ROCKY WORLDS

Néstor Espinoza (STScI) | CIT Lead

On behalf of the Core Implementation Team at STScI

rockyworlds.stsci.edu

June 29th, 2026

Famous DDT programs:
Hubble Deep Field

Williams et al. (1996, 2000); Beckwidth et al. (2005)

The Rocky Worlds DDT Program

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Main aim: look for **evidence of atmospheres** in rocky exoplanets orbiting **M-dwarf stars**.

How this program was selected:
Redfield, et al., 2024, arXiv:2404.02932

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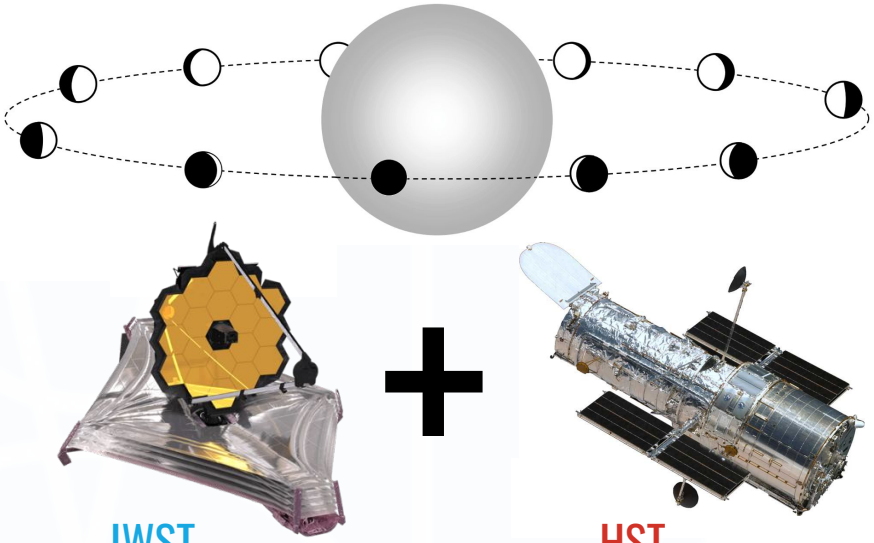

JWST
To characterize the exoplanets
500 hours

HST
To characterize the host stars
250 orbits

Image credit: Winn+2010

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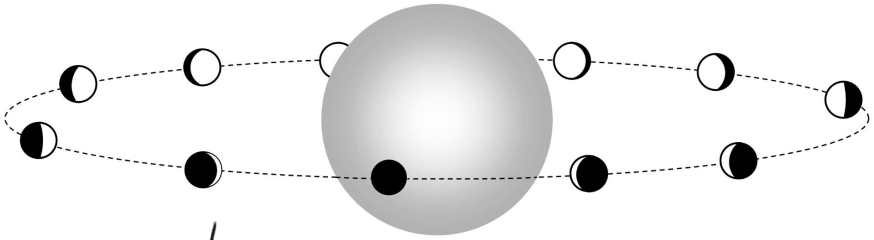

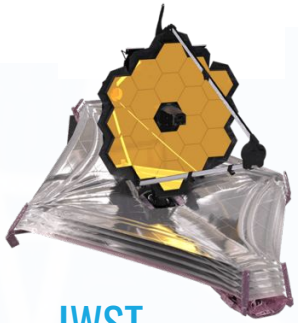

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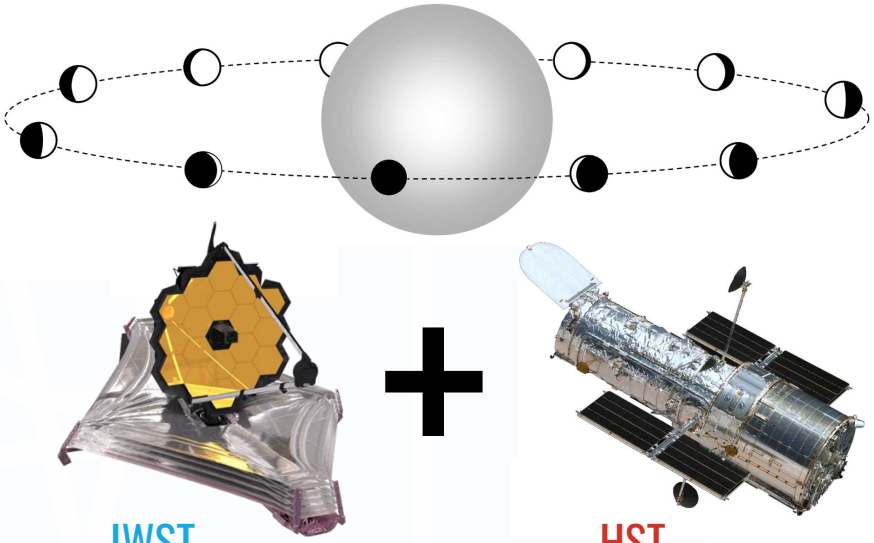

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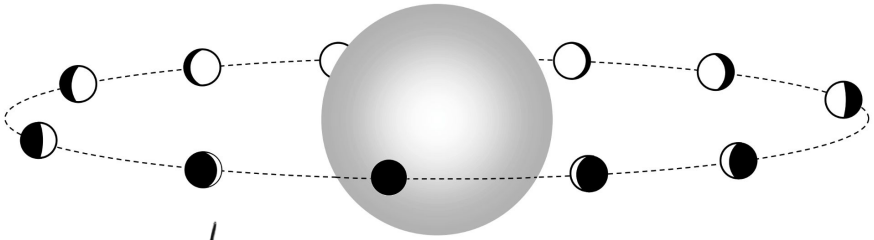

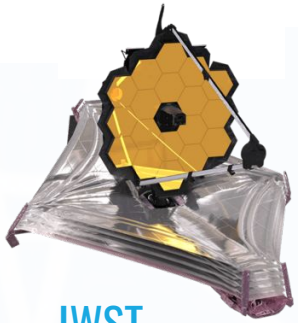

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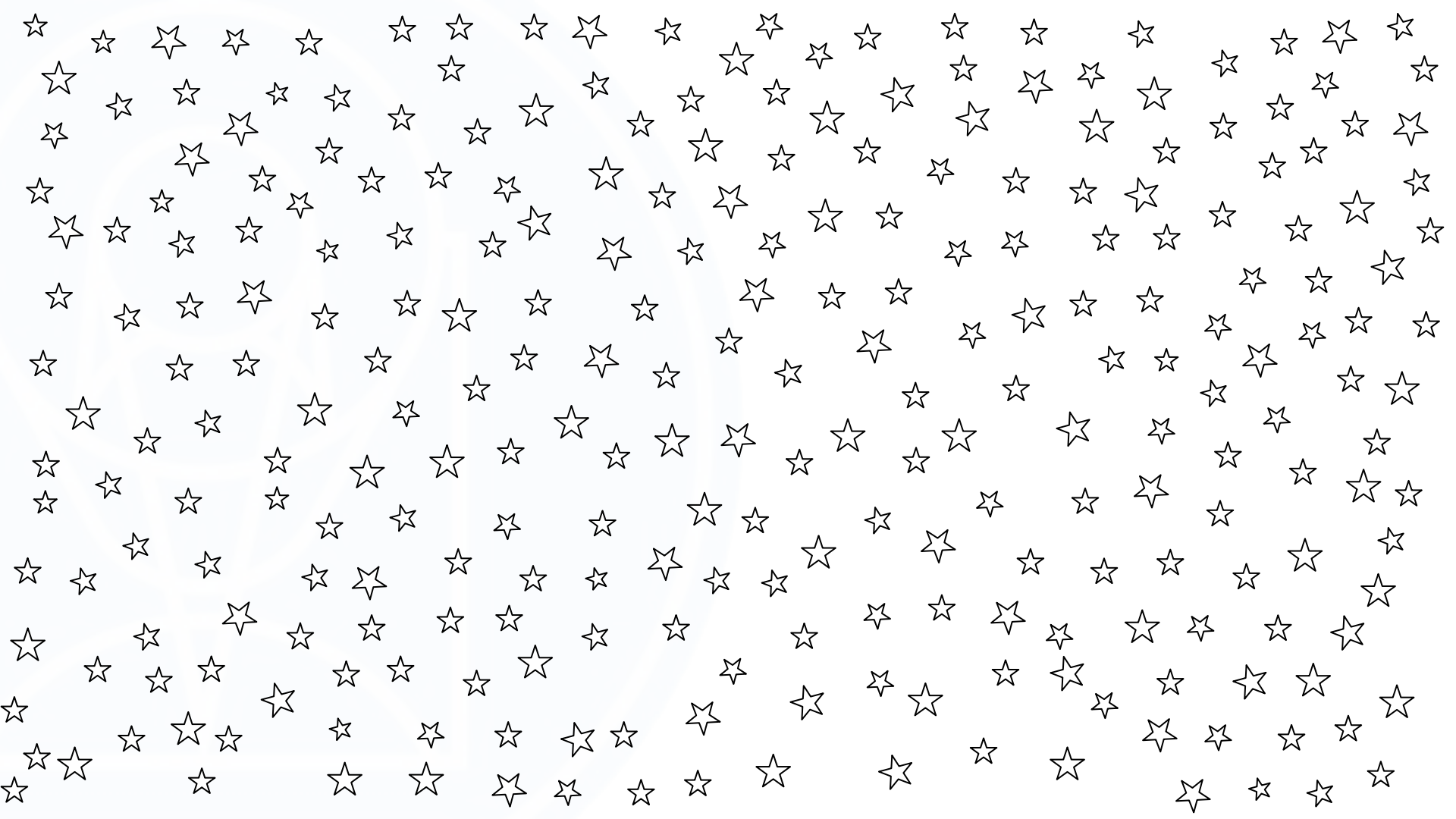
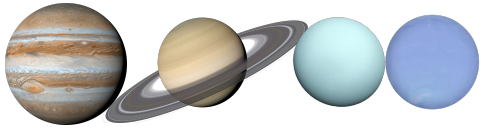
Community (i.e., you)
Provides feedback to CIT/SAC, squeezes science out of the data!

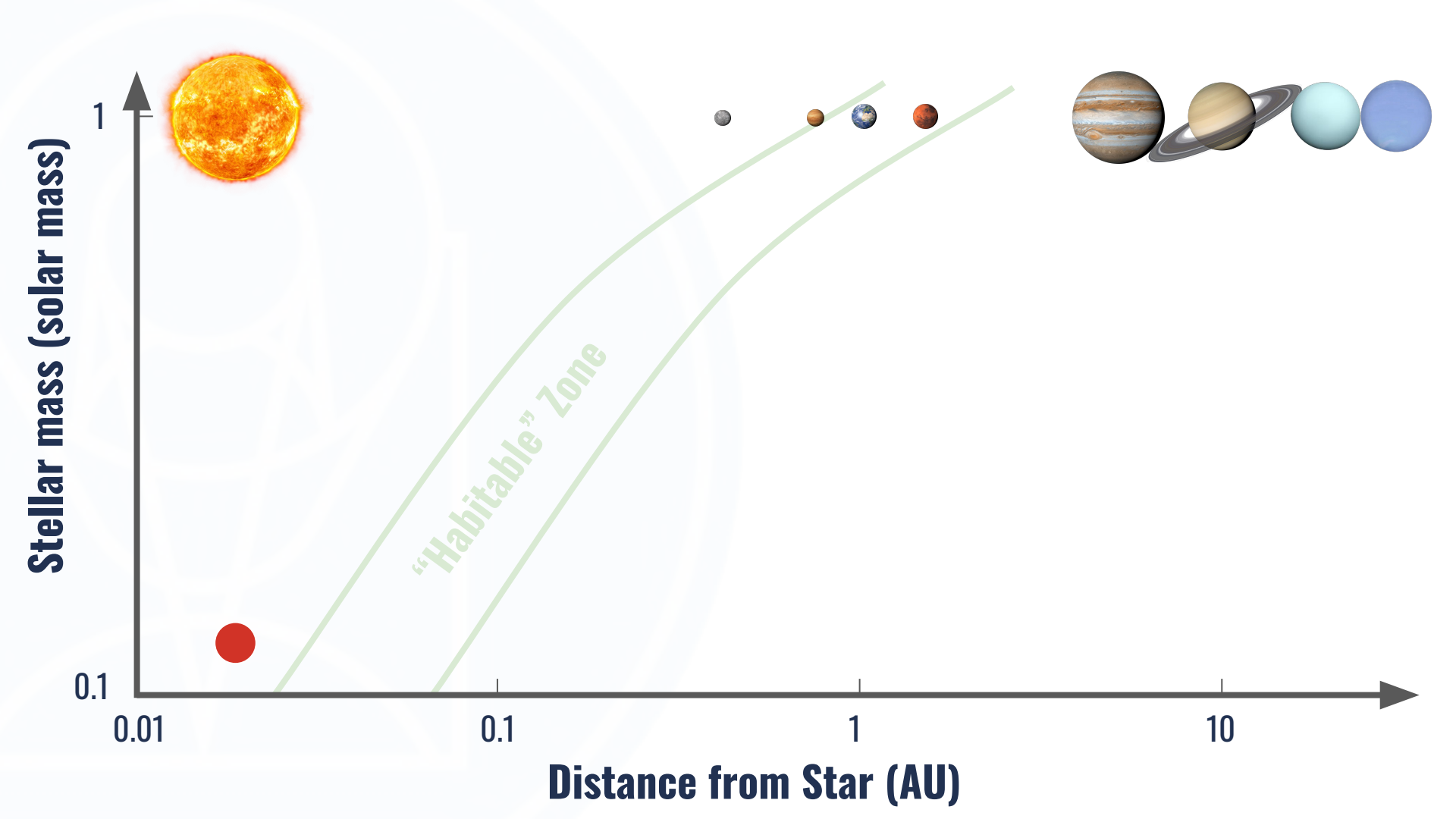
Why?

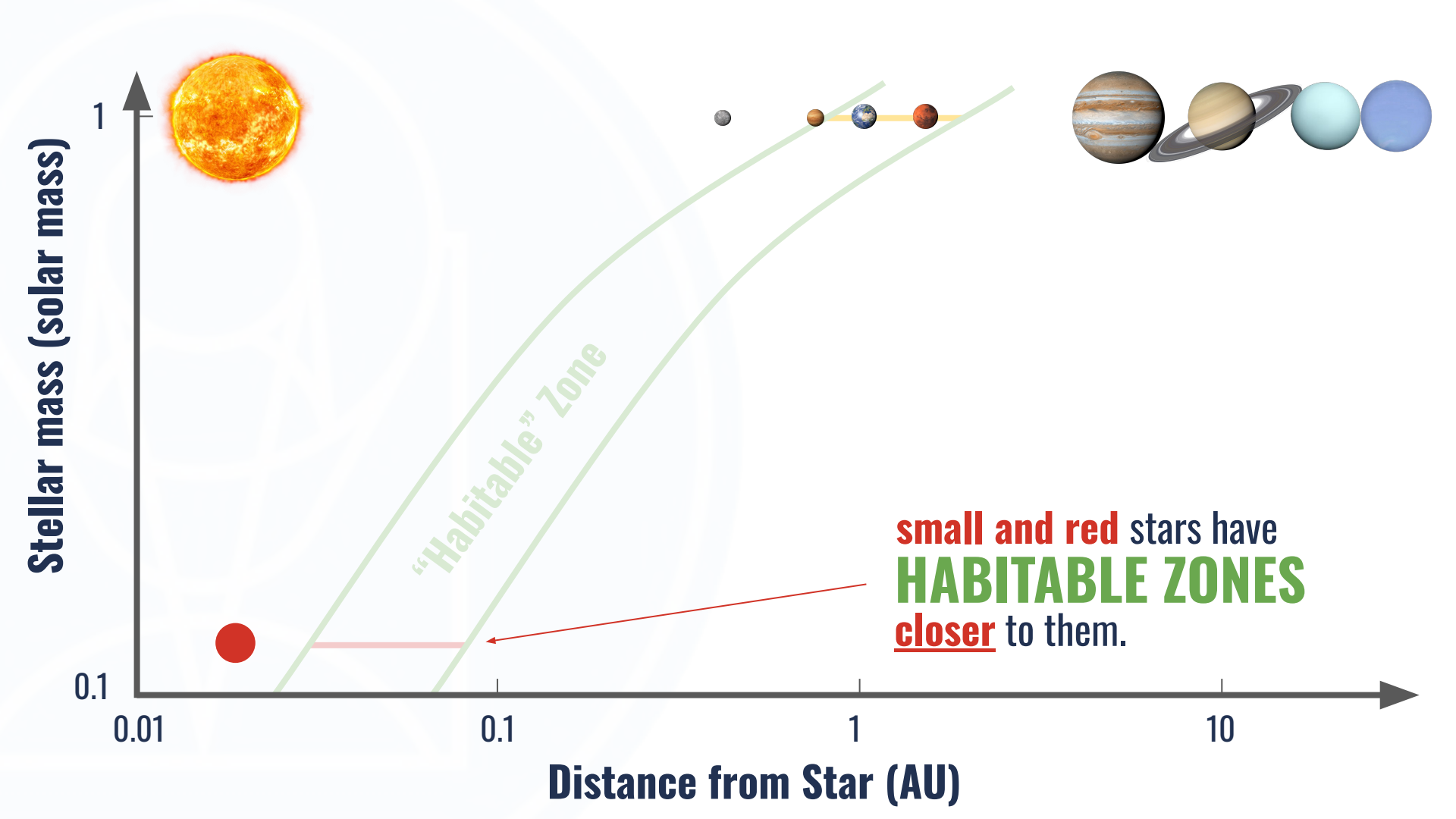


Most stars out there* are small and red.

*about 70% of stars within 10 pc are M-dwarfs a number that likely extends to the rest of our galaxy too!




1
0.1
Stellar mass (solar mass)
"Habitable" Zone
0.01
0.1
1
10
Distance from Star (AU)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0.1
Stellar mass (solar mass)
"Habitable" Zone
small and red stars have
HABITABLE ZONES
closer to them.
0.01
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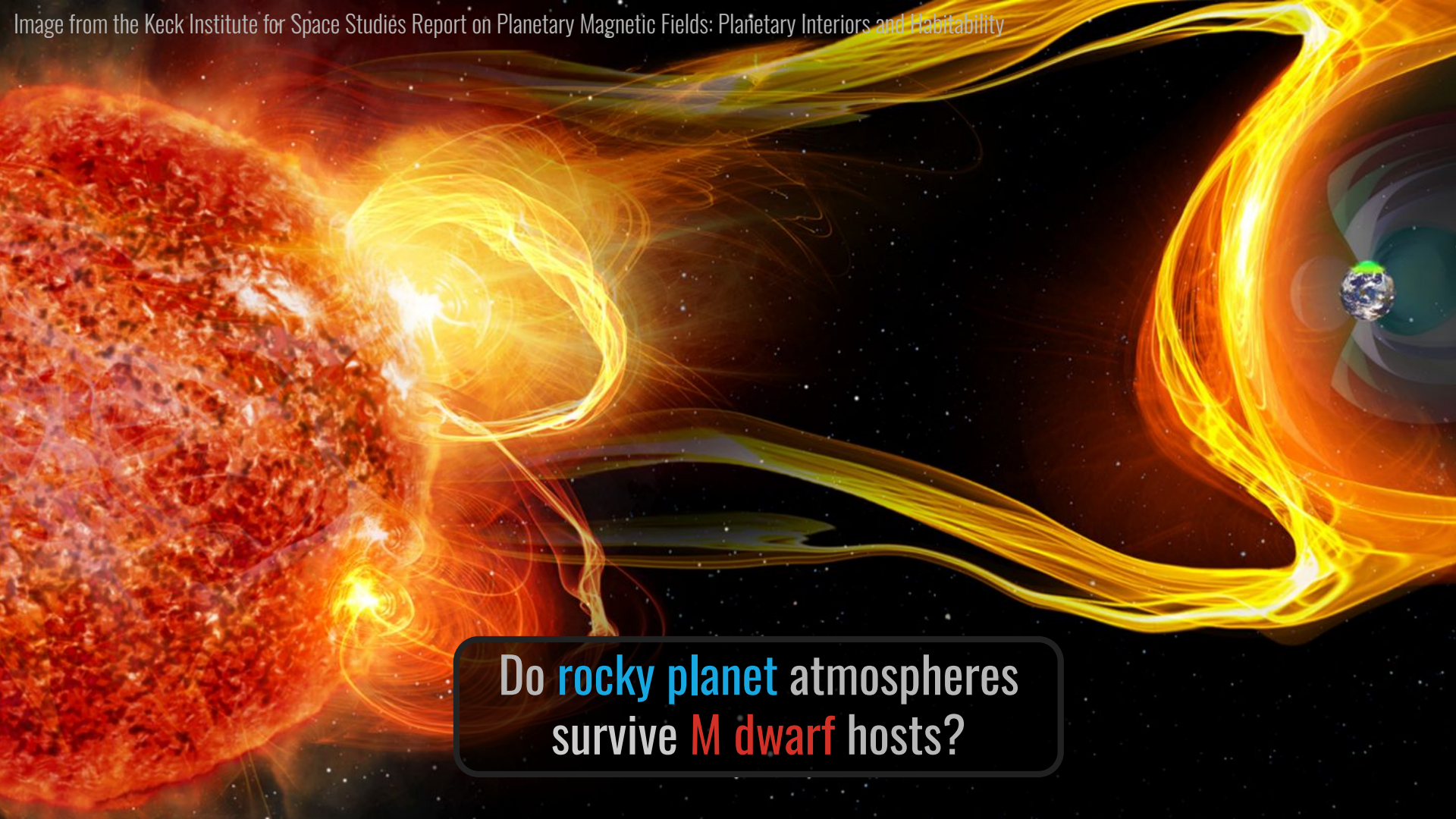
Distance from Star (AU)

Image from the Keck Institute for Space Studies Report on Planetary Magnetic Fields: Planetary Interiors and Habitability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Do rocky planet atmospheres survive M dwarf hosts?

The Cosmic Shoreline Concept

Zahnle & Catling (2017); Pass, et al., (2025) Ji, et al., (2025) Berta-Thompson (2025)

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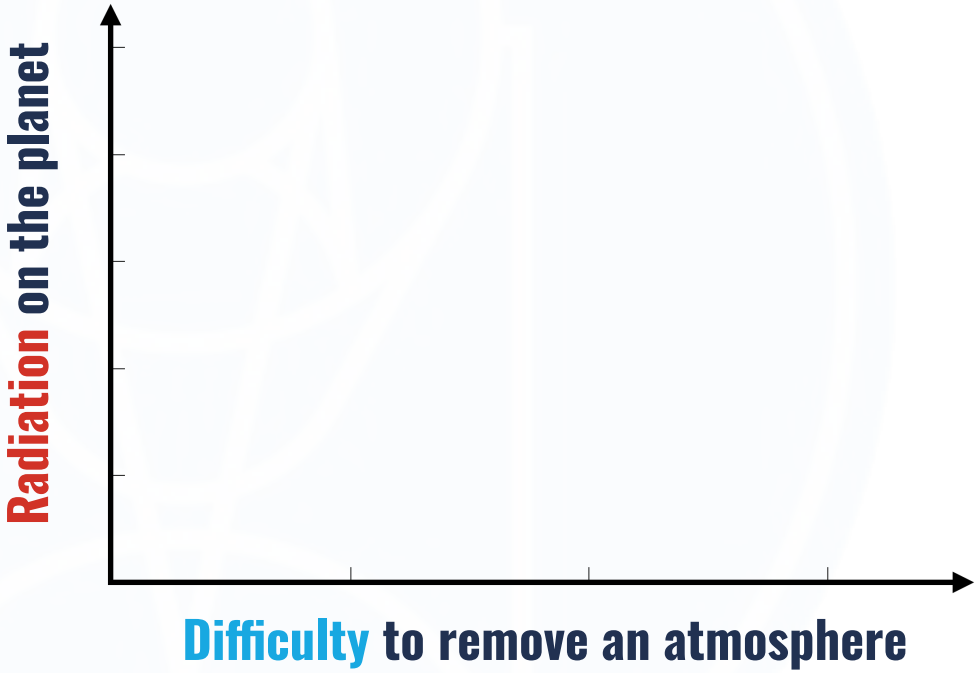

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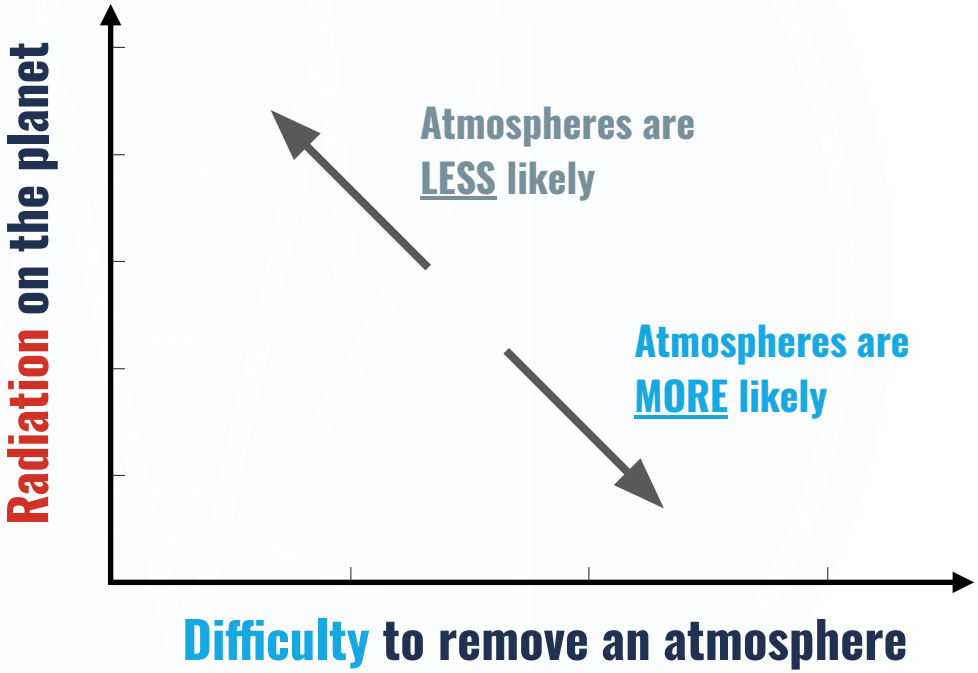

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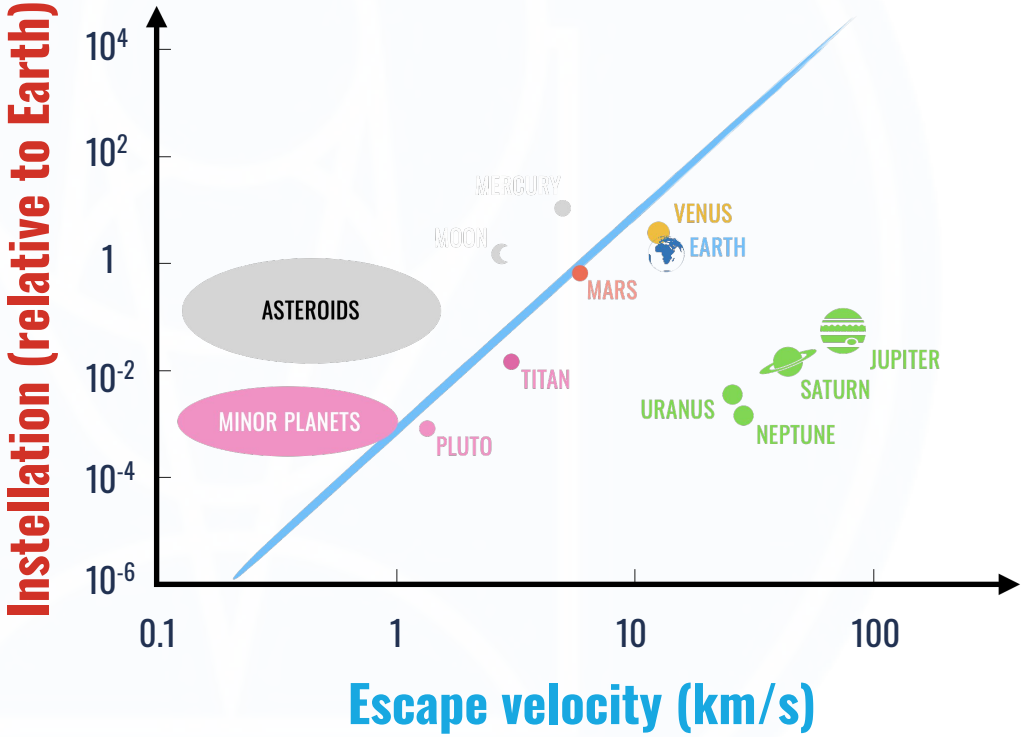

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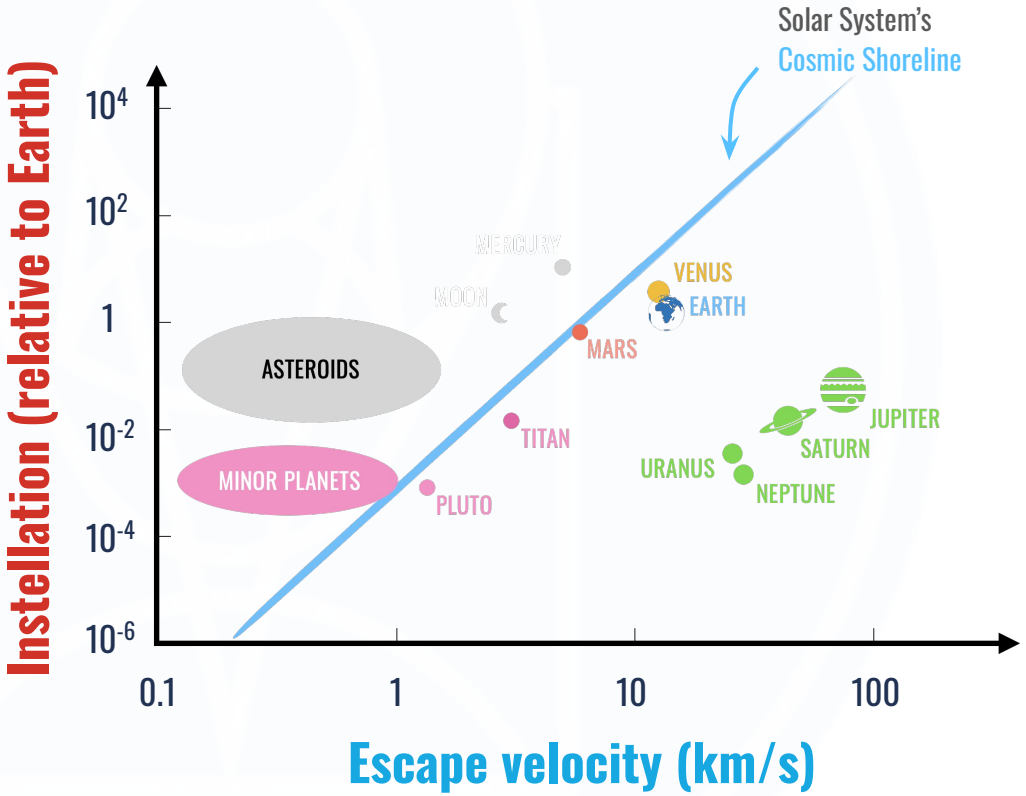

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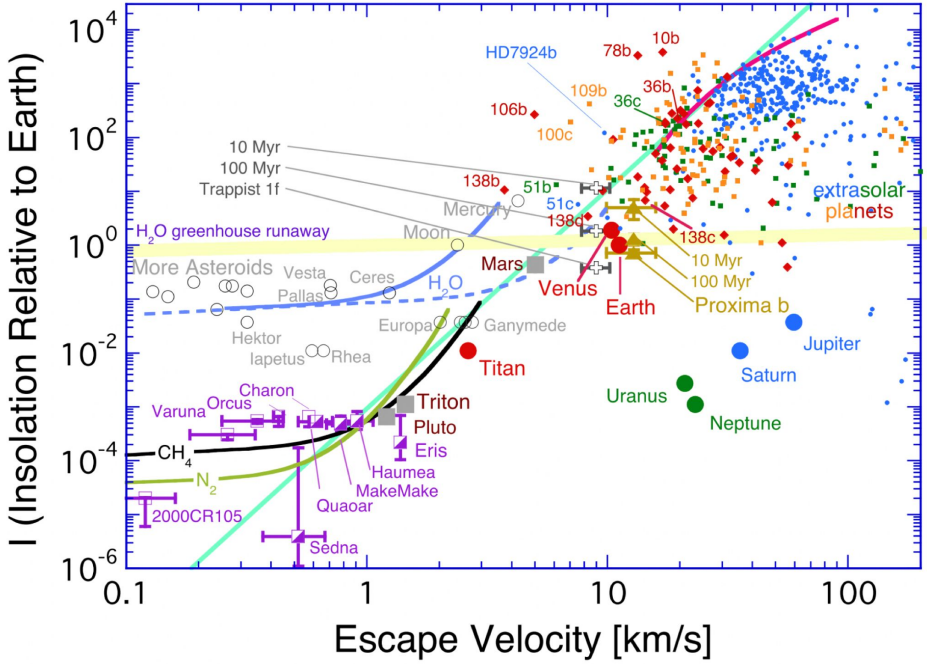

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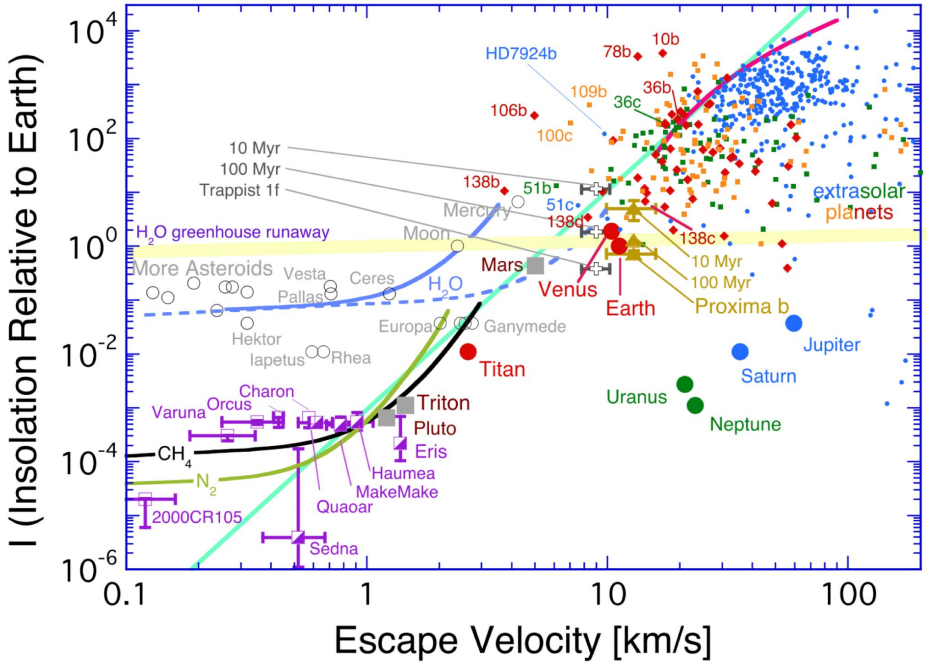

Does the Cosmic Shoreline apply for

EXOPLANETS?

Would the Cosmic Shoreline change for

OTHER STARS?

How?

How?

Rocky exoplanets orbiting M-dwarfs only doable with

transiting exoplanets

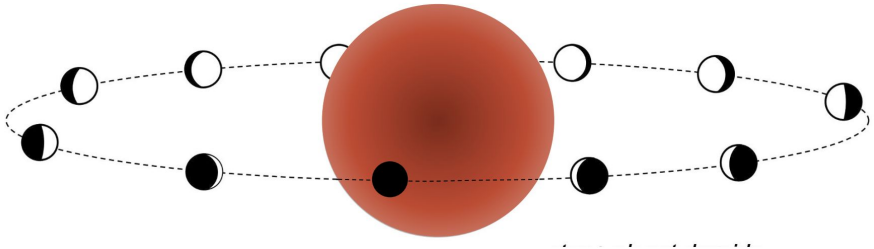

Image credit: Winn+2010

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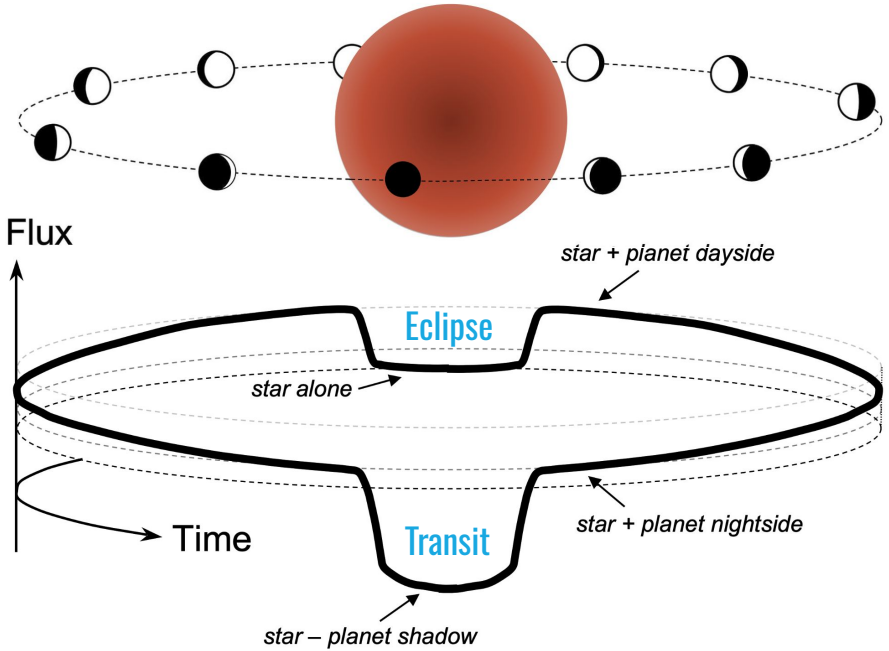

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Secondary eclipses

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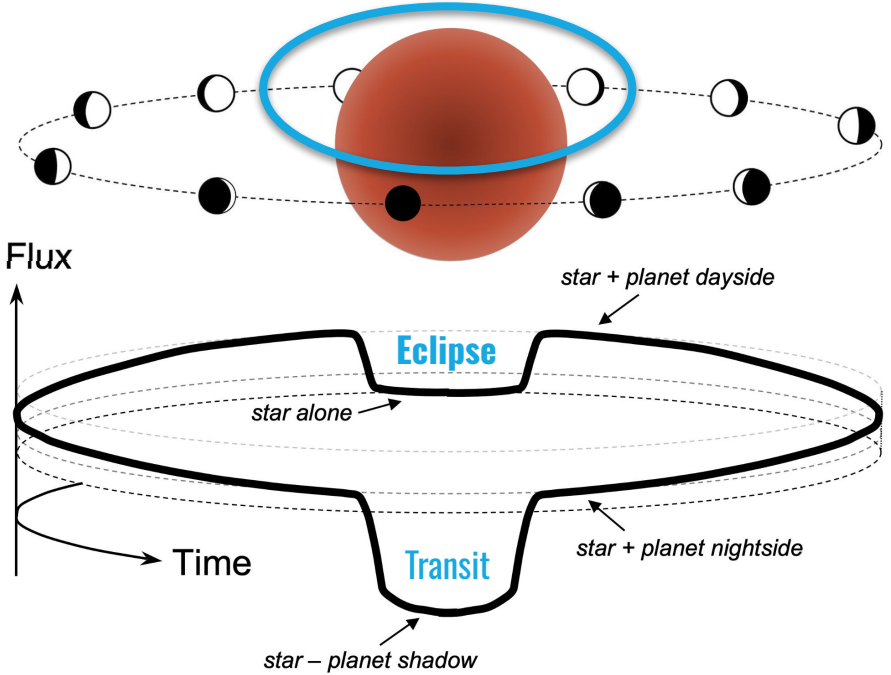

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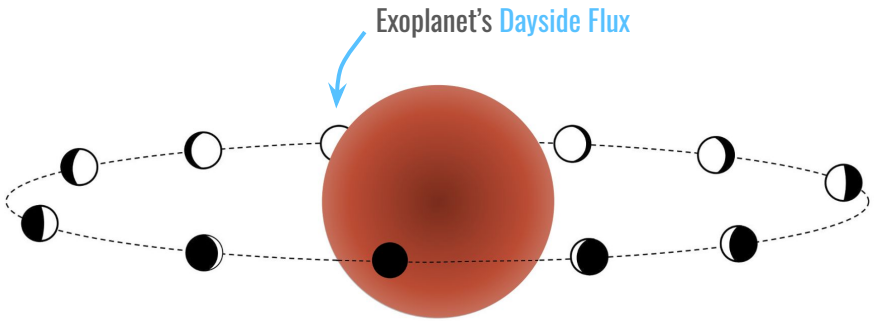

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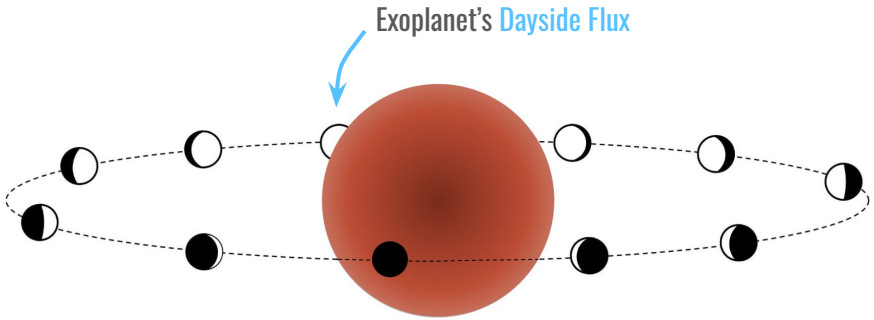
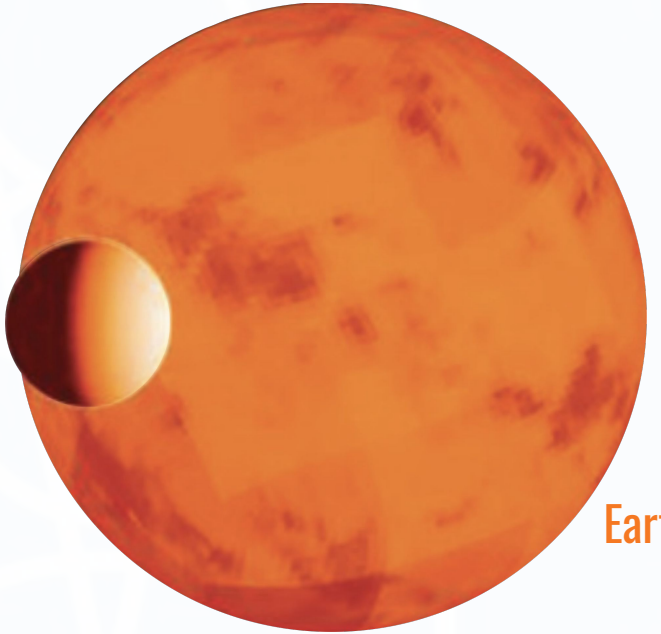
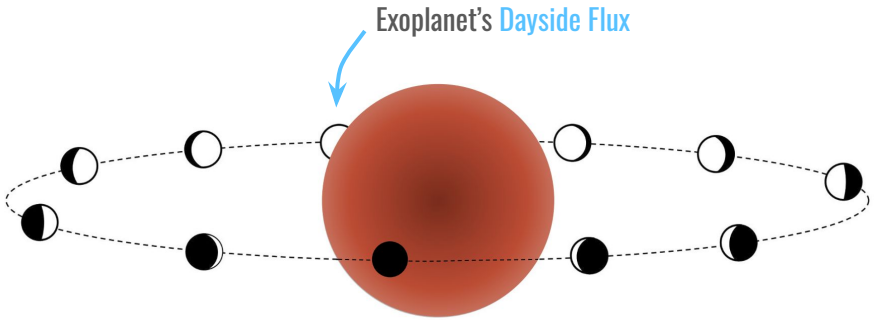


Moon & **Earth** at 0.6 μm (optical light)

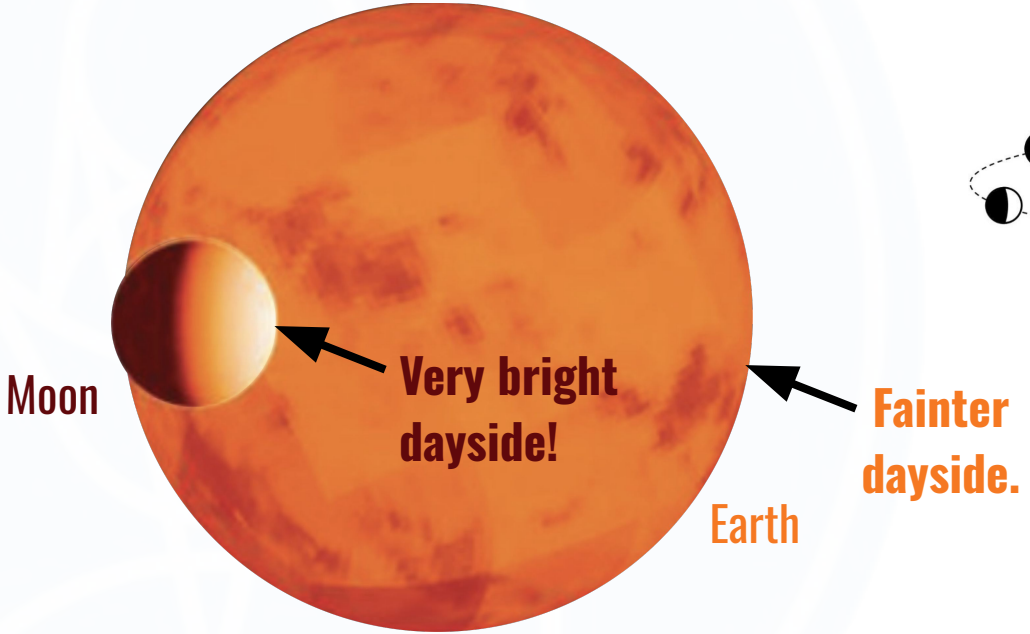
Secondary eclipses

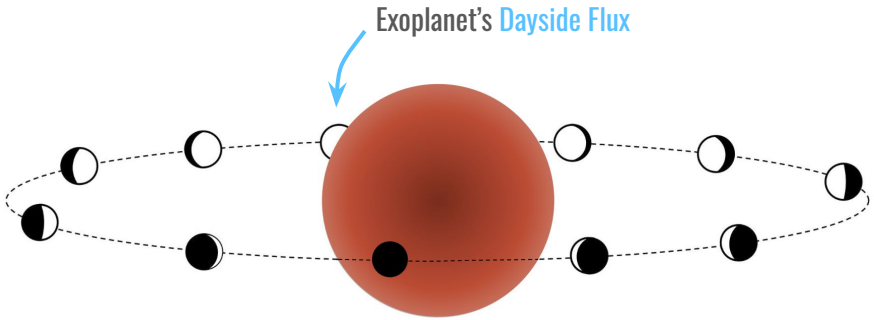




Moon & **Earth** at 10 μm (Robinson+2011)

Secondary eclipses: JWST gets thermal emission





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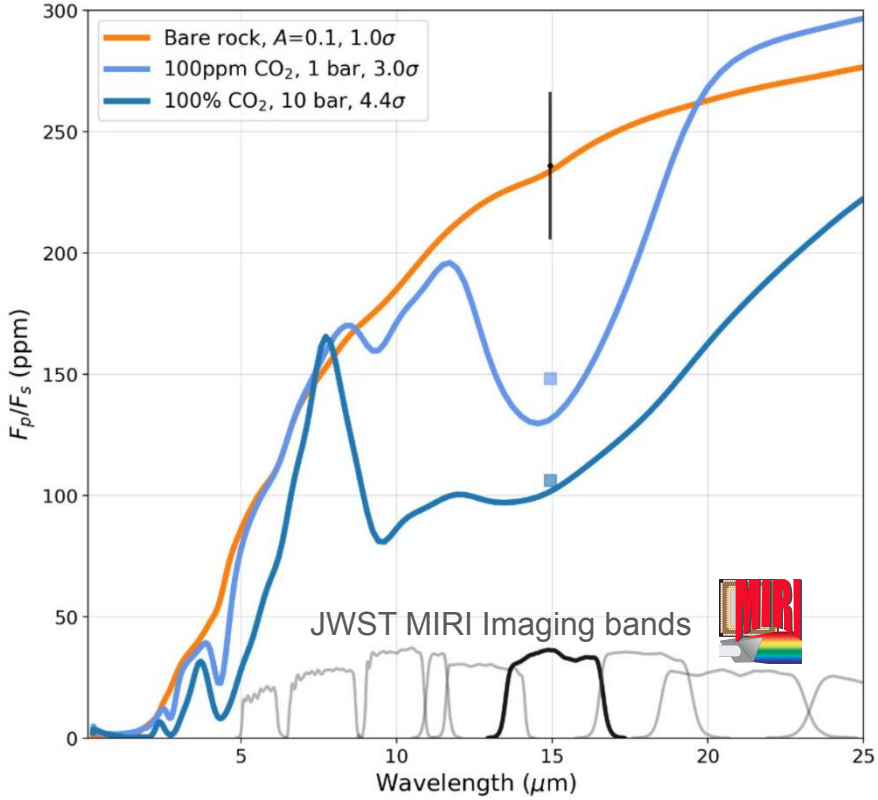

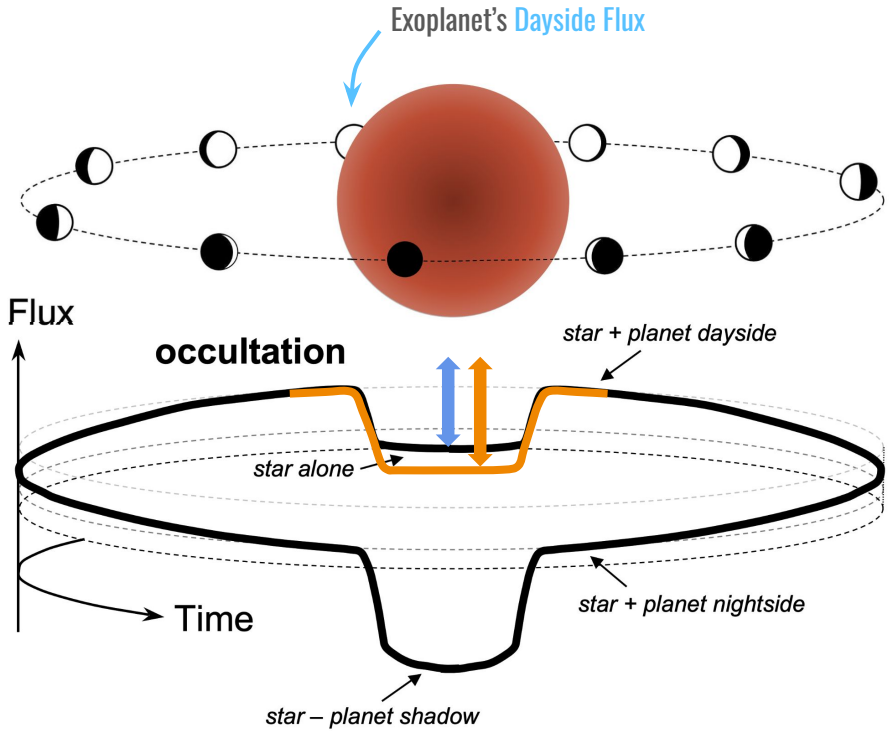

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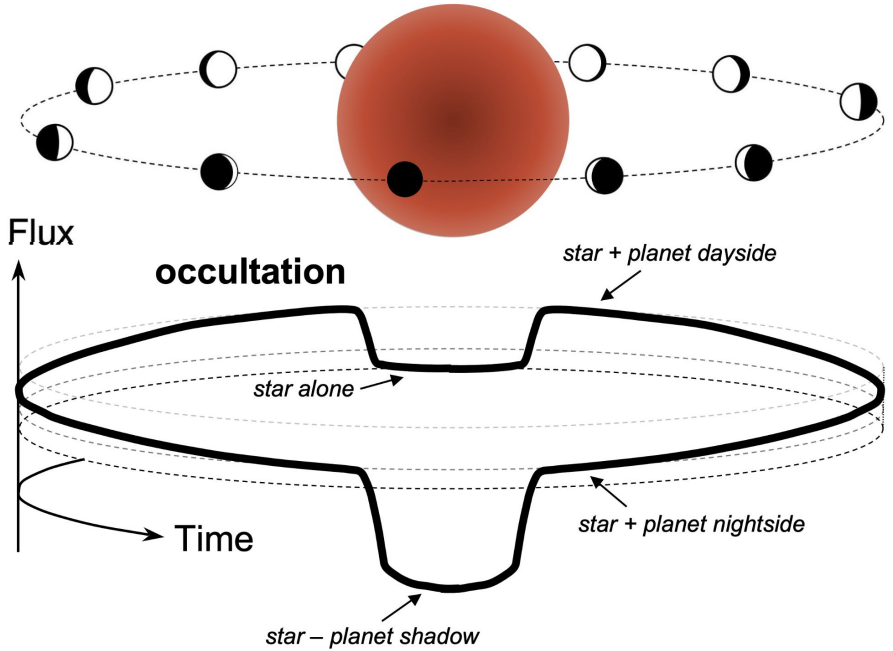
JWST MIRI Imaging bands



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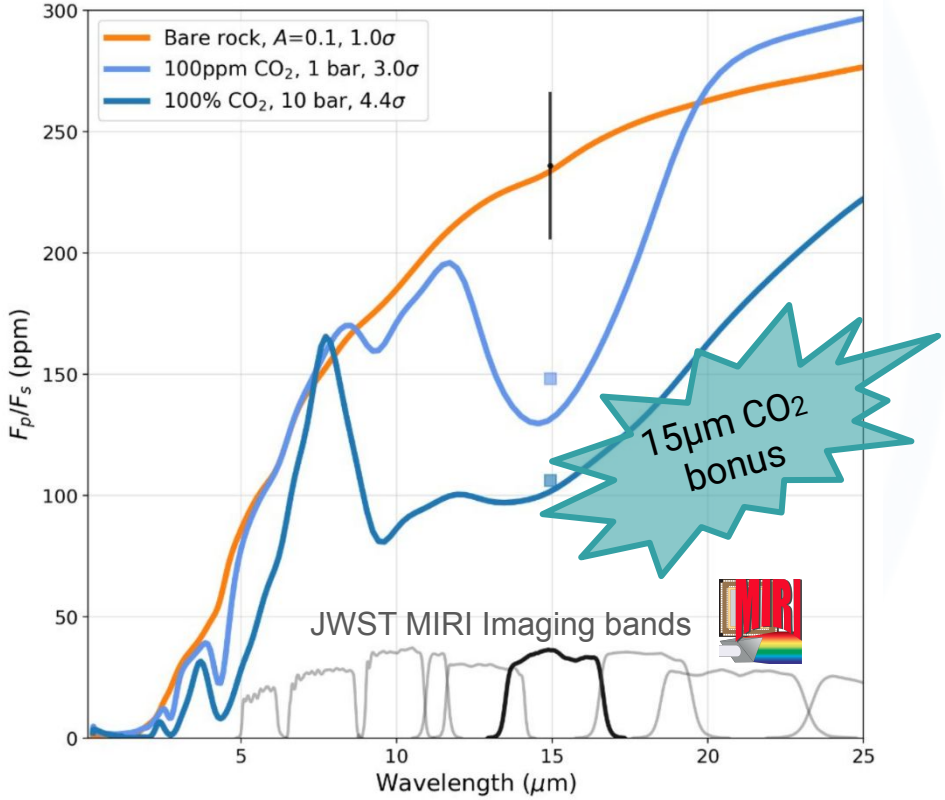

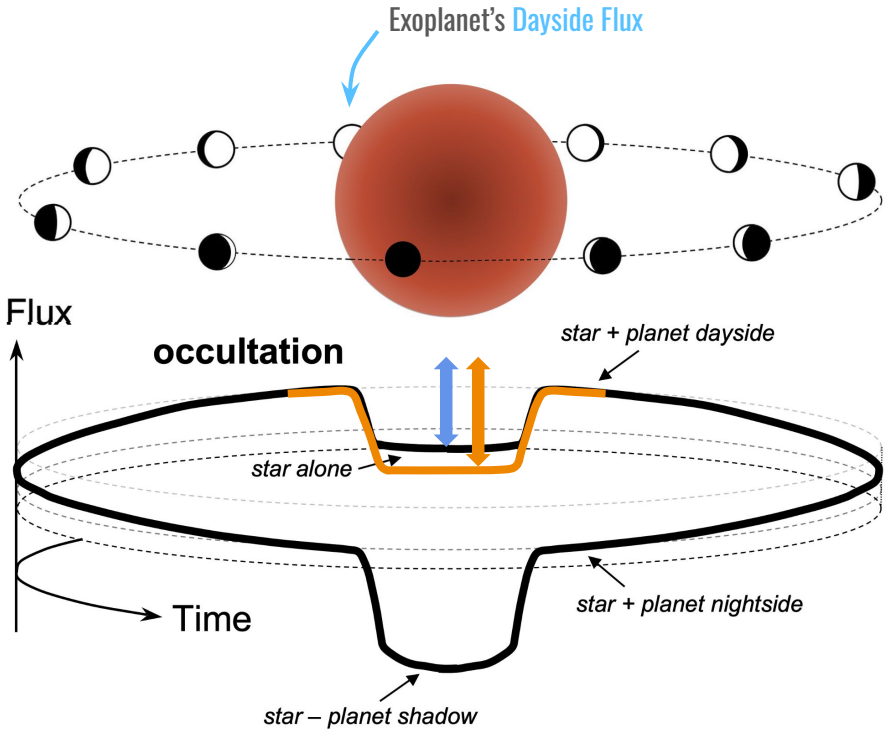

HST allows us to understand the star in the UV

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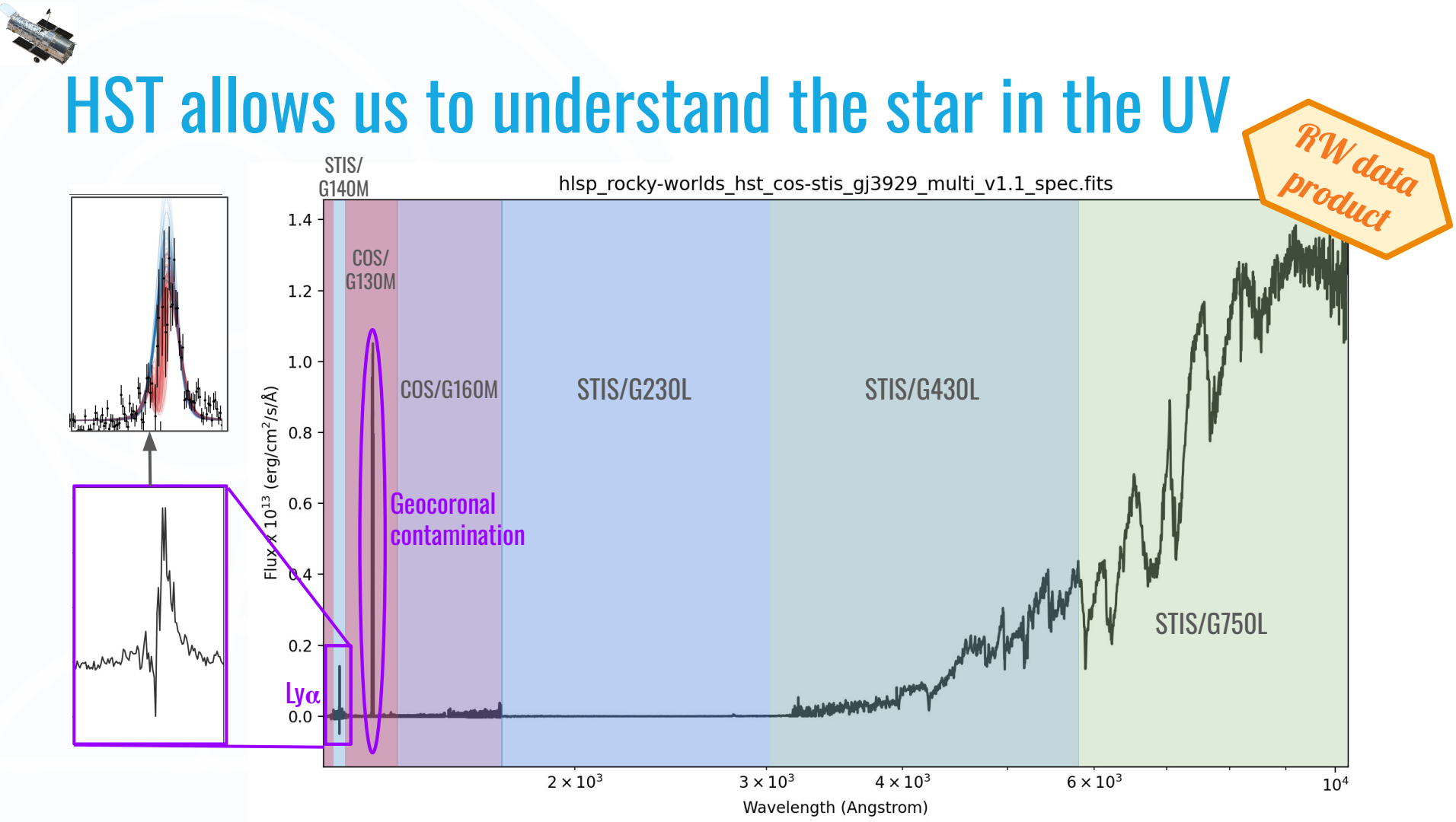

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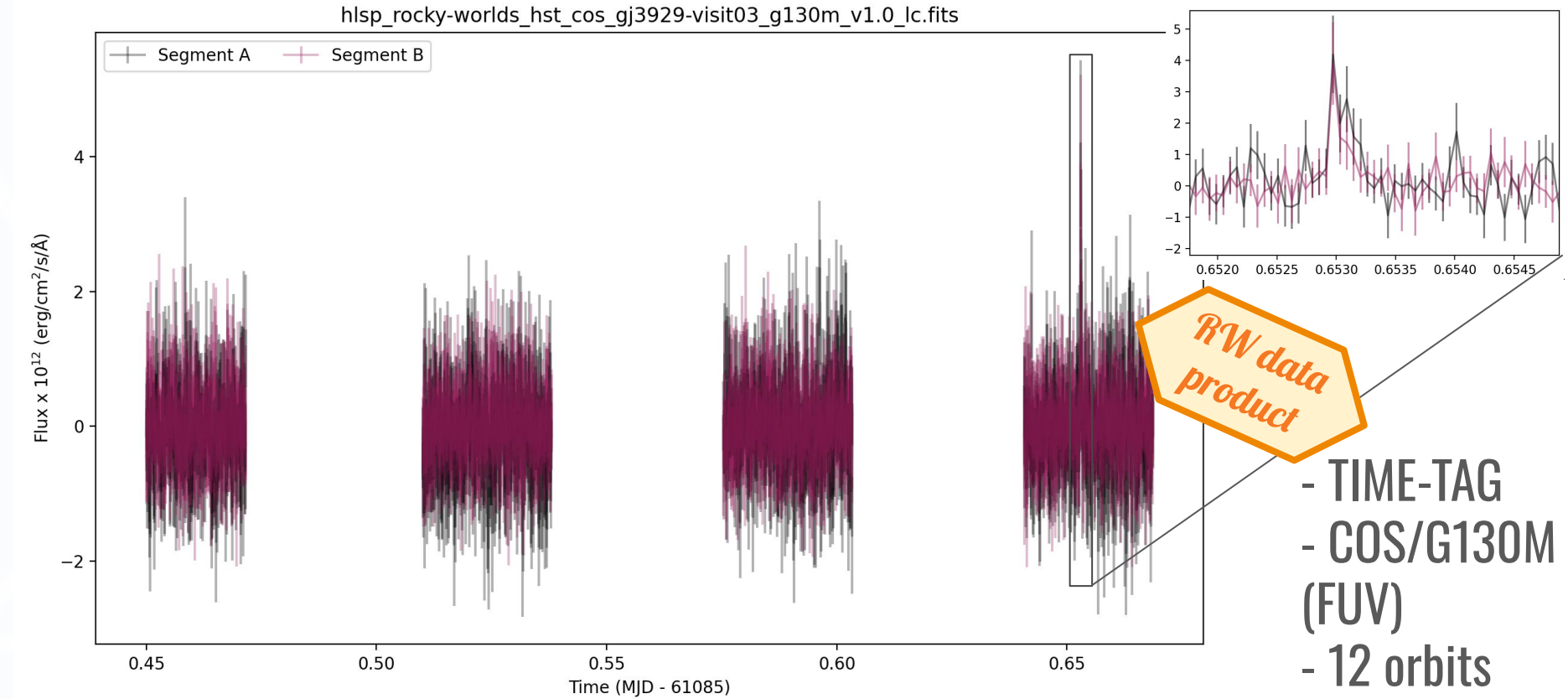

Looking for (CO_2) atmospheres

Sample: M dwarf rocky planets and the Cosmic Shoreline

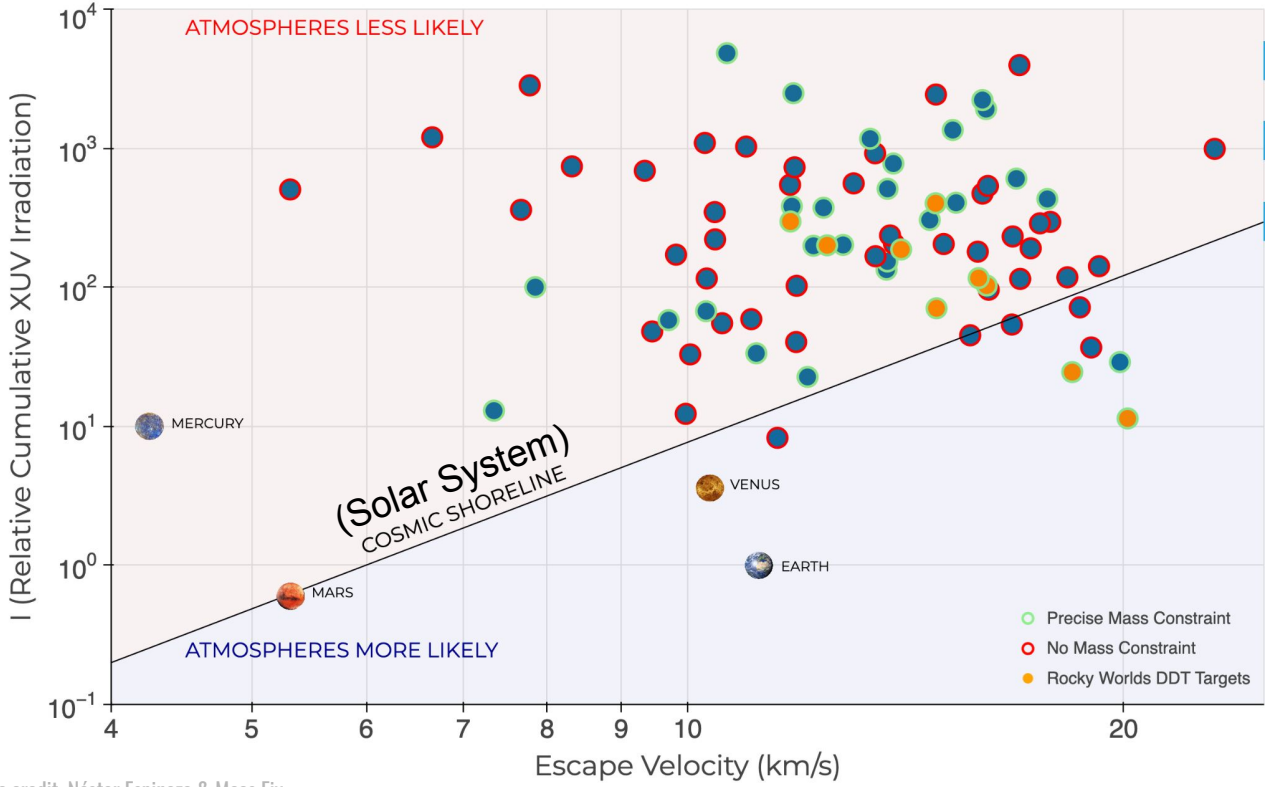

Image credit: Néstor Espinoza & Mees Fix

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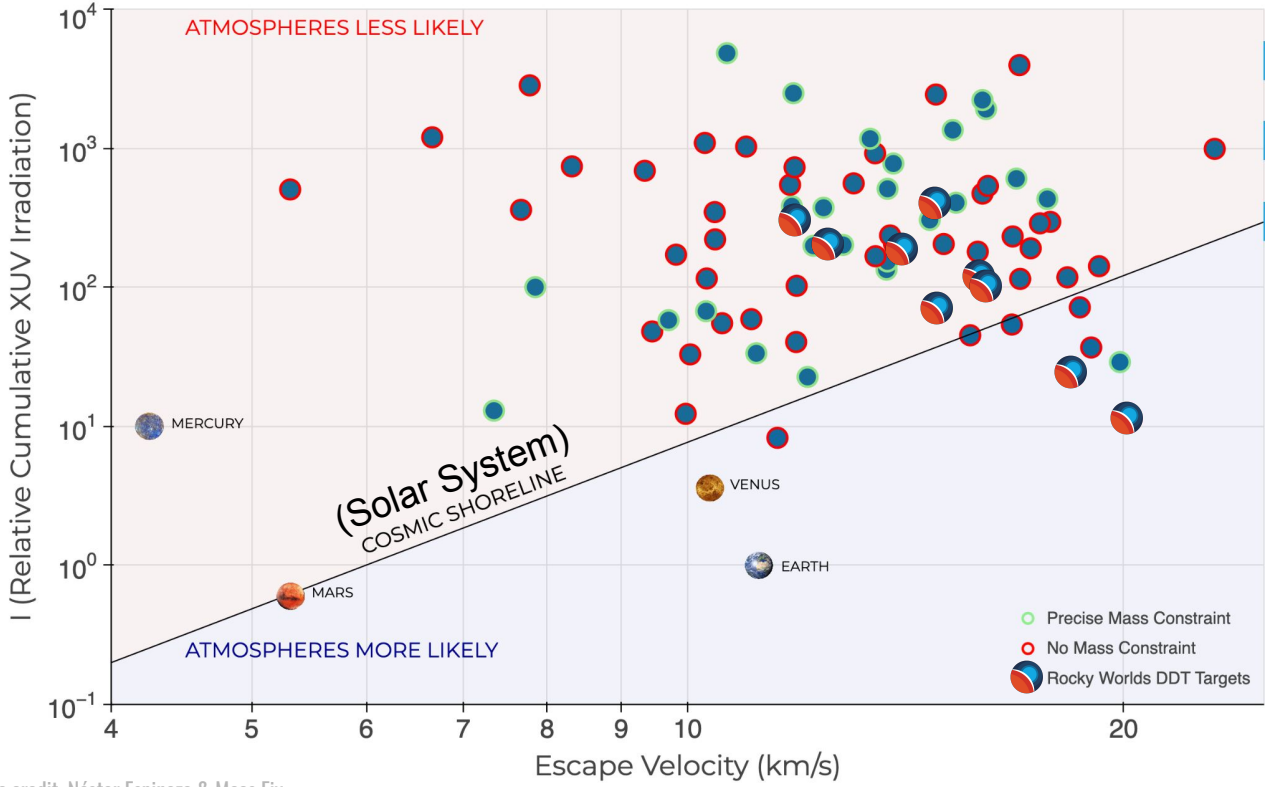

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The ROCKY WORLDS sample

- 9 planets around 8 M-dwarfs.
- Covers **both sides** of the **CS**.
- Uniform observing strategy.

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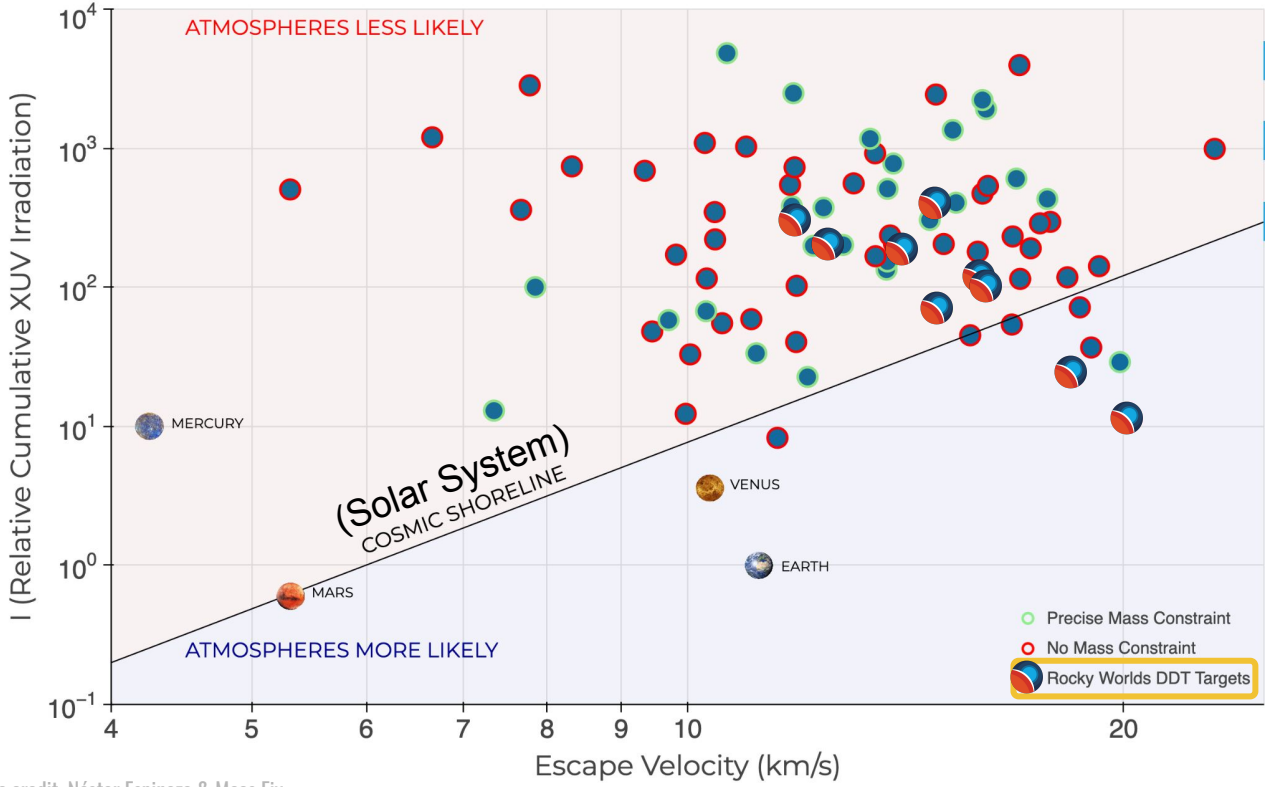

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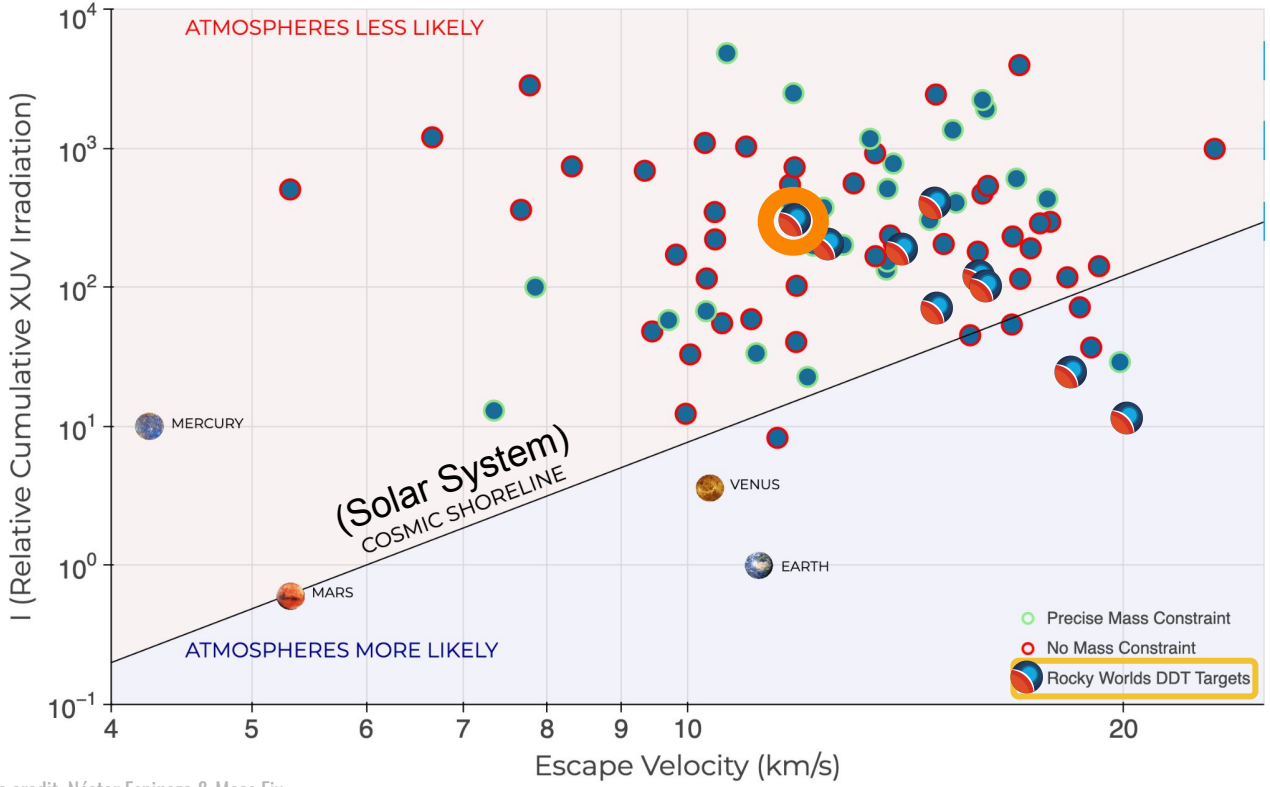

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Published results

GJ 3929 b

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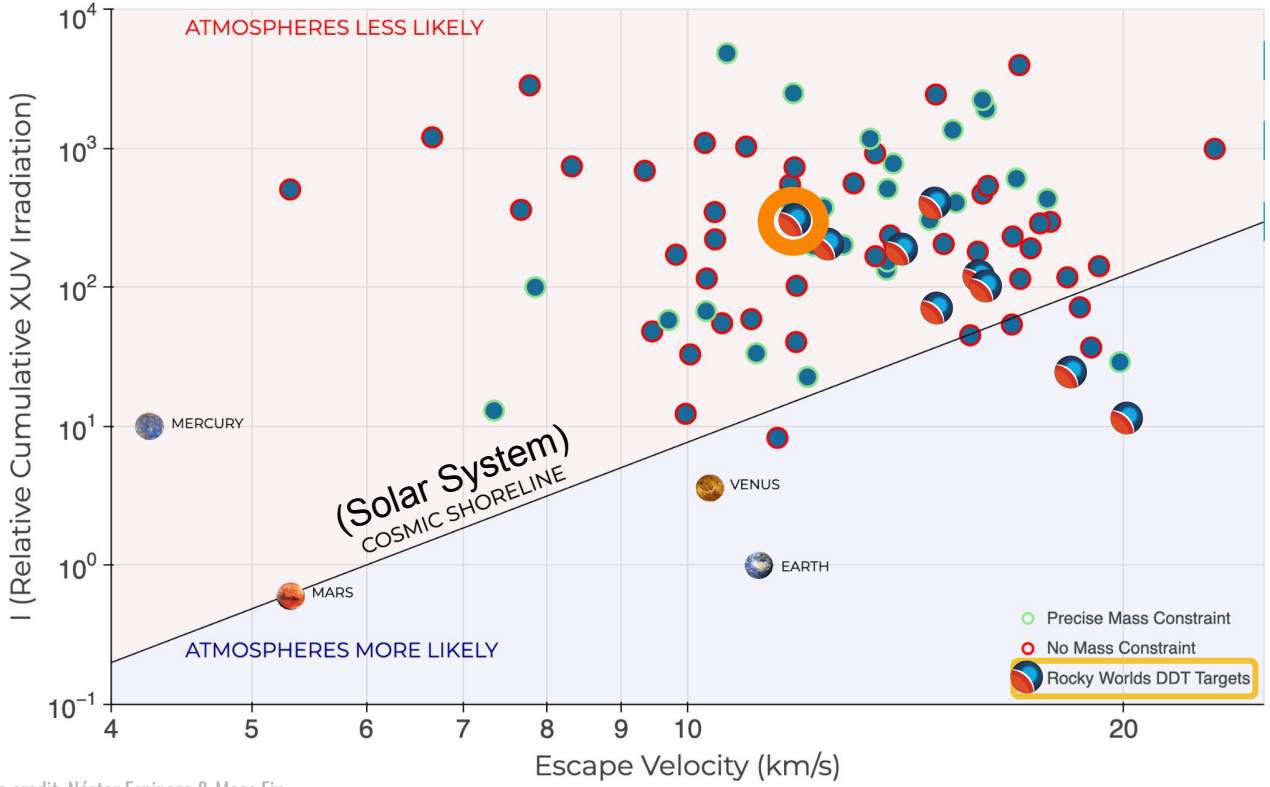

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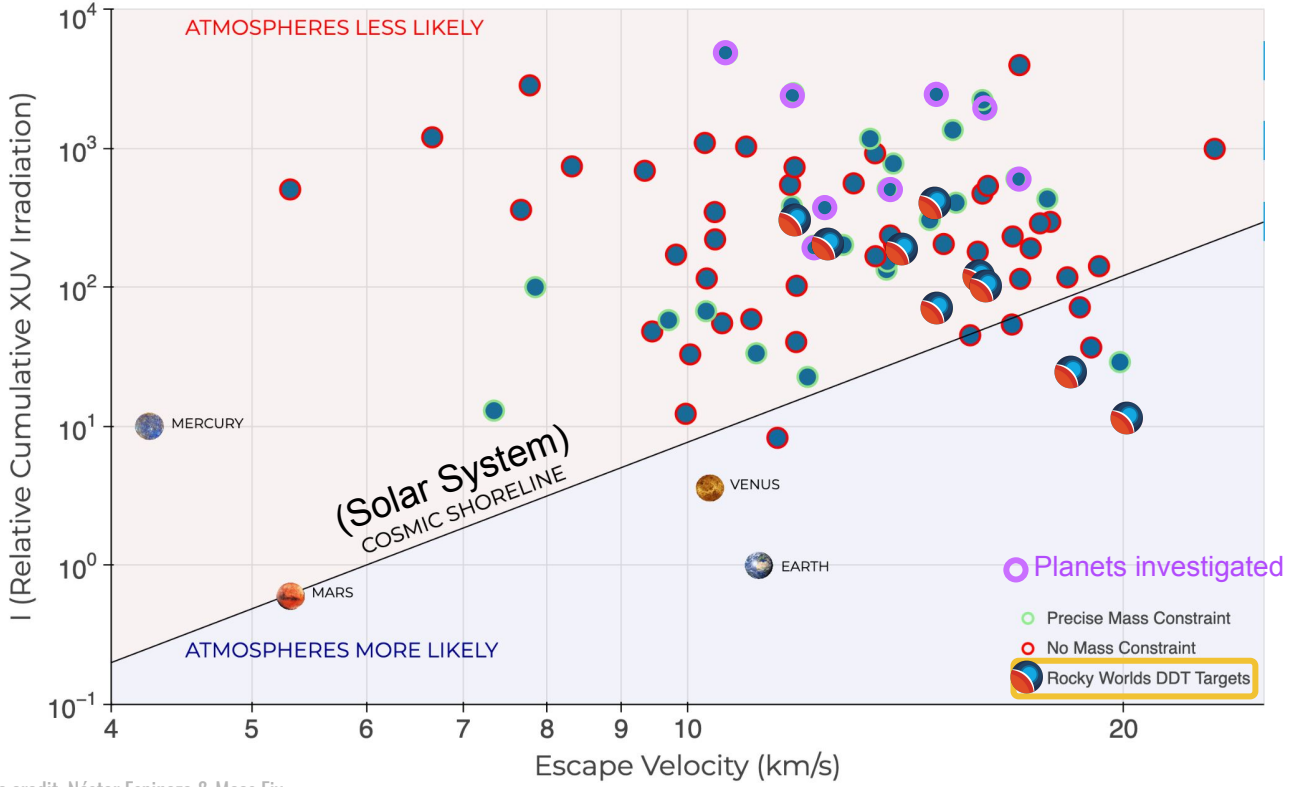

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LHS 3844 b (Kreidberg, et al., 2019)
GJ 1252 b (Crossfield, et al., 2022)
TRAPPIST-1 b (Greene, et al., 2023, Ih, et al., 2023, Gillon, et al., 2025)
TRAPPIST-1 c (Zieba, et al., 2023, Ducrot, et al., 2024, Gillon et al., 2025, Maurel, et al., 2025)
GJ 367 b (Zhang, et al., 2024)
GJ 1132 b (Xue, et al., 2024)
GJ 486 b (Weiner Mansfield, et al., 2024)
LTT 1445 A b (Wachiraphan, et al., 2025)
TOI-1685 b (Luque, et al., 2025)

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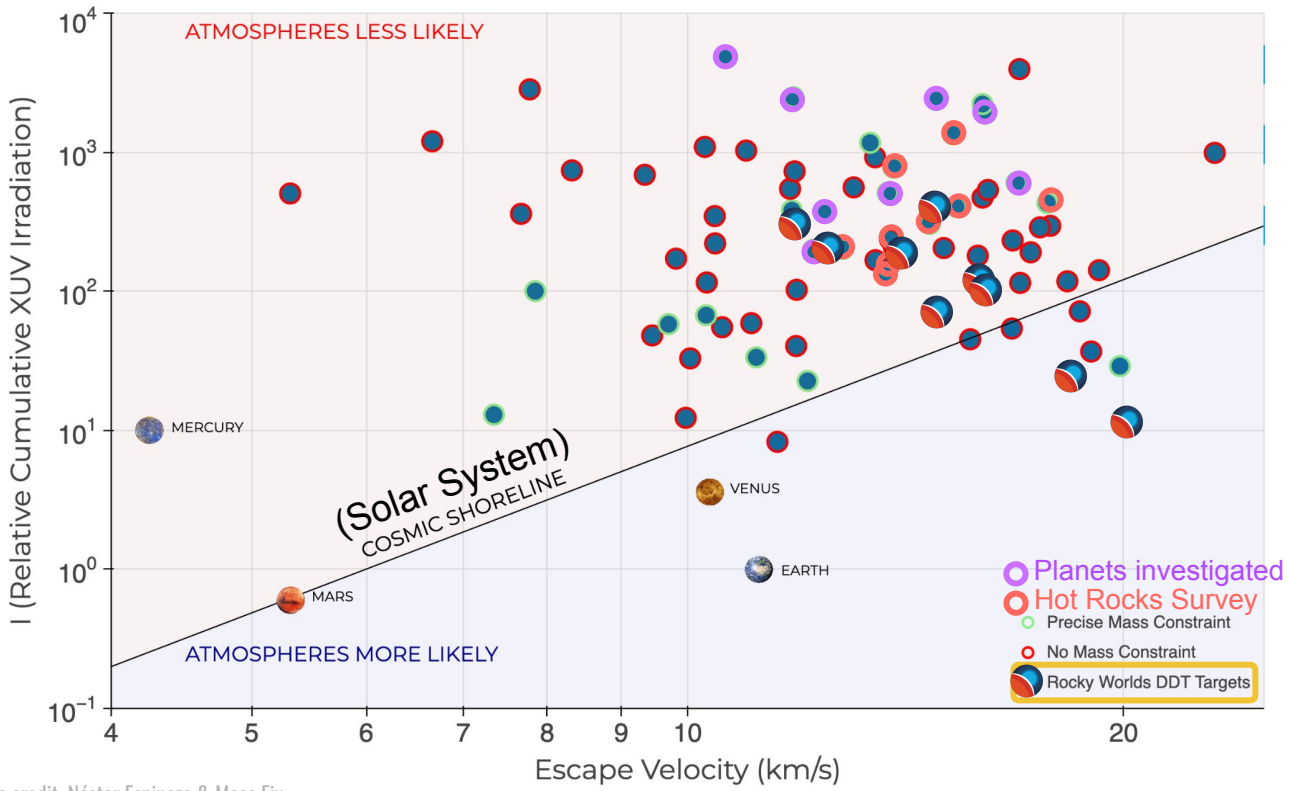

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hot-rocks.vercel.app

Hot Rocks Survey I: LHS 1478 b
(August, et al. 2025)
Hot Rocks Survey II: TOI-1468 b
(Meier Valdés, et al., 2025)
Hot Rocks Survey III: LHS 1140 c
(Fortune, et al., 2025)
Hot Rocks Survey IV: LTT 3780 b
(Allen, et al., 2025)
Hot Rocks Survey V: GJ 3473 b
(Holmberg, et al., 2026)
Hot Rocks Survey VI, VII, VIII, IX, X
(in prep)

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and you

Data & Schedule Access: rockyworlds.stsci.edu

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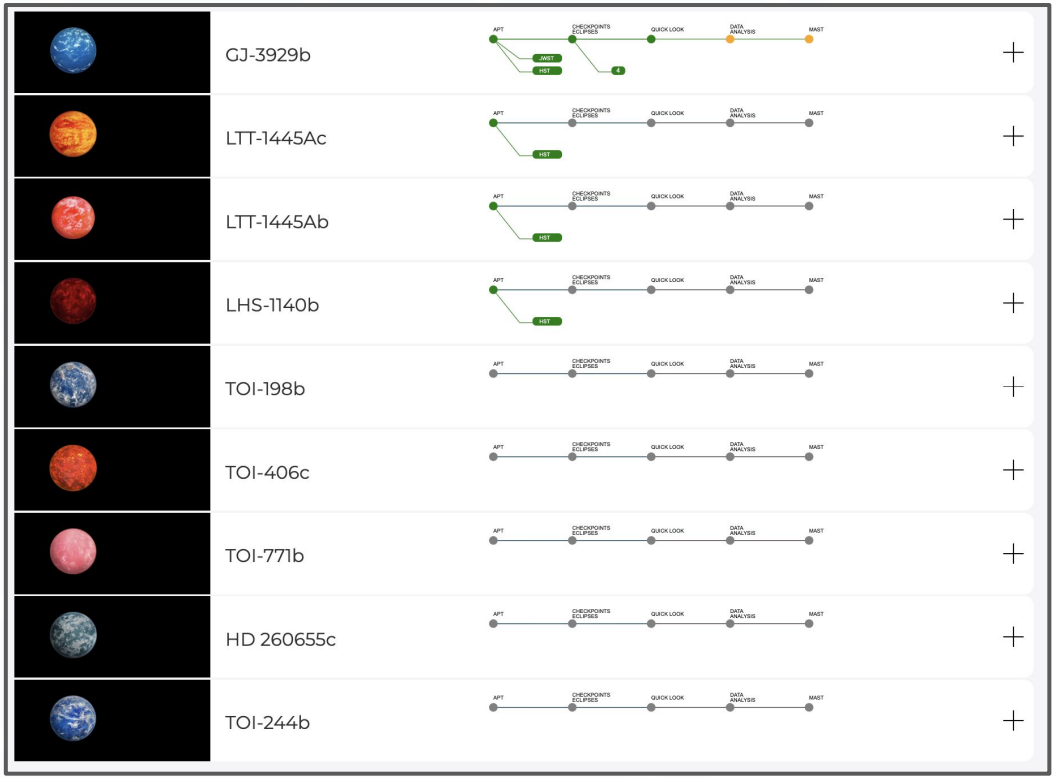

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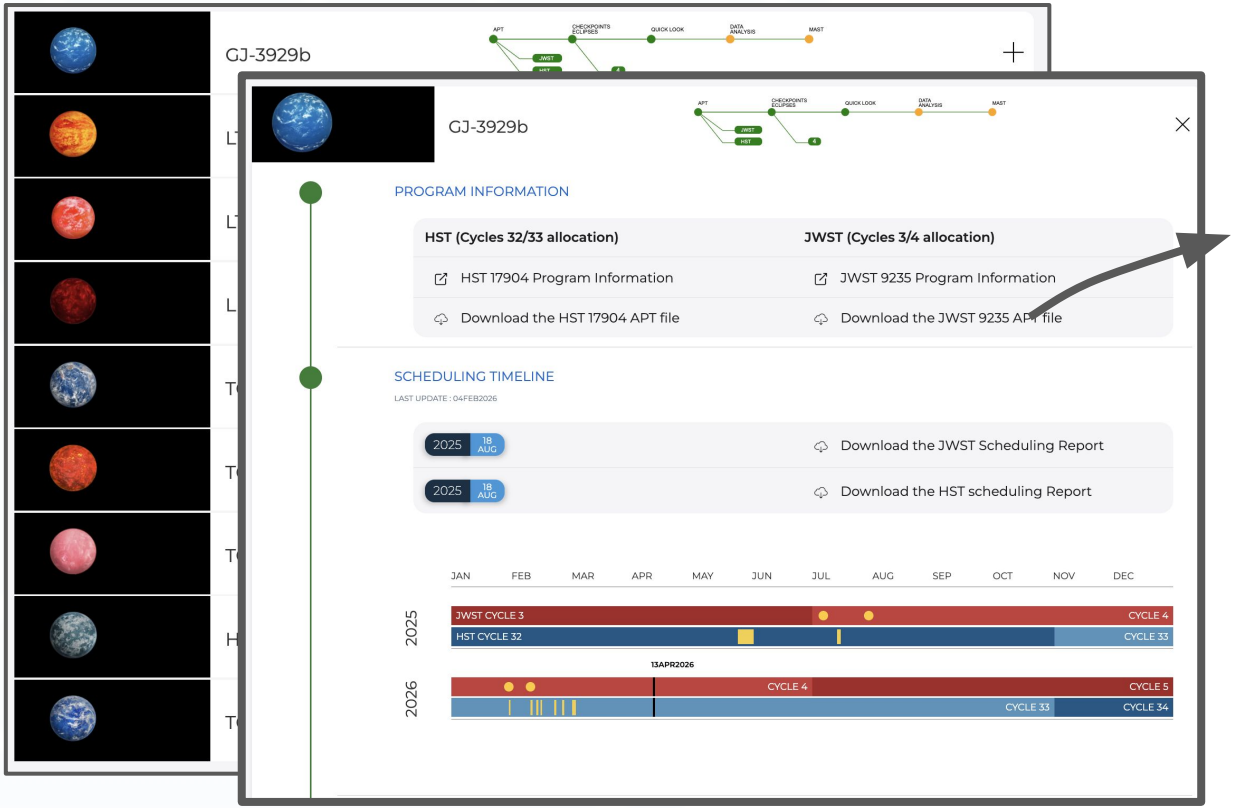

Most up-to-date information about every target!

Status of observations

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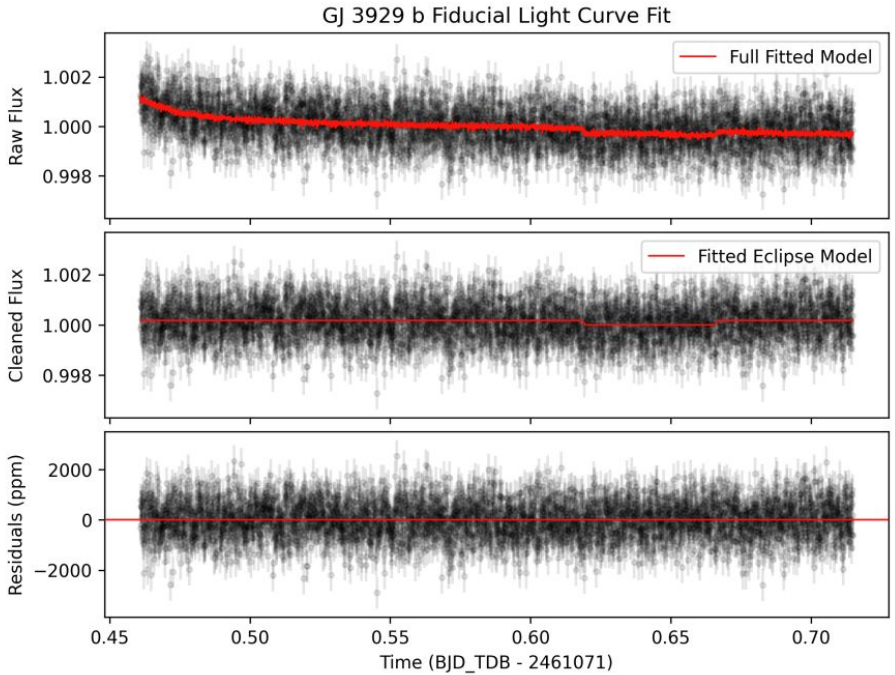
All **JWST eclipses of GJ 3929 b** already obtained, HLSPs published.



Status of observations

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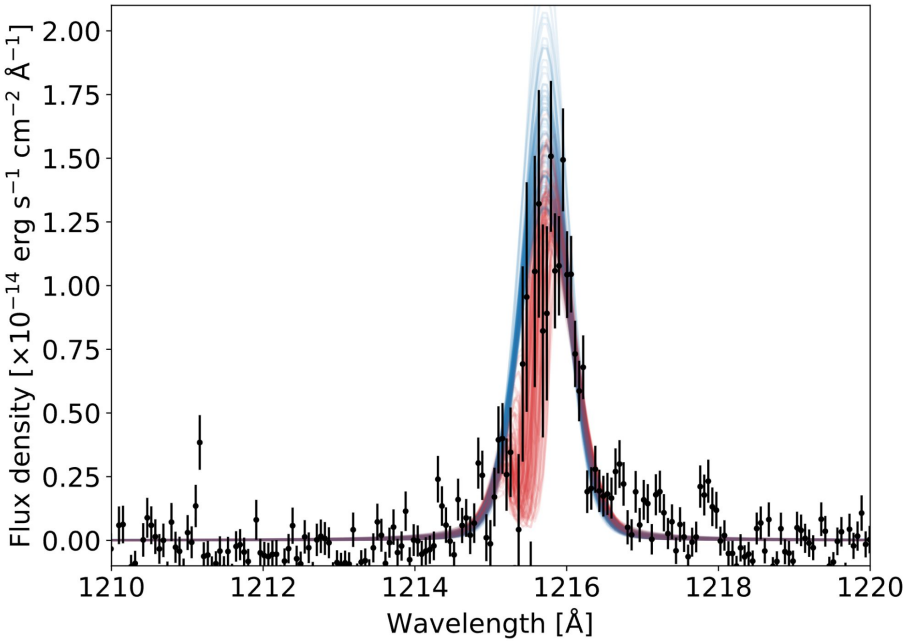
- ***All*** **HST/STIS+COS visits of GJ 3929** has been obtained, HLSPs hitting MAST as we speak!



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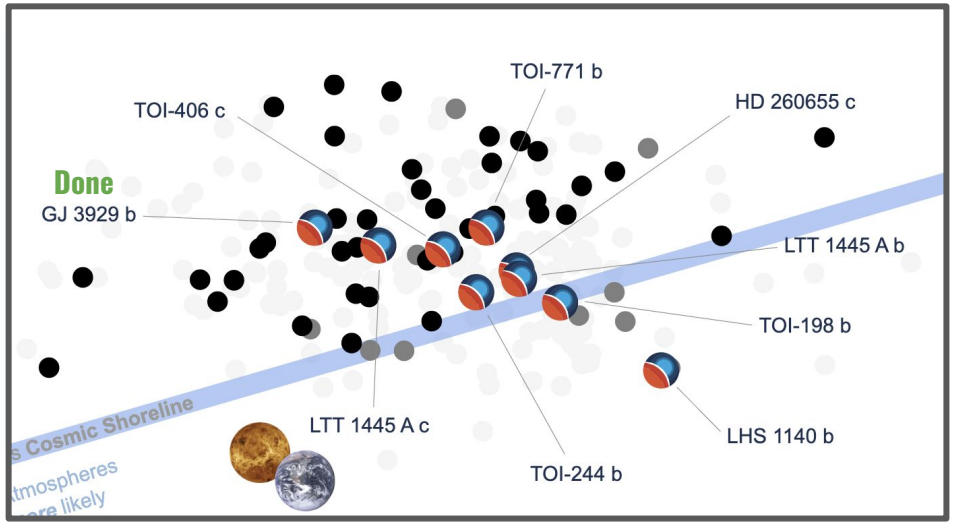

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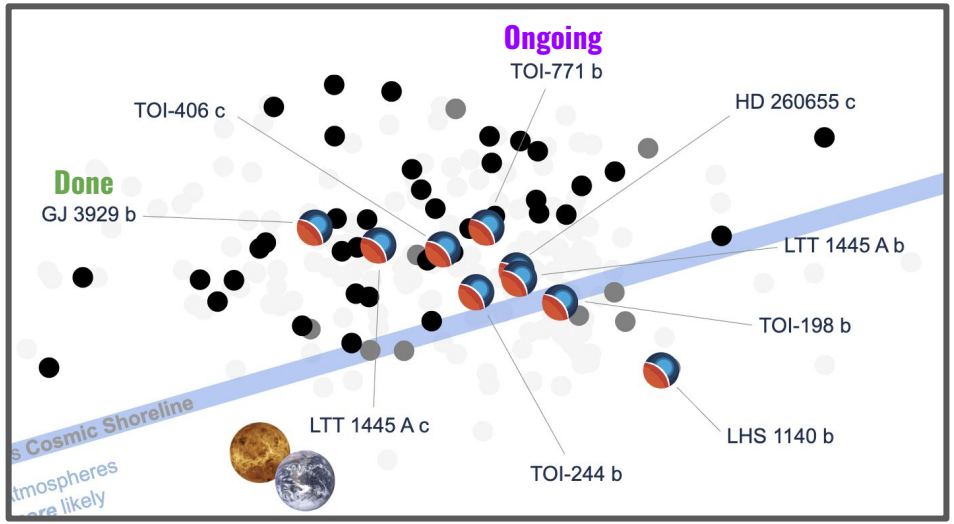

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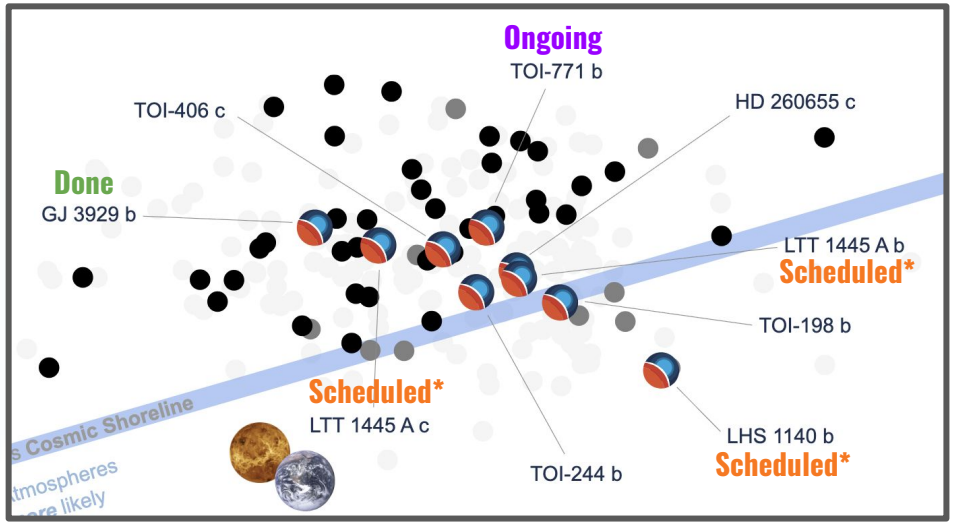

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The ROCKY WORLDS Community Involvement Initiative

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Want to get follow-up data for a Rocky Worlds DDT target — is anyone else taking data?

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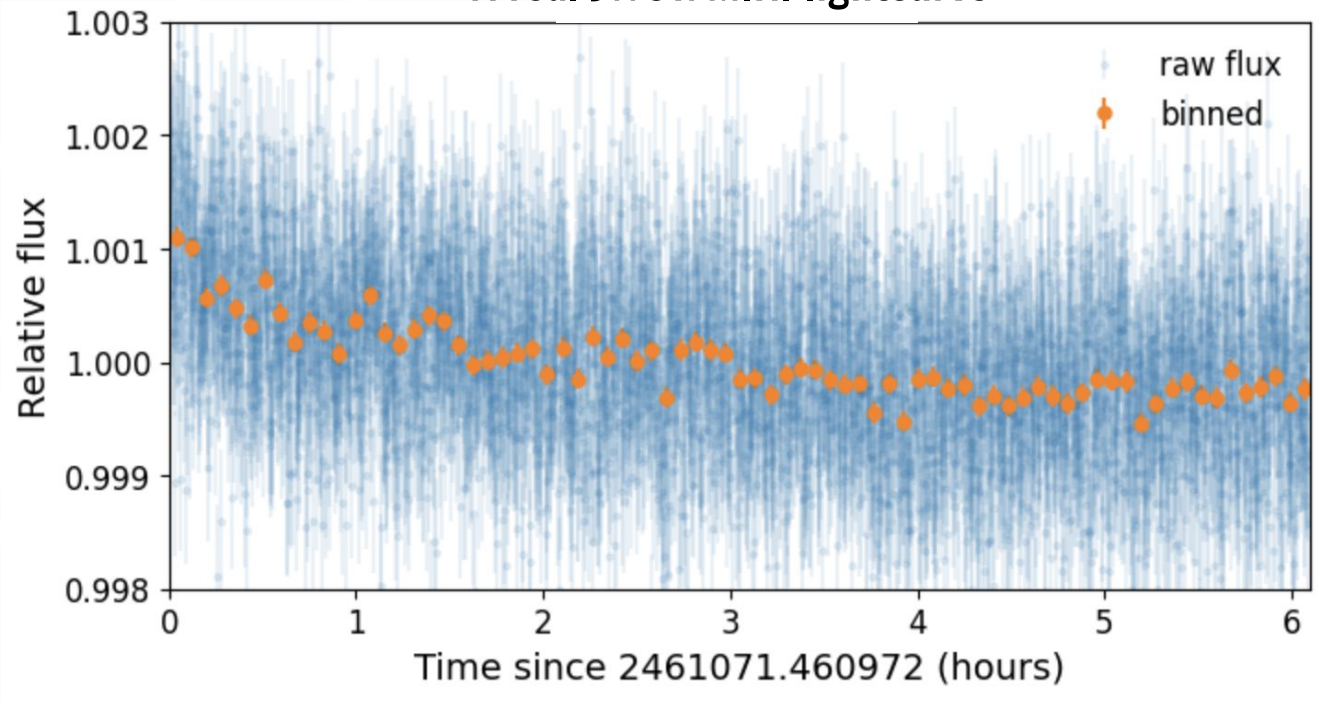
Want to help lead this?

Apply by July 17, 2026

Rocky Worlds Data Challenge & Workshop

Rocky Worlds Data Challenge & Workshop

A real JWST/MIRI lightcurve



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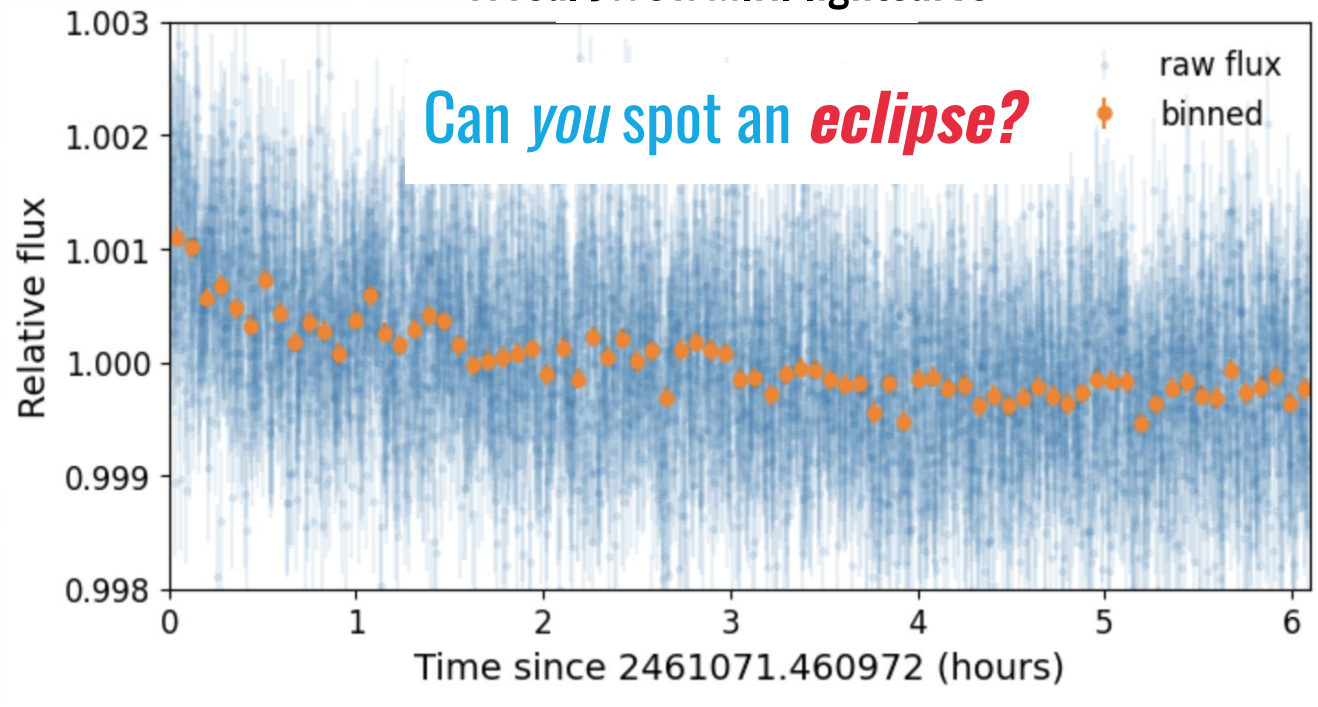

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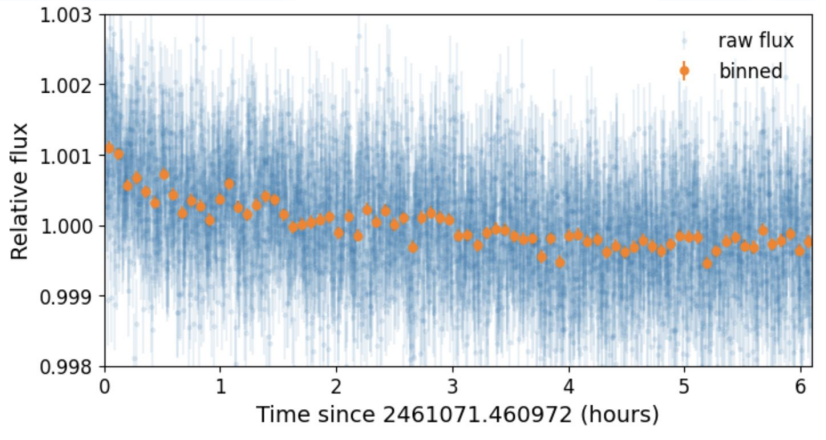

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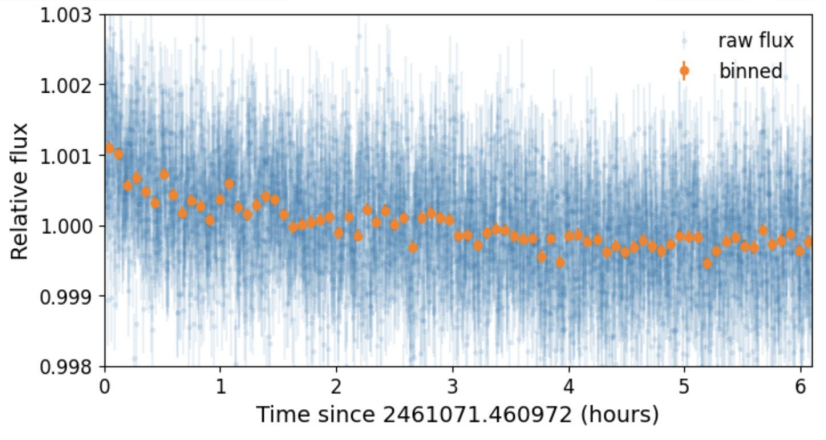

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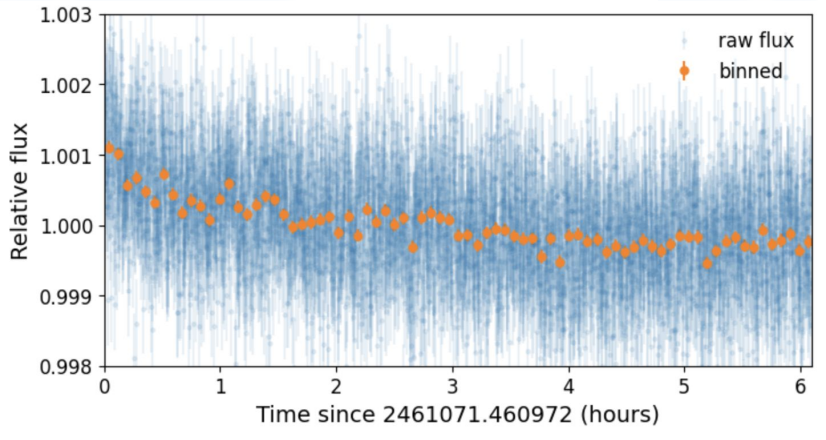
Rocky Worlds Data Challenge & Workshop



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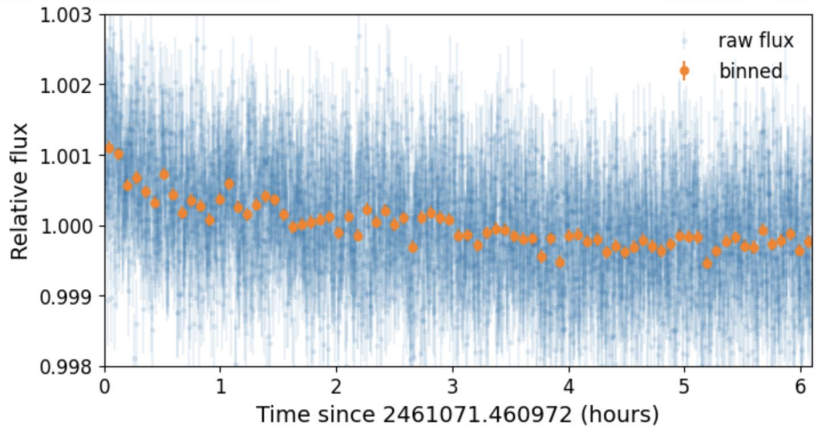

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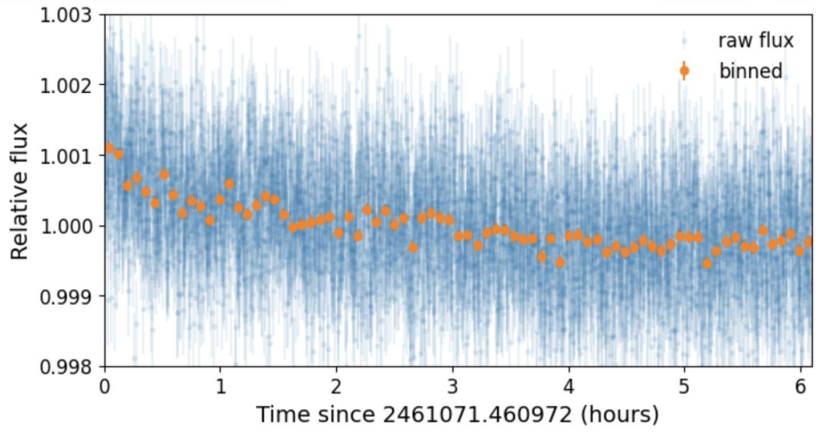

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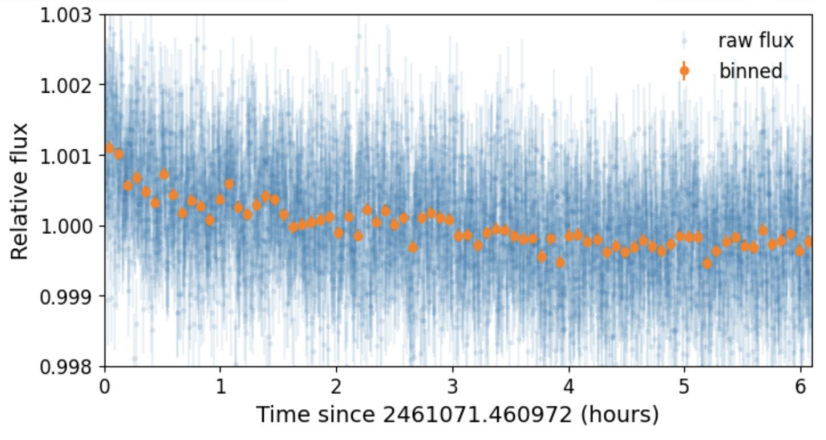
The Rocky Worlds **Data Challenge**

Deadline: August 28, 2026

Rocky Worlds Data Challenge & Workshop



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Real data: GJ 3929 b

Simulated data: LHS 1140 b

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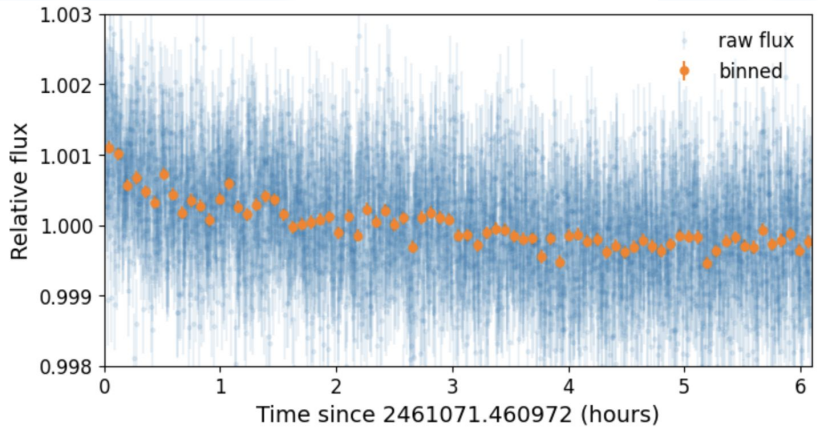

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Special Session this Wednesday!
15:00-17:00 (Room 2)

Rocky Worlds Data Challenge & Workshop

Rocky Worlds Data Challenge & Workshop

16–18 NOV 2026

MON 16 NOV 2026 - WED 18 NOV 2026

Add to Calendar

Location

Space Telescope Science Institute (STScI)
3700 San Martin Drive
Baltimore, MD 21218

Abstract + Funding Deadline
July 17, 2026

How to get involved in ROCKY WORLDS

MAST | data products

Website | information nexus

Mailing list

Data Challenge | JWST

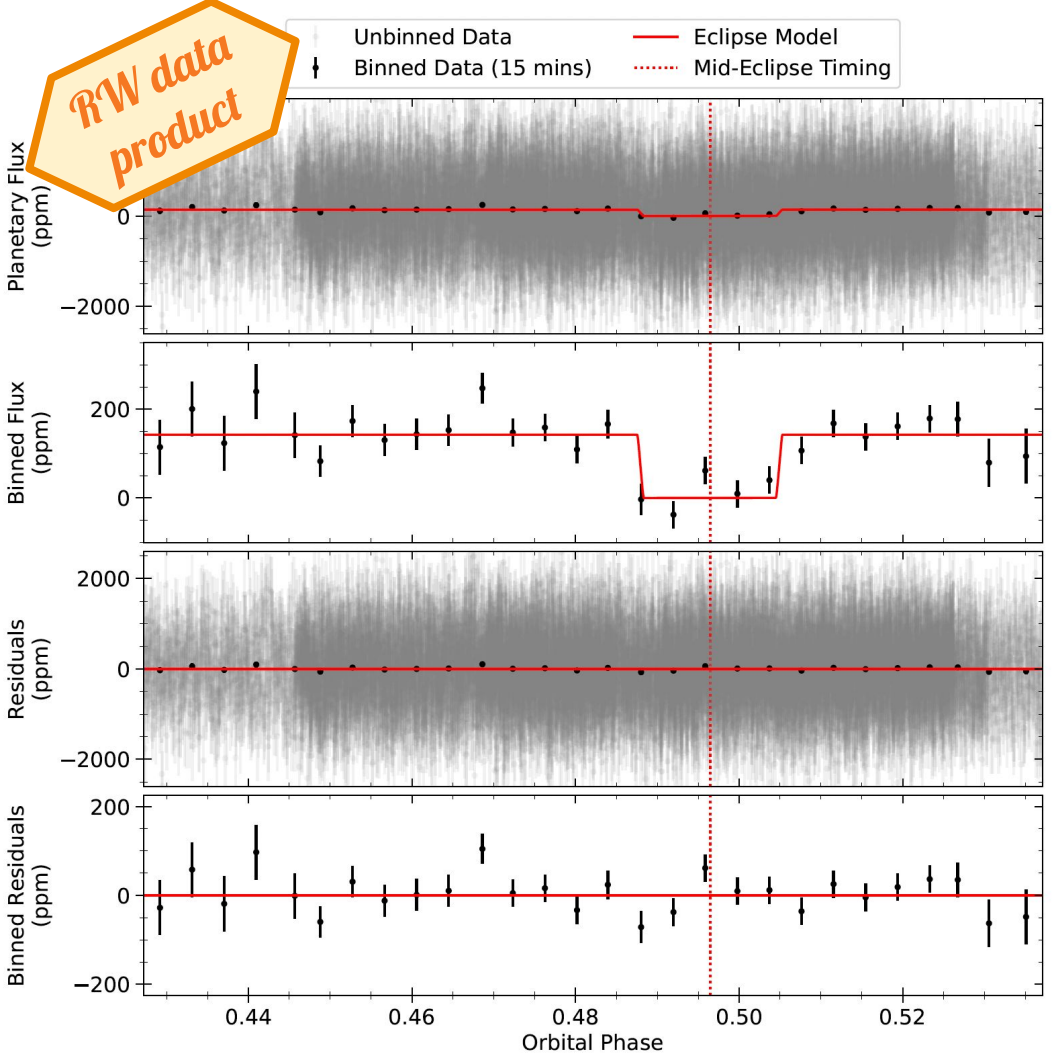
Workshop

16–18 NOV 2026

Connect | Community

Bonus slides

Products: **Time series**



Observing strategy: **Secondary eclipses, thermal emission**

Moon & **Earth** at 0.6 μm (optical light)

* Assume the rocky planet is tidally locked in 1:1 synchronous rotation

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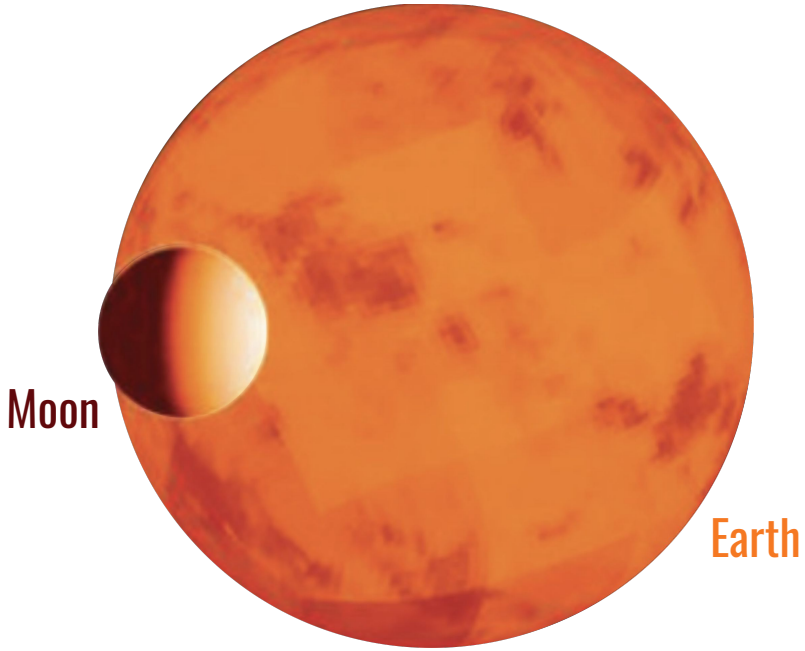

Moon & **Earth** at 10 μm (thermal emission)

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(Robinson+2011)

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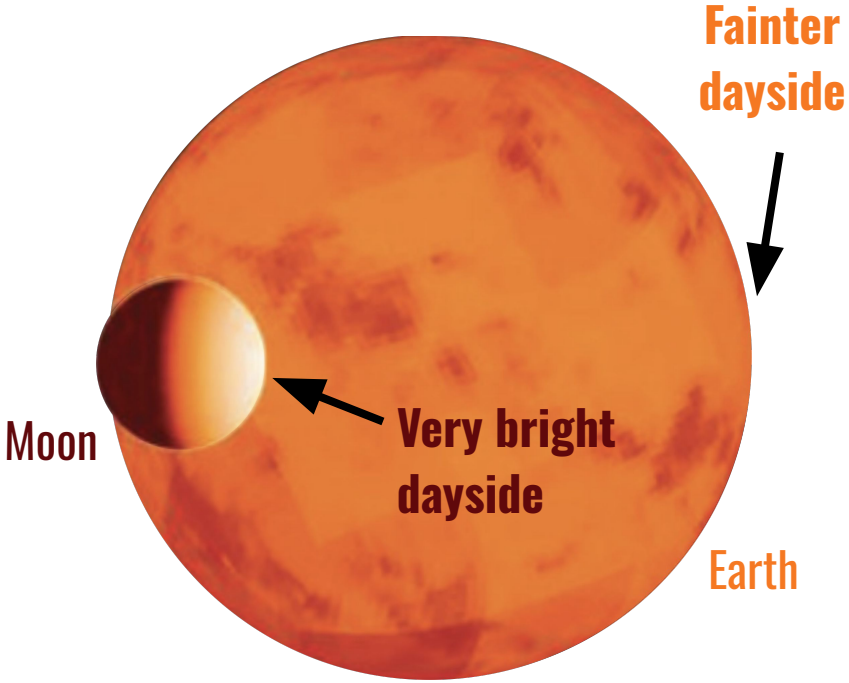

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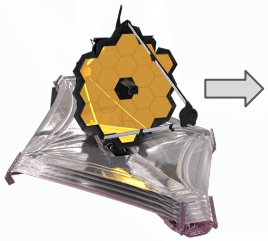
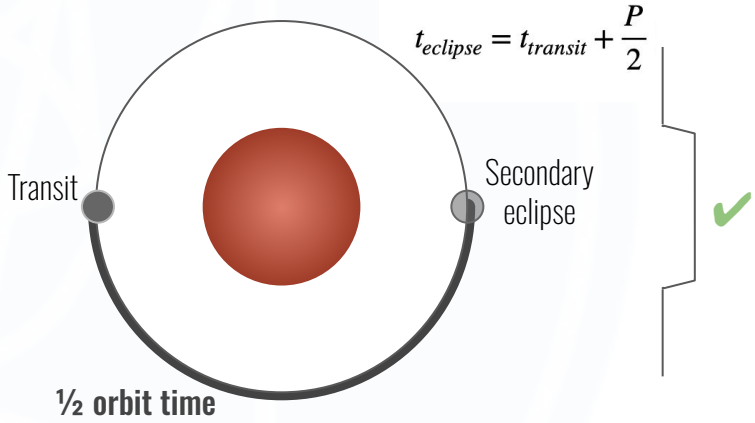
Scheduling Rocky Worlds targets

It's harder than it sounds!

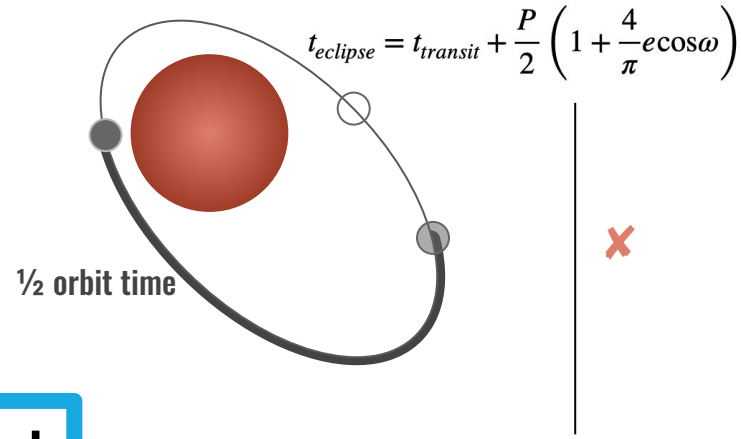


Circular orbit



✔

Eccentric orbit



✘

Need to calculate exact time for JWST to look

Scheduling Rocky Worlds targets

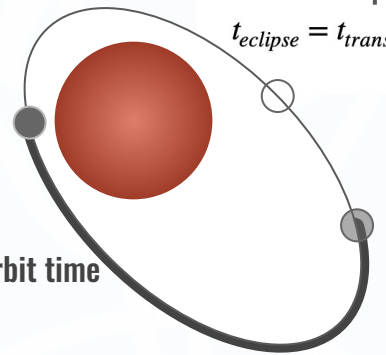
It's harder than it sounds!

Eccentric orbit

Well constrained from transit observations

$$t_{eclipse} = t_{transit} + \frac{P}{2}\left(1 + \frac{4}{\pi} e\cos\omega\right)$$

e and ω are somewhat constrained by RVs and highly correlated



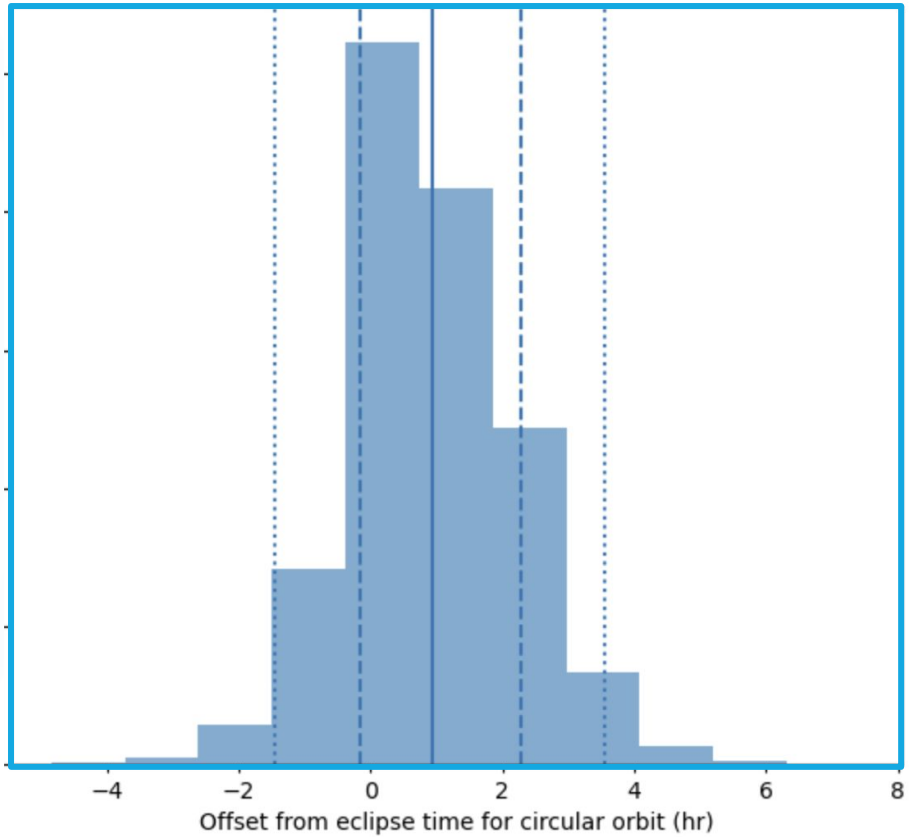
½ orbit time

Scheduling Rocky Worlds targets

Target scheduling: GJ 3929 b

MAROON-X RVs constrain the eccentricity to be consistent with 0 at 2-sigma. *(Thank you to Madison Brady and Jacob Bean for sharing proprietary MAROON-X RVs and analyses; results now published in Xue et al., 2025, arXiv:2508.12516)*

ExofastV2 global fits (that include MAROON-X RVs) favor a slightly eccentric orbit consistent with e=0 at 1-sigma.



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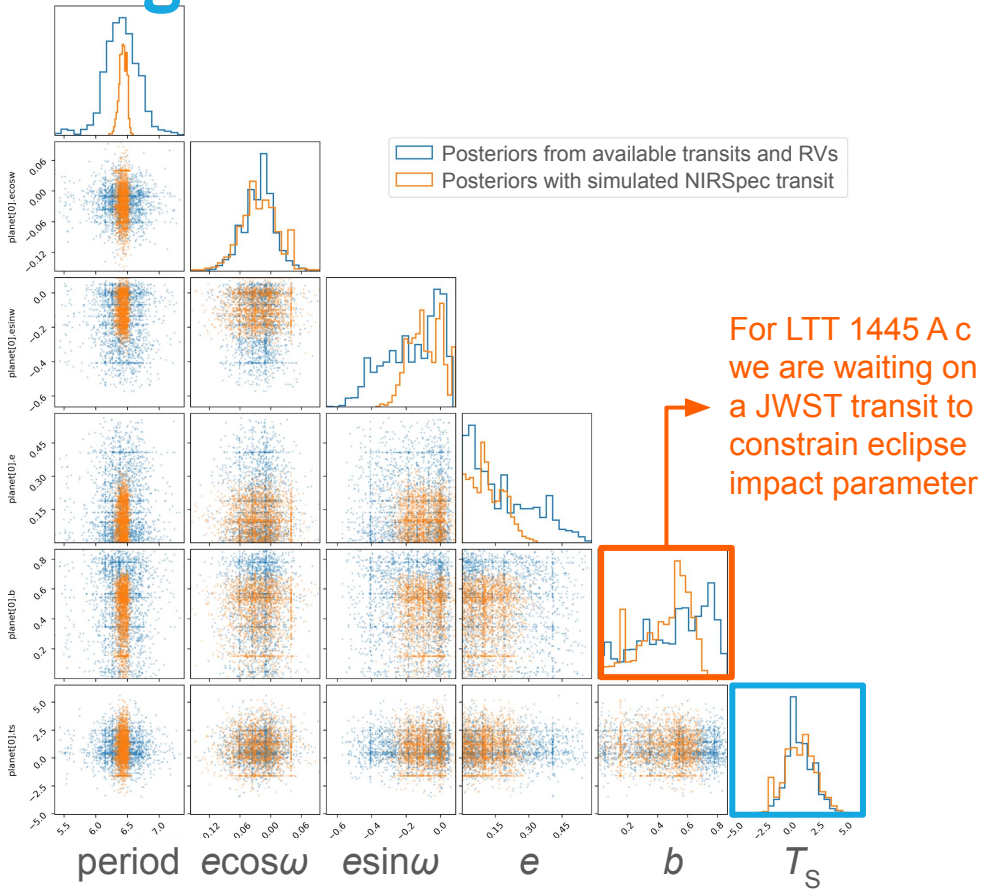
Adding a JWST/NIRSpec transit does not really help (orange posteriors).



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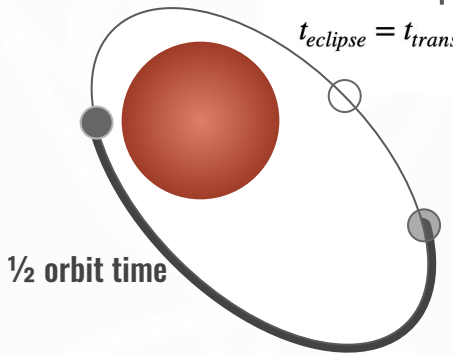


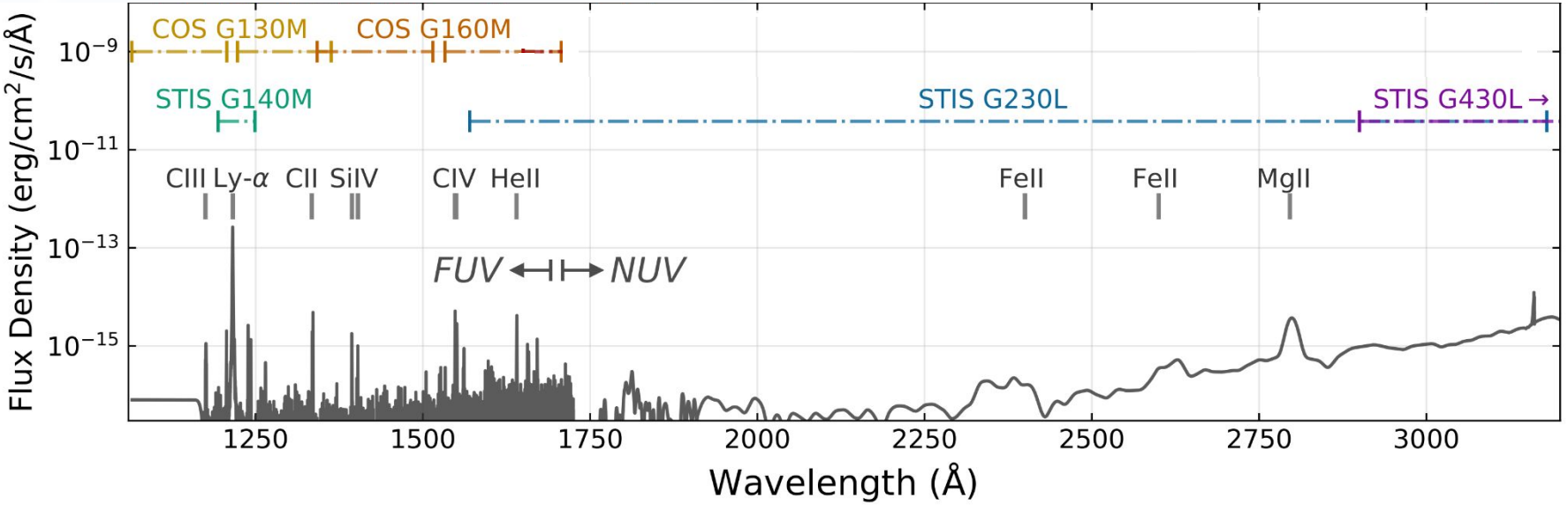
CIT Scheduling Team performs global fits using all available

- Radial velocities*
- Transit lightcurves*

to constrain orbital parameters.
***High-precision data* is the most effective**.

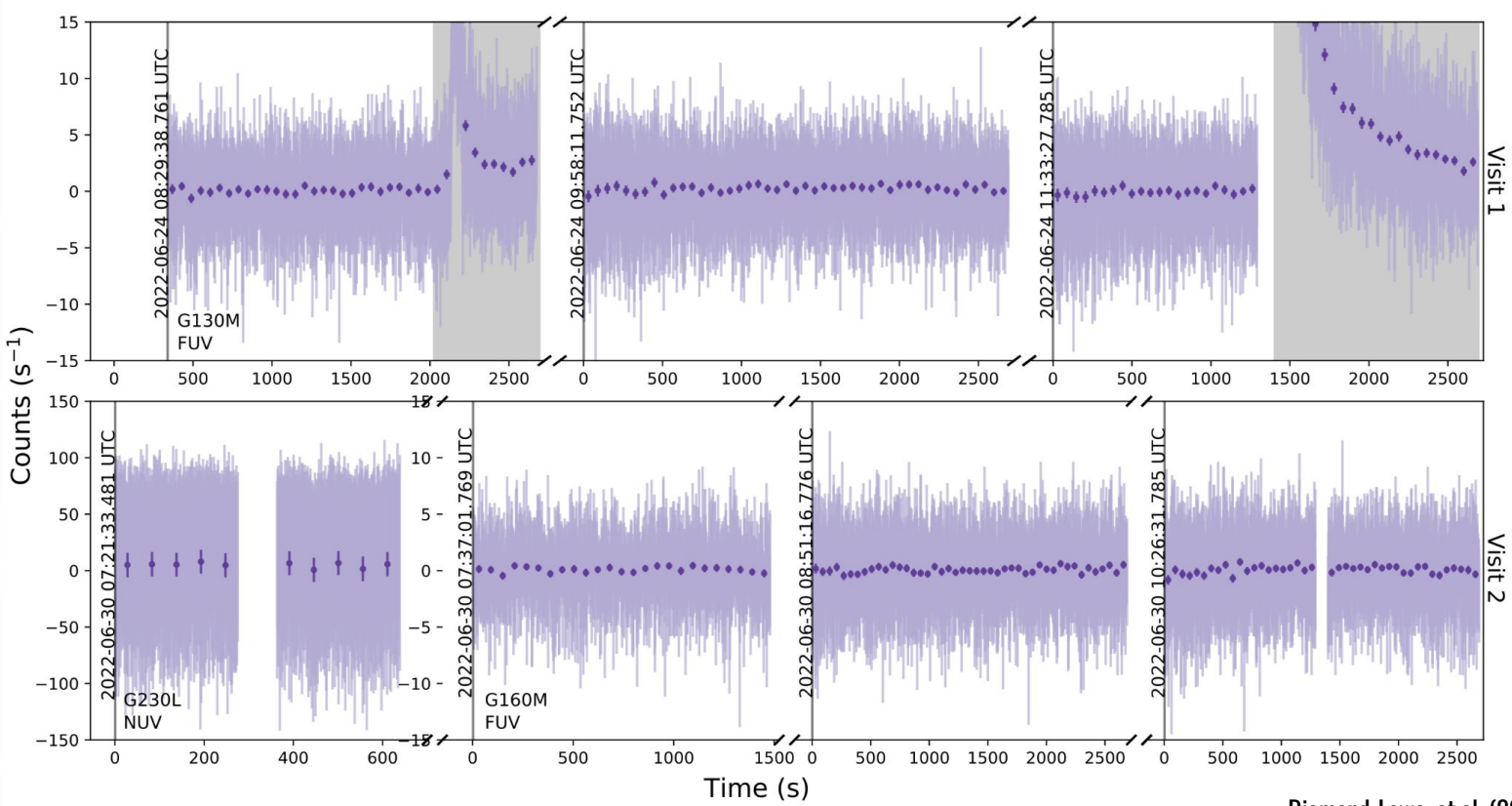
(If you have any data like this for the Rocky Worlds targets and would like to share, we would be very grateful!)

Observing strategy: **UV-optical spectra**



Observing strategy: UV-optical spectra, flare monitoring

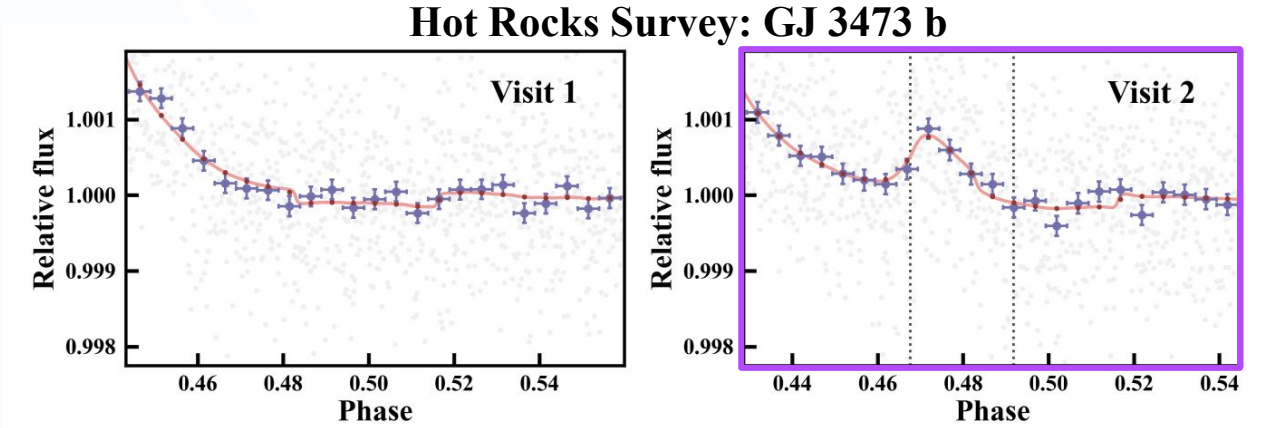
- TIME-TAG
- G130M
- 12 orbits



Diamond-Lowe, et al. (2024)

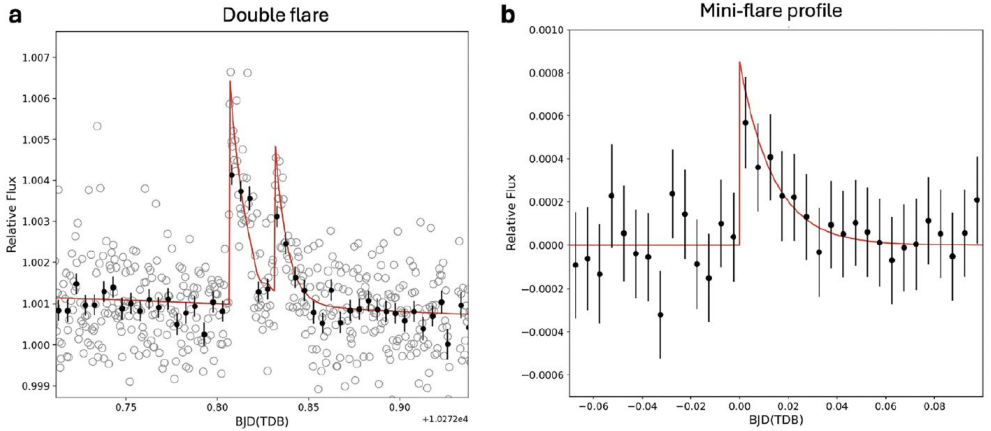
What does a flare from a “quiet” M dwarf look like at 15 μm?

Possible 15μm flare in a “quiet” M dwarf →



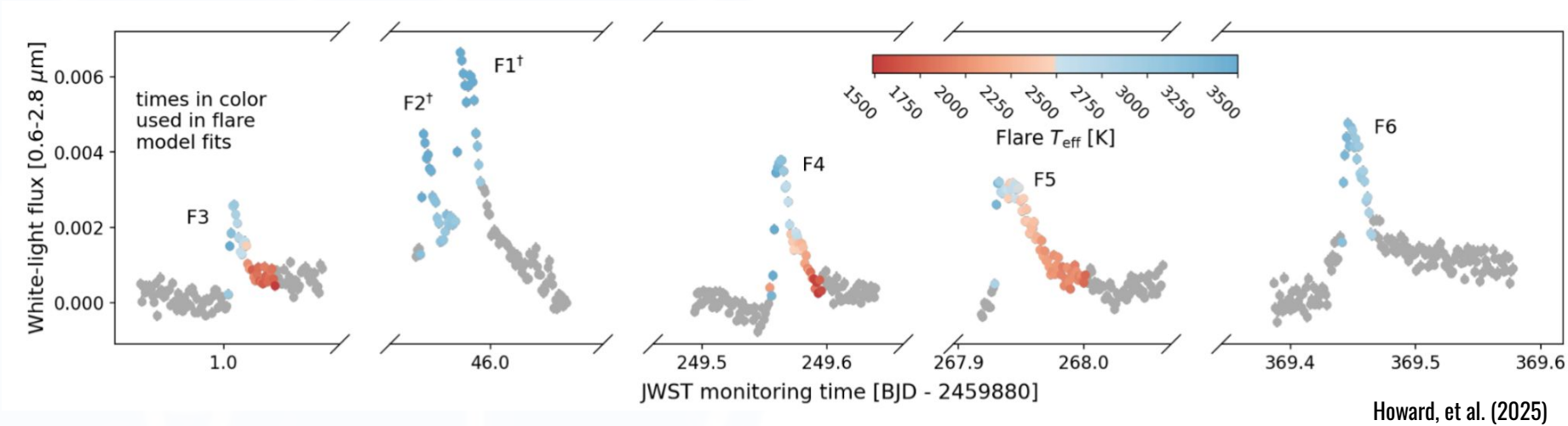
Holmberg, Diamond-Lowe, et al. (2026)

15μm flare in TRAPPIST-1 →



Gillon, et al. (2026)

Flares: TRAPPIST-1 in the NUV



Howard, et al. (2025)

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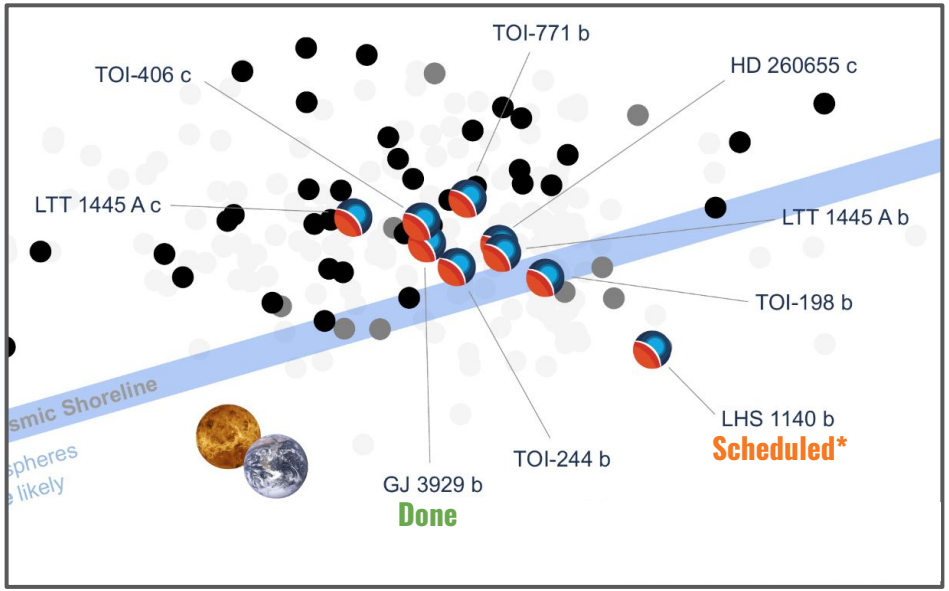

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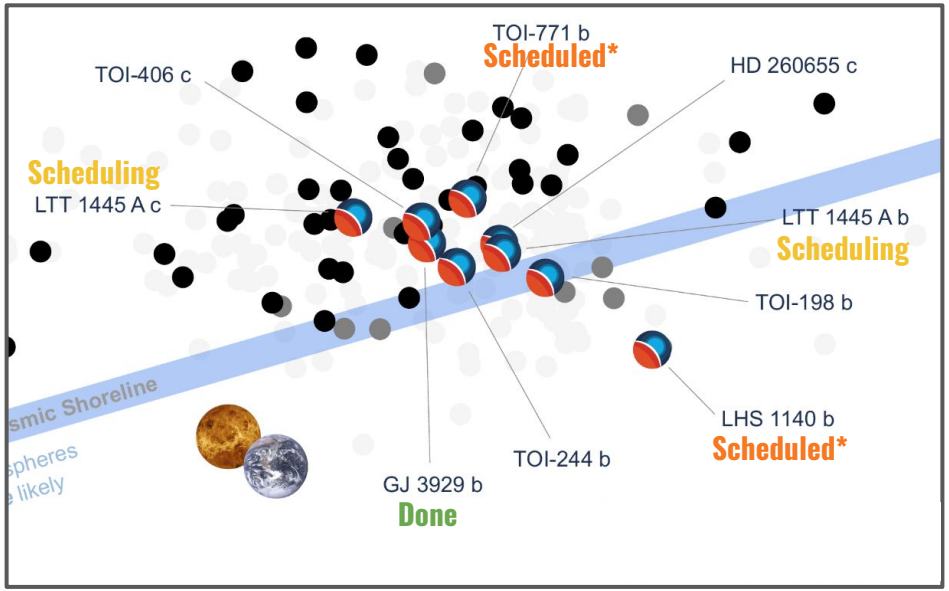

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Rocky Worlds Data Challenge & Workshop

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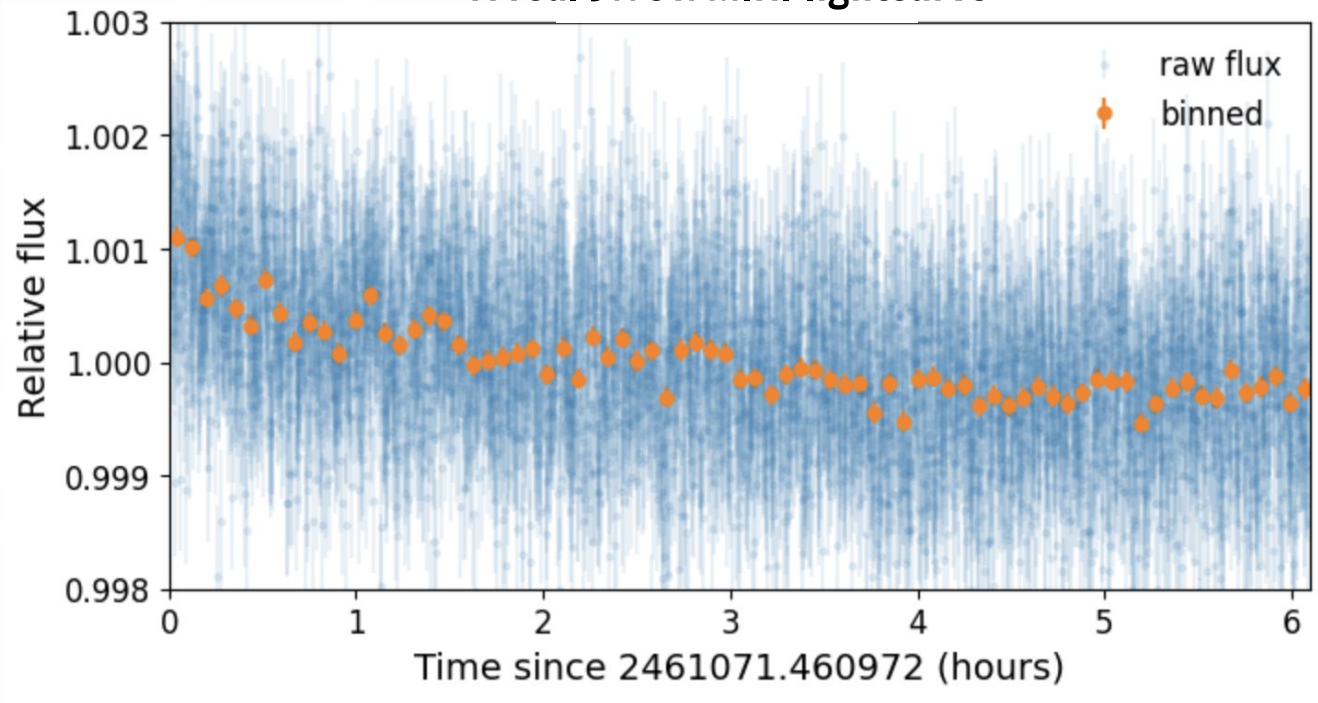

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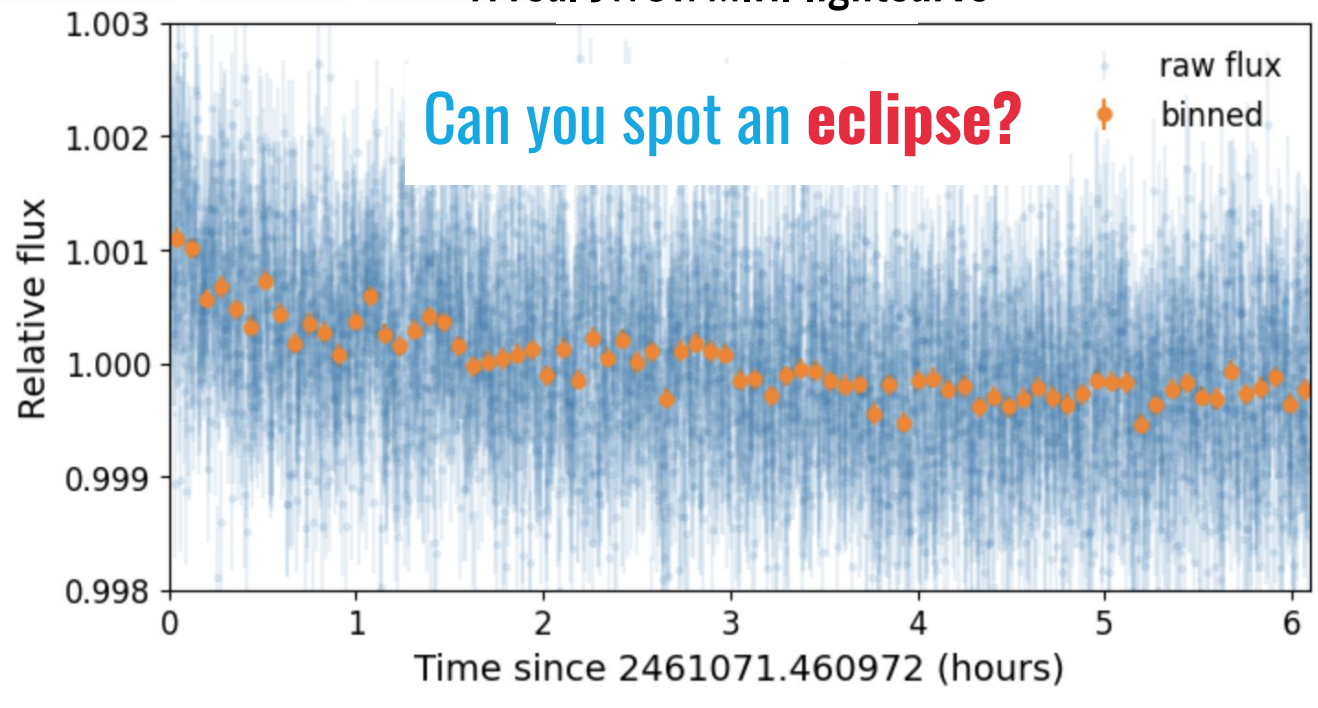

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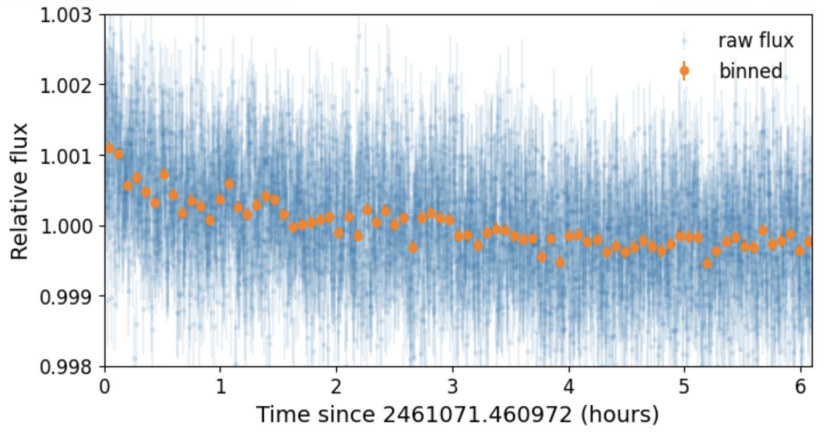

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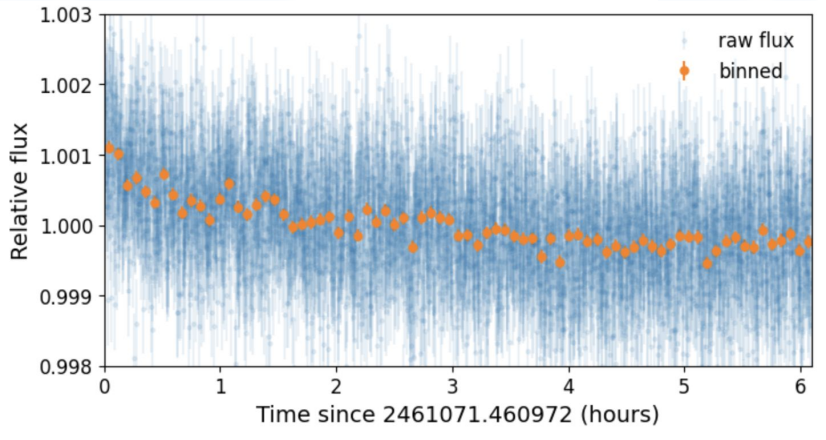

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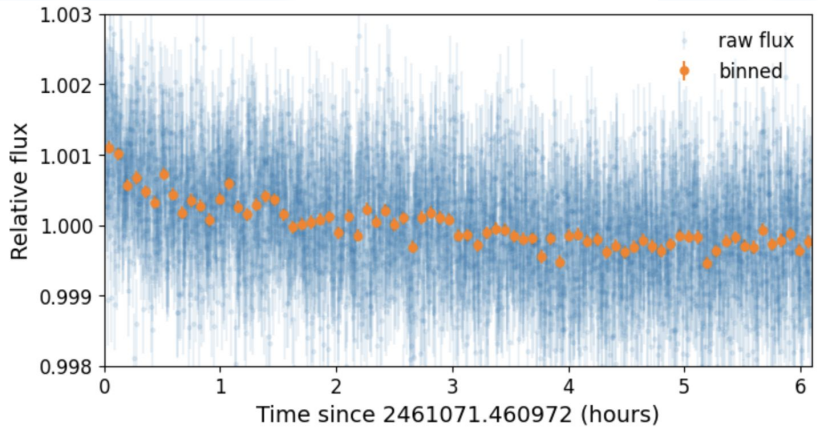

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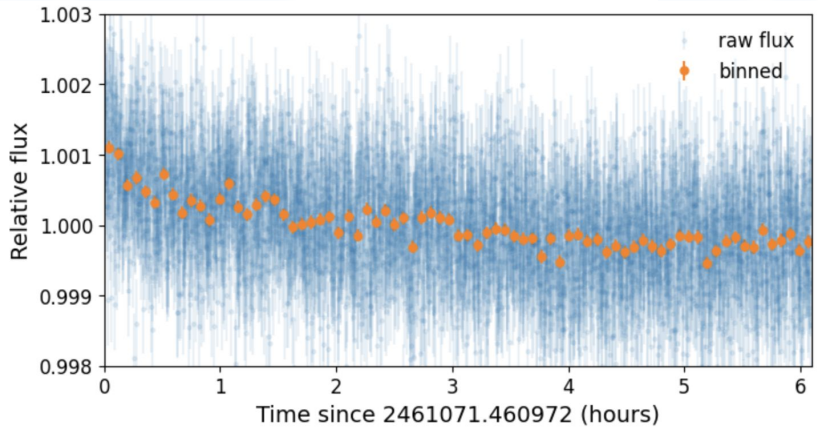

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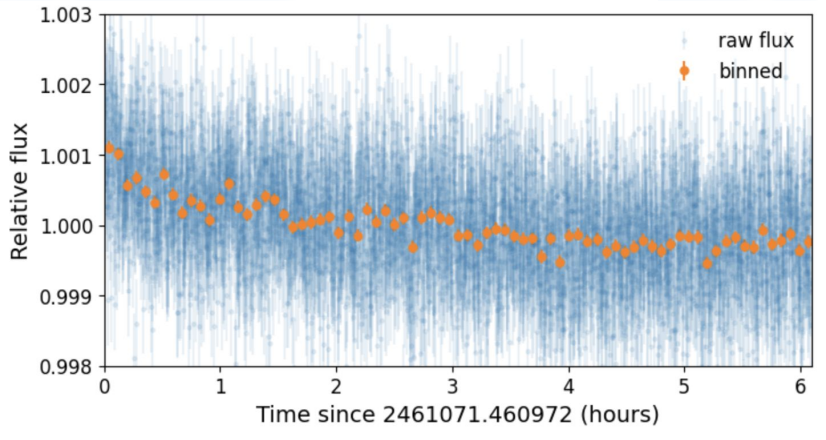

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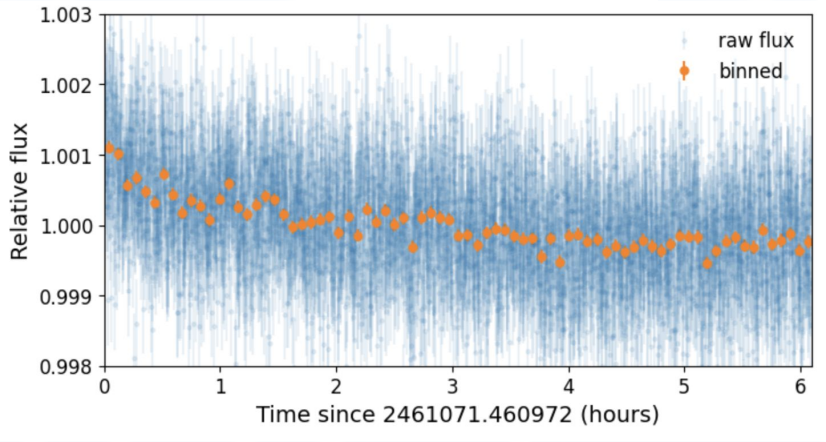

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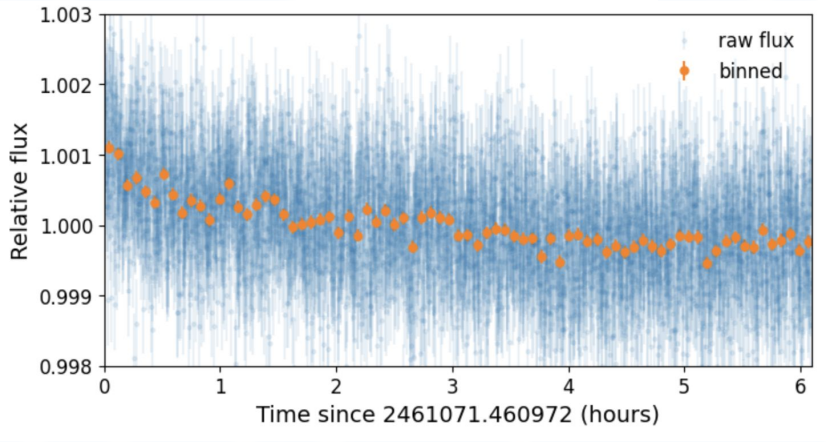
Simulated data: LHS 1140 b

Rocky Worlds Data Challenge & Workshop



The Rocky Worlds Data Challenge

Apr - Aug, 2026

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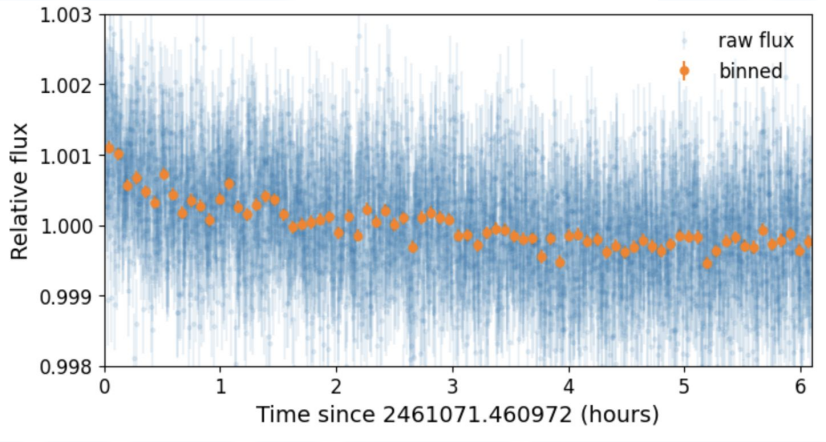

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The Rocky Worlds Data Challenge

Apr - Aug, 2026

Data Challenge Workshop

Nov 16-18, 2026 @ STScI

Past DDT programs:
Hubble Deep Field

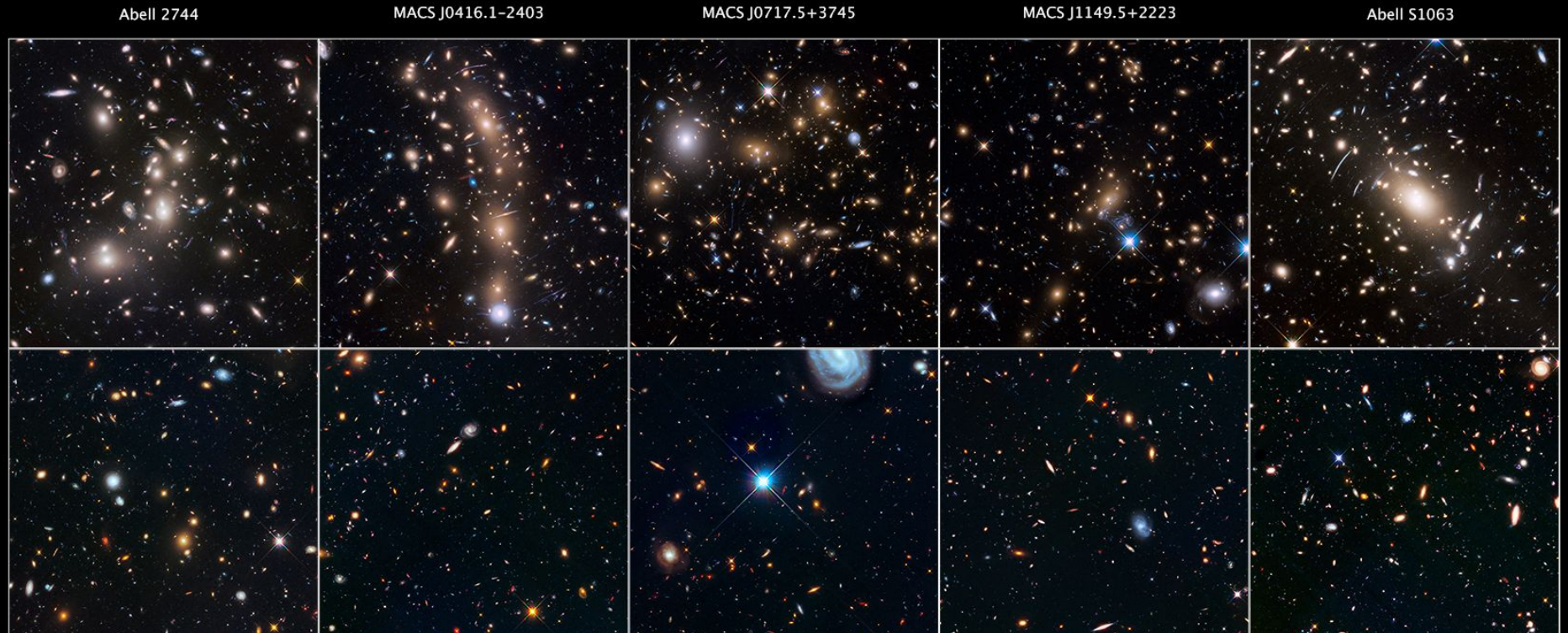
150 HST orbits

Williams et al. (1996, 2000); Beckwith et al. (2005)

Past DDT programs:
Hubble Frontier Fields

840 HST orbits + 1000 Spitzer hours

Lotz et al. (2017)



ULLYSES

HUBBLE'S ULTRAVIOLET SURVEY OF YOUNG STARS

NASA's Hubble Space Telescope surveyed actively forming and recently formed stars in ultraviolet light over three years. The result is ULLYSES, the Ultraviolet Legacy Library of Young Stars as Essential Standards, an unmatched set of information known as spectra that will help researchers pin down how young stars form and shape their nearby environments.

Why was Hubble tapped for this role? Only Hubble has the space-based location and instruments to capture spectra in ultraviolet light, making ULLYSES a data set of lasting importance.

Ultraviolet light traces some of the hottest material and the most energetic processes of stars.

Hubble observed stars that are actively forming or recently formed.

141

Number of low-mass stars in the library

355

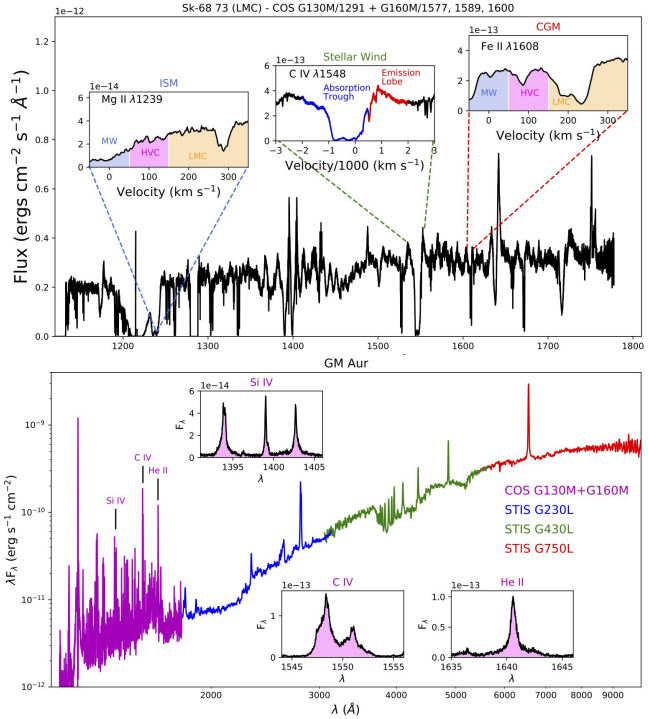
Number of high-mass stars in the library

63 DAYS

Amount of time Hubble spent building this library

Past DDT programs: **ULLYSES**

1000 HST orbits

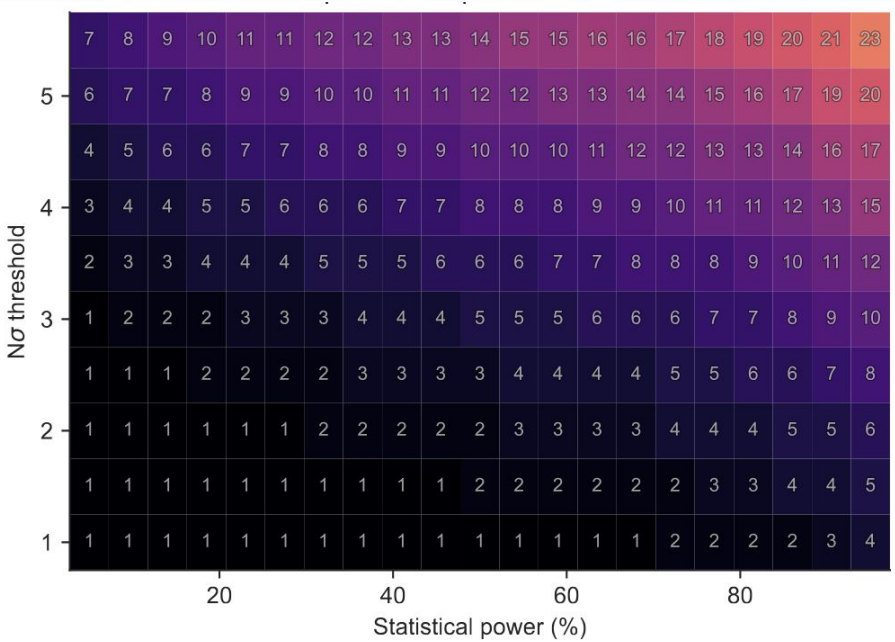


Roman-Duval et al. (2025)

The case of LHS 1140 b

Checkpoint 1

If planet is a bare rock, how many eclipses to detect?



The case of LHS 1140 b

Checkpoint 1

If planet is a bare rock,
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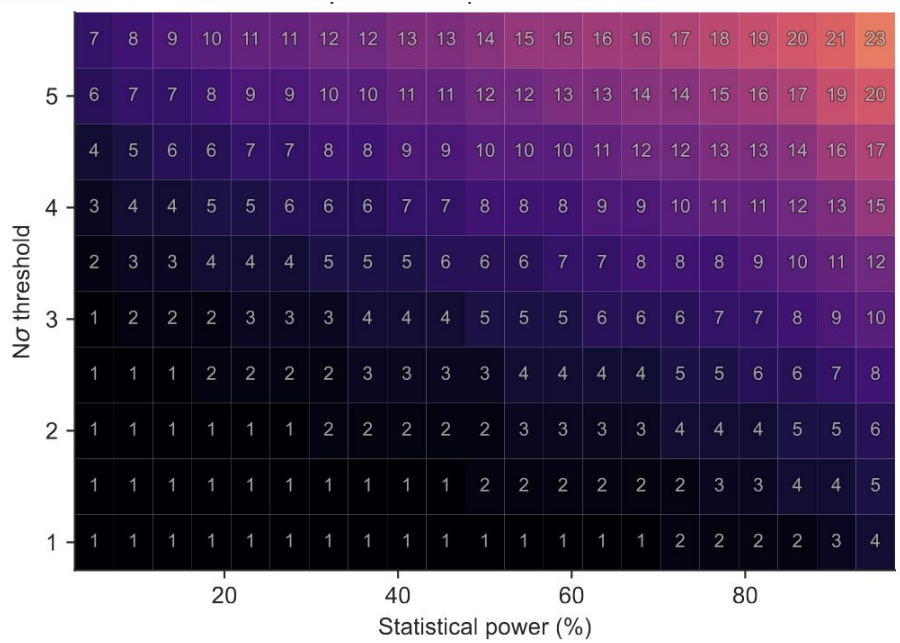

Checkpoint 2

If planet has a (1 bar) CO_2 atmosphere —
eclipses to differentiate from bare rock?