

Exoplanet Science with TMT

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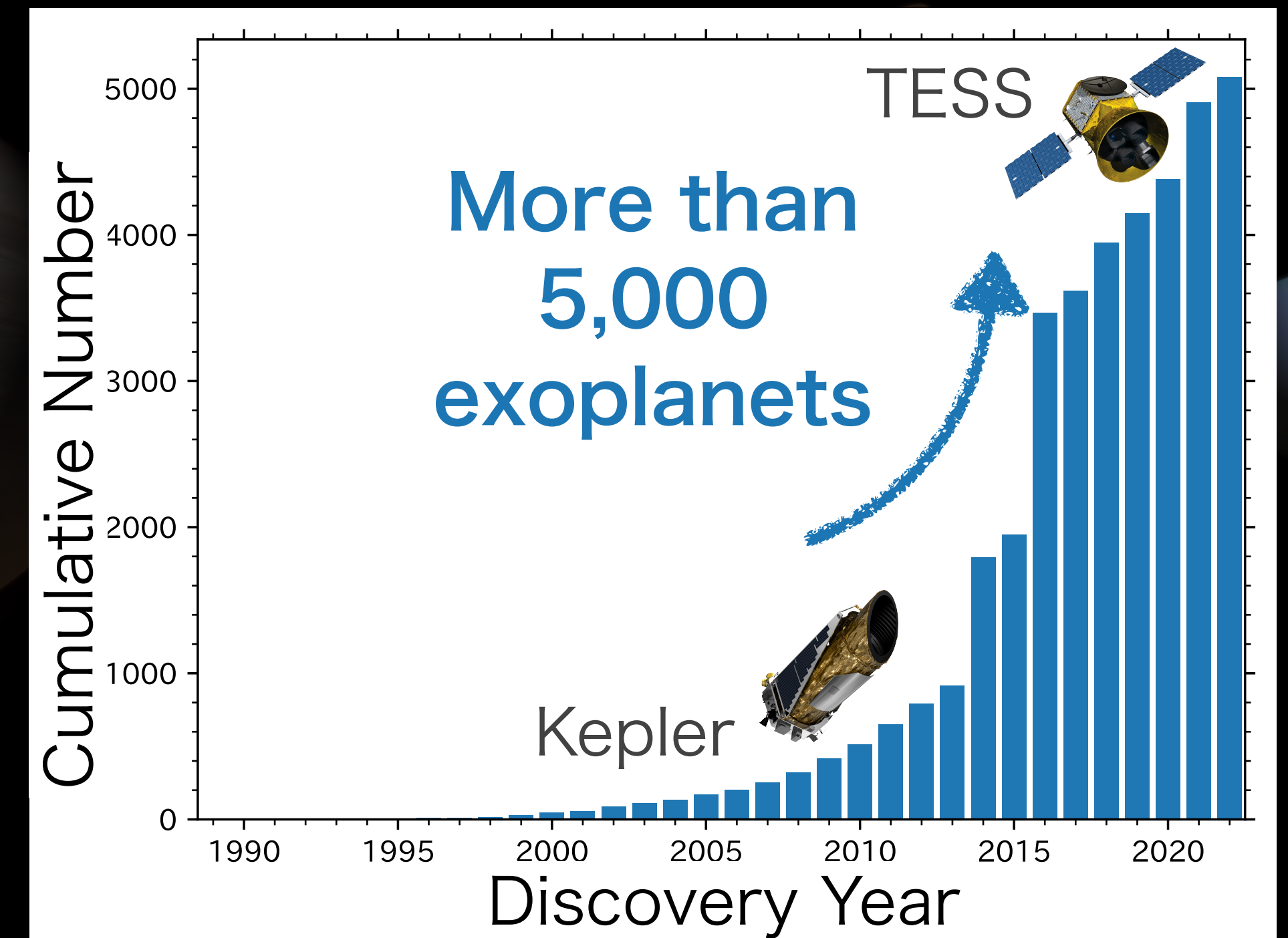
Kyoto University

2025.1.30 Subaru Users Meeting FY2024

NASA, ESA, CSA, Joseph Olmsted (STScI)

General Understanding of Planetary Systems

- What kinds of planetary systems exist in the universe?
- Is our solar system common among those planetary systems?
- Is there any other planet like the Earth?

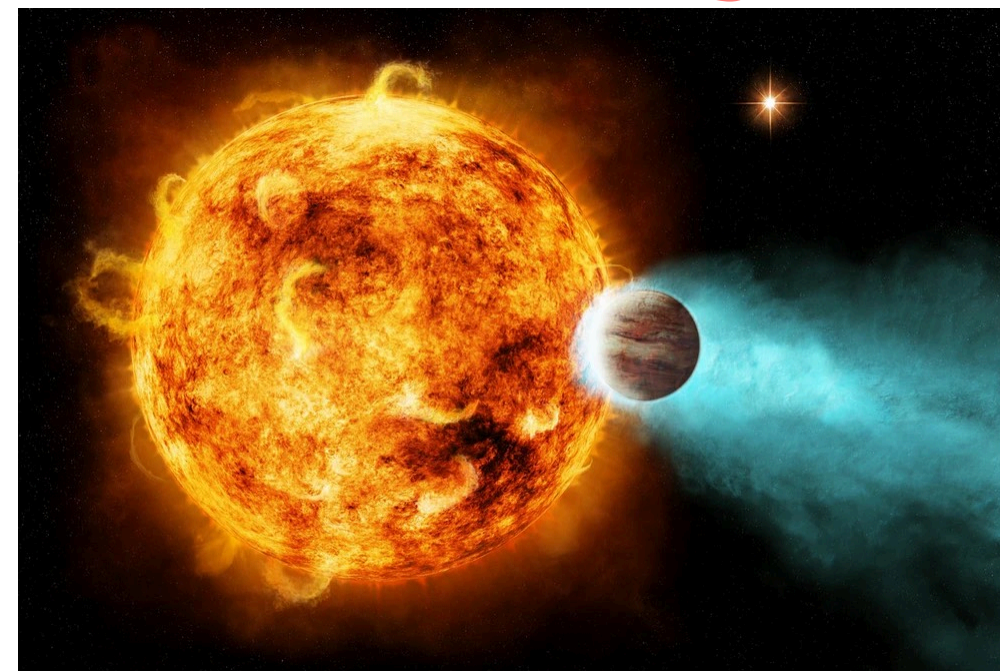


We can utilize the abundant extrasolar planetary system samples to obtain general understanding of planetary systems

Currently Discovered Exoplanets

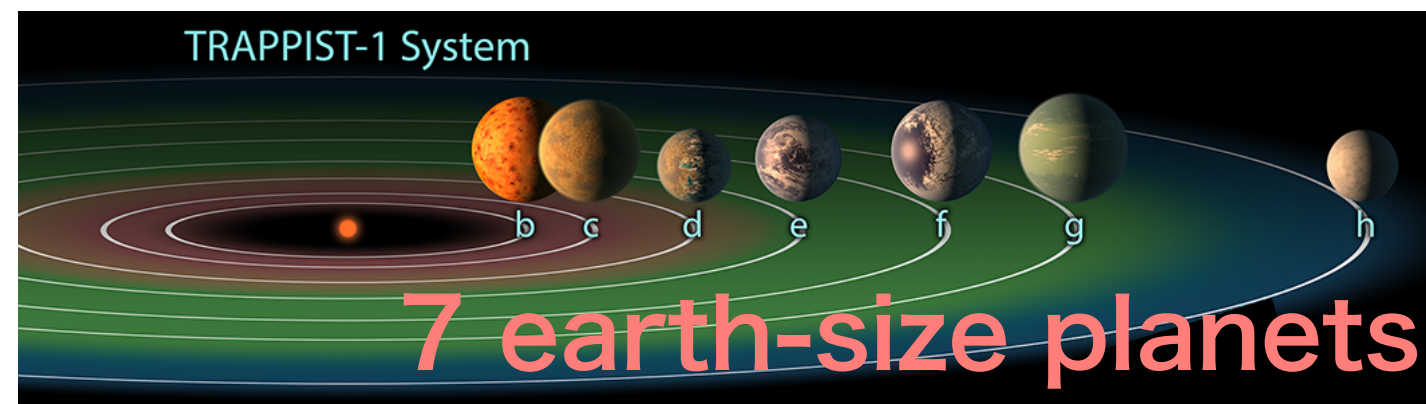
Currently discovered exoplanets are located either **far from (~1%)** or **close to (~99%)** the central star due to the ease of detection

Indirectly discovered



<https://www.skyatnightmagazine.com/space-science/hot-jupiter/>

<https://hubblesite.org/contents/media/images/2017/07/3986-Image.html?news=true>

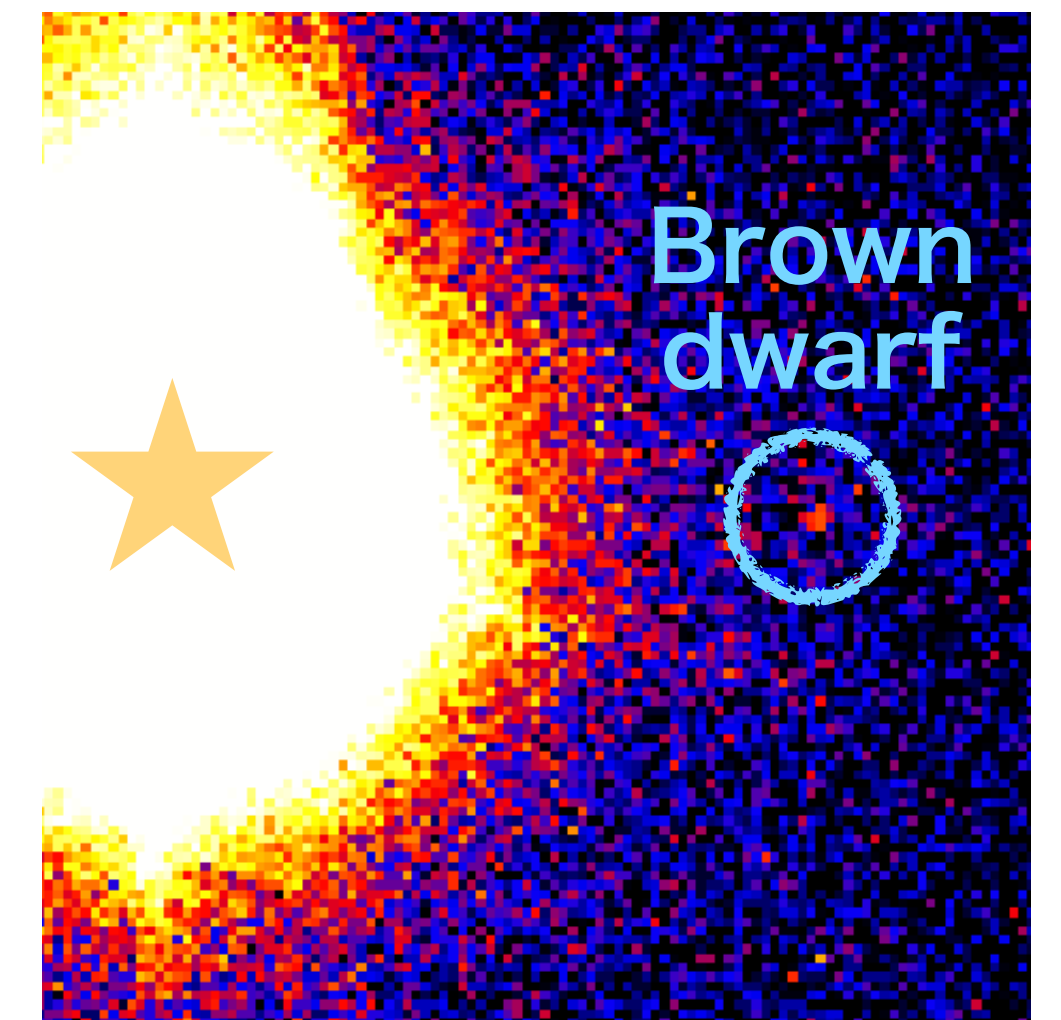


Directly discovered



<https://jasonwang.space/orbits.html>

System with four giant planets



Brown dwarf



Toward the Characterization Era

2000s

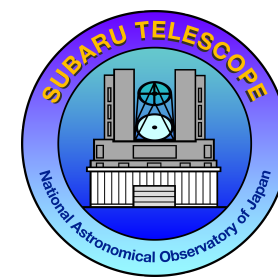
Detection of Planets

2010s

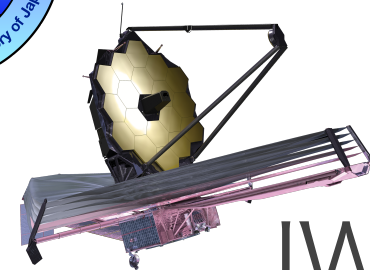
Systematic Detection of Planets

2020s~

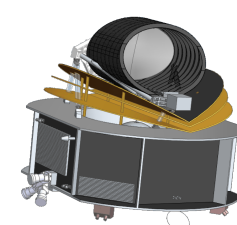
Characterization of
Gaseous Planets



Subaru

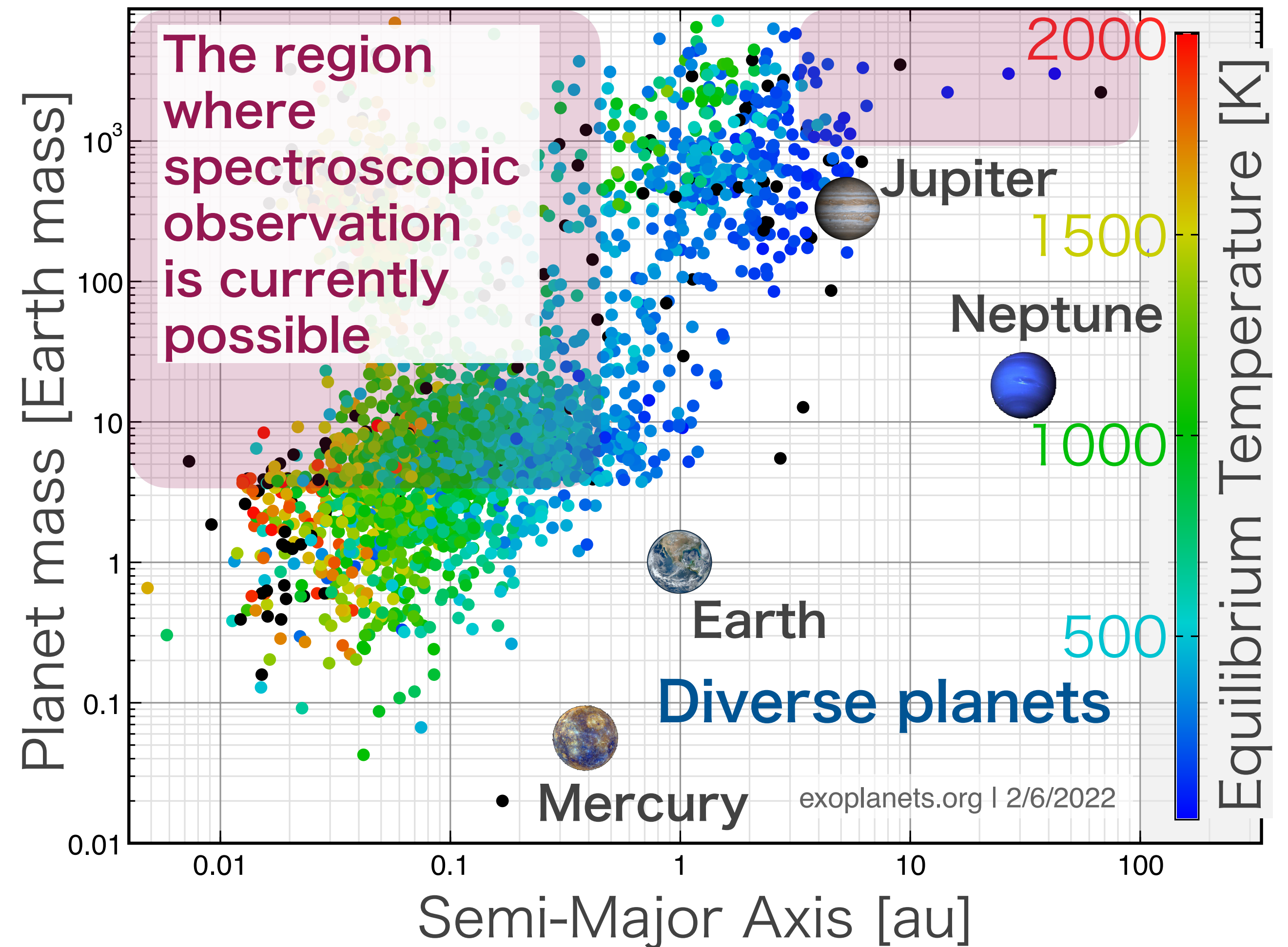


JWST

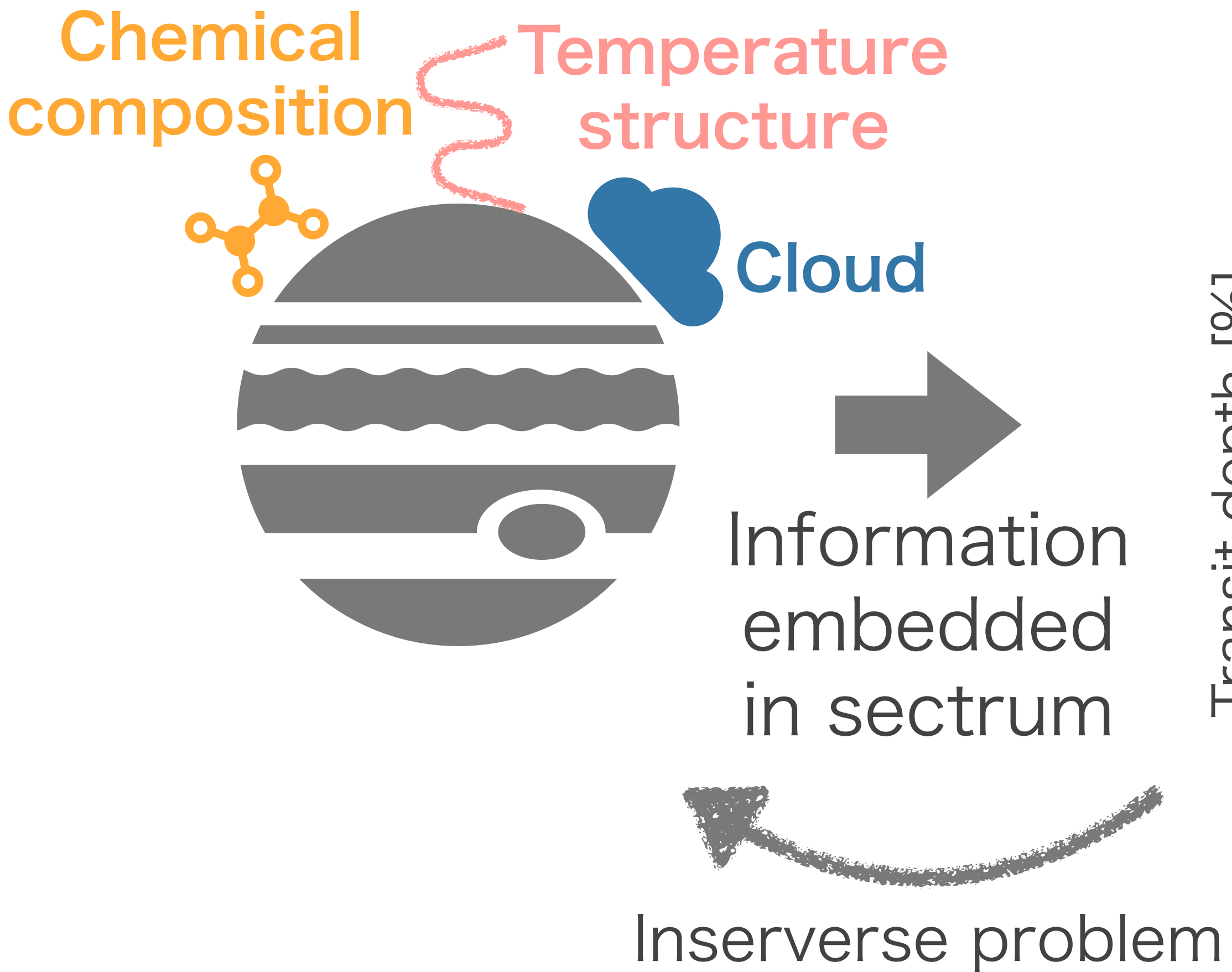


Ariel

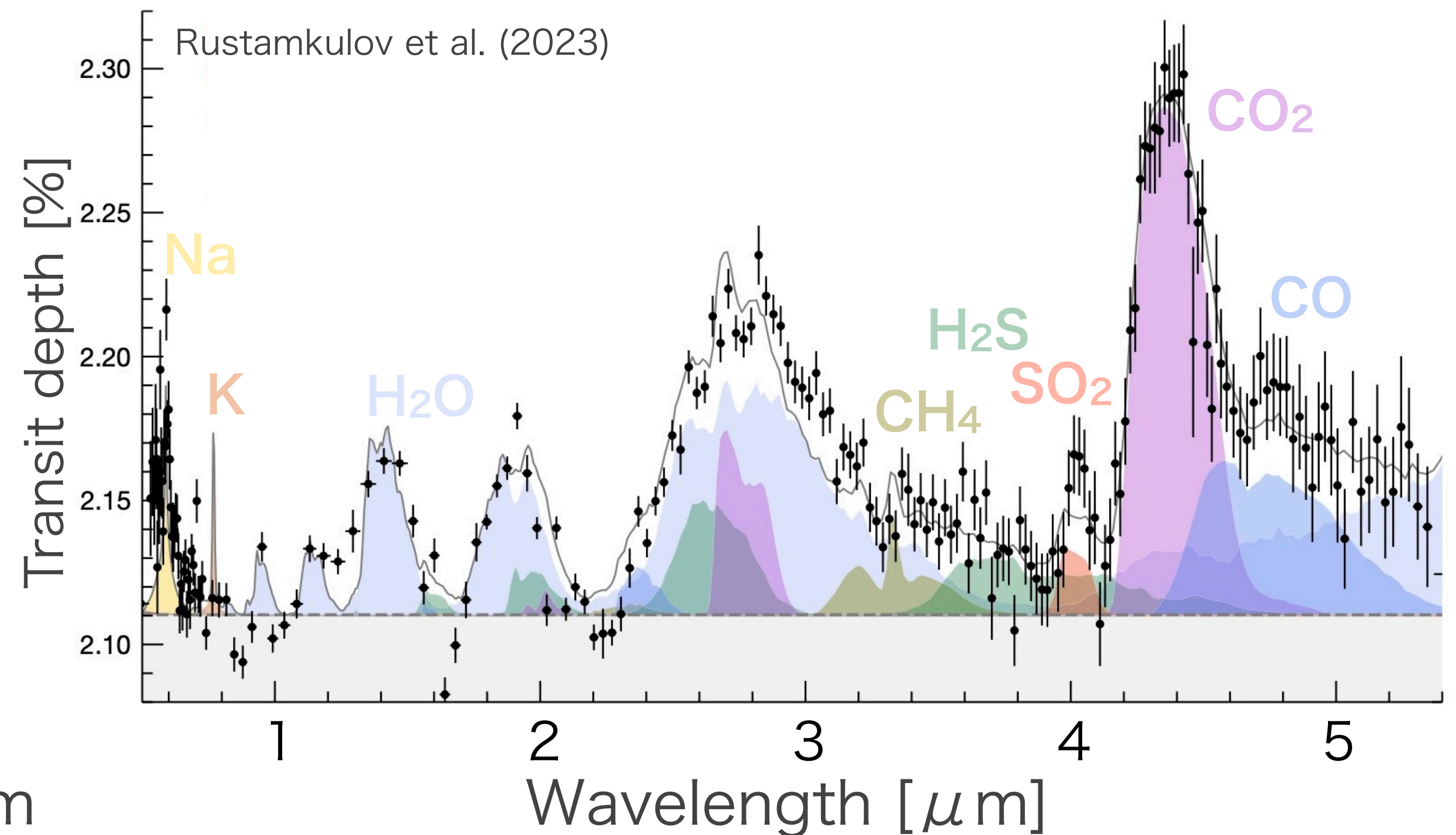
Distribution of discovered exoplanets



Atmospheric spectrum \Rightarrow Planetary environment



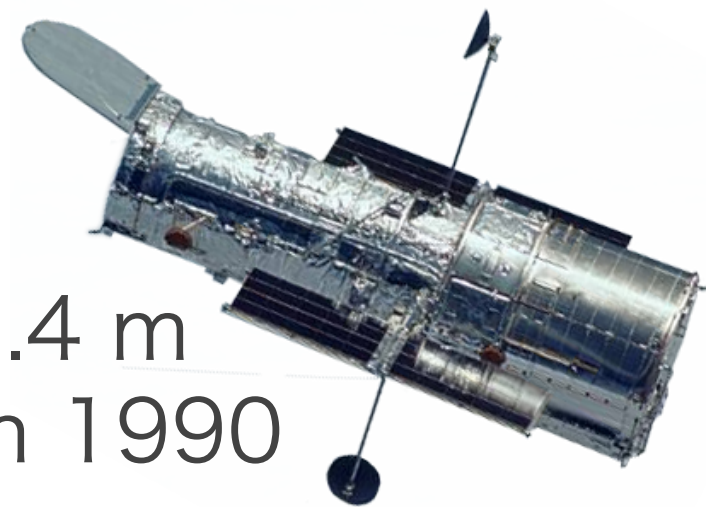
Observed atmospheric spectrum



\Rightarrow Understanding of atmospheric processes/habitability/origin

New era opened by JWST

Hubble Space Telescope



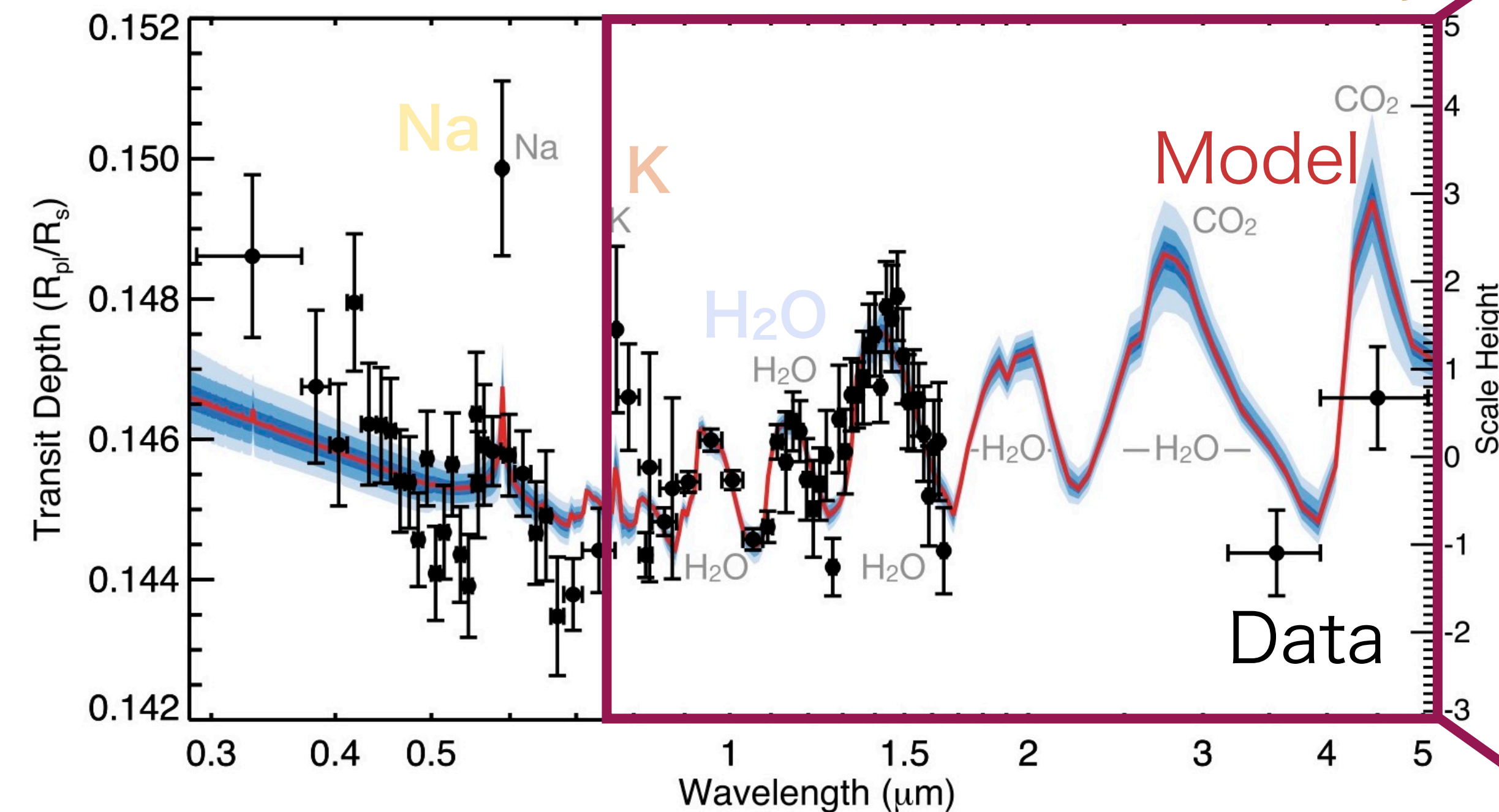
Diameter: 2.4 m
Launched in 1990

Spitzer Space Telescope

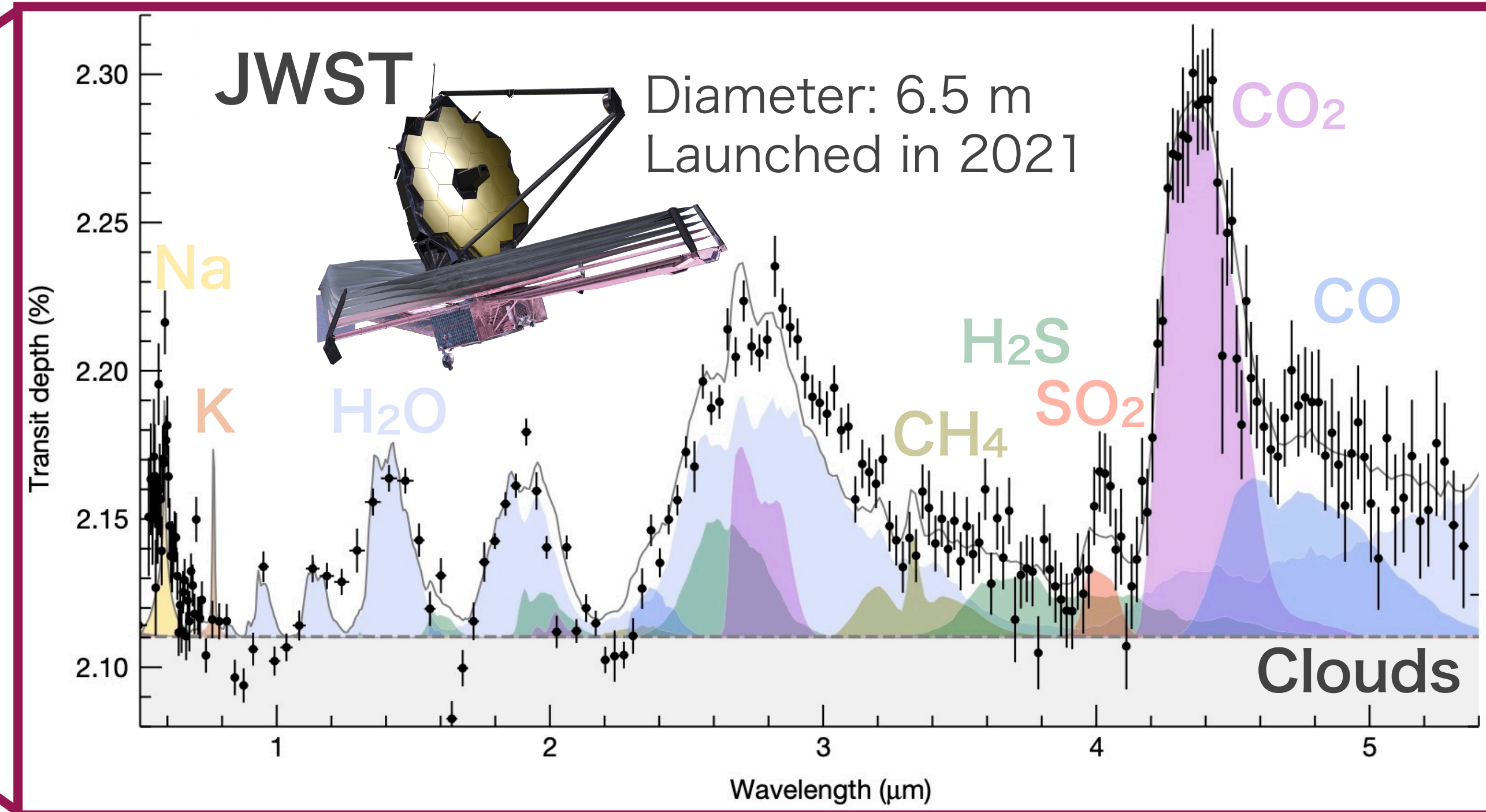


Diameter: 0.85 m
Launched in 2003

The wavelength range, thus chemical species, we could probe was strongly limited before the era of JWST (H_2O , cloud, Na, K)



Wakeford et al. (2018)



The same planet but with JWST

Rustamkulov et al. (2023)

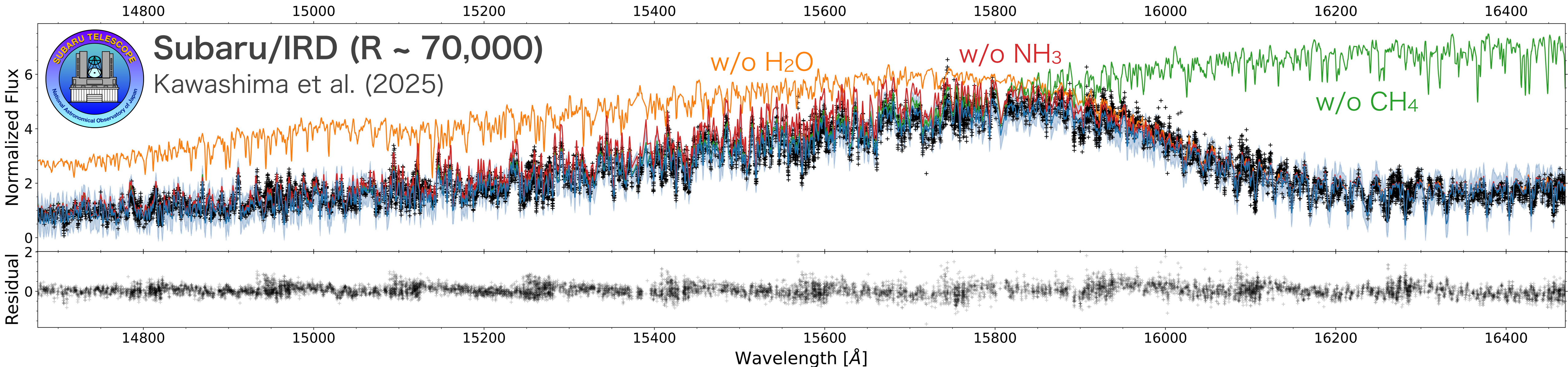
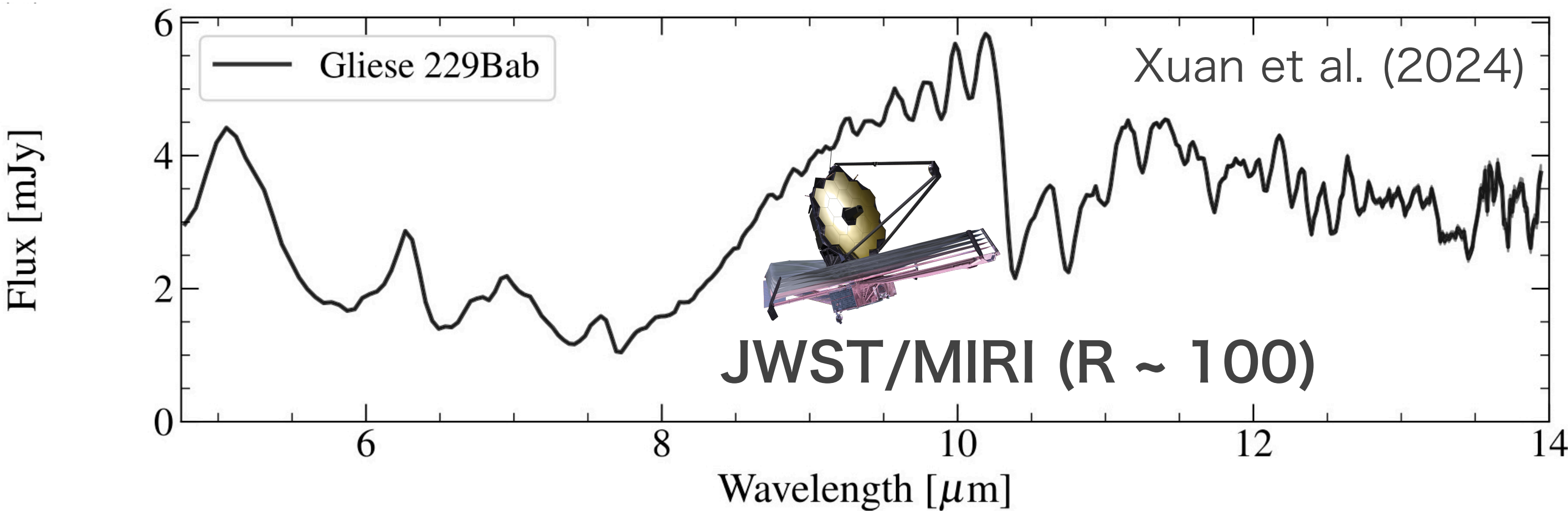
High-resolution spectroscopy from ground

High-resolution spectroscopy
resolves each absorption line



- ▶ Robust chemical detection
- ▶ Precise temperature structure
- ▶ Rotation/wind

Complementary information



Toward the Characterization Era

2000s

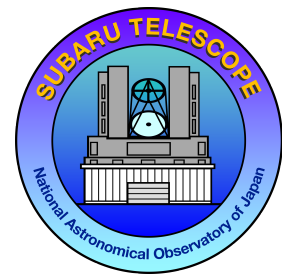
Detection of Planets

2010s

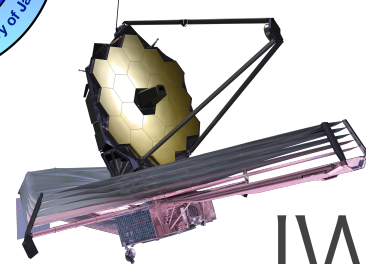
Systematic Detection of Planets

2020s~

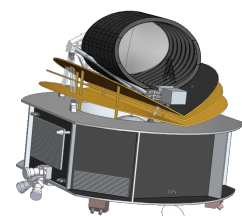
Characterization of
Gaseous Planets



Subaru



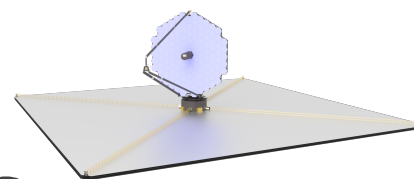
JWST



Ariel

2030/40s~

Characterization of
Earth-like Planets

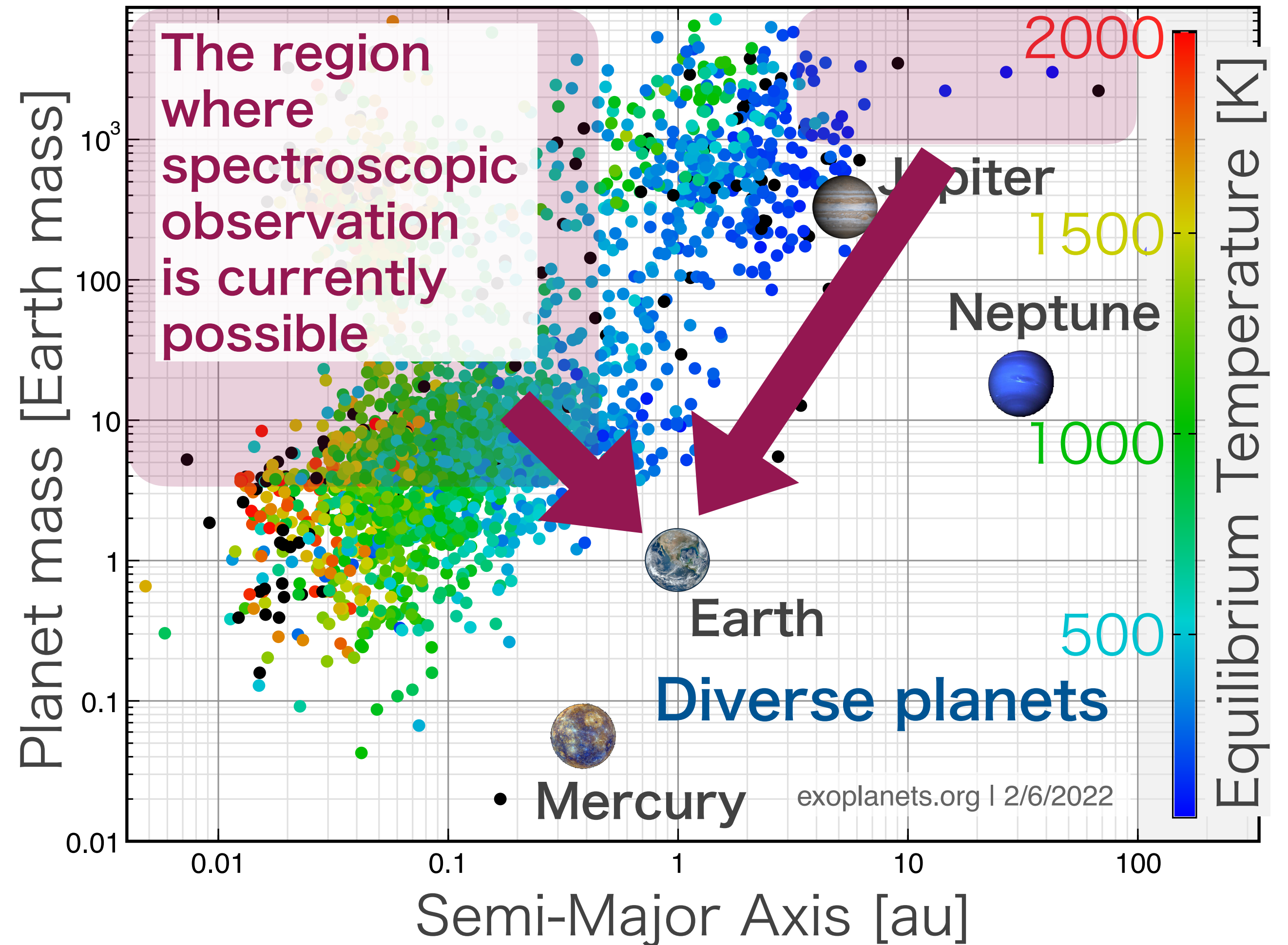


HWO

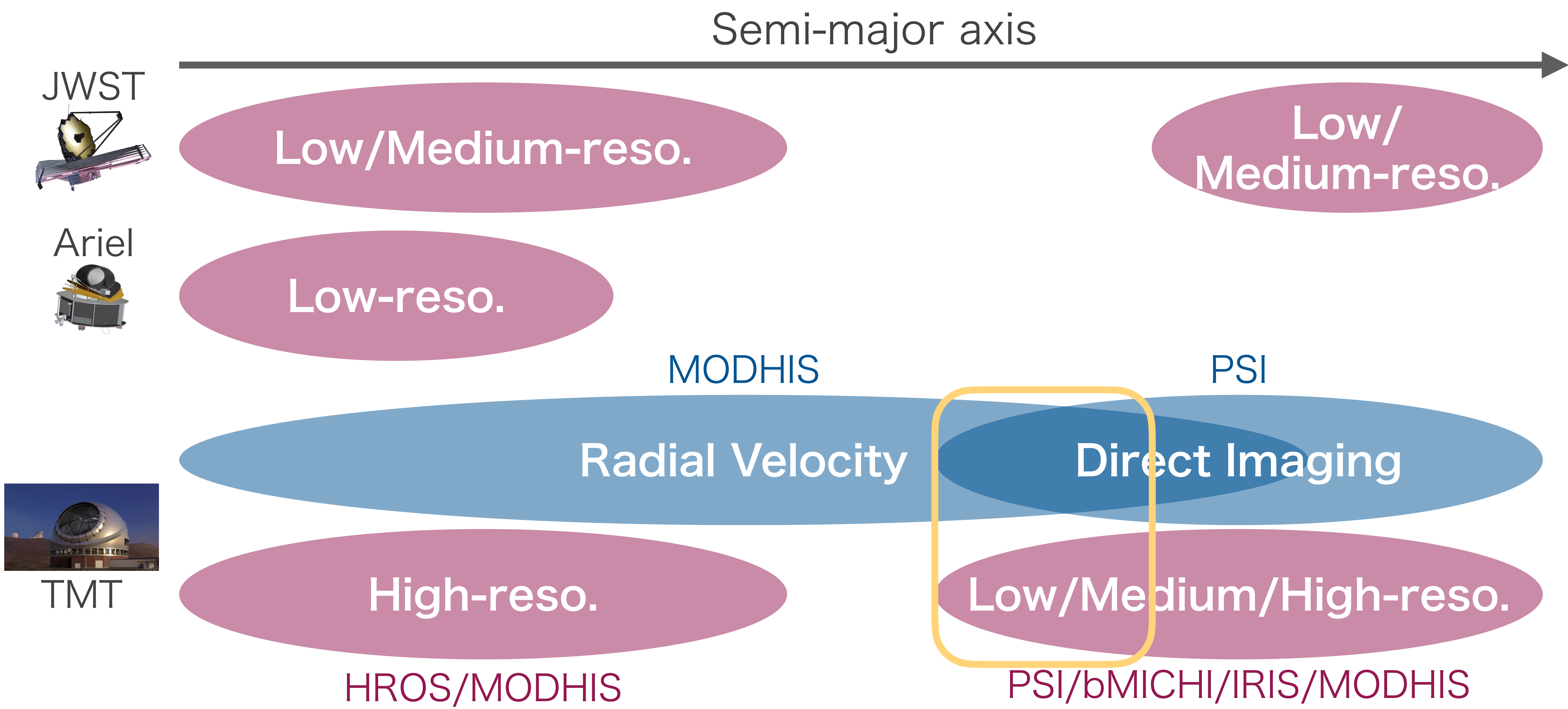


TMT

Distribution of discovered exoplanets

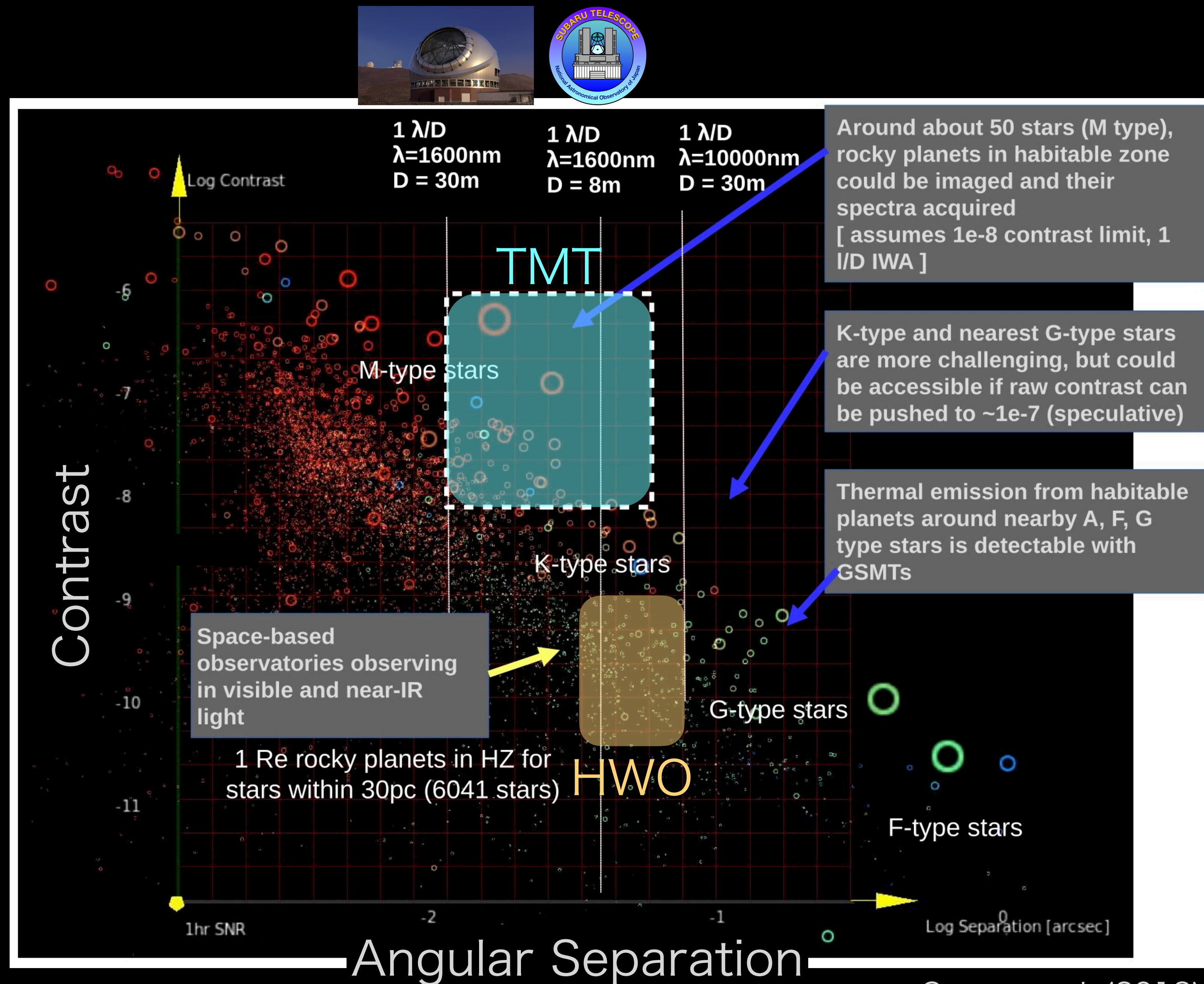


Detection & Characterization in TMT era



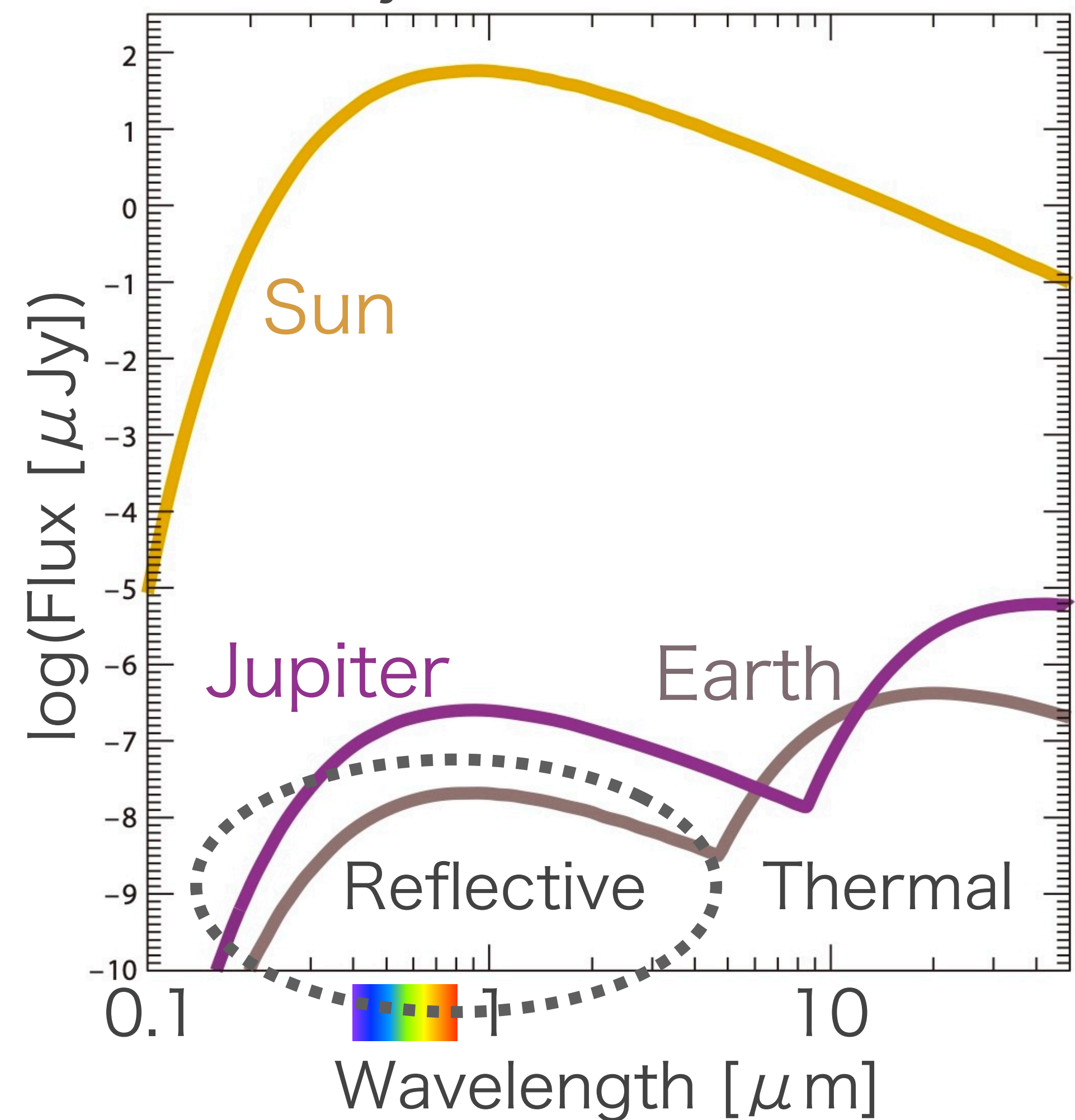
TMT advantage

Large diameter of TMT
has a direct advantage
of small inner working
angle for direct
imaging observation



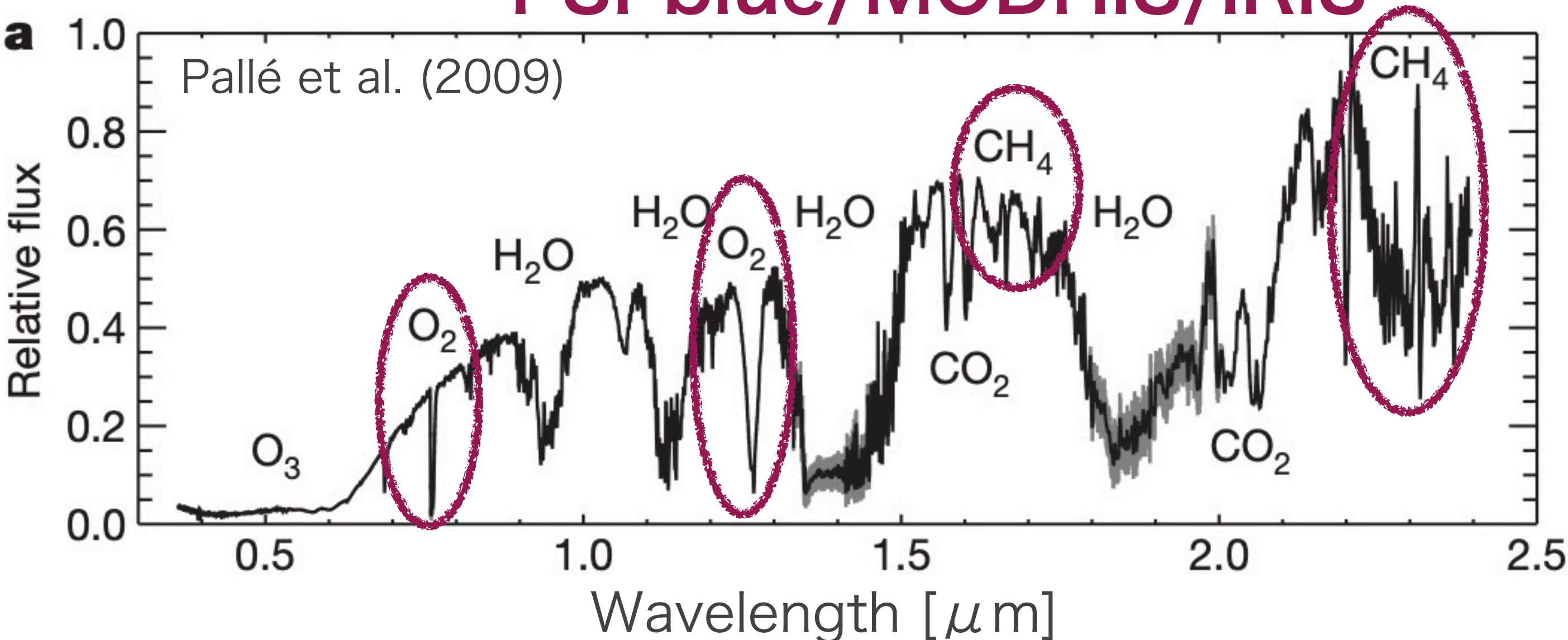
Detection of biosignatures

Black-body flux of the Sun & Earth

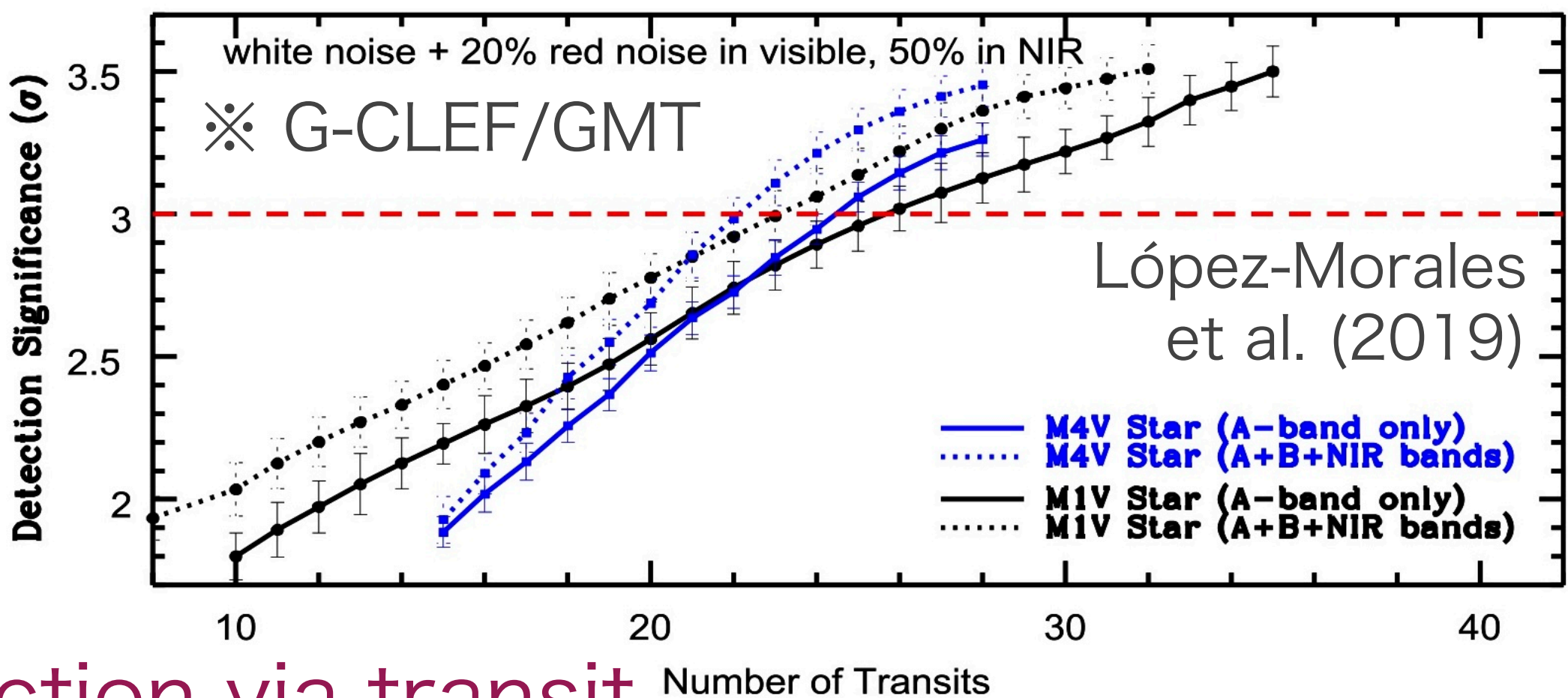


Seager & Deming (2010)

PSI-blue/MODHIS/IRIS



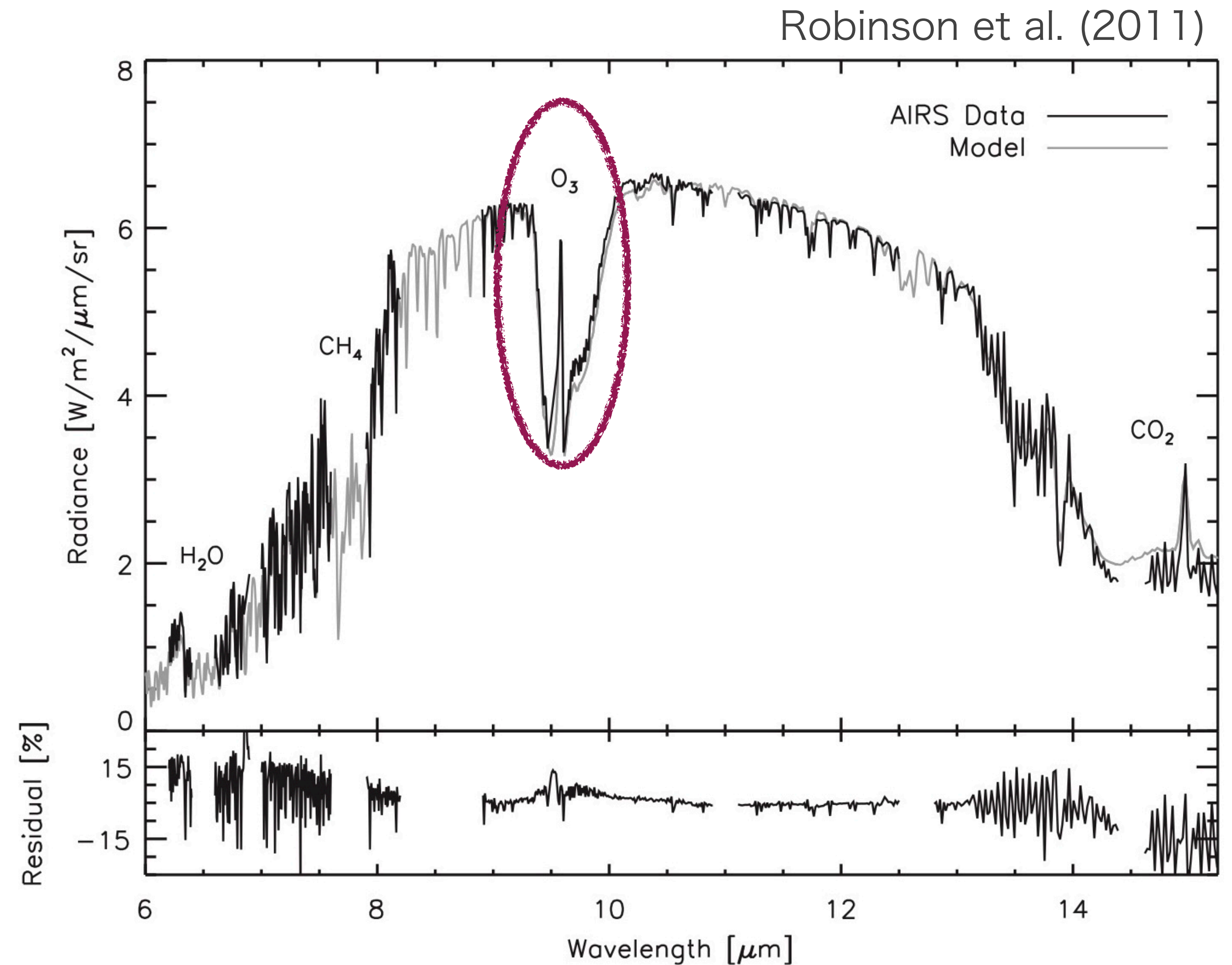
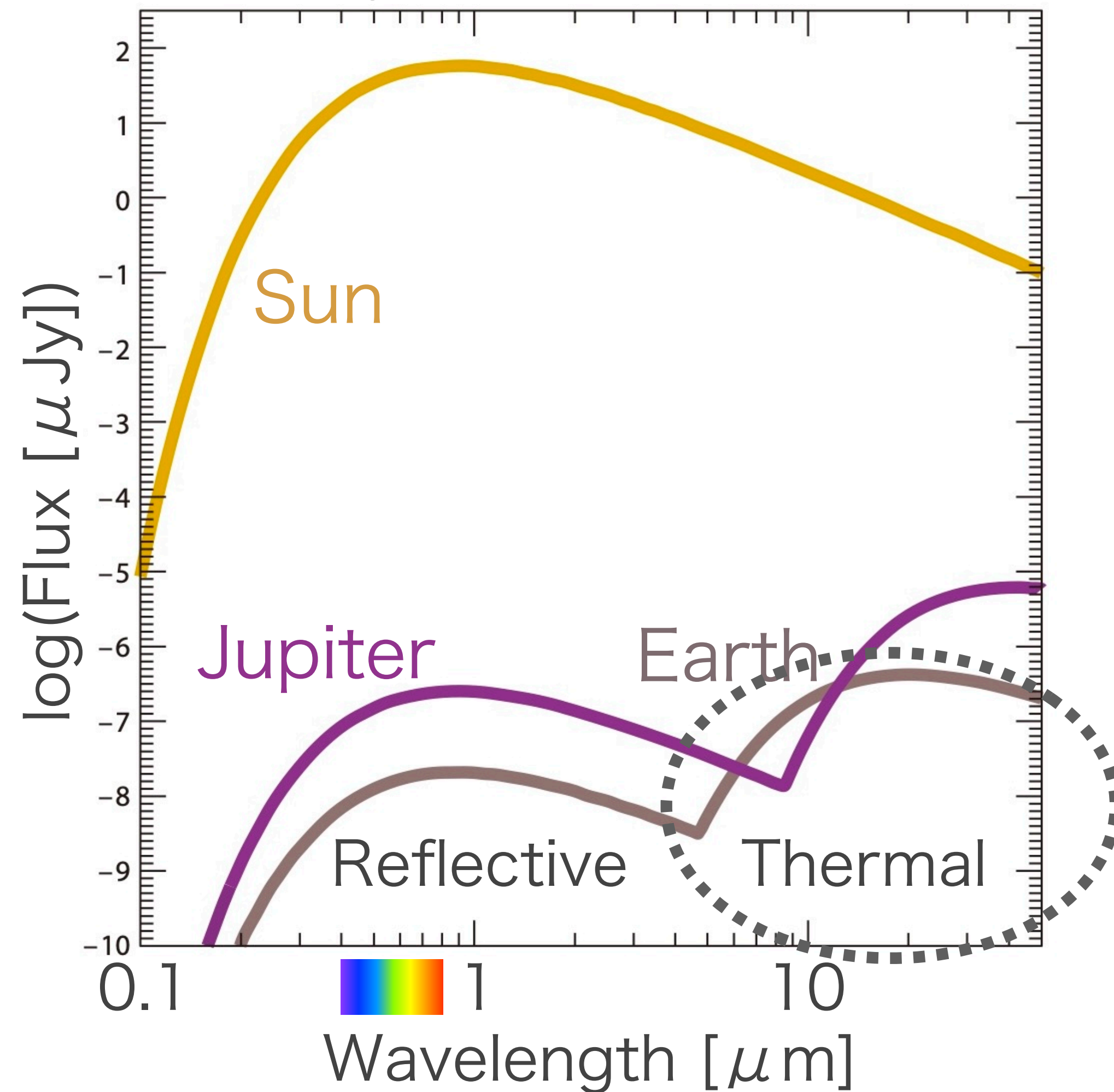
HROS/
MODHIS



Oxygen detection via transit

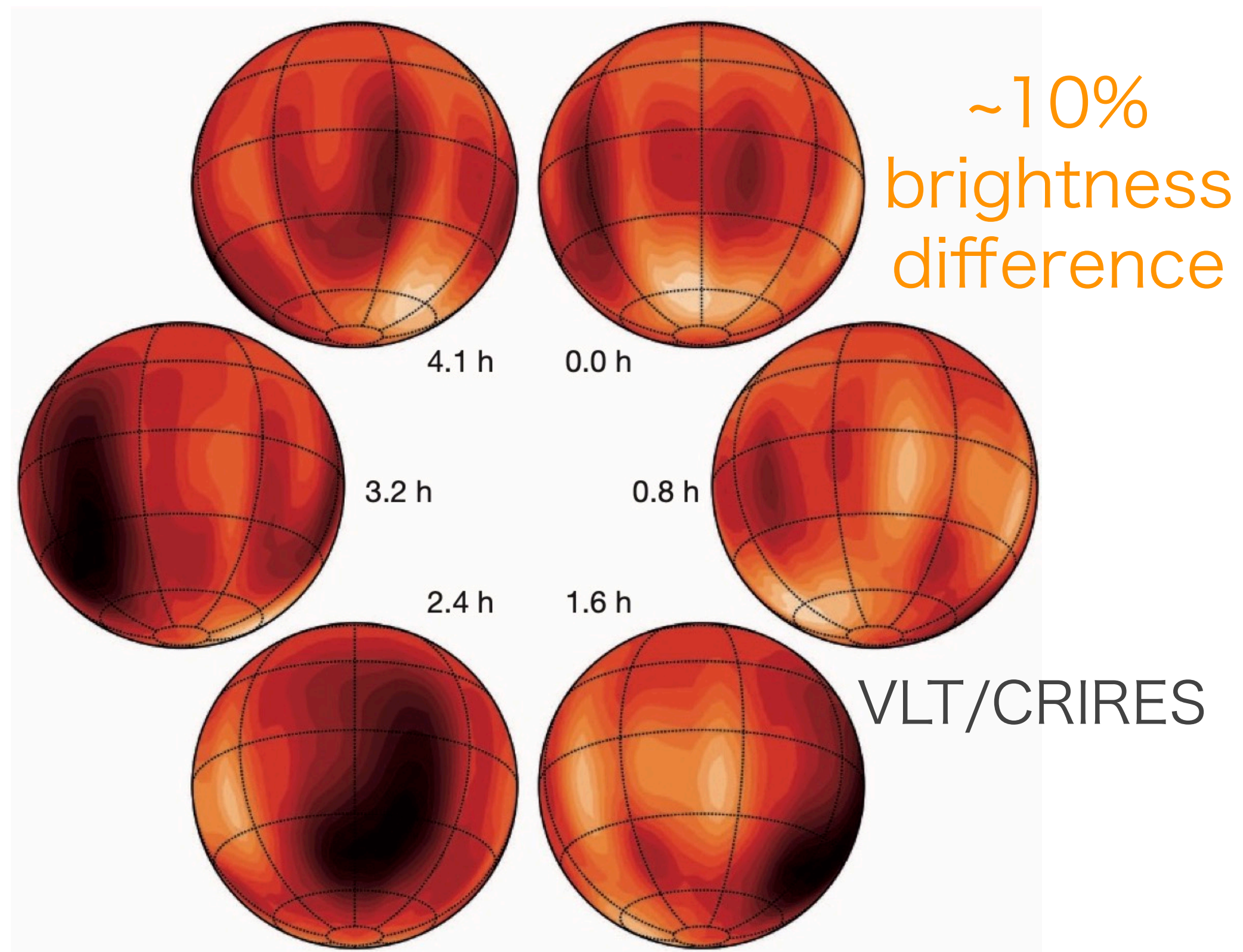
Detection of biosignatures

Black-body flux of the Sun & Earth



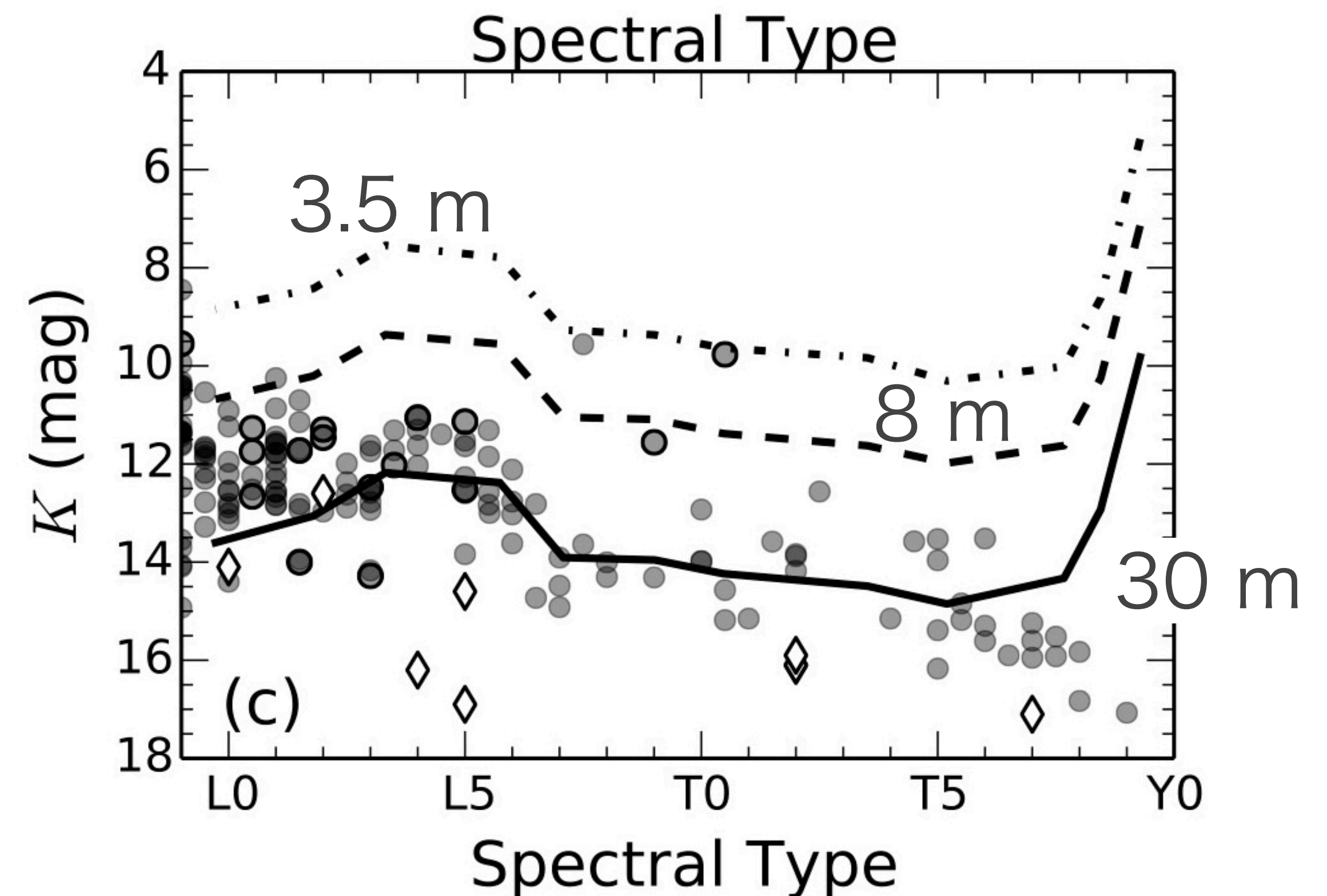
Doppler imaging with high-resolution spectroscopy

Surface map of Luhman 16B by doppler imaging



Crossfield et al. (2014)

Understanding of atmospheric dynamics/cloud formation



Crossfield (2014)

Summary

- More than 5,000 exoplanets have been found so far
- After 20 years of the detection era, characterization era has just begun thanks to the successful launch of JWST and advancements in high-resolution spectrographs on 10 m-class ground telescopes
- Atmospheric characterization of detected planets is essential to understand atmospheric processes, habitability, and origin
- Observation with TMT is complementary to JWST and HWO: Smaller inner working angle & high-resolution spectroscopy