Planetary Habitability Under the Light of a Rapidly Changing Star

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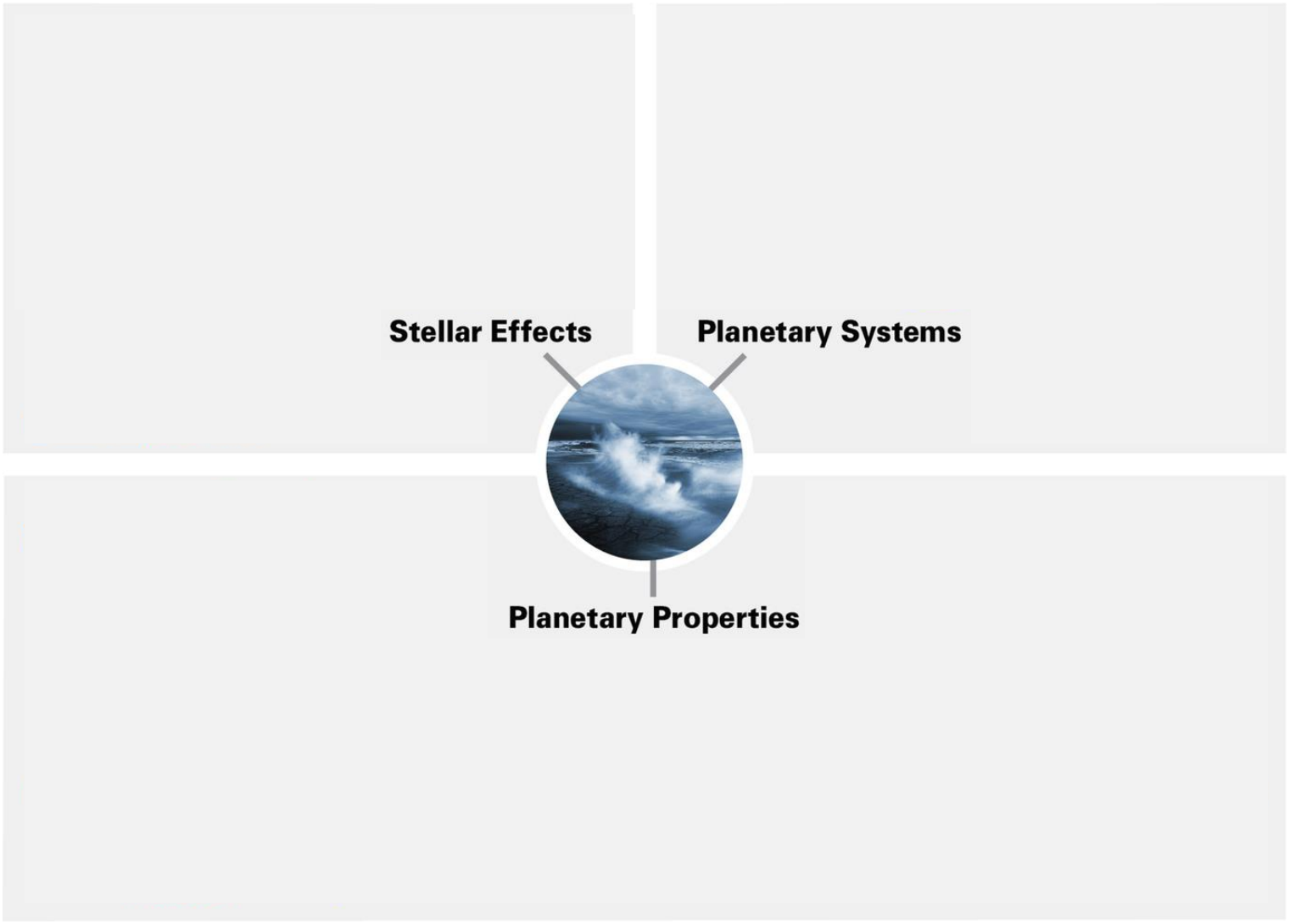
ExSoCal 2025

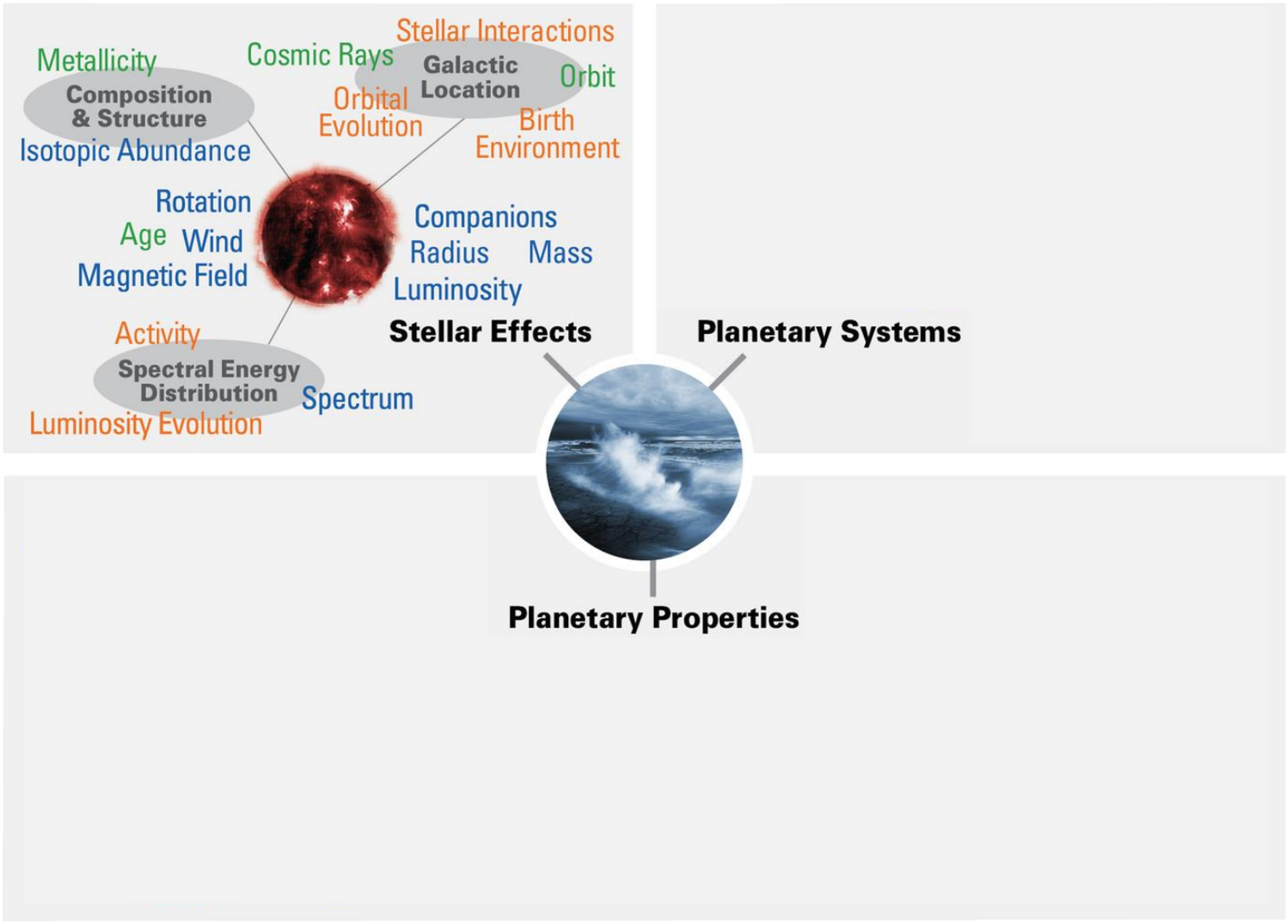
December 15, 2025

Planetary Habitability



Meadows & Barnes (2018)

Planetary Habitability



Meadows & Barnes (2018)

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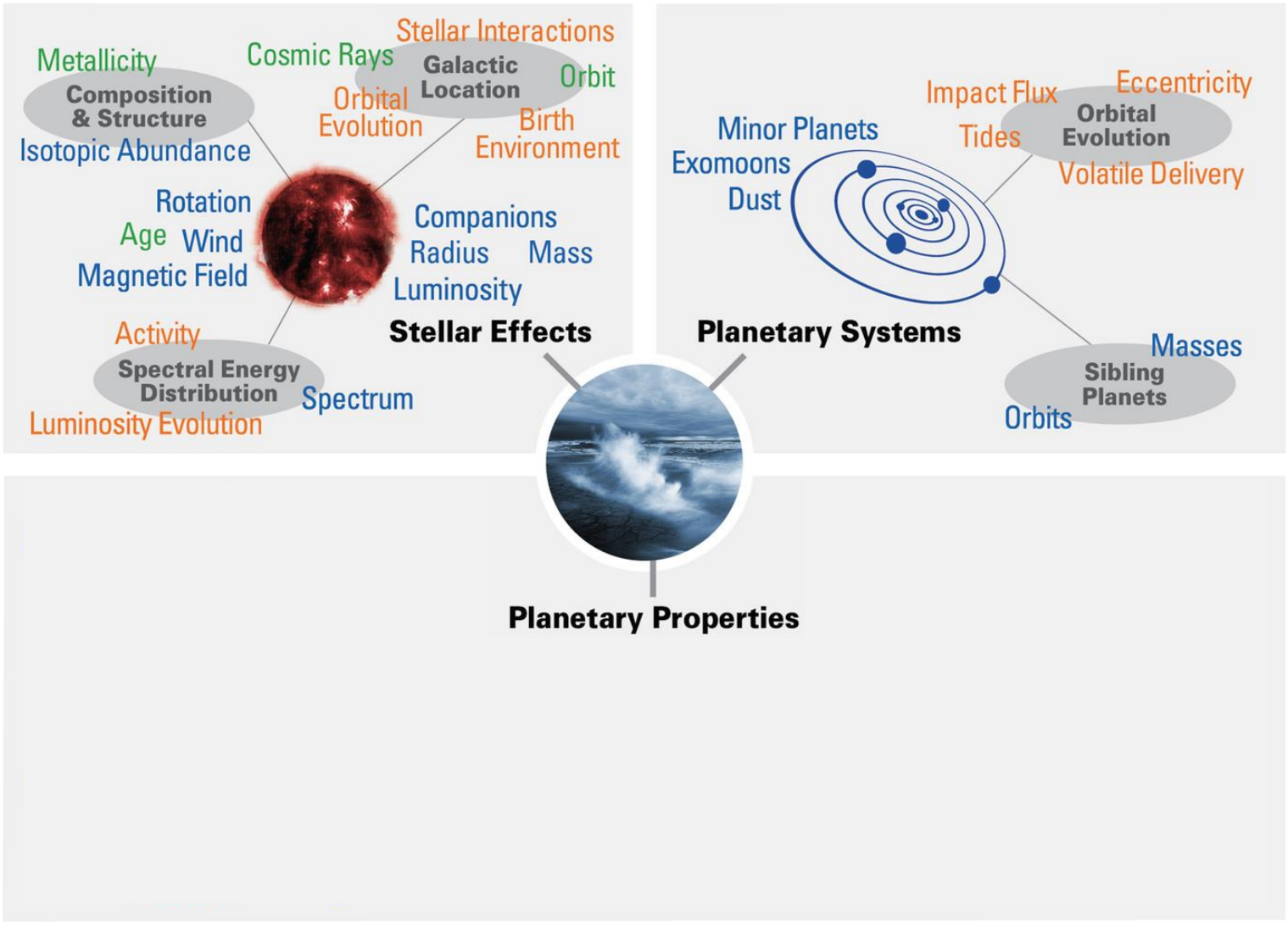

Meadows & Barnes (2018)

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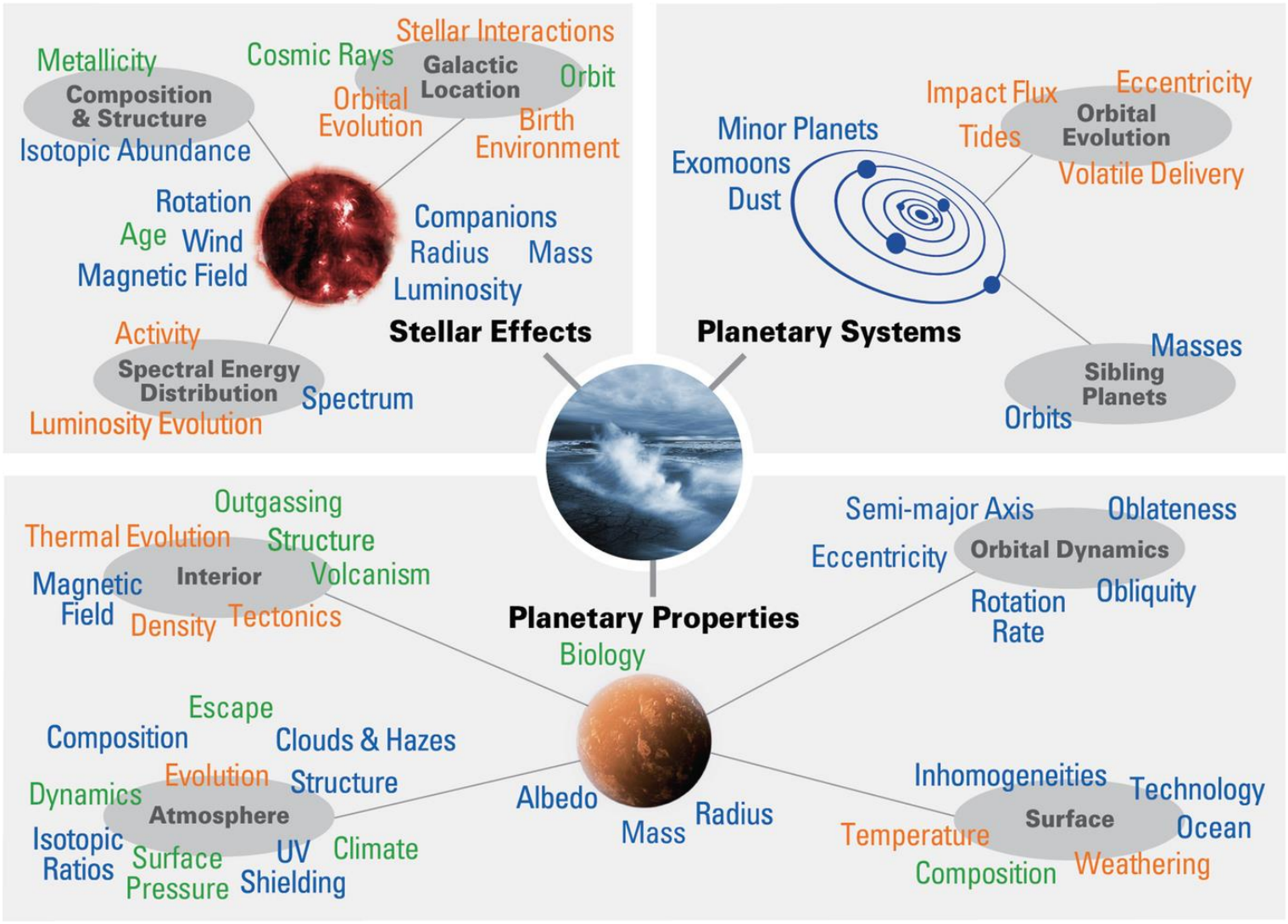
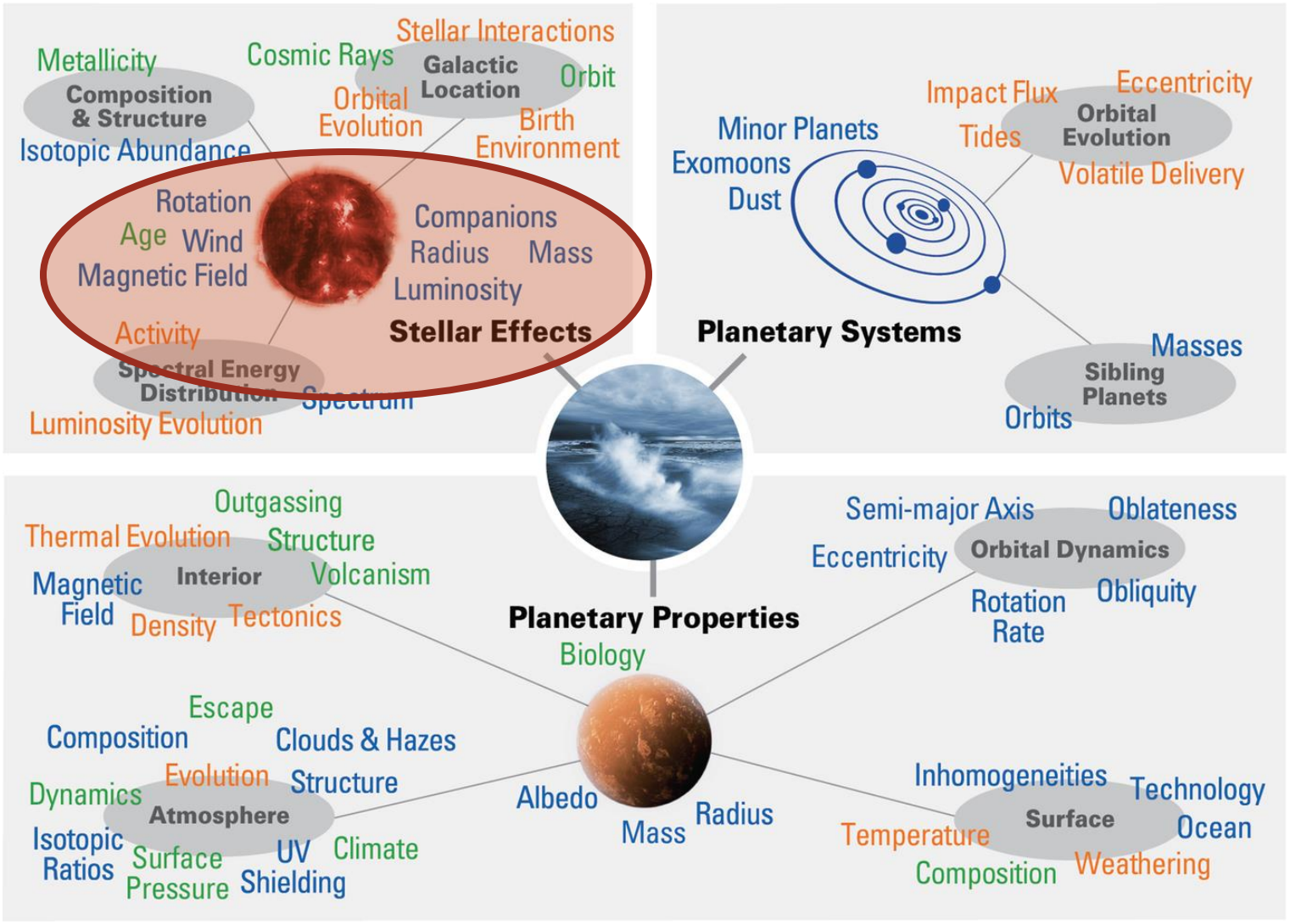


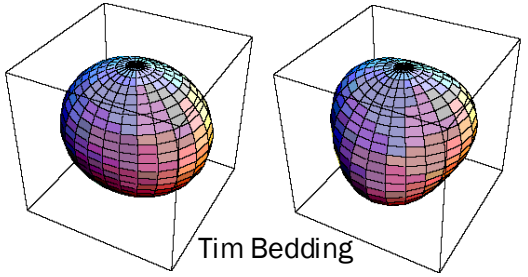
Meadows & Barnes (2018)

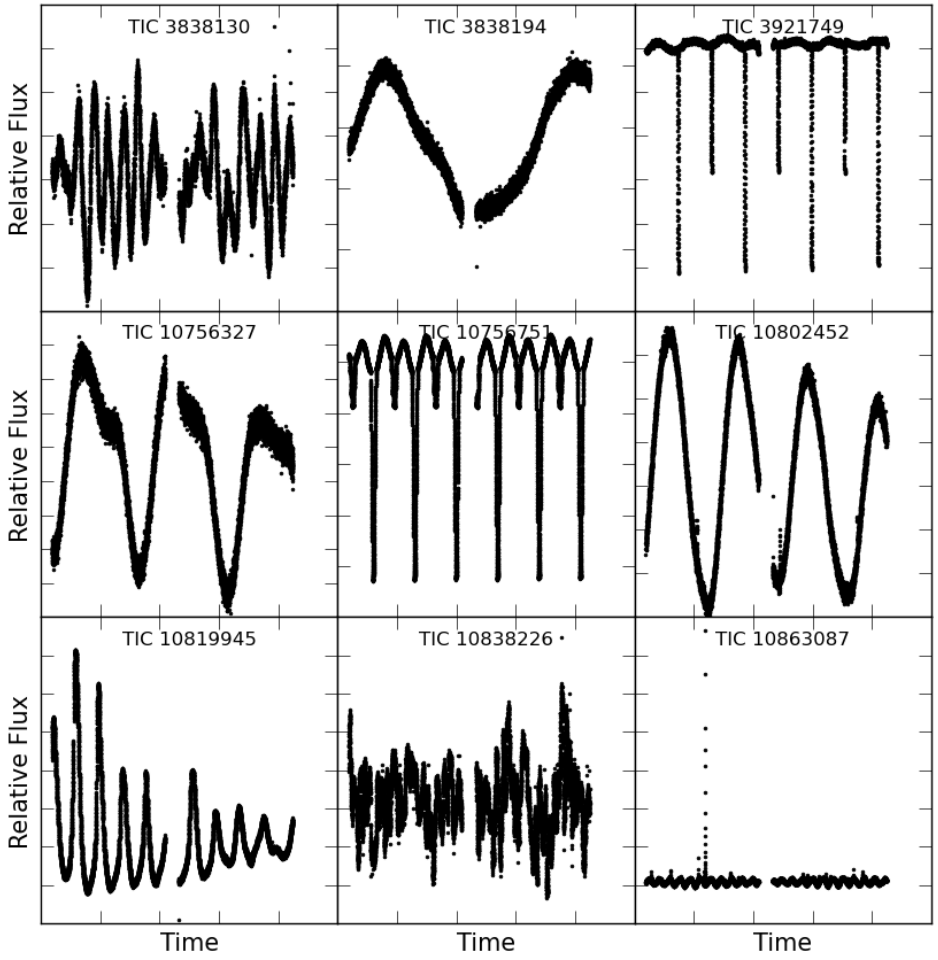
“Know thy Star, Know thy Planet”

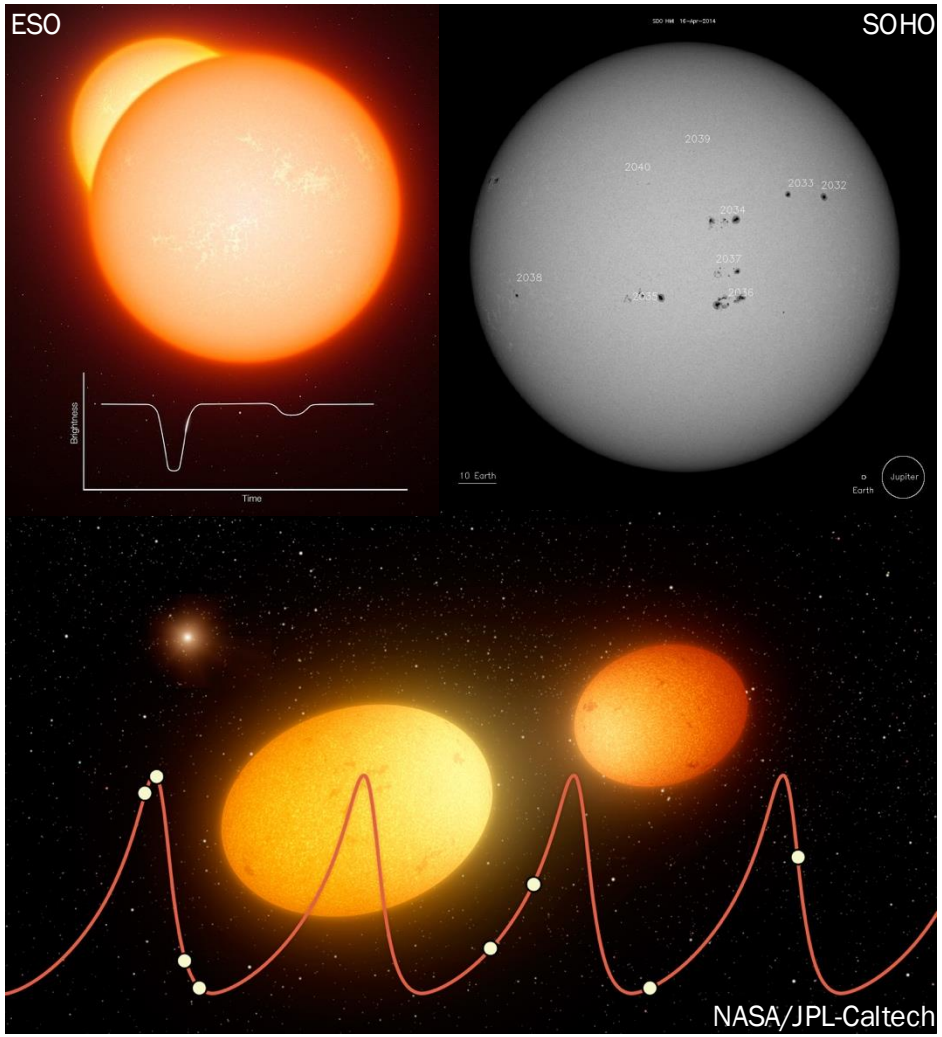


Meadows & Barnes (2018)

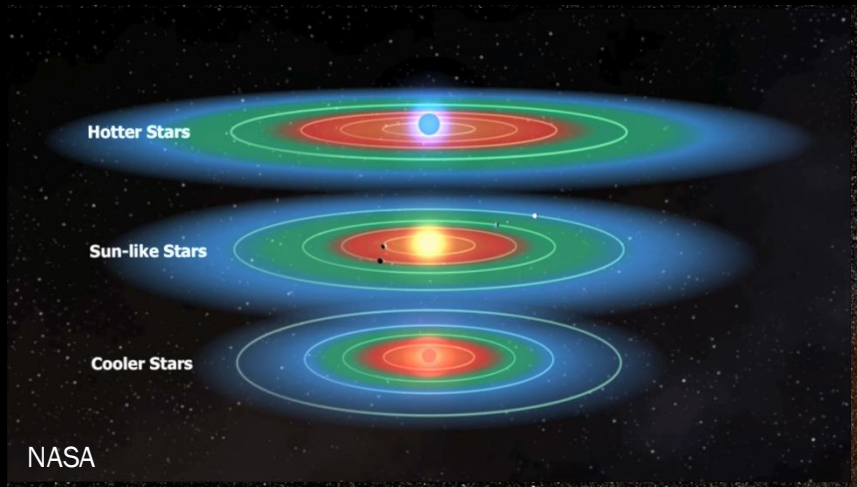
Stellar Variability







Does Variability Affect Habitability?



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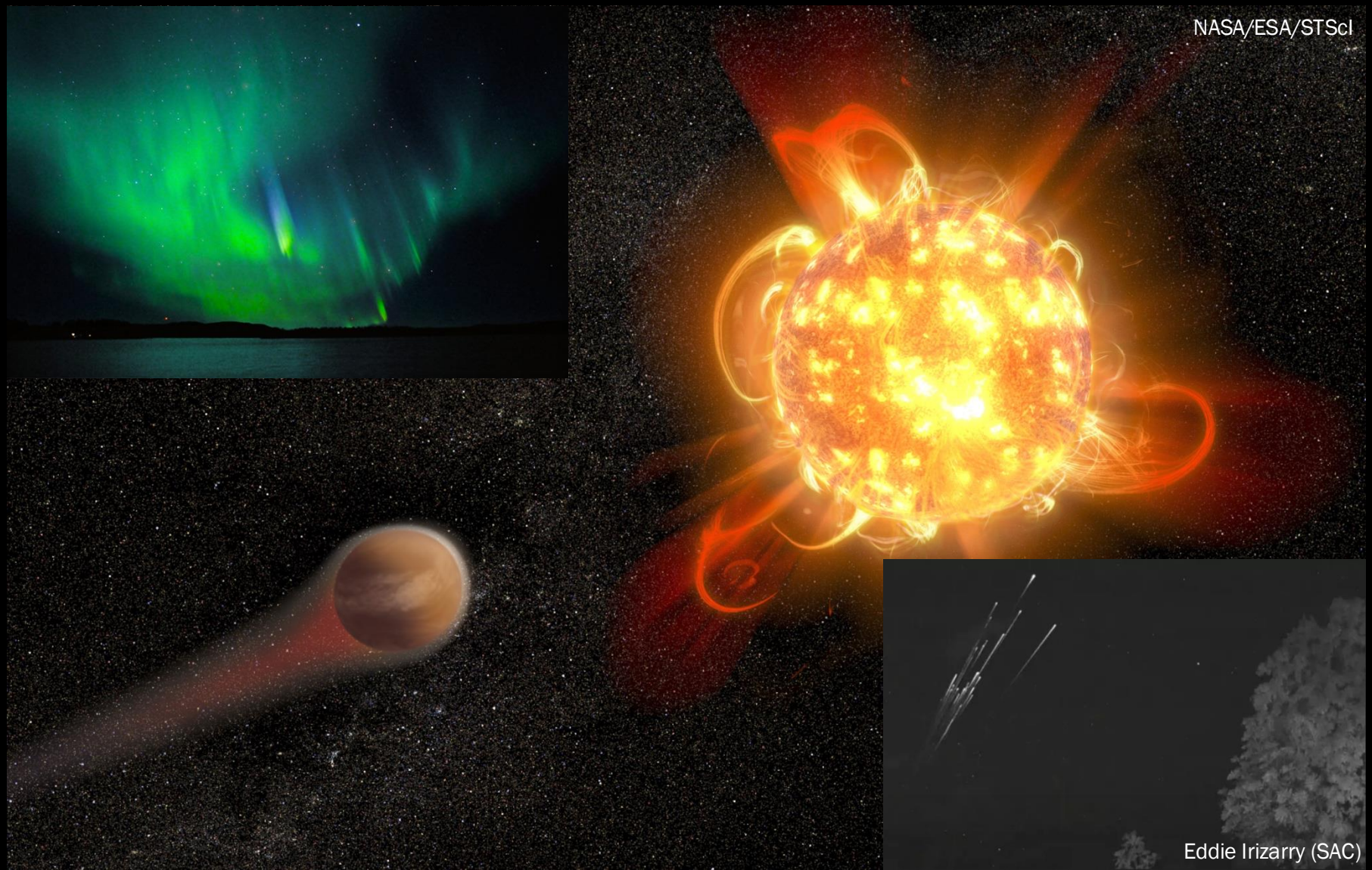
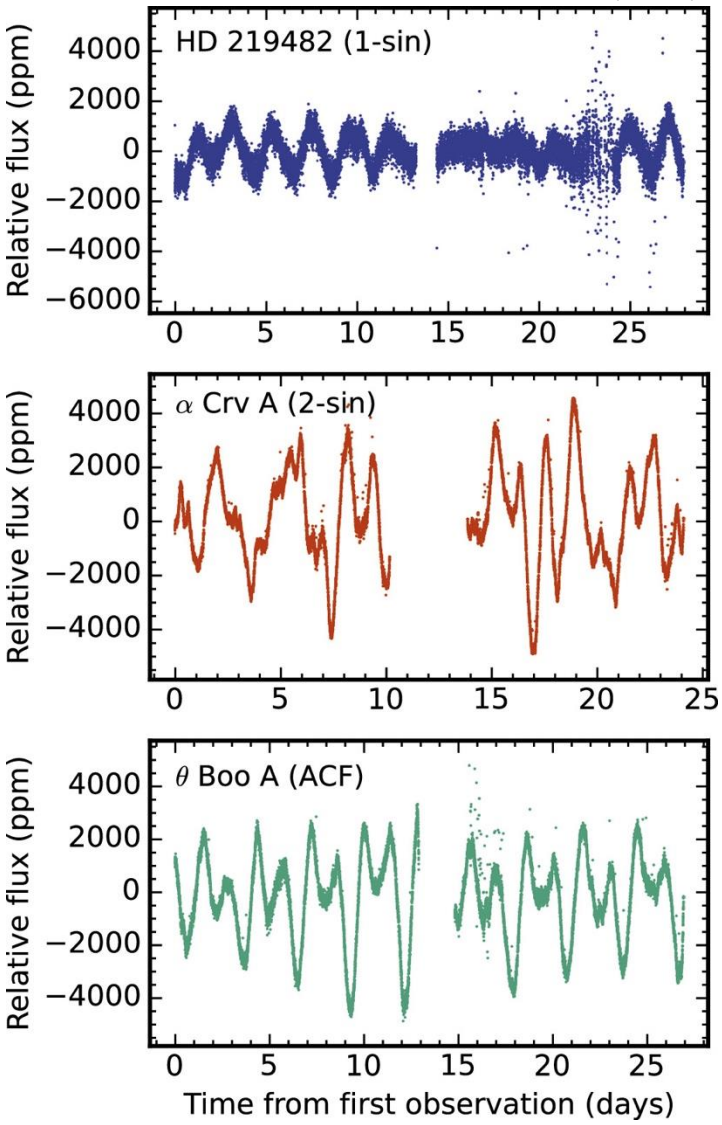
Effects of Solar Activity on Earth

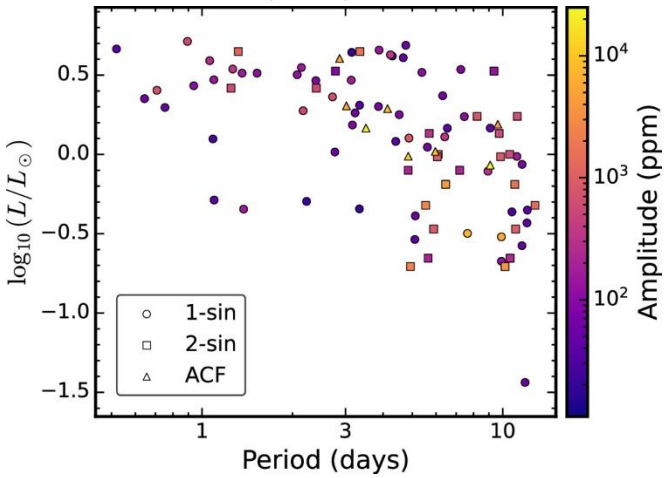


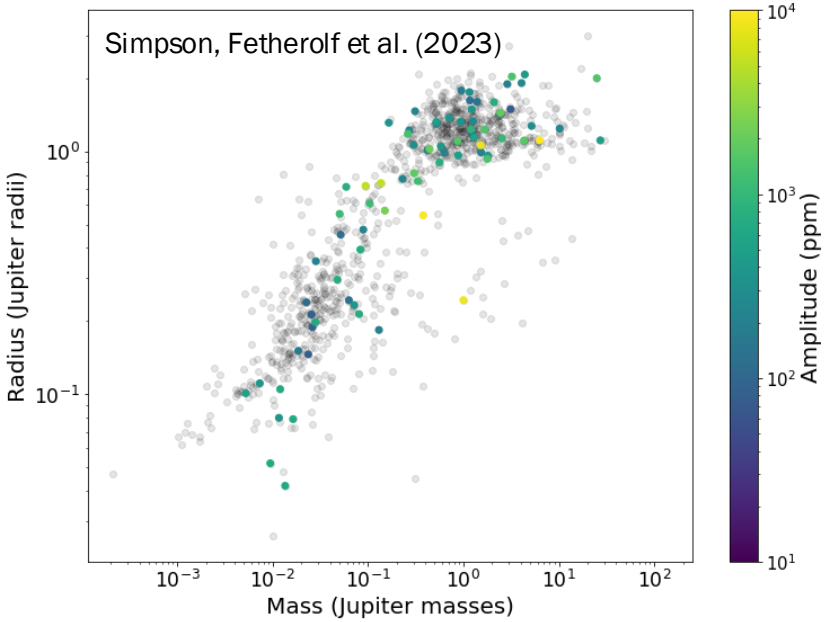
Variable Exoplanet Host Stars

Harada et al. (2024)

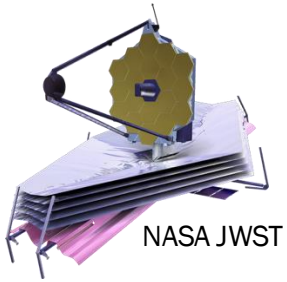


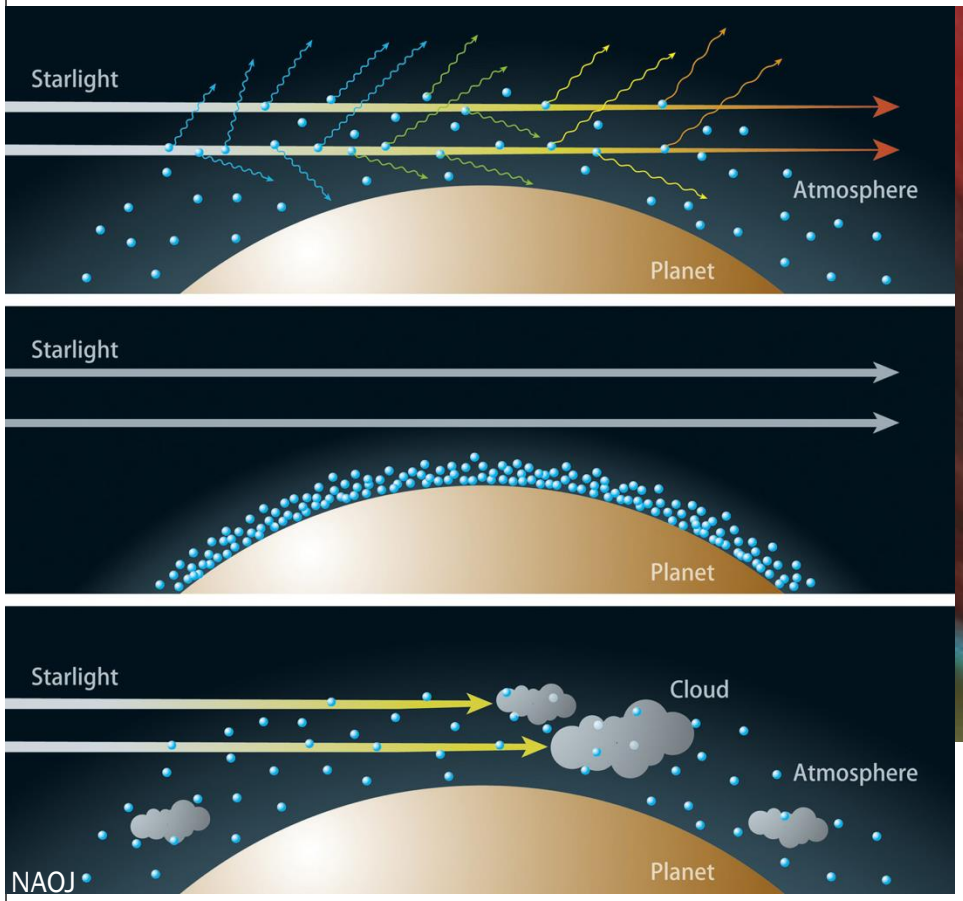
Harada et al. (2024)

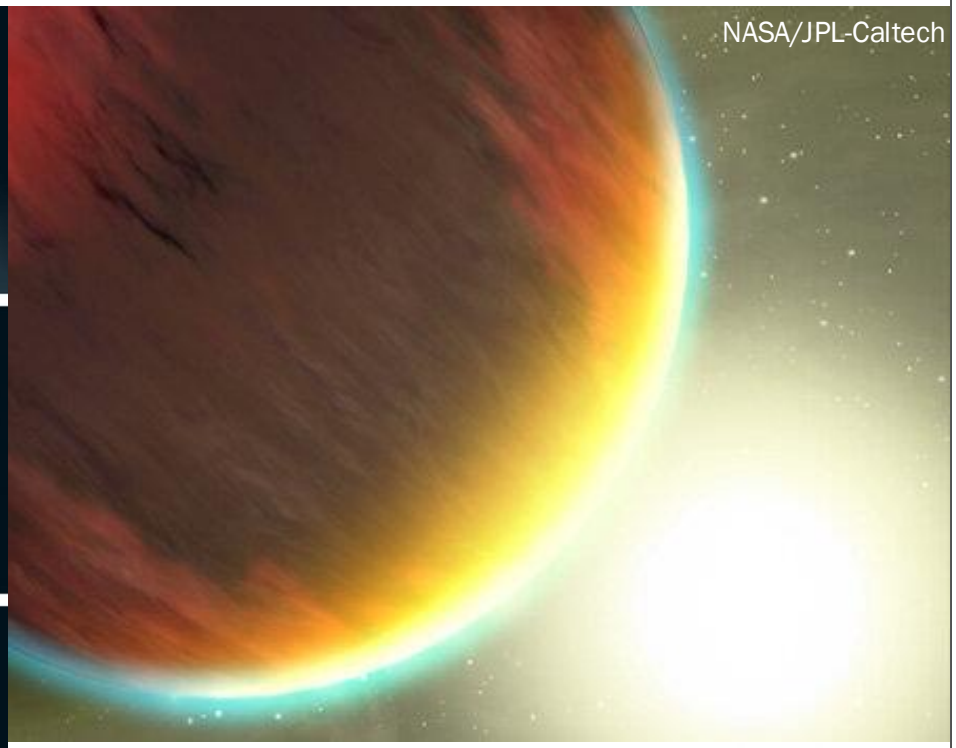


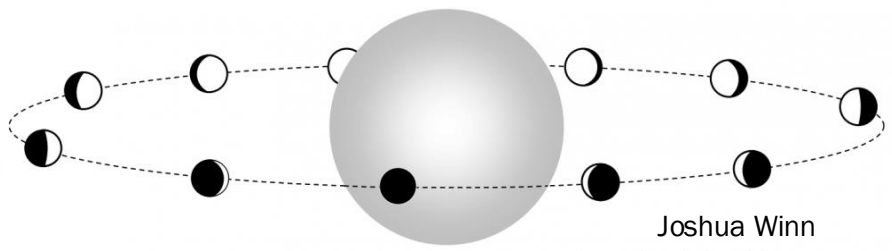


Exoplanet Atmospheres

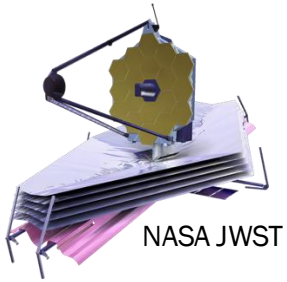






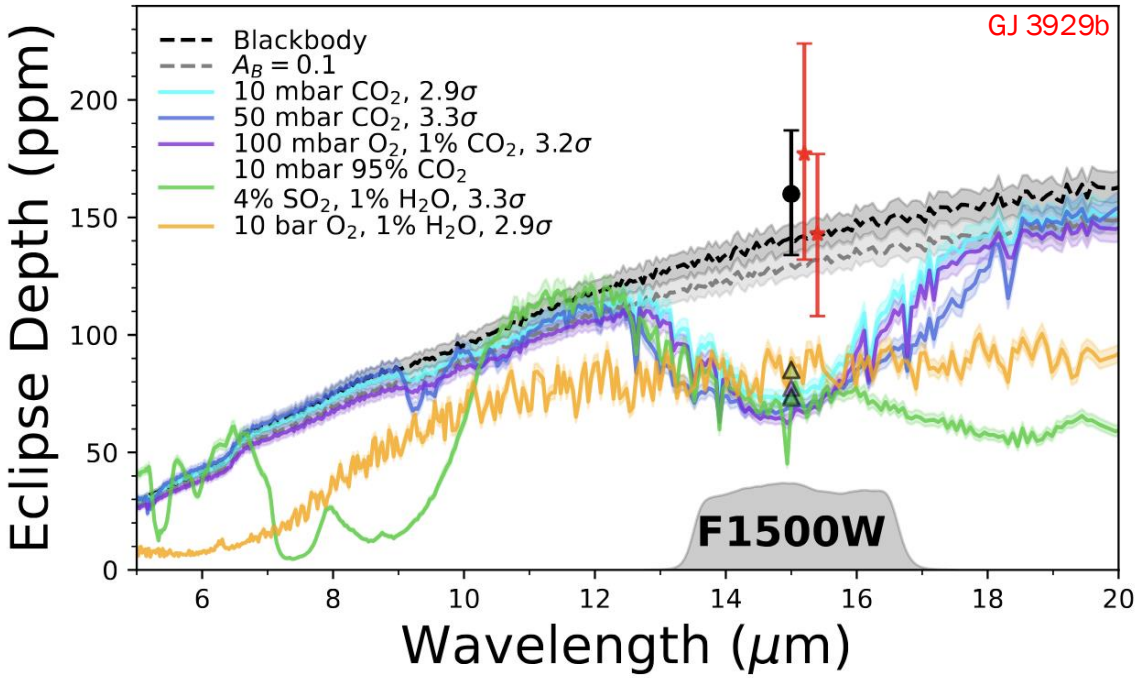


What Atmosphere?

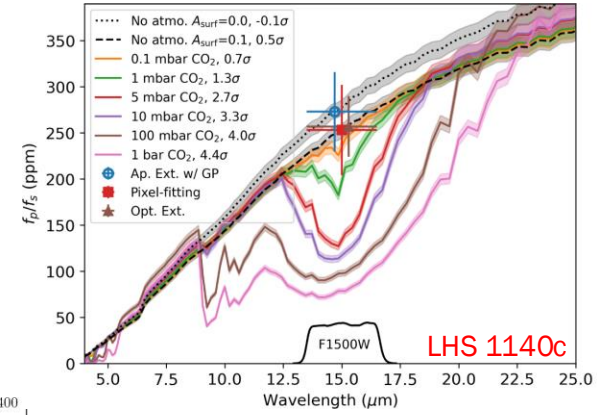


- Exoplanets around M dwarfs tend to be “bare rocks”

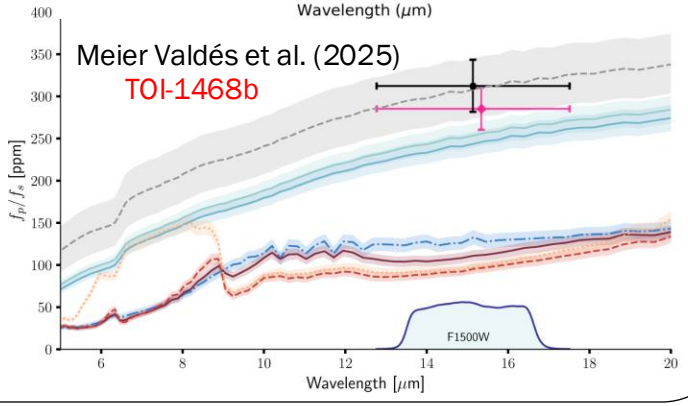
Xue et al. (2025)



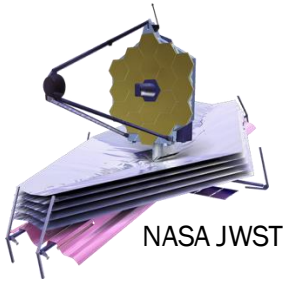
Fortune et al. (2025)



Meier Valdés et al. (2025)

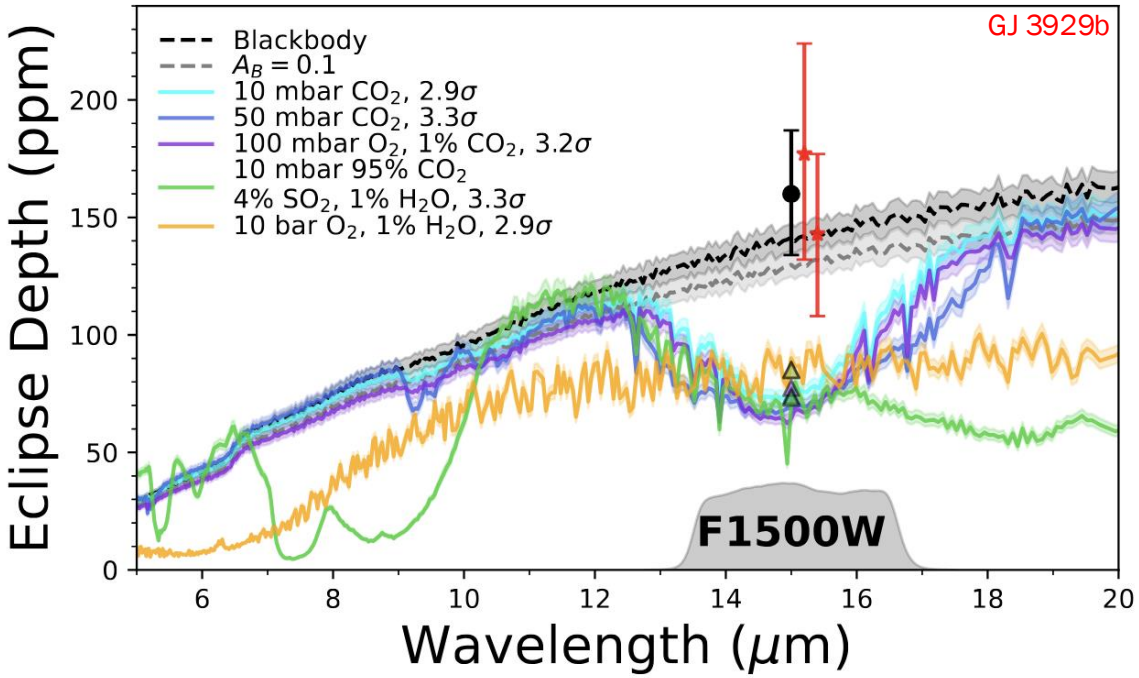


What Atmosphere?

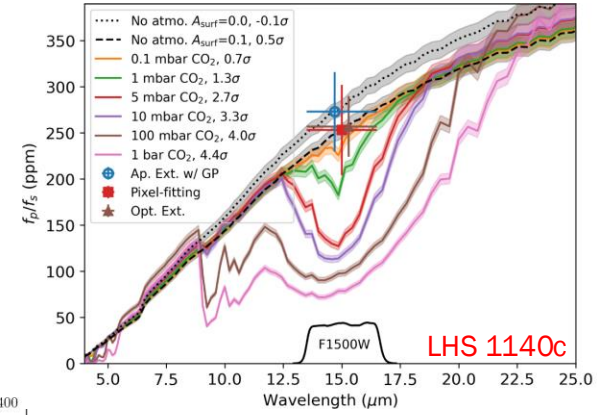


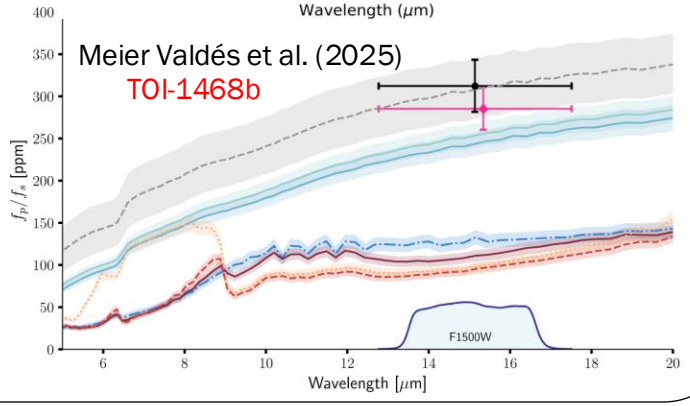
- Exoplanets around M dwarfs tend to be “bare rocks”
- Are the planets old and dead?

Xue et al. (2025)

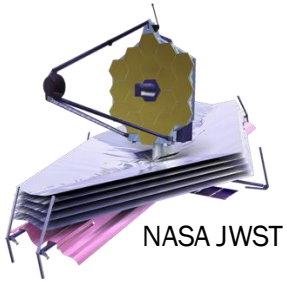


Fortune et al. (2025)



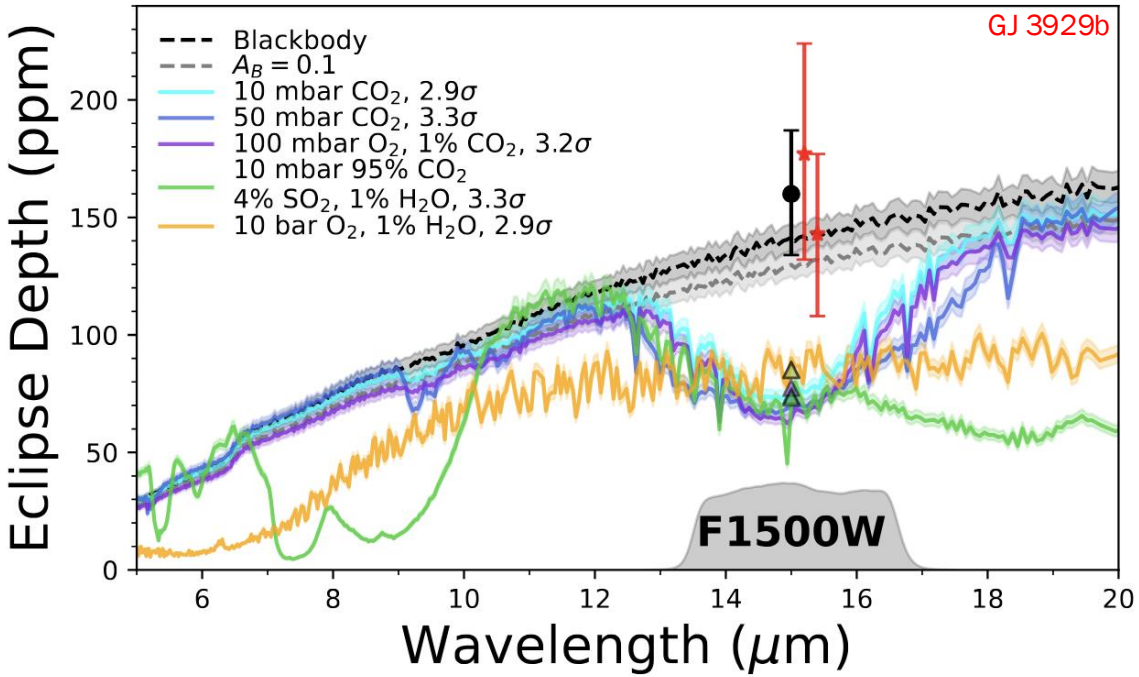


What Atmosphere?

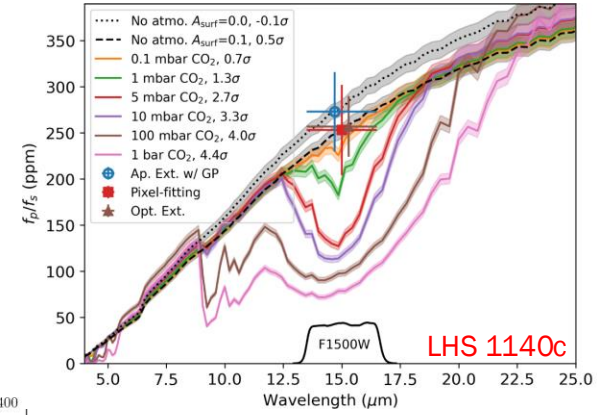


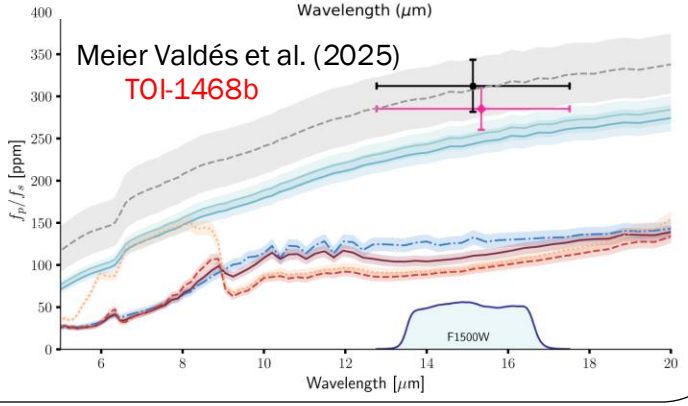
- Exoplanets around M dwarfs tend to be “bare rocks”
- Are the planets old and dead?
- Did stellar activity strip the atmosphere?

Xue et al. (2025)

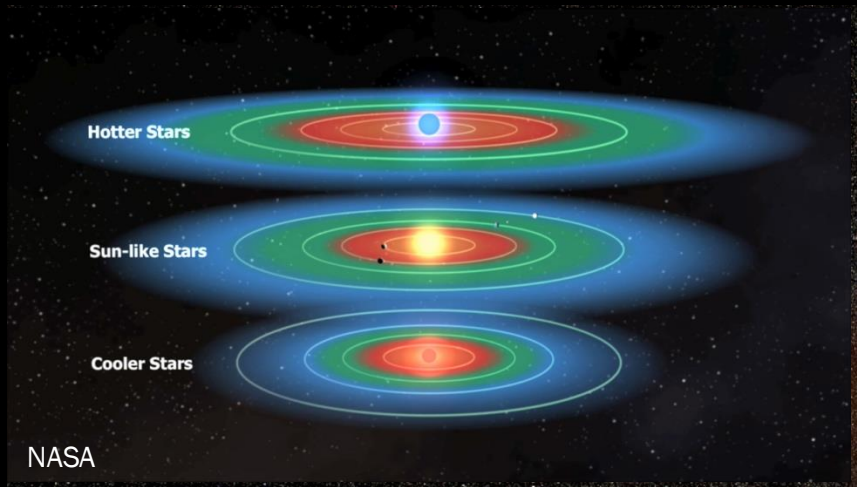


Fortune et al. (2025)





Does Variability Affect Habitability?



NASA/ESA/STScI

Fetherolf et al. (2023)

TESS Stellar Variability Catalog

- https://archive.stsci.edu/hlsp/tess-svc

The TESS Stellar Variability Catalog (TESS-SVC)

Primary Investigator: Tara Fetherolf

HLSP Authors: Tara Fetherolf, Joshua Pepper, Emilie Simpson, Stephen R. Kane, Teo Mocnik, John Edward English, Victoria Antoci, Daniel Huber, Jon M. Jenkins, Keivan Stassun, Joseph D. Twicken, Roland Vanderspek, Joshua N. Winn

Released: 2023-08-15

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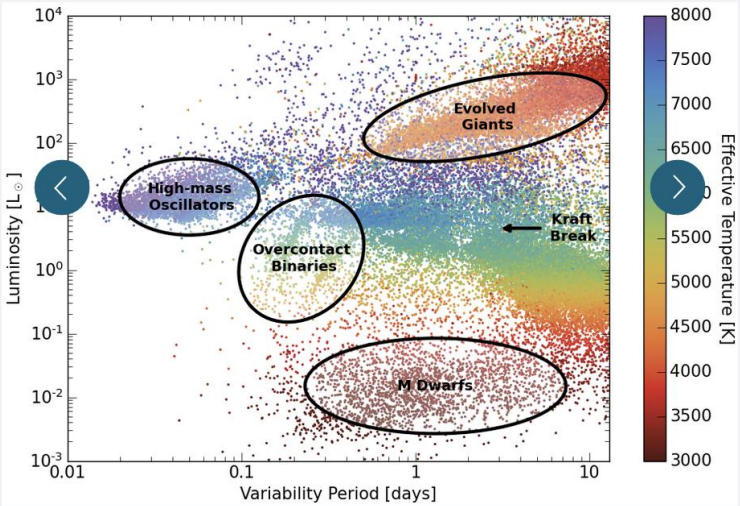
Primary Reference(s): Fetherolf et al. 2023

DOI: 10.17909/f8pz-vj63

Citations: See ADS statistics

Read Me

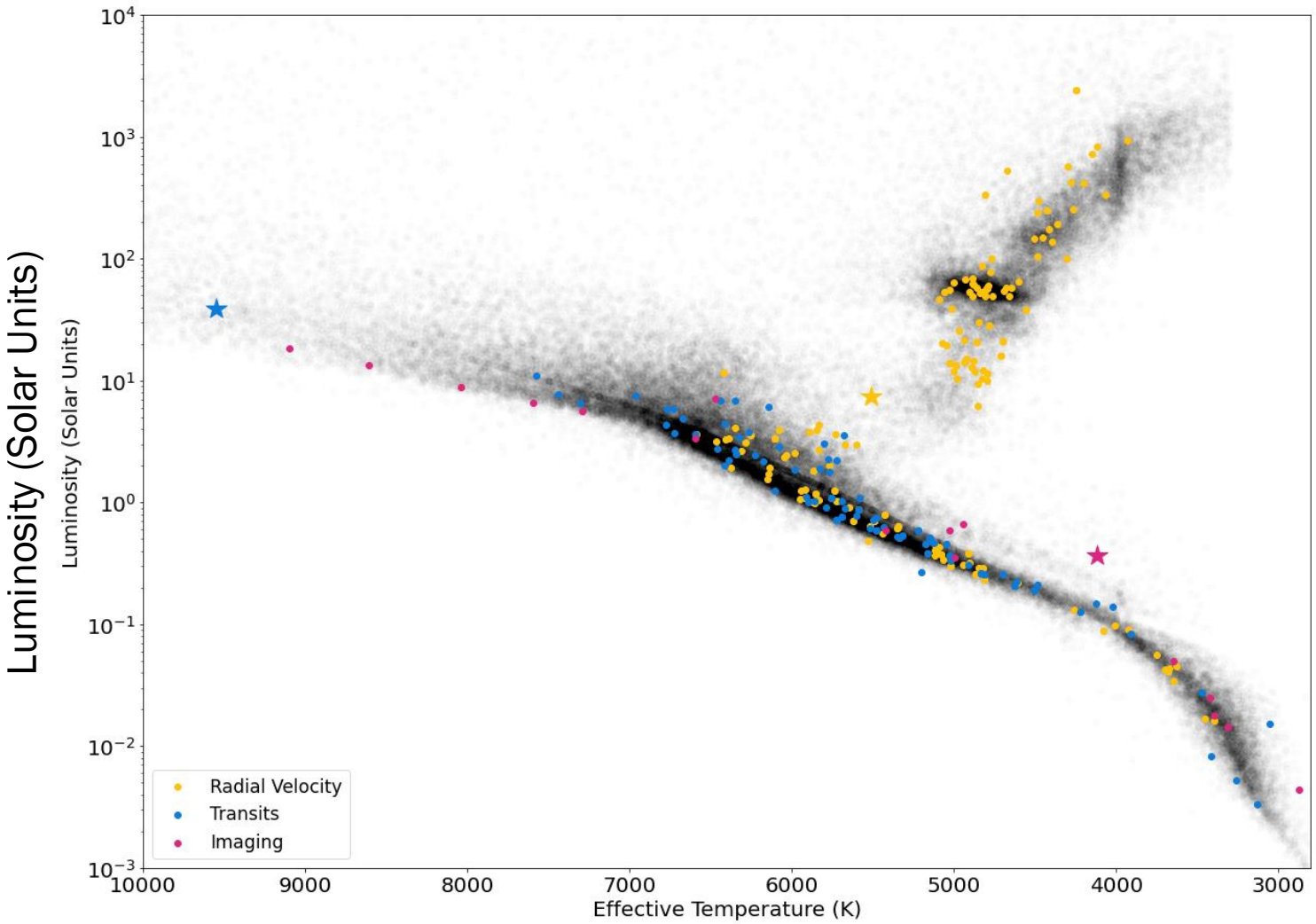


Luminosity Versus Variability Period

Calculated stellar luminosities versus the measured variability periods of stars that are identified as significantly variable, and thus are included in TESS-SVC. The points are colored by the effective temperatures reported by the TESS Input Catalog (TIC; Stassun et al. 2018; Stassun et al. 2019), and luminosities are calculated from the effective temperatures and stellar radii available in the TIC (Stassun et al. 2018; Stassun et al. 2019). Several known astrophysical relationships are highlighted and labeled with faded ellipses.

Simpson, Fetherolf et al. (2023)

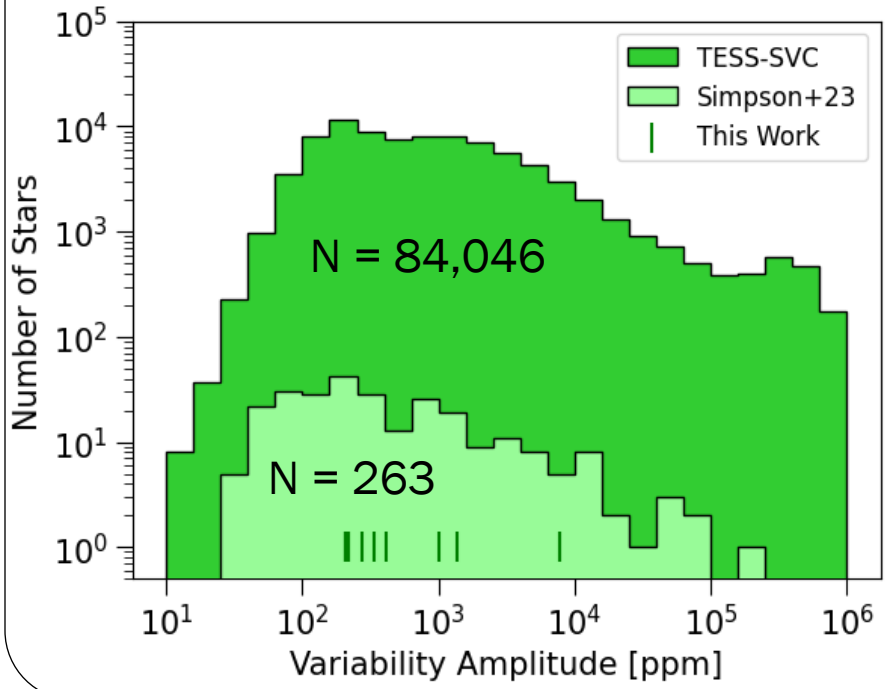
Exoplanets Around Variable Stars

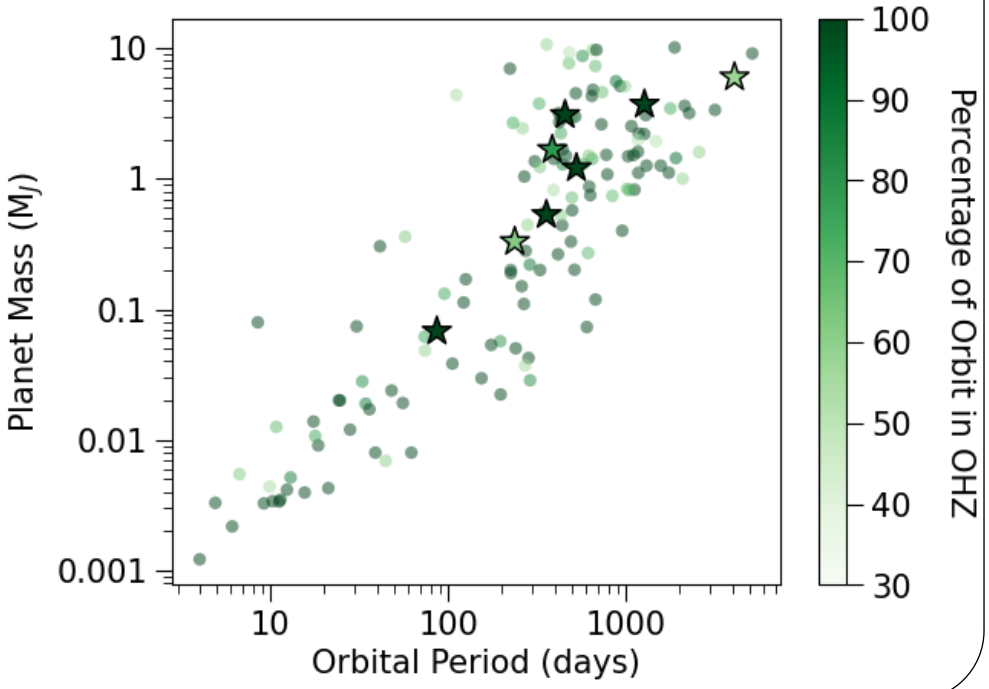


Fetherolf et al. (2025)

Habitable Zone Exoplanets

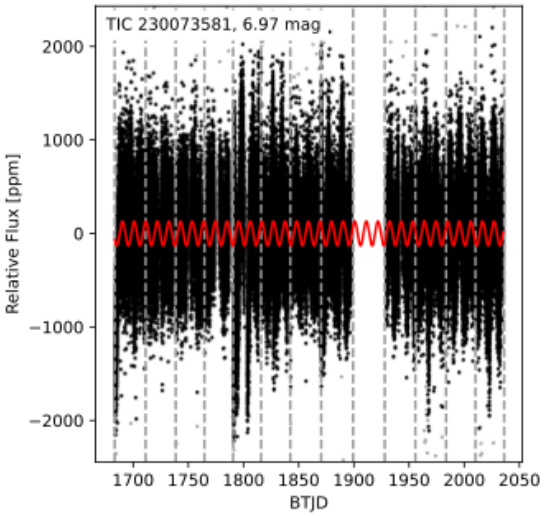
- Currently only 9 known habitable zone exoplanets around variable stars!
- There is an observational bias against finding exoplanets around variable stars.

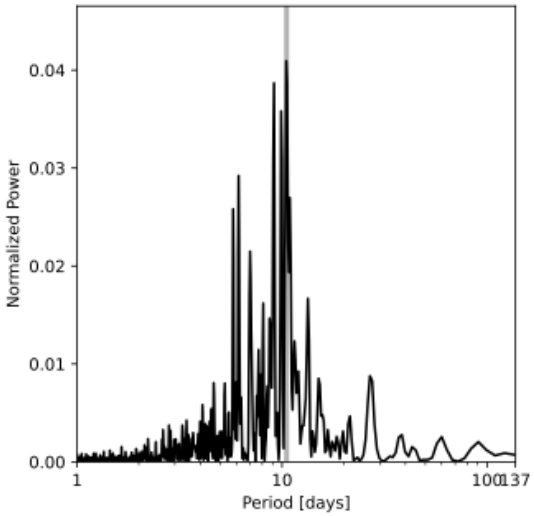


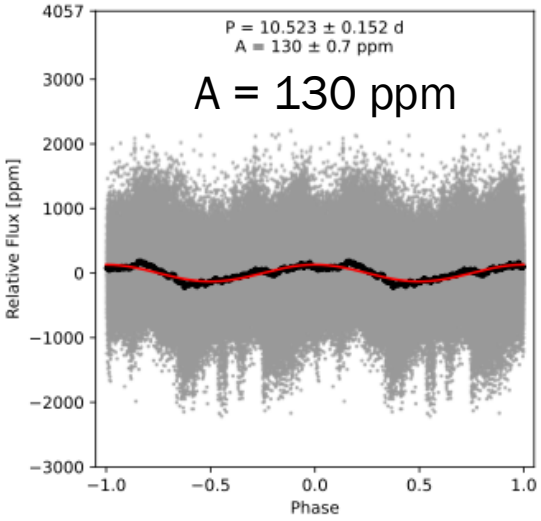


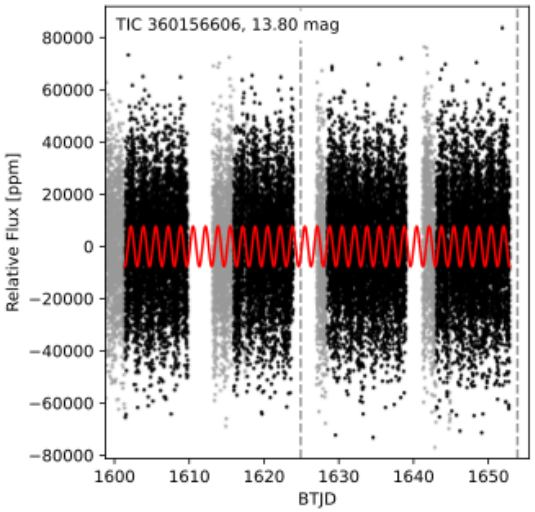
Fetherolf et al. (2025)

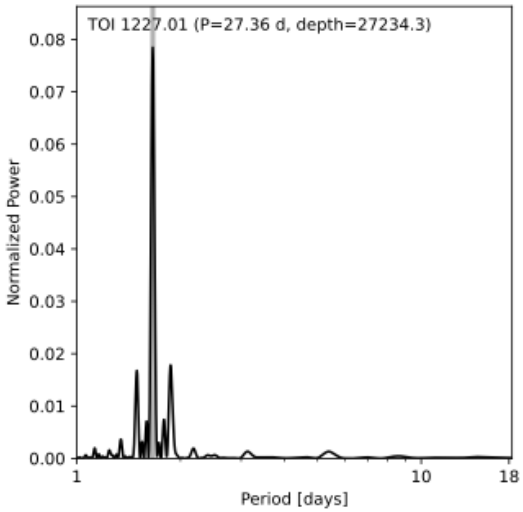
Amplitude Range of Variability

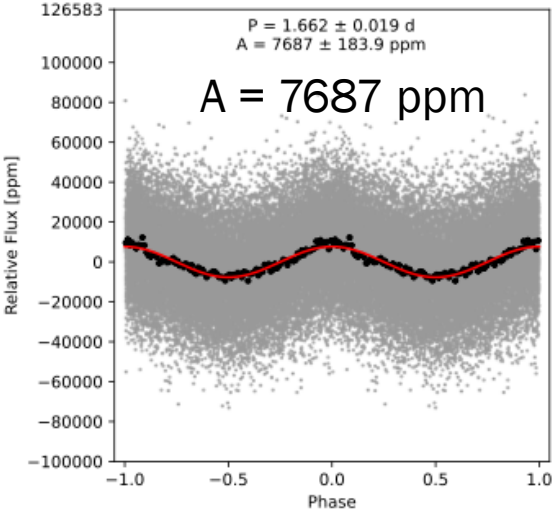










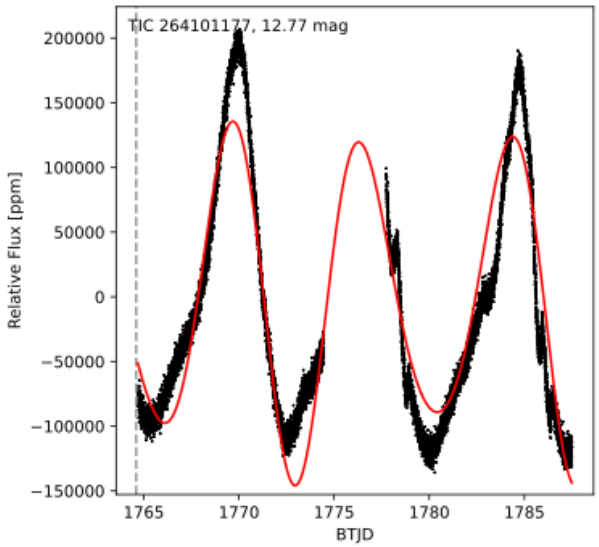


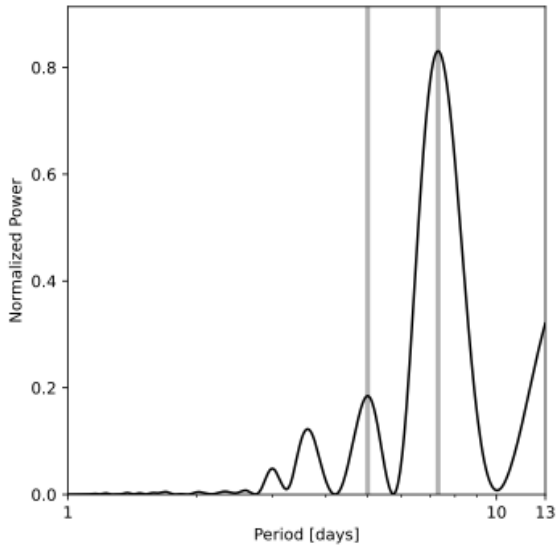
Fetherolf et al. (2025)

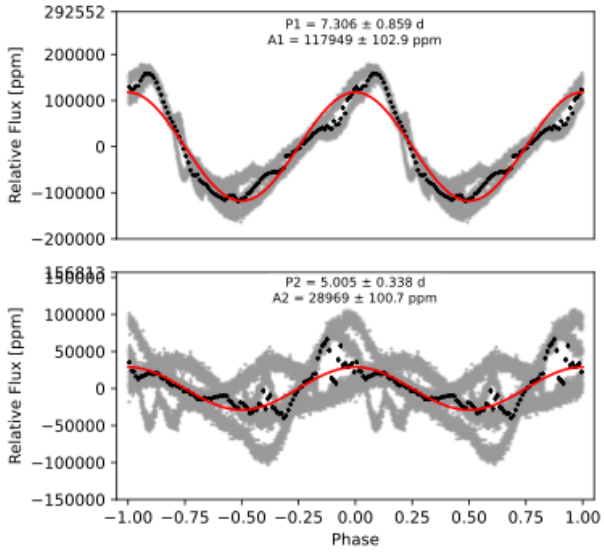
Extreme Variability in the TESS-SVC

TIC 264101177:

- A_1 = 117,949 ppm
- A_2 = 28,969 ppm





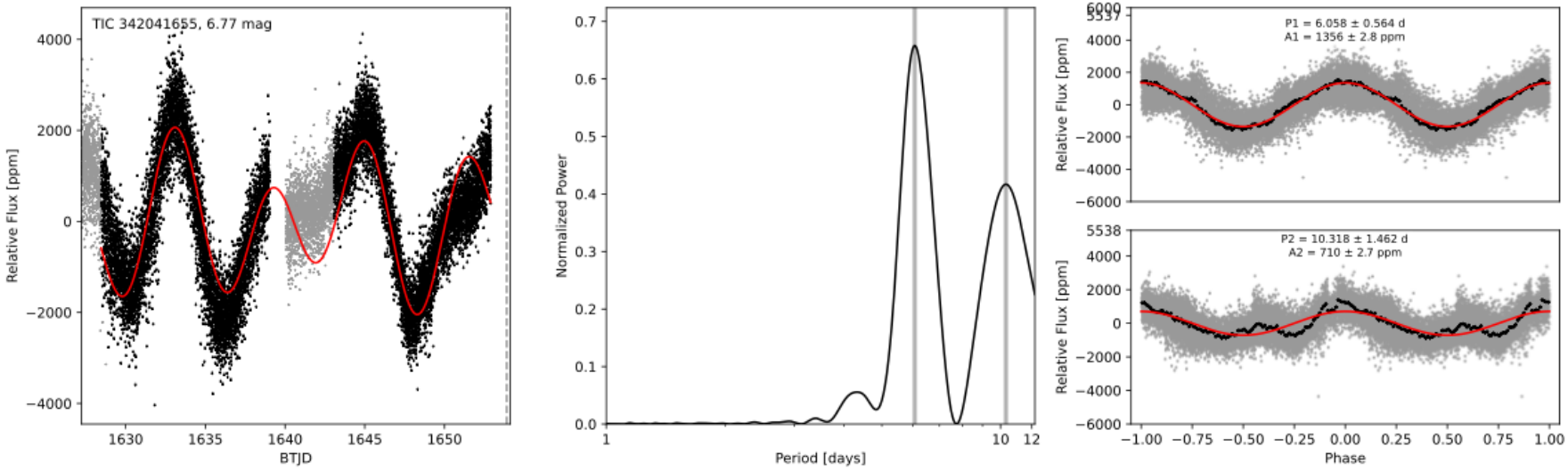


Fetherolf et al. (2025)

Eccentricity & Complex Variability

HD 142415 b:

- Porb = 386.3 days
- e = 0.5
- A_1 = 1356 ppm
- A_2 = 710 ppm



Fetherolf et al. (2025)

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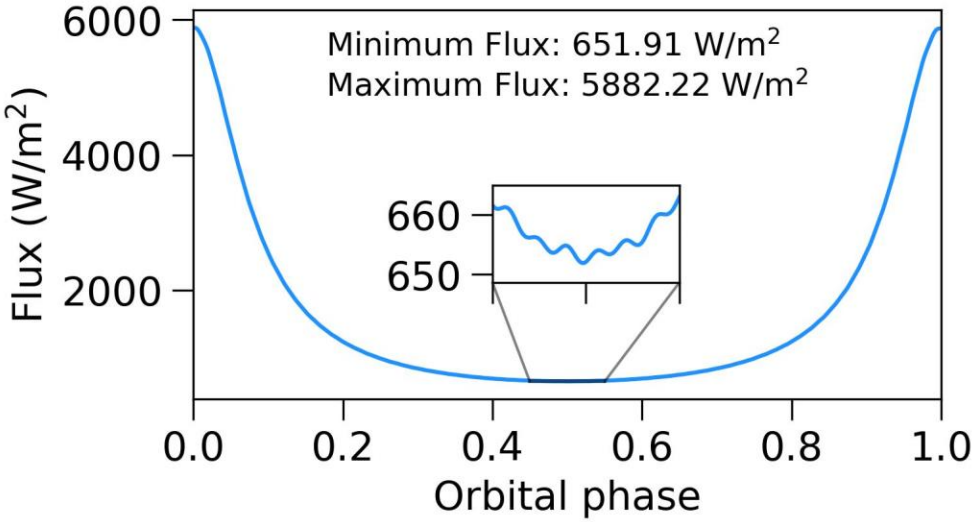
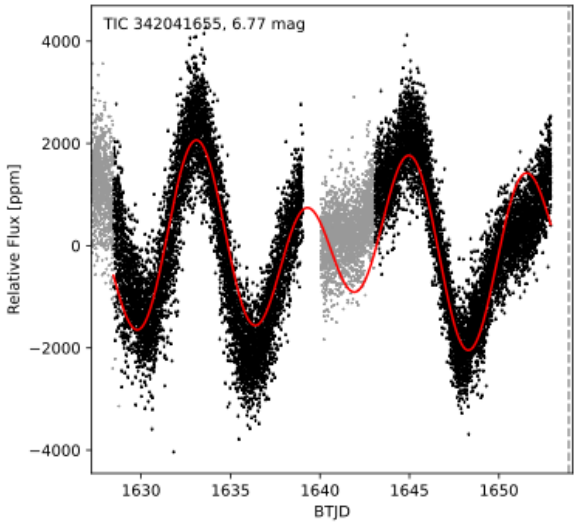
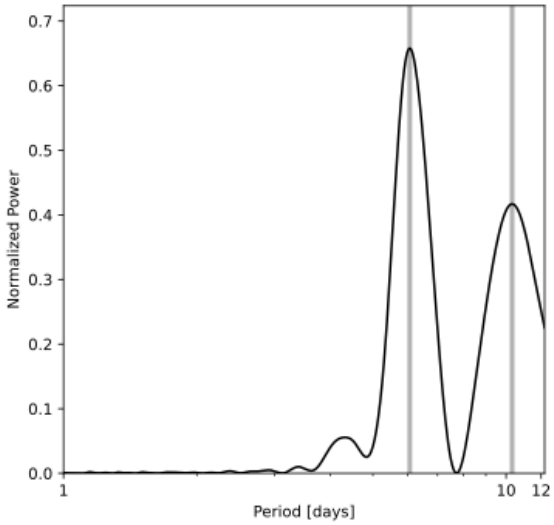
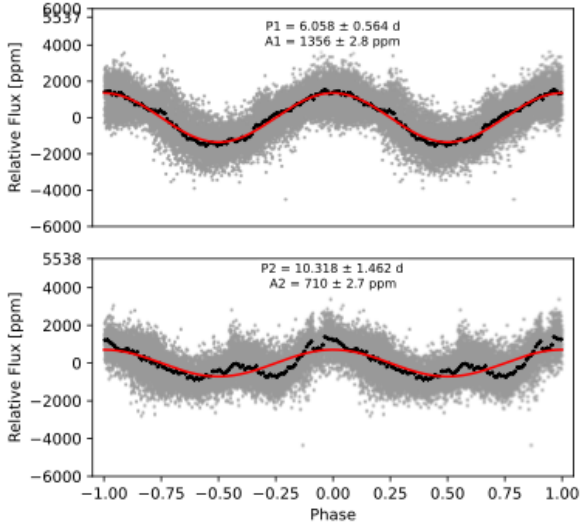


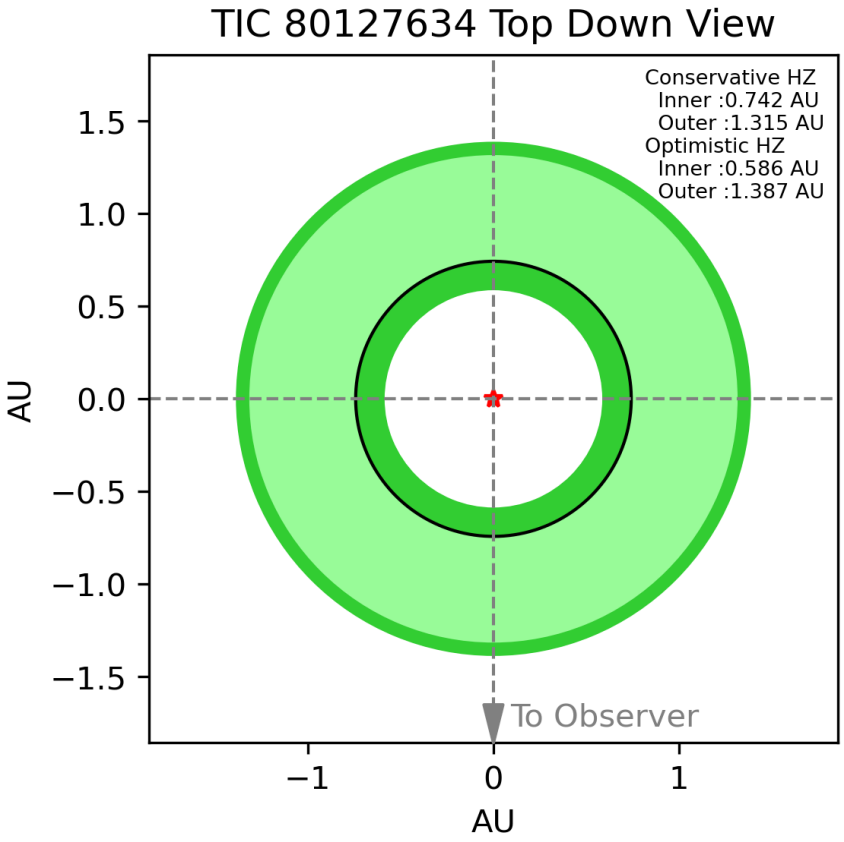






Planet Water Loss Evolution

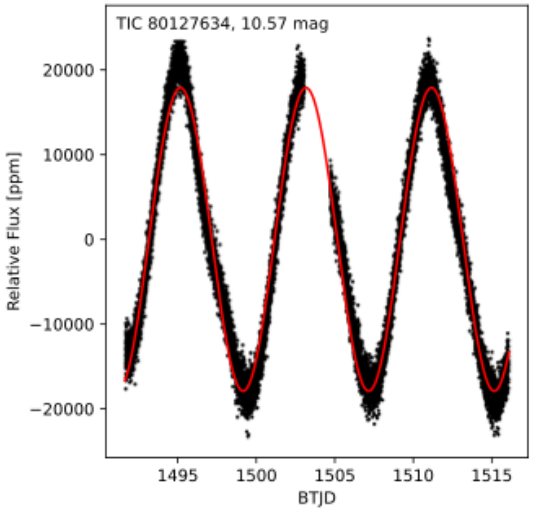
- How does water loss evolution vary for a HZ exoplanet around a quiet star versus a variable star?

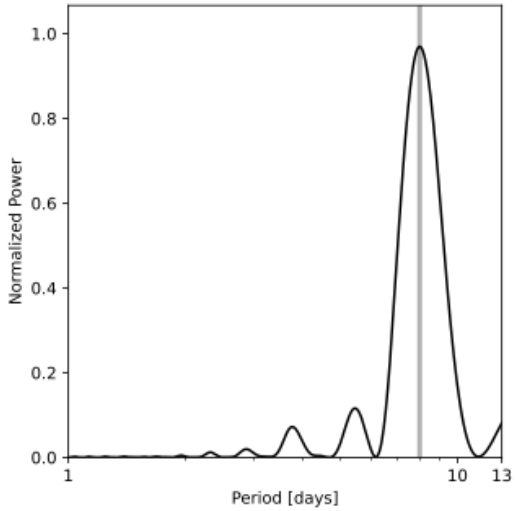


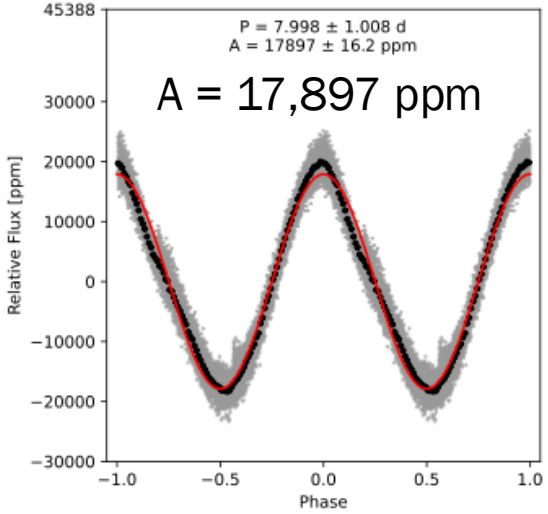
VPLanet

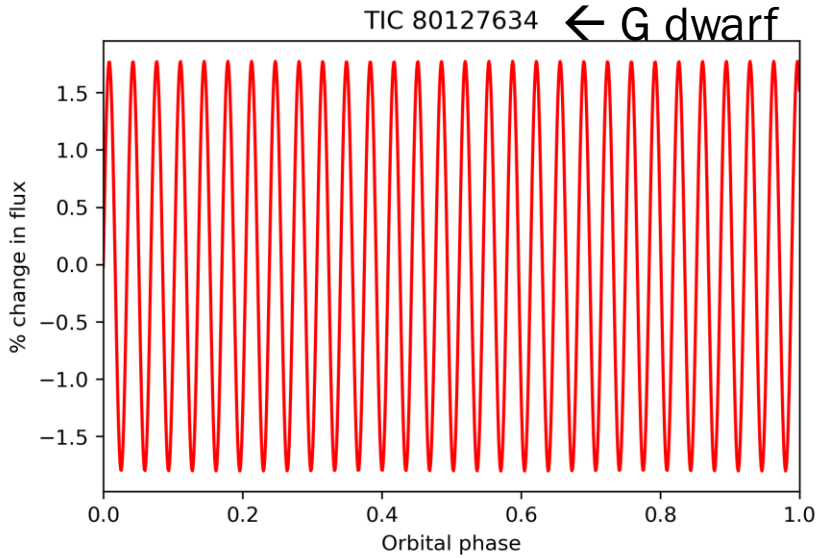
Fetherolf et al. (2025)

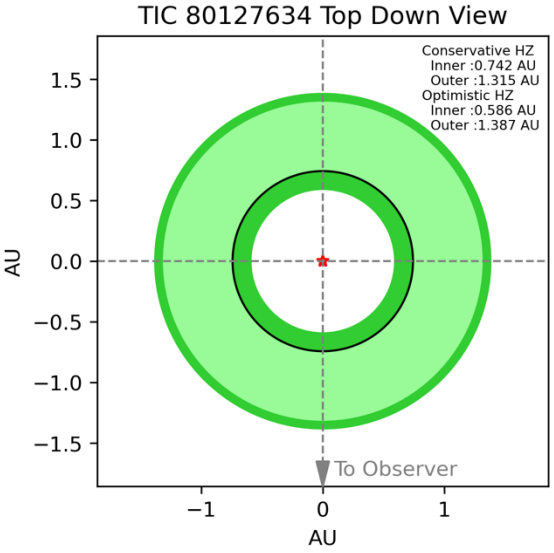
Simulated Variable HZ System









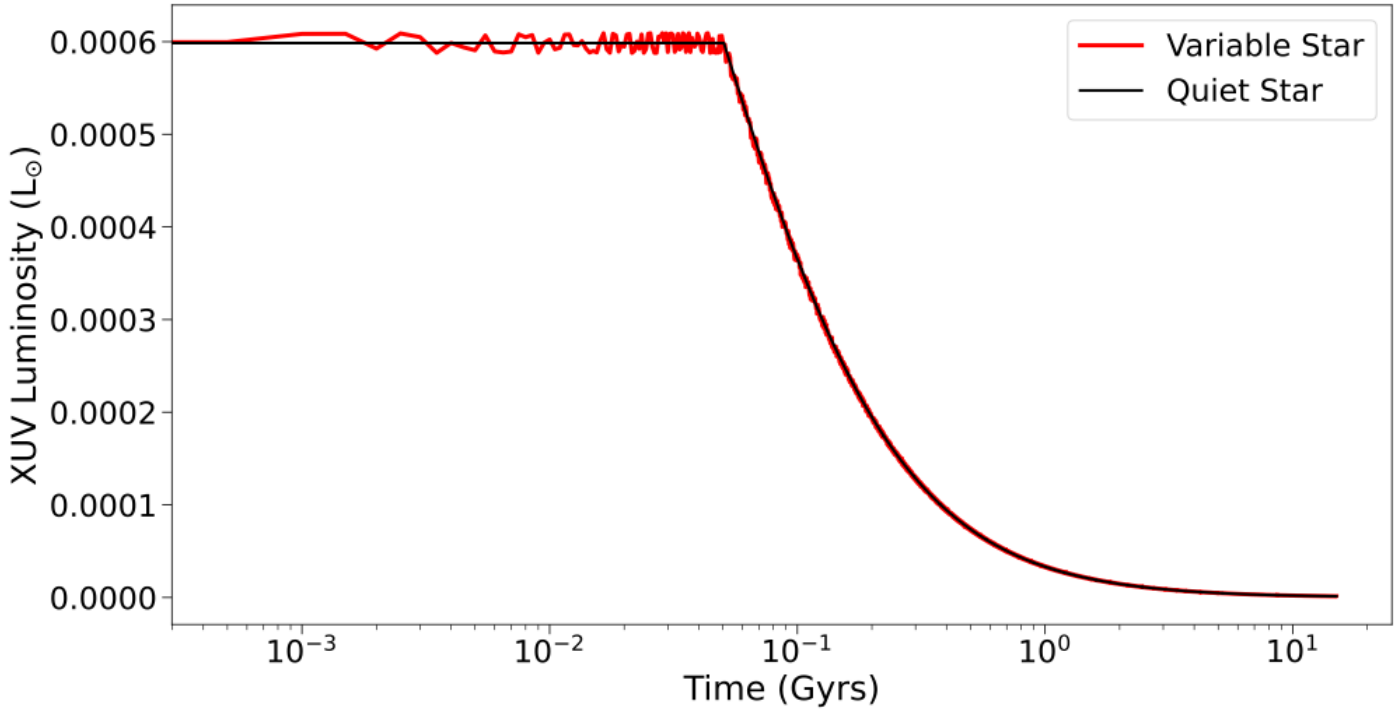


VPLanet

Fetherolf et al. (2025)

Extreme UV Luminosity

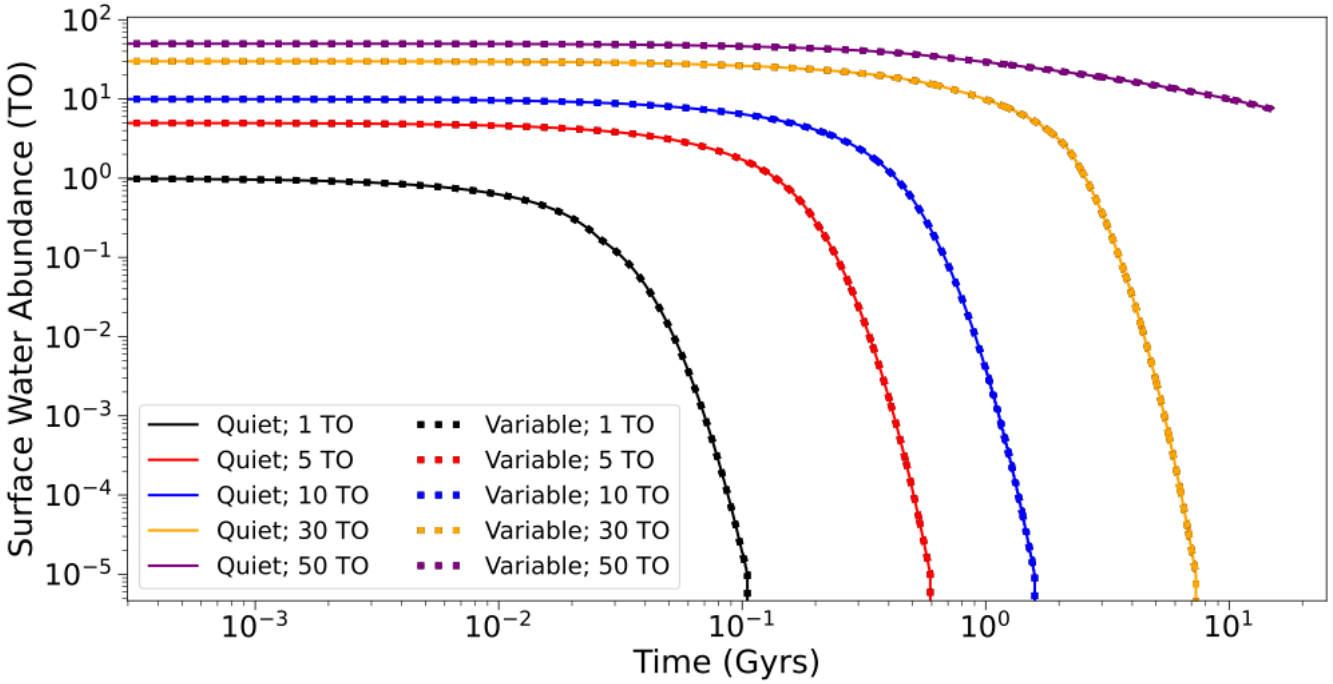
- Extreme UV luminosity has a significant effect on exoplanet water loss evolution.
- Average extreme UV luminosity of the variable star was closely matched to the quiet star.



Fetherolf et al. (2025)

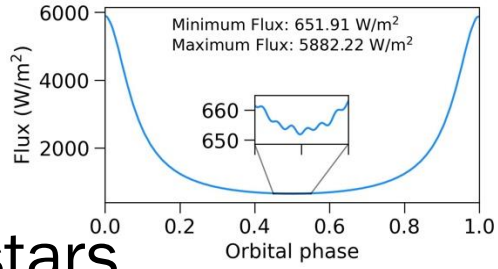
Planet Water Loss Evolution

- Water loss evolution is extremely comparable between quiet and typical variable stars, regardless of the number of initial terrestrial oceans.
- ***Effects of extreme variability are still unknown.***

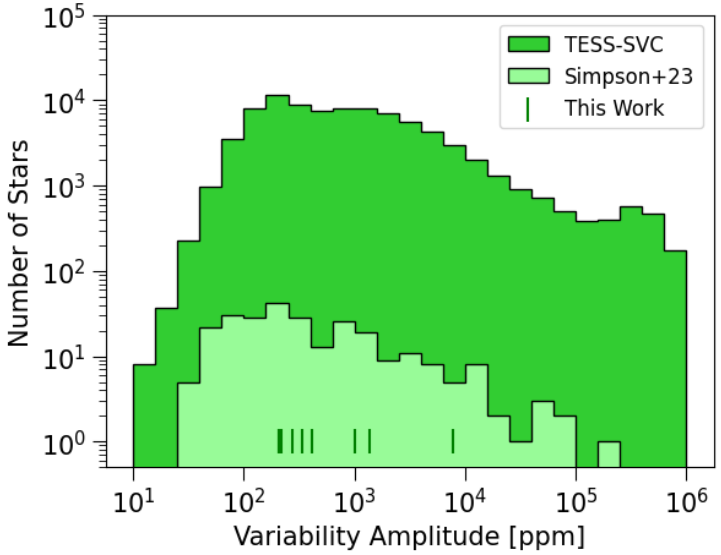


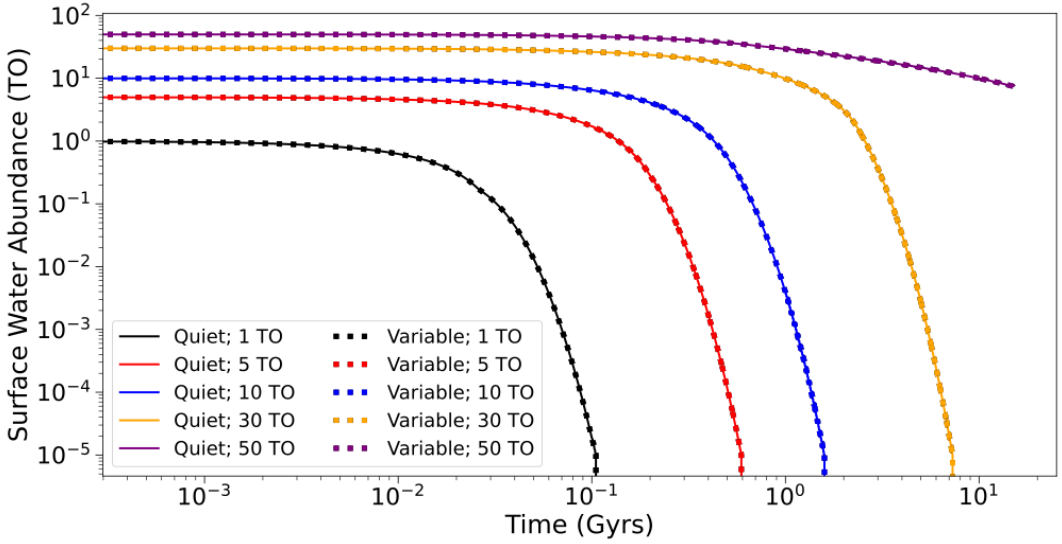
Summary

Fetherolf et al. (2025)



- Only 9 HZ exoplanets around variable stars
- Exoplanets around variable stars are difficult to find
- Eccentricity > Variability
- Similar water loss for typical variability
- Future Work → Extreme variability!

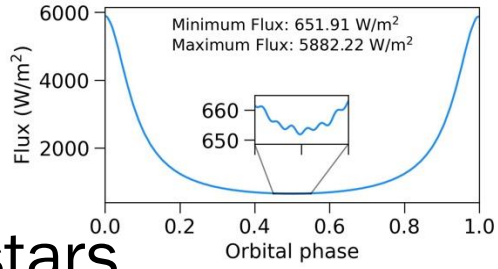




Thank You!

Summary

Fetherolf et al. (2025)



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