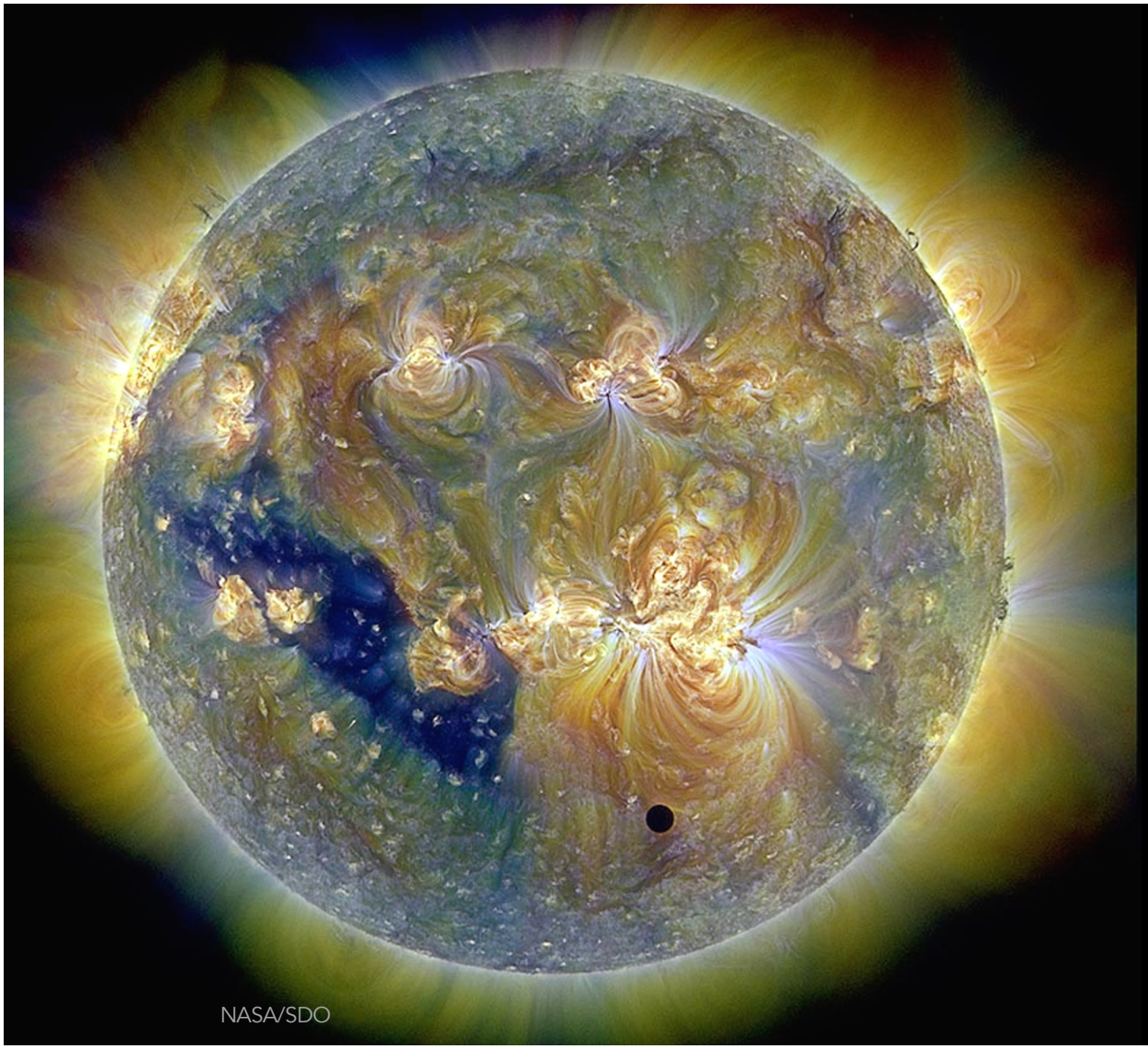
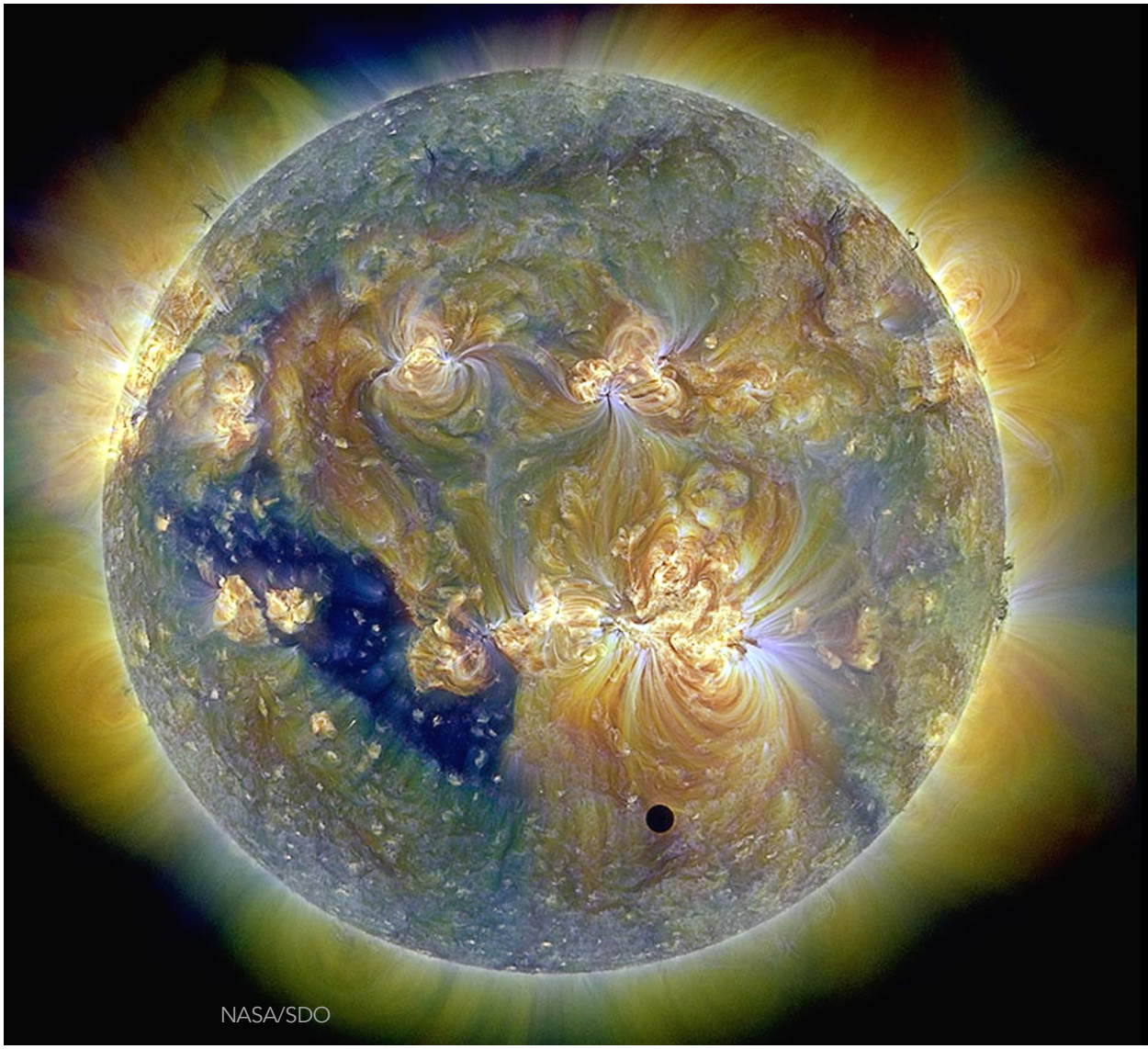


X-ray and UV photons both *impact and probe* exoplanets

Evgenya Shkolnik
Arizona State University
(Visiting Center for Astrophysics)



X-ray and UV photons both *impact and probe* exoplanets

Impact: heat and chemically modify a planet's atmosphere.

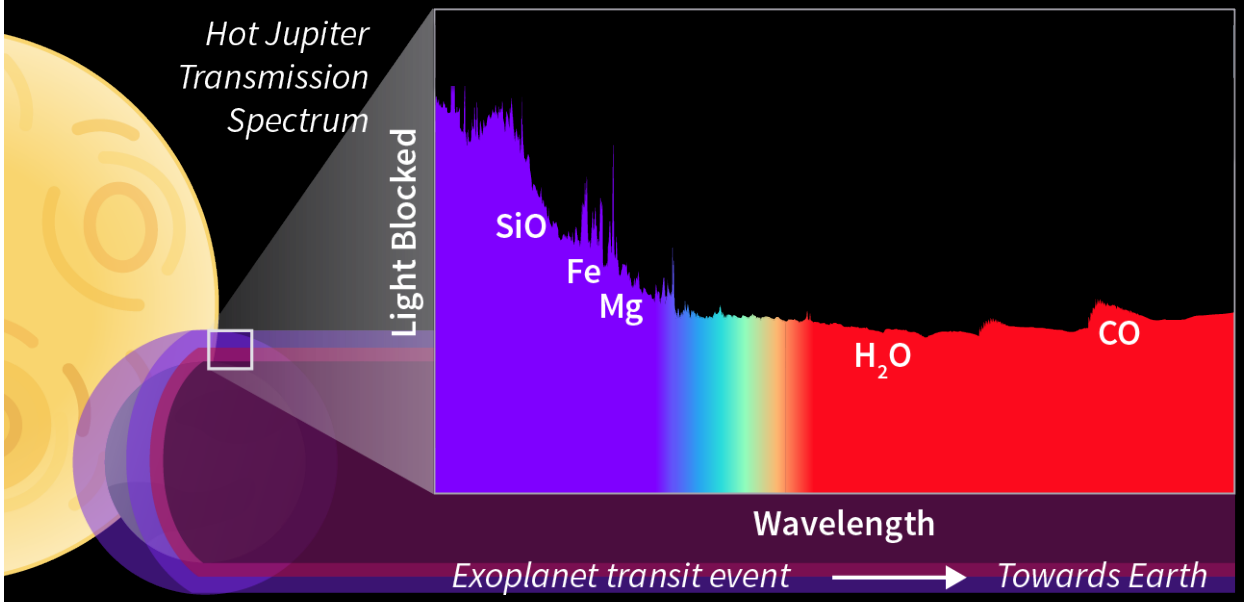
Probe: uniquely study regions high up in the planet's atmosphere.

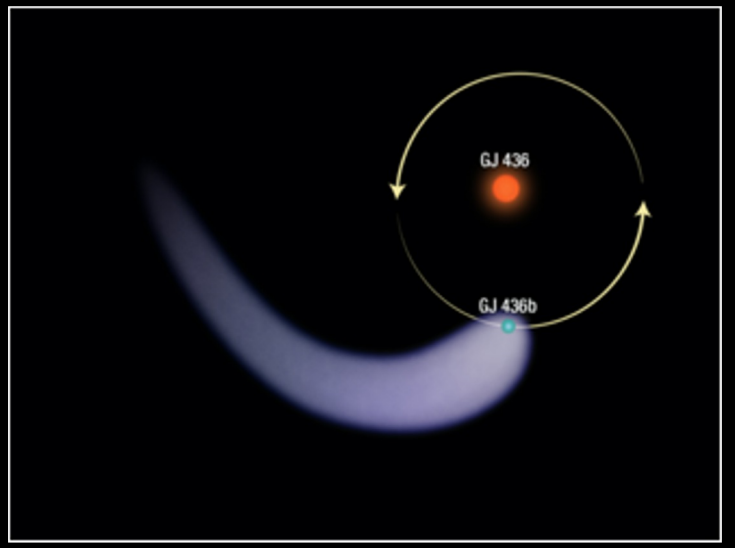
Evgenya Shkolnik

Arizona State University

(Visiting Center for Astrophysics)

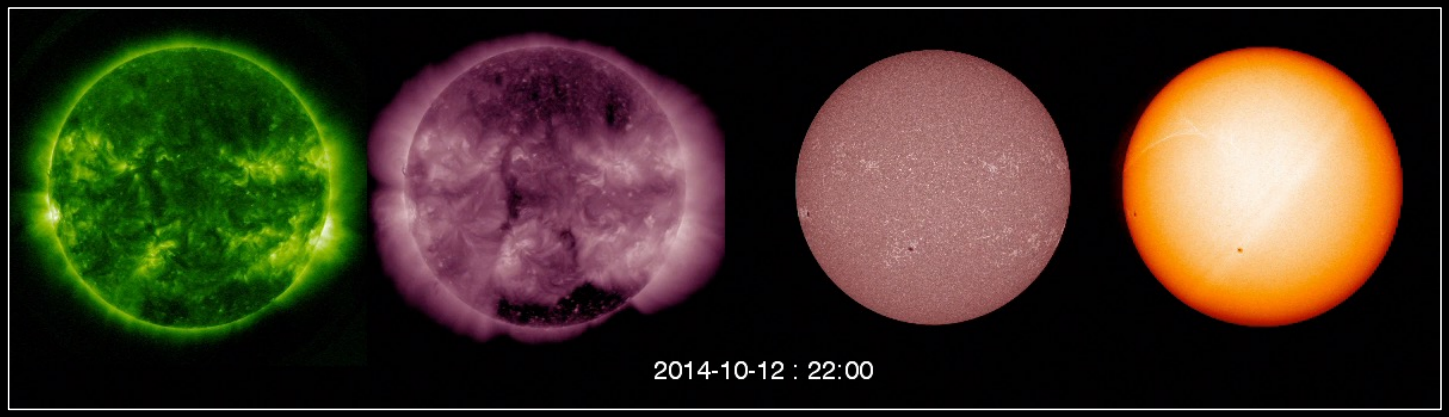
Transmission spectroscopy of large and small exoplanets is a leading way to study their atmospheric composition and dynamics.





Credit: D. Sing / JPL

The Sun's High Energy Radiation

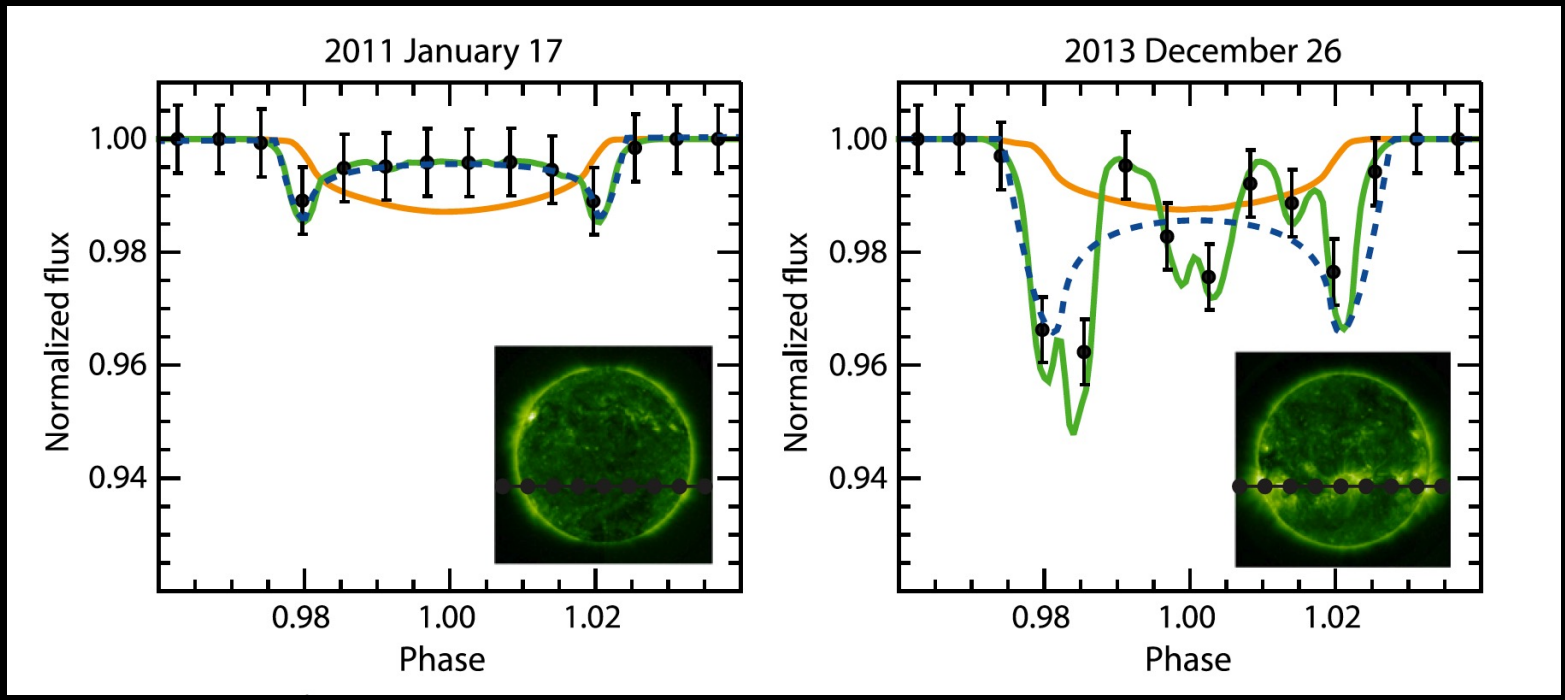


Credit: NASA/SDO/J. Llama/E. Shkolnik

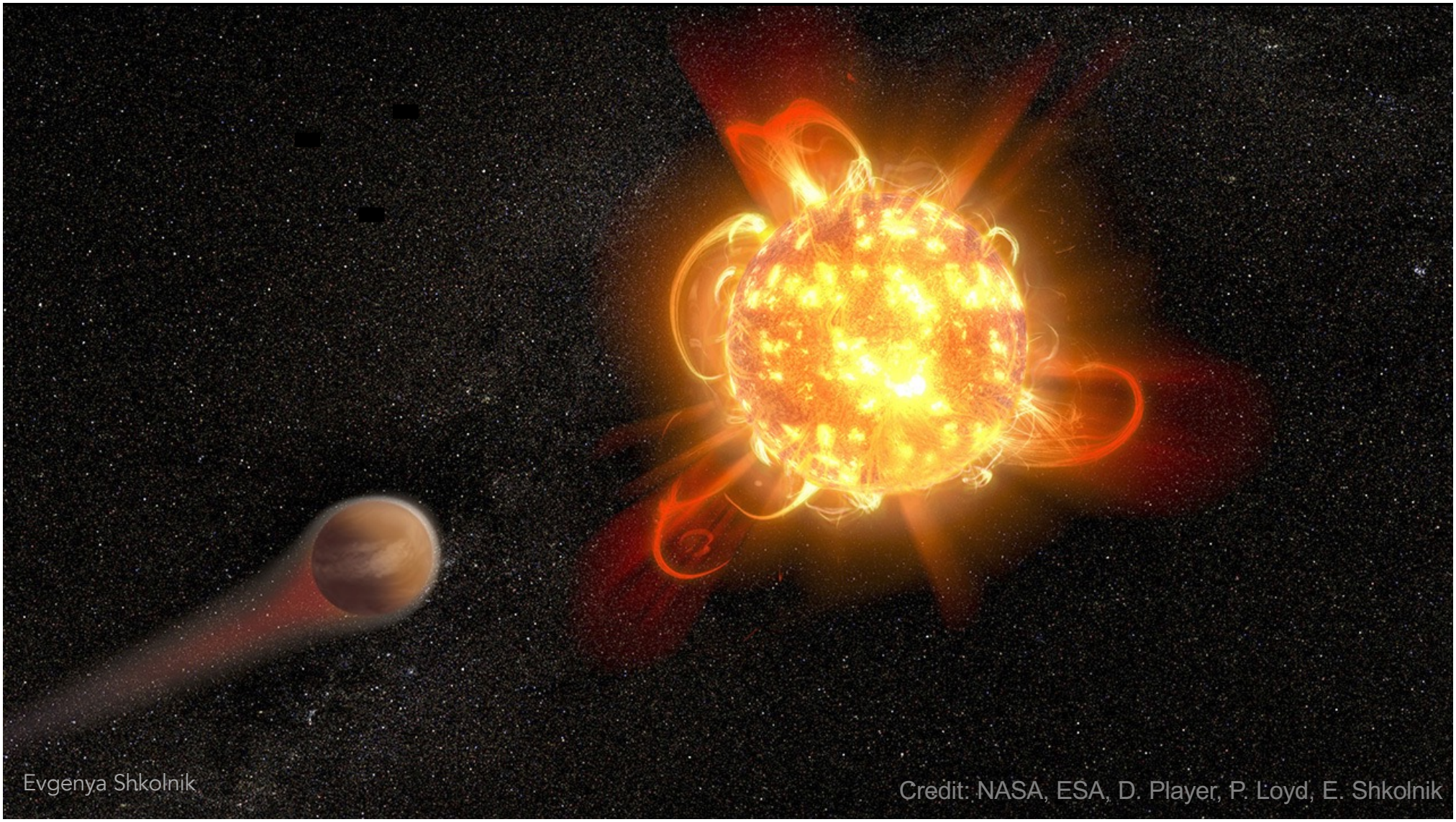
Evgenya Shkolnik

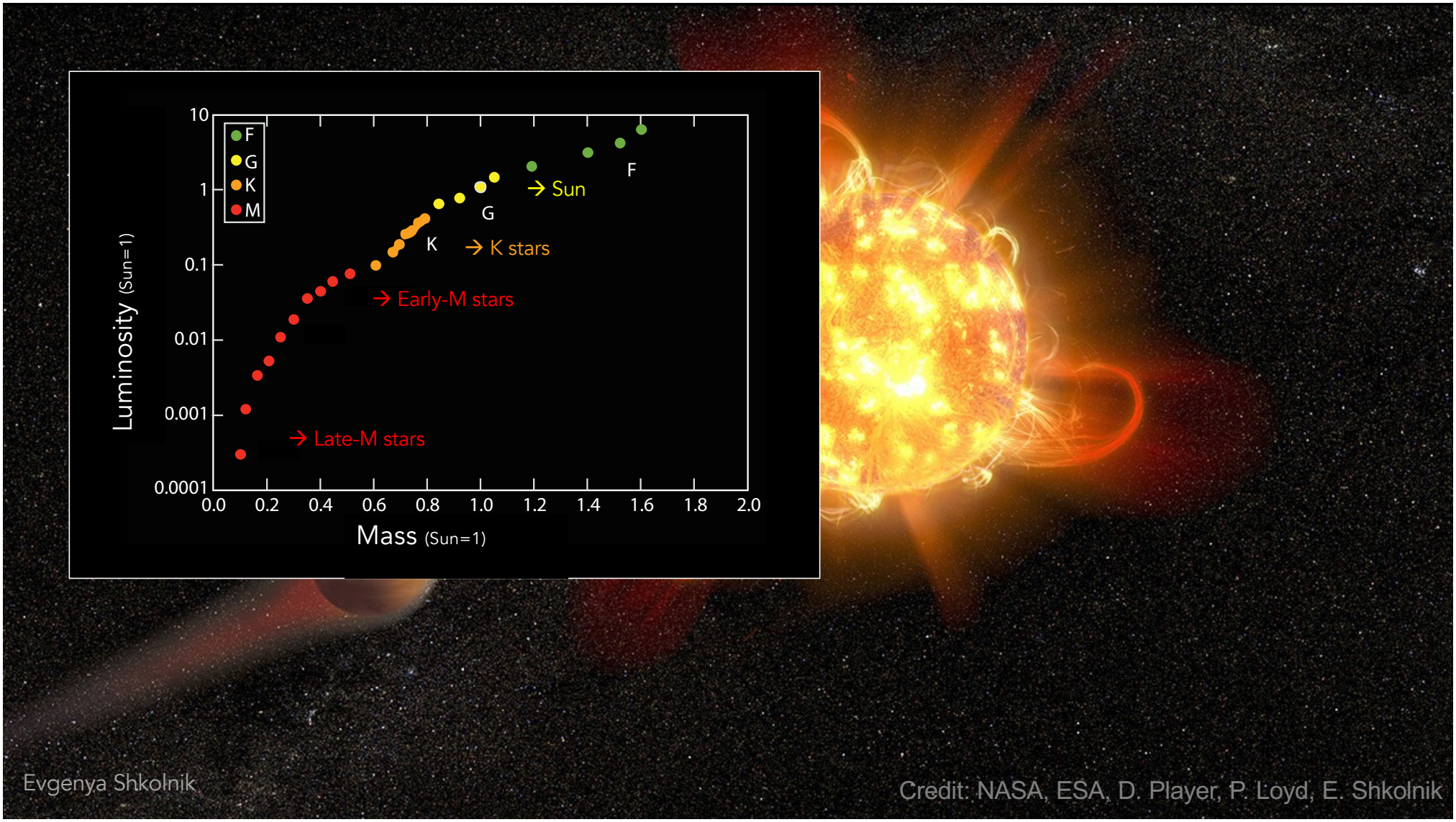
Transits at short-wavelengths are more susceptible to stellar inhomogeneities and variability.

Simulated hot-Jupiter transits across the Sun at 94 Å using SDO data



Llama & Shkolnik 2015; see Llama & Shkolnik 2016 for Ly-α transits


Evgenya Shkolnik
Credit: NASA, ESA, D. Player, P. Loyd, E. Shkolnik


F
G
K
M
10
1
0.1
0.01
0.001
0.0001
Luminosity (Sun=1)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Mass (Sun=1)
→ Sun
→ K stars
→ Early-M stars
→ Late-M stars
F
G
K
Evgenya Shkolnik
Credit: NASA, ESA, D. Player, P. Loyd, E. Shkolnik

Spectrum of a low-mass star

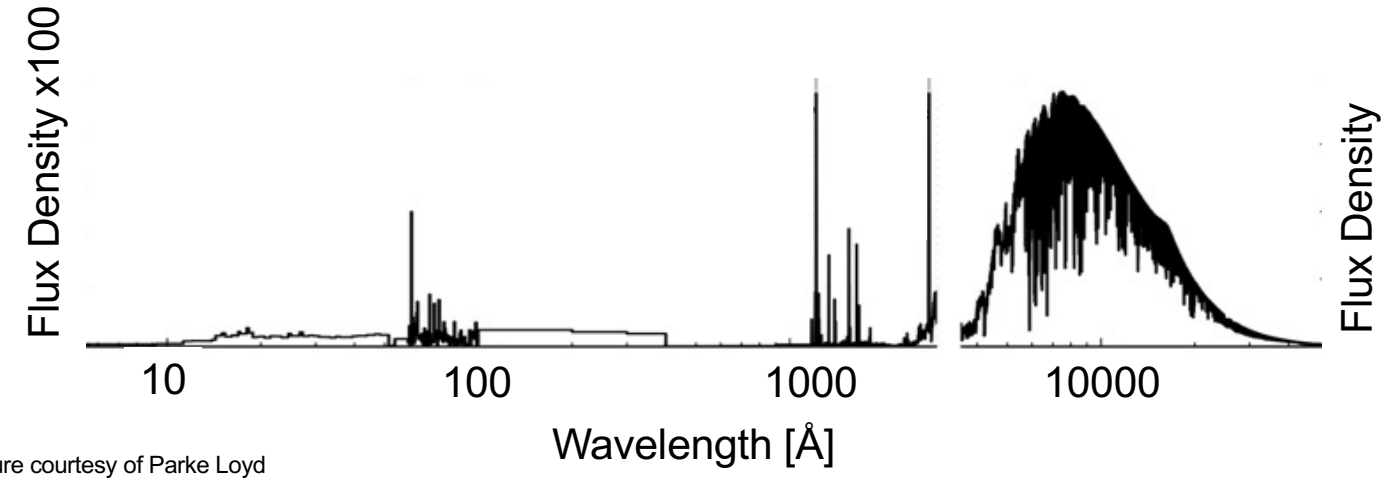
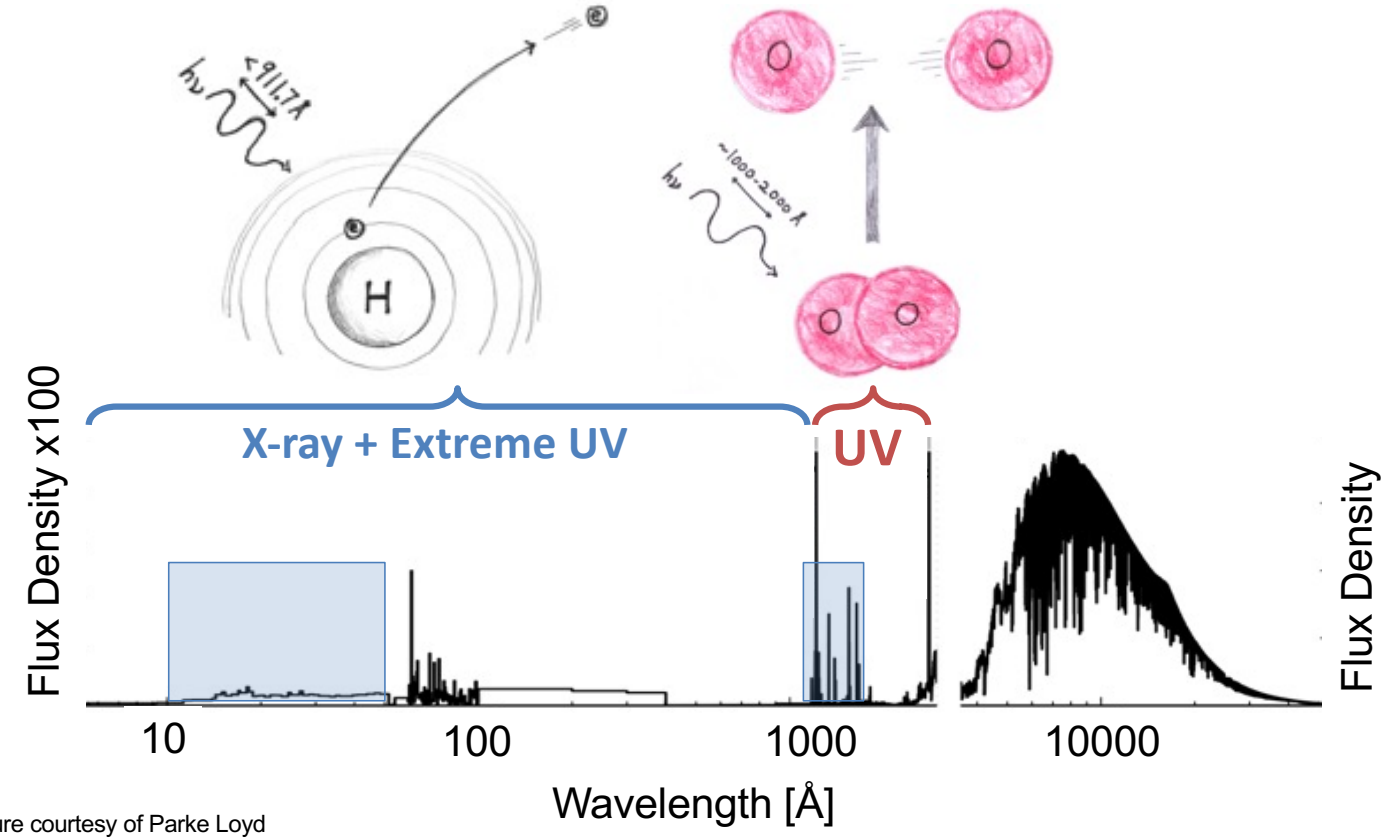


Figure courtesy of Parke Loyd

The UV and X-ray drive photochemistry and thermal escape

Spectrum of a low-mass star

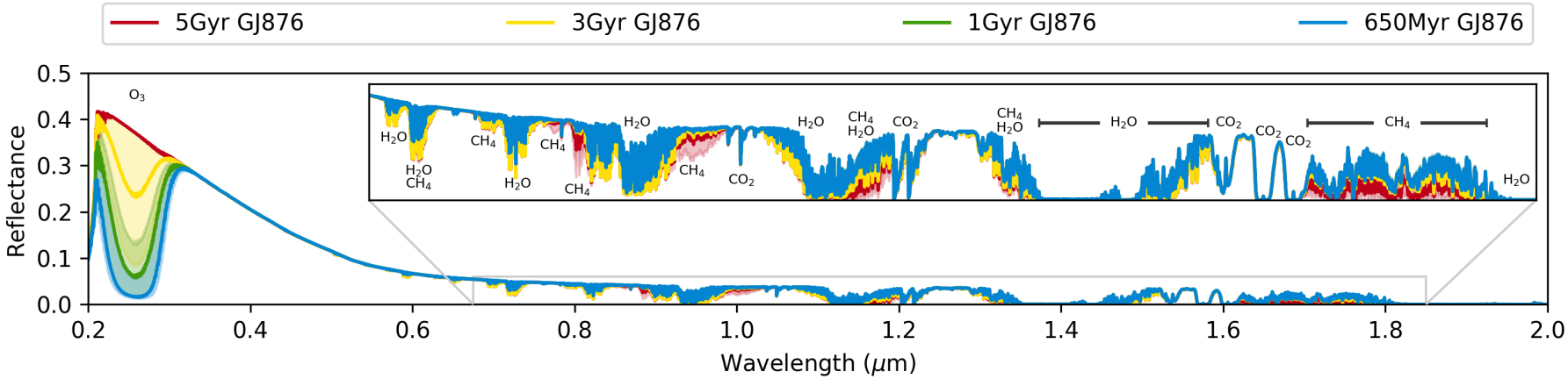


ARCUS coverage →

Figure courtesy of Parke Loyd

The UV and X-ray drive photochemistry and thermal escape

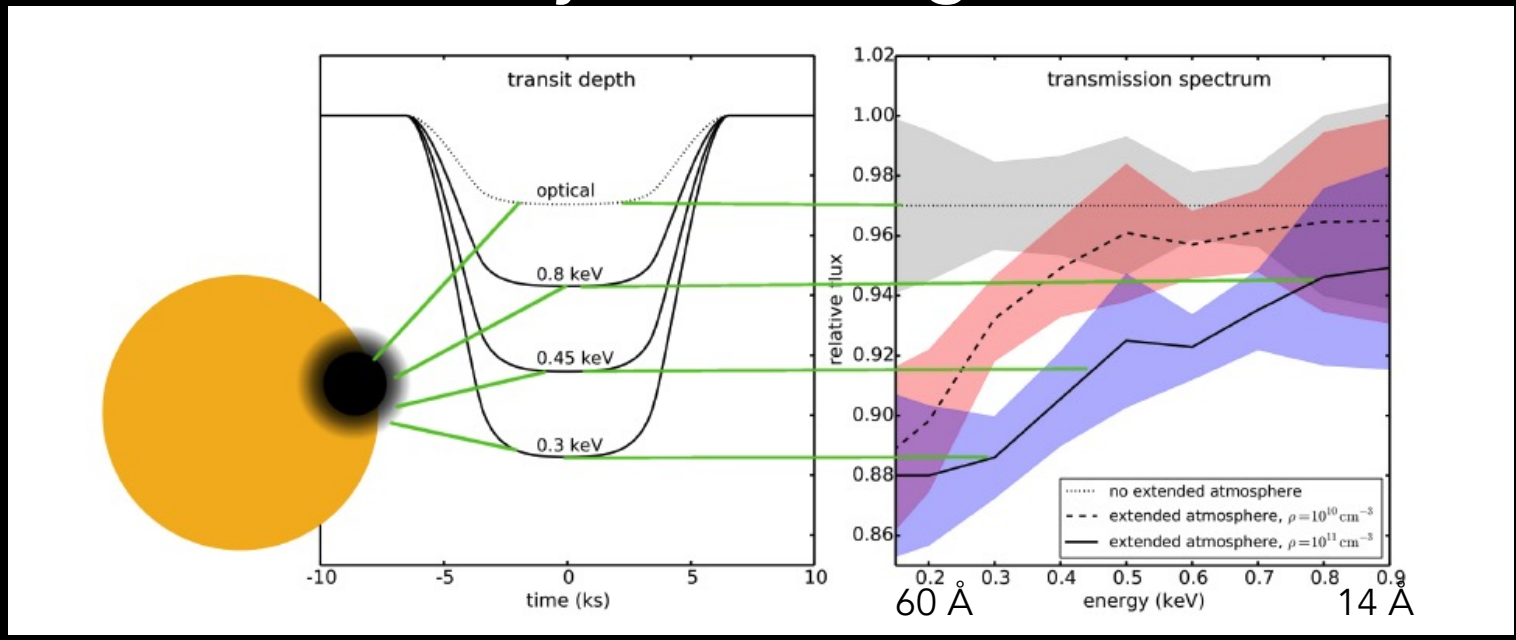
Photochemical impacts on Earth-like atmospheres



In collaboration with the Virtual Planet Laboratory, we apply new UV observations to improve planetary atmospheric modeling suite to assess the effects of stellar UV emission and variability and the robustness of abiotic biosignature production.

Davis et al., submitted.

Probing the upper-most atmospheres of planets with transits at X-ray wavelengths



Schematic of transit light curves observed at various energies due to different absorption cross-sections.

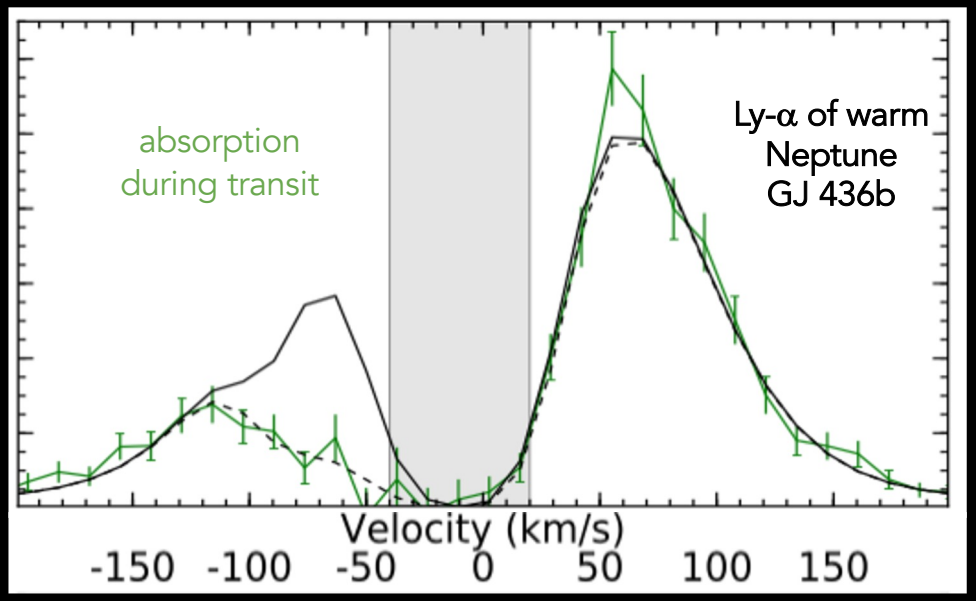
Simulation of detection of the 0.5 keV oxygen absorption edge using transits of a super-earth around an M dwarf.

Evgenya Shkolnik

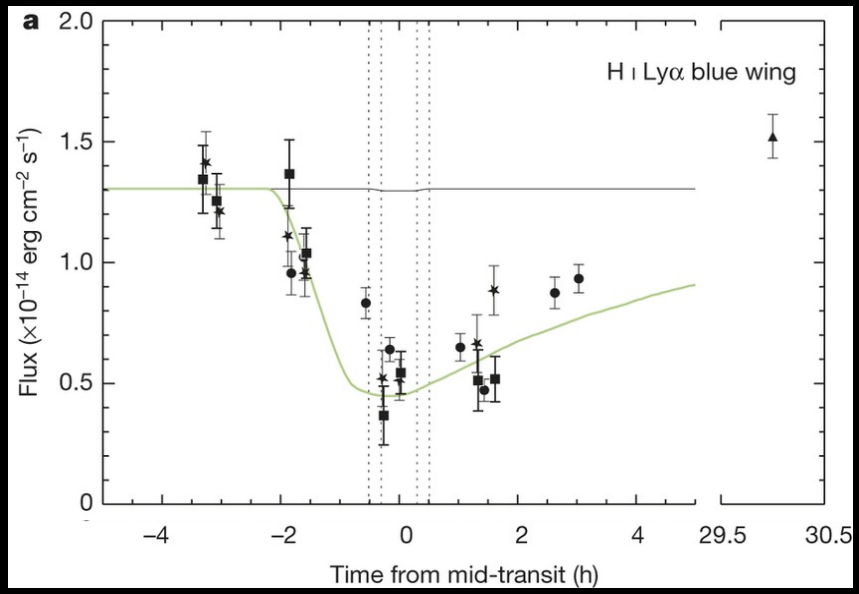
Credit: K. Poppenhaeger; Wolk et al. 2019

Planet transits at FUV wavelengths

Directly measuring exospheric hydrogren escape from the atmosphere of warm Neptune, GJ 436n with Ly-α transits (at 1216 Å)



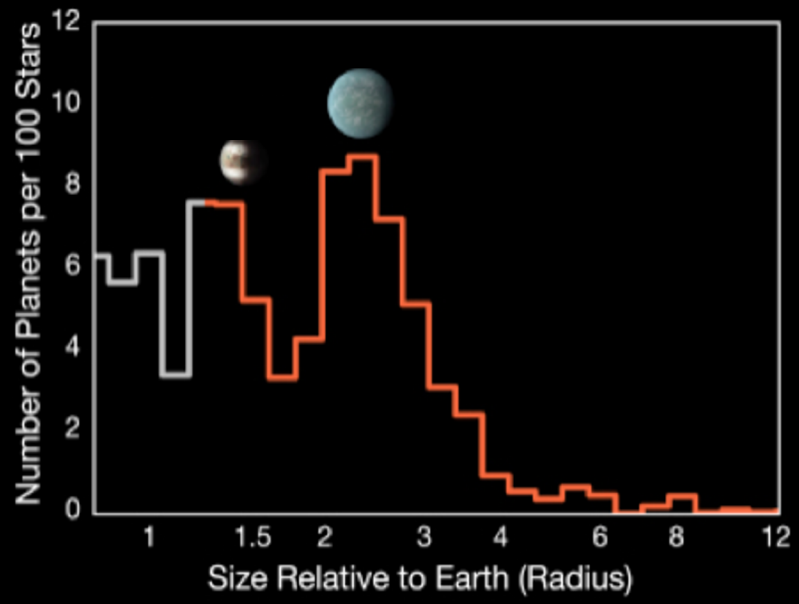
Bourrier et al. 2016



Ehrenreich et al. 2015

Small planets come in two sizes.

Do planets form or evolve into these two populations?

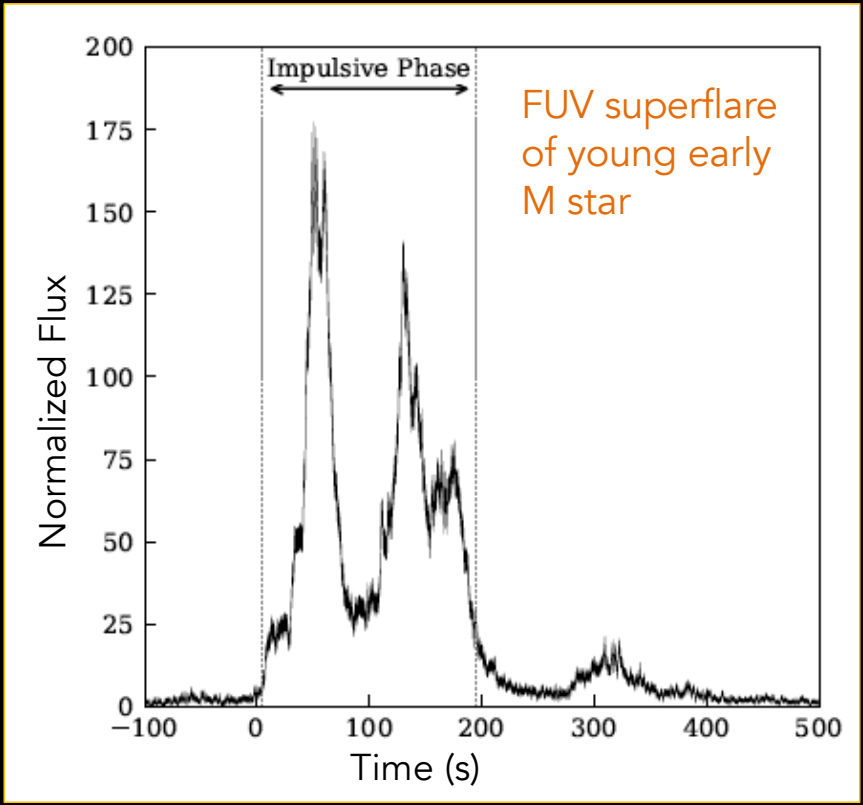


The Kepler mission showed that close-in, small exoplanets (super-earths) come in two sizes, separated by a radius gap at ≈2 R_{earth}.

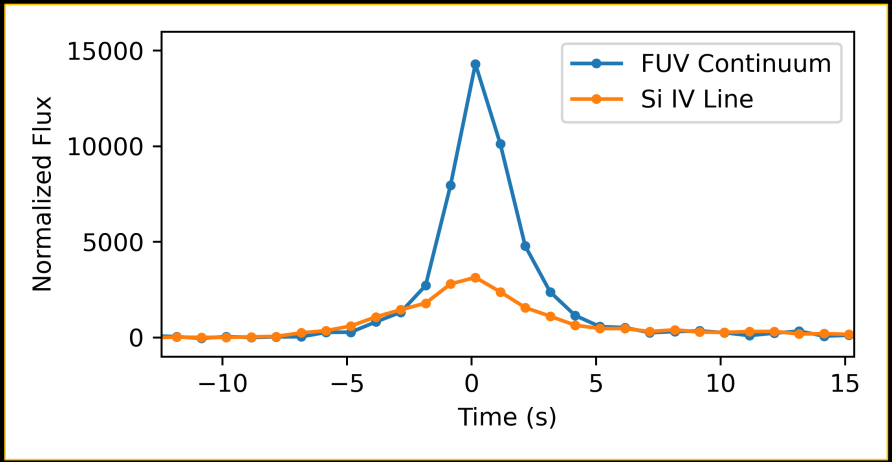
Owen & Wu, 2017
Fulton et al. 2017, 2018

Evgenya Shkolnik

Daily flares on M stars

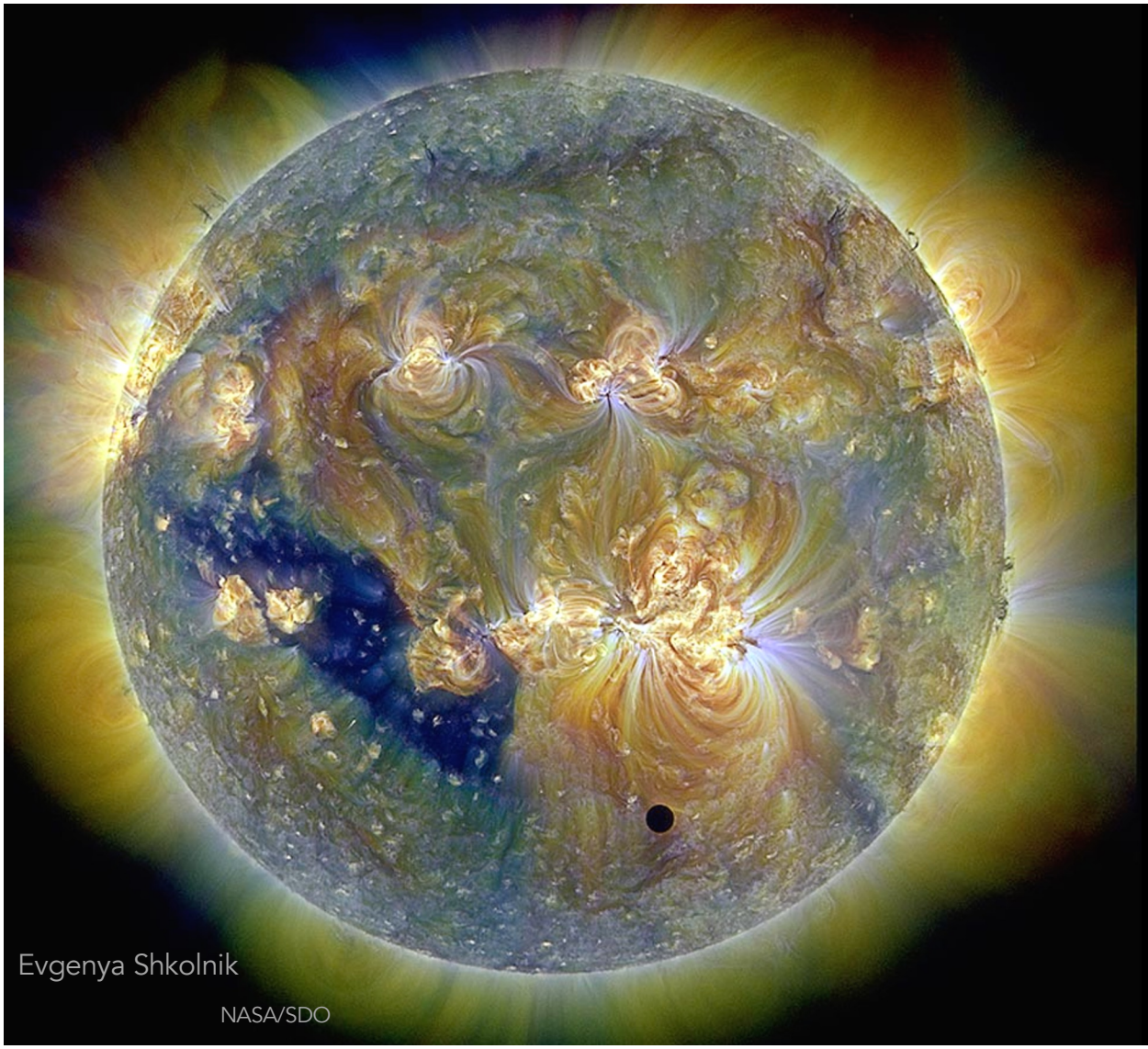


HAZMAT IV; Loyd et al., 2018



Proxima Cen's daily flare = 14,000x increase in FUV continuum while optical flare only 10x.
(MacGregor et al. 2021)

See also Jackman et al. 2022



Evgenya Shkolnik

NASA/SDO

X-ray and UV photons both *impact and probe* exoplanets

- Planet atmospheric escape
- Planet photochemistry
- Stellar flares

- Planet upper-atmospheric composition
- Stellar upper-atmospheric dynamics
- Stellar particles + impact on planet
- Star-planet magnetic interactions
- and more…