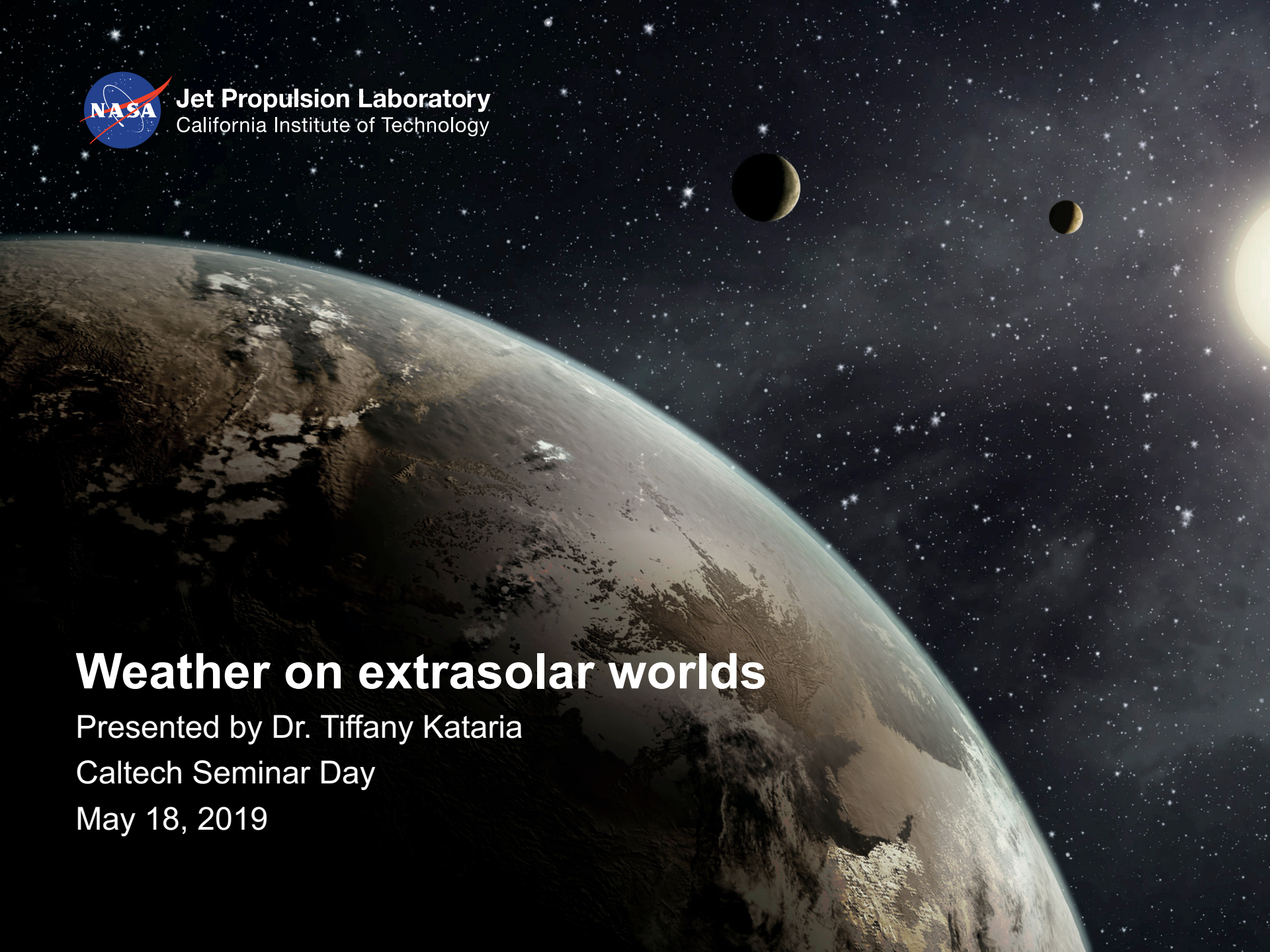


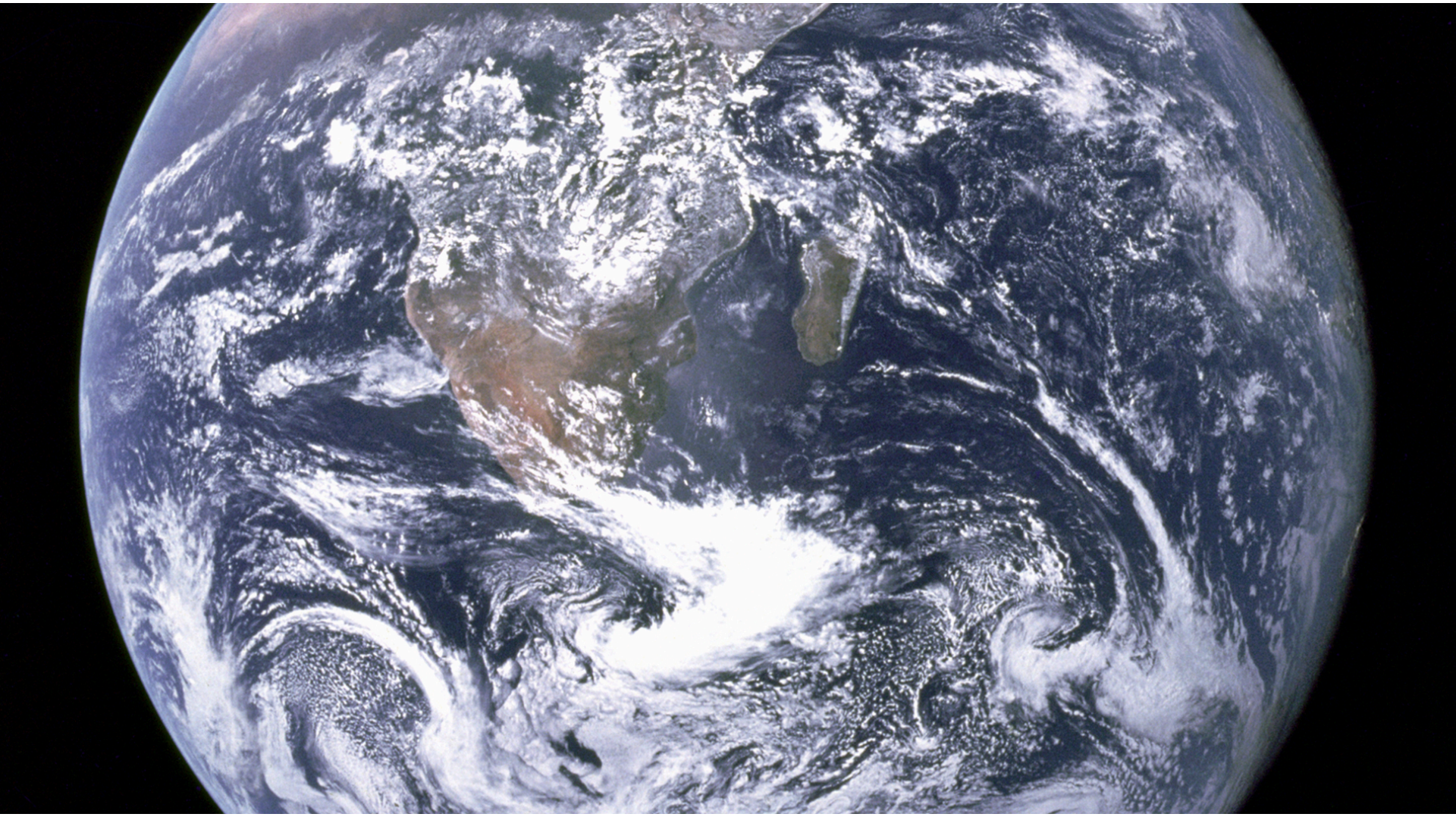
Jet Propulsion Laboratory
California Institute of Technology

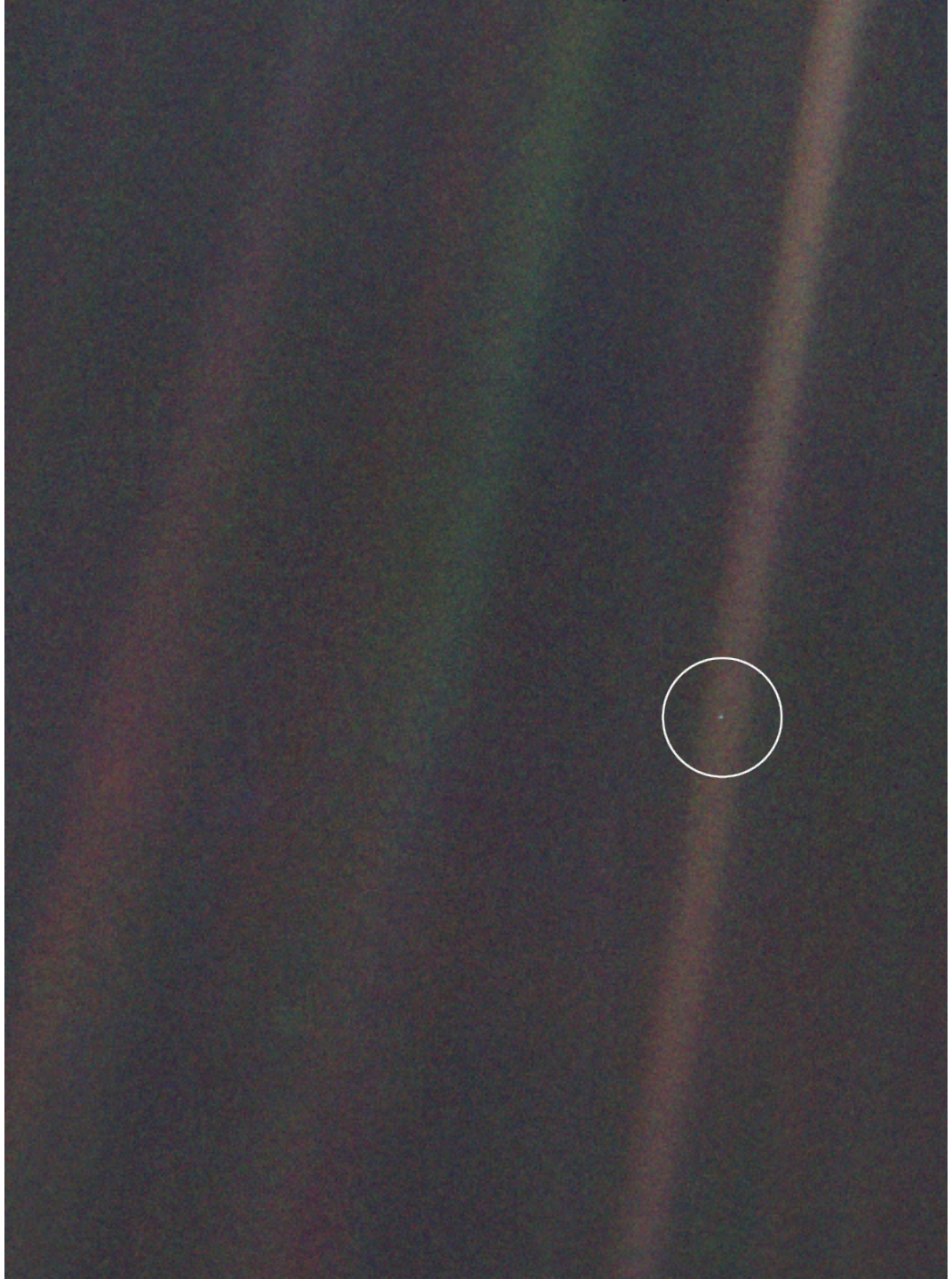
Weather on extrasolar worlds

Presented by Dr. Tiffany Kataria

Caltech Seminar Day

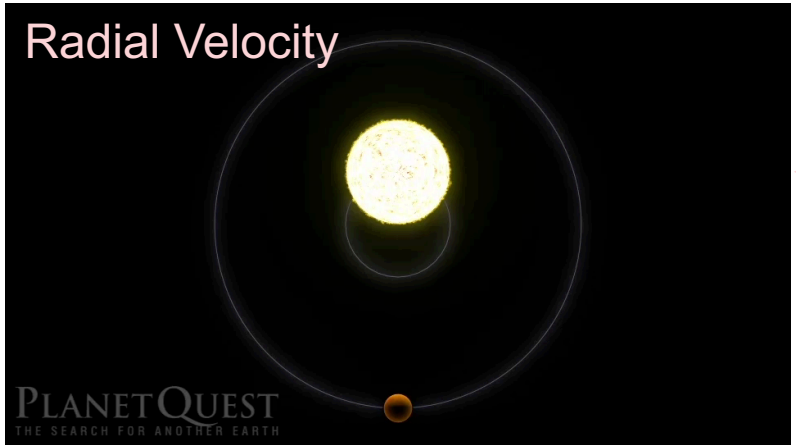
May 18, 2019

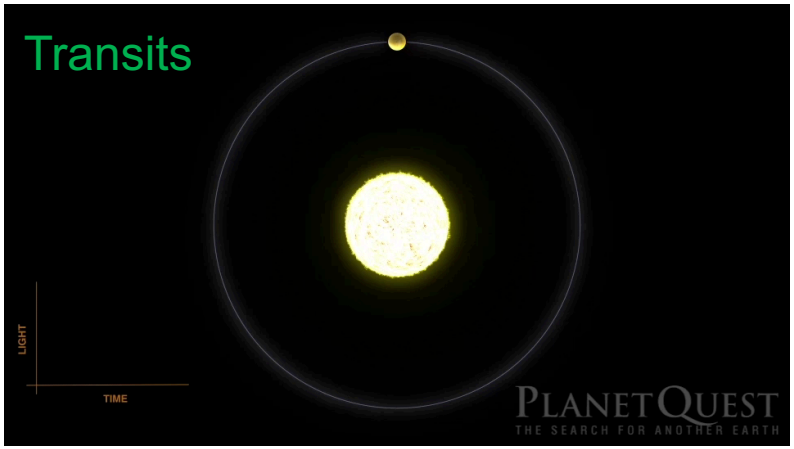


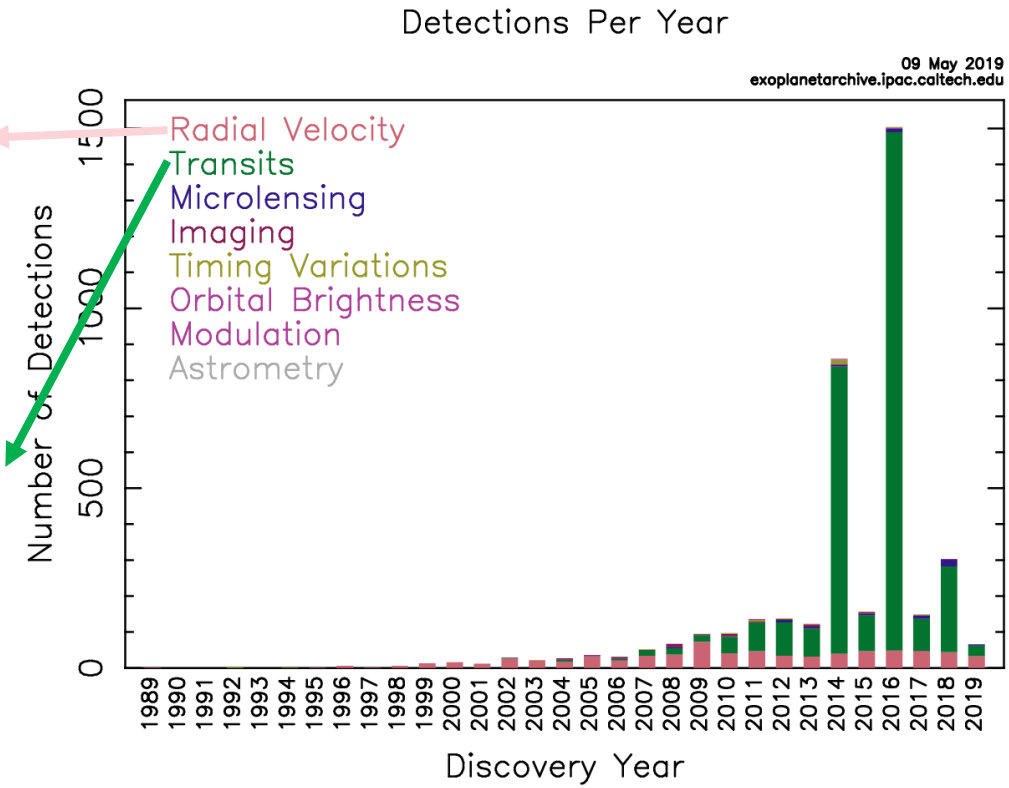


Exoplanets: Planets beyond the Solar System

From detection to characterization

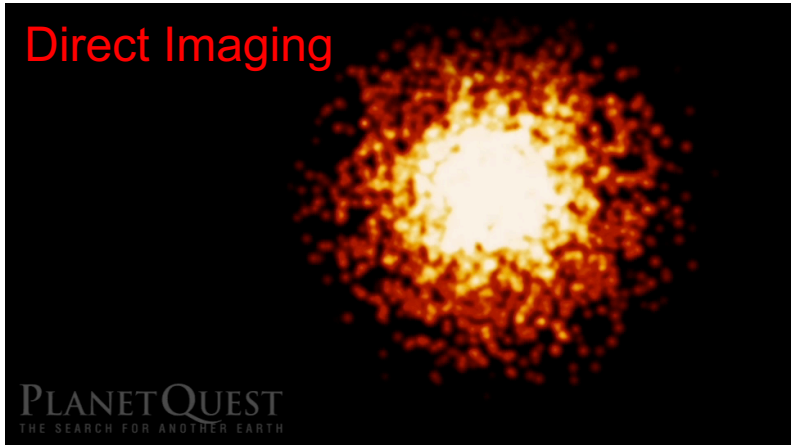


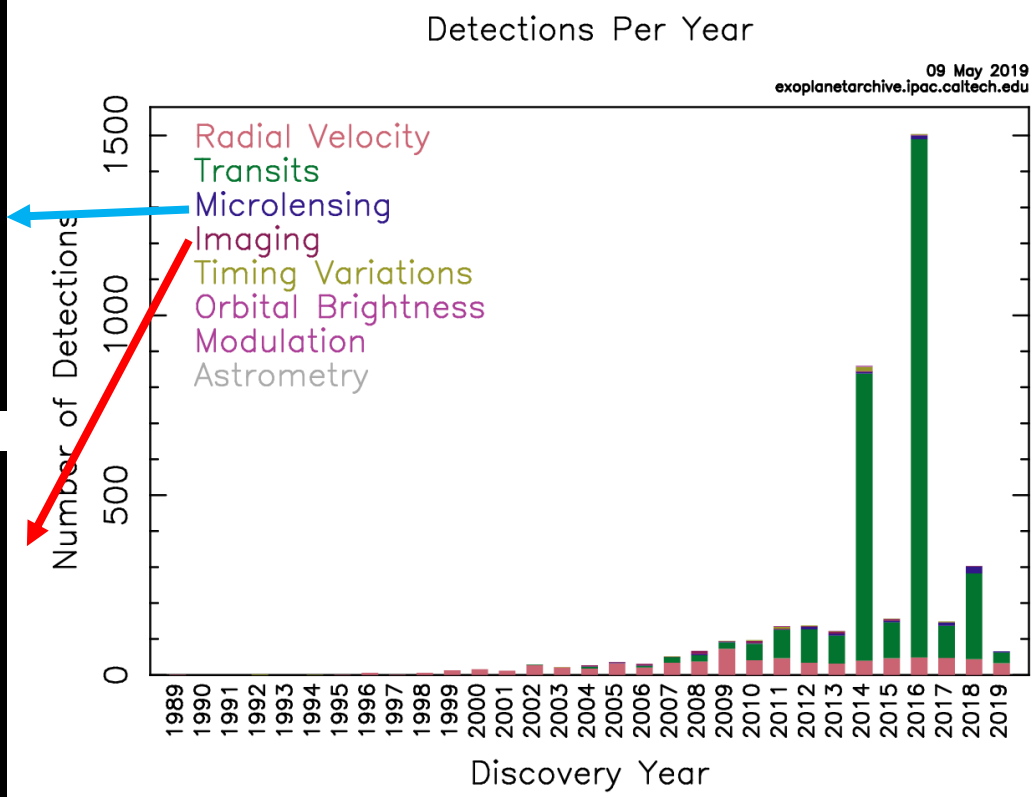




Exoplanets: Planets beyond the Solar System

From detection to characterization





Exoplanets: Big Questions

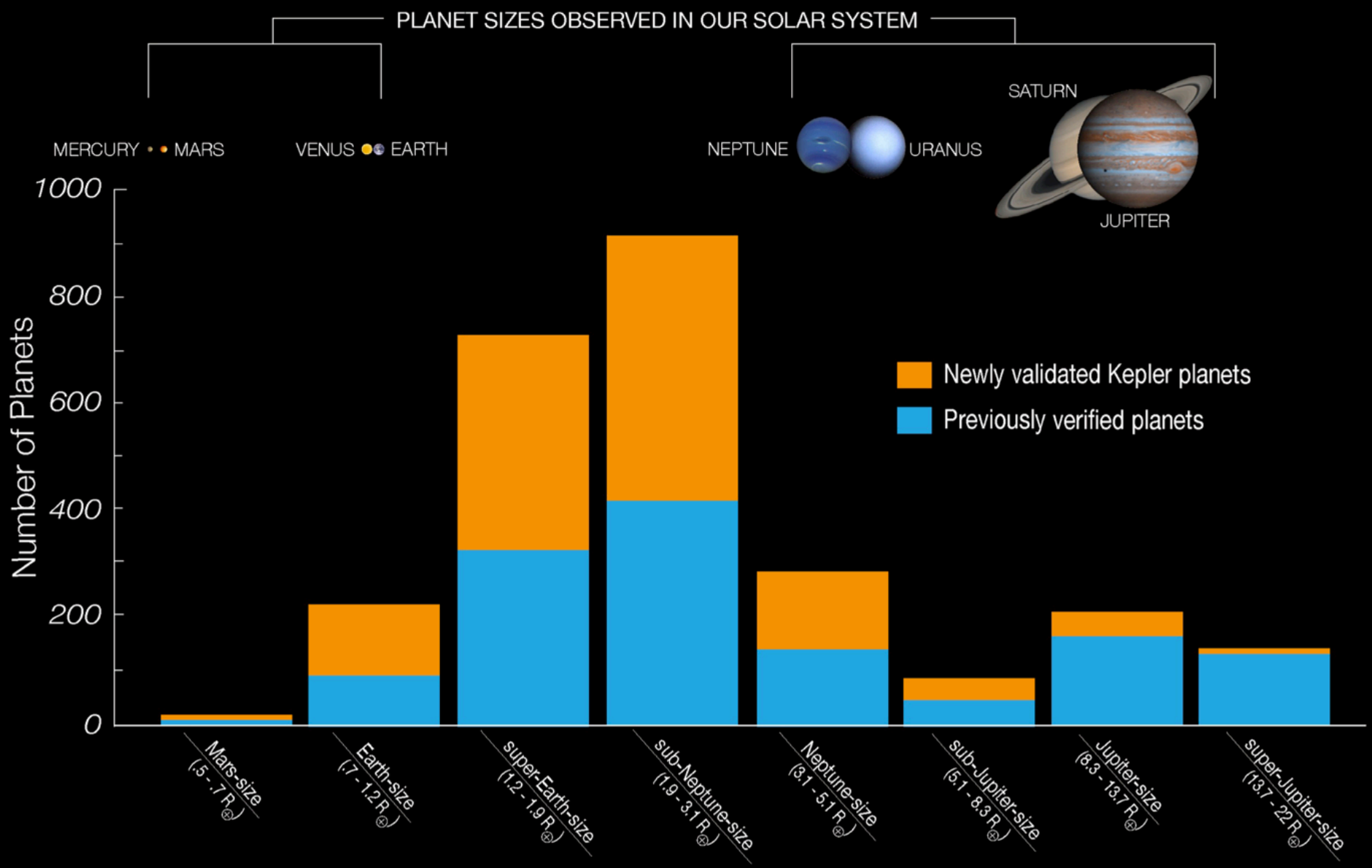
Where did we come from? Are we alone?

Weather and Climate of Exotic Worlds

Habitability and Biogenic Gases

Known Transiting Planets by Size

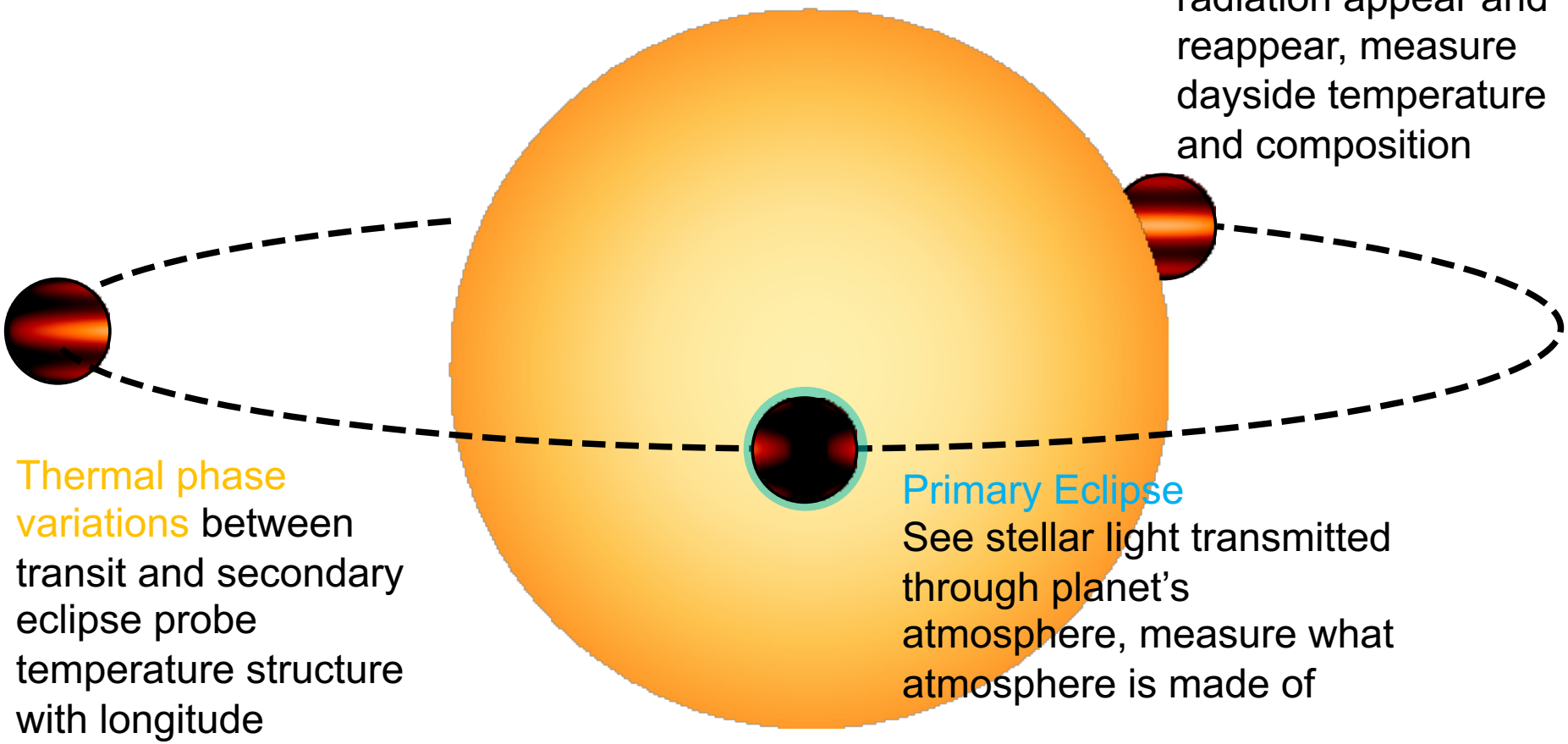
As of May 10, 2016



Transiting Extrasolar Planets

What can we learn?

Secondary Eclipse
See planet's thermal radiation appear and reappear, measure dayside temperature and composition

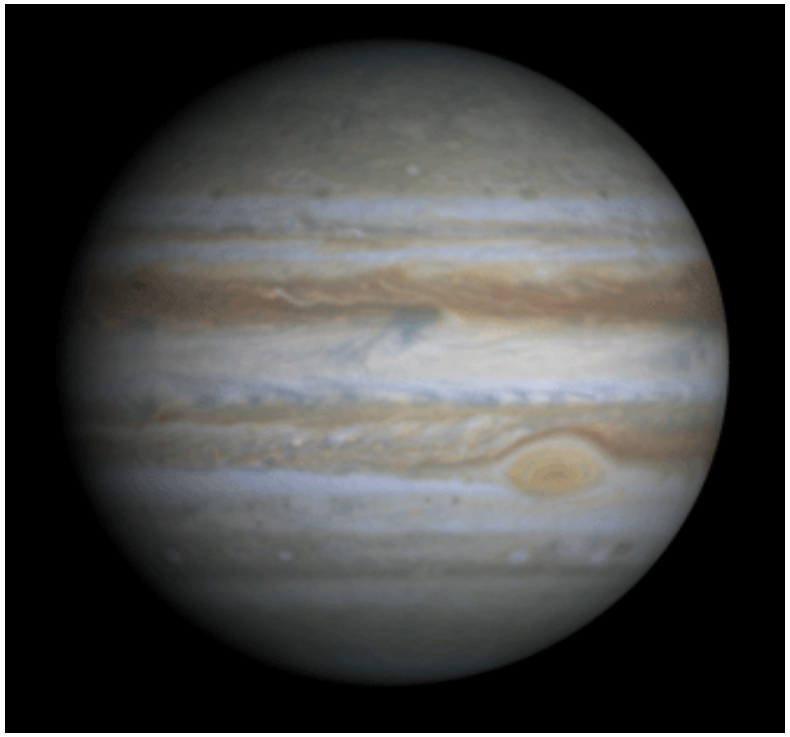


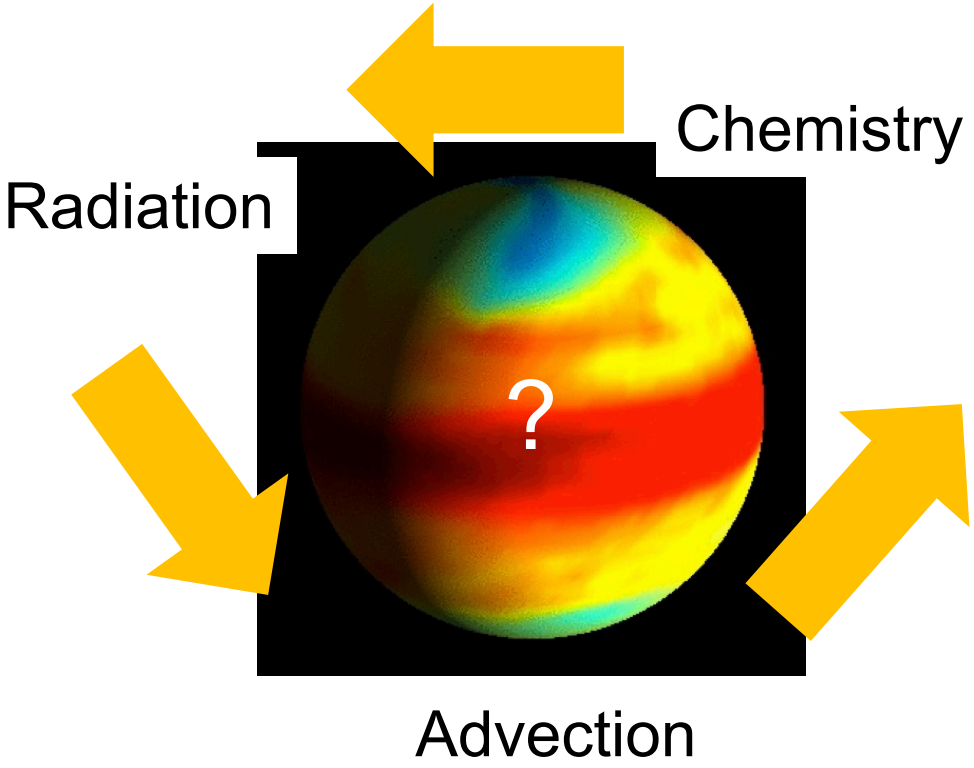
Thermal phase variations between transit and secondary eclipse probe temperature structure with longitude

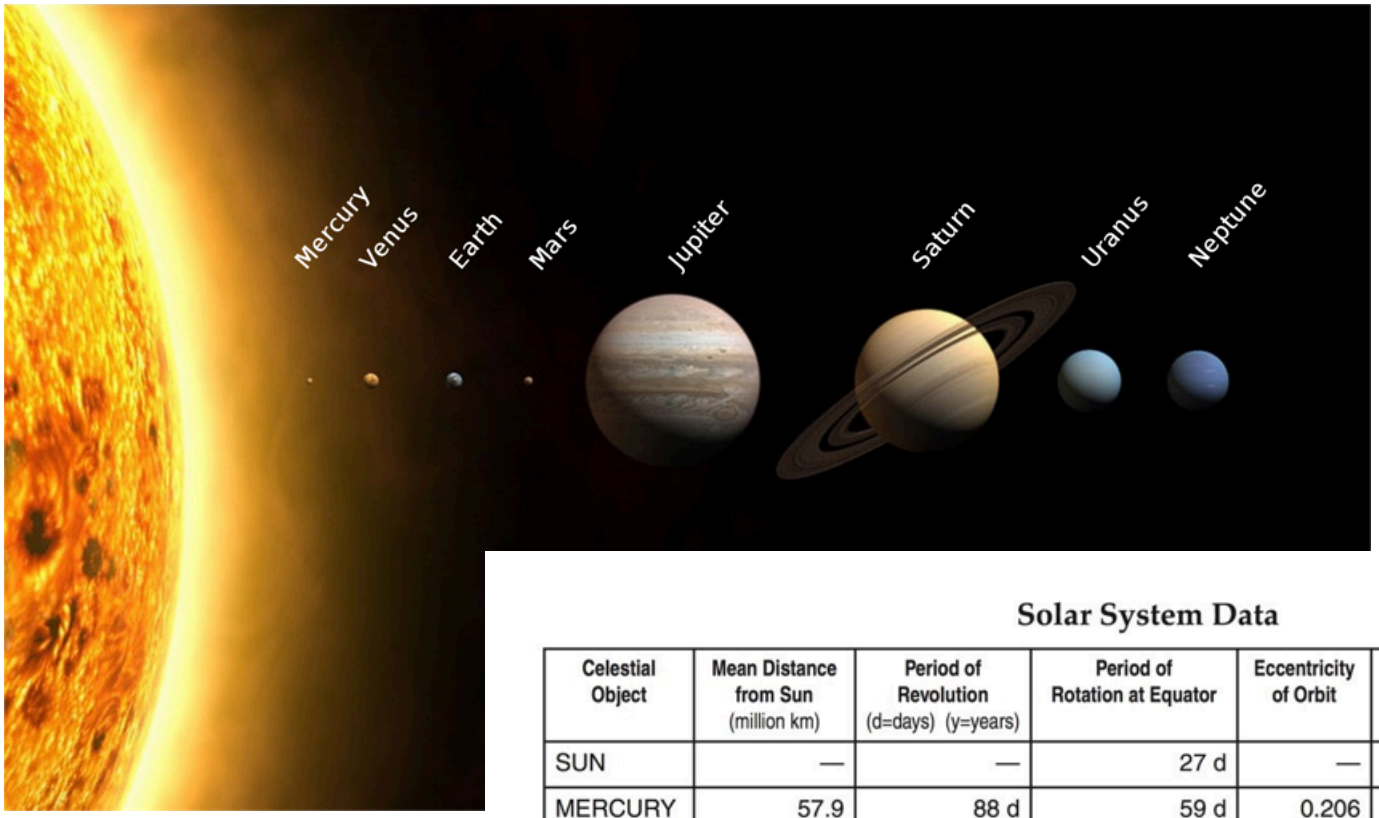
Primary Eclipse
See stellar light transmitted through planet's atmosphere, measure what atmosphere is made of

Image Credit: Kevin Stevenson

What drives the atmospheric circulation in exoplanets?







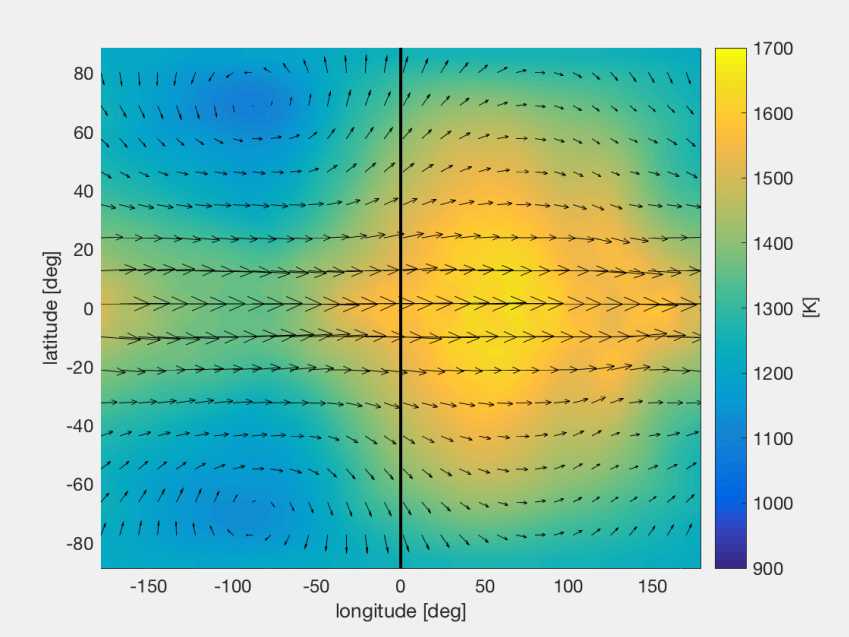
Solar System Data

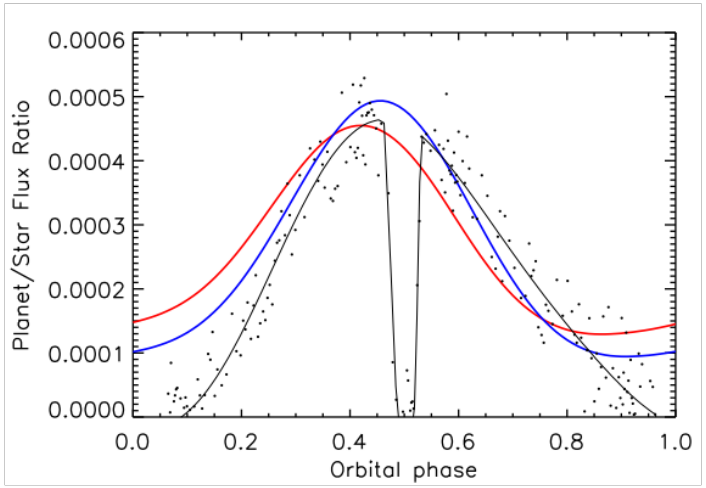
Celestial Object	Mean Distance from Sun (million km)	Period of Revolution (d=days) (y=years)	Period of Rotation at Equator	Eccentricity of Orbit	Equatorial Diameter (km)	Mass (Earth = 1)	Density (g/cm^3)
SUN	—	—	27 d	—	1,392,000	333,000.00	1.4
MERCURY	57.9	88 d	59 d	0.206	4,879	0.06	5.4
VENUS	108.2	224.7 d	243 d	0.007	12,104	0.82	5.2
EARTH	149.6	365.26 d	23 h 56 min 4 s	0.017	12,756	1.00	5.5
MARS	227.9	687 d	24 h 37 min 23 s	0.093	6,794	0.11	3.9
JUPITER	778.4	11.9 y	9 h 50 min 30 s	0.048	142,984	317.83	1.3
SATURN	1,426.7	29.5 y	10 h 14 min	0.054	120,536	95.16	0.7
URANUS	2,871.0	84.0 y	17 h 14 min	0.047	51,118	14.54	1.3
NEPTUNE	4,498.3	164.8 y	16 h	0.009	49,528	17.15	1.8
EARTH'S MOON	149.6 (0.386 from Earth)	27.3 d	27.3 d	0.055	3,476	0.01	3.3

My research

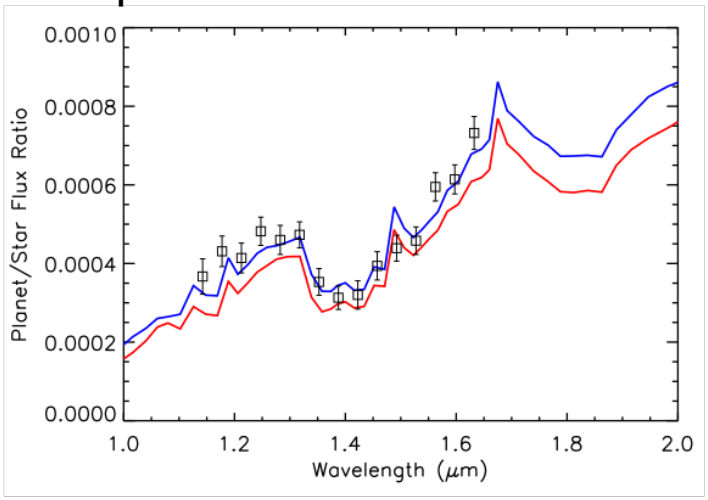
From theoretical modeling to characterization

Circulation Models of Hot Jupiter WASP-43b



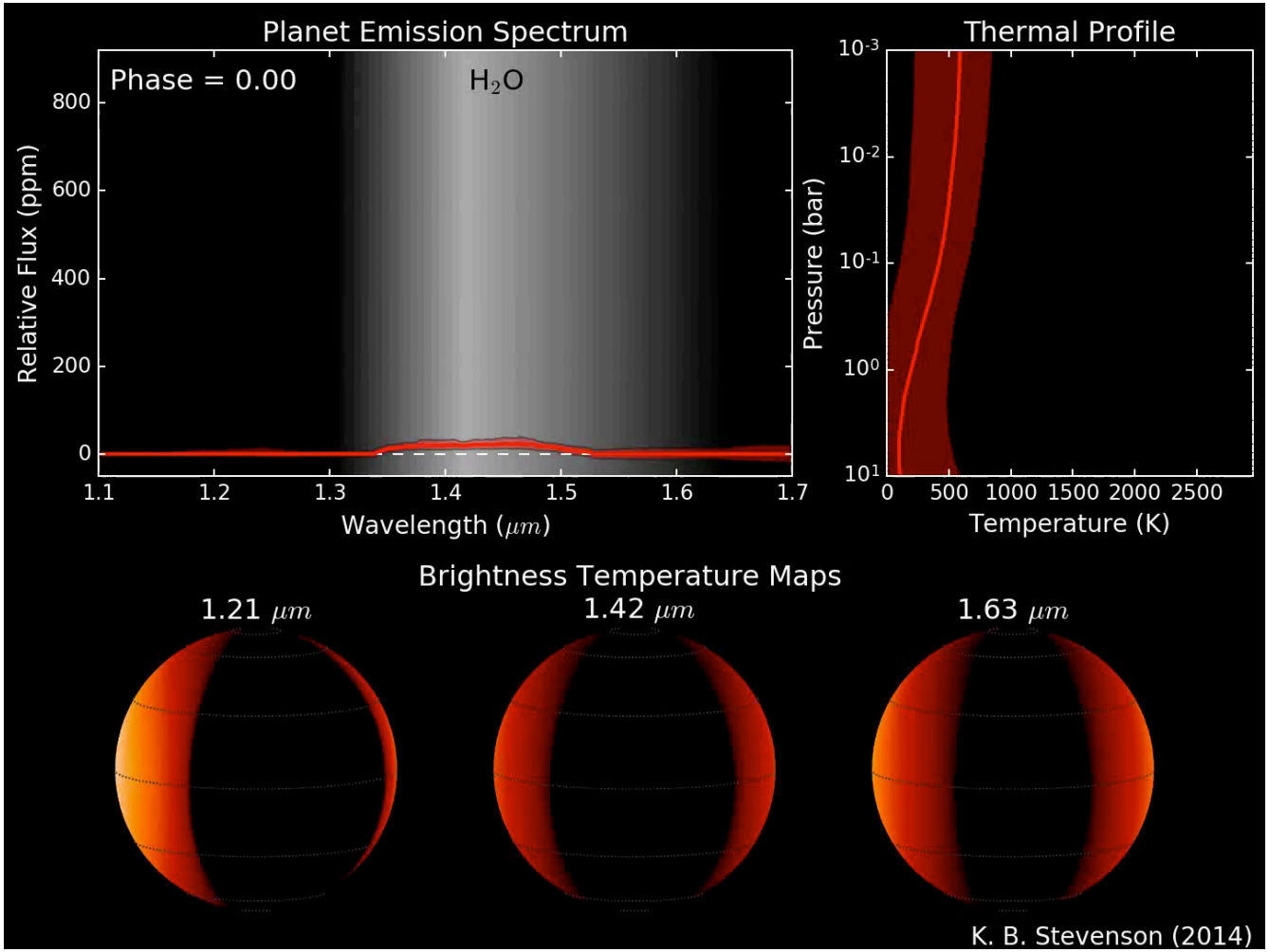


Comparisons to HST observations



Better Data:

2D Thermal Mapping of a Jupiter-sized exoplanet



Stevenson, Desert, Line, Bean, Fortney, Showman, **Kataria** et al. 2014, *Science*

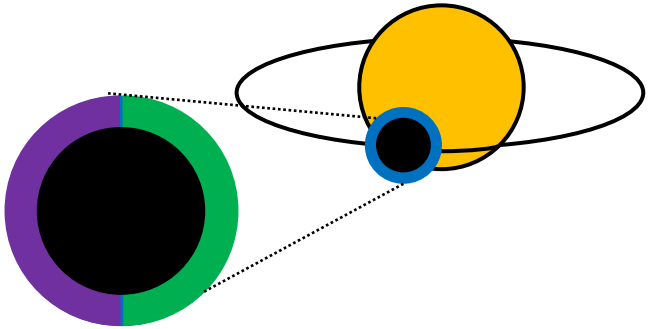
More Planets

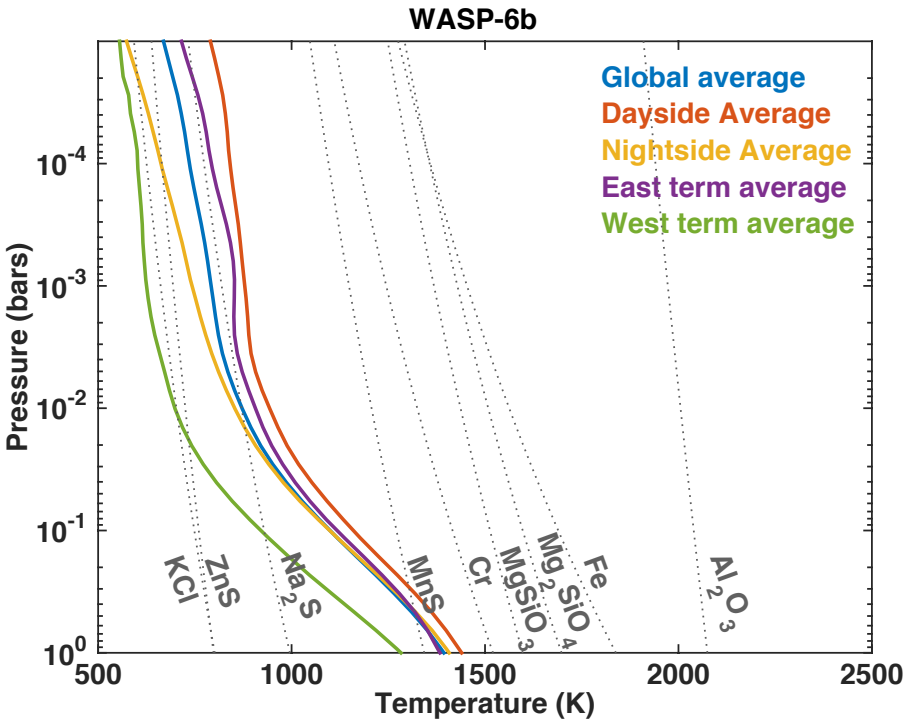
Comparative Exoplanetology with Space-Based Telescopes (HST/Spitzer)

Population probes a wide range of rotation rates, planetary radii, planetary gravities, and temperatures, all of which influence the planet's weather

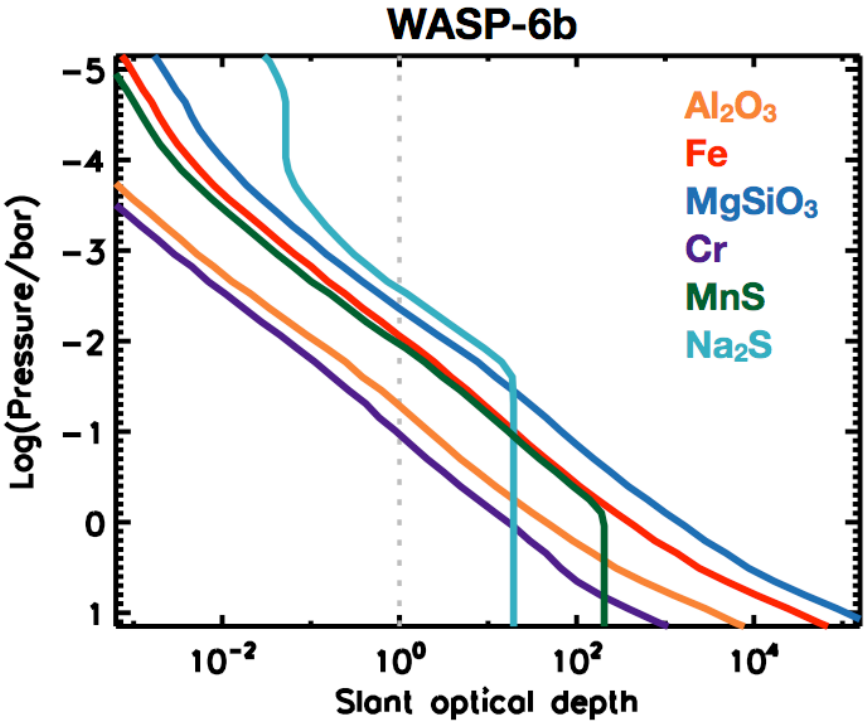
Sing et al. 2016, *Nature*

Comparative Exoplanetology





Kataria et al. 2016, *ApJ*

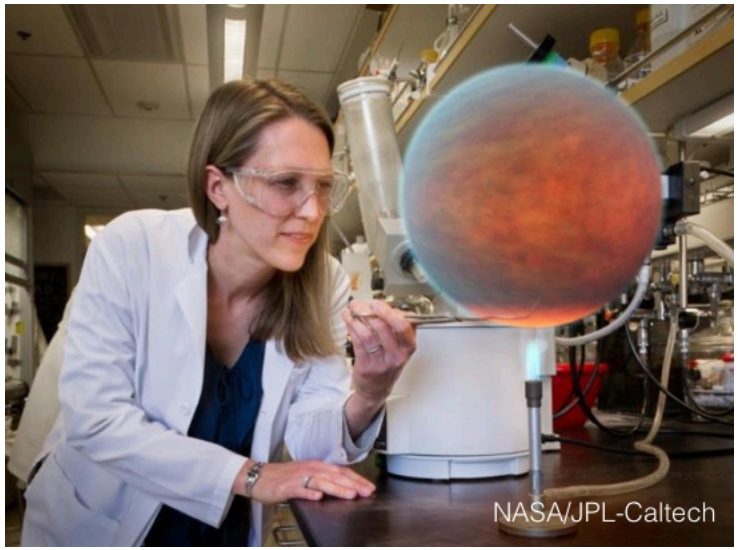


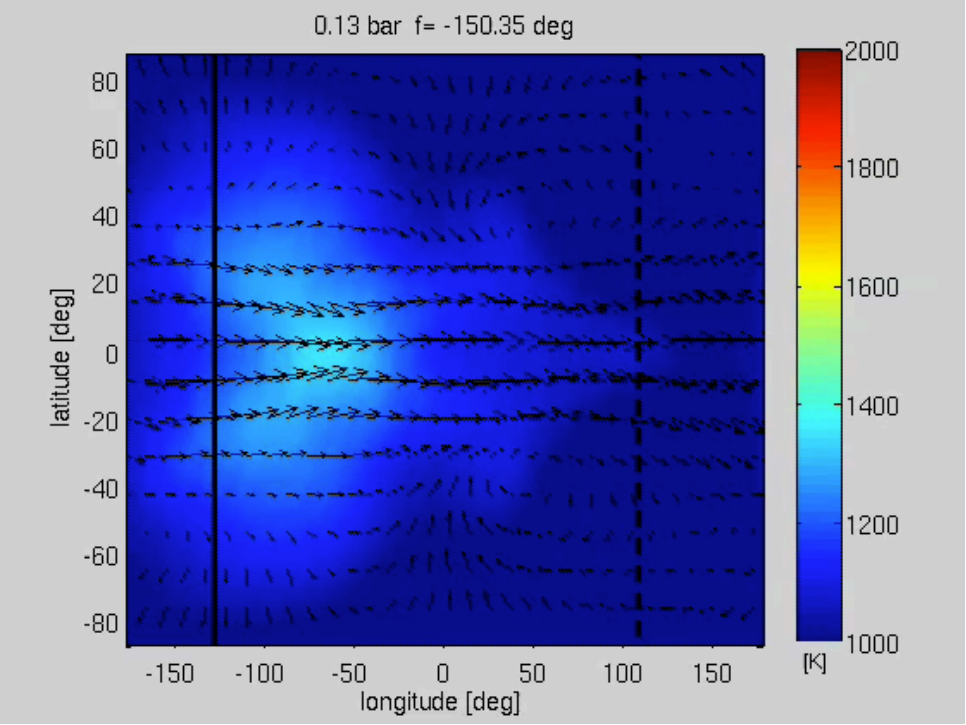
Kataria et al. 2018, in prep

By studying individual planets, we can identify trends in chemistry and dynamics over a range in planetary properties

Eccentric Exoplanets

Planets on eccentric orbits provide critical insights into the atmospheres and interiors of exoplanets.



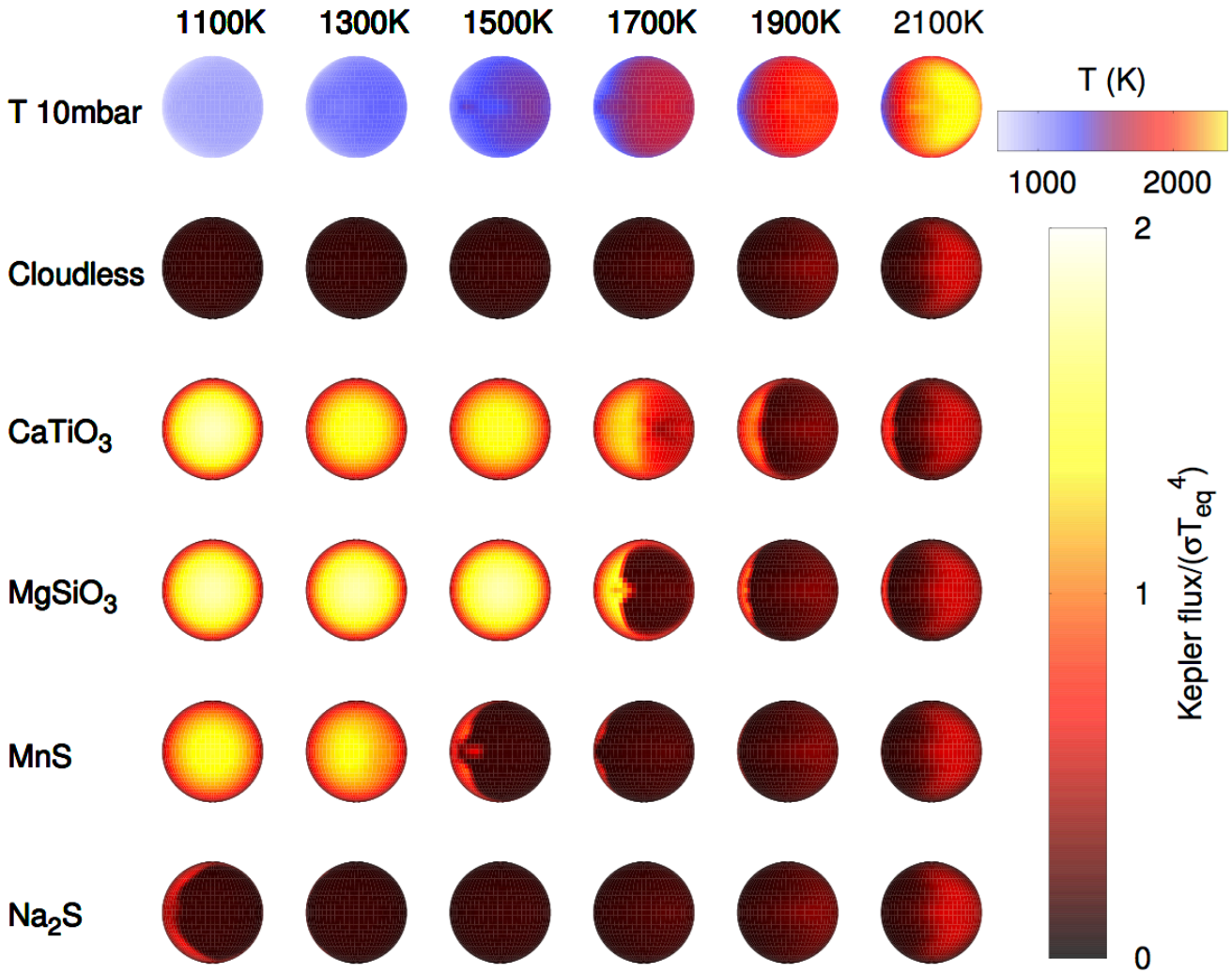


HAT-P-2b (Lewis et al. 2013)

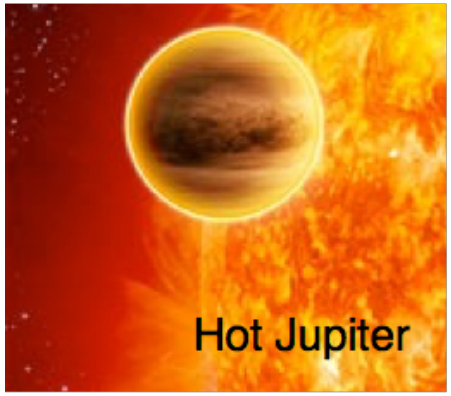
Time-variable heating:

- Radiative timescales
- Chemical timescales
- Advective timescales (rotation+winds)
- Planet-Star tidal interaction
- Orbital evolution

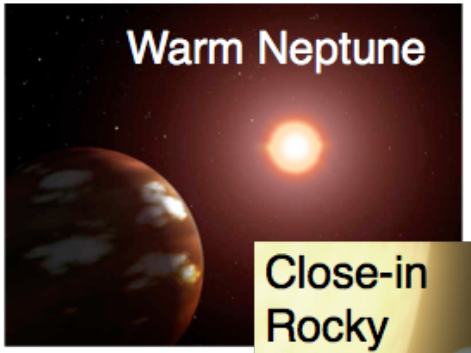
Understanding Clouds in Hot Jupiters

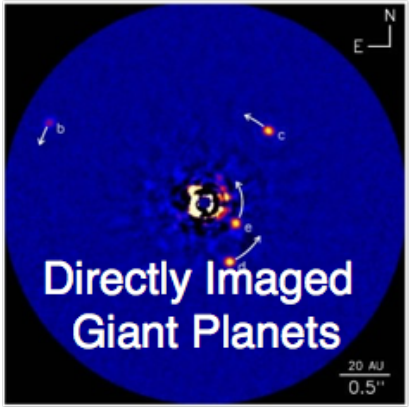


The Future of Exoplanet Detection, Observations and Characterization



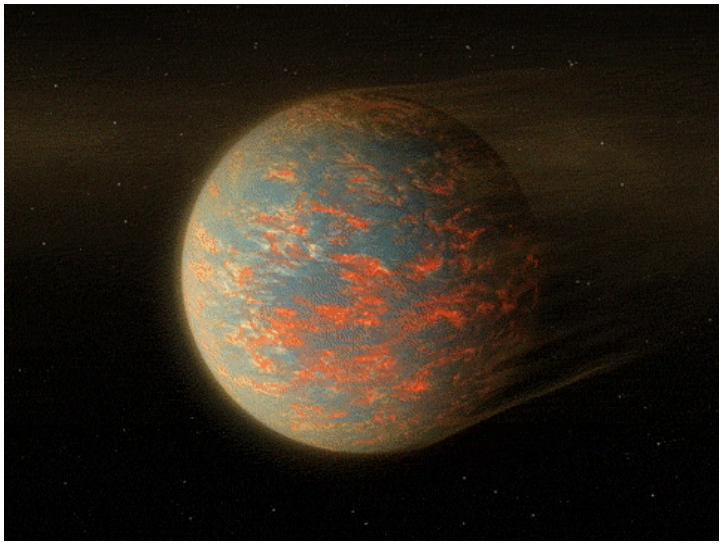
Forecast Complexity





Smaller planets:

The First Thermal Map of a Super-Earth



Demory et al. 2016, *Nature*

Probing Climates on TRAPPIST-1

"All the News That's Fit to Print"

The New York Times

Late Edition

Today, patchy morning fog, partly sunny, warm, high 64. **Tonight,** mostly cloudy, mild, low 52. **Tomorrow,** clouds and sunshine, showers, high 66. Weather map is on Page B9.

VOL. CLXVI . . . No. 57,517 © 2017 The New York Times Company NEW YORK, THURSDAY, FEBRUARY 23, 2017 $2.50

JPL-CALTECH/NASA

A rendering of newly discovered Earth-size planets orbiting a dwarf star named Trappist-1 about 40 light-years from Earth. Some of them could have surface water.

TRUMP RESCINDS OBAMA DIRECTIVE ON BATHROOM USE

ENTERING CULTURE WARS

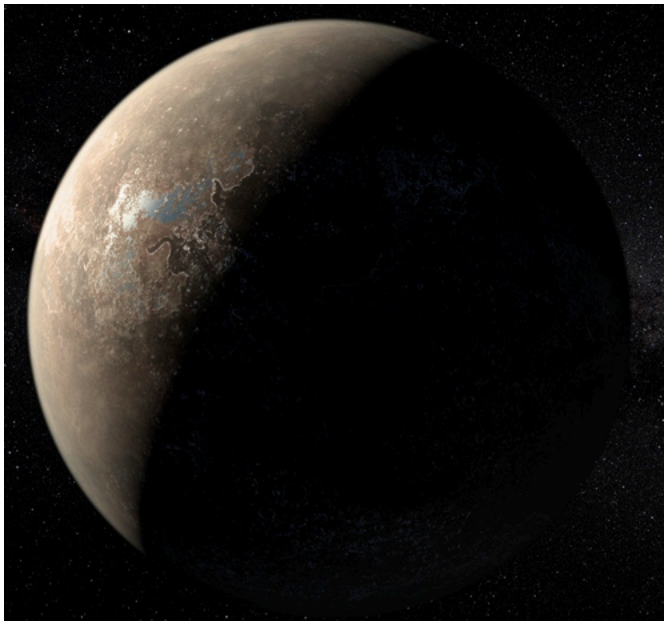
Question of Transgender Rights Splits DeVos and Sessions

This article is by ***Jeremy W. Peters, Jo Becker*** *and* ***Julie Hirschfeld Davis.***

WASHINGTON — President Trump on Wednesday rescinded protections for transgender students that had allowed them to use bathrooms corresponding with their gender identity, overruling his own education secretary and placing his administration firmly in the middle of the culture wars that many Republicans have tried to leave behind.

In a joint letter, the top civil

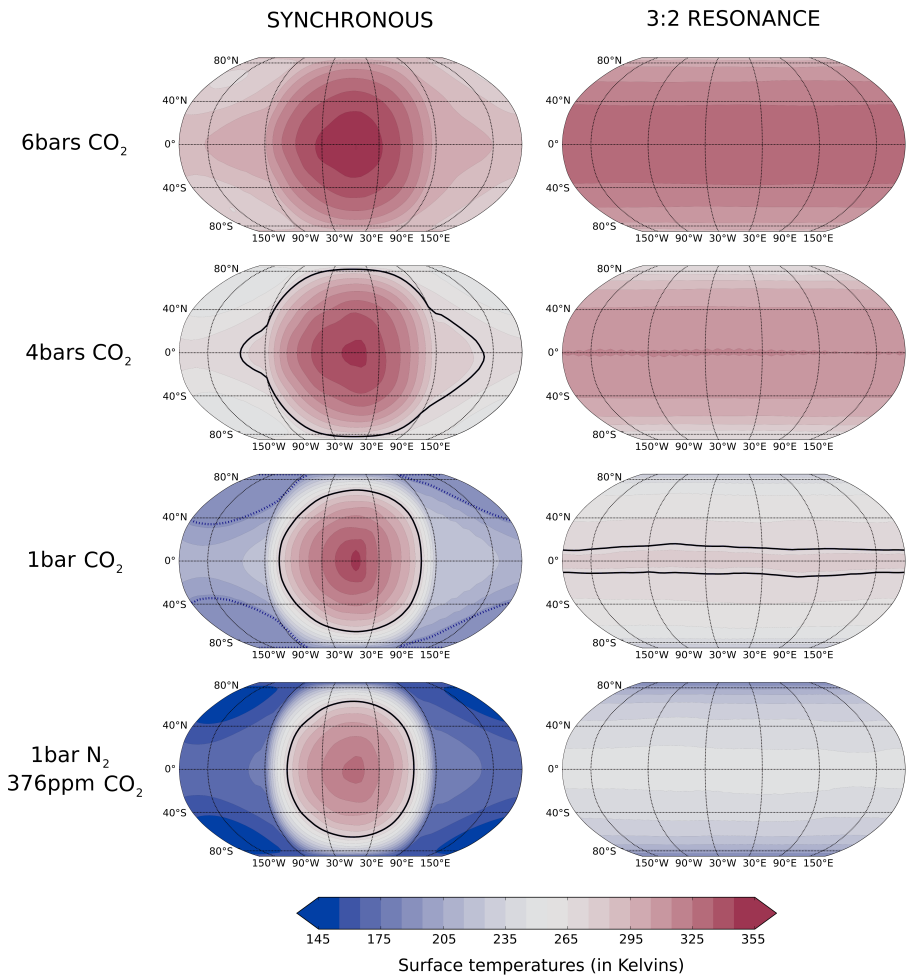
Terrestrial Exoplanet Circulation



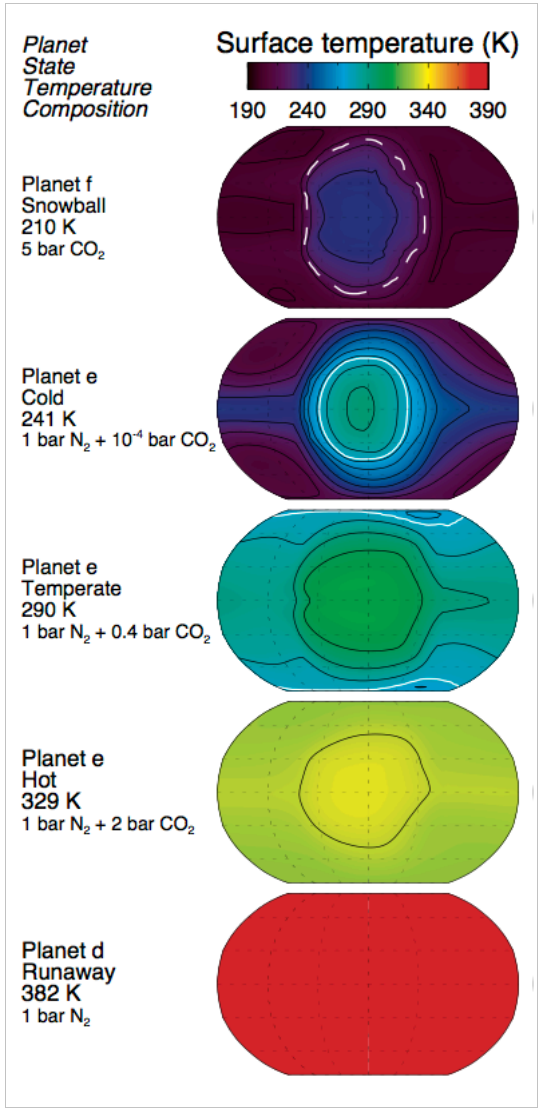
Proxima Centauri b

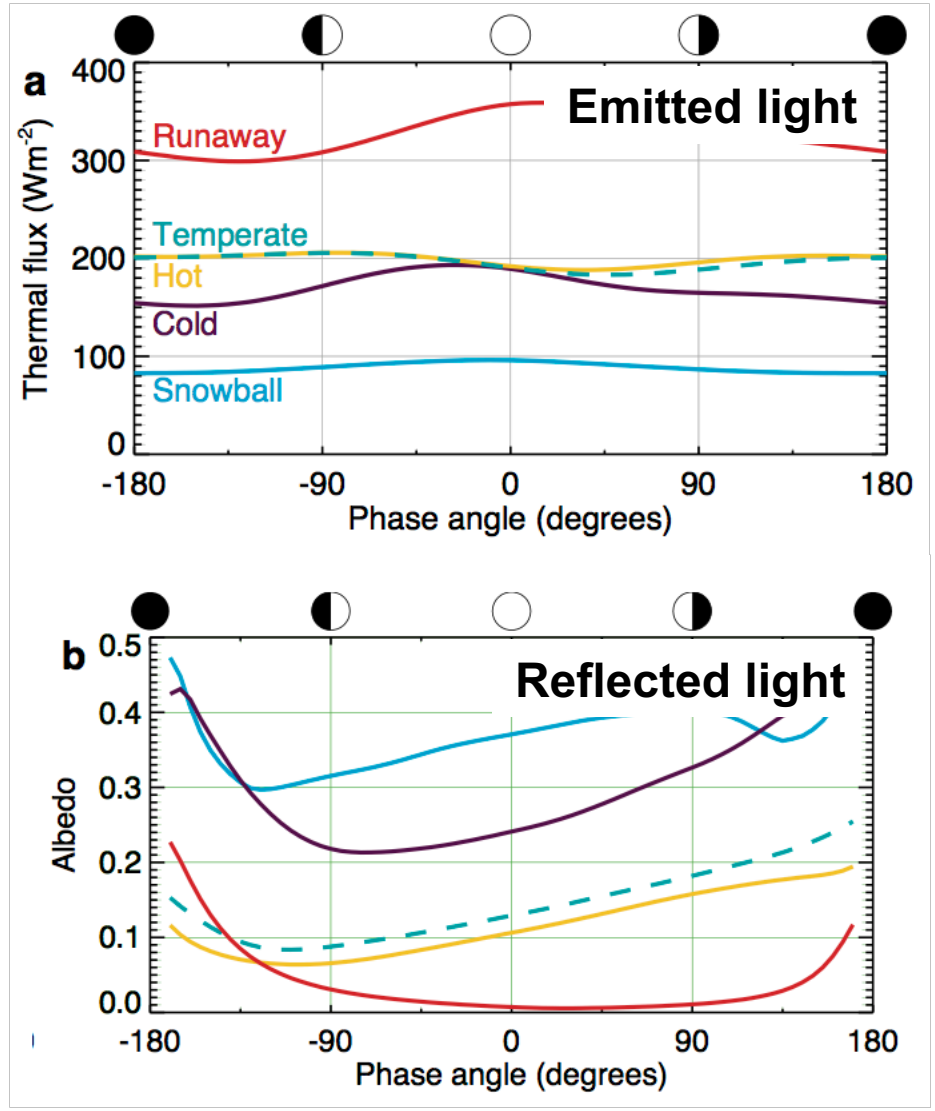
T_{eq} ~ 230 K (-45°F)

P_{orb} ~ 11 days

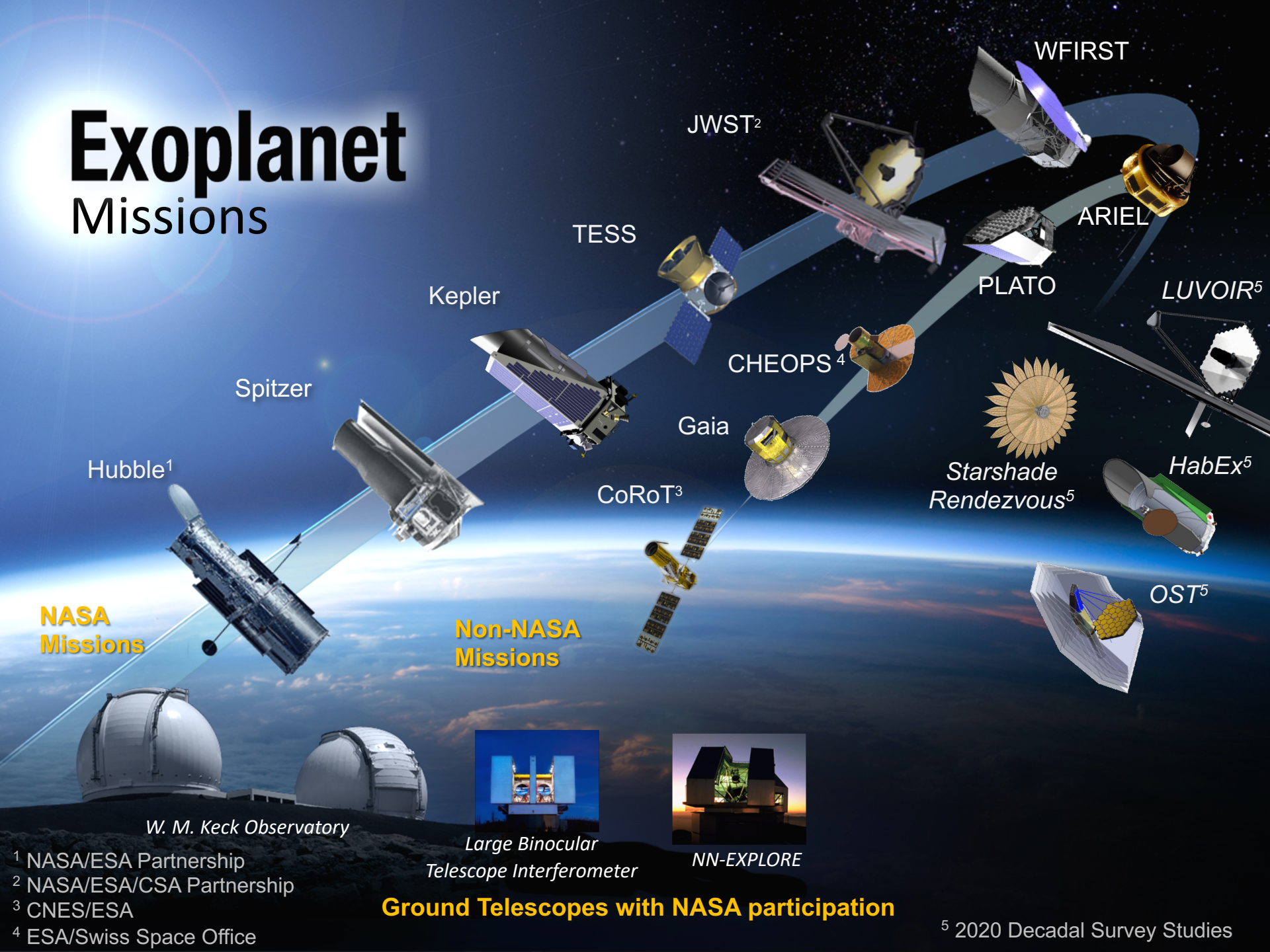


Probing Climates on TRAPPIST-1





Exoplanet Missions



[1] NASA/ESA Partnership
[2] NASA/ESA/CSA Partnership
[3] CNES/ESA
[4] ESA/Swiss Space Office

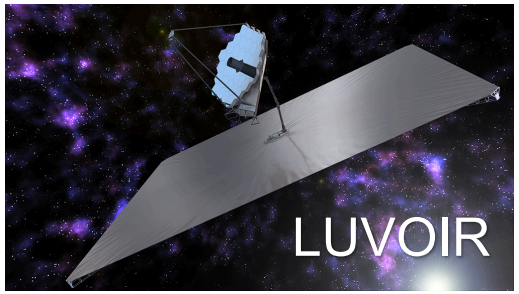
[5] 2020 Decadal Survey Studies

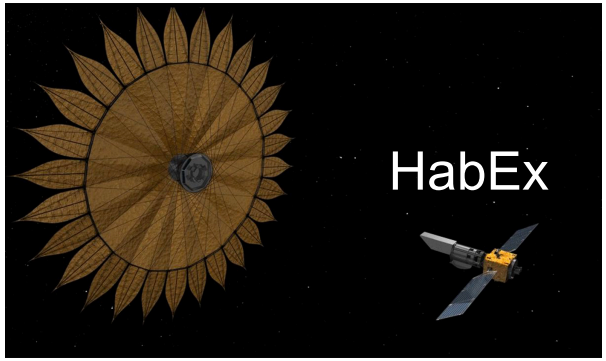
Future Exoplanet Missions

On the cusp of detecting and characterizing habitable worlds

Already launched!
Finding the nearest, brightest exoplanets

Launch 2030s
Dedicated facility for exoplanet characterization





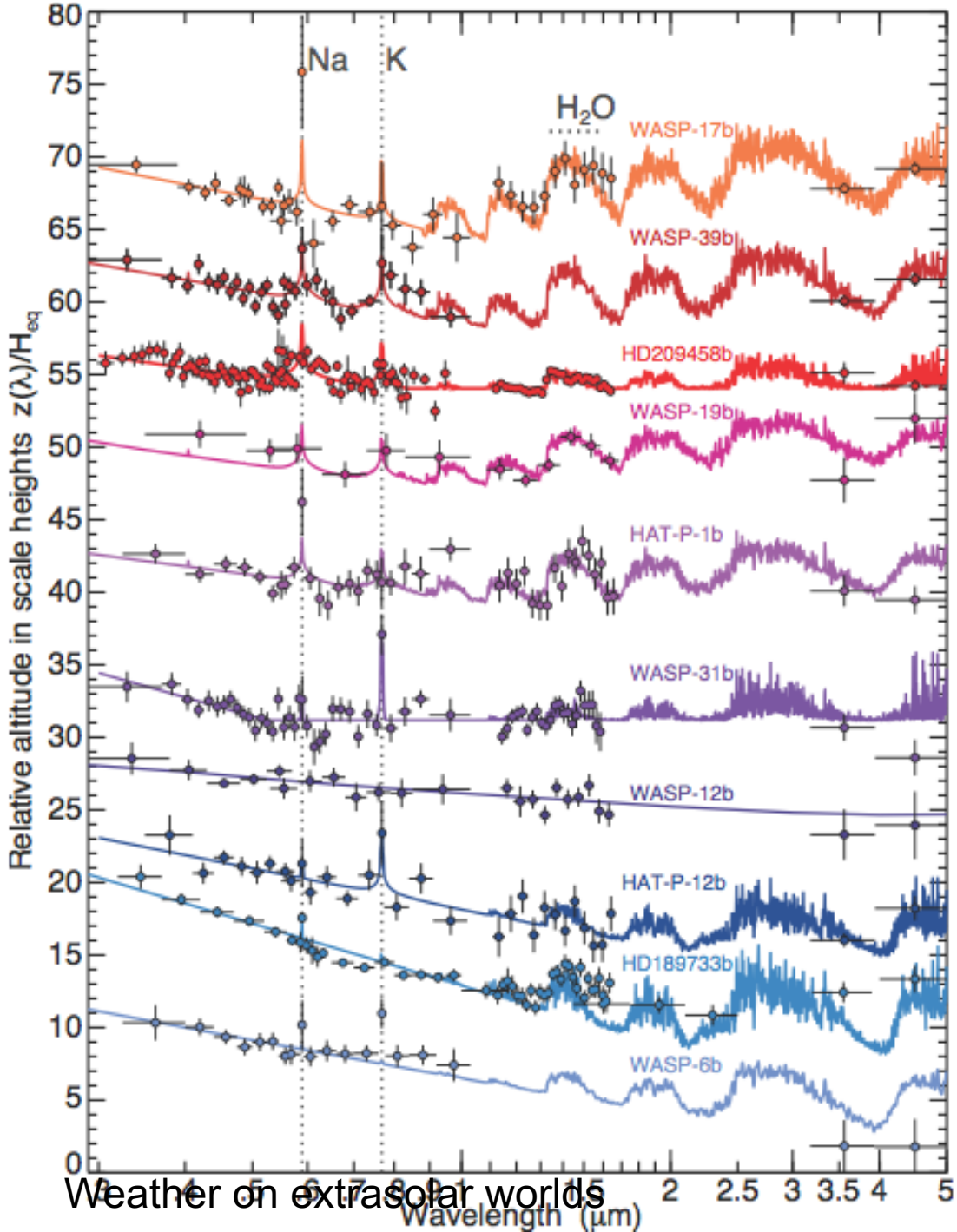
Launch March 2021
Exoplanet characterization in HD

Launch mid-2020s
Imaging planets in reflected light

Flagship concepts for 2020 Astrophysics Decadal Survey

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov



Sing et al. 2016