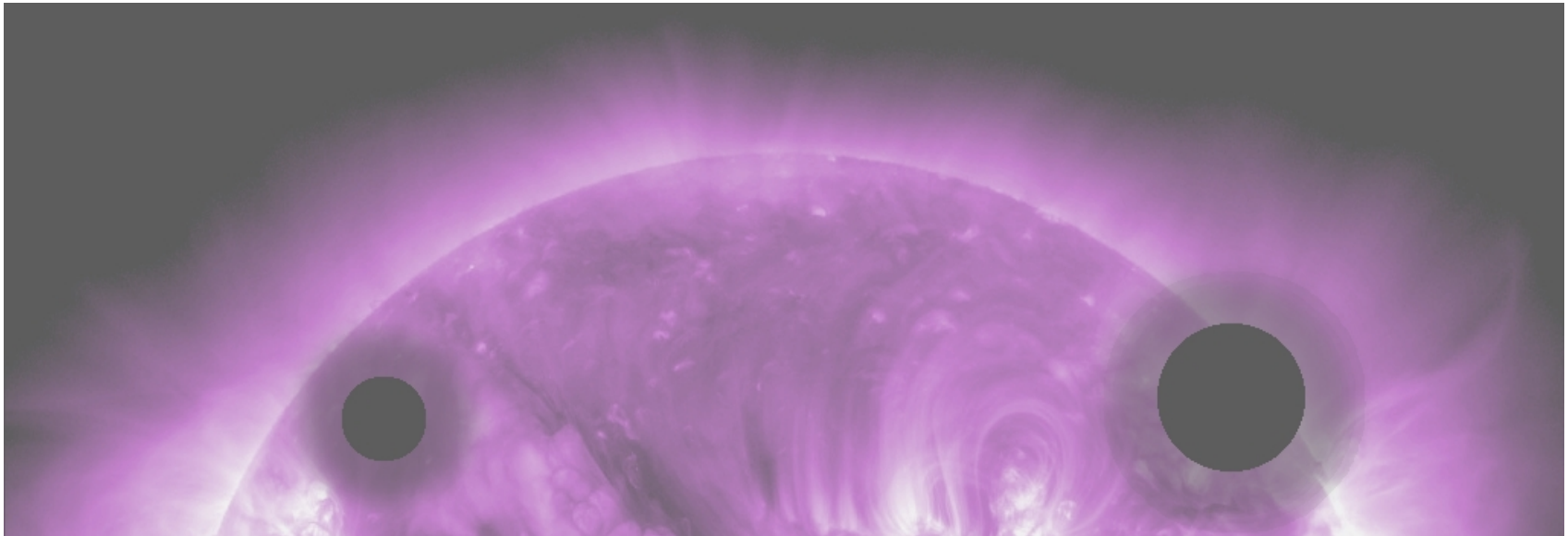
Probing the physics of exoplanet systems with X-ray observations

Dr. Katja Poppenhaeger
Sagan Fellow CfA $\rightarrow$ Queen's University Belfast



Exoplanets

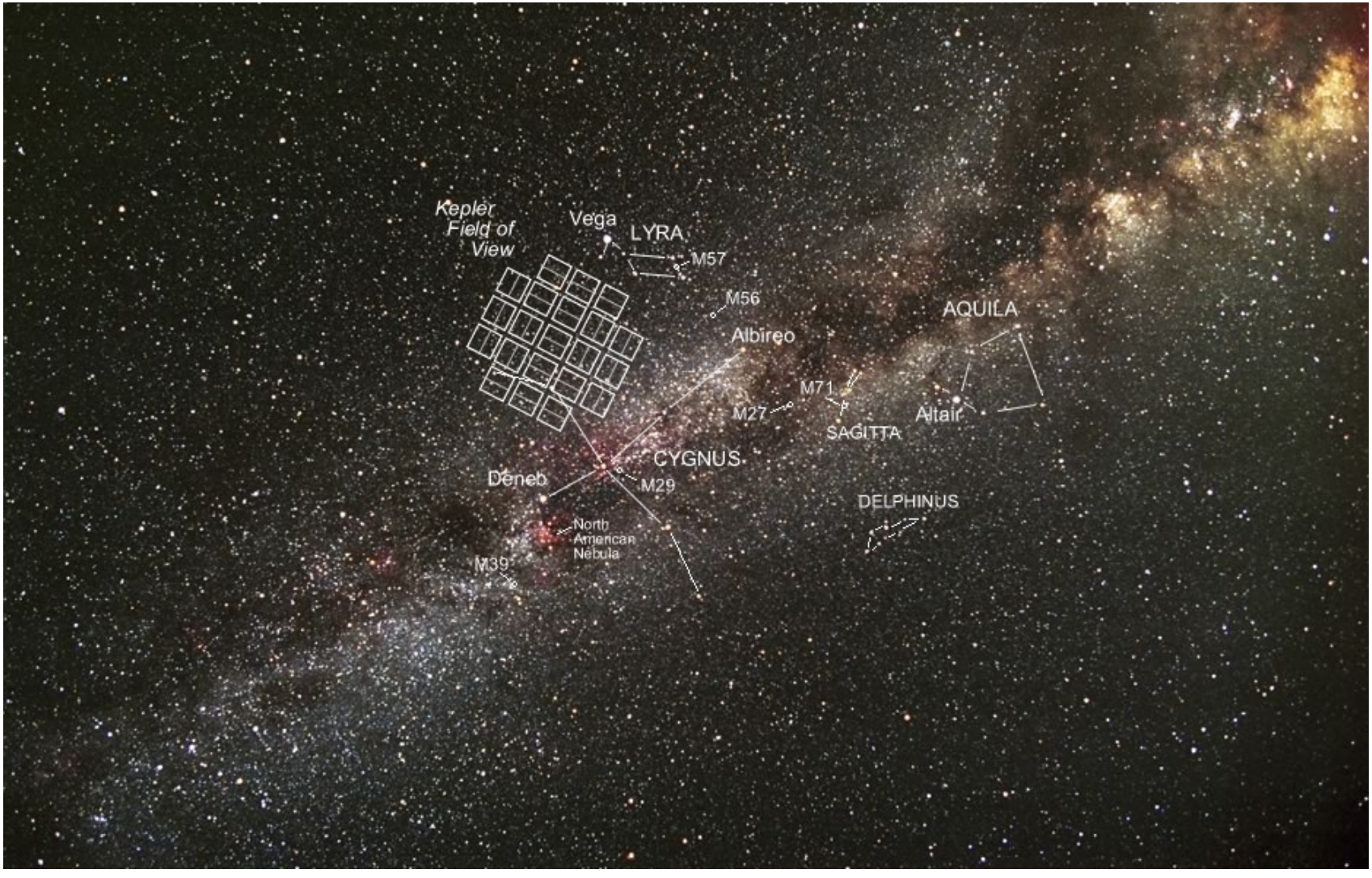
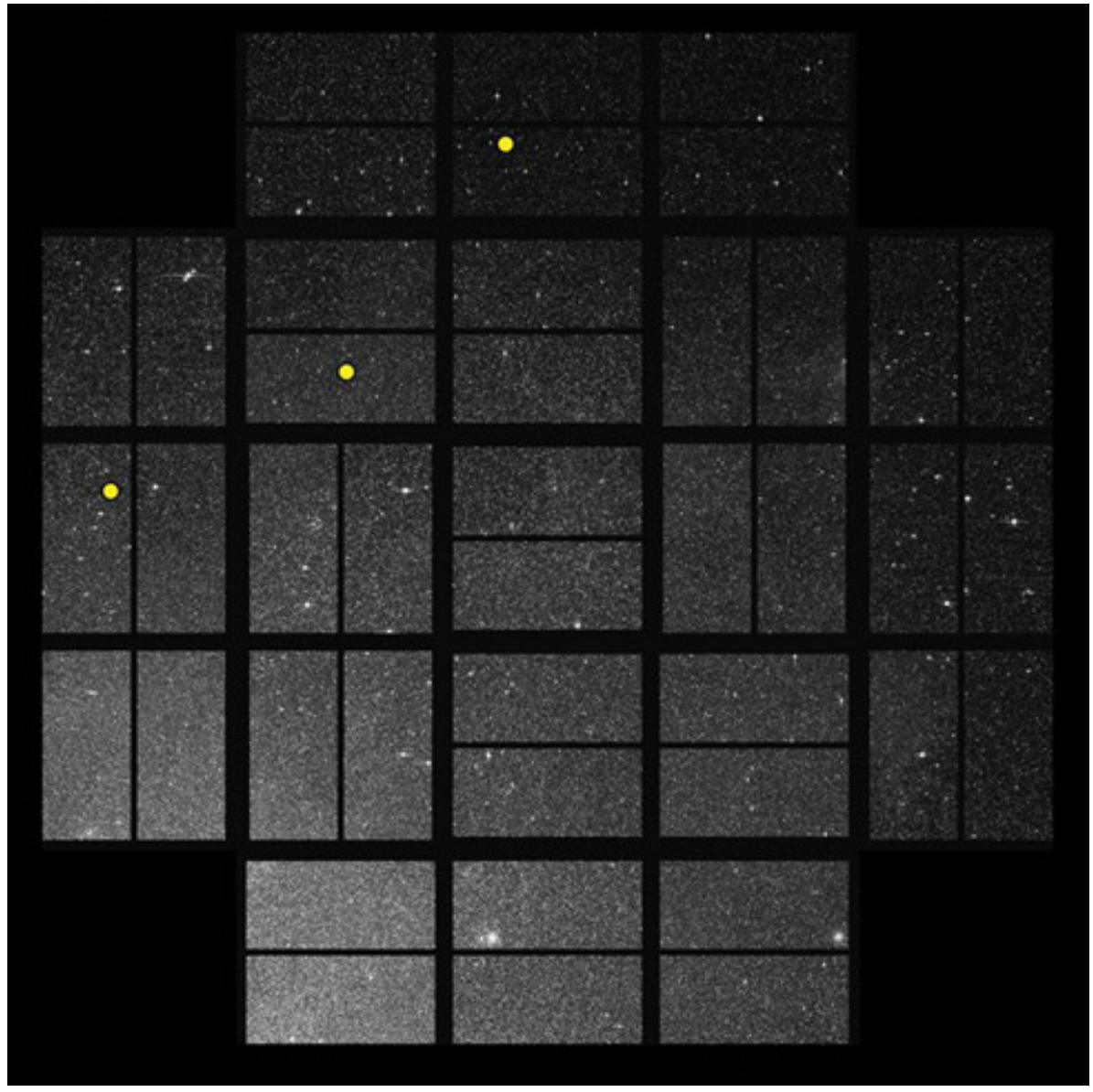


image credit: NASA/Kepler Team

Exoplanets



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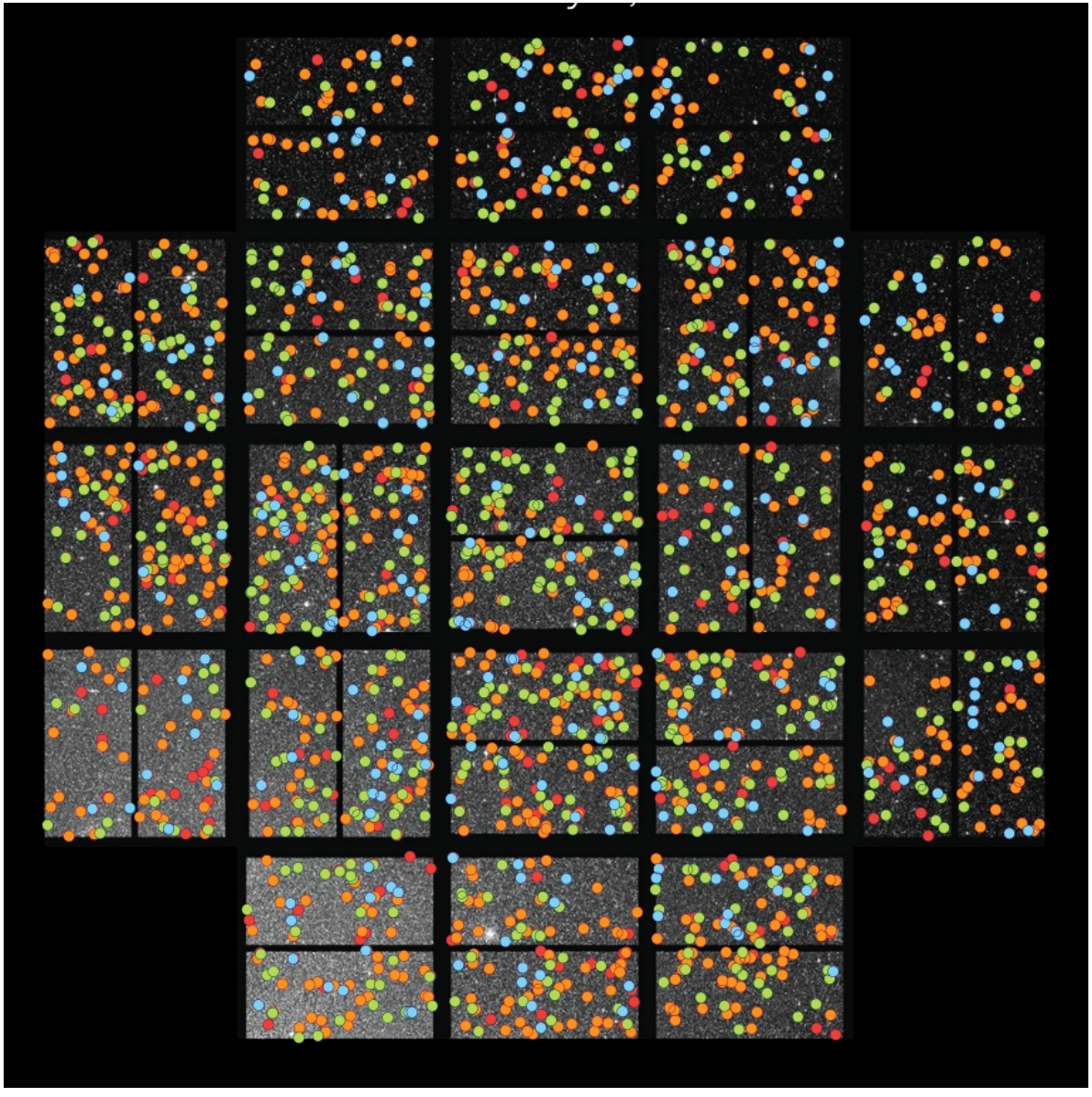
Exoplanets



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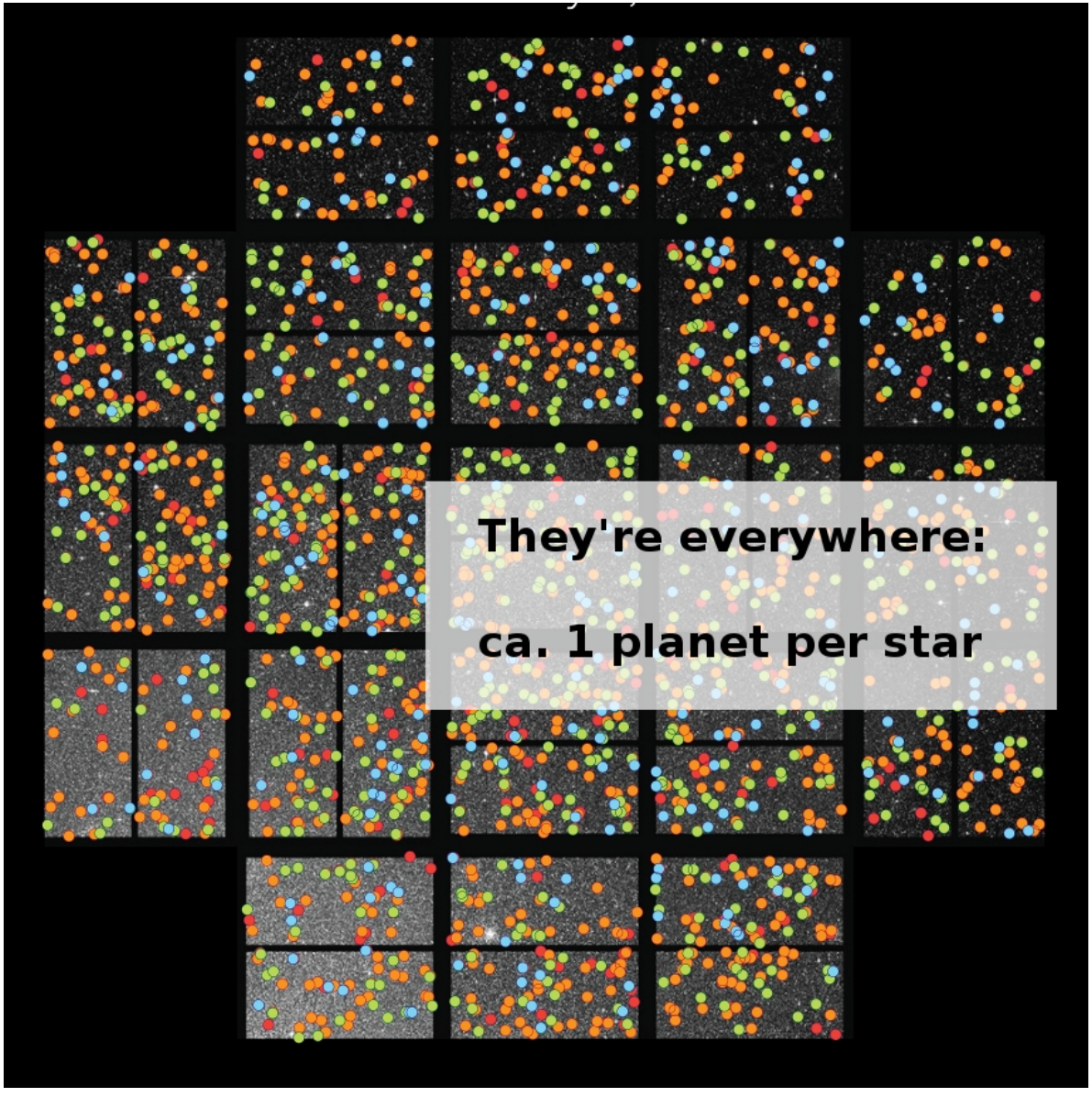
Exoplanets



Dressing et al. (2013), Batalha(2014), Burke et al. (2015)

System architectures

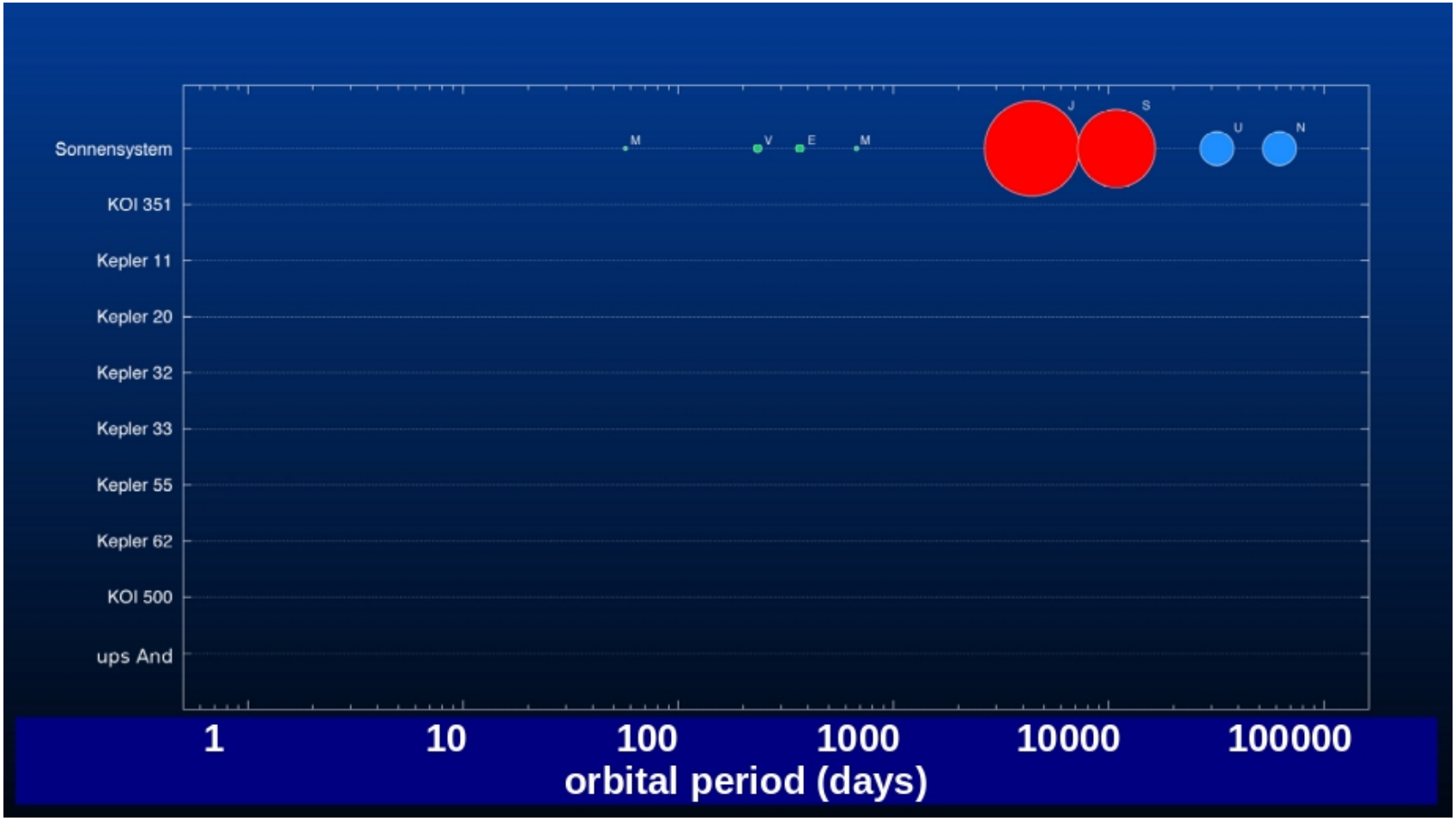


image credit: German Air & Space Center (DLR)

System architectures

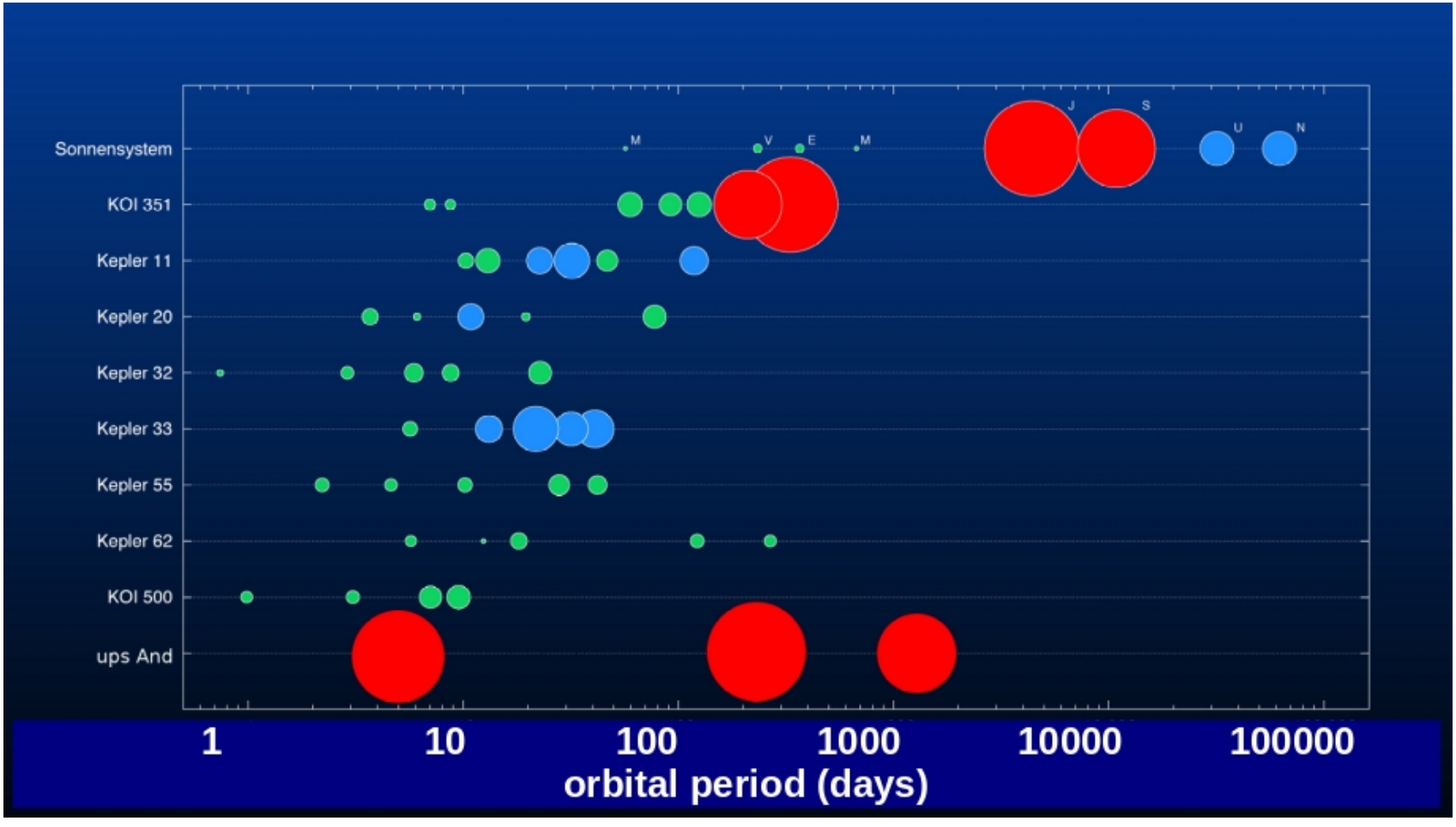


image credit: German Air & Space Center (DLR)

Habitable zones

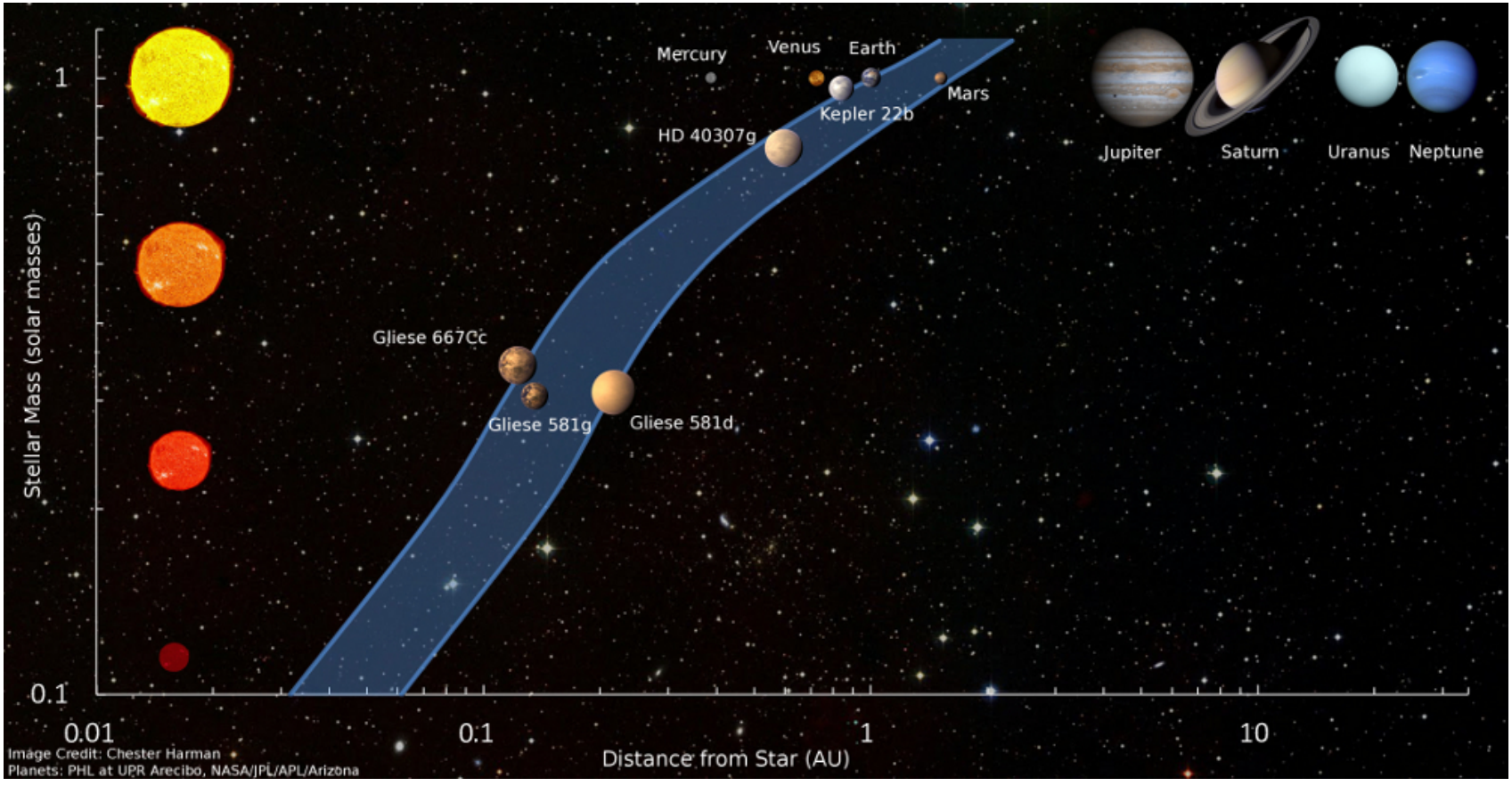
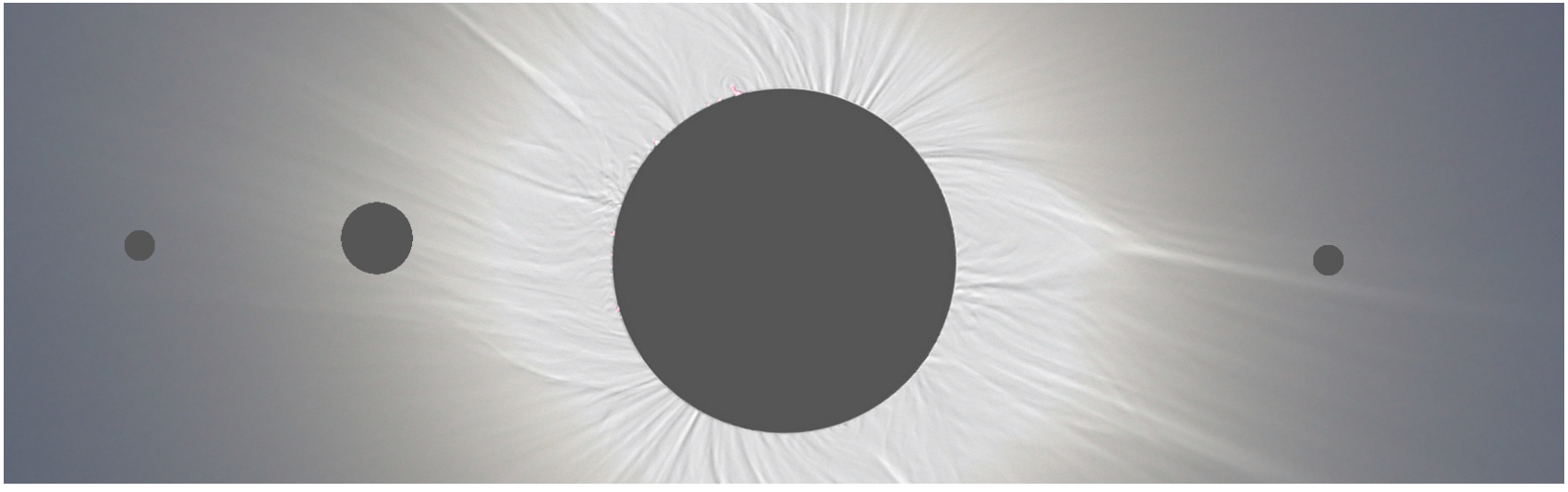


image credit: C. Harman

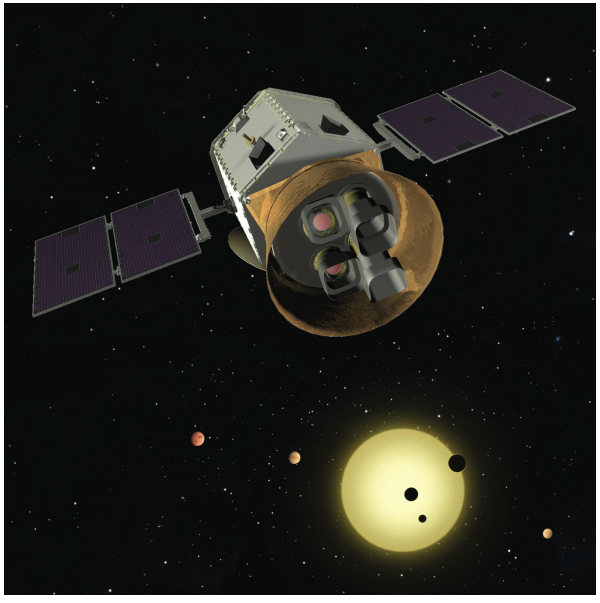
Big questions

- How diverse are exoplanet atmospheres?
- Which exoplanets have the potential to host life?

... Which (exo)planets do host life?



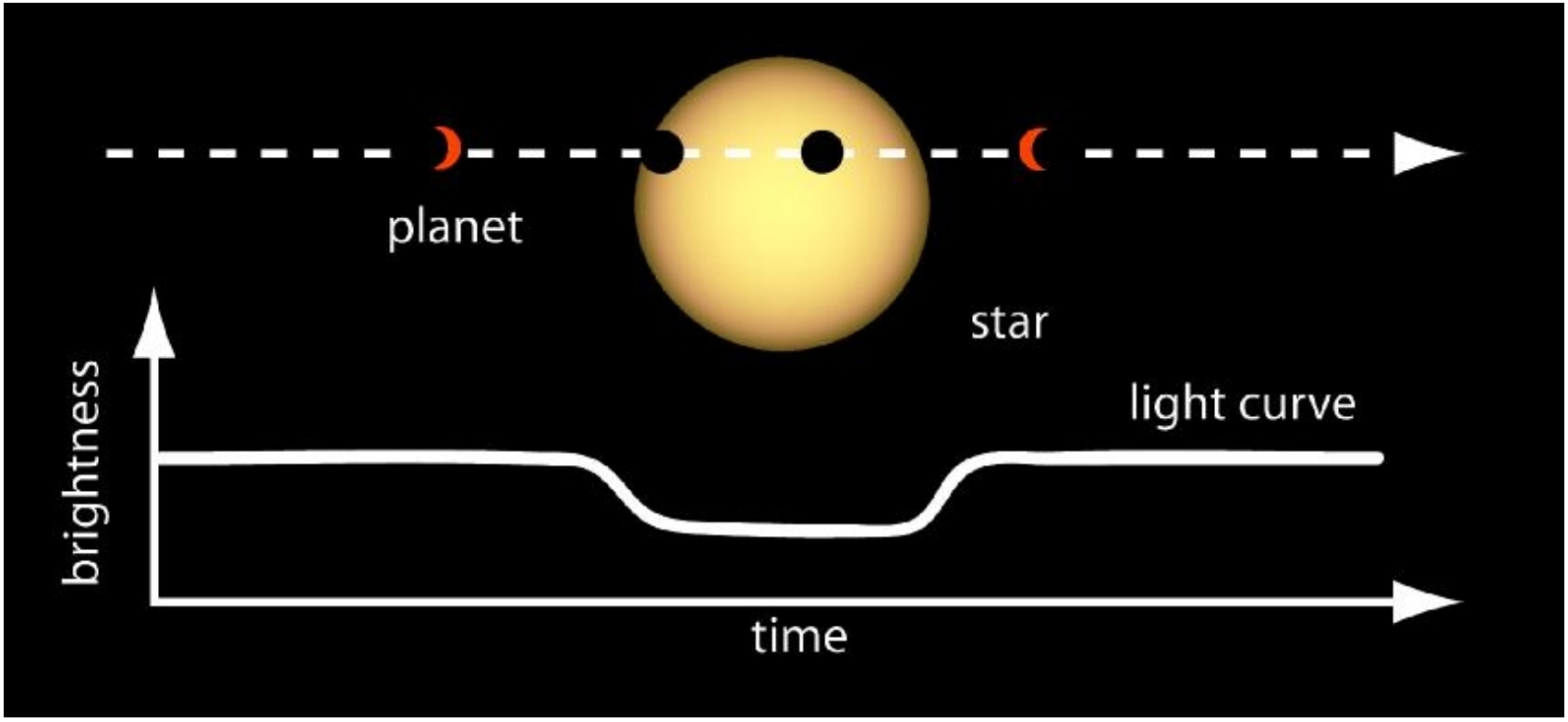
Upcoming exoplanet observatories



TESS, Transiting Exoplanet Survey Satellite
All-Sky search for transiting exoplanets
image credit: MIT

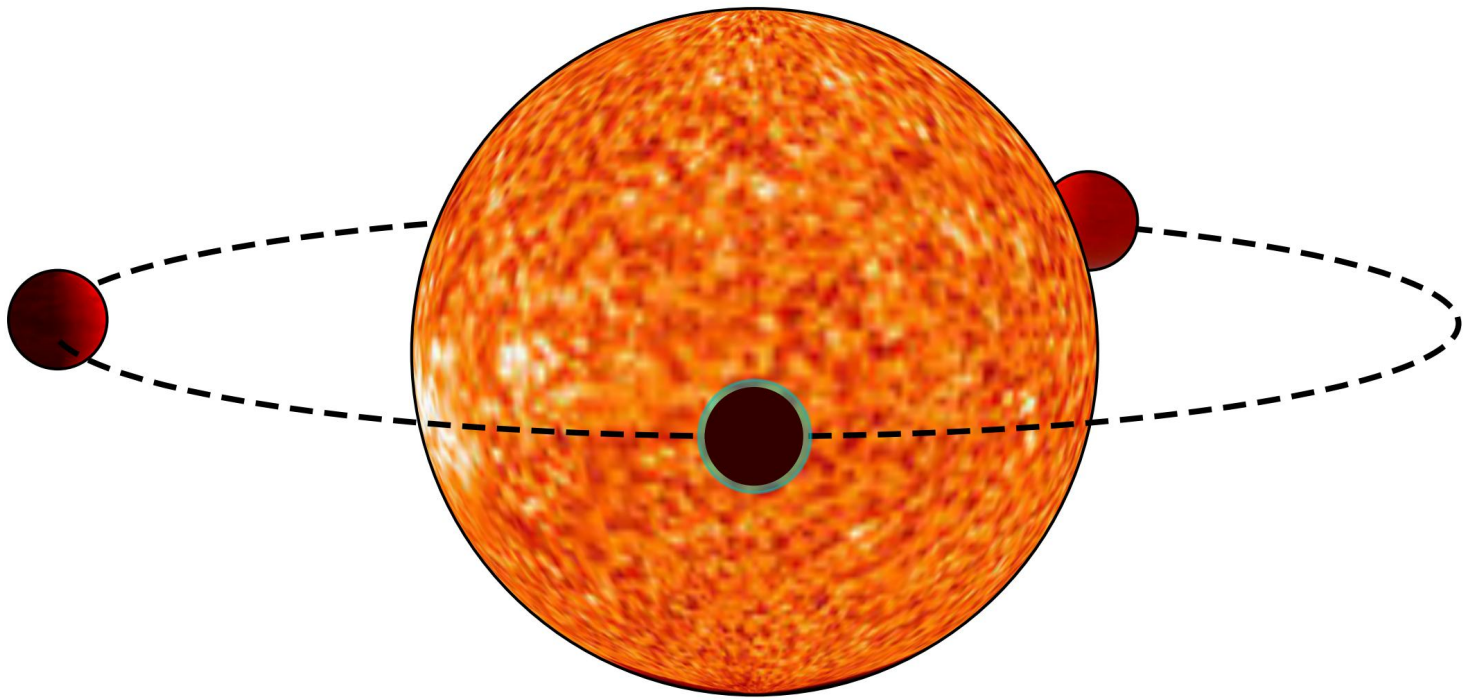
JWST, James Webb Space Telescope
infrared spectroscopy of exoplanet atmospheres
image credit: NASA

Exoplanets: transits



picture credit: NASA

Exoplanet atmospheres: transmission spectroscopy



K. B. Stevenson

Charbonneau et al. (2002), Sing et al. (2011), Pont et al. (2013), Deming et al. (2013), Kreidberg et al. Nature (2014)

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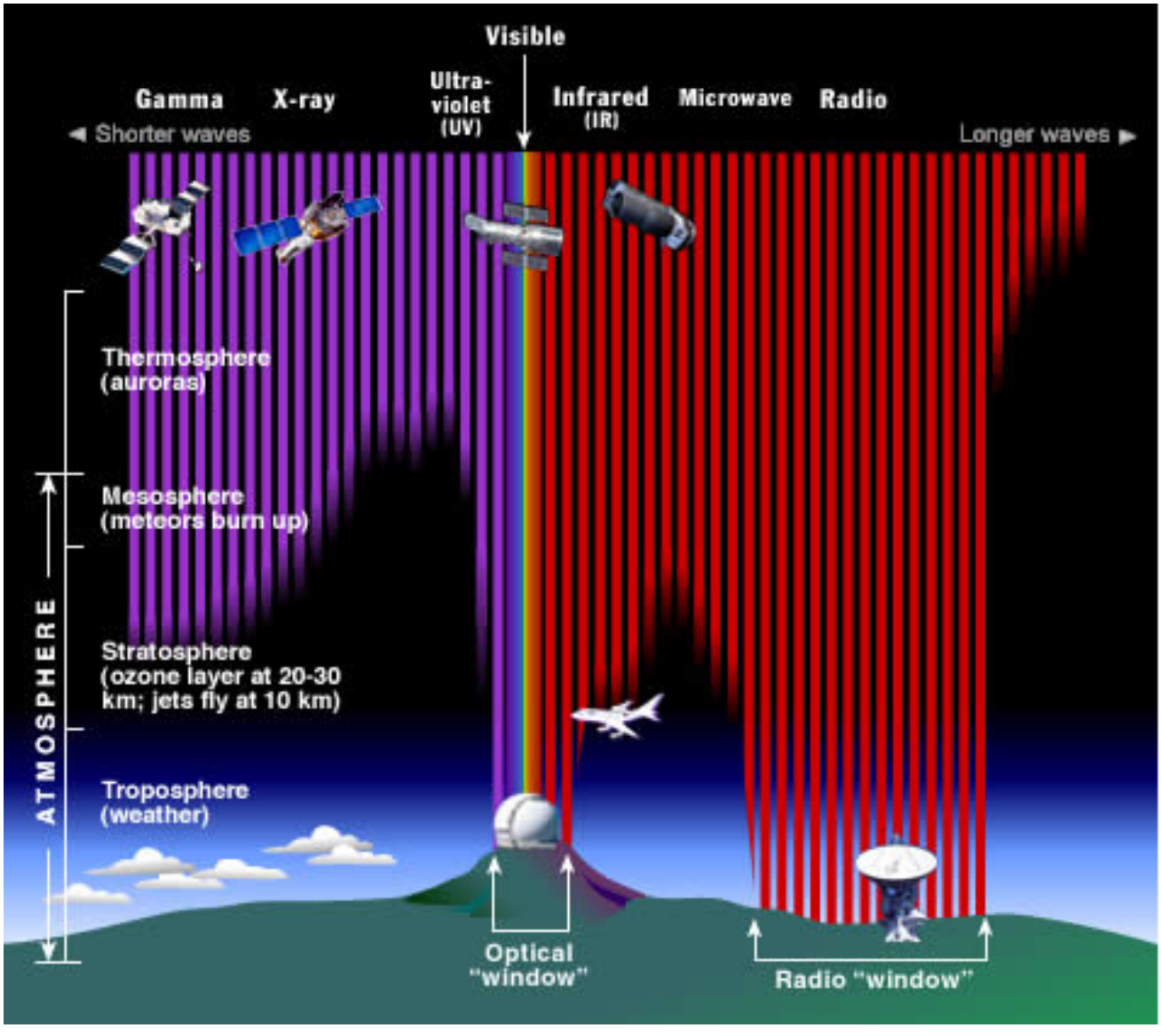
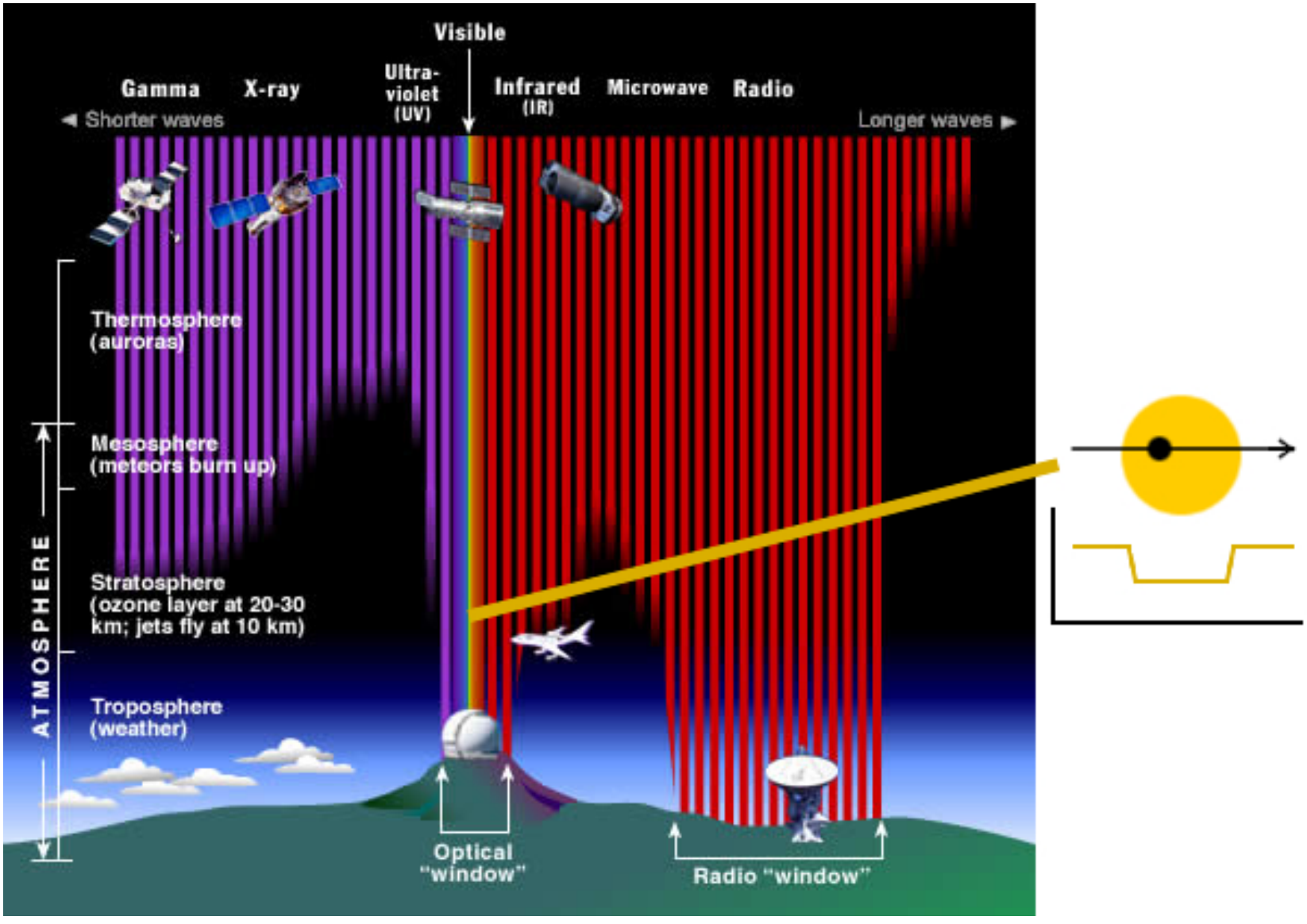


picture credit: NASA, modified by K.P.

Exoplanet atmospheres: transmission spectroscopy



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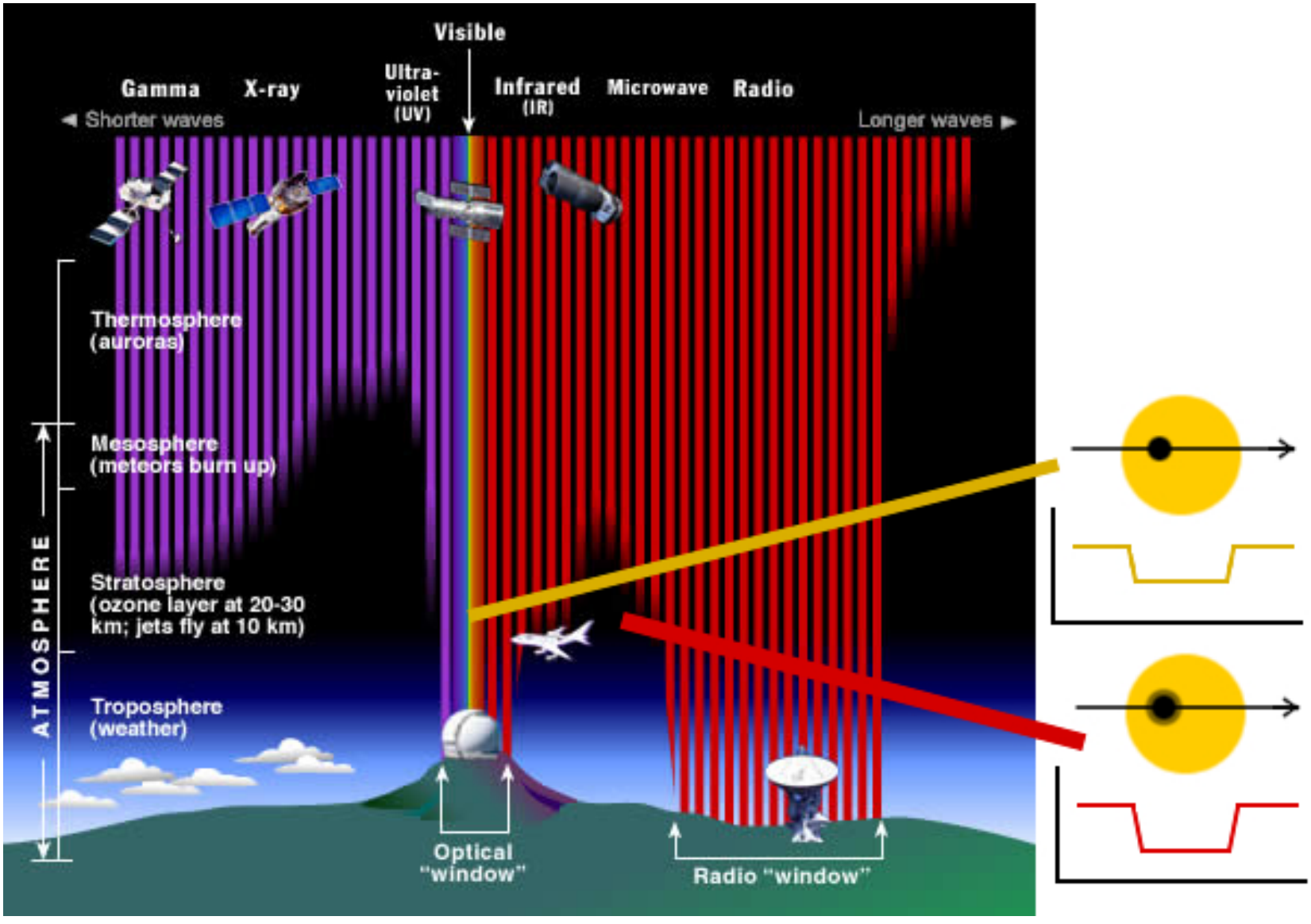
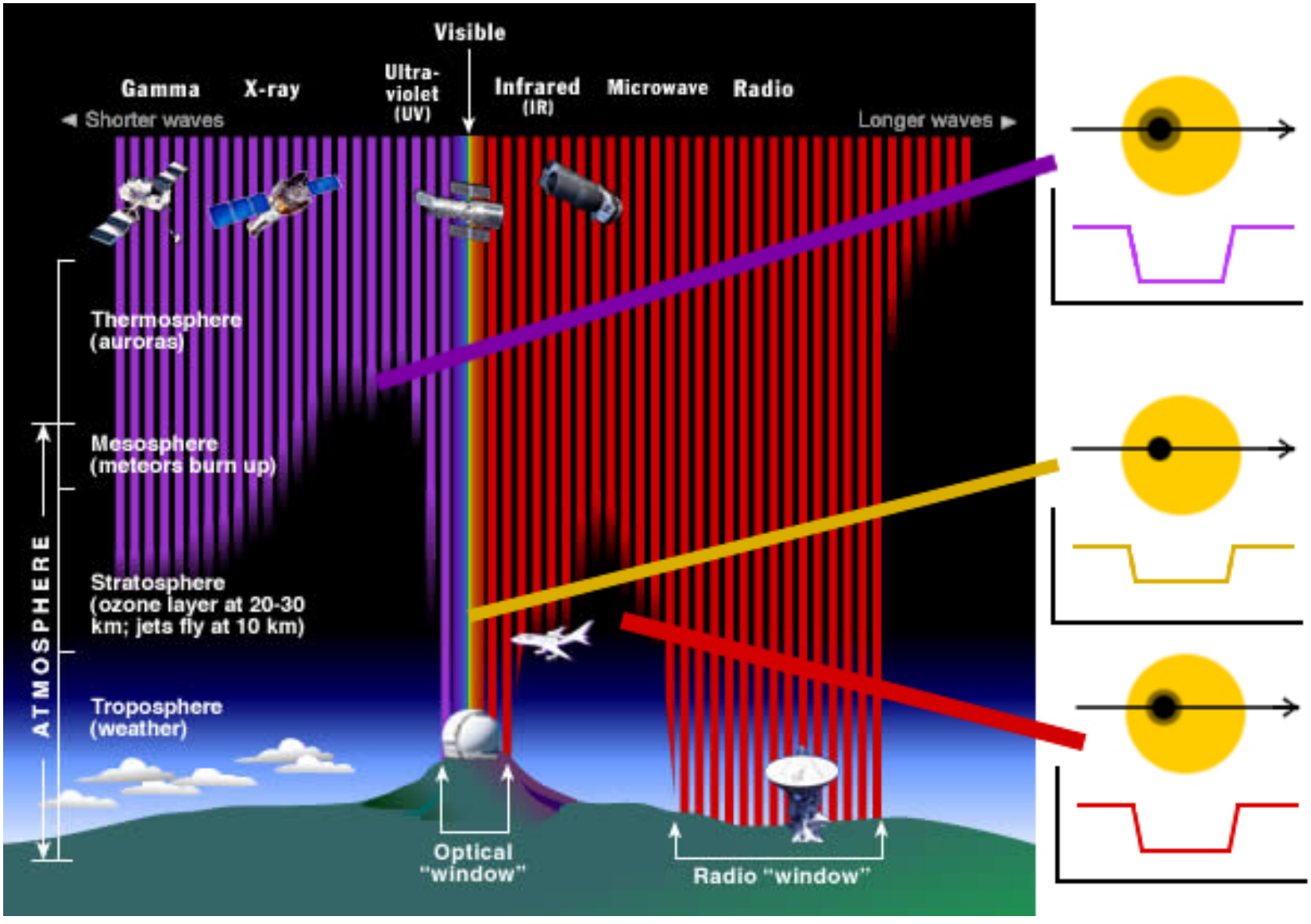
Exoplanet atmospheres: transmission spectroscopy



picture credit: NASA, modified by K.P.

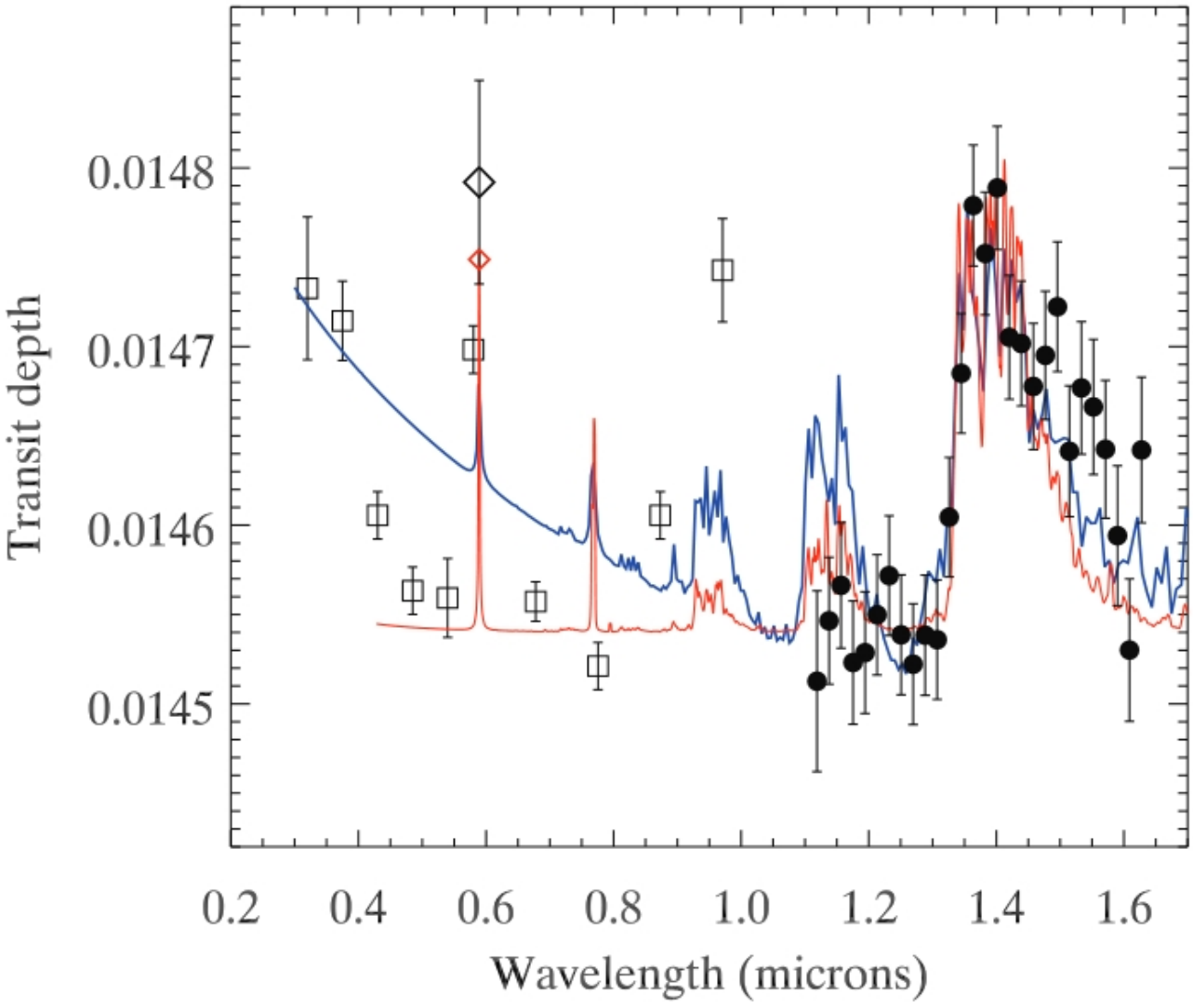
Exoplanet atmospheres: transmission spectroscopy



picture credit: NASA, modified by K.P.

Exoplanet atmospheres: transmission spectroscopy

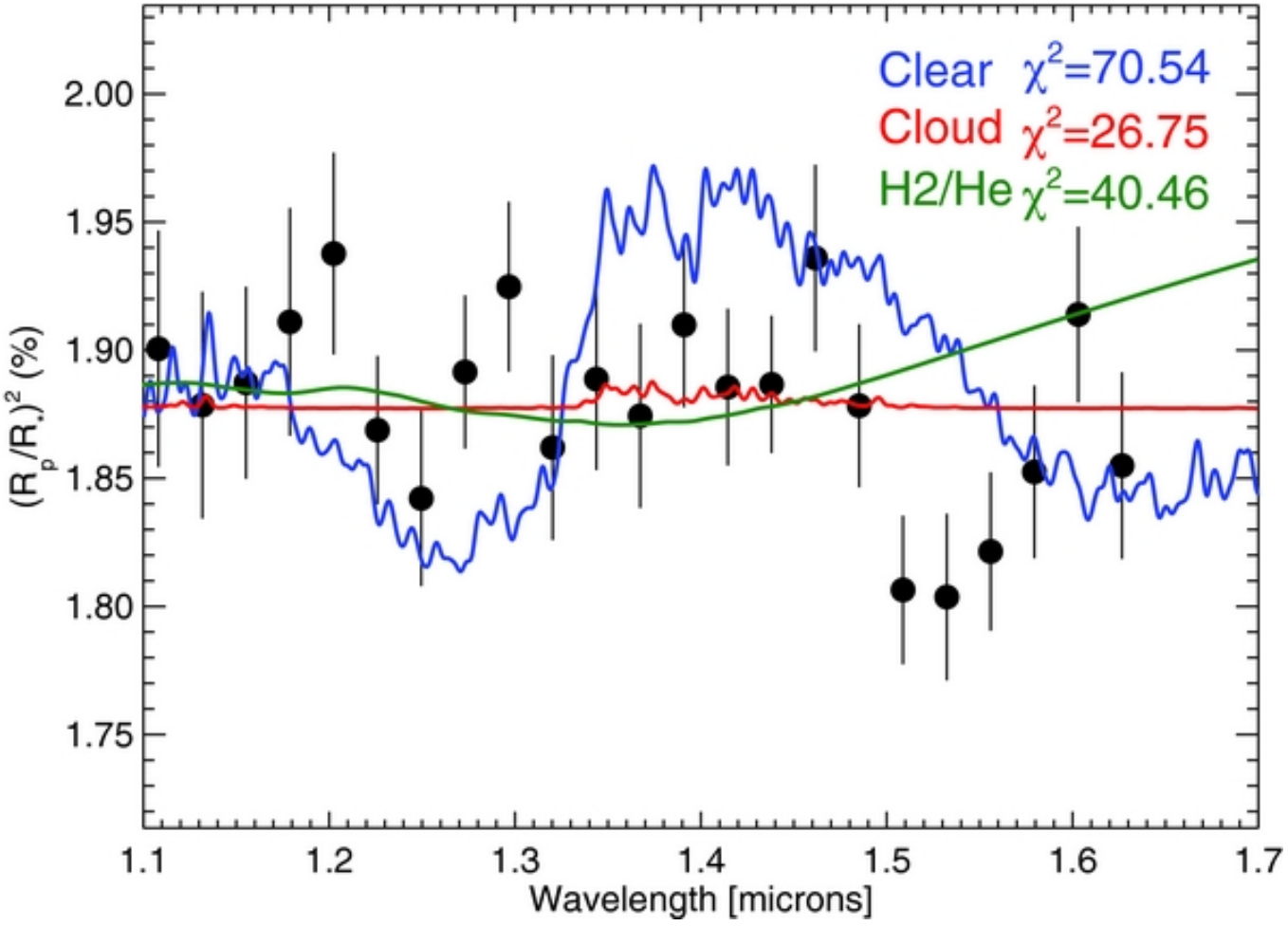
HD 209458b (hot Jupiter)



Deming et al. 2013

Exoplanet atmospheres: cloud layers

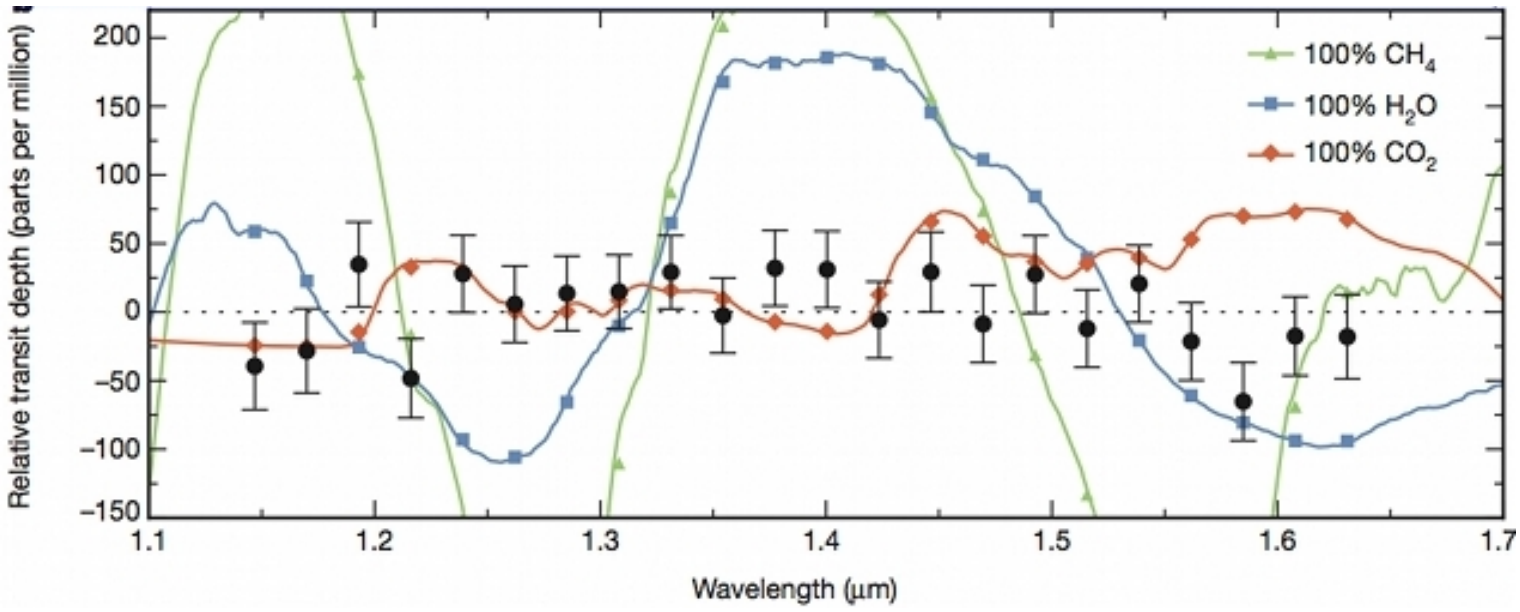
HAT-P-12b (warm Saturn)



Line et al. 2013

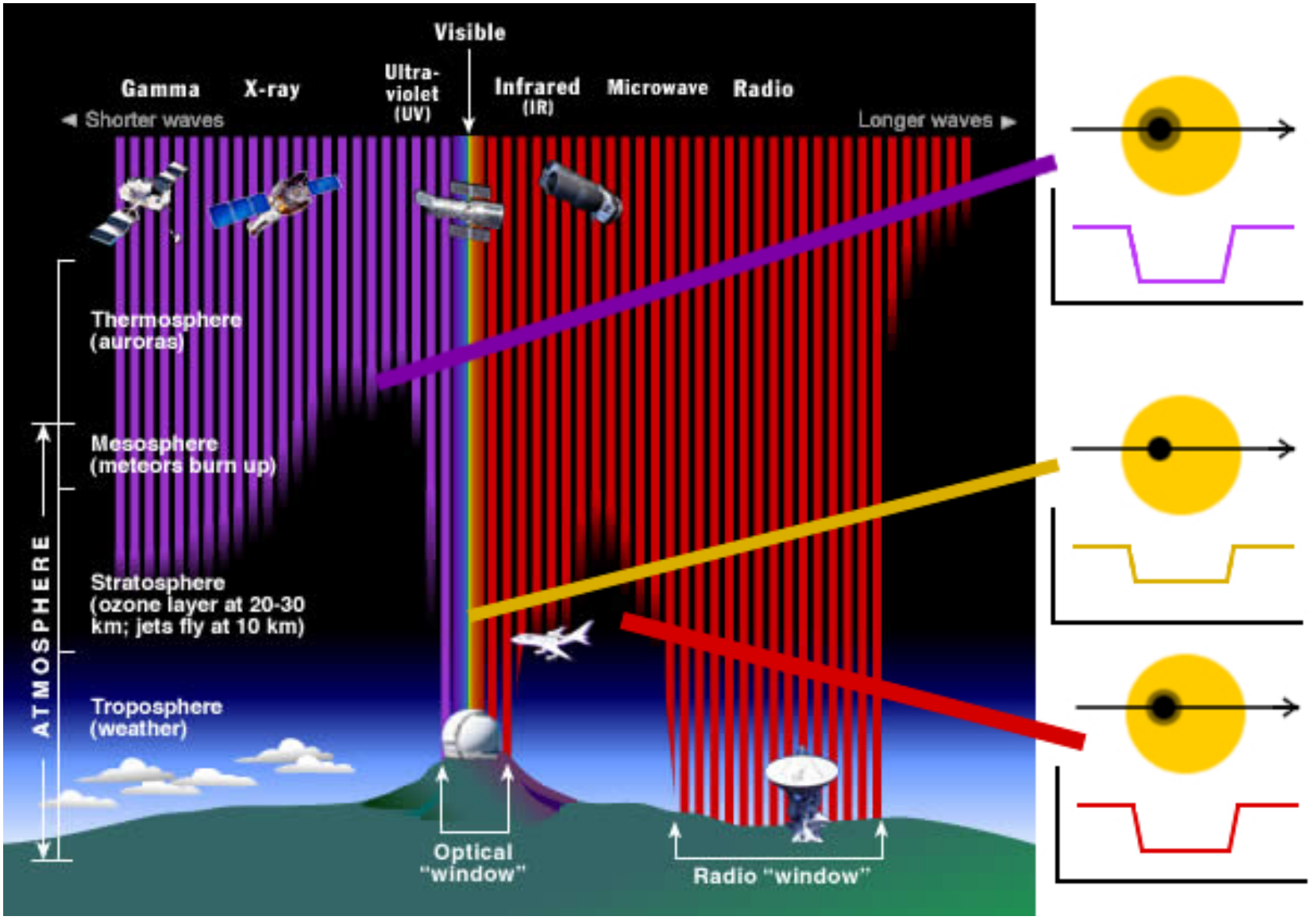
Exoplanet atmospheres: cloud layers

GJ 1214b (super-earth)



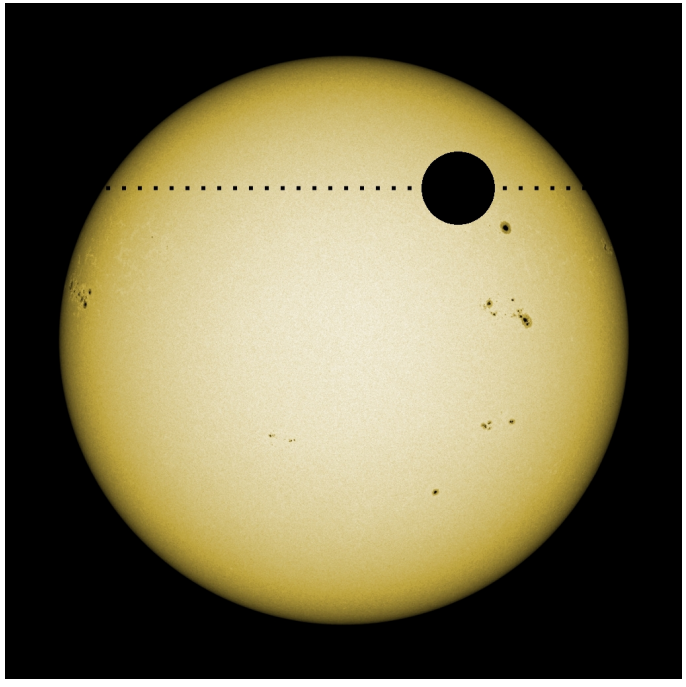
Kreidberg et al. Nature 2014

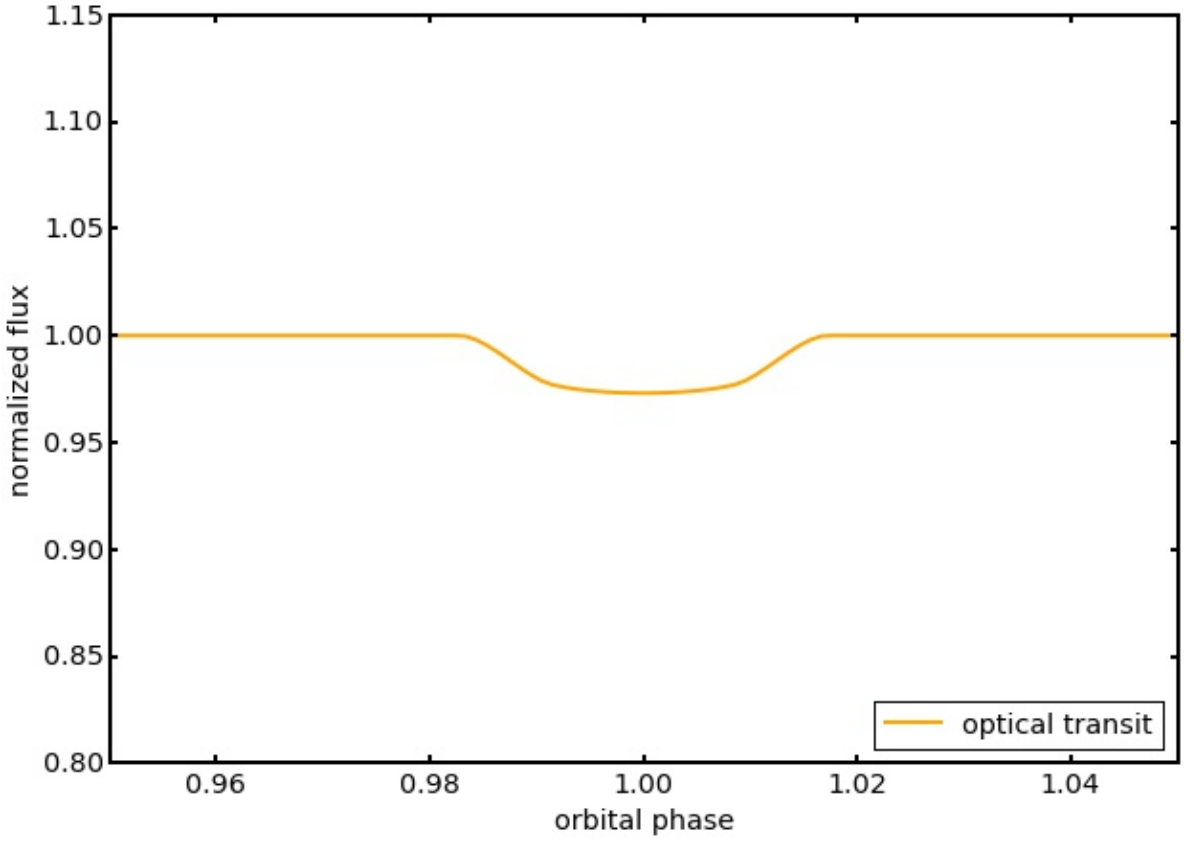
Exoplanet atmospheres: transmission spectroscopy



picture credit: NASA, modified by K.P.

X-ray transits (hot Jupiter HD 189733b)





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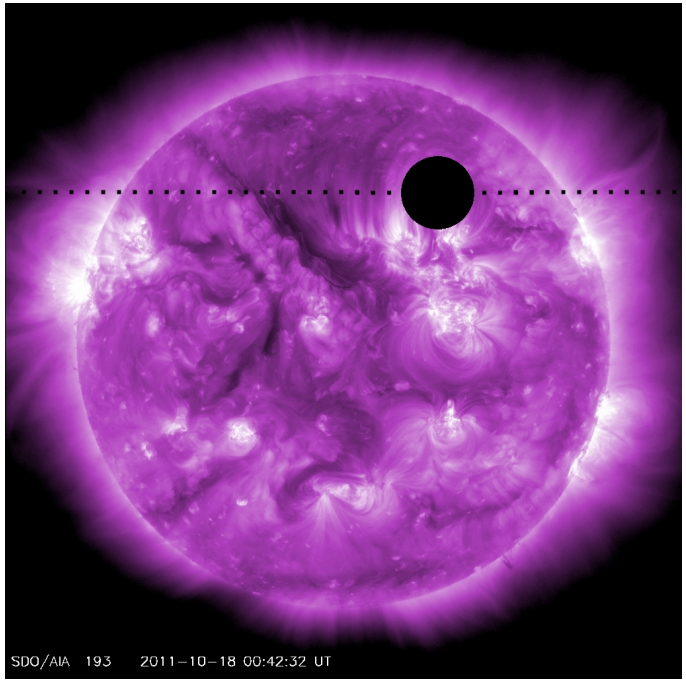

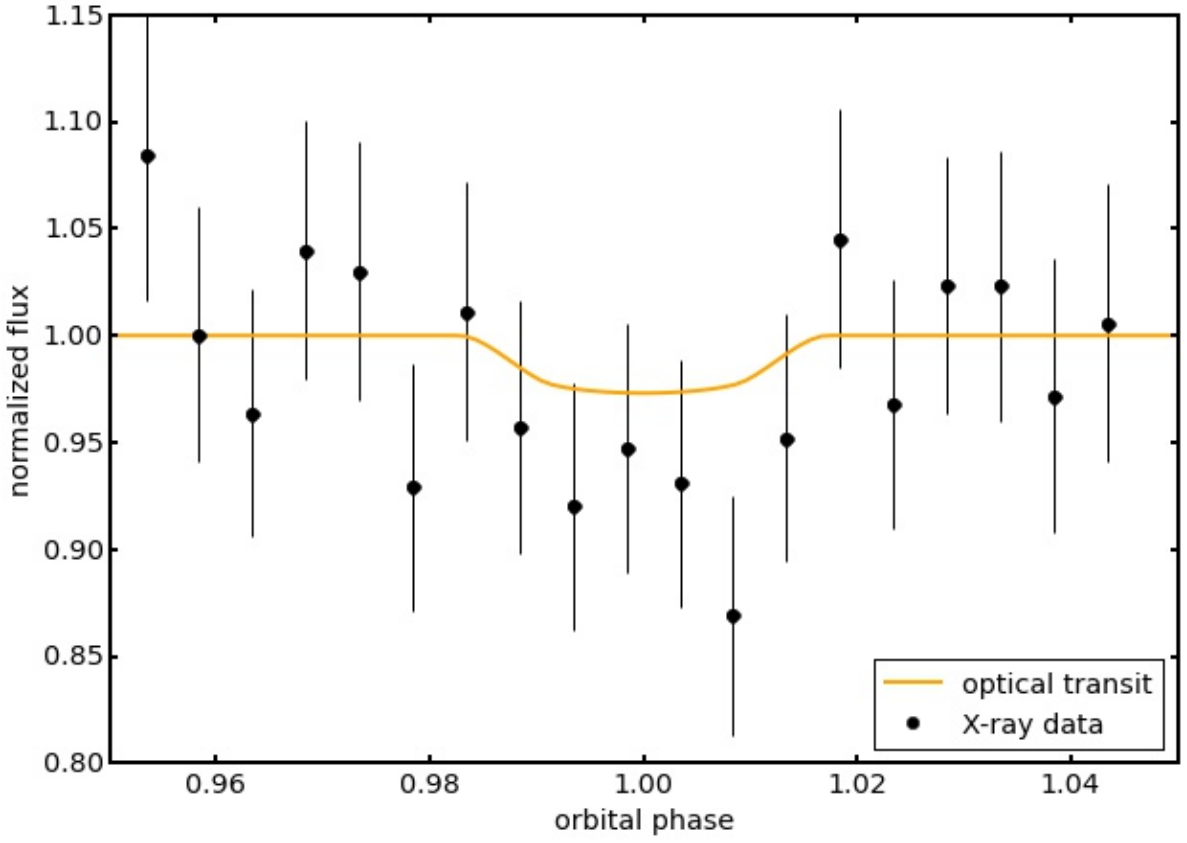

5 Chandra observations co-added,
20 ks each, 0.2-2 keV
Poppenhaeger et al., ApJ 2013

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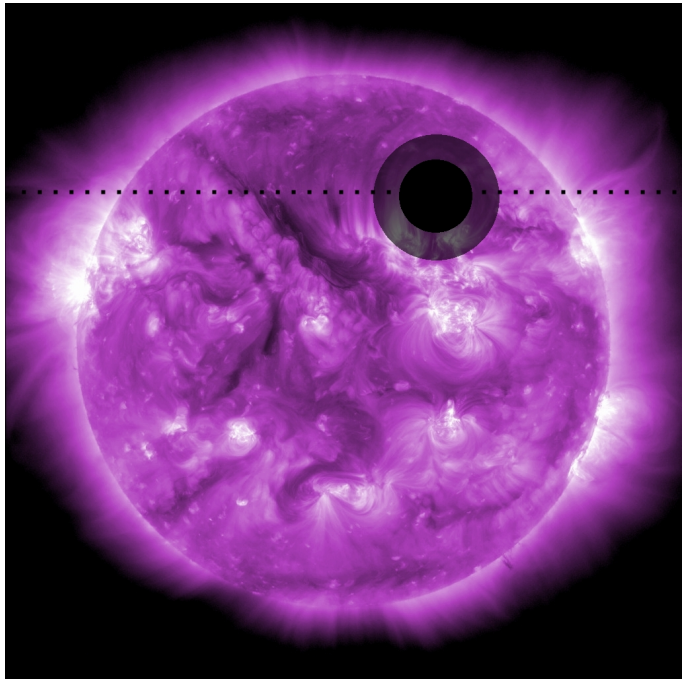

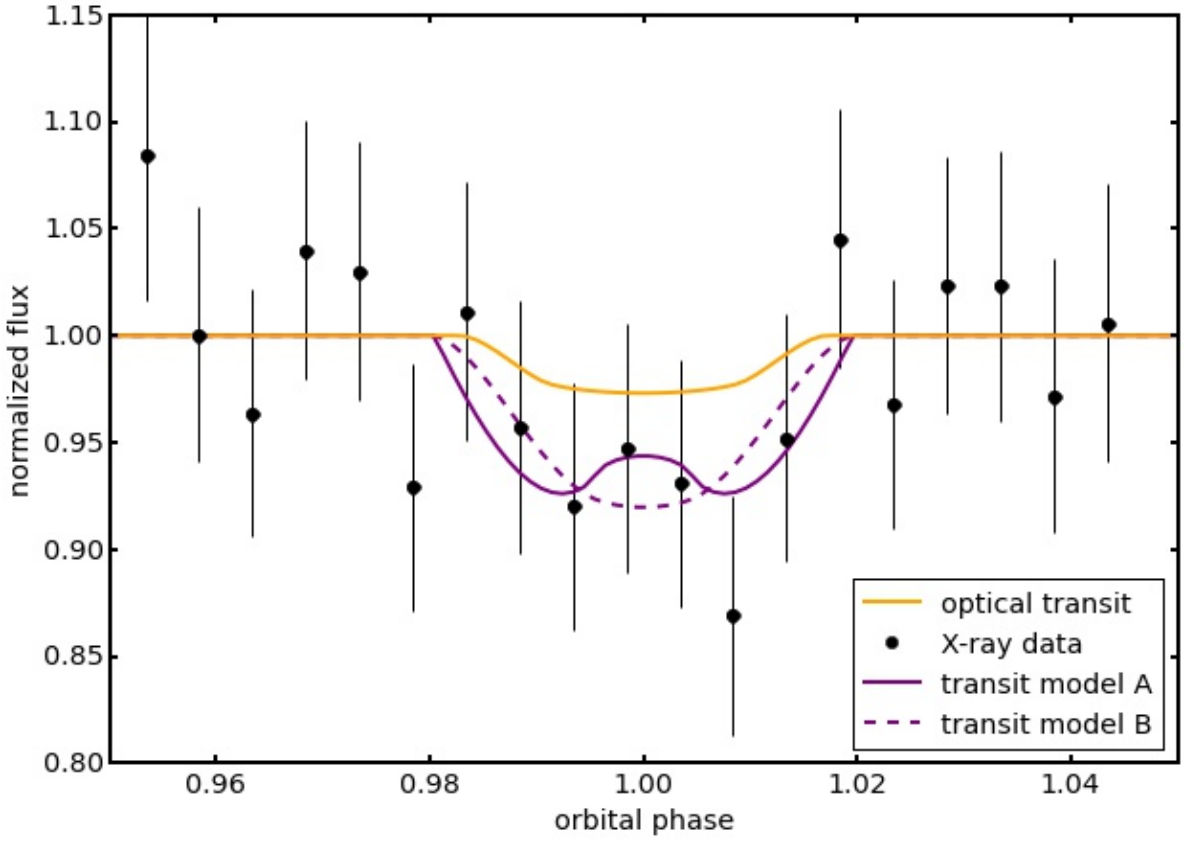

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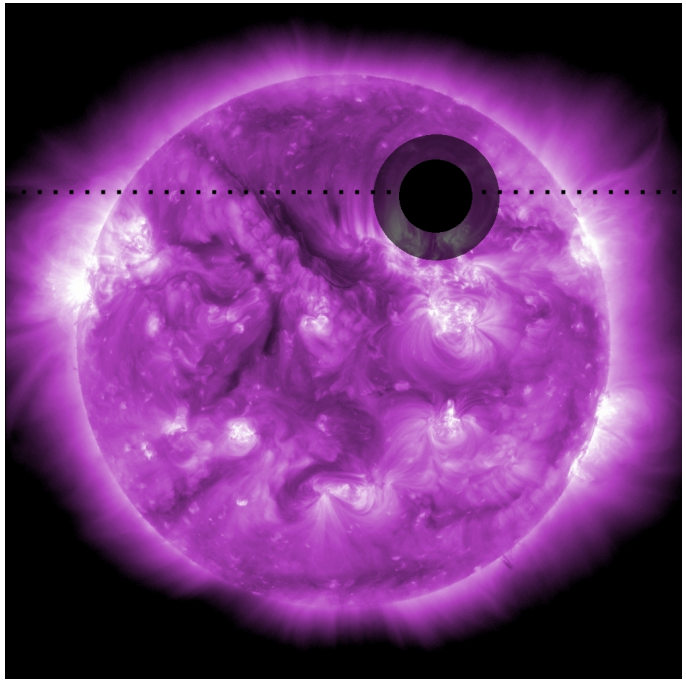
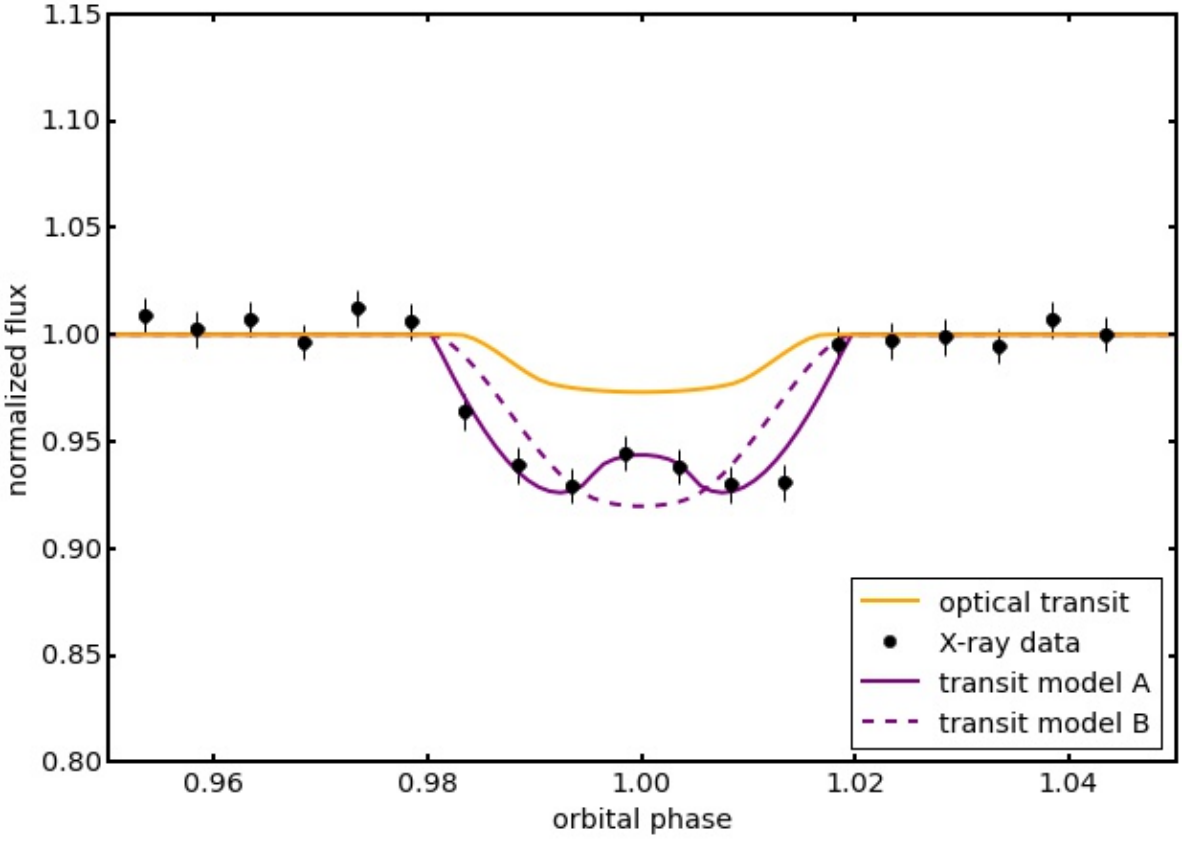
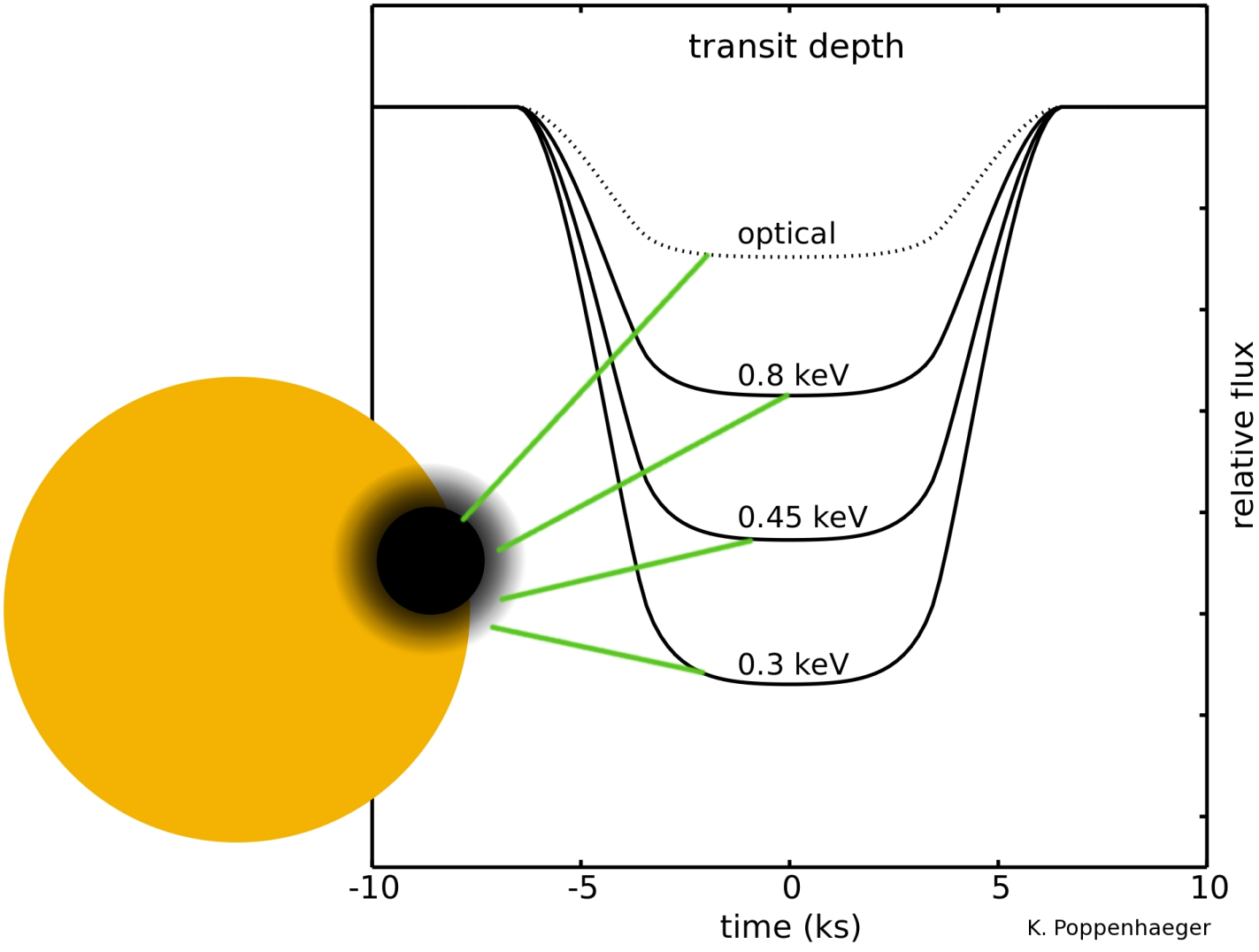
X-ray transits - X-ray Surveyor



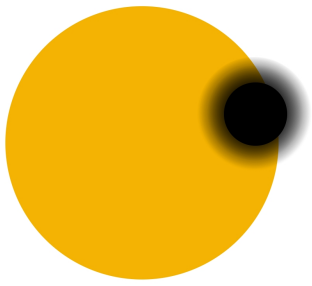


5 observations with X-ray Surveyor, co-added

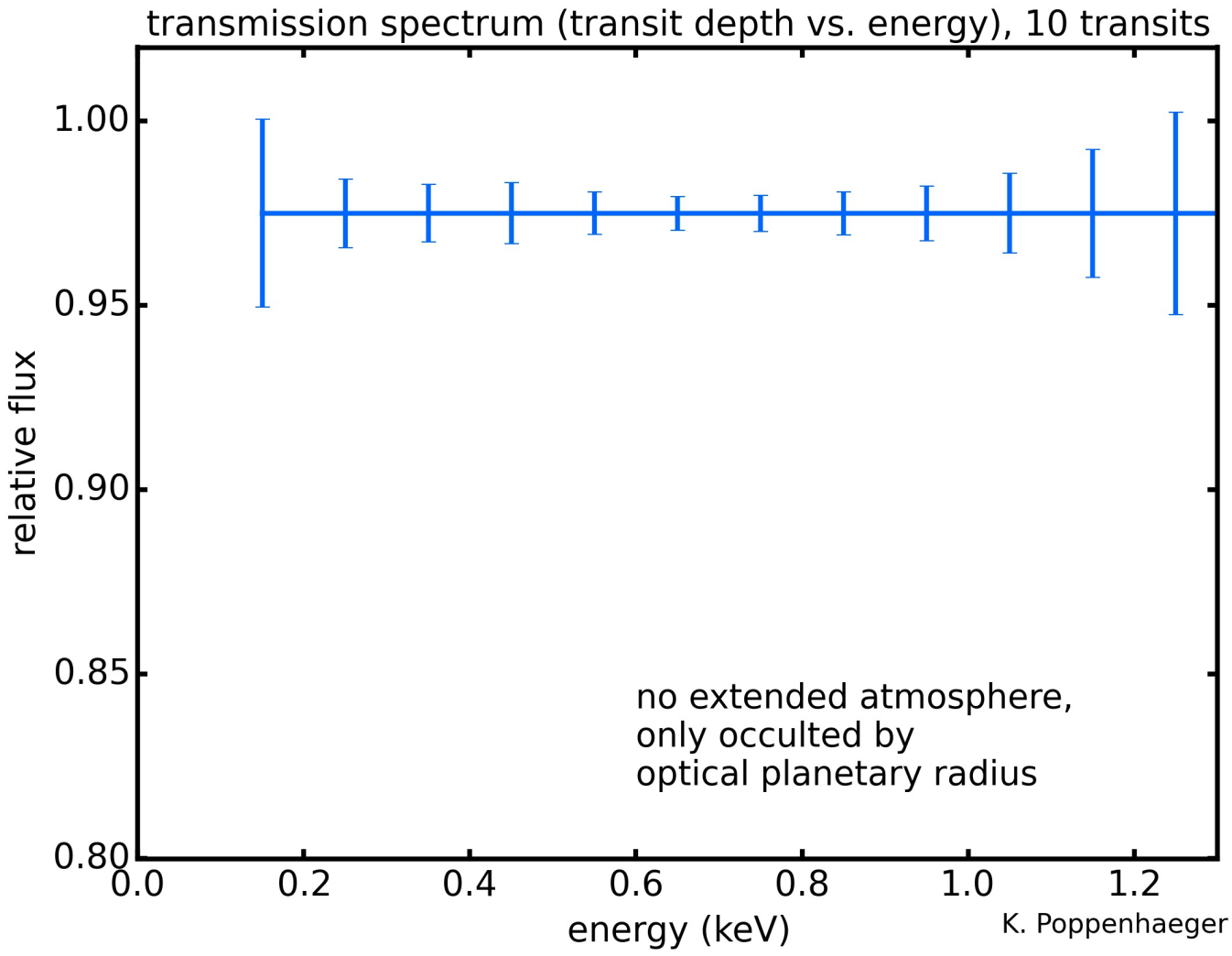
Different altitudes probed with X-rays



X-ray transmission spectrum of exoplanet atmosphere



Hot Jupiter,
10 × 30 ks



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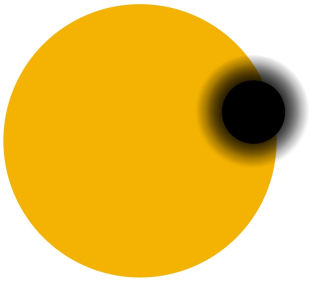

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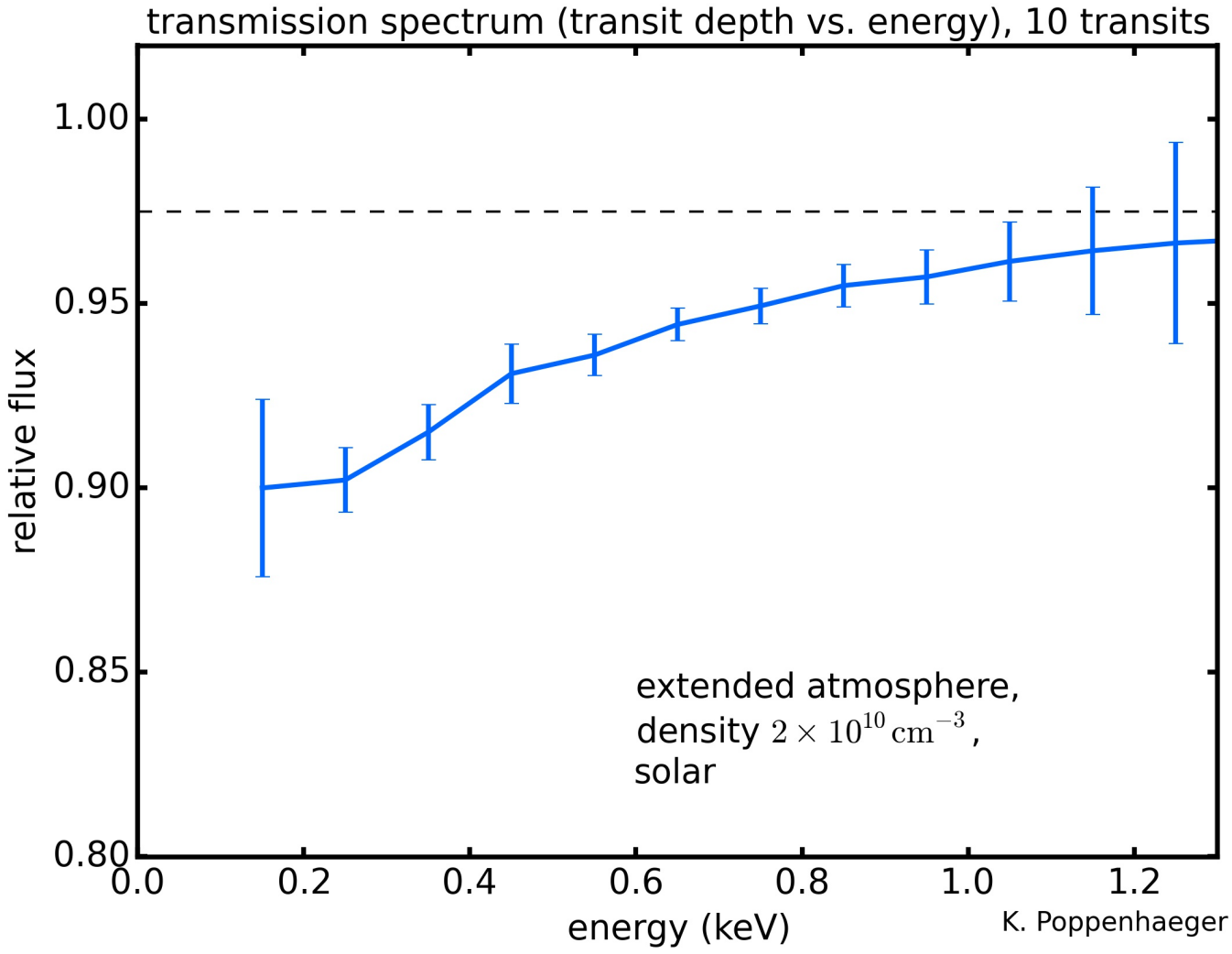

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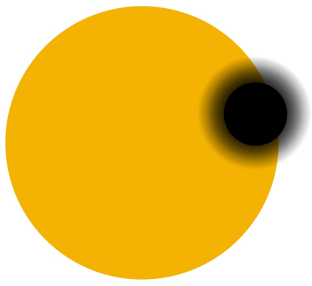

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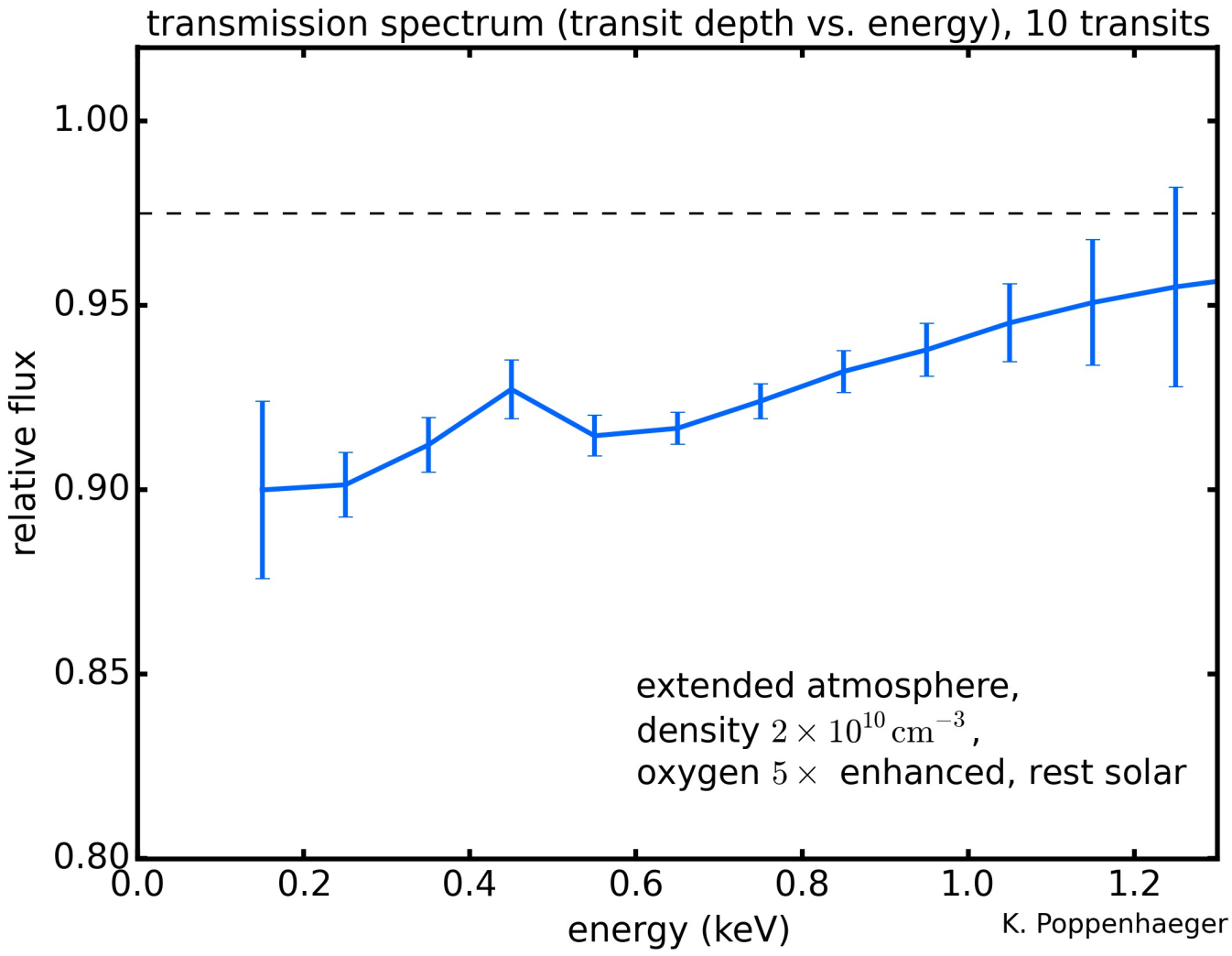

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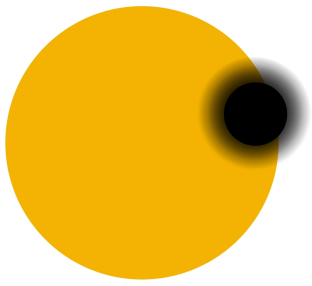

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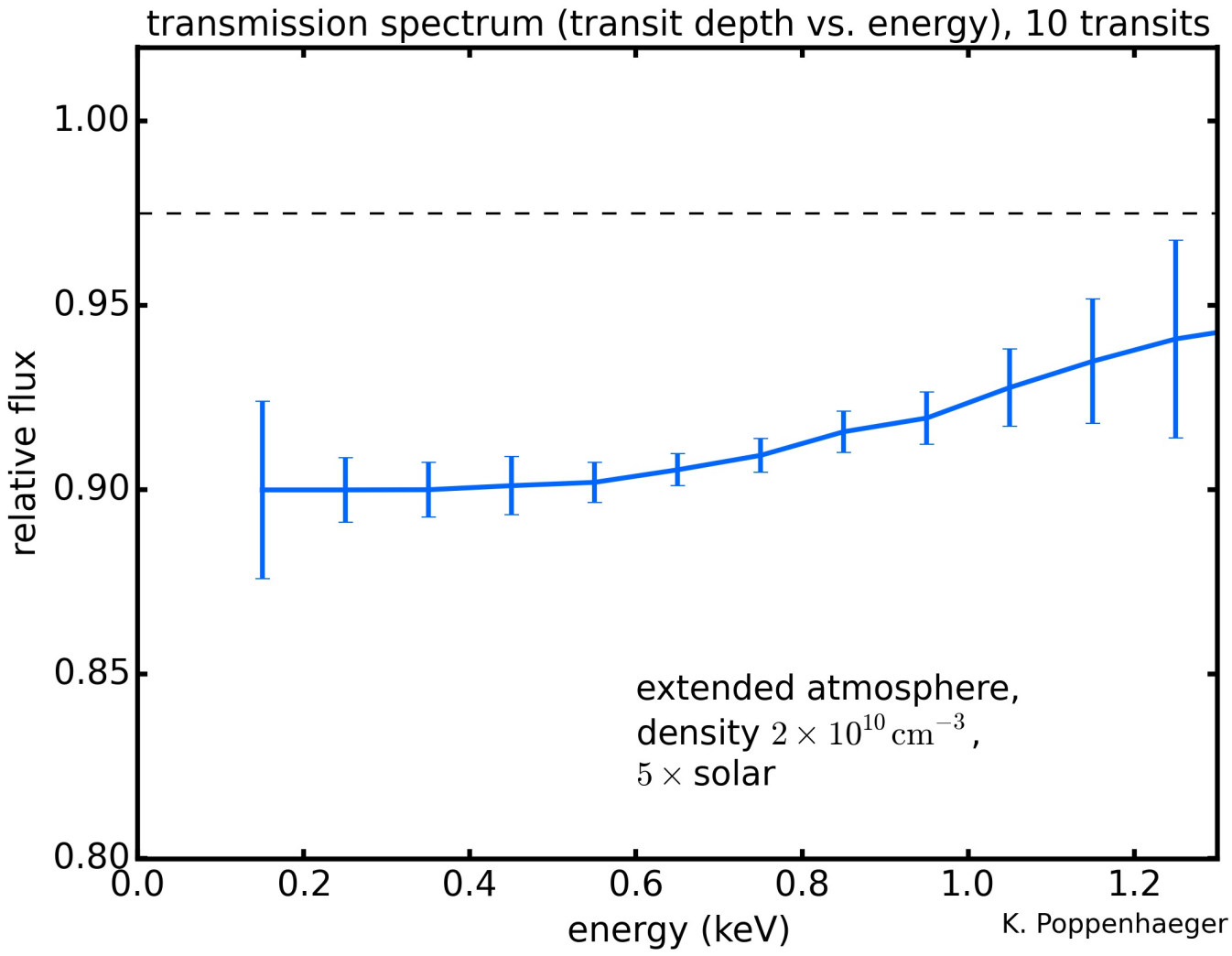
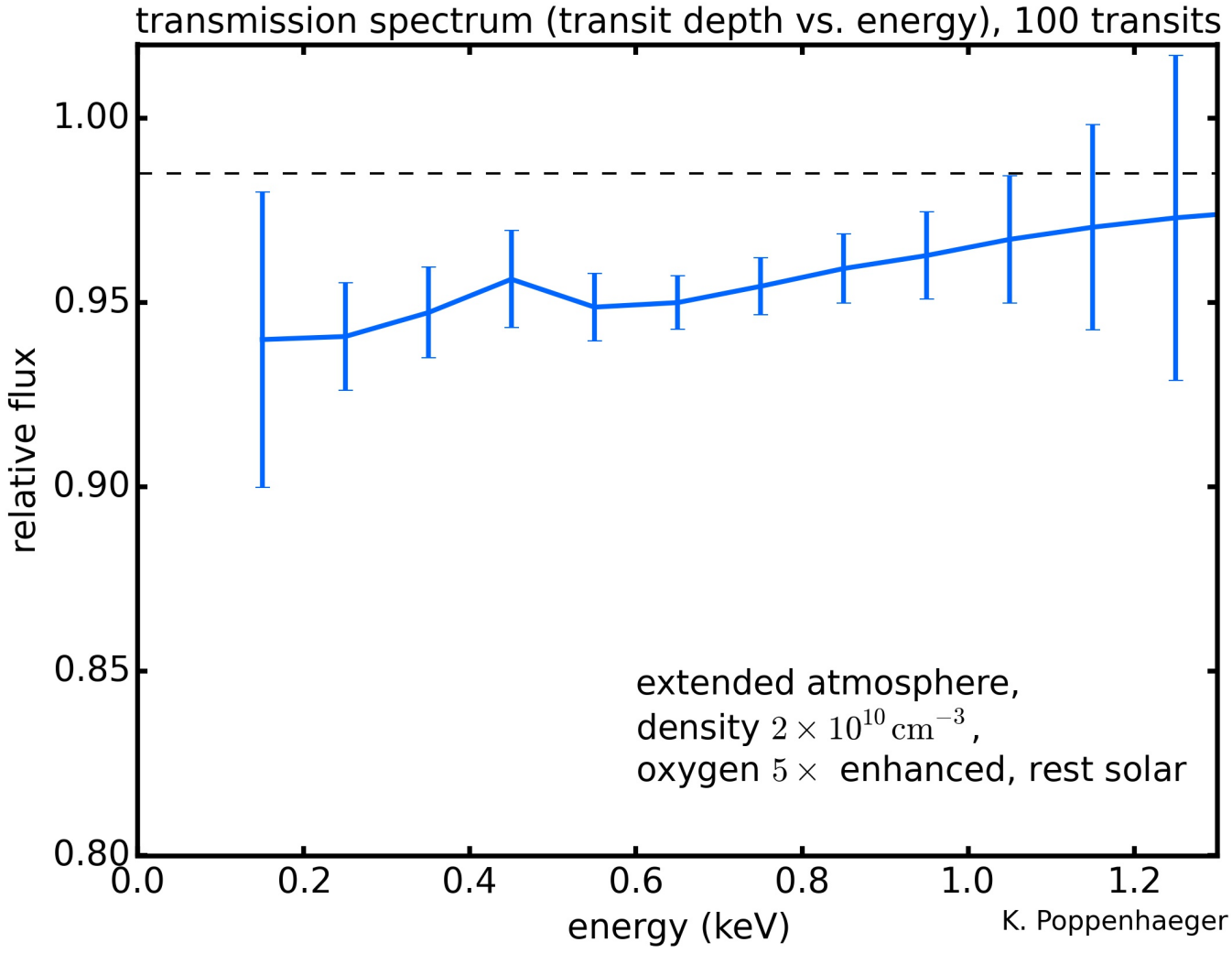


X-ray transmission spectrum of exoplanet atmosphere

Superearth around M dwarf, 100×20 ks



Exoplanets in habitable zones around M dwarfs

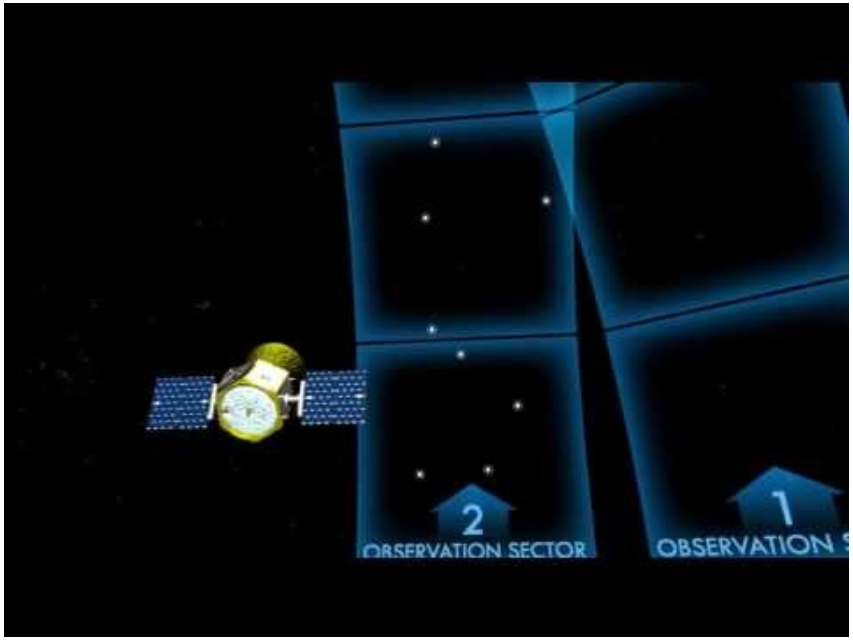


image credit: MIT

TESS all-sky exoplanet search: ca. **60** detections of **Earth-sized planets in habitable zones** expected, mostly around M dwarfs.

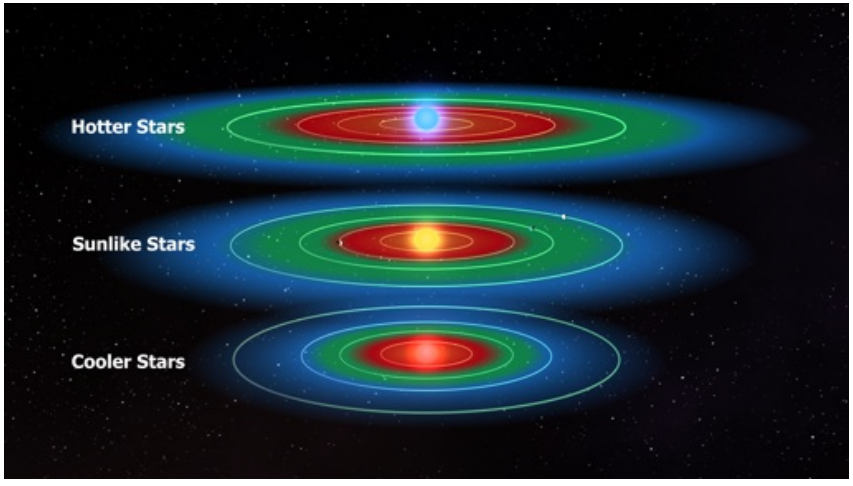


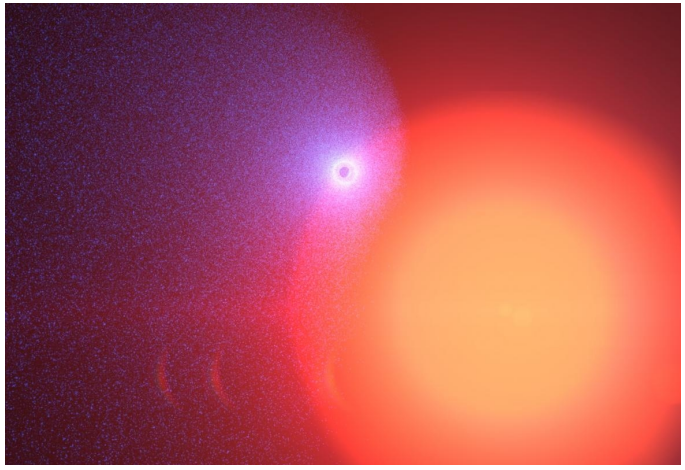
image credit: Kepler Team

Habitable zones close to host star for M dwarfs; low bolometric luminosity, but fairly high X-ray luminosity!

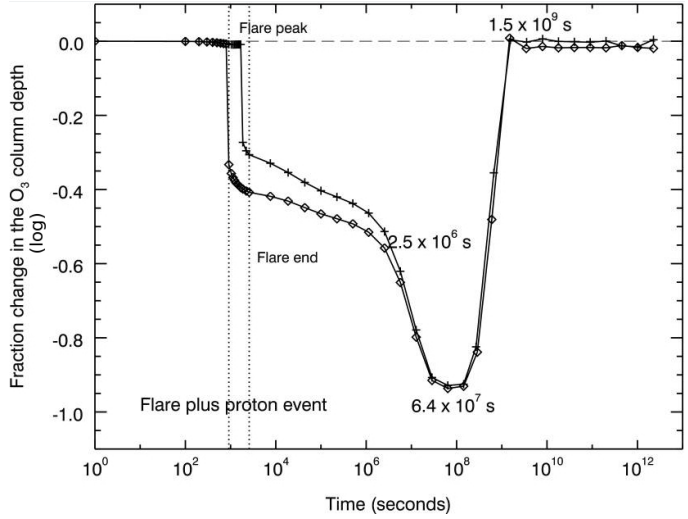
Stellar X-rays & flares: damage to exoplanet atmospheres

- High X-ray/UV irradiation: evaporation of atmosphere

- Large flares: 90% ozone depletion for several years

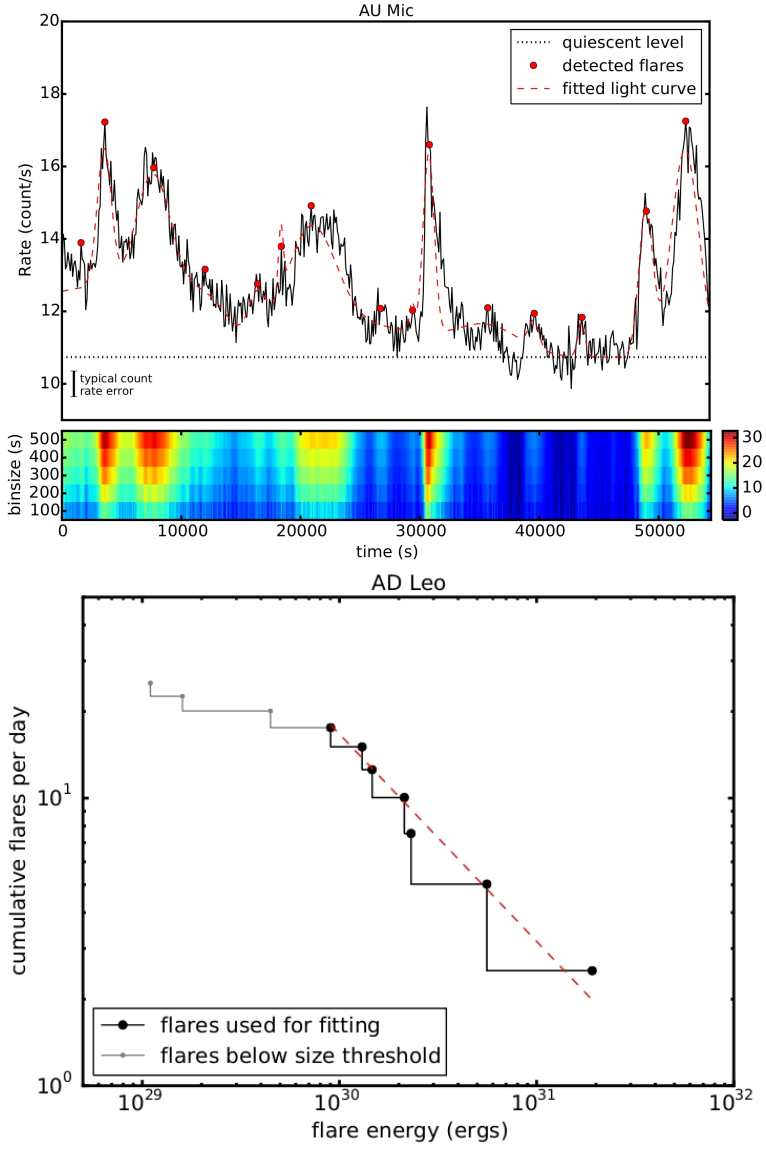


Kulow et al. (2014); illustration: Ehrenreich & Bourrier



Segura et al. (2010)

Big X-ray flares: common among low-mass stars

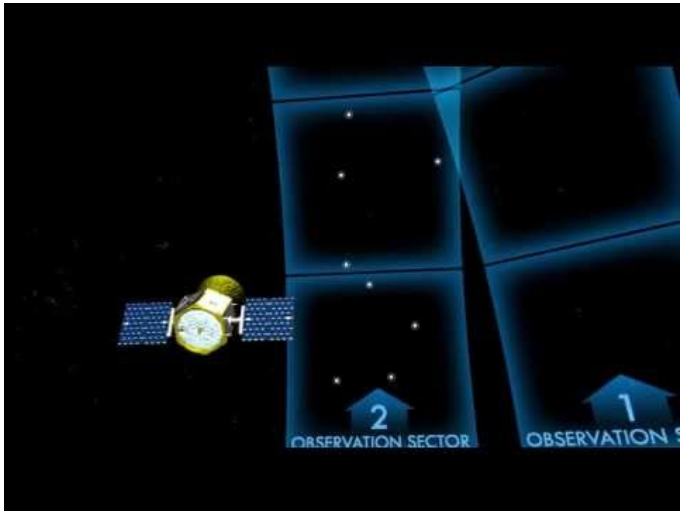


Feng, Poppenhaeger et al. to be submitted

flares big enough to cause ozone depletion for $\sim$ 5 years in habitable zone

every $\sim$ 100 days!

Exoplanets in habitable zones around M dwarfs



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typical distance: $\lesssim$ 80 pc

baseline luminosity: $L_X \gtrsim 3 \times 10^{26}$ erg/s

ca. 30% of host stars have stellar companions $\rightarrow$ spatial resolution

Chandra: ca. 200 ks per target, 12 Msec for all

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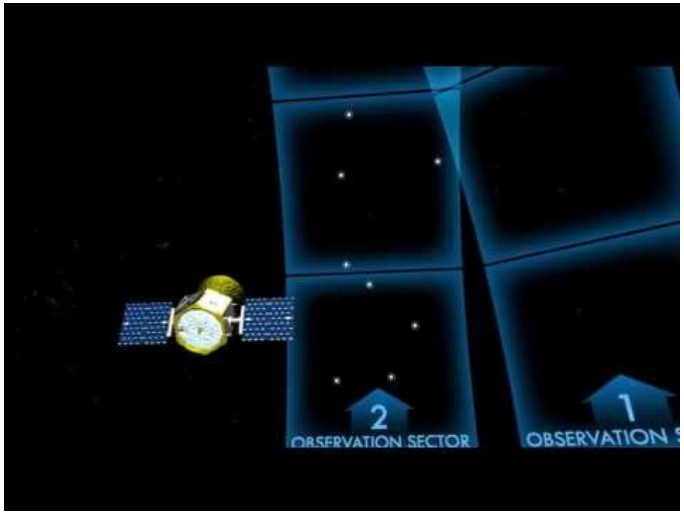

image credit: MIT

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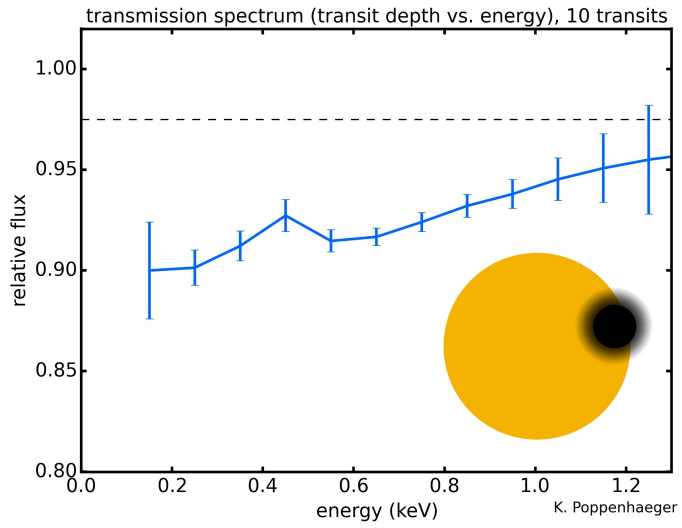
Detectable in 2 ks with X-ray Surveyor

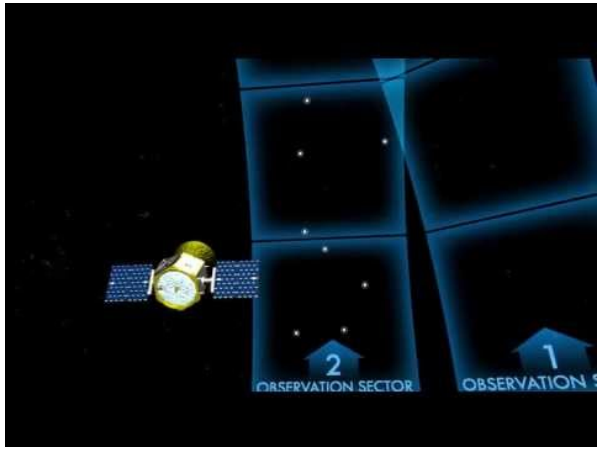
X-ray detect host star of every Earth-like habitable zone planet in $\sim$120 ks!

Big questions - X-ray Surveyor

- How diverse are exoplanet atmospheres?



- Which exoplanets have the potential to host life?



... Which (exo)planets do host life?