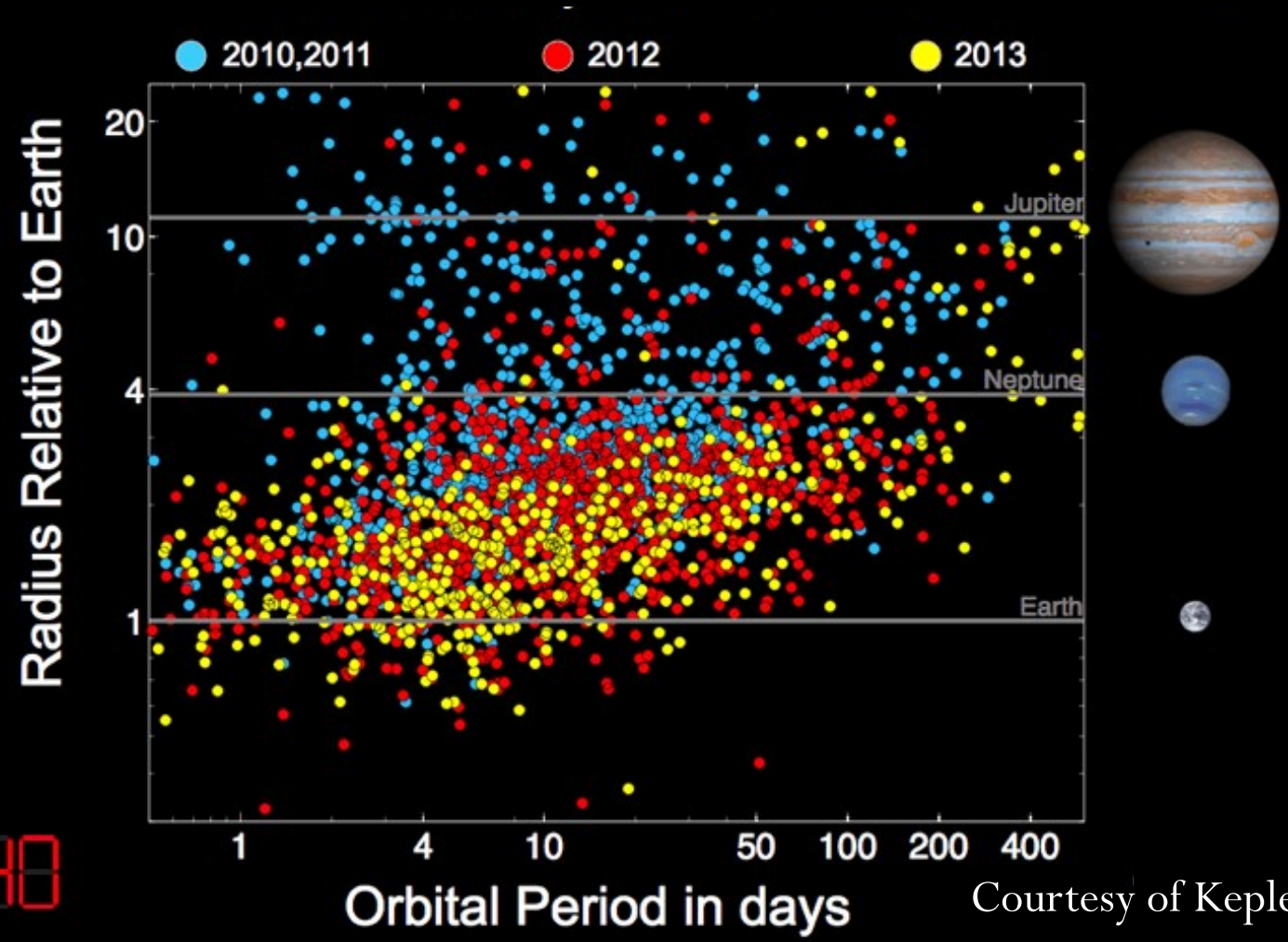
What are Exoplanets made of?

Giovanna Tinetti

University College London, Royal Society

“The Exoplanet Revolution”

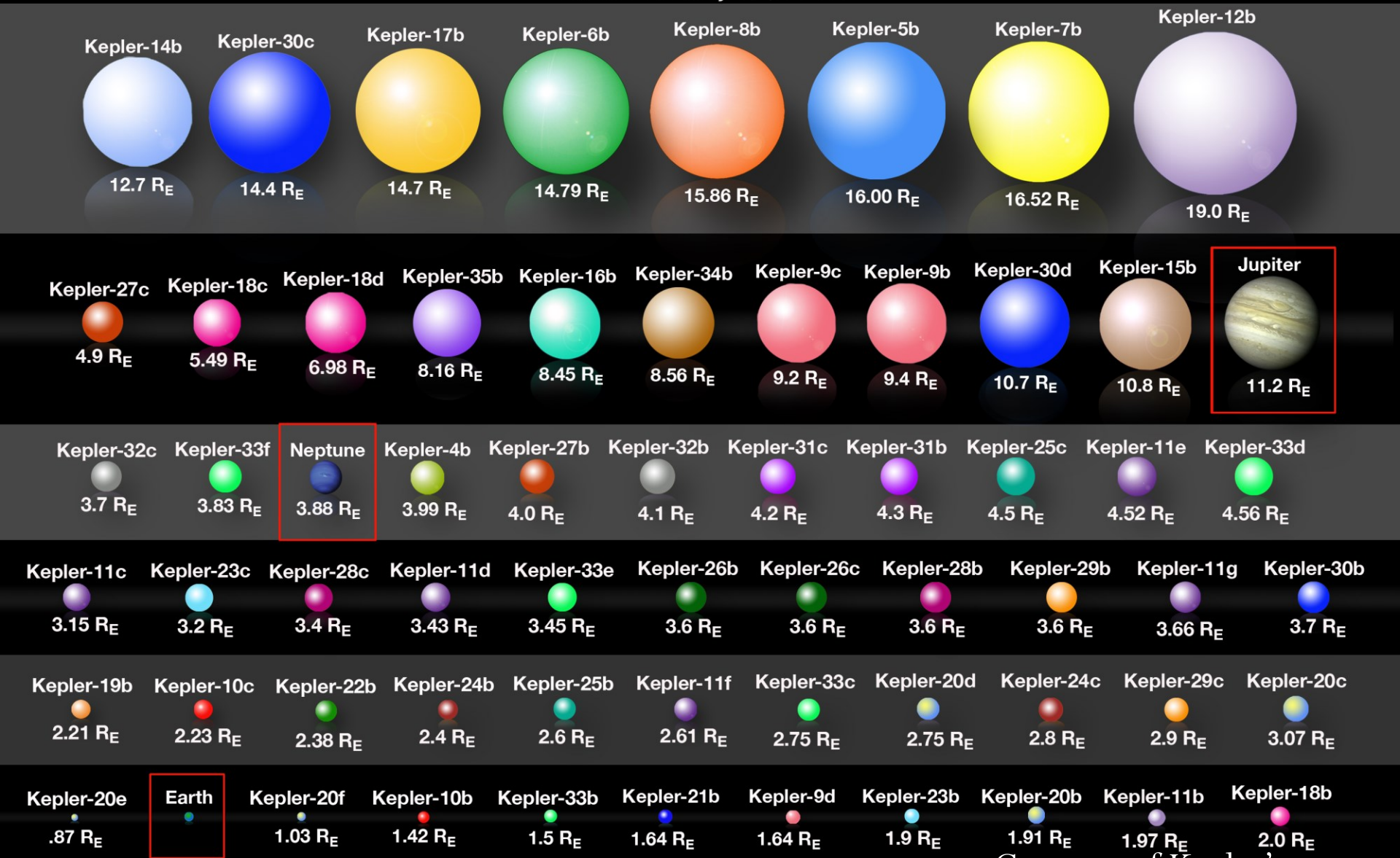
9 to 1000 in 20 years!



Courtesy of Kepler’s team

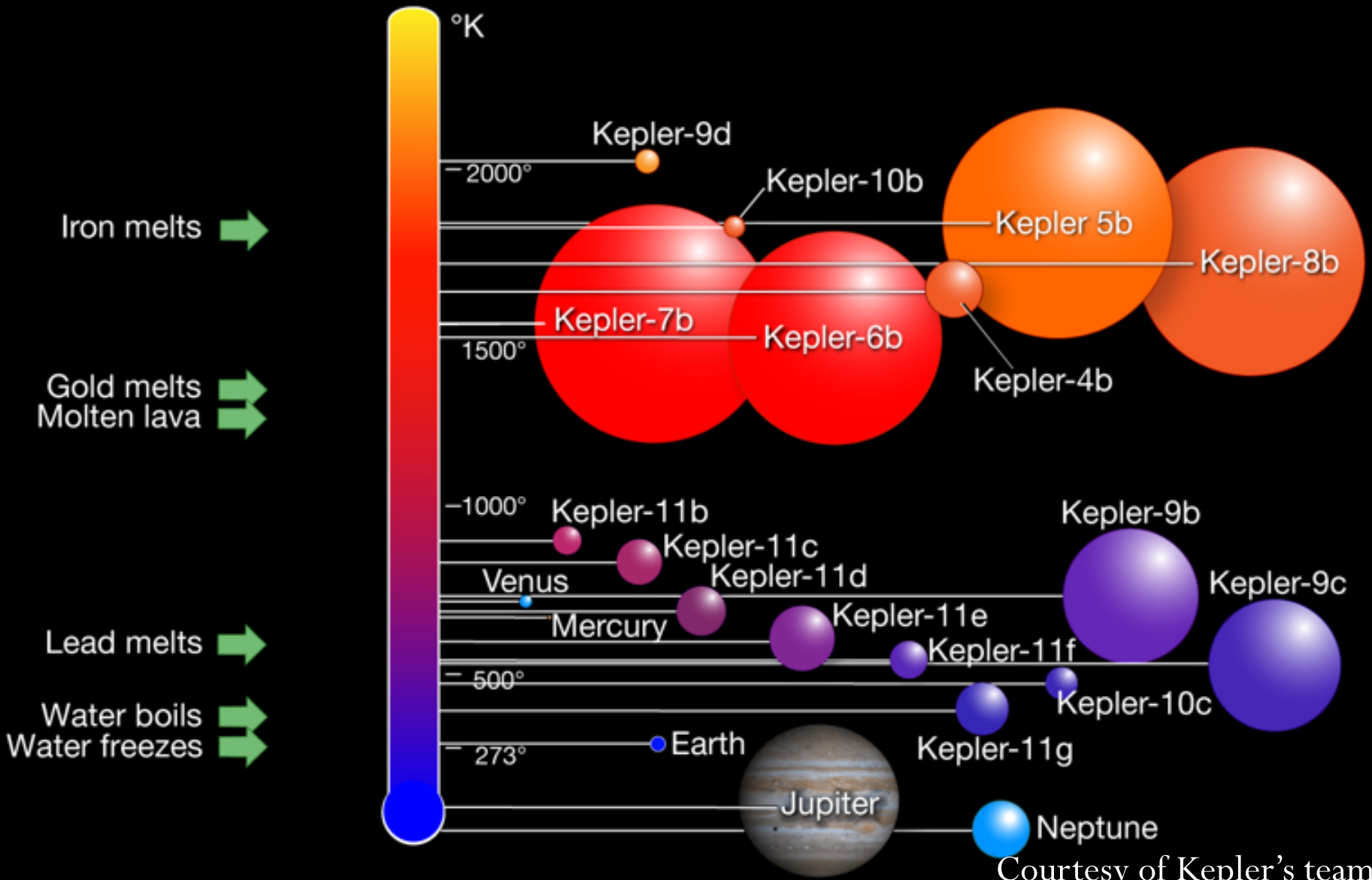
Kepler Planets

As of February 27, 2012



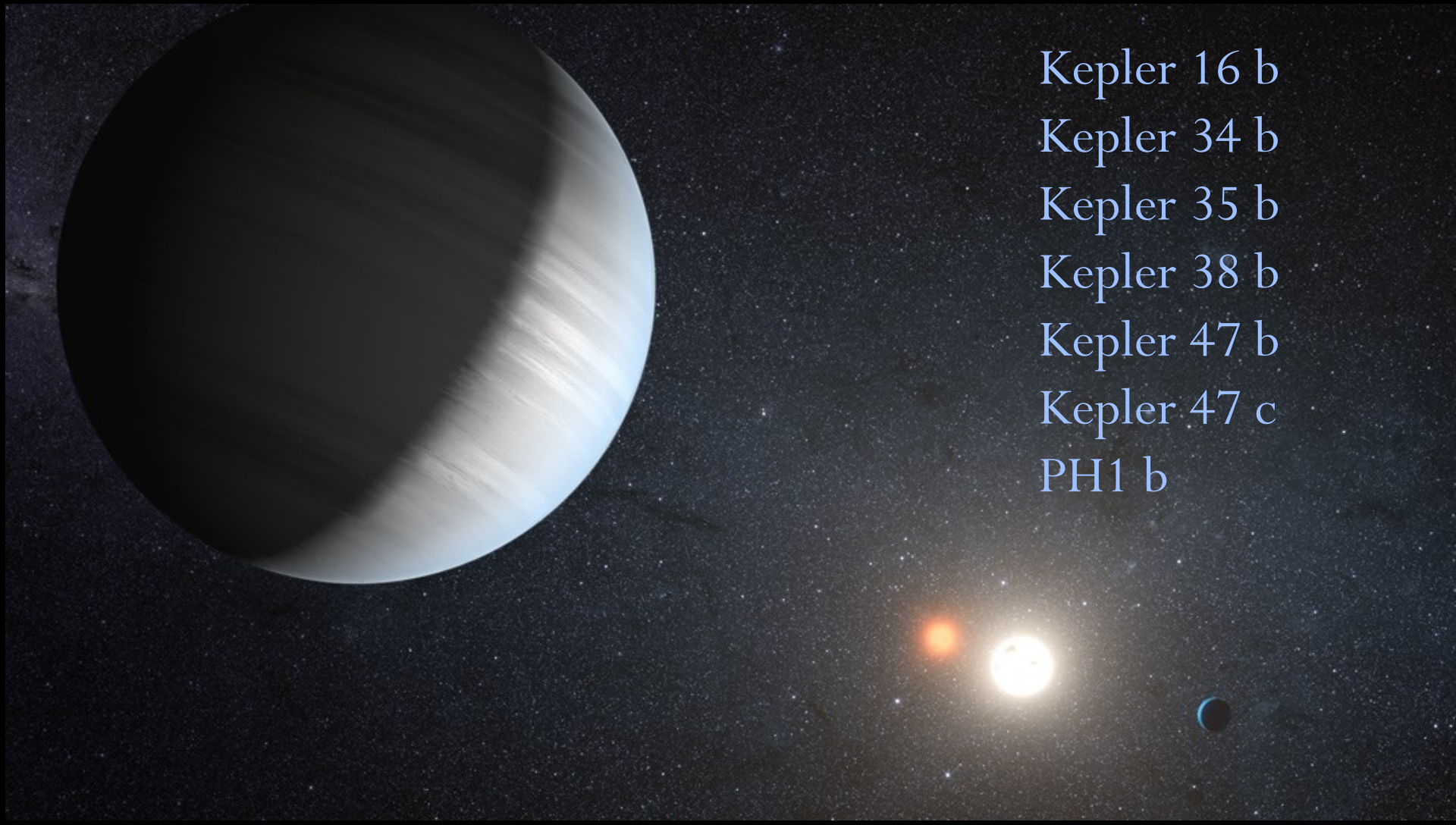
Courtesy of Kepler's team

Planet Temperature & Size



Courtesy of Kepler's team

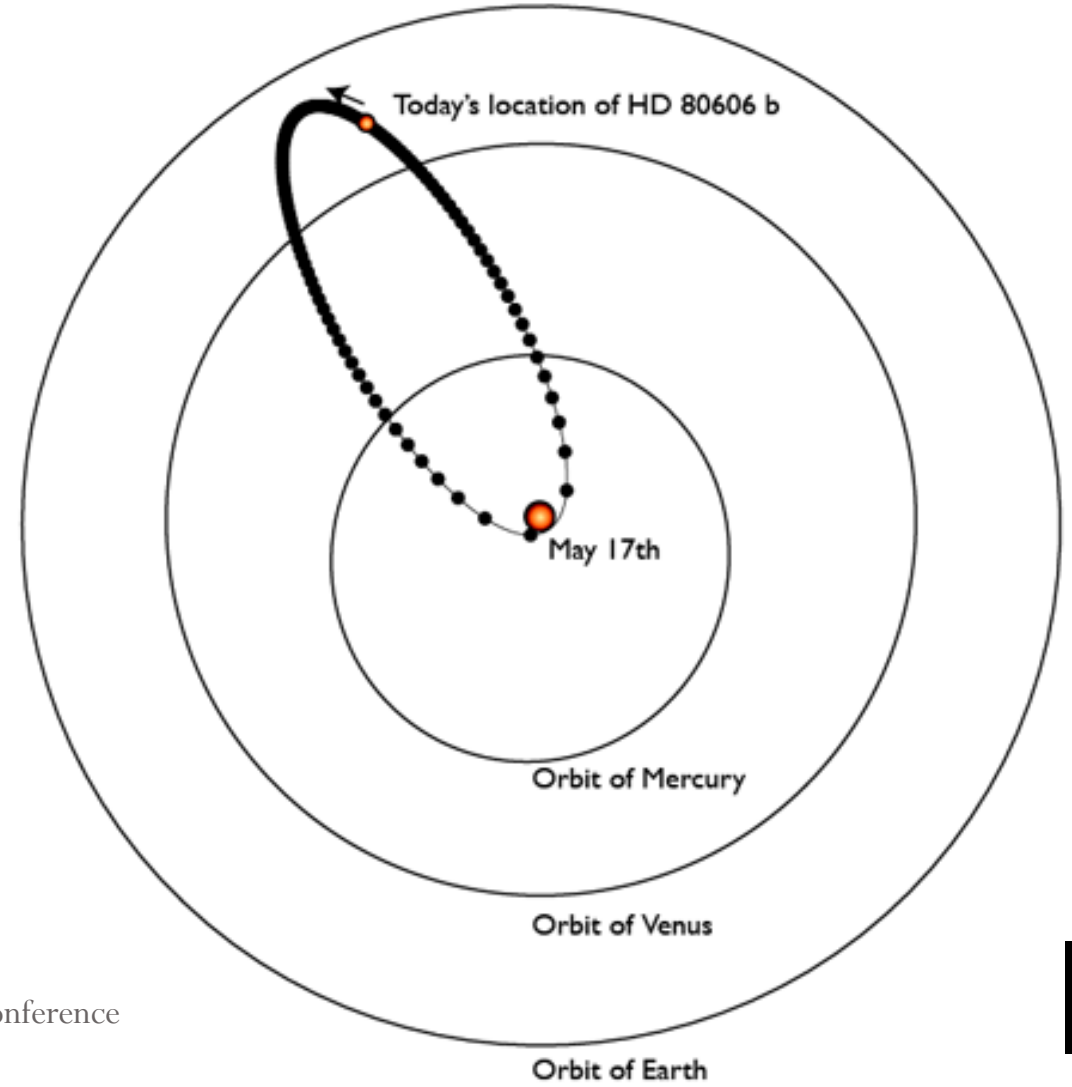
Planets with 2 Suns



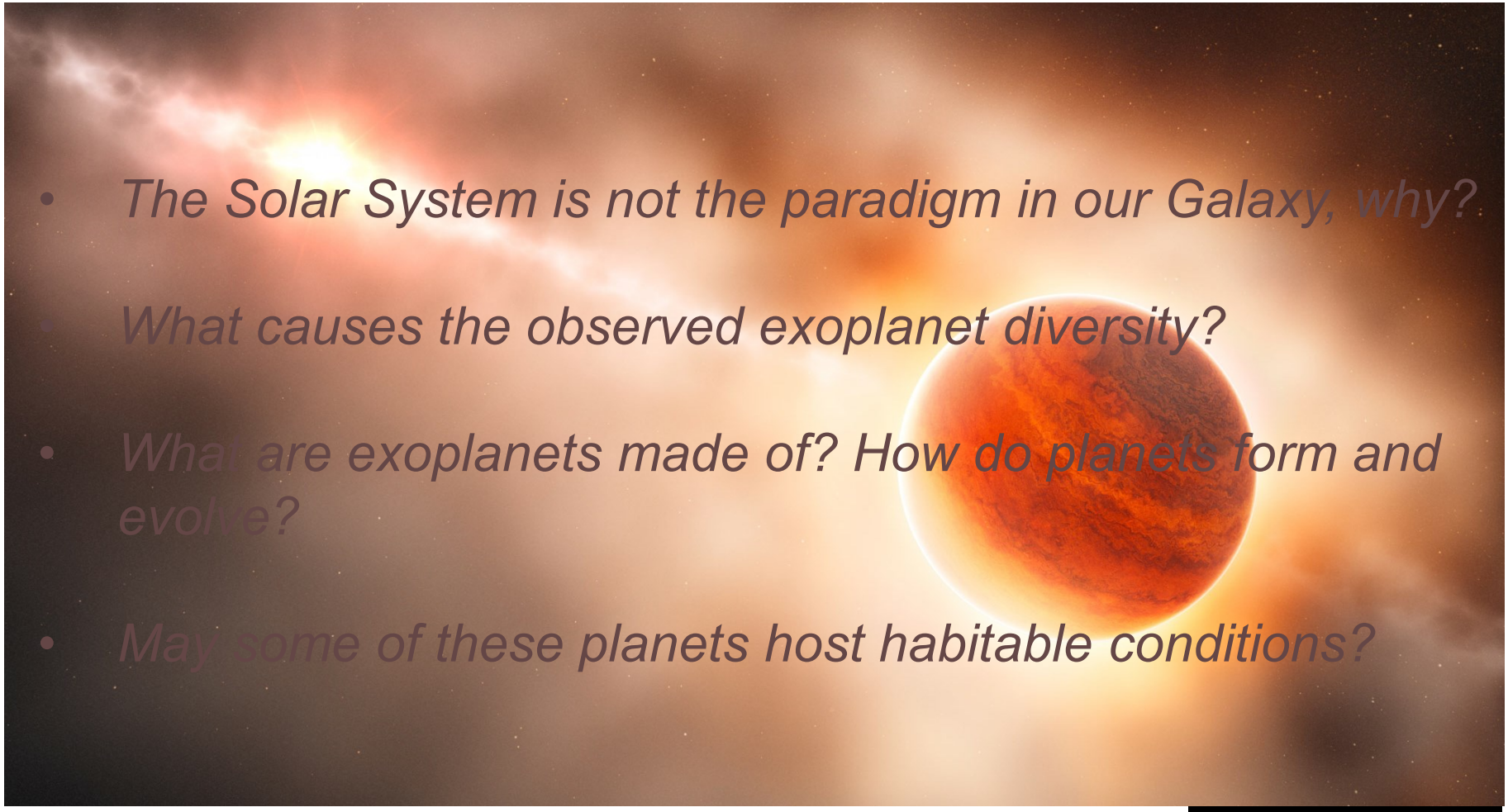
Kepler 16 b
Kepler 34 b
Kepler 35 b
Kepler 38 b
Kepler 47 b
Kepler 47 c
PH1 b

“Eccentric planets” HD80606b,

its orbit is as eccentric as the one of comet Halley



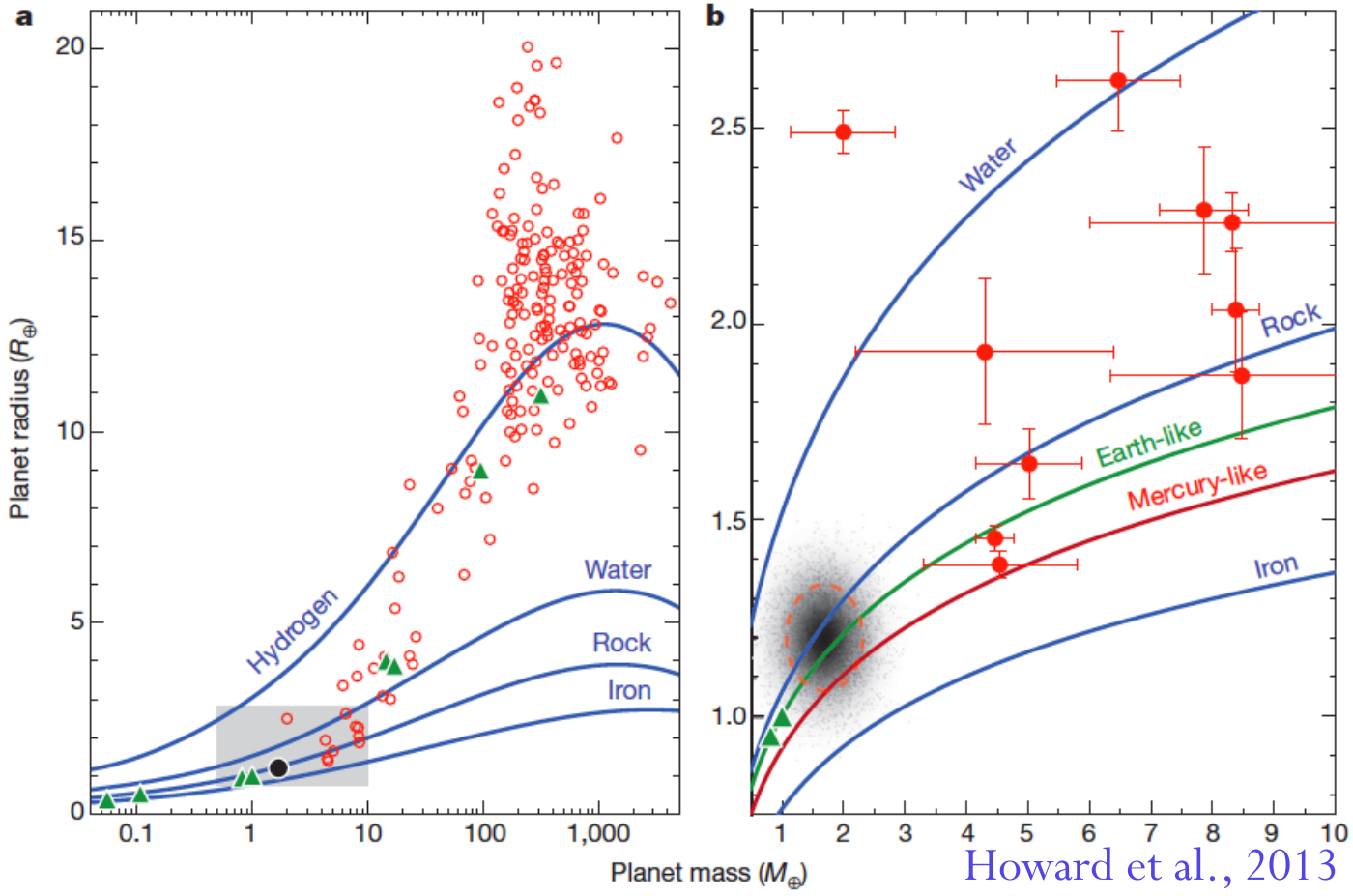
Outstanding Science Questions



- *The Solar System is not the paradigm in our Galaxy, why?*
- *What causes the observed exoplanet diversity?*
- *What are exoplanets made of? How do planets form and evolve?*
- *May some of these planets host habitable conditions?*

Understanding the exoplanet diversity,

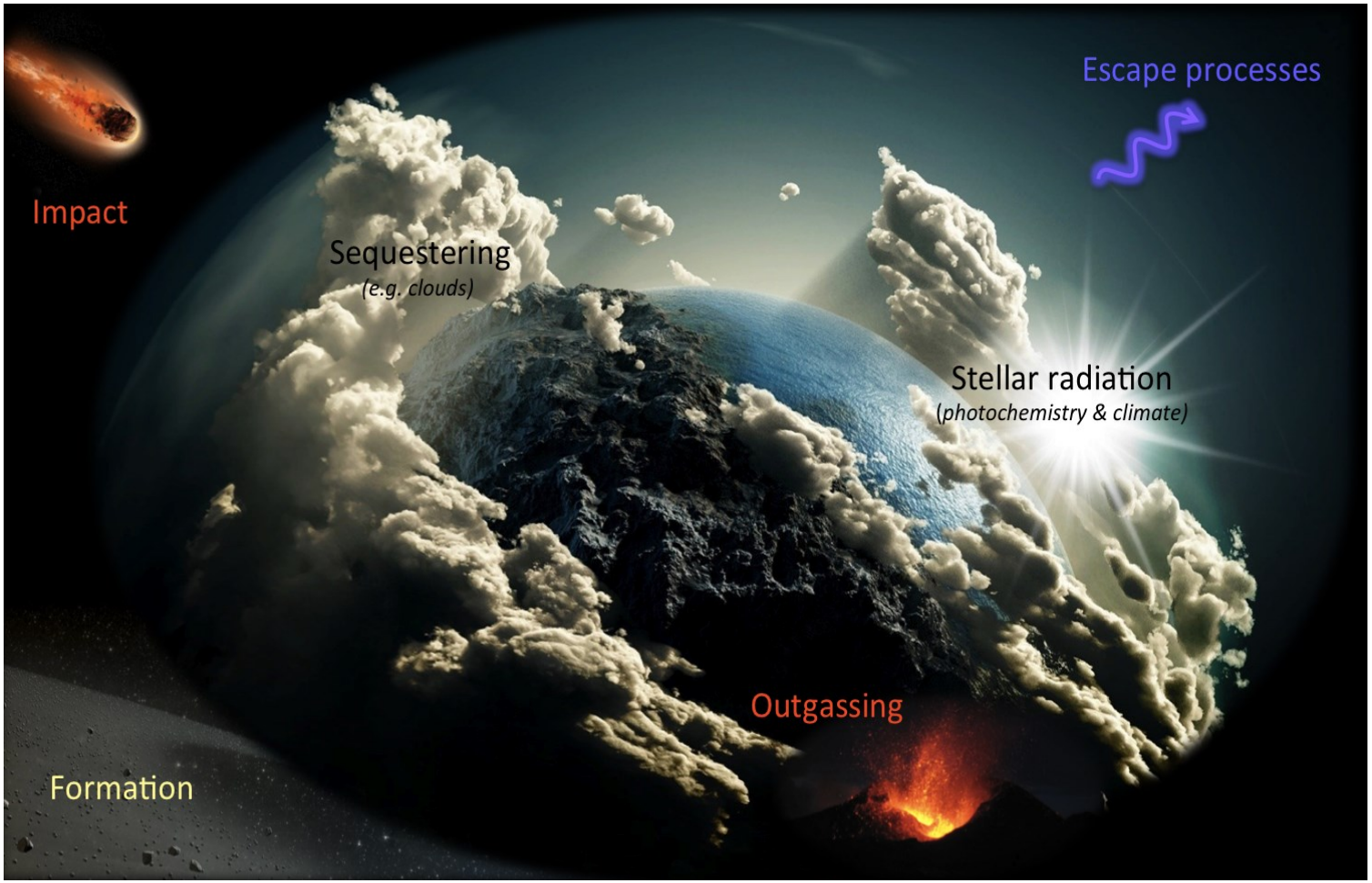
Mass & radius?



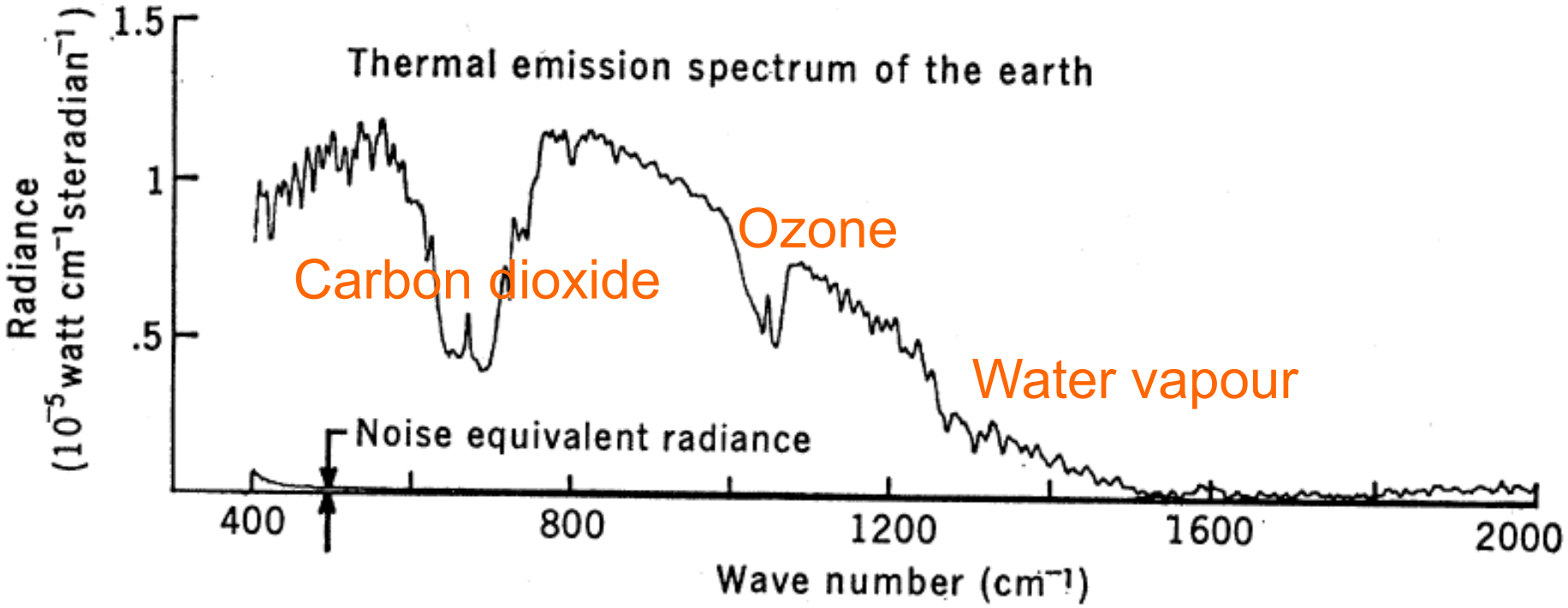
Howard et al., 2013

Understanding exoplanet diversity

The atmosphere



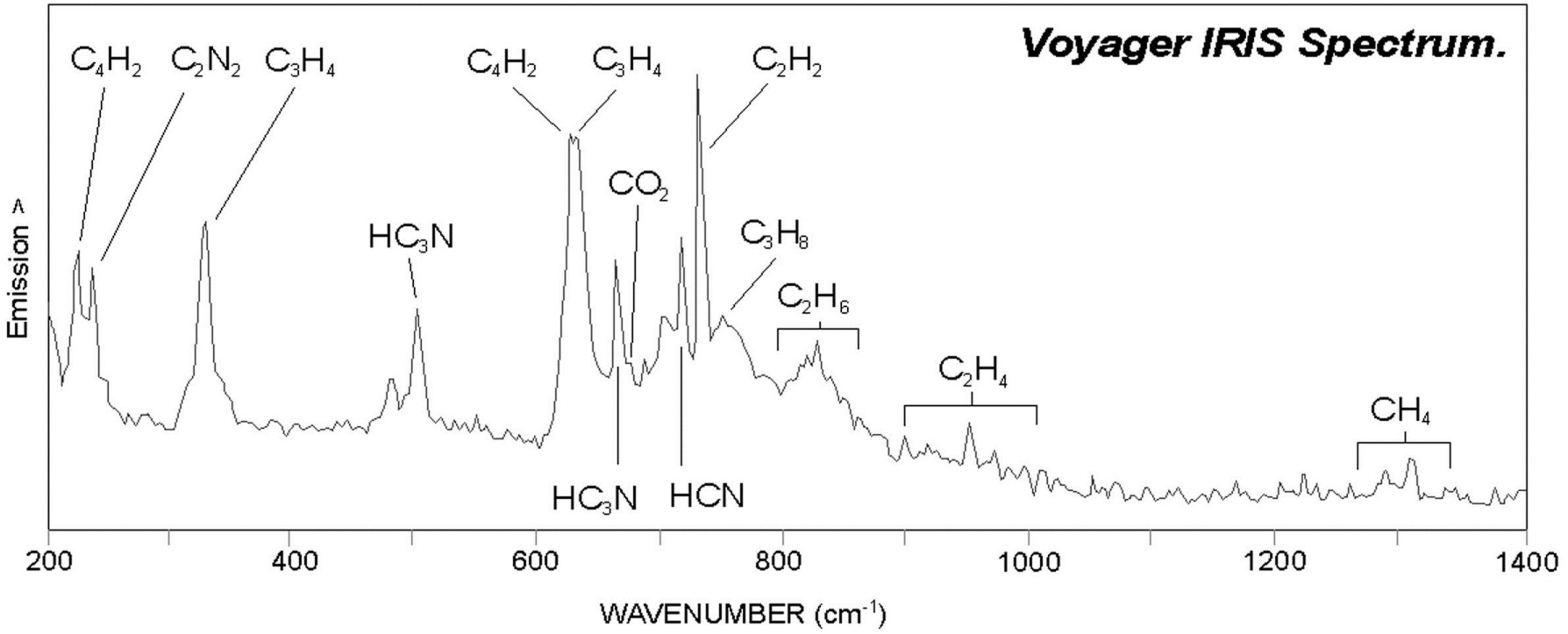
1969 – Nimbus 3: *The Earth*



Hanel & Conrath (1969)

1980 – *The outer solar system*

Titan's atmosphere

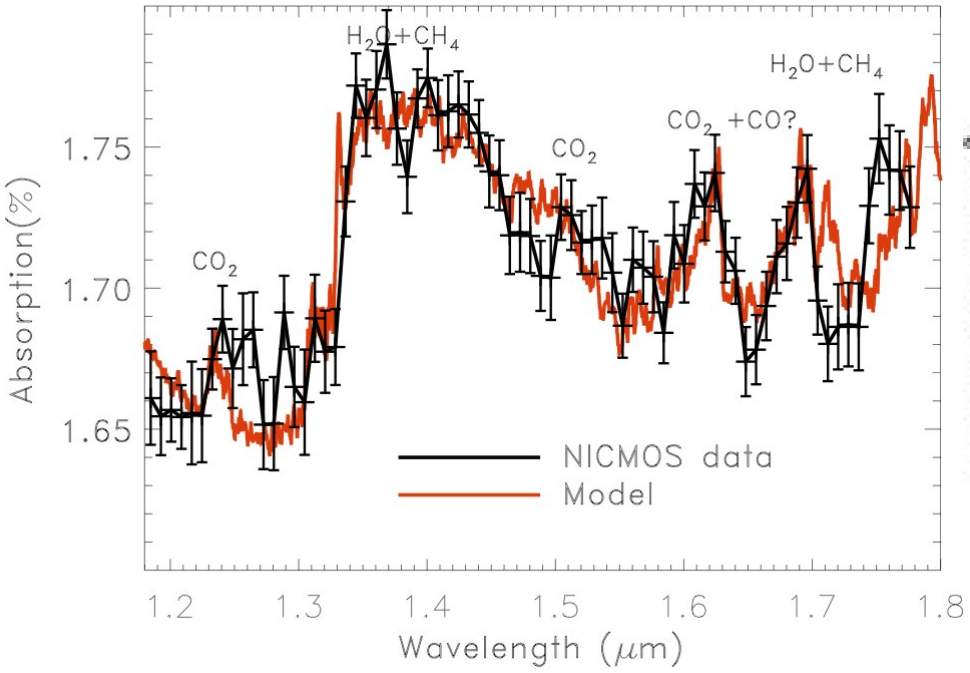


Samuelson et al. (1983)

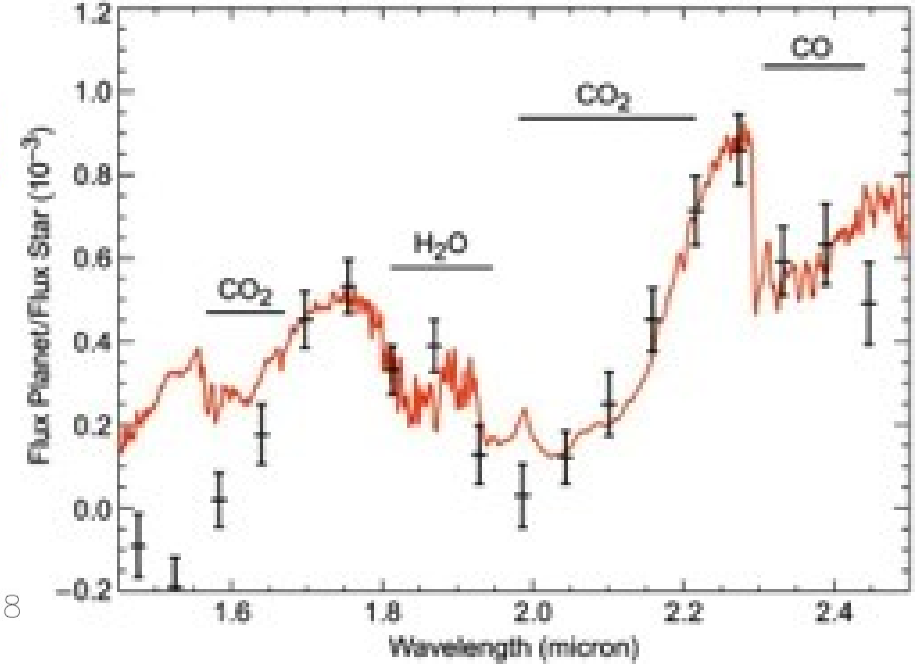
Pioneering work on Exoplanet Atmospheres

Transit spectra with Hubble, Spitzer, ground…

Hot-Jupiters, Temperatures ~ 1200 K

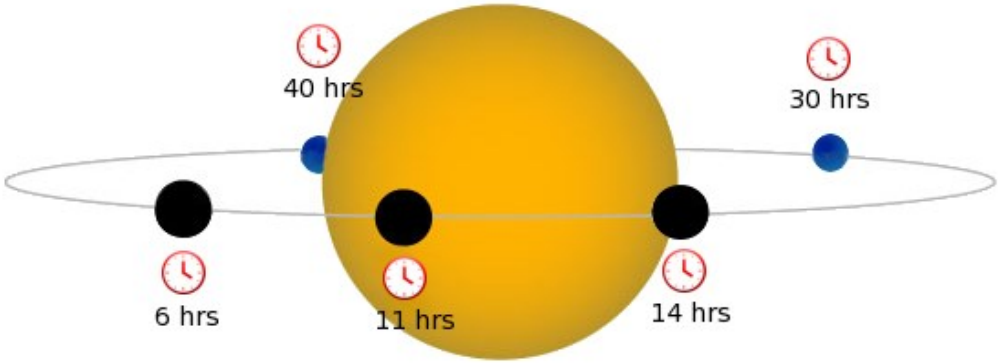


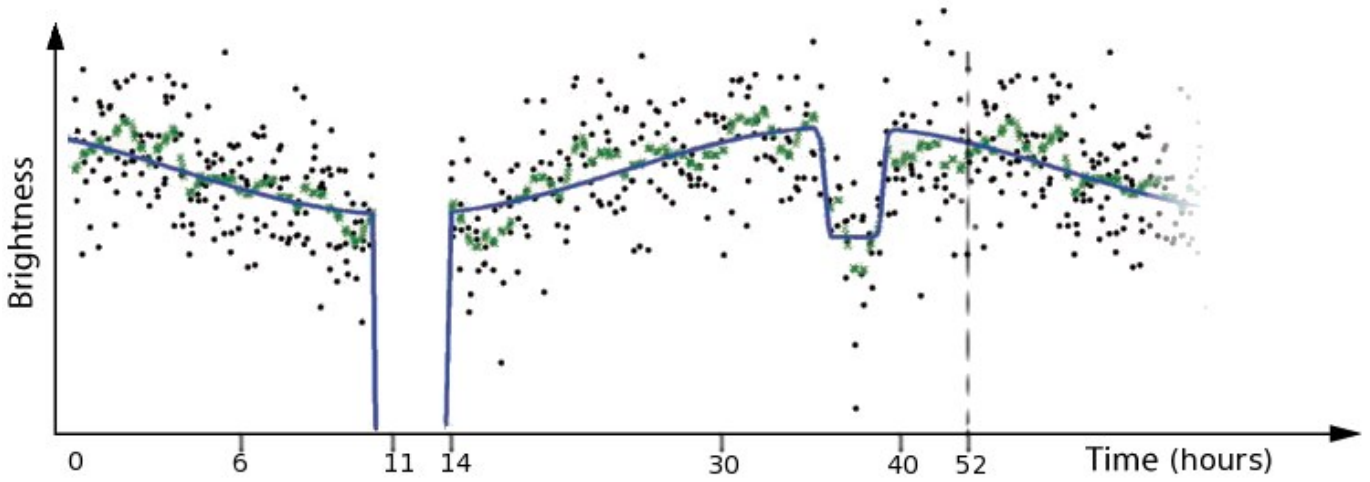
Tinetti et al., *ApJ*, 2010



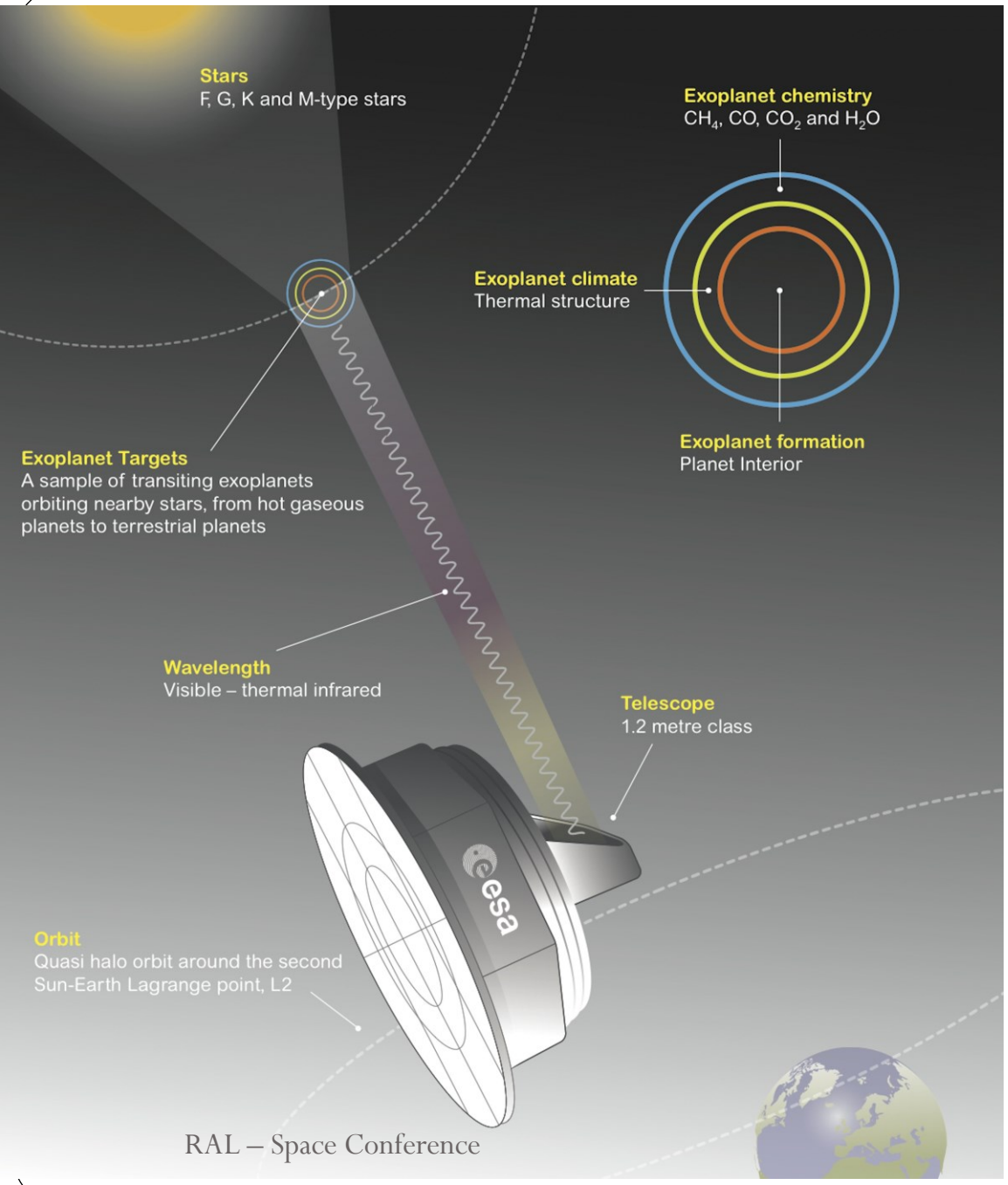
Swain et al, *ApJ*, 2009a,b

Transiting planets





HAT-P7b observed by Kepler
(Borucki et al, 2010)



EChO

European Space Agency
M3 mission candidate
(~500MEuros)

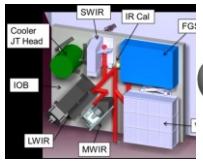
1m class telescope in space

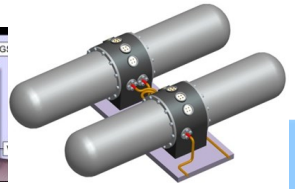
Spectroscopy of hundreds of planets in our Galaxy, from VIS to IR

Stability: 1 part in 10000 over 10 hours

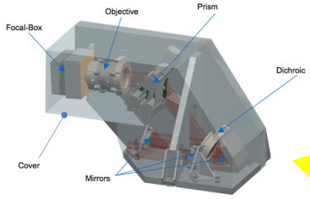
The EChO consortium

UK-led, with participation from other European countries

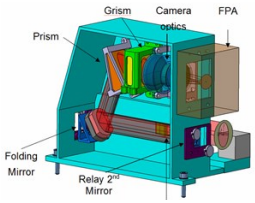




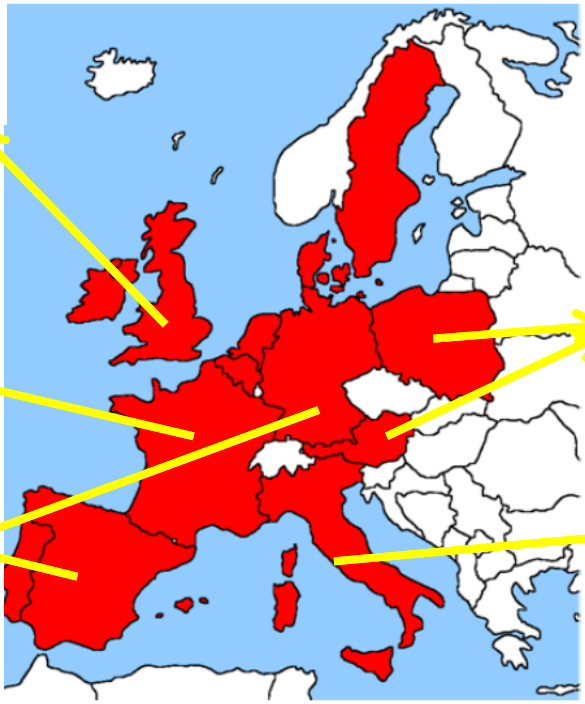
Project technical/scientific leadership

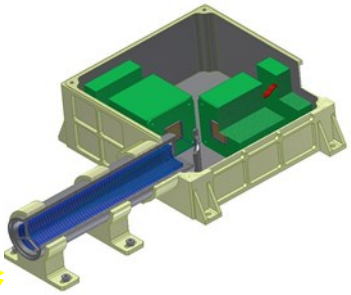


MWIR Channel

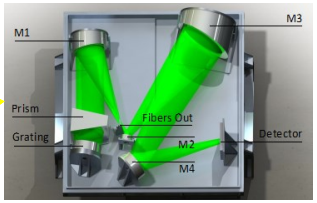


SWIR Channel





FGS Channel

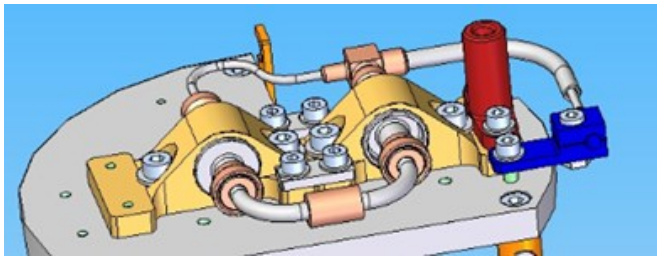


VNIR Channel

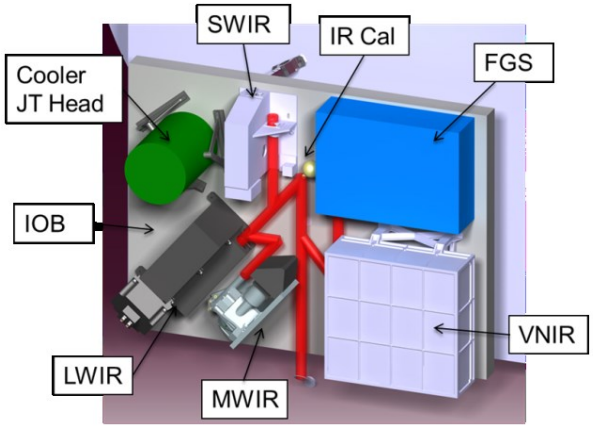
Large, but well integrated, consortium with experience and heritage in space IR instrumentation and exoplanet observations

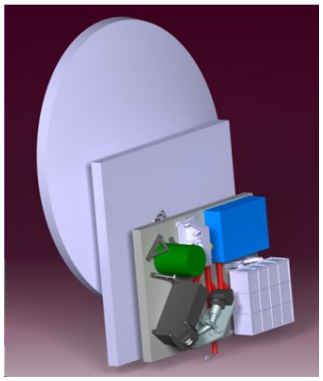
UK Key Technology

- UK has leading role in development of mission concept and instrument design (Herschel, JWST-MIRI, Solar Orbiter)

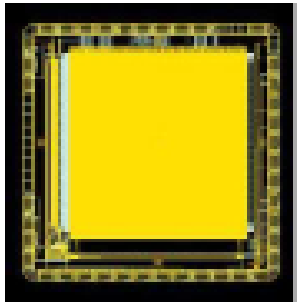


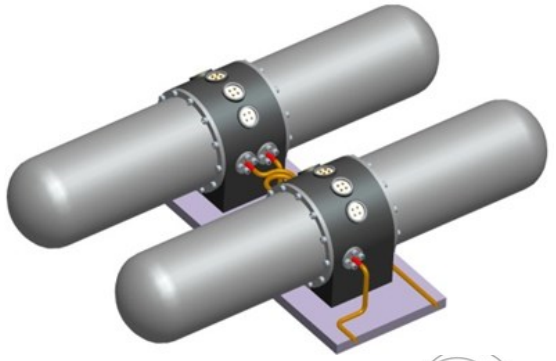
- This role requires and nurtures highly skilled workforce across academia, government institutes and industry





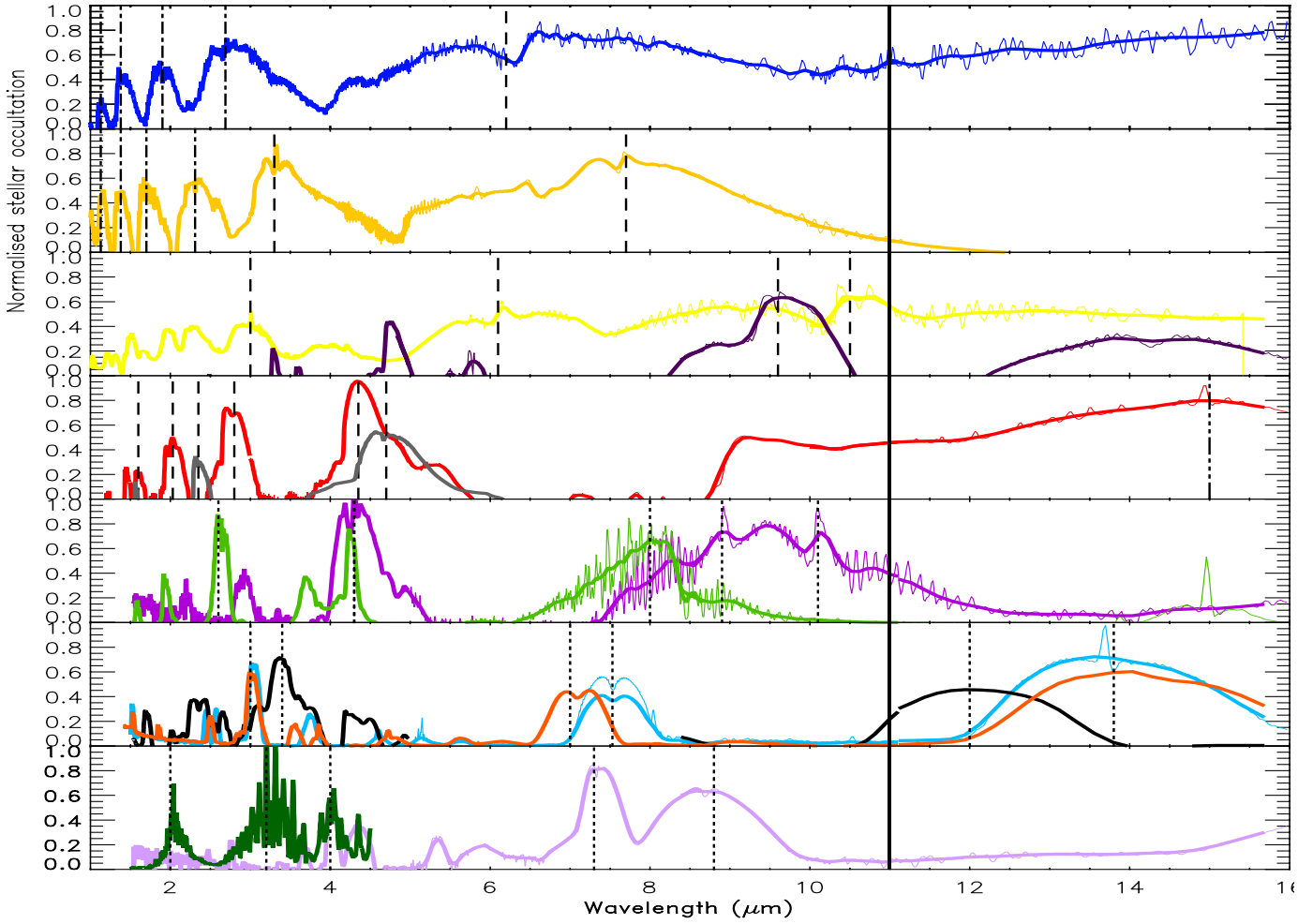
- UK technology features highly in the EChO mission:
  - *IR Sensor technology*
  - *Cryogenic coolers*
  - *Advanced spacecraft controls*





Broad wavelength coverage:

Optimised for molecular detections



Water vapour

Methane

Ammonia

Ozone

Carbon dioxide

Carbon monoxide

H_2S, PH_3

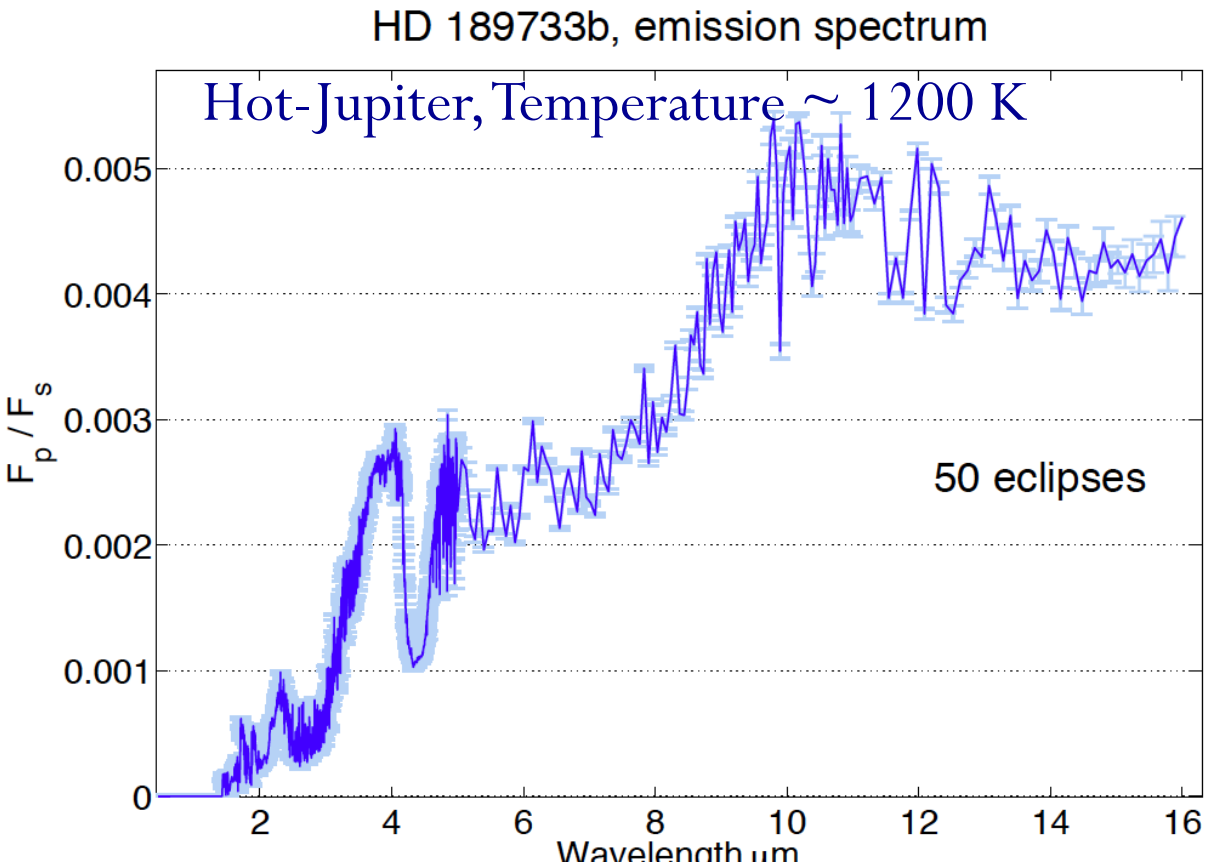
C_2H_2, HCN, C_2H_6

SO_2, HCN

ECHO

EChO performances:

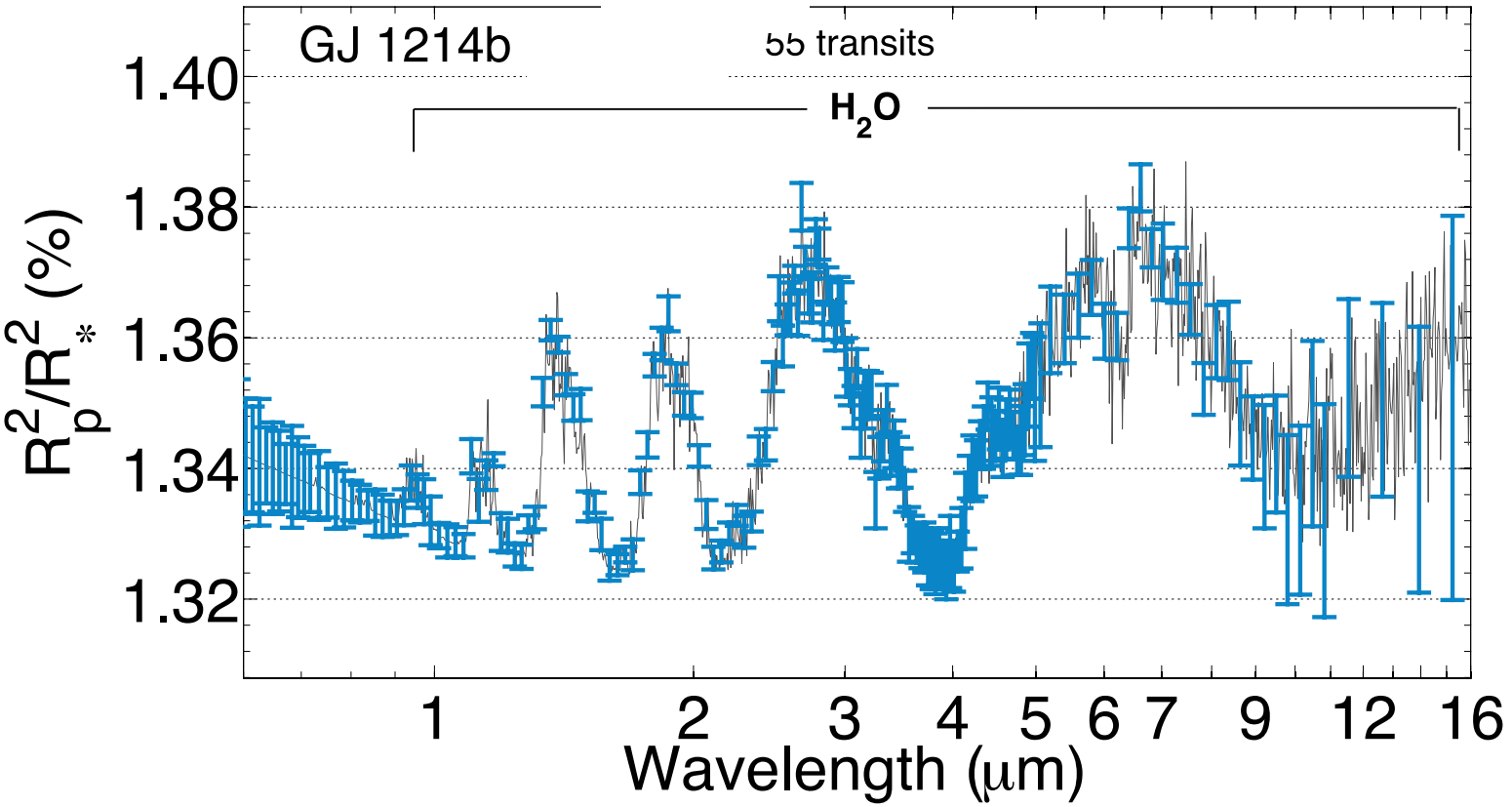
Simulated spectrum of HD189733b



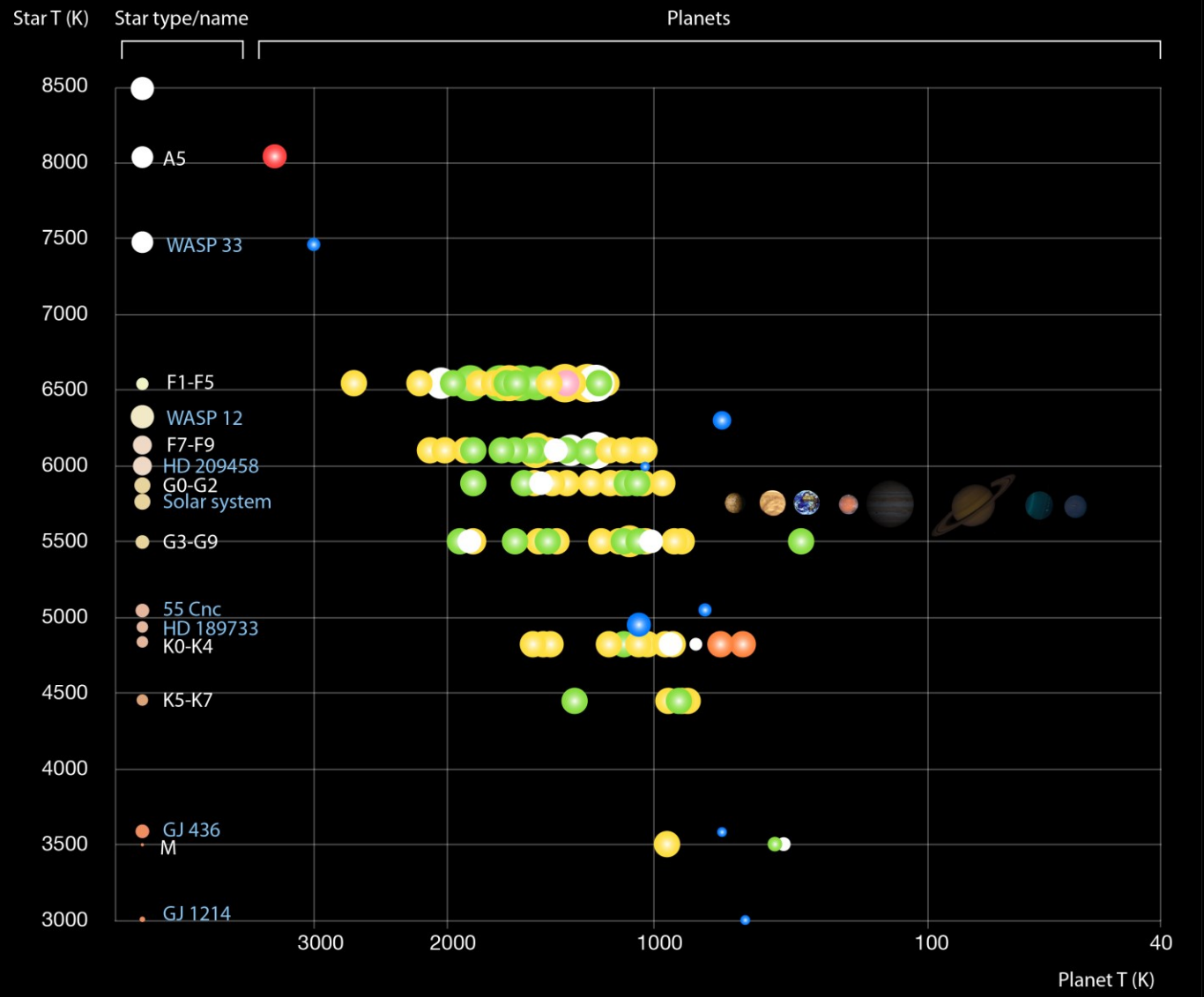
EChO performances

Simulated spectrum of super-Earth GJ1214b

5 Earth-masses, temperature of boiling water



Known Planets observable by EChO today (>140)

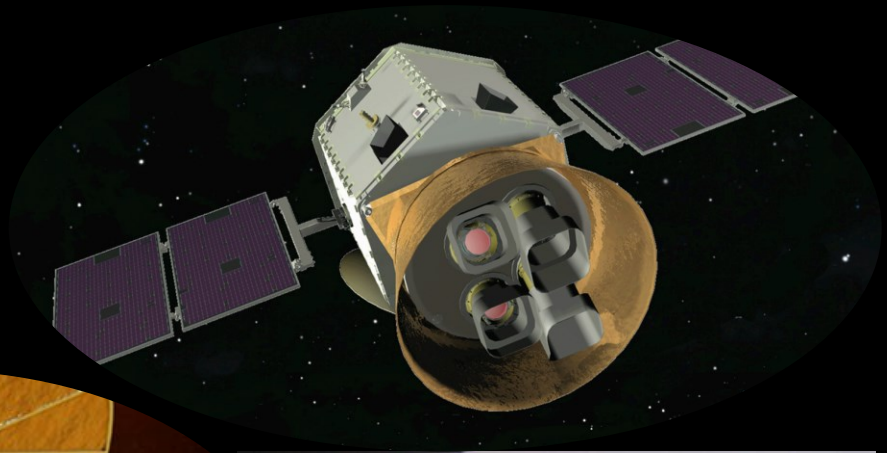


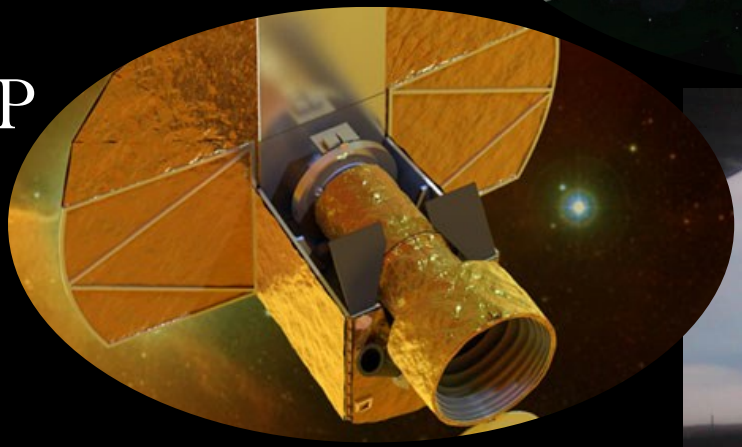
Exoplanet surveys

Expected to provide additional targets for EChO

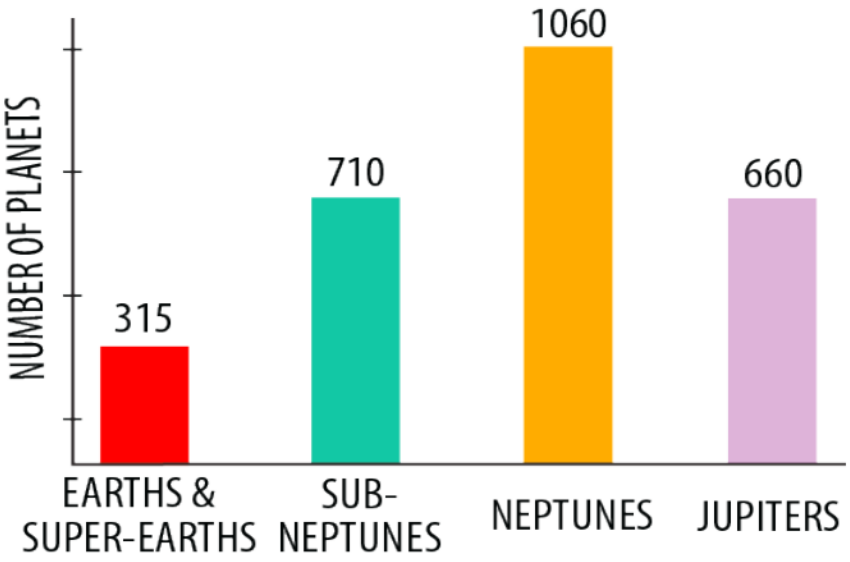
- ESA GAIA
- ESA Cheops
- NASA TESS

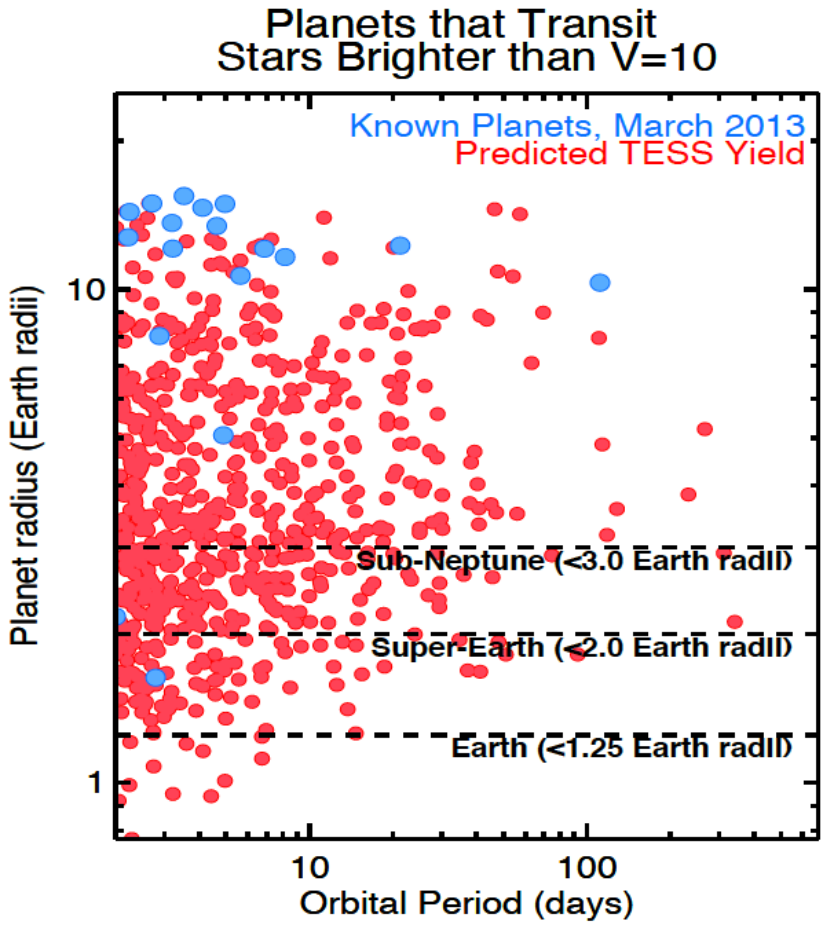
- HARPS North
- HAT-NET
- Super-WASP
- Carmenes
- M-Earth
- NGTS
- APACHI
- Spirou
- MASCARA





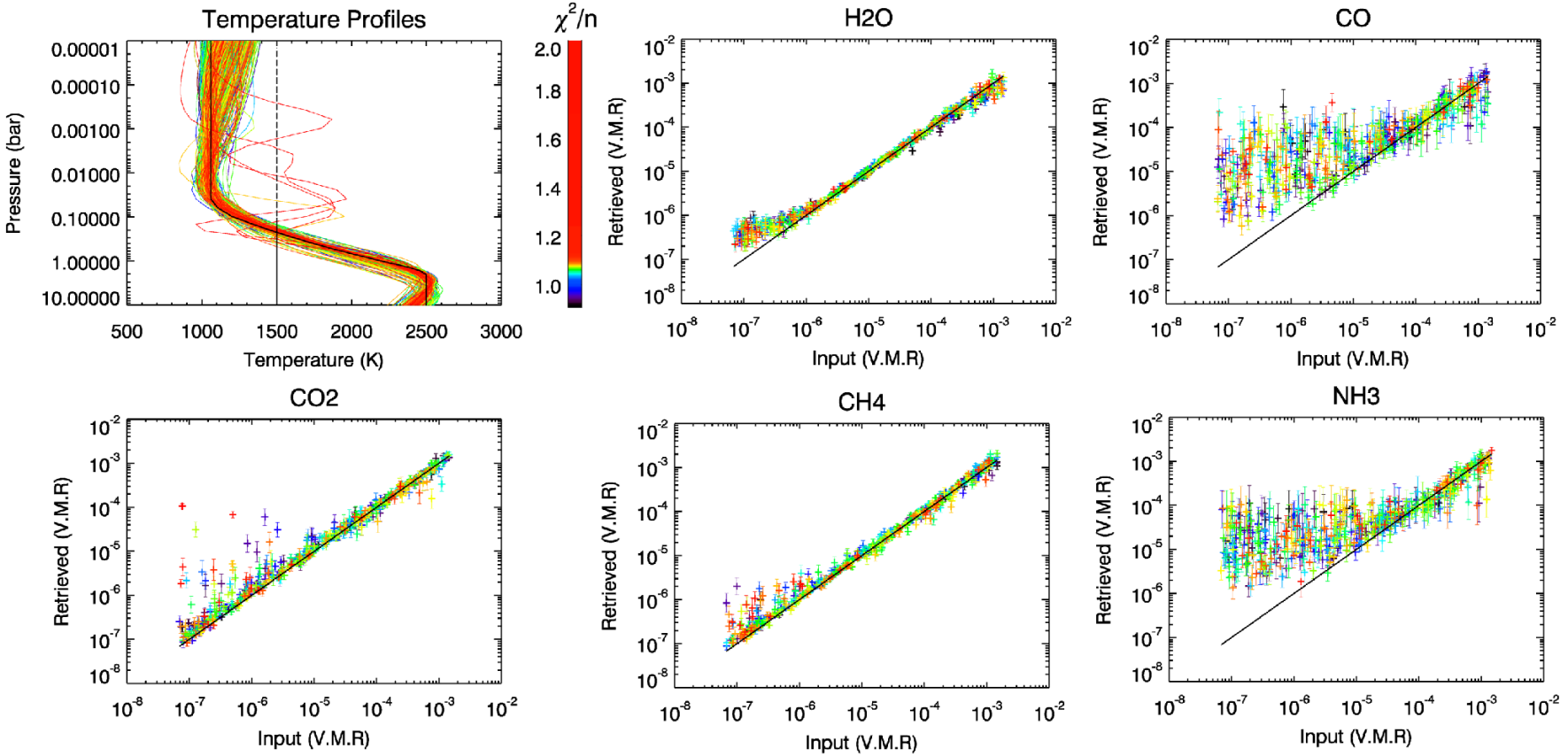
Expected results from TESS





Science return

Chemistry and thermal properties



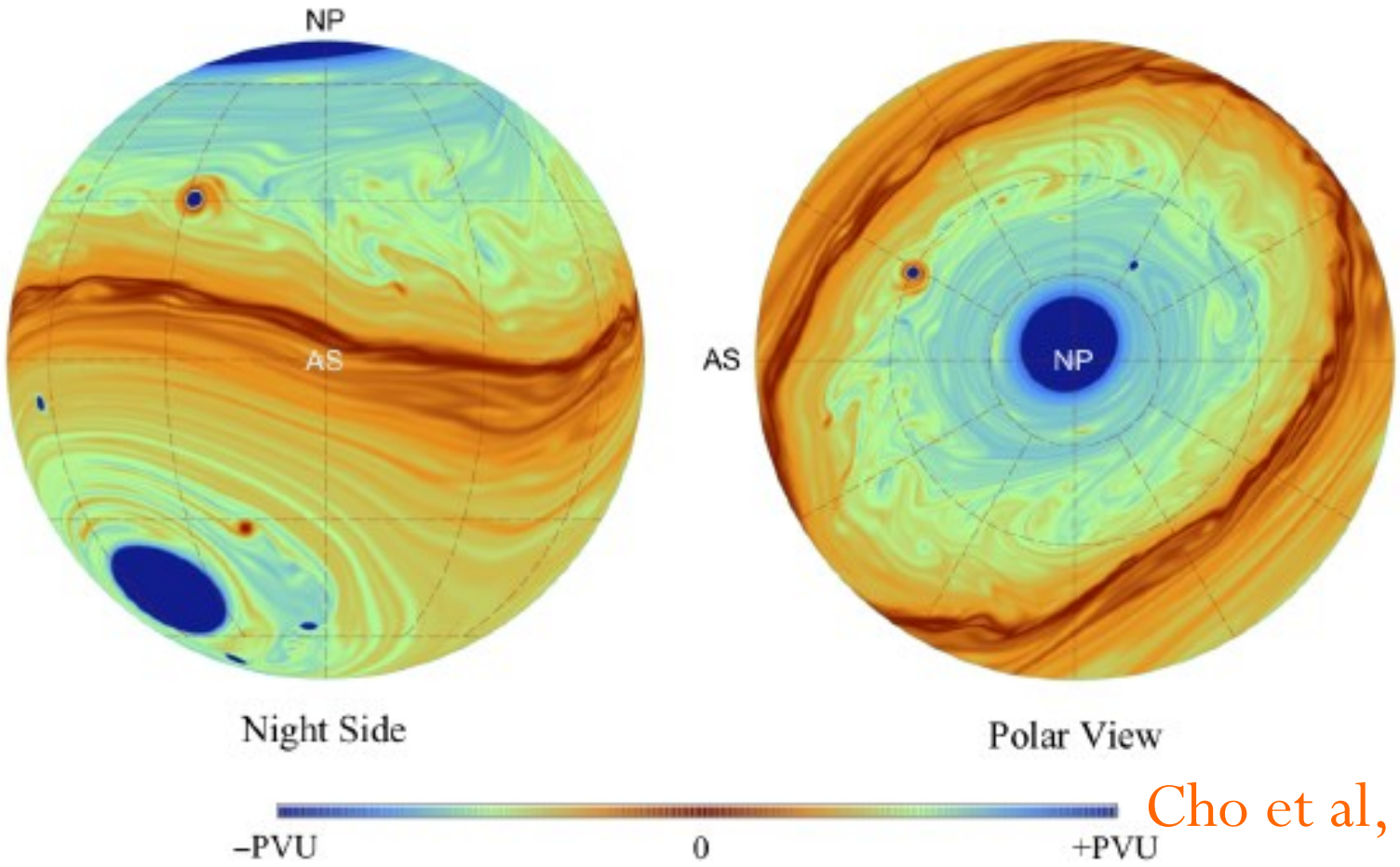
Barstow et al., 2013

Science return

Understanding planet formation/migration processes

Weather: temporal variability

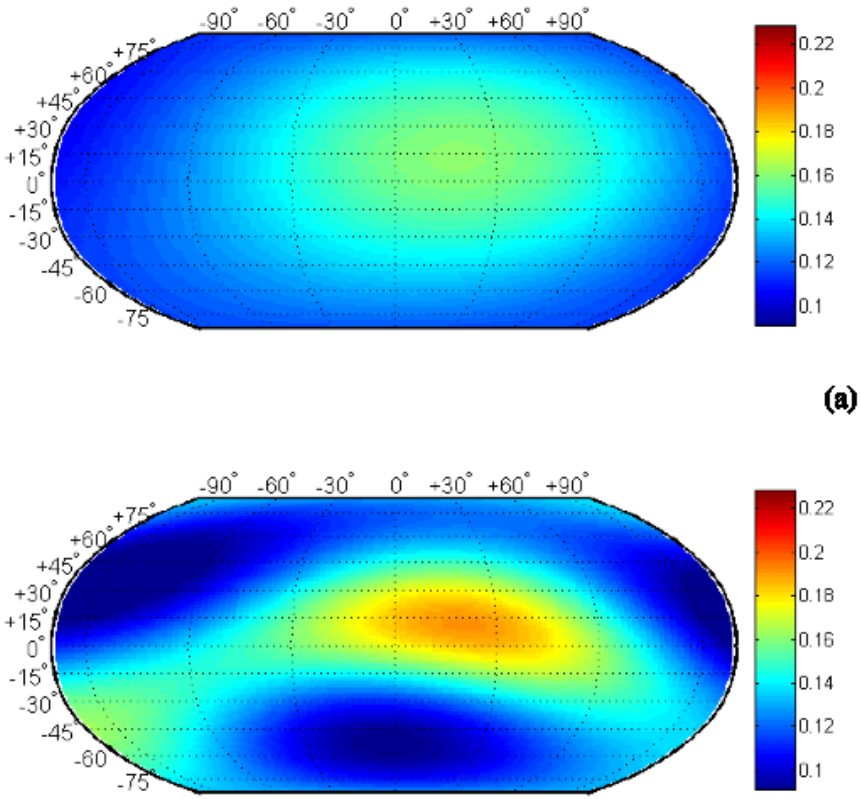
Understanding the role of dynamics)

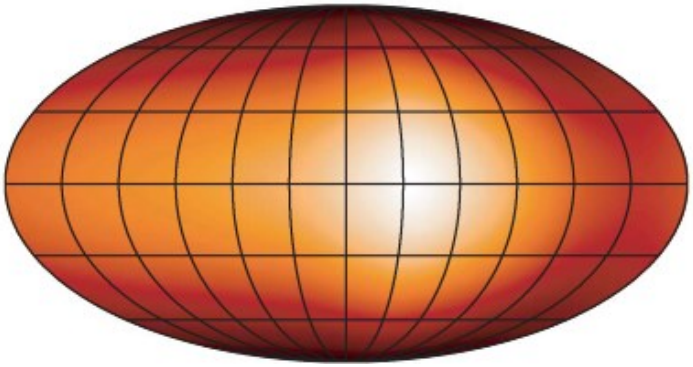


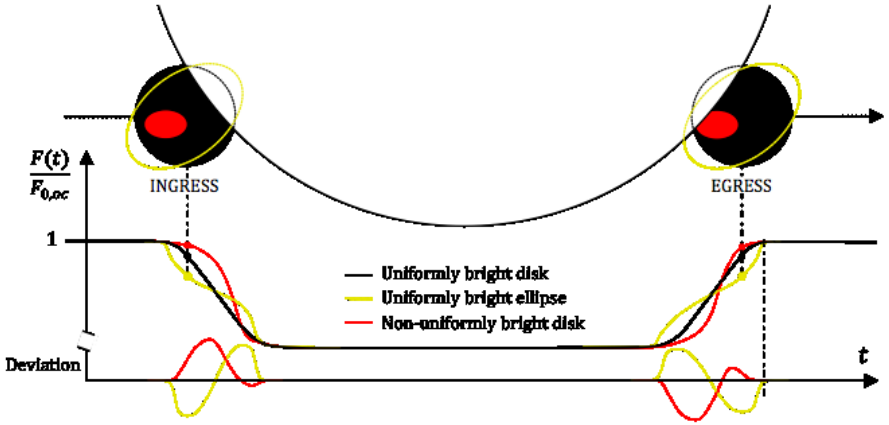
Cho et al, 2006

Climate: orbital phases

Understanding the role of dynamics in 3D





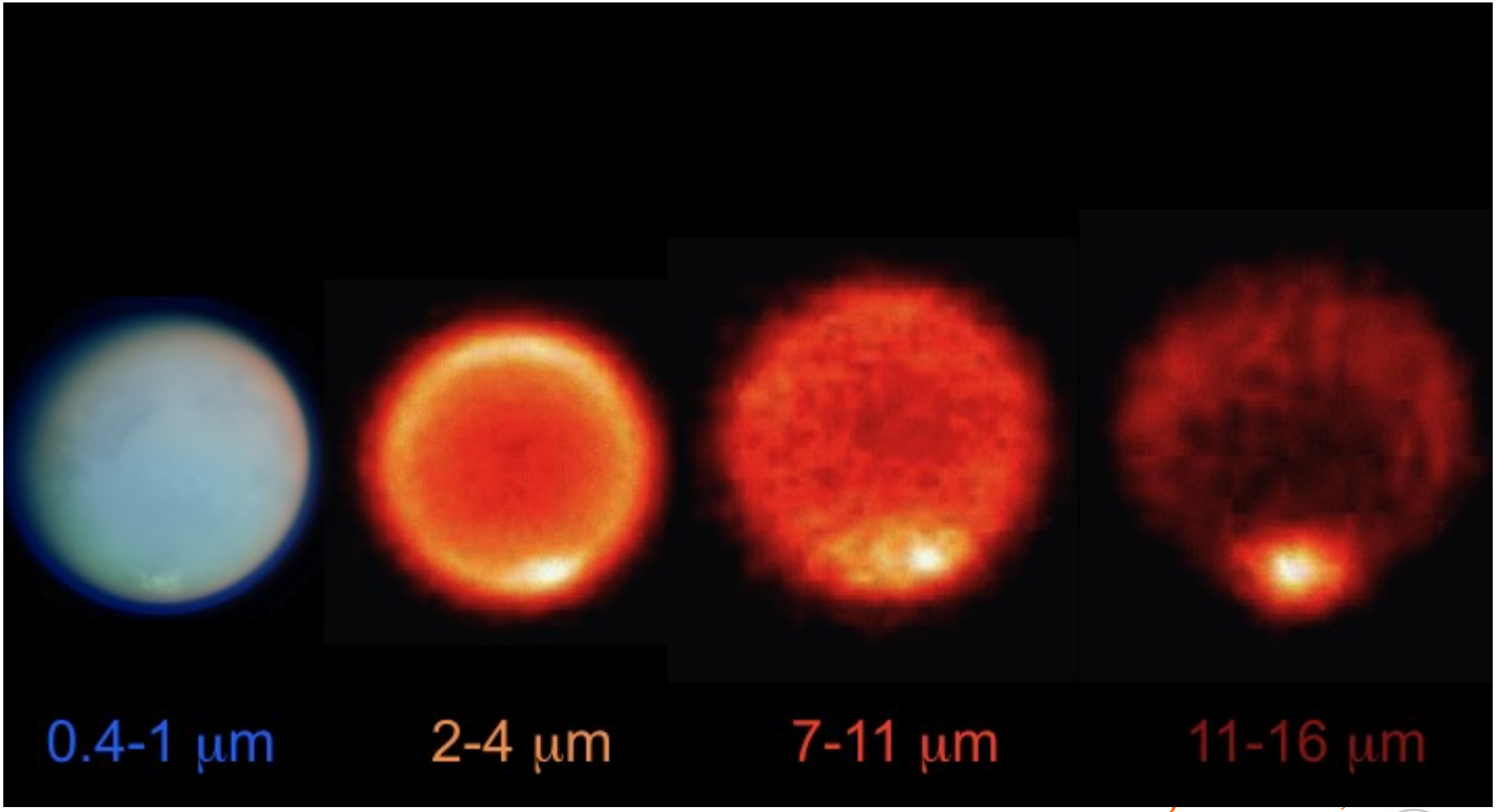


Knutson et al, 2007; De Wit et al., 2012

ECHO

2D Images of the planet

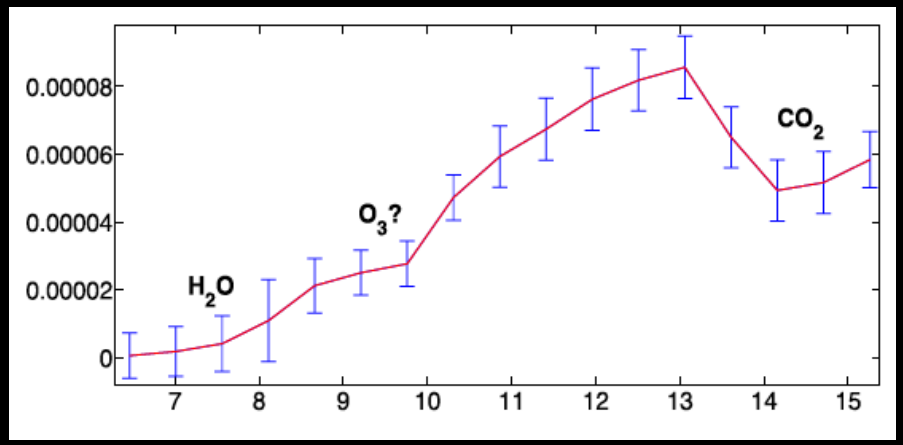
Spatial variability



Super-Earths around M-dwarfs:

are they habitable?

Spectrum for habitable super-Earth late M @ ~10 pc



Conclusions

- The exoplanet field is going through a "Revolution": 1000 planets in less than 20 years, and the Solar System is no longer the paradigm!
- To understand the Exoplanet diversity and the role of the Solar System in a broader context, we need to understand how planet form & evolve in our Galaxy
- Our only way to understand these processes, is to study the atmospheres of exoplanets, using molecules as tracers.
- We need a large number of exoplanetary atmospheres, and we need very accurate, coherent, measurements
- We need a dedicated mission: we need EChO!