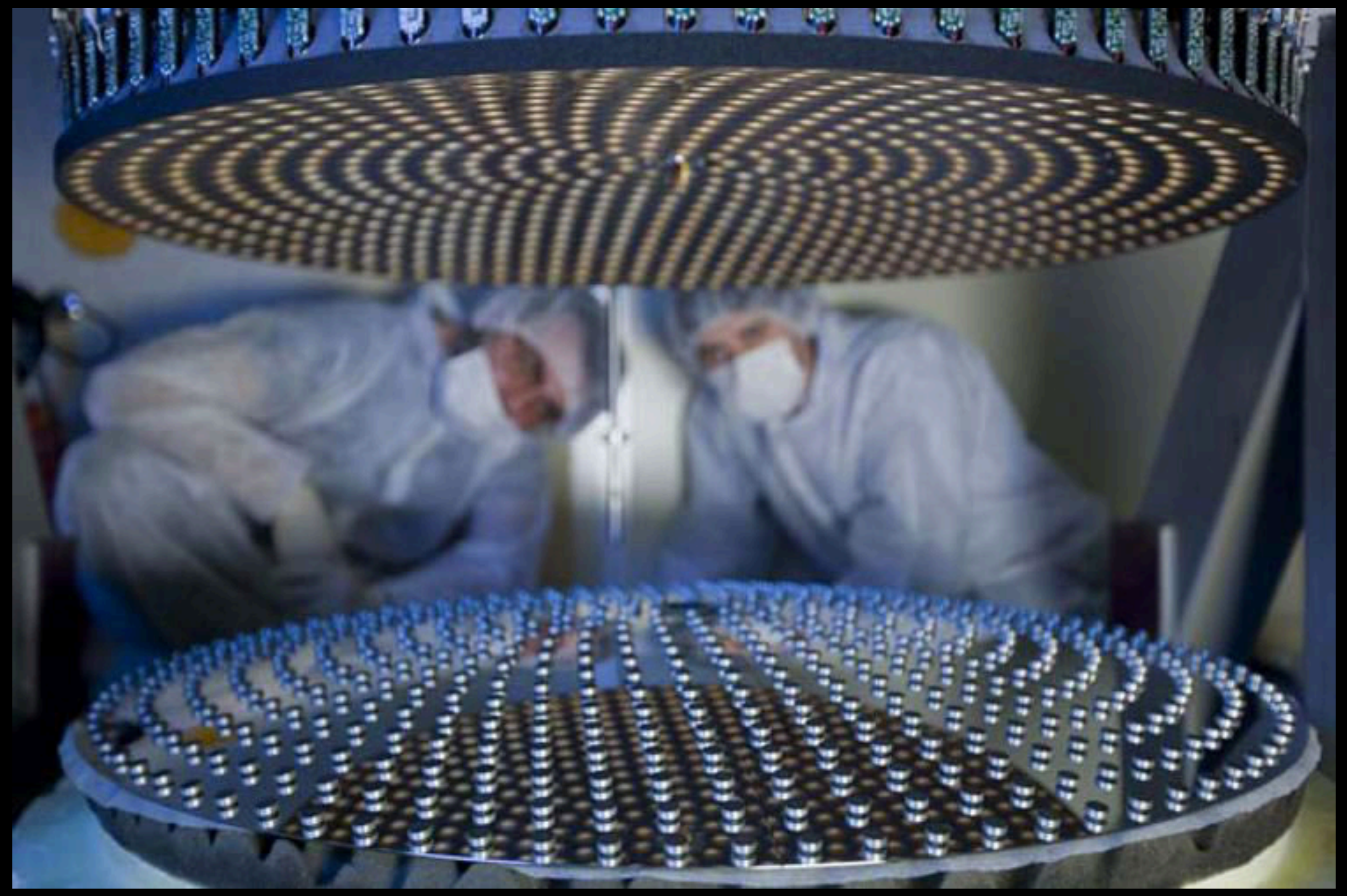
…but stars twinkle.



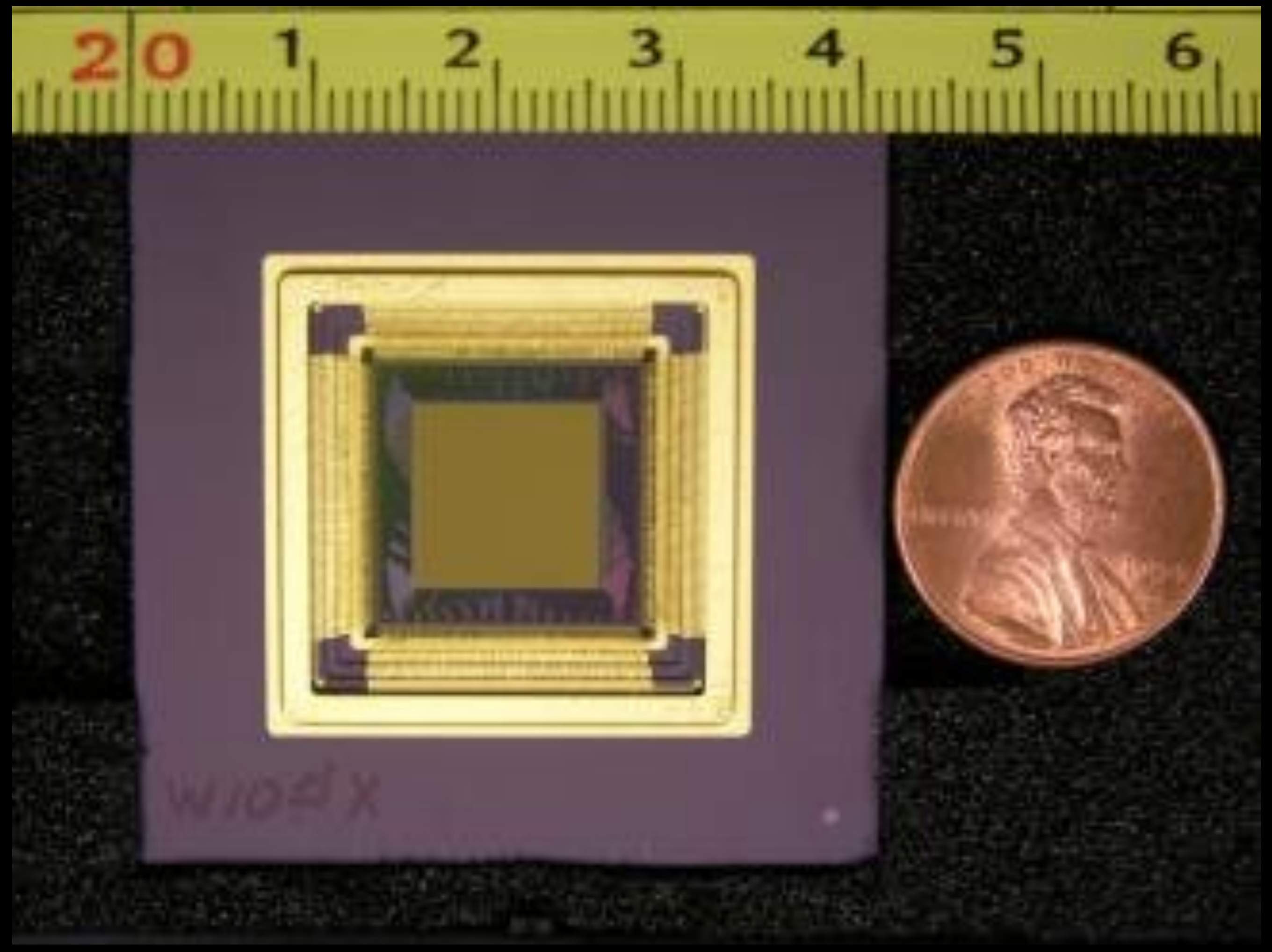




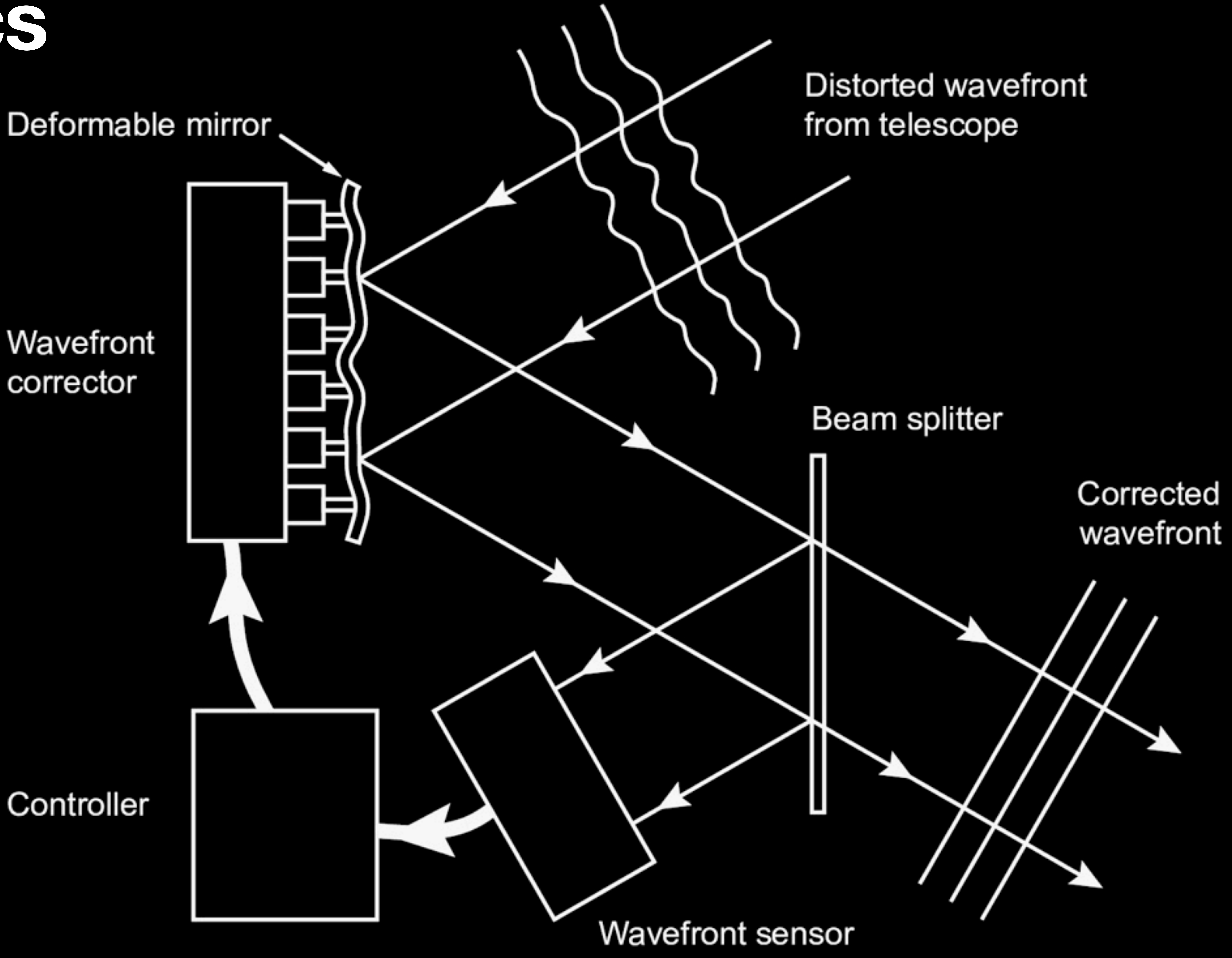
Adaptive Optics

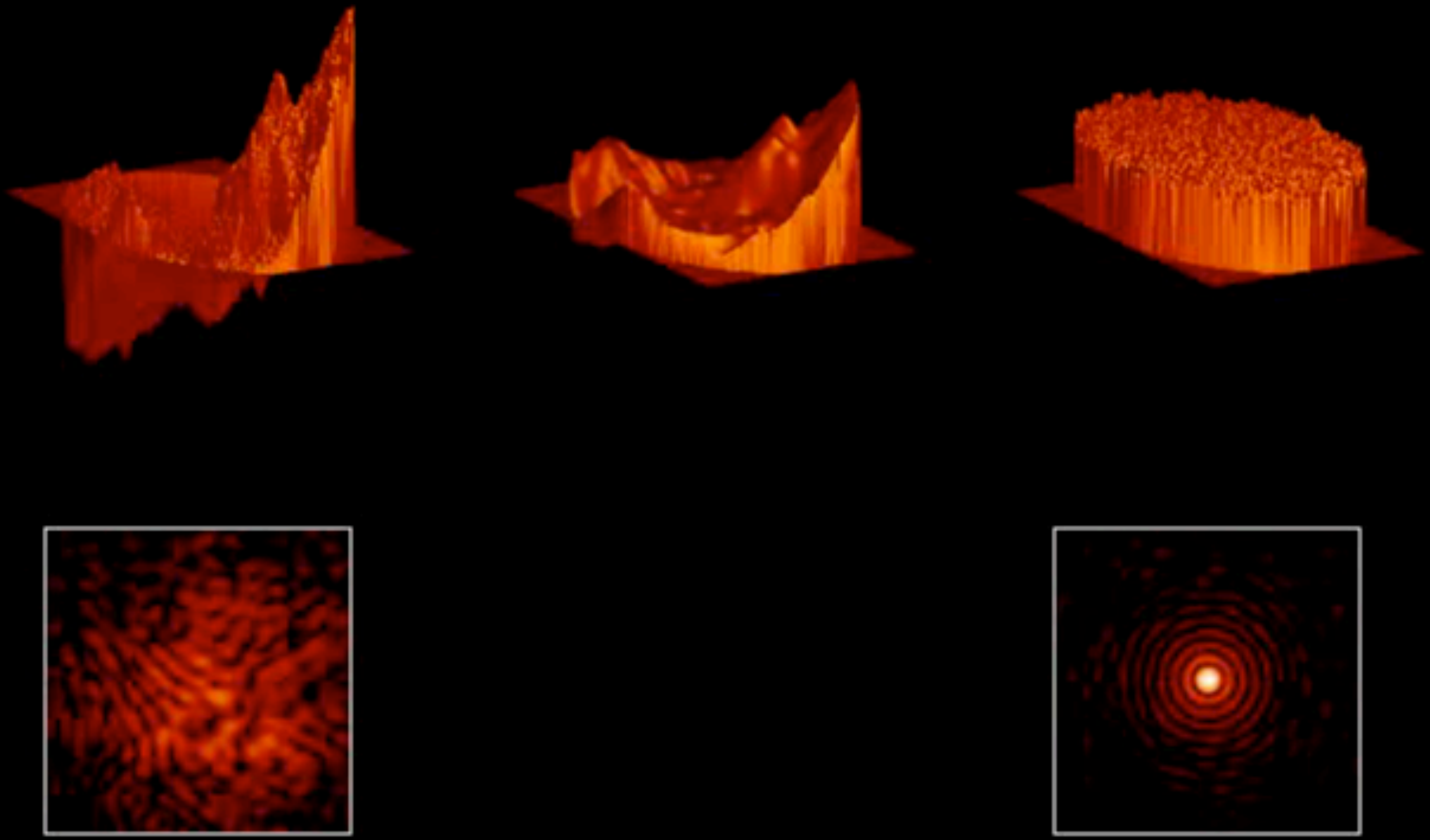


Microgate



Morzinski+2008

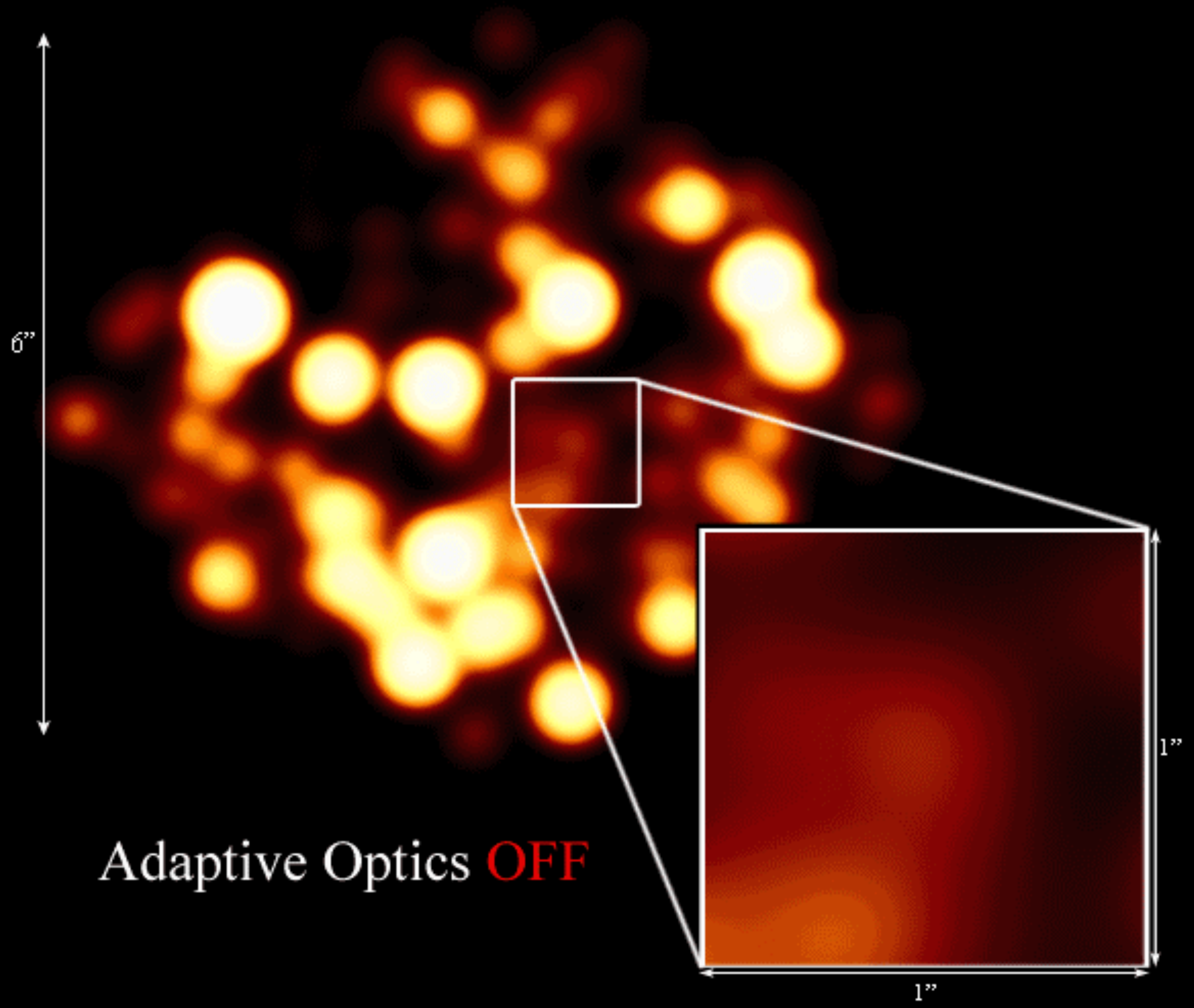




Without Adaptive Optics

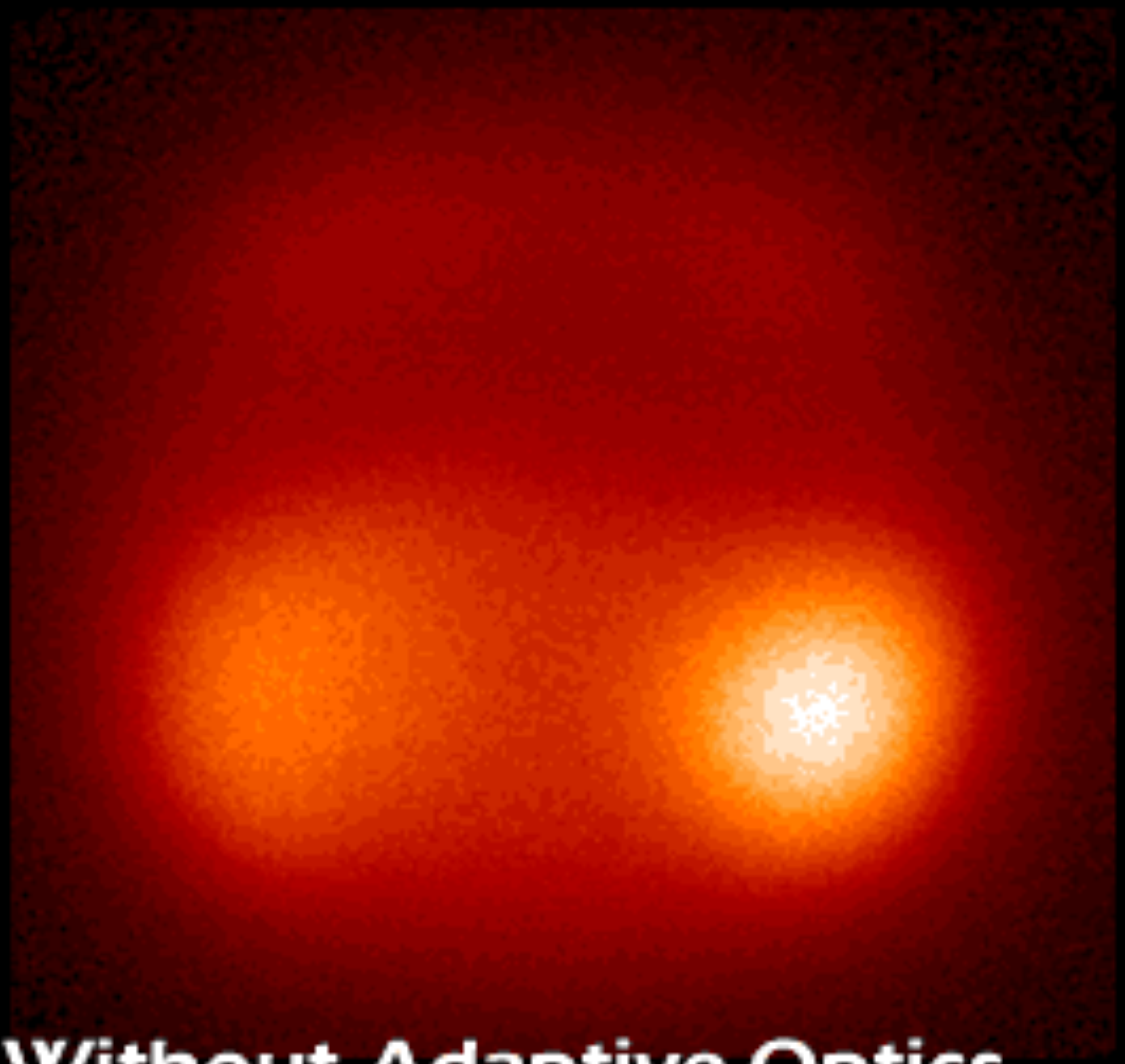
With Adaptive Optics

The Galactic Center at 2.2 microns



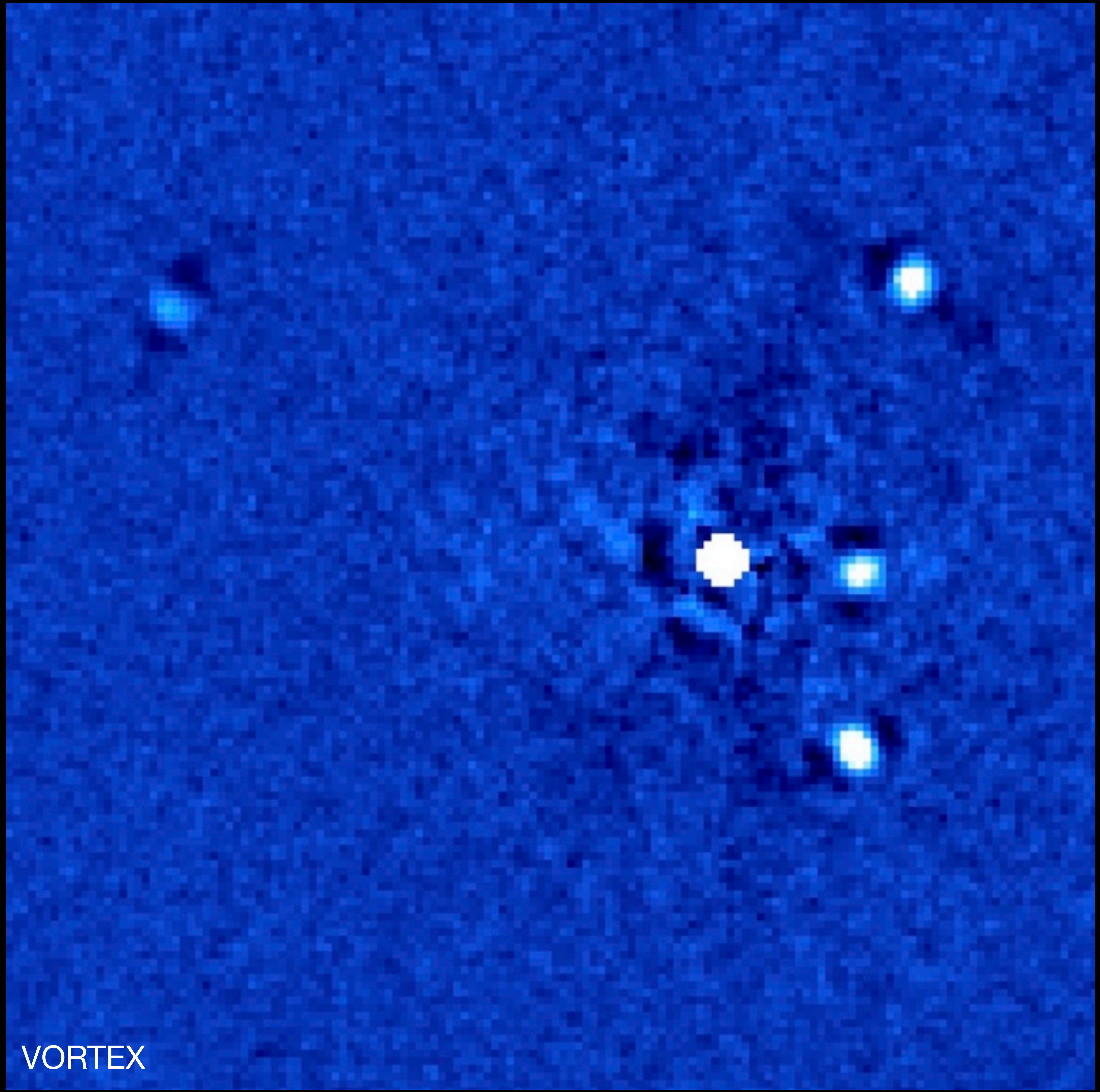
Adaptive Optics OFF

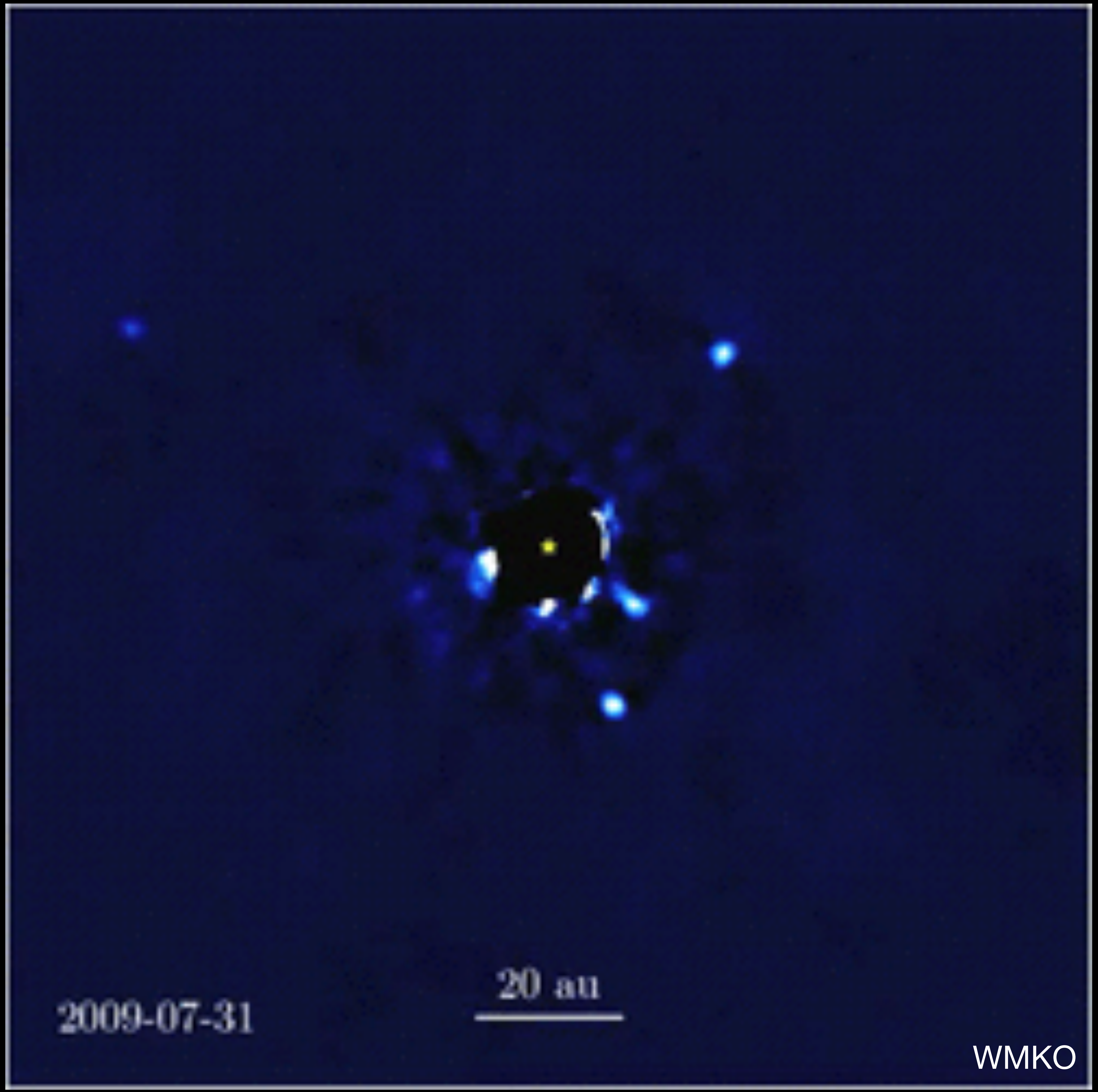
Neptune at 2.2 microns



Without Adaptive Optics

Directly Imaged Exoplanets





How faint is a fully-formed exoplanet?

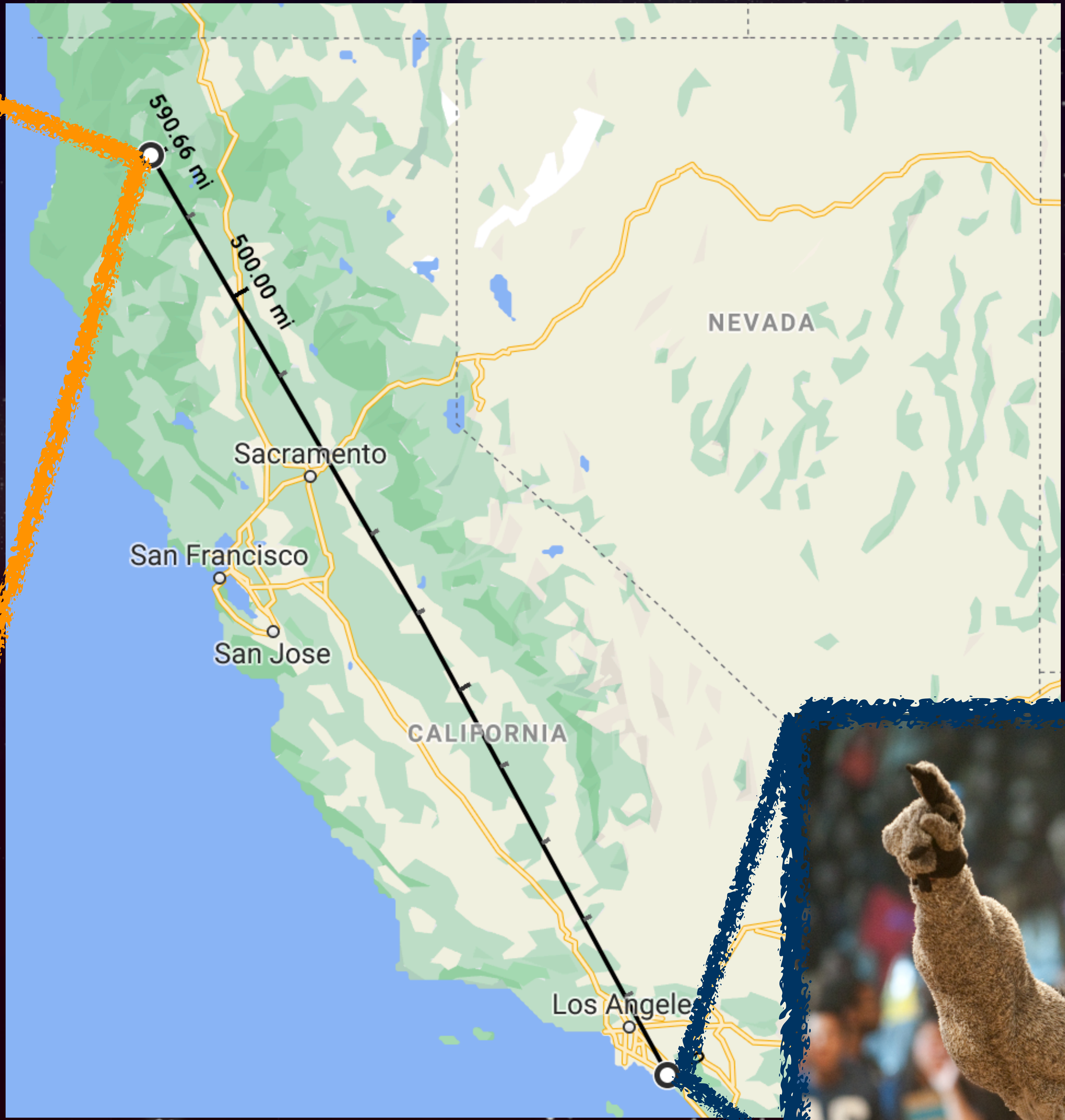
Typical giant exoplanets are 1 MILLION times fainter than the stars they orbit!

How faint is a forming exoplanet?

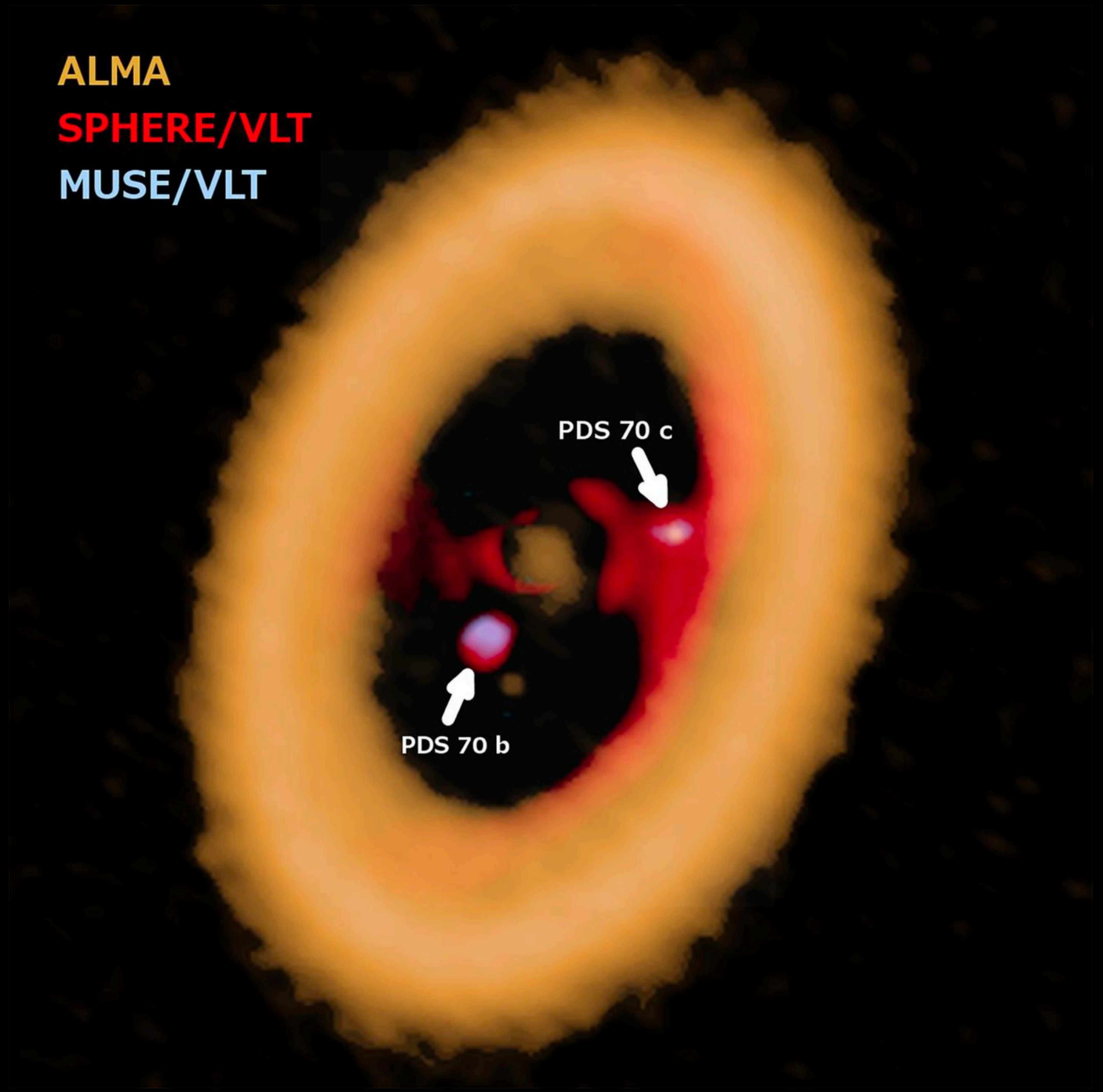
Forming giant planets are 1 HUNDRED to 10 THOUSAND times fainter than the stars they orbit!

Young stars are really far away!

What does that mean?



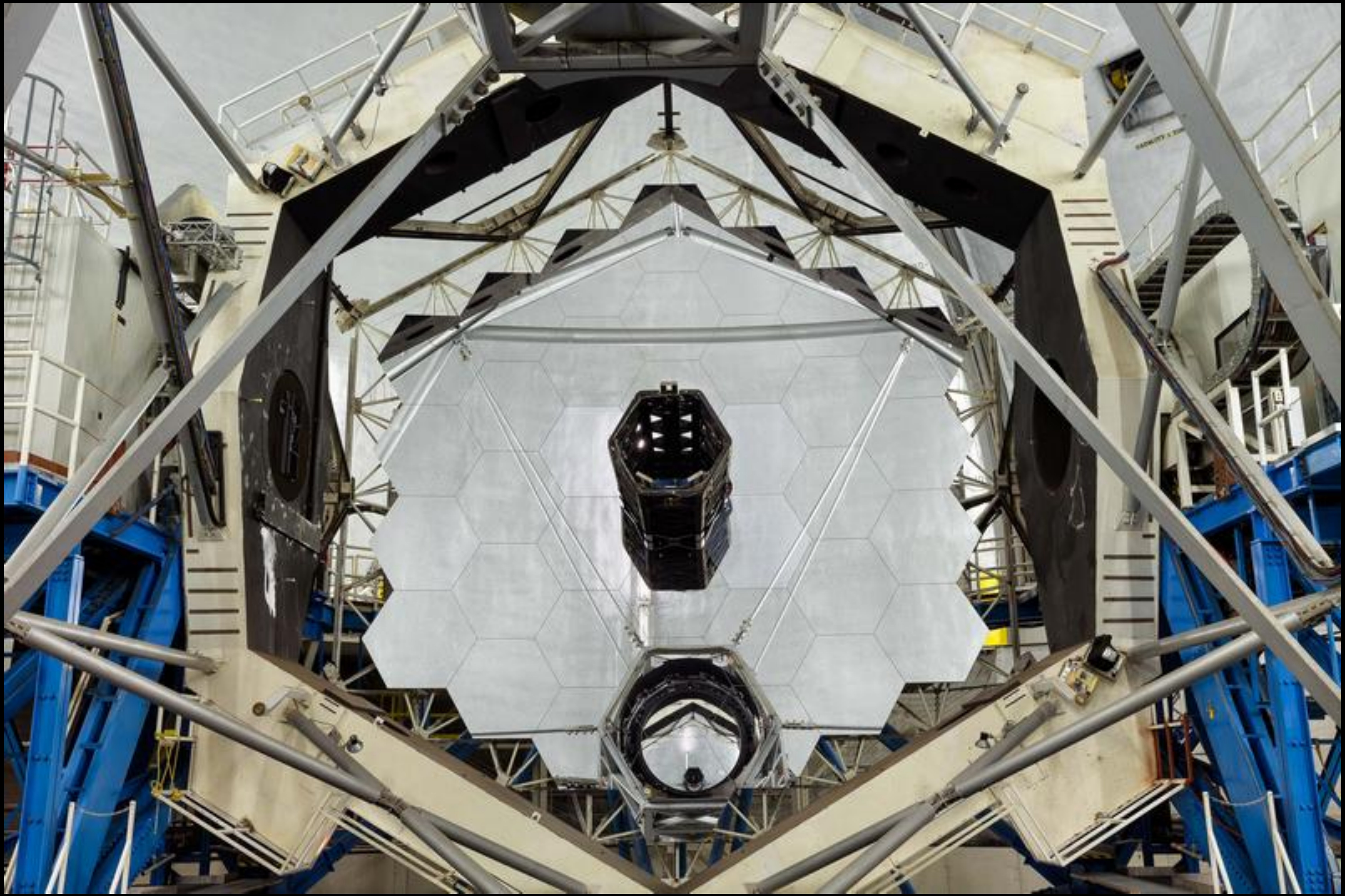
PDS 70: State of the Art with “Traditional” Methods



- We are now directly imaging protoplanets!
- Wide angular separations (> 20 AU)
- High masses (~ 5-10 Jupiter masses)
- <u>Goals for the protoplanet census:</u>
  - Tighter orbital separations
  - Lower masses
  - Detect and characterize at longer wavelengths (3 - 5 μm)

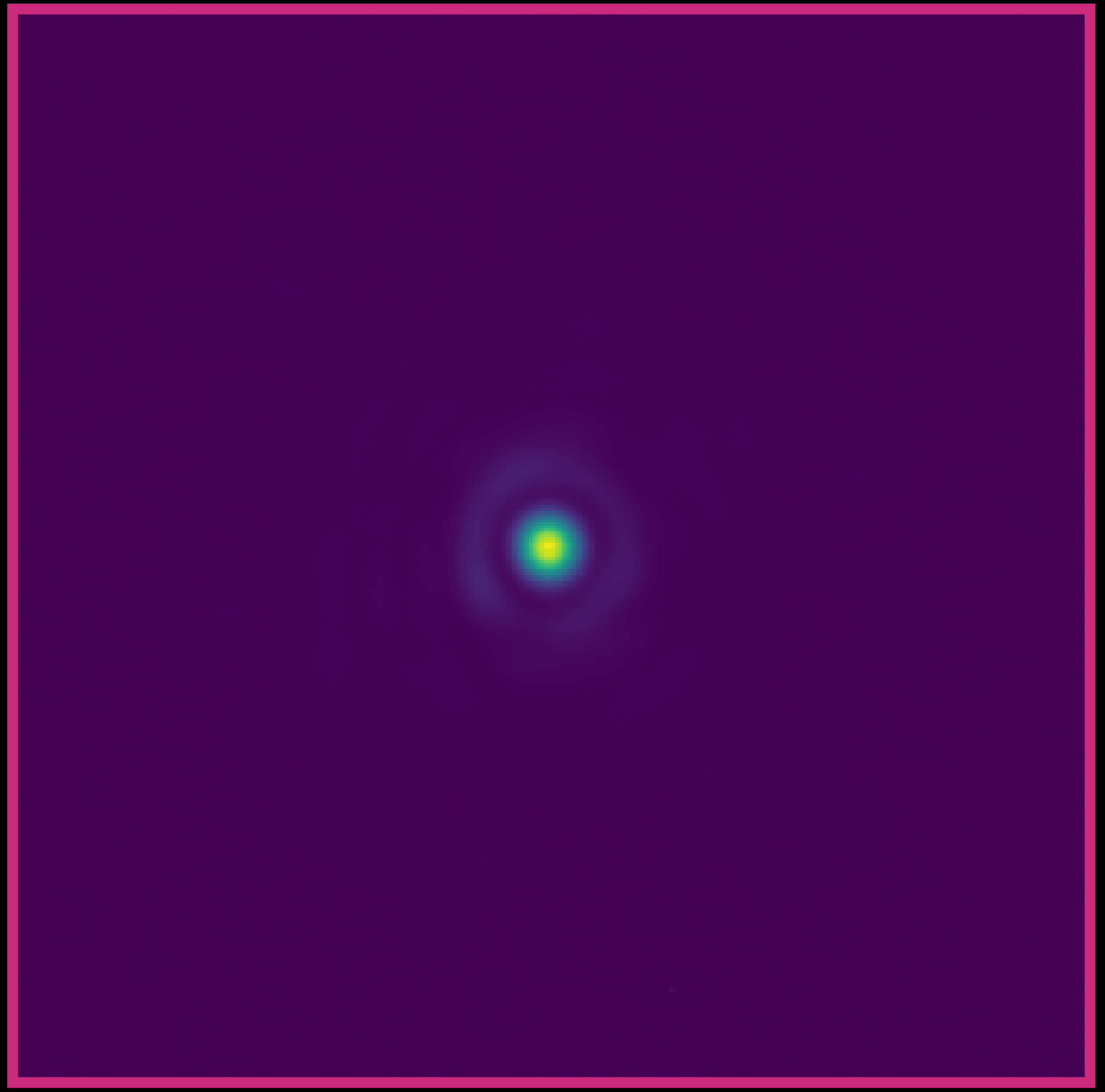
Keppler+(2018); Haffert+(2019); Isella+(2019)

Aperture Masking: Super Resolution

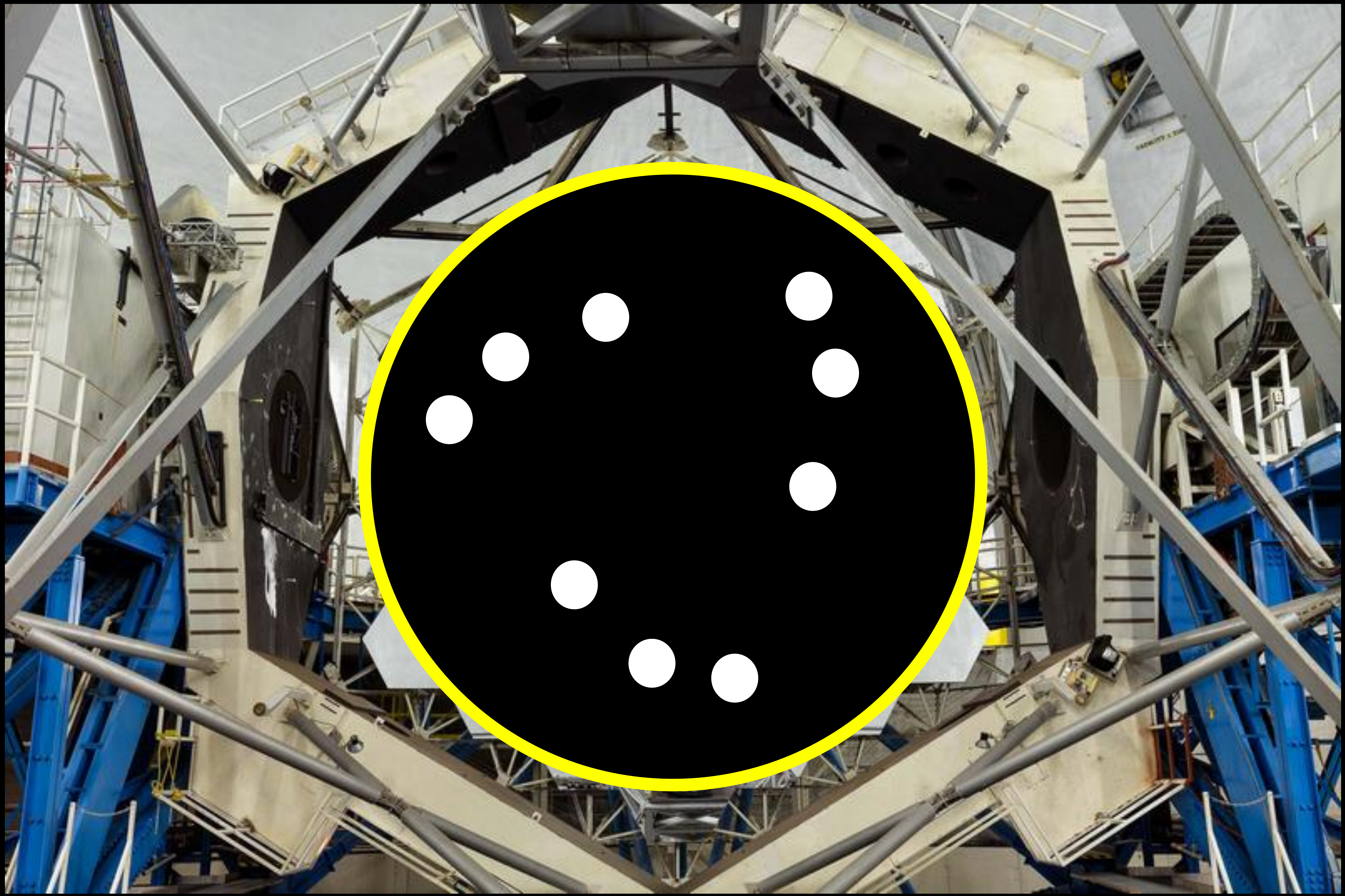


W. M. Keck Observatory

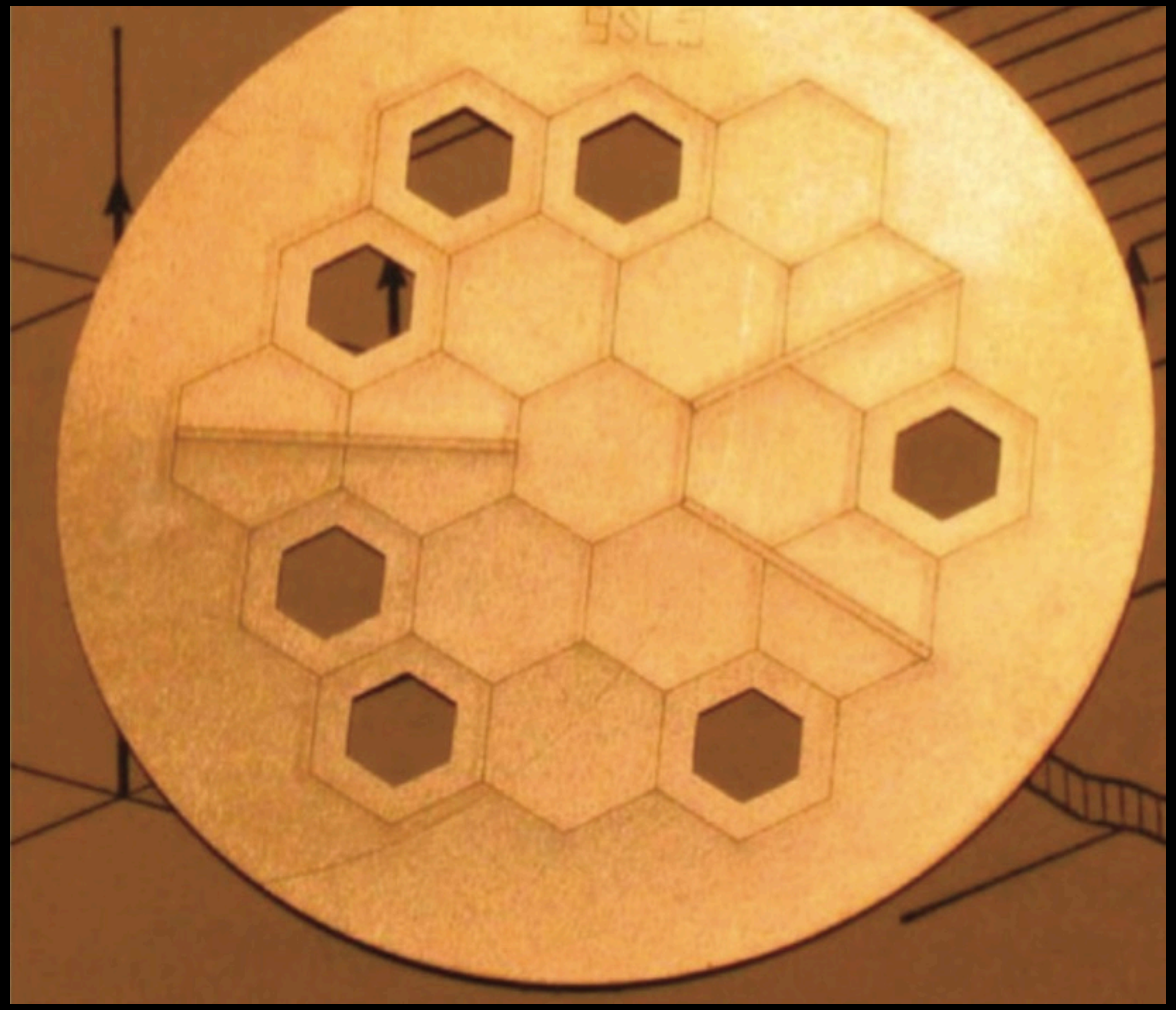
Image



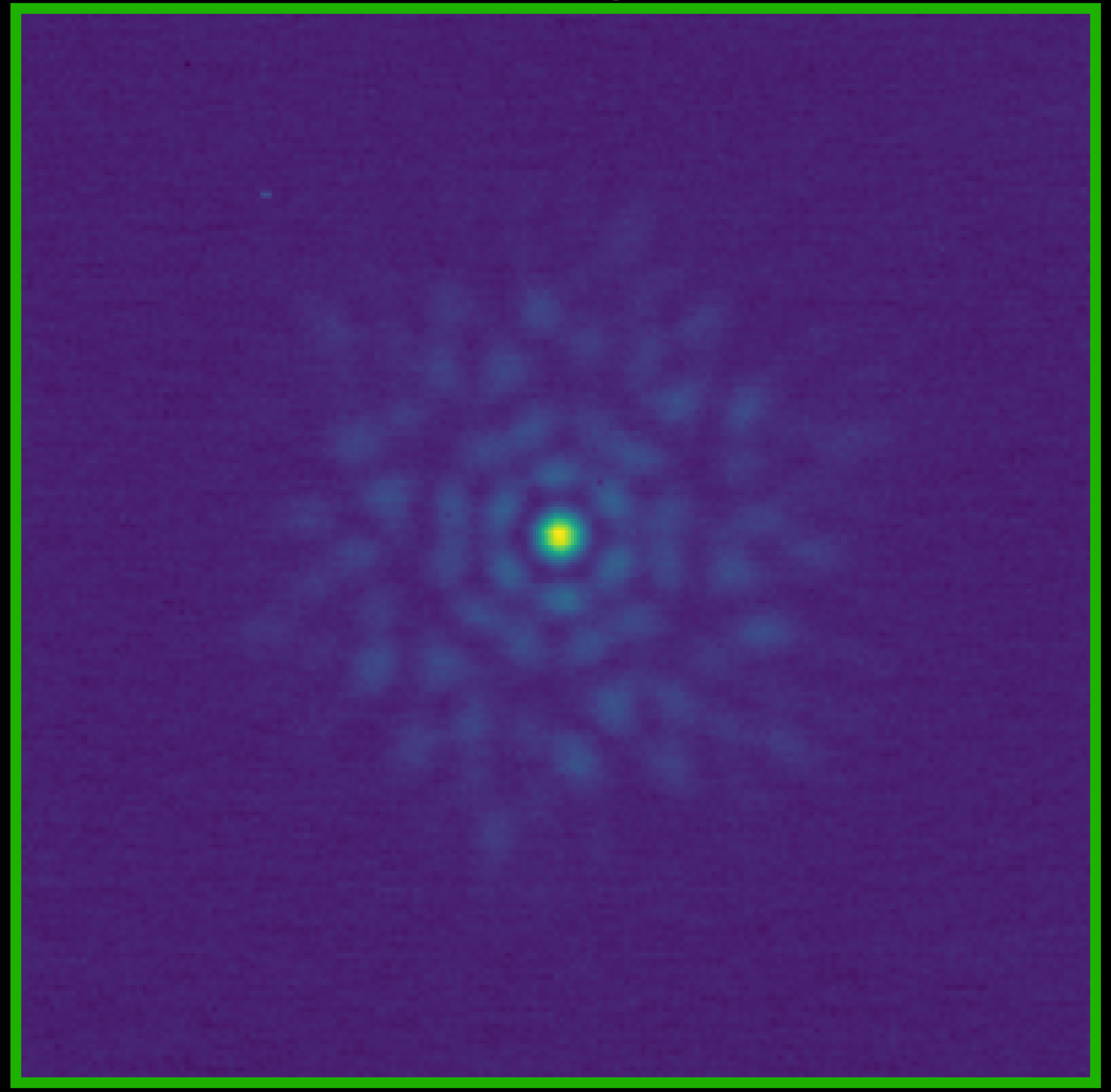
Aperture Masking: Super Resolution



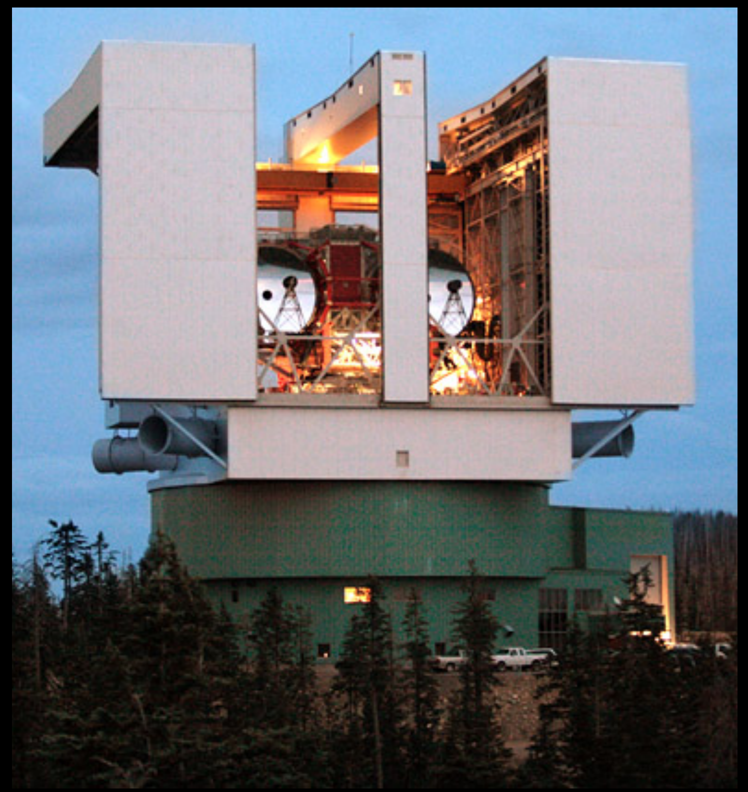
W. M. Keck Observatory

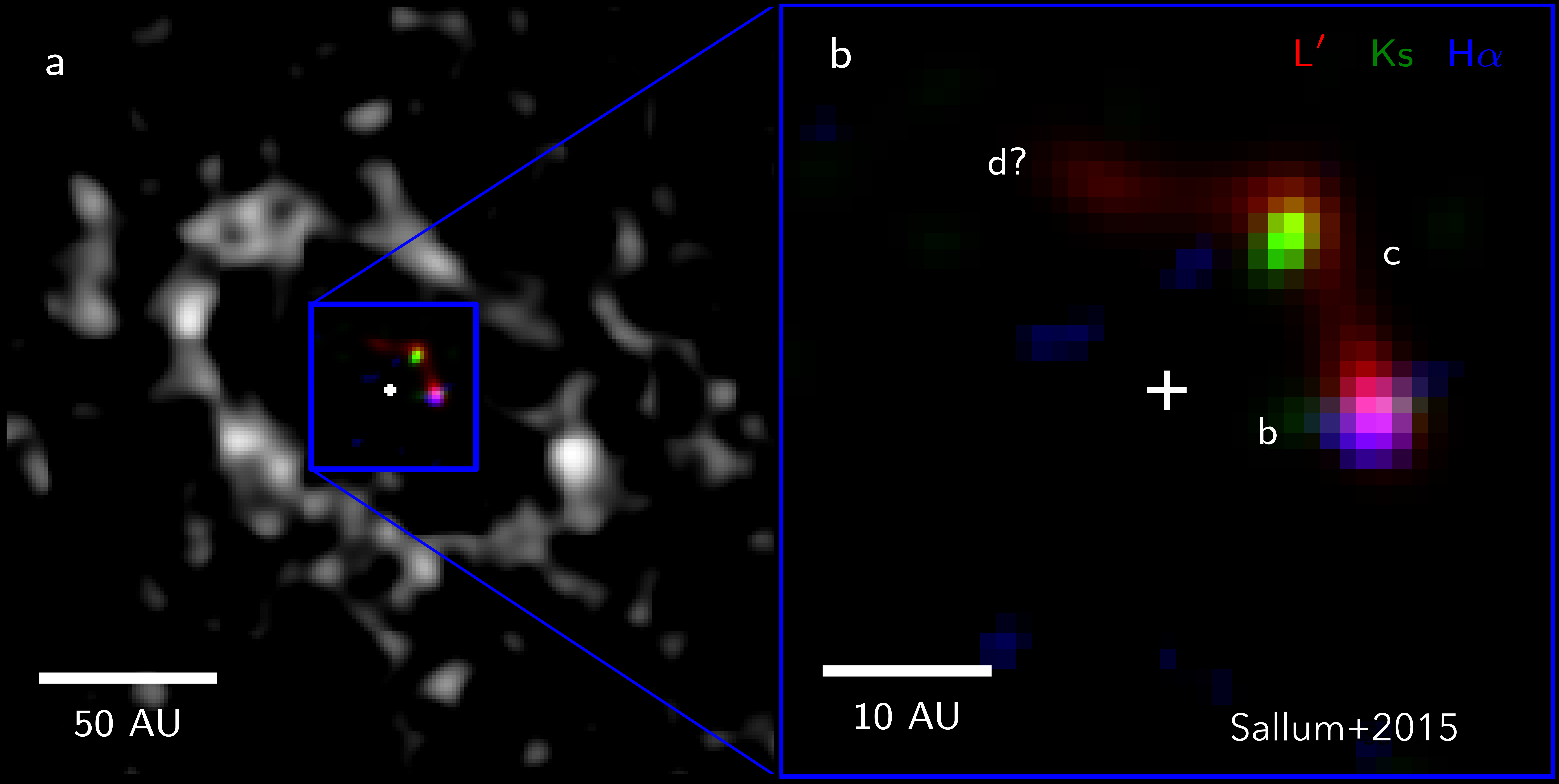


Image



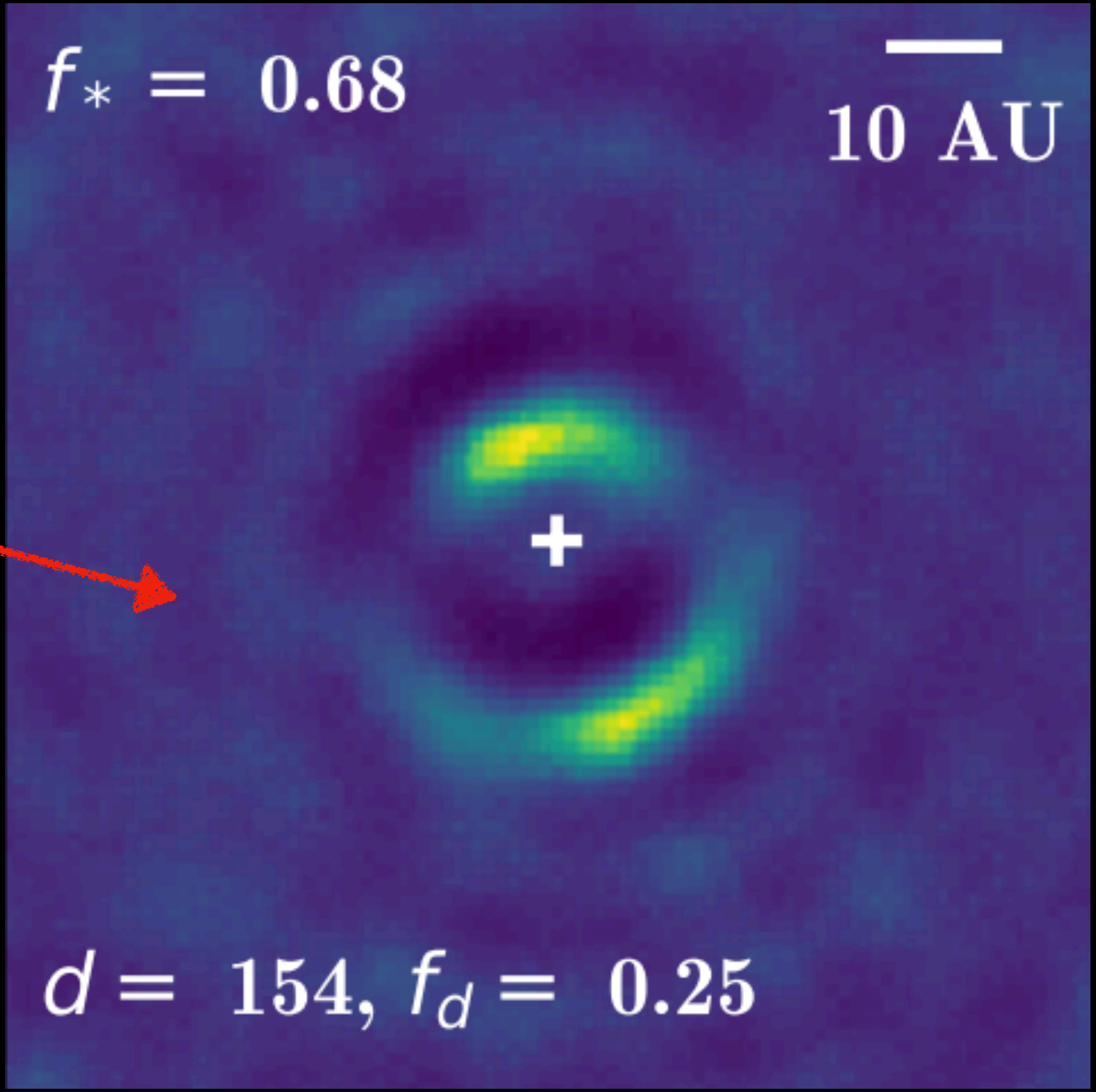
Highlights: planet candidates in protoplanetary disks





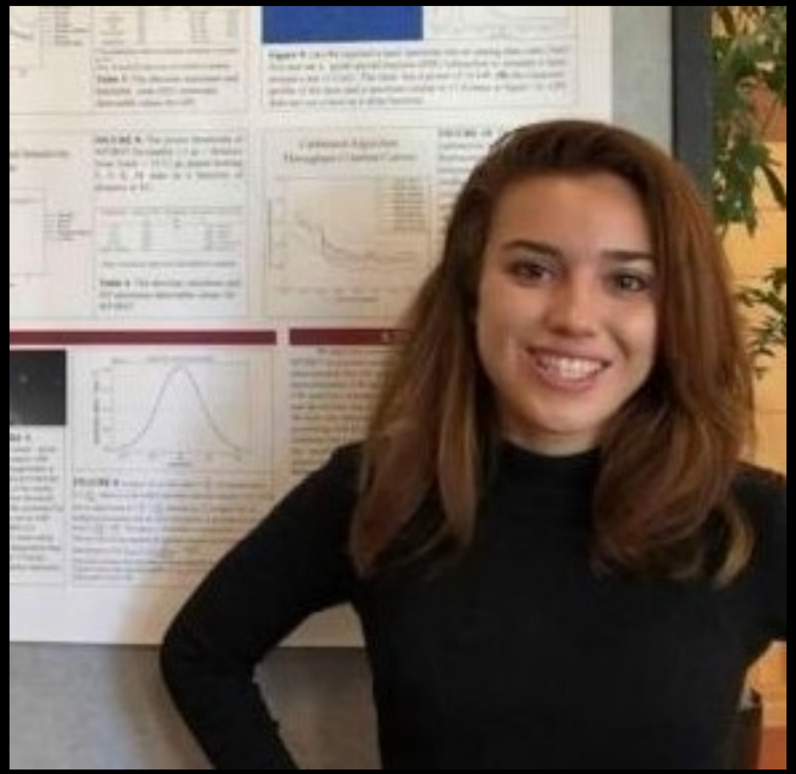
Highlights: characterizing the innermost regions of protoplanetary disks

Spirals within a protoplanetary disk millimeter clearing - possible disk-planet interaction!



Sallum+2019

A Keck Masking Survey of Gapped Protoplanetary Disks



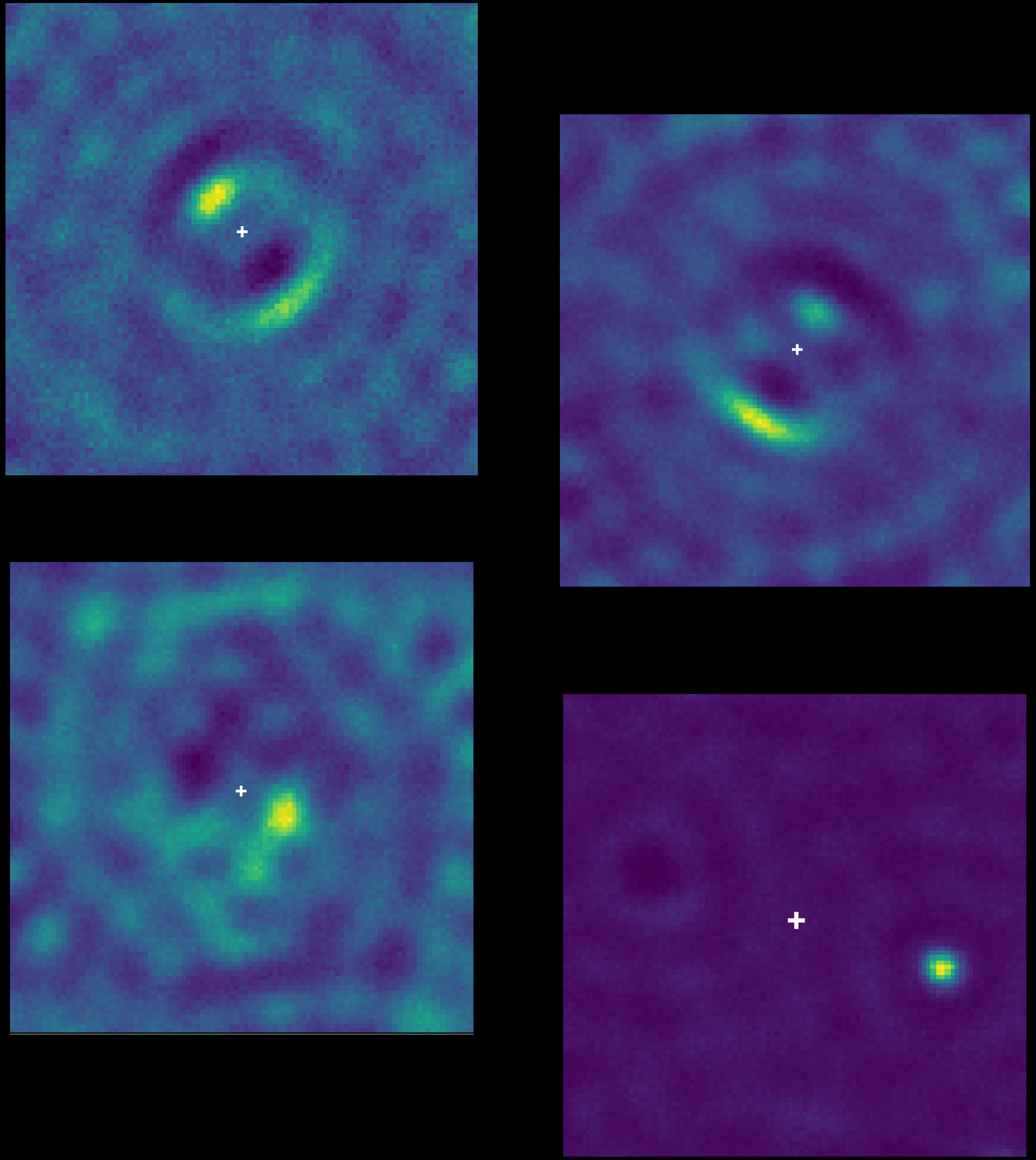
Christina Vides

<u>A few big questions:</u>

How common are giant forming planets in gapped protoplanetary disks?

How quickly do forming planets sweep up material?

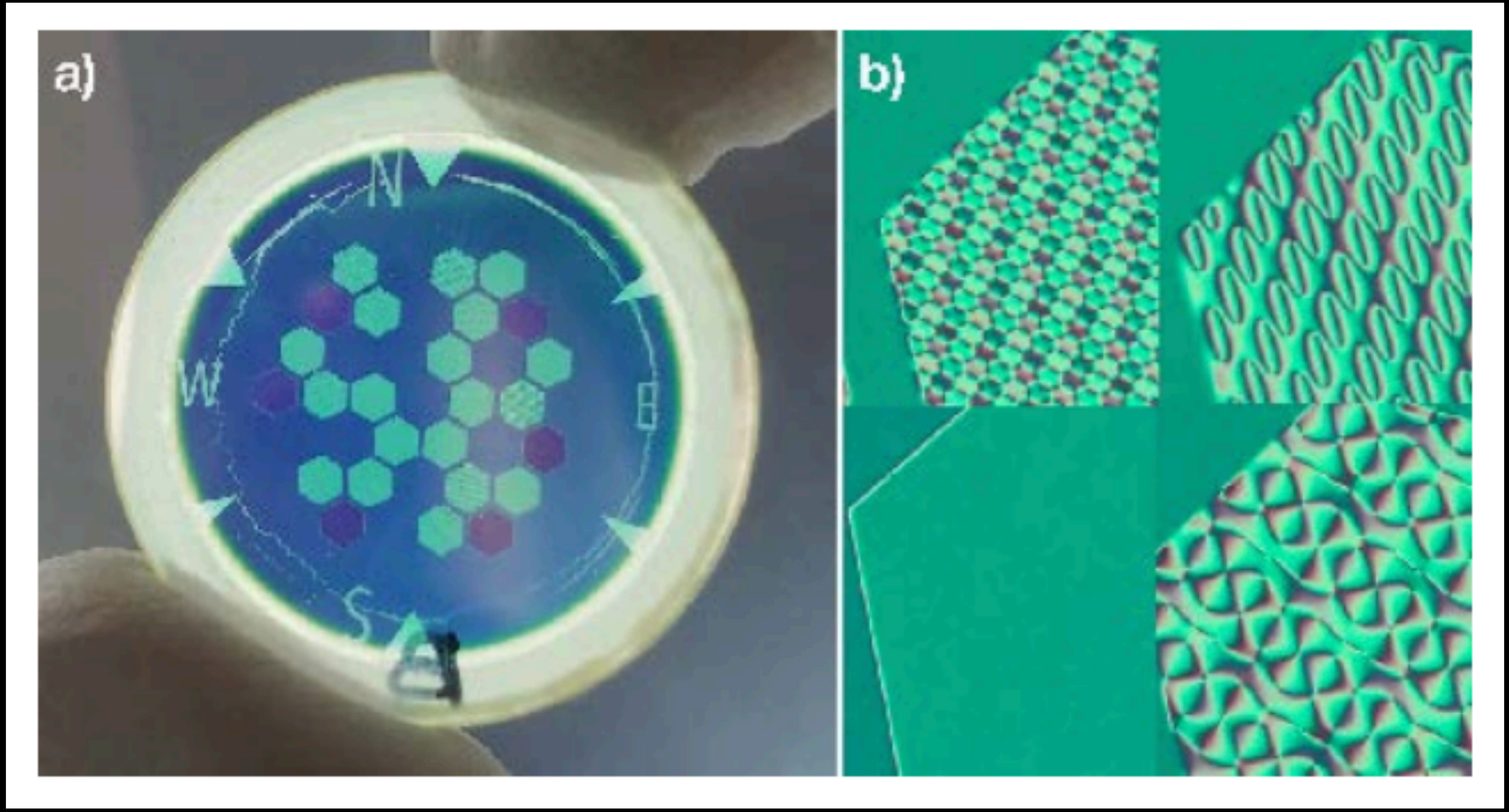
What are the orbital architectures of the youngest planetary systems, and how do they compare to mature ones?

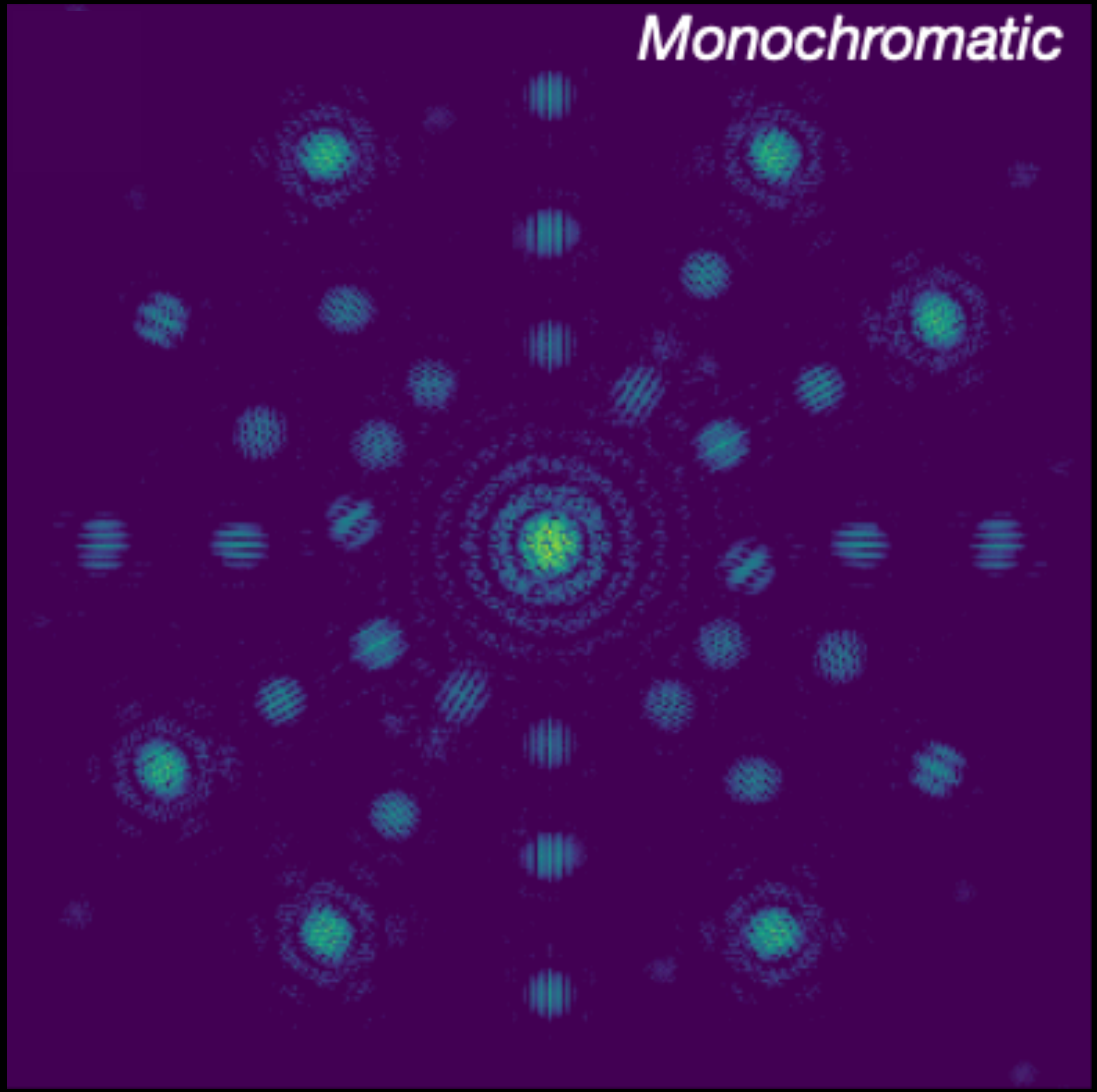


Upcoming Instruments

Holographic Aperture Masking (HAM)

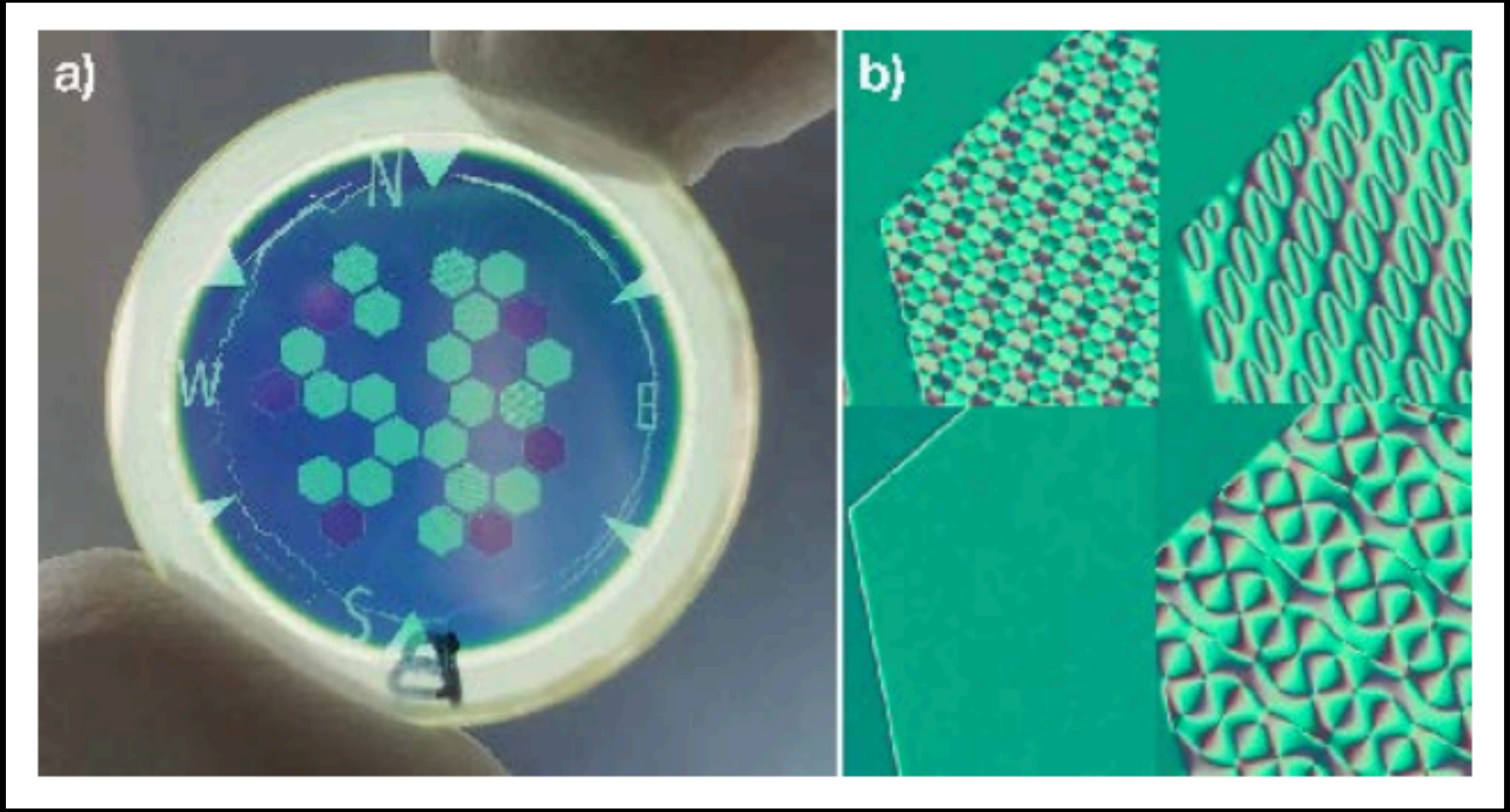
Adaptive Optics + Interferometry + *Spectral Resolution*

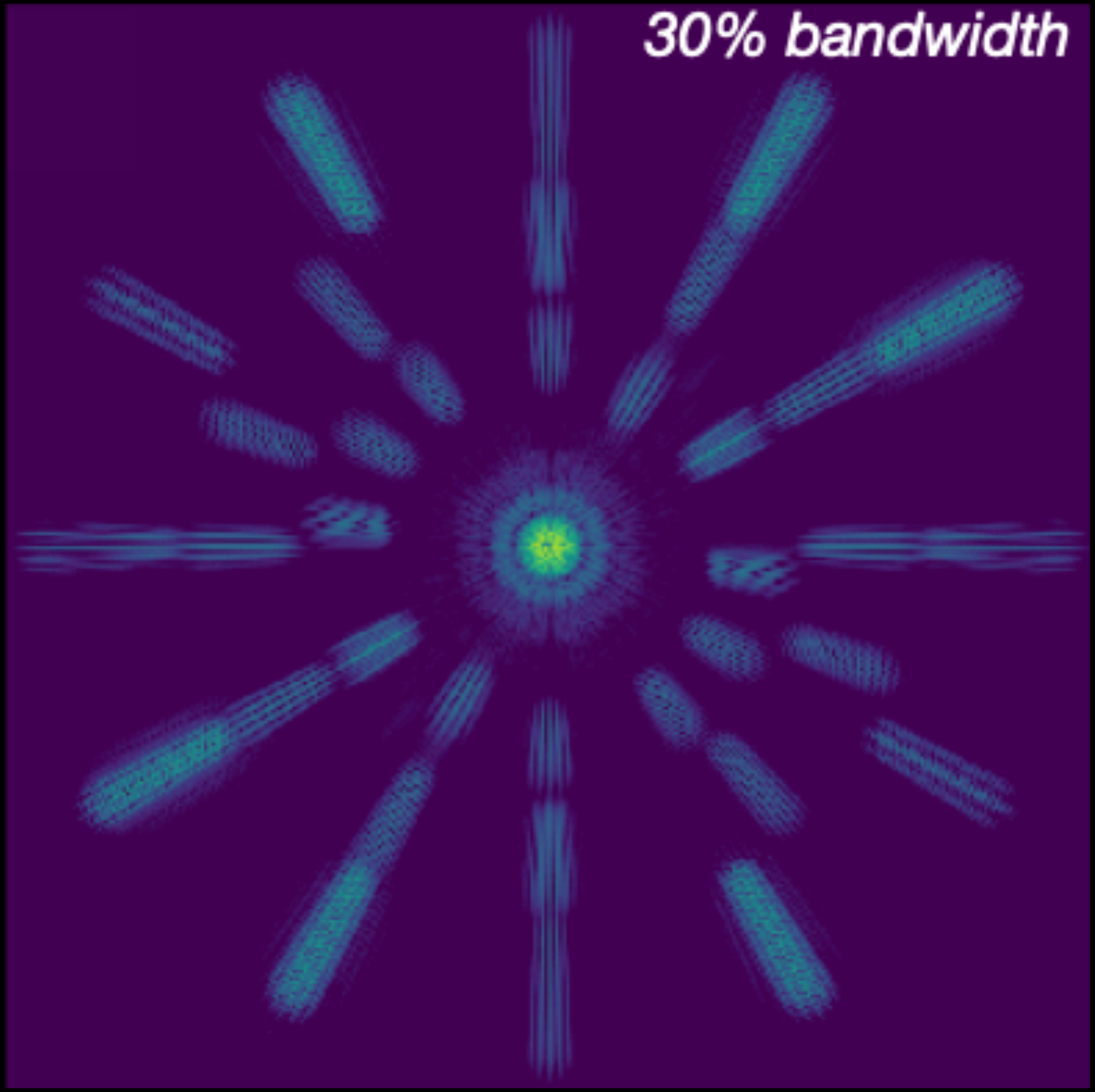




Holographic Aperture Masking (HAM)

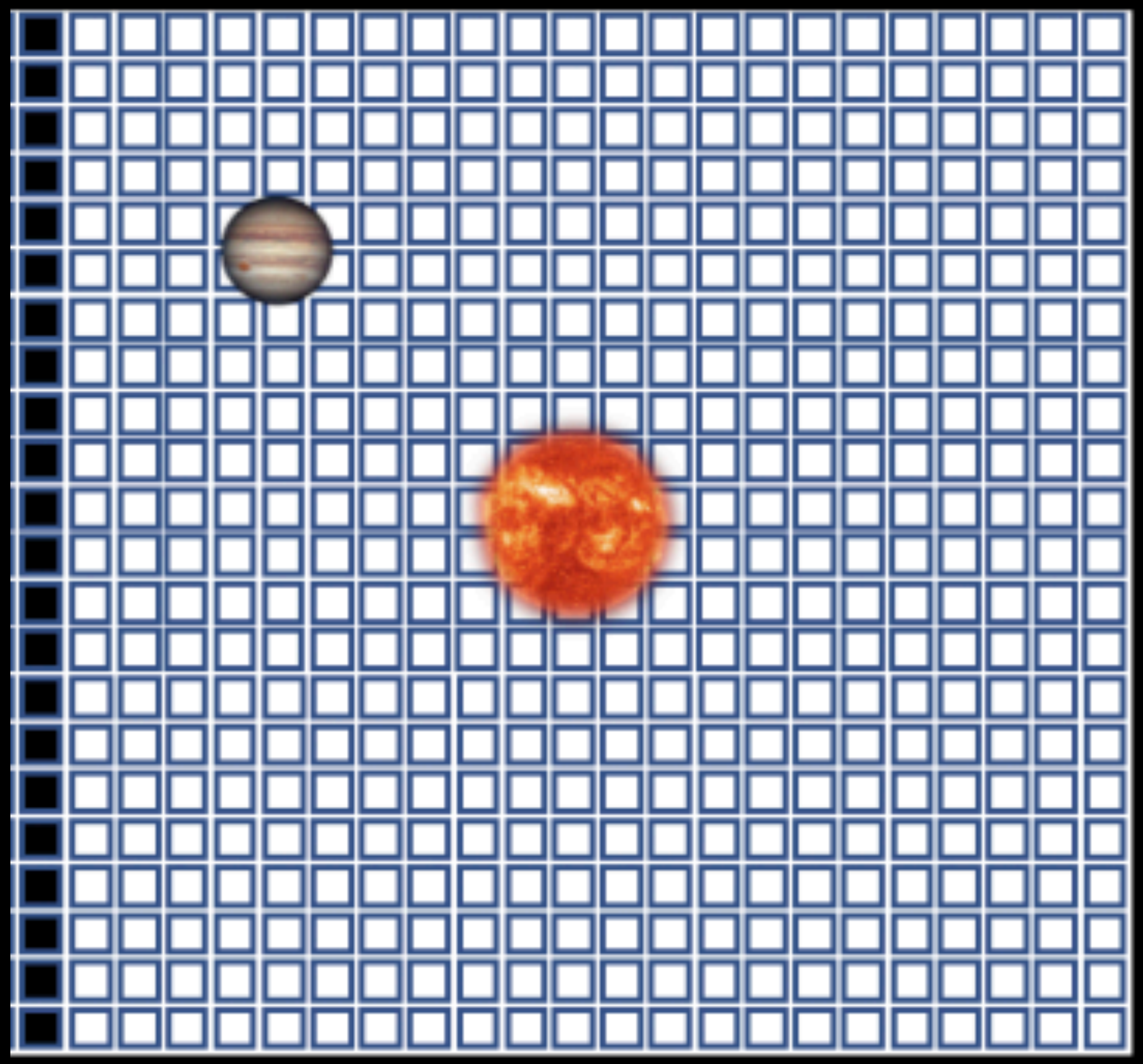
Adaptive Optics + Interferometry + *Spectral Resolution*

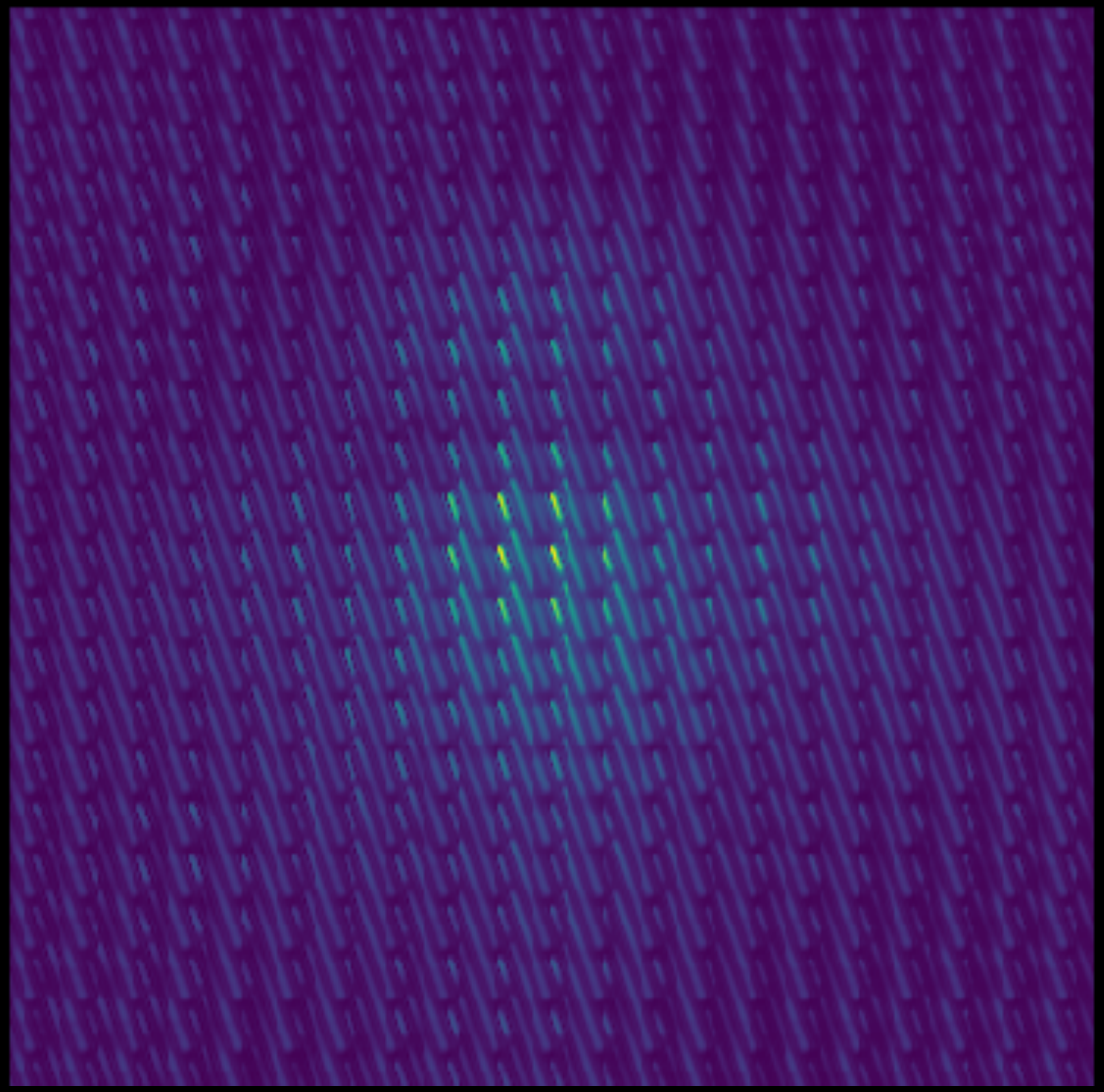




Santa Cruz Array of Lenslets for Exoplanet Spectroscopy

SCALES

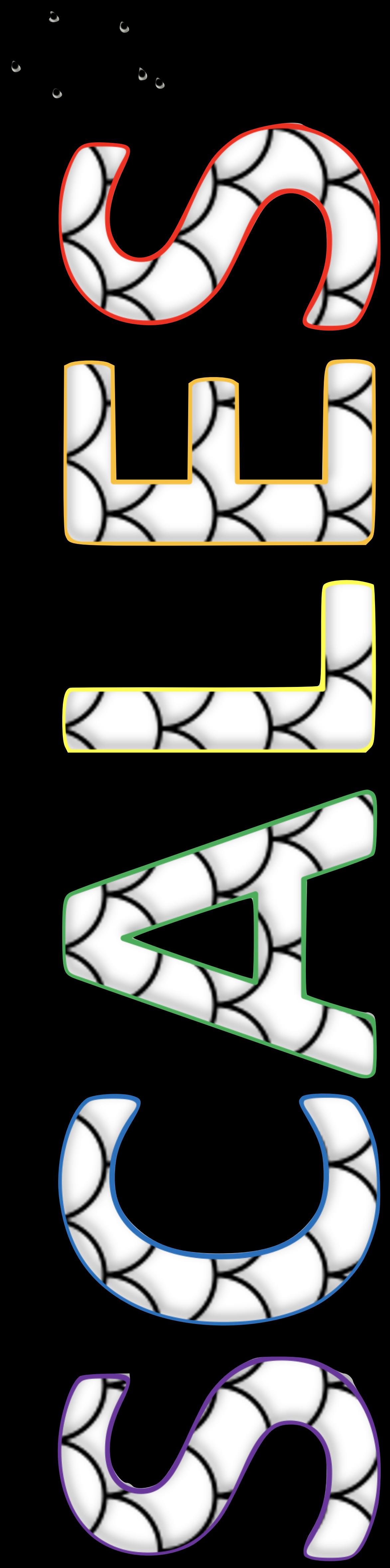


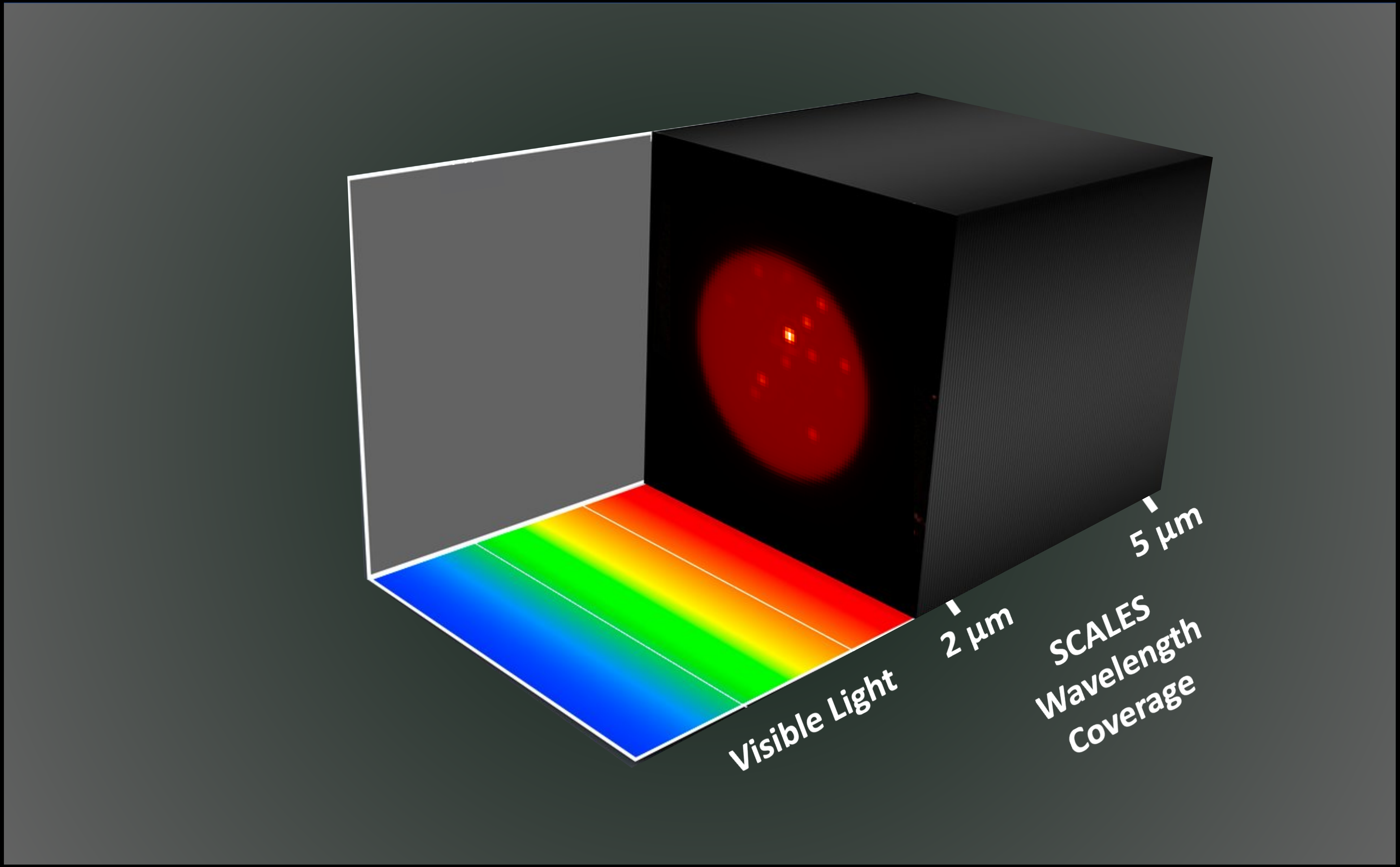


<u>**Instrument Team**</u>: **Andy Skemer (PI)**, **Deno Stelter (IS)**, **Nick MacDonald (PM),** Dimitri Mawet, Mike Fitzgerald, Steph Sallum, Marc Kassis, Phil Hinz, Reni Kupke, Chris Ratliffe, Becky Jensen-Clem, Tim Brandt, Olivier Absil, Itsuki Sakon, Zack Briesemeister, Emily Martin, Brittany Miles, Evan Morris

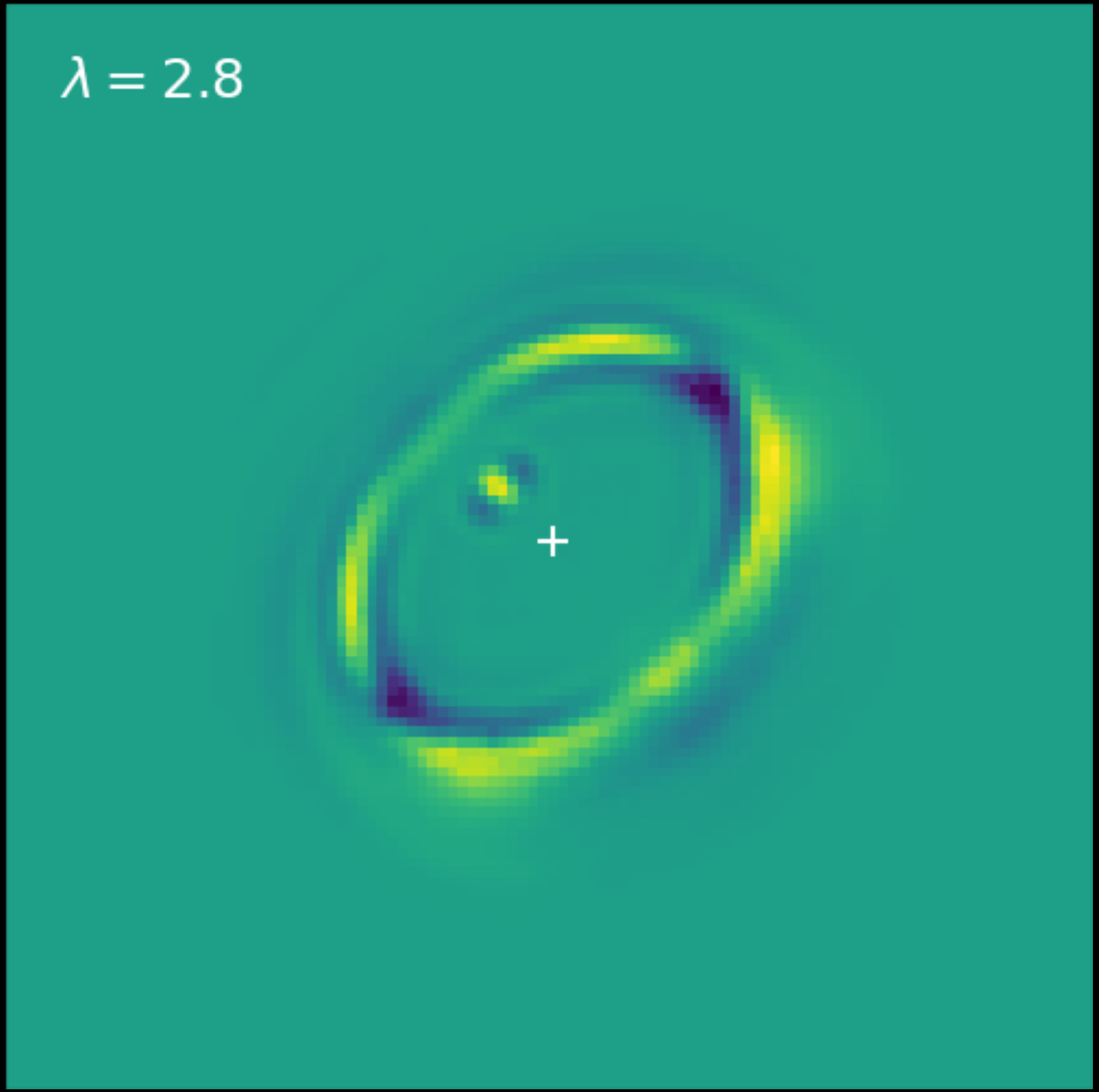
<u>**Science Team**</u>: **Steph Sallum (PS)**, Andy Skemer, Natalie Batalha, Natasha Batalha, Geoff Blake, Tim Brandt, Zack Briesemeister, Josh Eisner, Wen-fai Fong, Thomas Greathouse, Tom Greene, Mitsuhiko Honda, Charles Kilpatrick, Katherine de Kleer, Mike Liu, Dimitri Mawet, Brittany Miles, Caroline Morley, Imke de Pater, Diana Powell, Justin Spilker, Kevin Wagner, Yifan Zhou

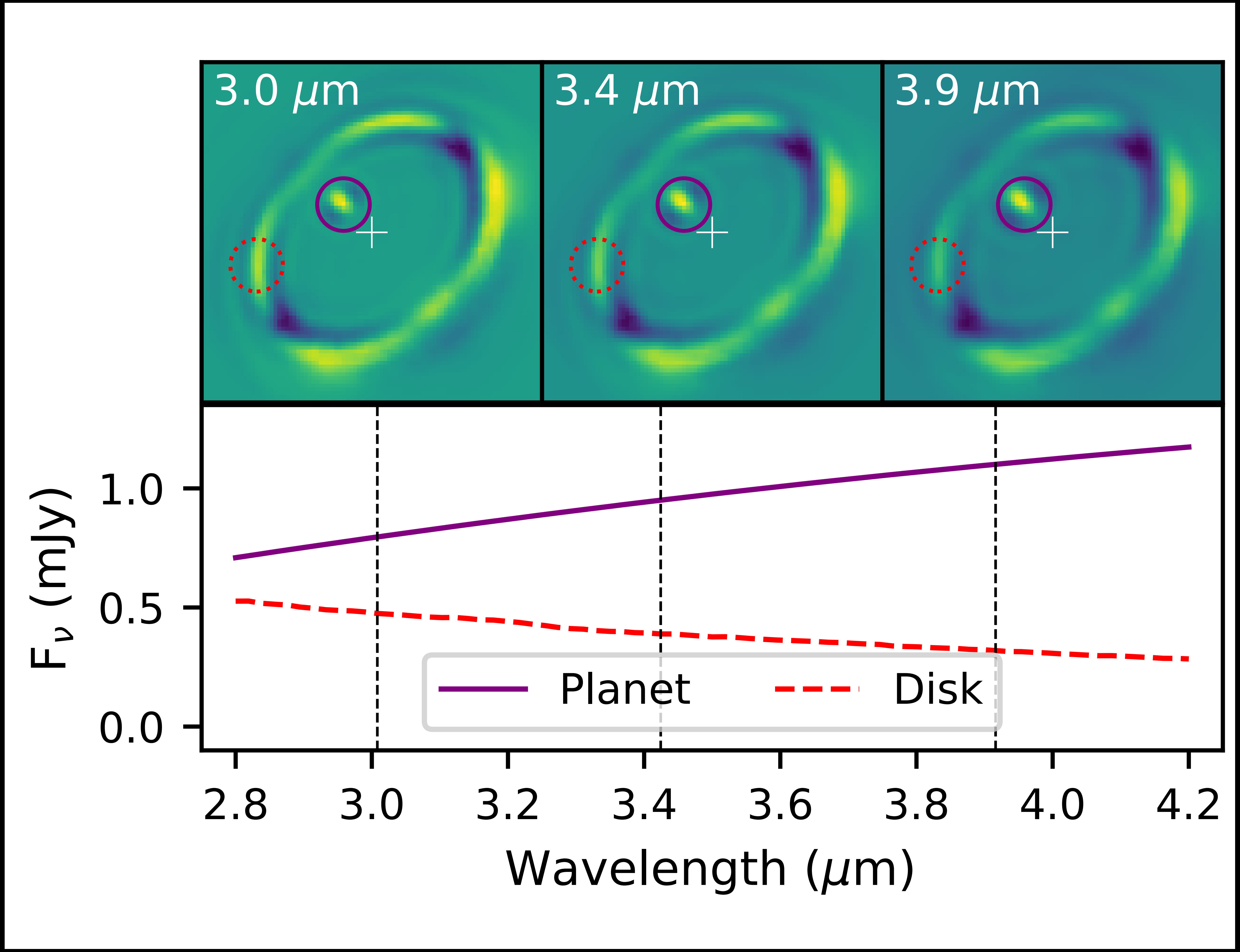
Santa Cruz Array of Lenslets for Exoplanet Spectroscopy



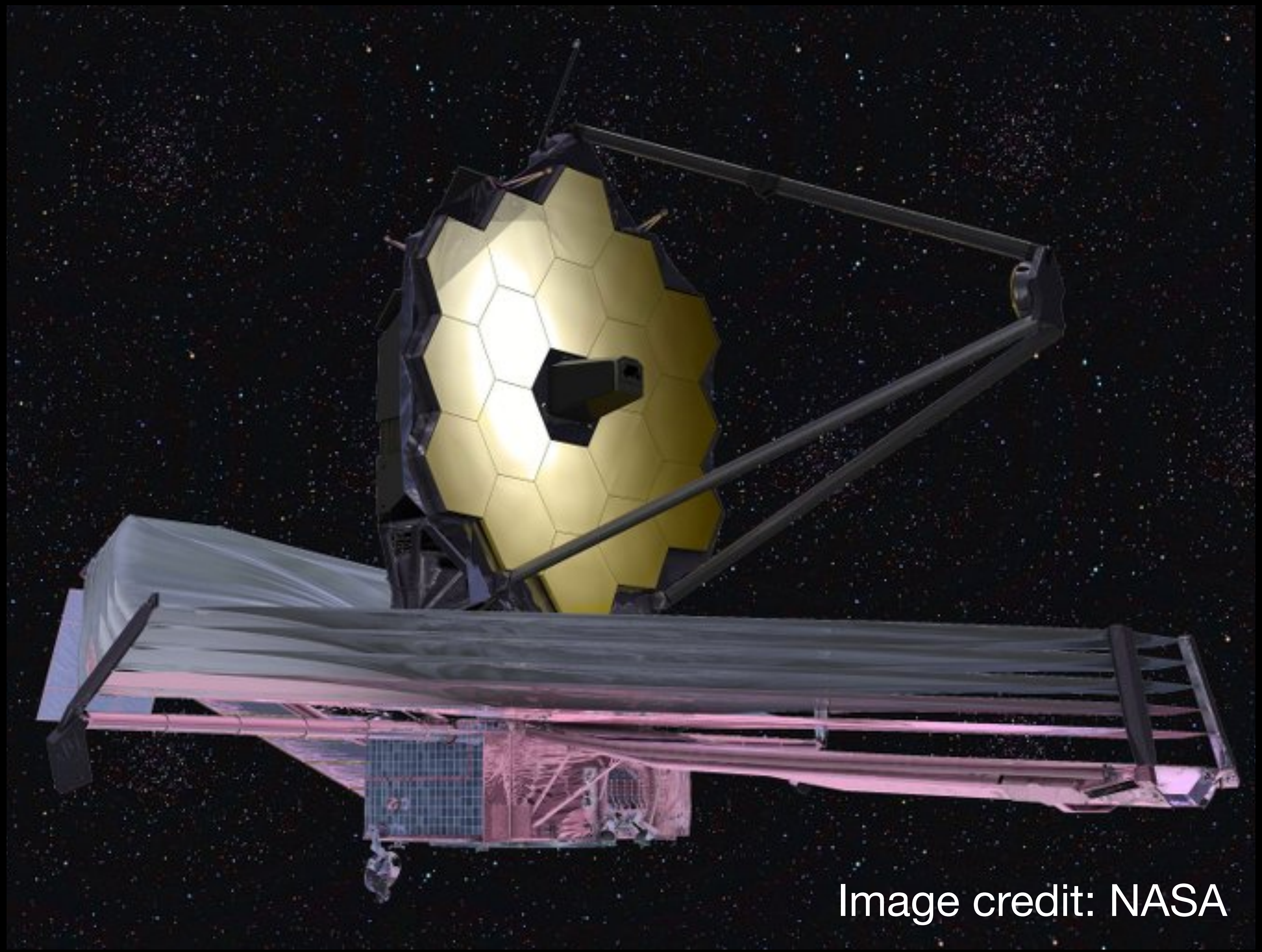


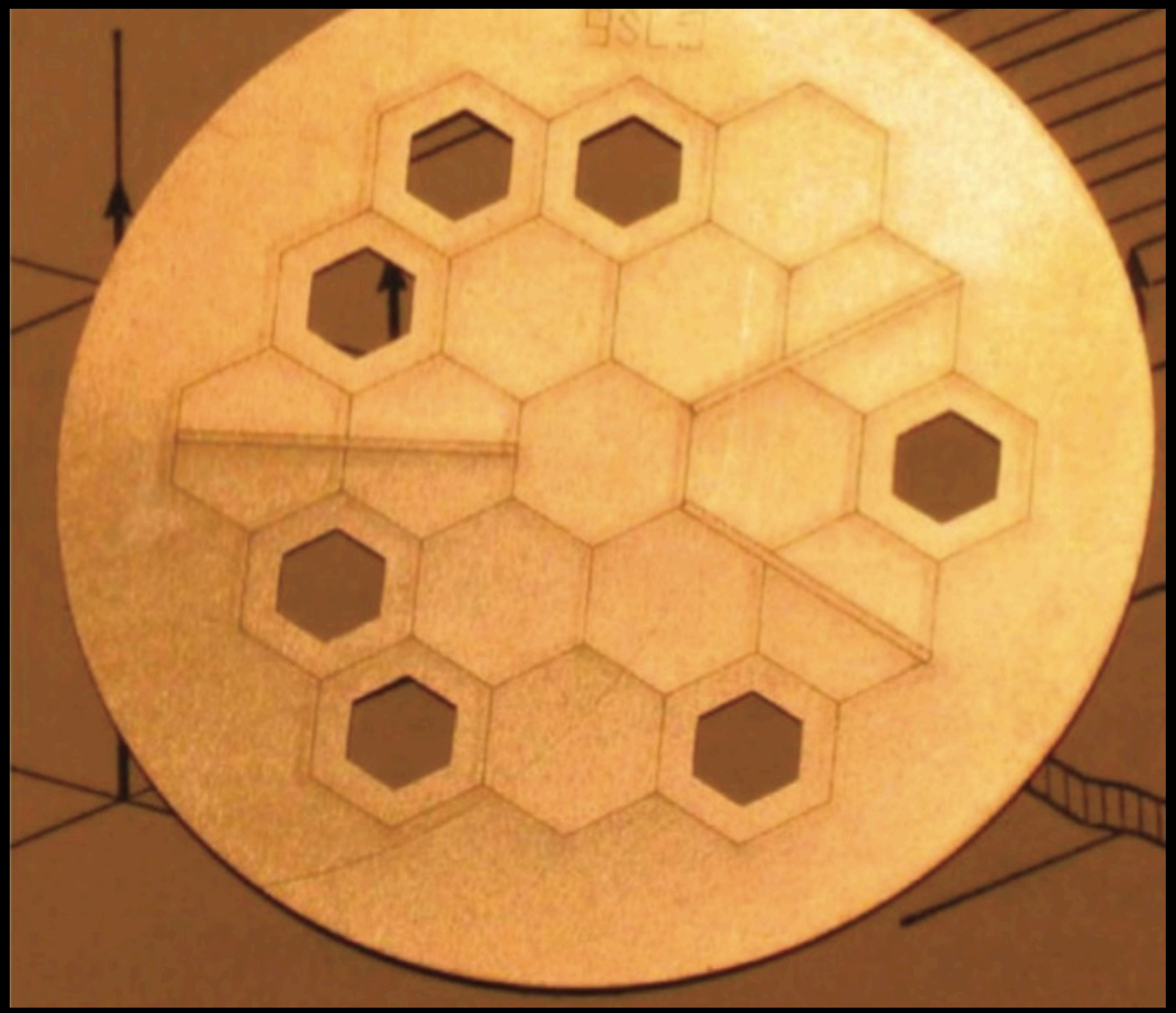
SCALES: Planet Formation Science

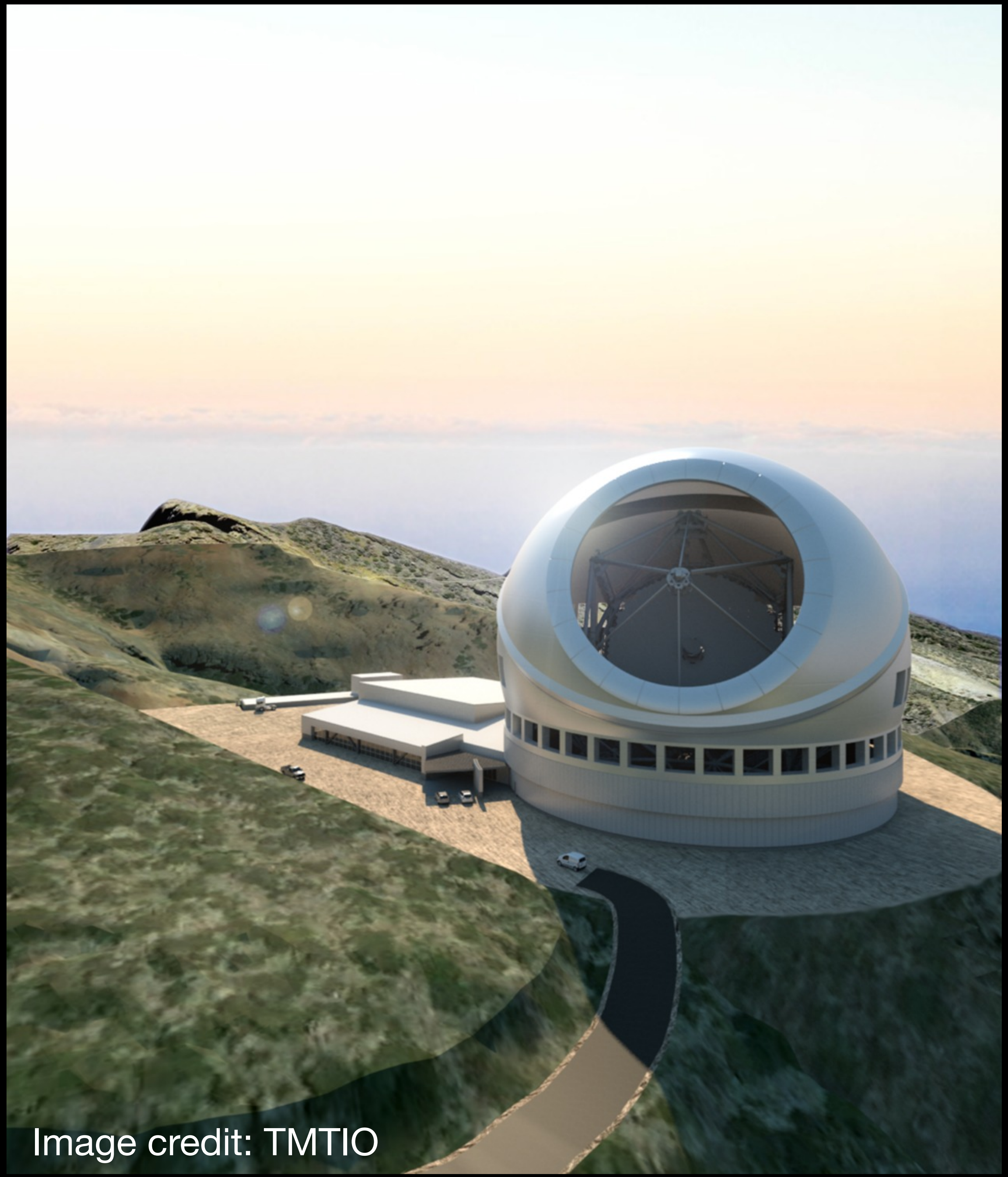


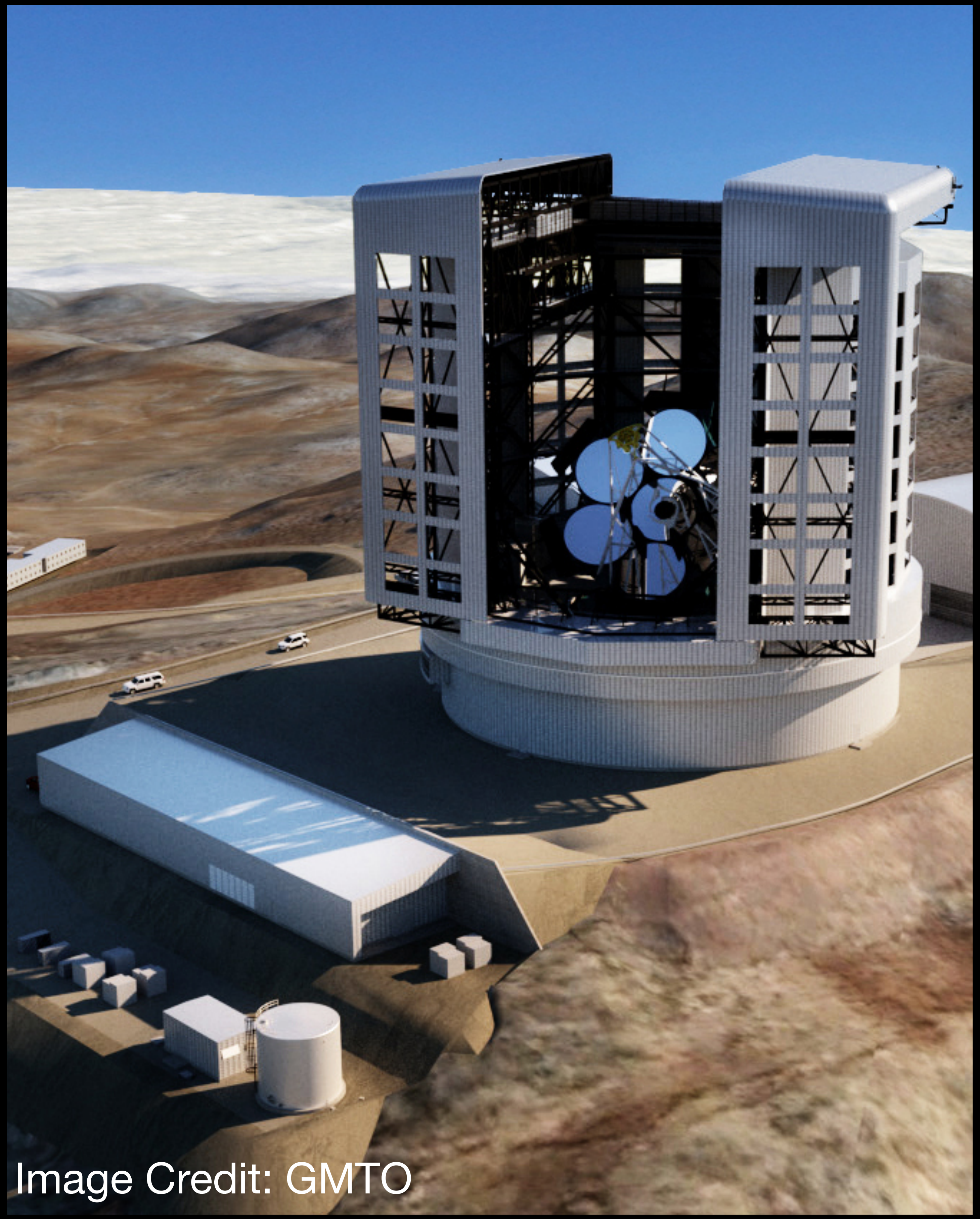


Looking Ahead









UCI School of Physical Sciences

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with Professor Steph Sallum

Welcome, we will begin shortly

For questions, please utilize the Q&A feature at the bottom of your screen

Text PSBLS to 41444 to give!