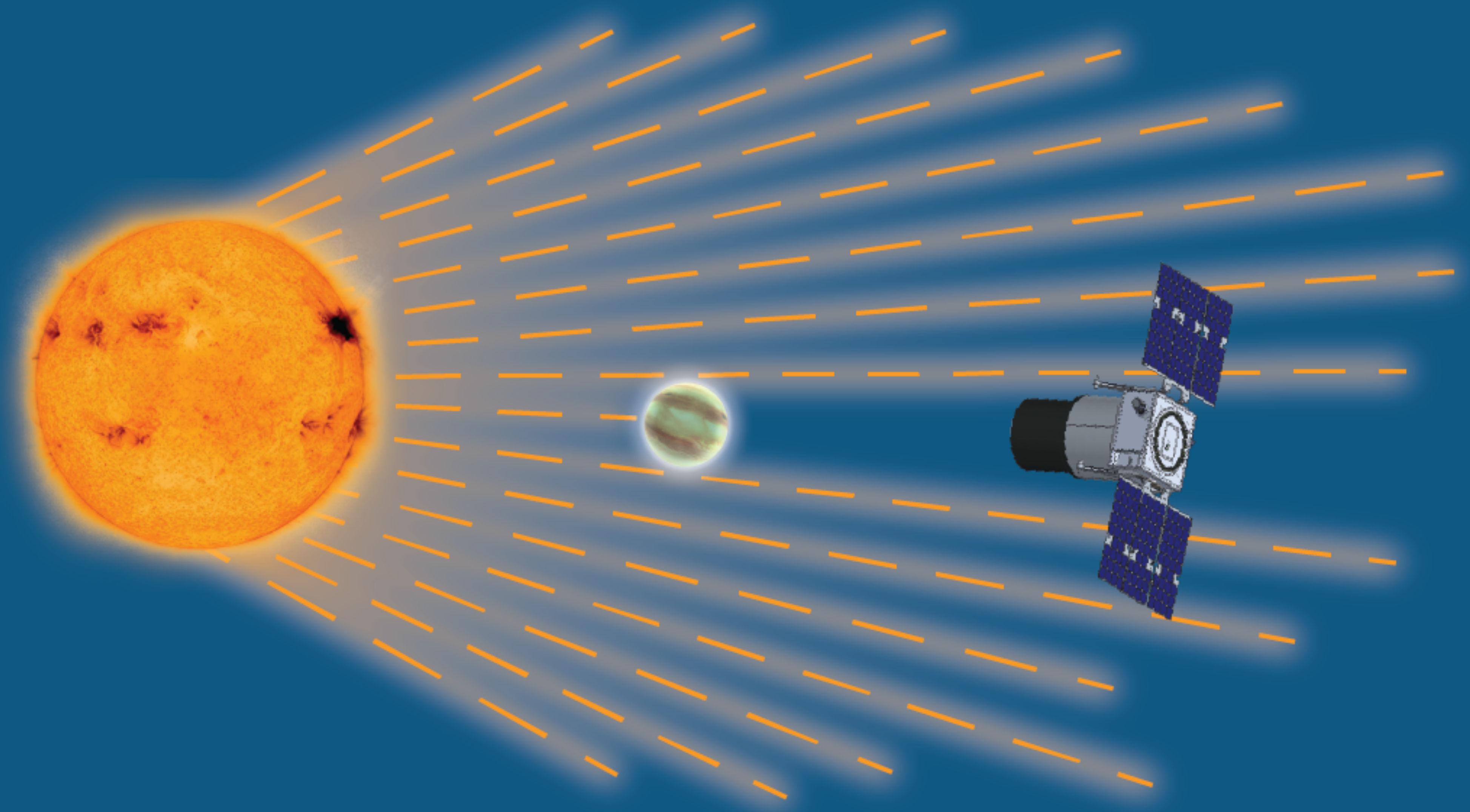
Pandora

Multiwavelength Characterization of Exoplanets and their Host Stars



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NASA ARC
Project Scientist: Knicole Colón
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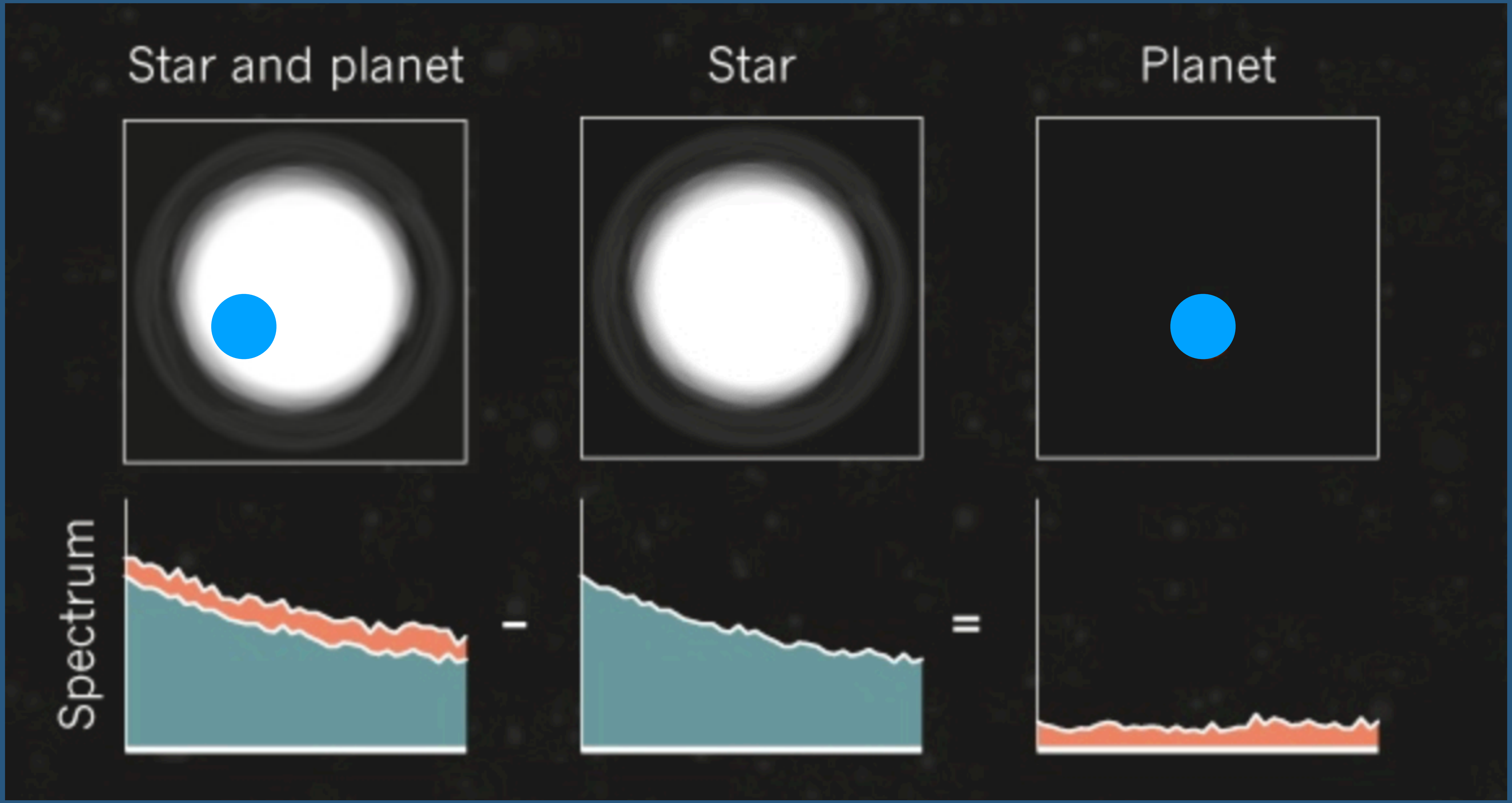
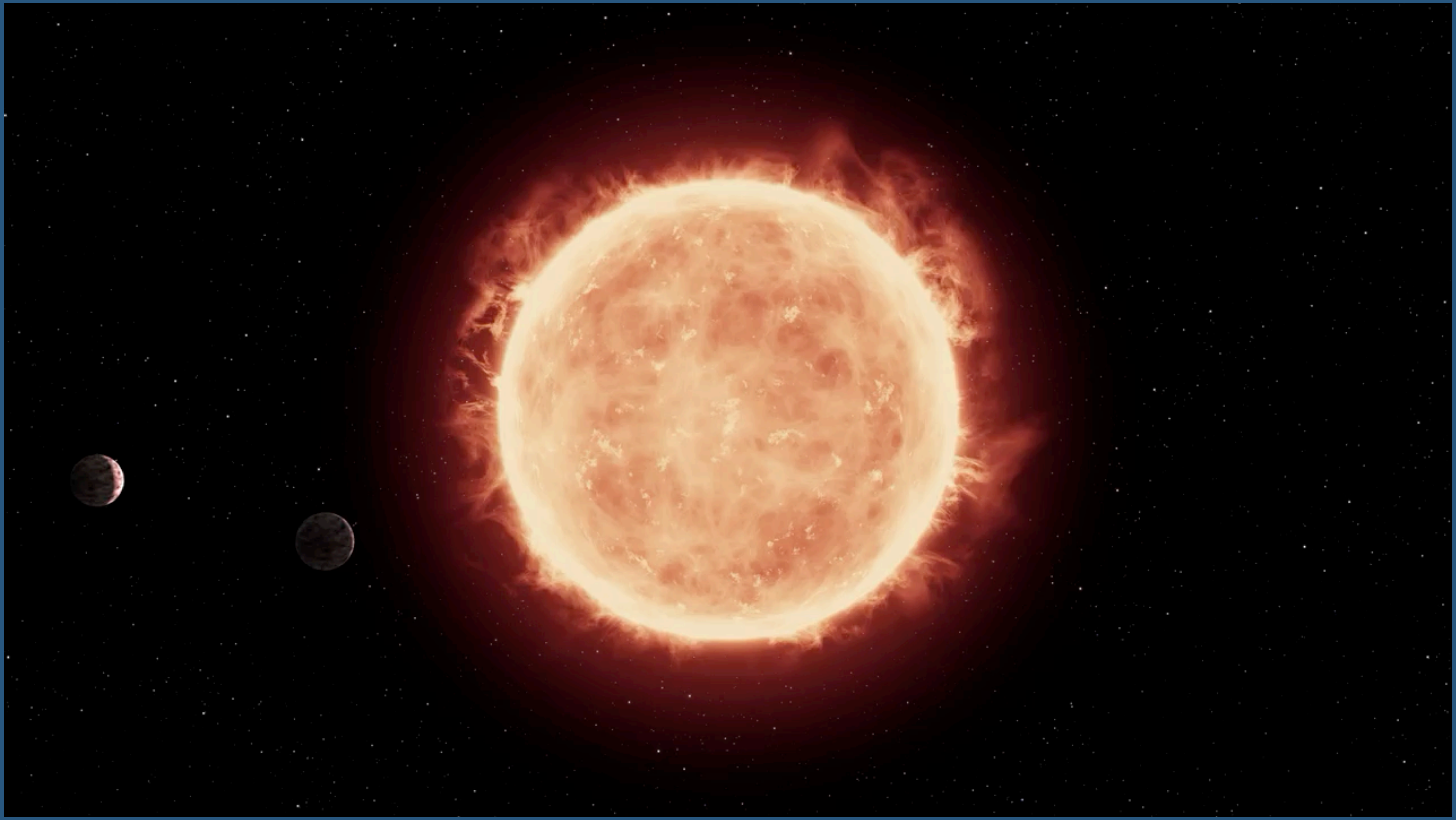
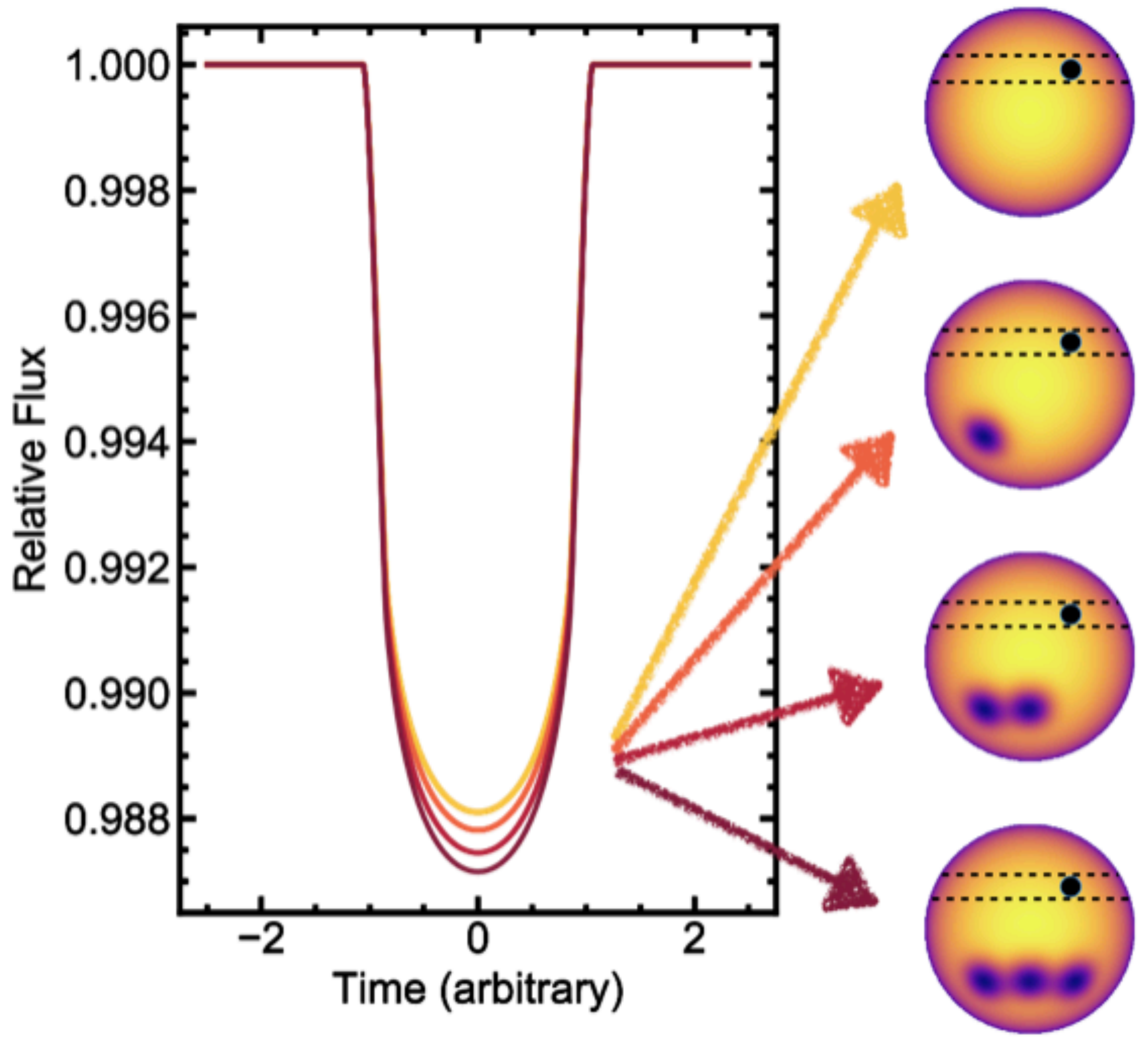
Exoplanet Transmission Spectroscopy

A differential measurement

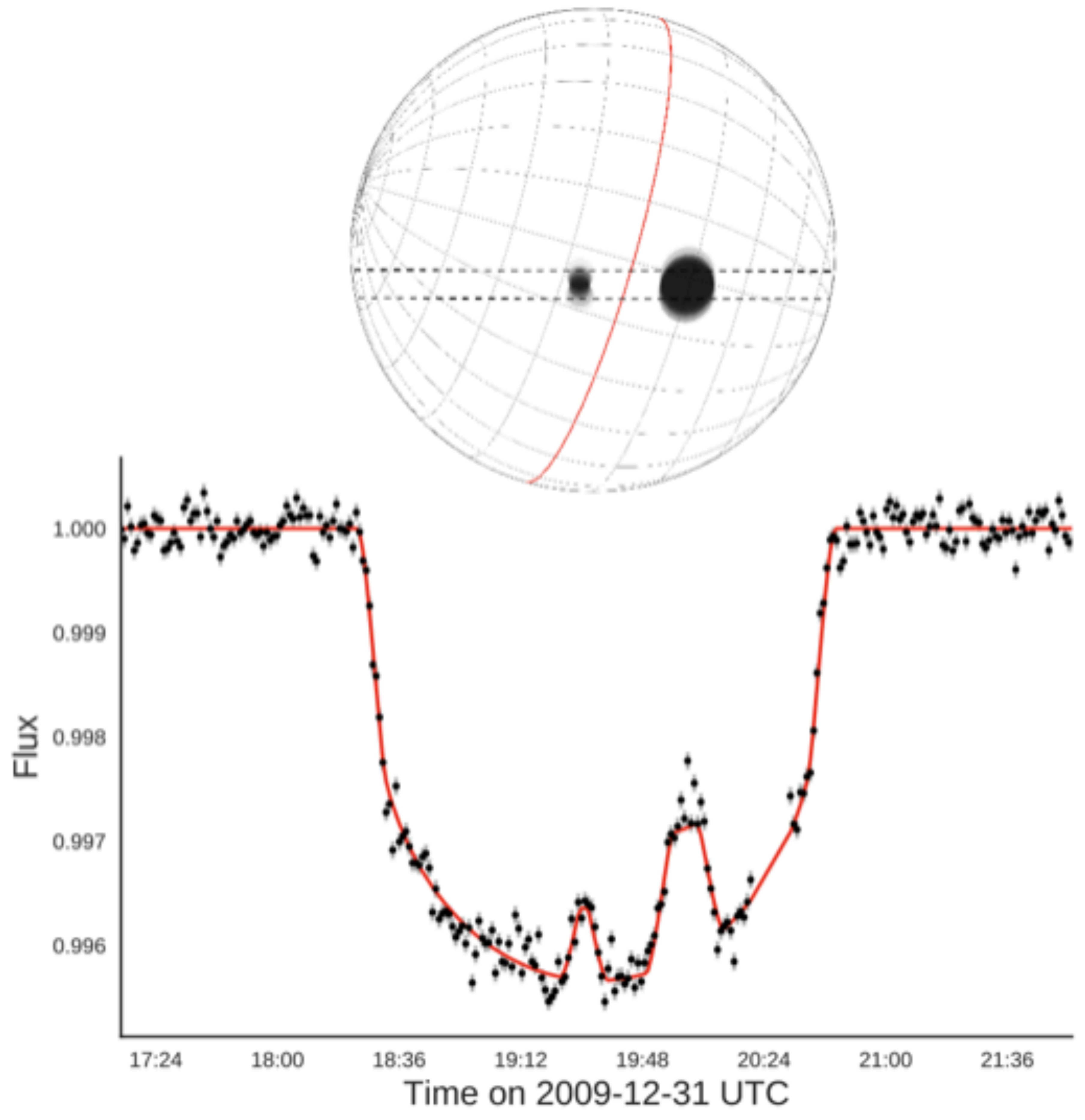


The Myth of a Perfect Star



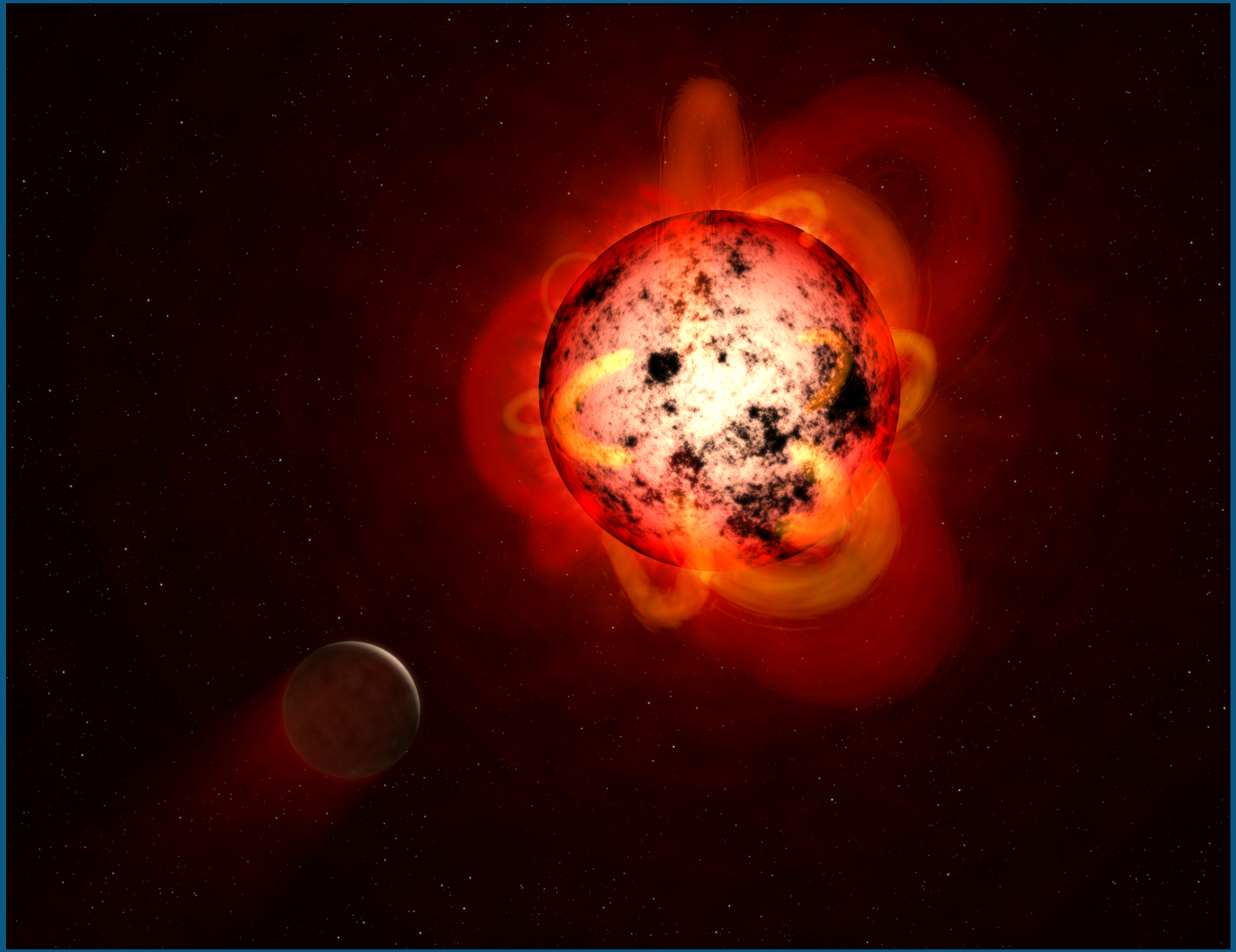


Transit Light Source Effect (Rackham 2018)



Morris et al. (2017)

Challenges of observing low mass stars



Small, young stars can be highly active on long timescales

Stellar rotation can be hours-days

Variability timescales can be comparable to planet transit periods and durations

When obtaining spectra, different faces of the star could be showing during a transit, from transit to transit, and from planet to planet!

Why low mass stars should be your favorite too

- Majority of stars (>70%) in the Milky Way are M dwarfs
- Planets orbiting low mass stars produce stronger signals in both RV and transit
- Habitable Zones are closer in, so HZ planets are easier to find and follow up
- Planetary atmospheric features through transit spectroscopy scale inversely with the size of the star

Transit Spectroscopy is a primary science case for JWST

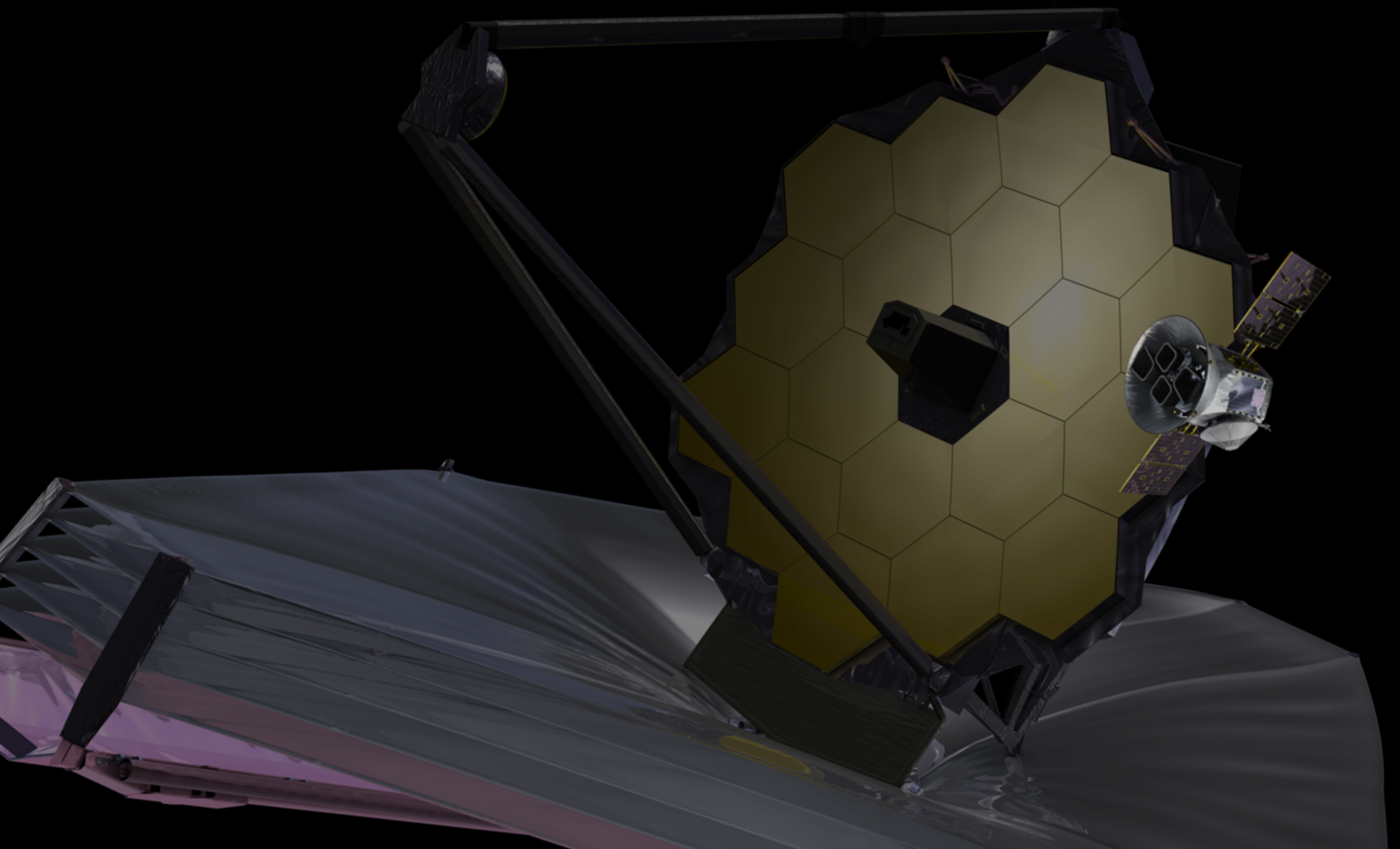
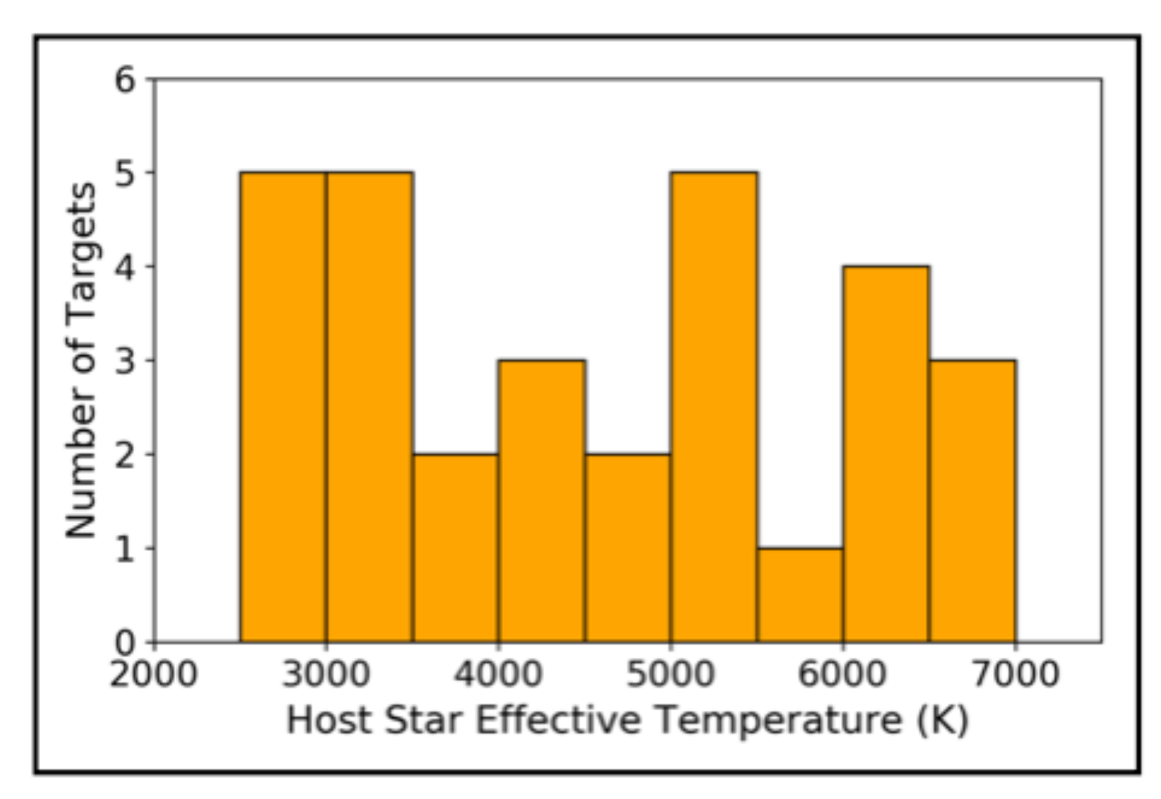
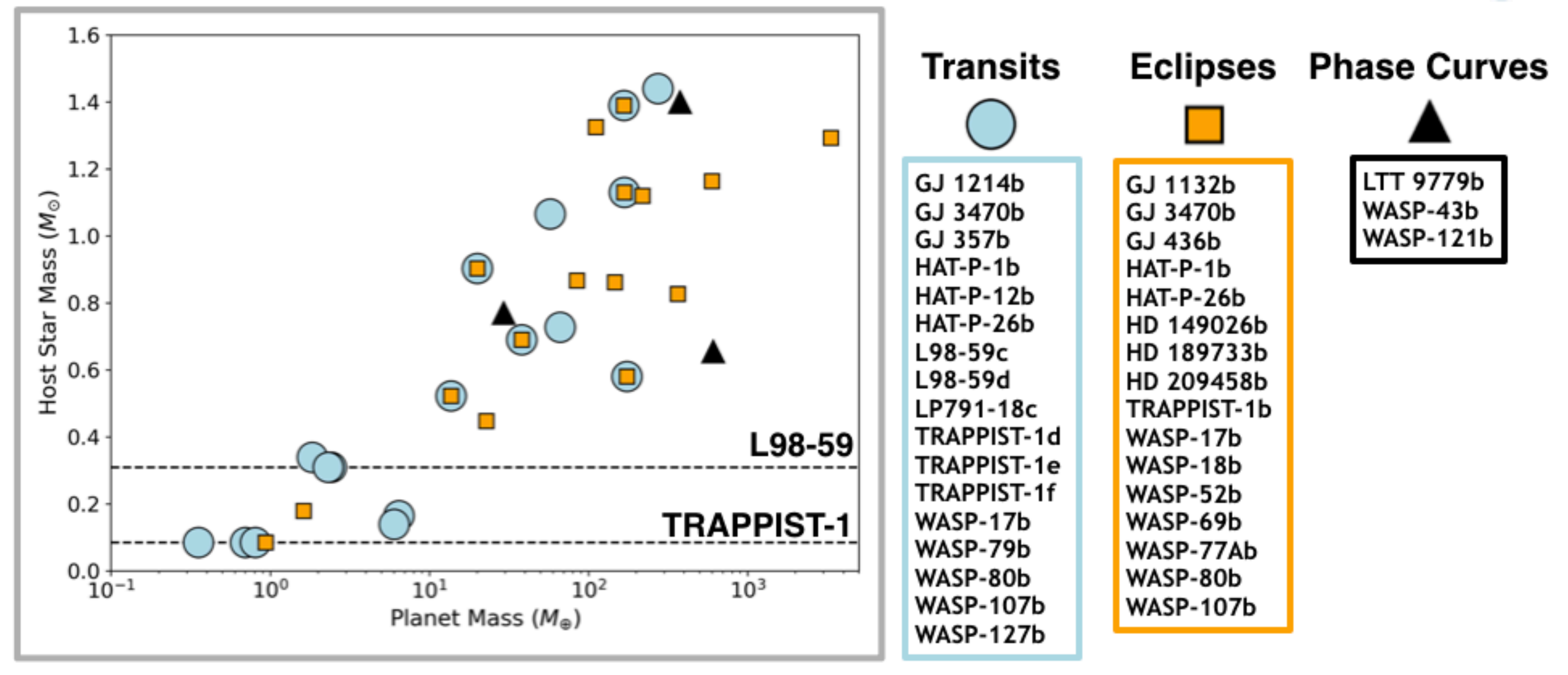


image:
NASA

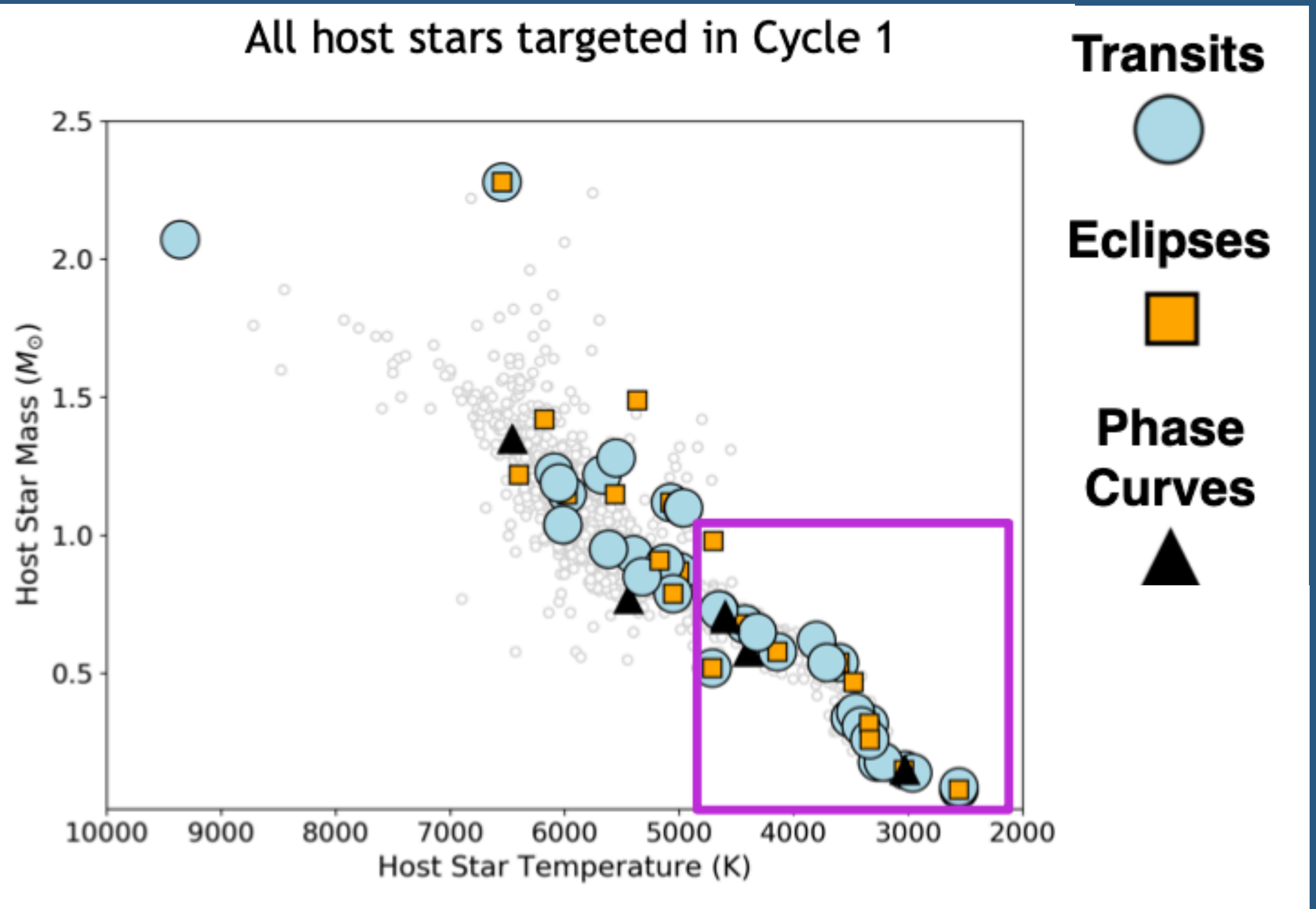
JWST Exoplanet Transmission Spectroscopy Targets

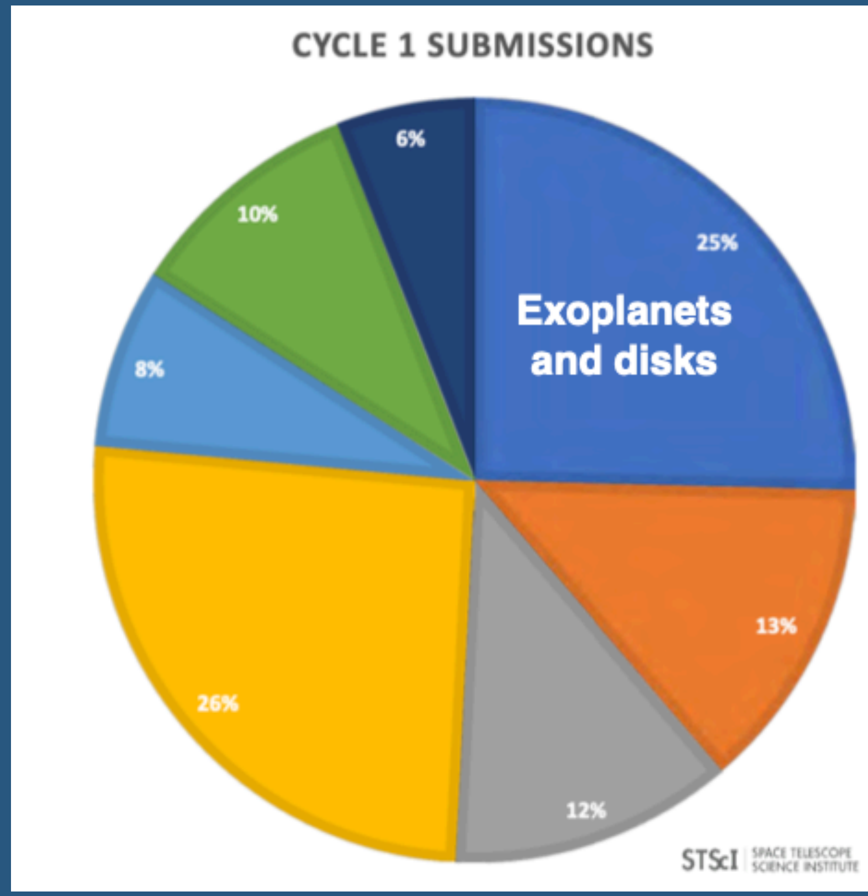
30 transiting exoplanets in JWST Guaranteed Time Observations (GTO) + Early Release Science (ERS) programs





38 transiting exoplanets added for JWST Guest Observer (GO) Cycle 1 (including 25 discovered by TESS!)

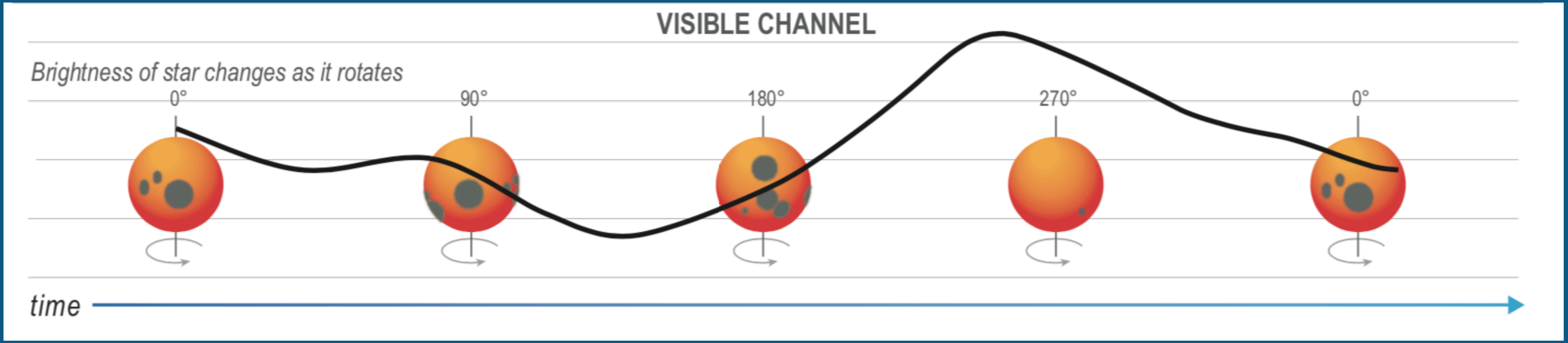




Plots by Knicole Colon

How can we mitigate spatial inhomogeneities on the stellar surface?

Photometric monitoring!



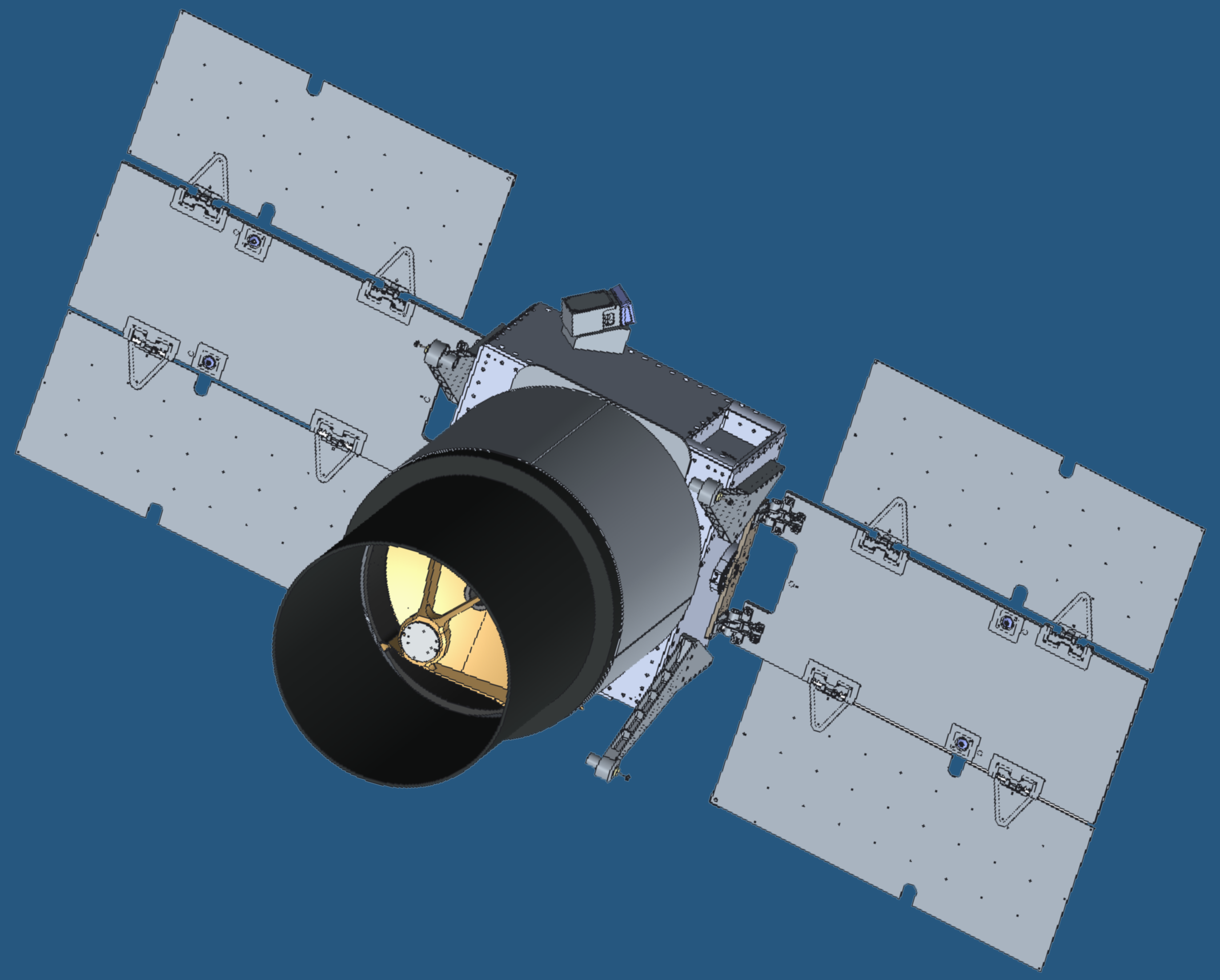
Pandora

Pandora is a SmallSat designed to observe transiting exoplanets and their host stars with long time-baseline, simultaneous visible photometry and infrared spectroscopy to:

Science Objectives

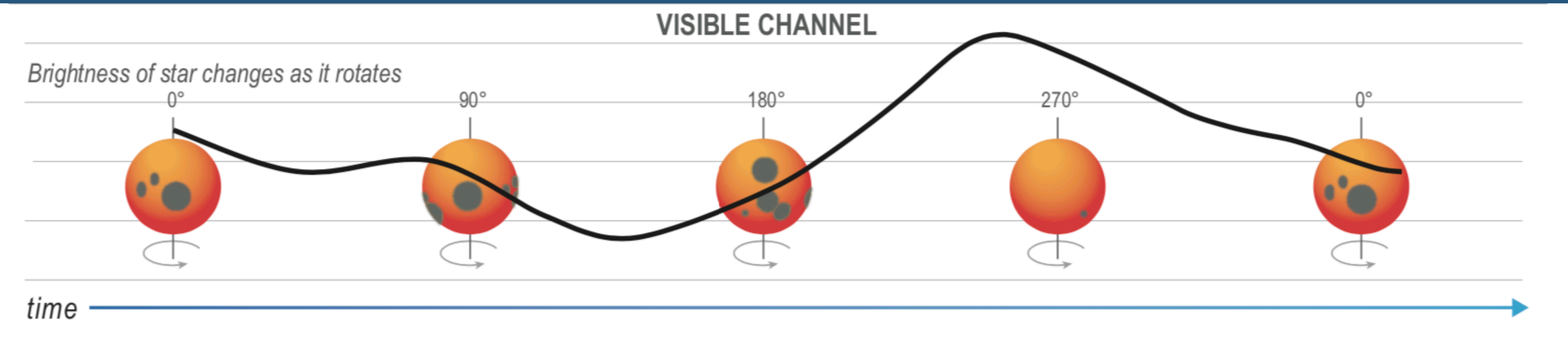
1. determine the spot and faculae covering fractions of exoplanet host stars and the impact of these active regions on exoplanet transmission spectra

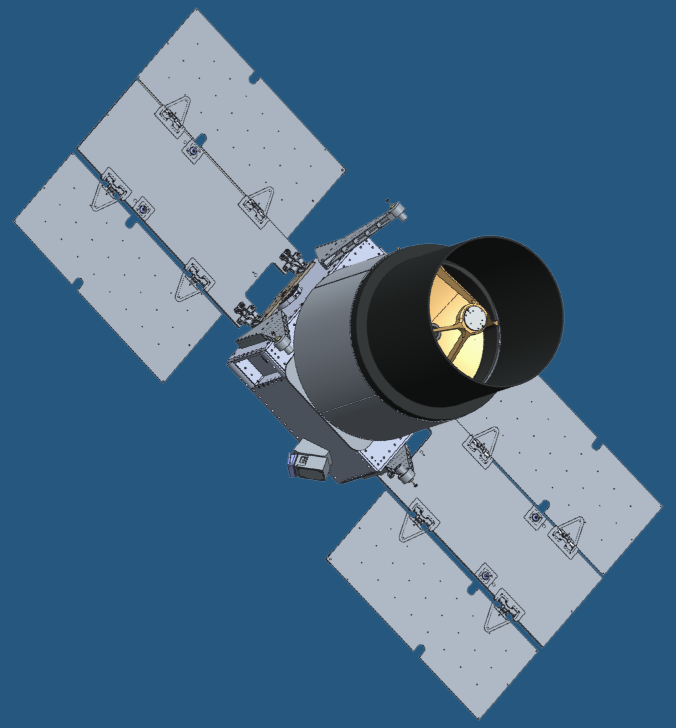
2. identify exoplanets with hydrogen- or water-dominated atmospheres, and determine which types of planets are covered by clouds and hazes



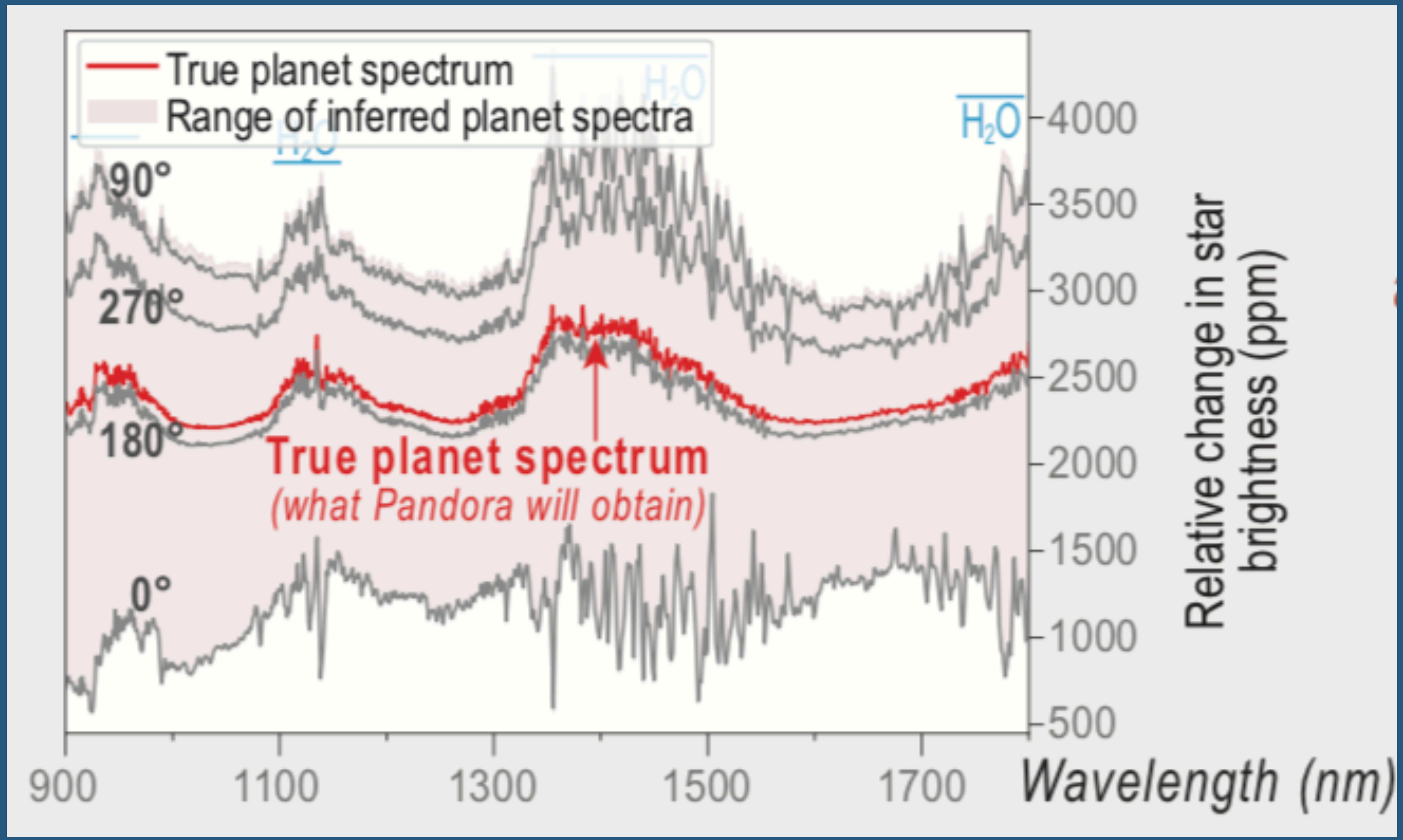
Pandora's Observing Strategy

Visible photometry captures stellar brightness over time



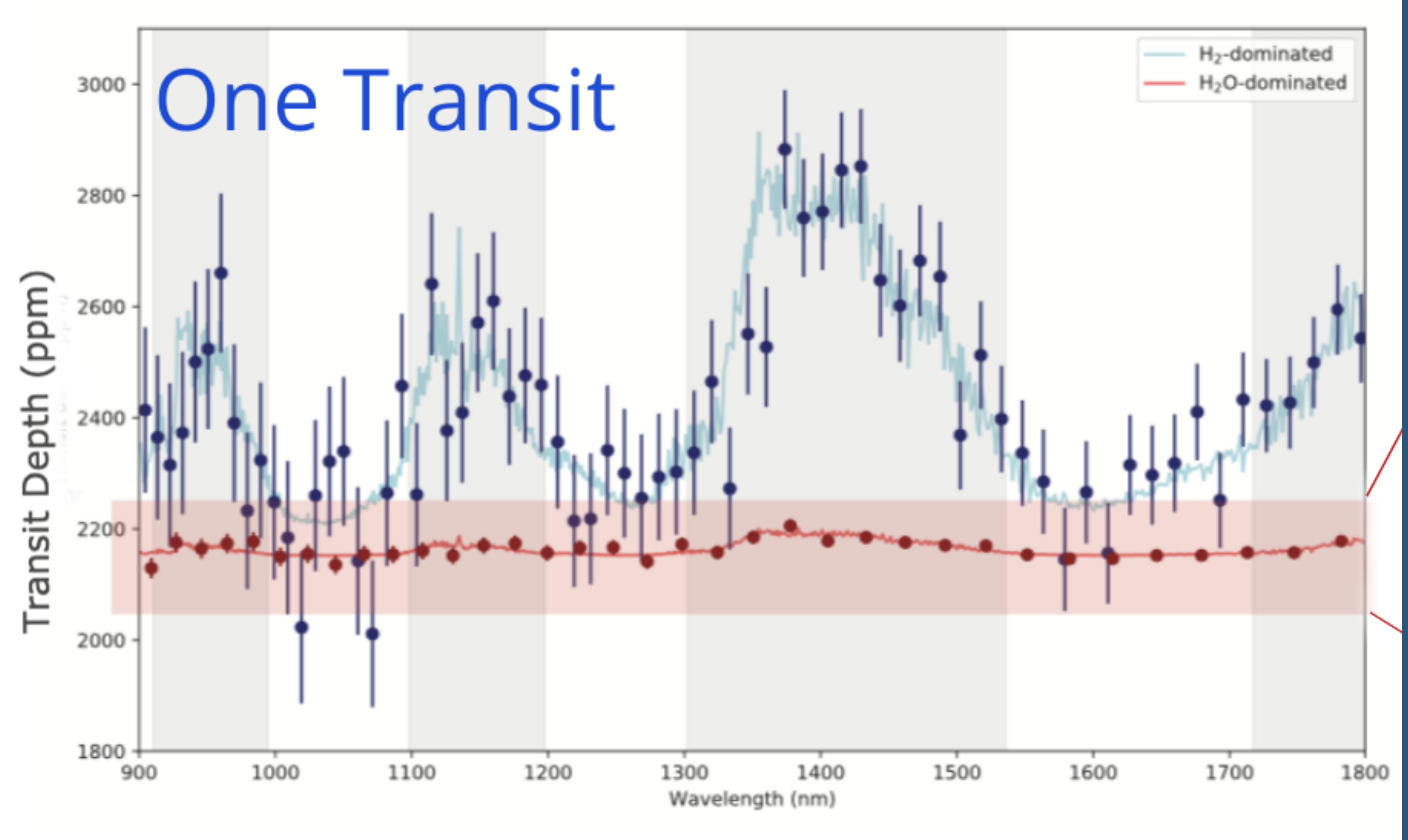


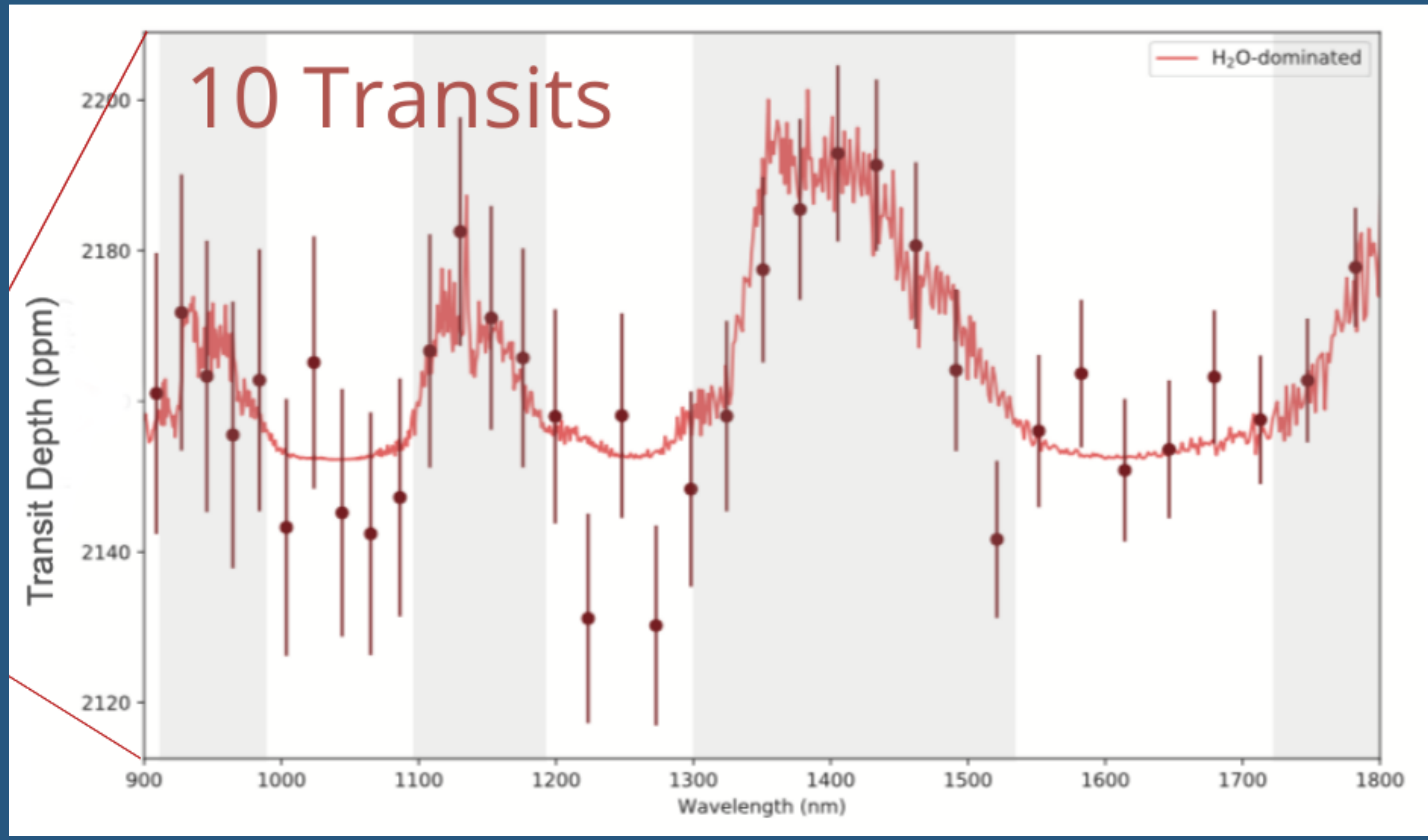
Simultaneous IR spectroscopy captures variations in spectra over time



Together, the visible photometry + spectroscopy provides constraints on star spot coverage, which is needed to disentangle the star and planet spectra, **providing robust measurements of the planet's true atmospheric makeup**

Pandora will obtain transmission spectra in IR wavelengths similar to those covered by HST/Wide Field Camera 3 (WFC3), where water is a known strong molecular absorber in both hydrogen- and water-dominated atmospheres.



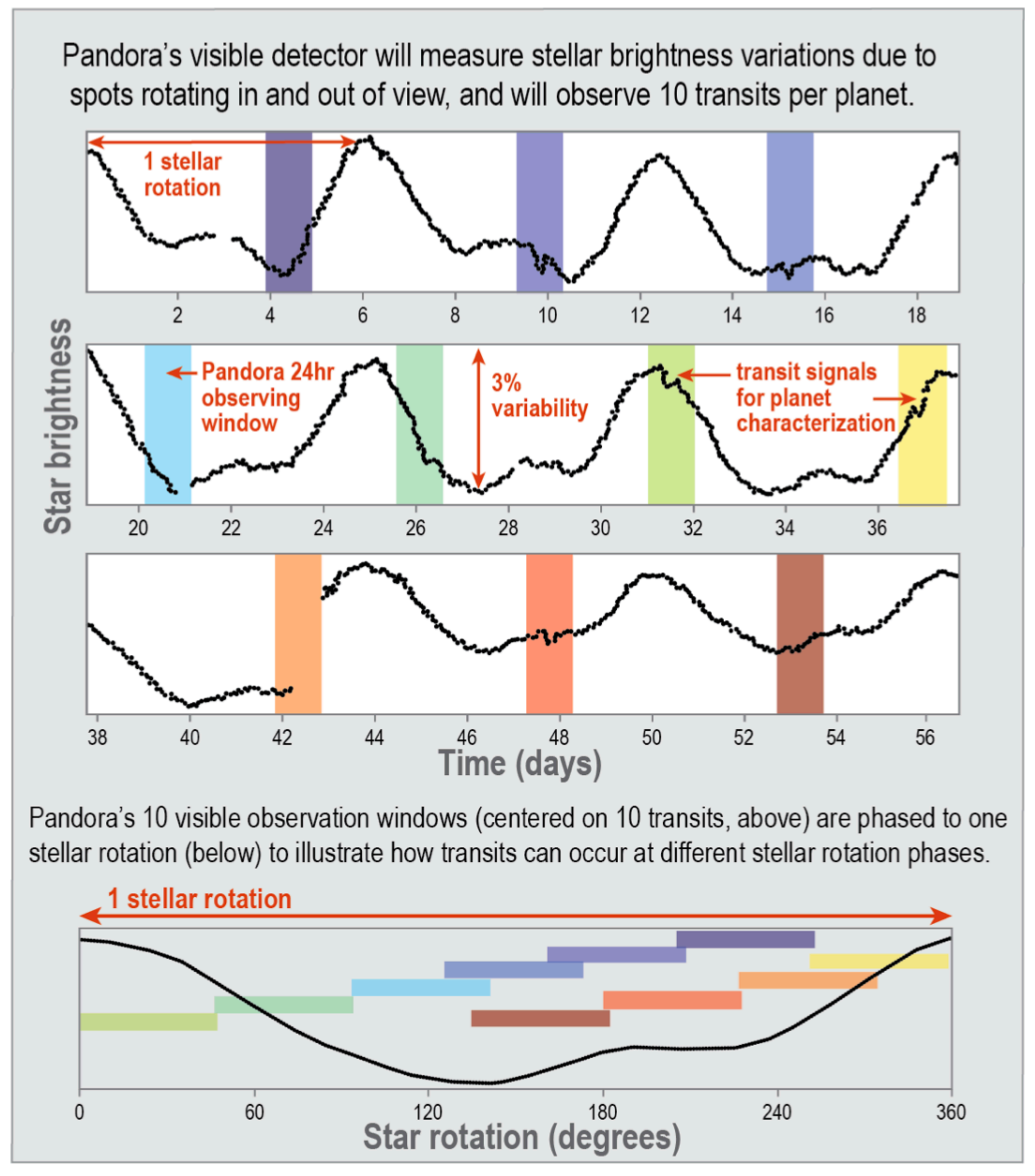


Pandora's goal is to detect H-dominated atmosphere with 1 transit and an H_2O-dominated atmosphere with 10 transits

Long duration baseline is key

~10 transits for each planet

~ 24 hour observation for each transit



Pandora

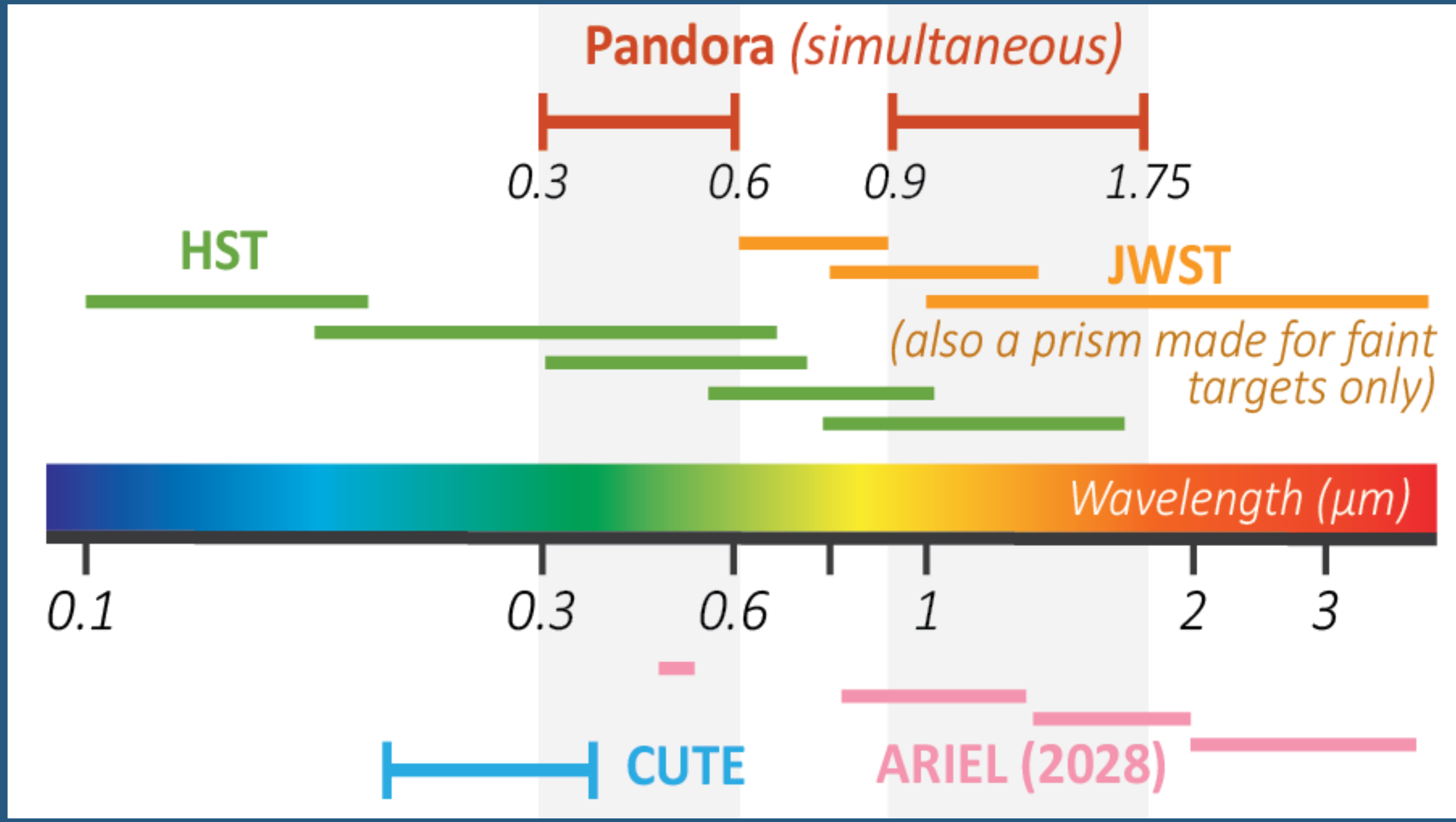
Notional Target List

Star Name	Spec. Type	Rotation (days)	V mag	H mag	Num. Planets (Radius $R_\oplus$)
HAT-P-11	K3V	29	9.2	7.6	1 (4.4)
K2-121	K4V	10	13.3	10.7	1 (7.5)
K2-136	K5V	12	10.9	8.5	*3 (1.0–2.9)*
WASP-43	K5V	16	12.4	9.4	1 (10.5)
WASP-107	K5V	18	11.5	8.8	1 (11)
GJ 9827	K6V	17	10.3	7.4	*3 (1.2–2.0)*
K2-266	K6V	100	11.8	9.0	*4 (0.7–3.3)*
K2-3	M0V	37	12.2	8.8	*3 (1.0–1.4)*
Kepler-138	M0V	18	12.5	9.7	*3 (0.5–1.2)*
AU Mic	M0V	5	8.6	4.8	1 (4.2)
GJ 357	M2V	78	10.9	6.7	1 (1.2)
GJ 3470	M2V	20	12.3	8.2	1 (4.6)
K2-18	M3V	38	13.5	9.0	1 (2.4)
GJ 436	M3V	44	10.7	6.3	1 (4.2)
L 98-59	M3V	100	11.7	7.4	*3 (0.8–1.6)*
K2-33	M3V	6	15.7	10.3	1 (5)
LTT 1445 A	M4V	1	10.5	6.8	1 (1.4)
K2-25	M4V	2	15.9	10.7	1 (3.4)
LHS 3844	M5V	100	15.3	9.4	1 (1.3)
TRAPPIST 1	M8V	3	18.8	10.7	*7 (0.8–1.2)*
Colors indicate: mid-K / late-K+early-M mid-M / late-M		rapid rotators	brighter than H=9 / V=13		multiplanet hosts

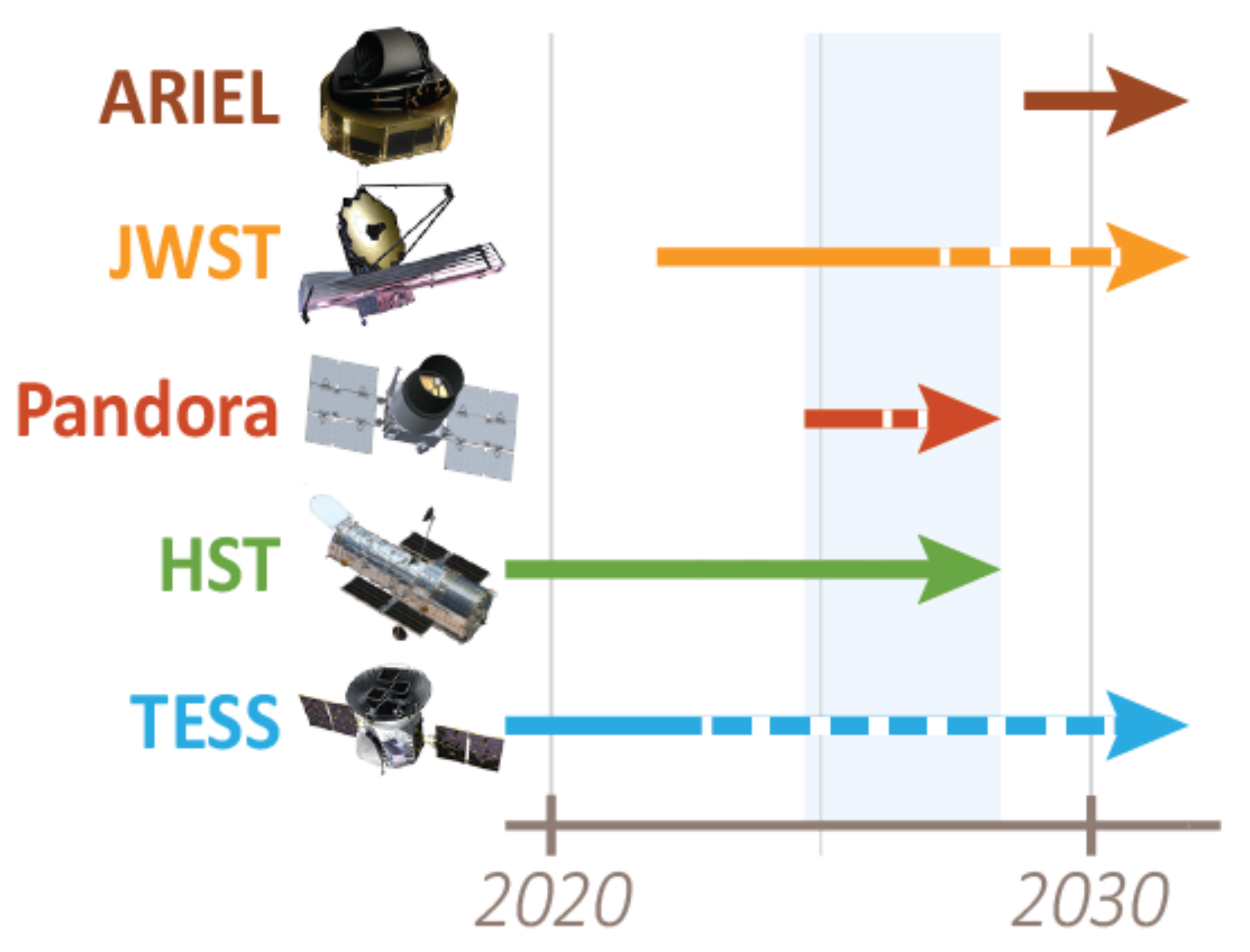
Targets are chosen to maximize both the range of stars and planets probed and the observing efficiency.

The precise target list will be prepared 6 mos before launch, but more than 20 suitable target stars have been identified for our notional target list.

Pandora's Unique Capabilities

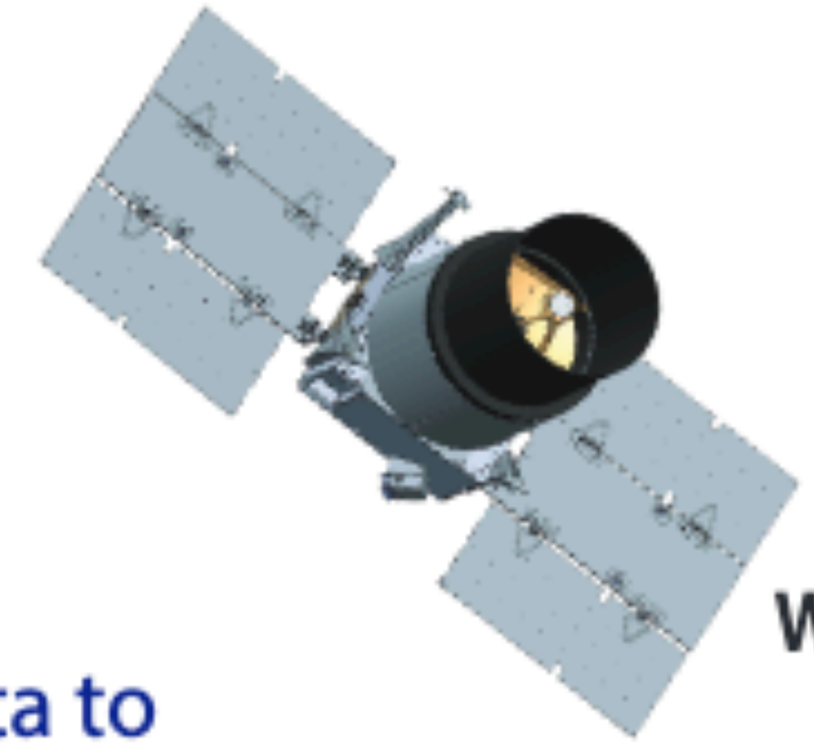


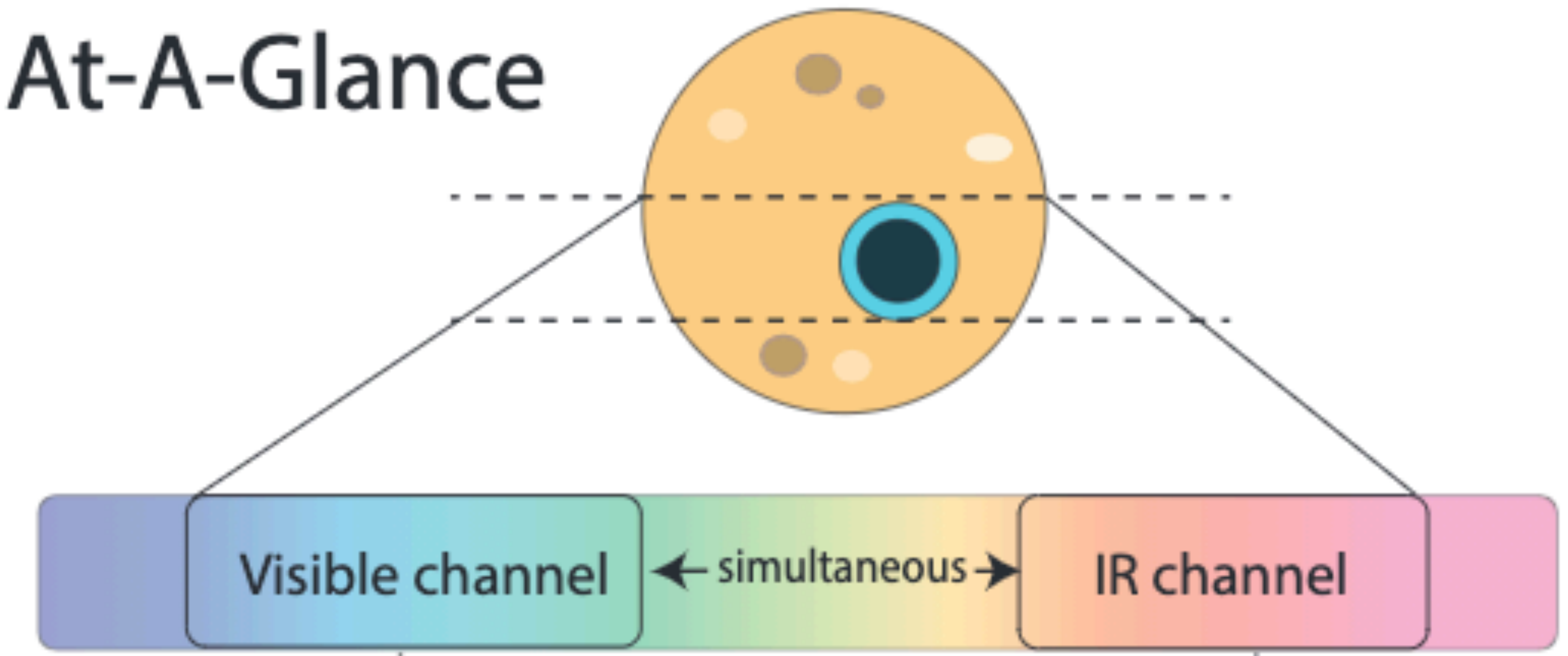
Note: Pandora's exact wavelength range under development



	Long time baseline	IR Observations	Visible Observations	**Simultanious** IR and Visible Observations	Low Cost	Available in mid-2020s
TESS	✓	X	✓	X	~	?
HST	X	✓	✓	X	X	?
JWST	X	✓	X	X	X	✓
ARIEL	X	✓	✓	✓	X	X
Ground	X	~	✓	~	~	✓
Pandora	✓	✓	✓	✓	✓	✓

Pandora Mission At-A-Glance





Pandora provides unique, continuous dual-band data to determine stellar photosphere properties and disentangle star and planetary signals in trans-mission spectroscopy.

Mission Overview

Launch Date	Mid-2020s
Payload	Telescope (0.45m)
Channels	Visible photometry IR spectroscopy
Orbit	Sun-sync LEO
Science Operations	1+ years

What do we measure?

Visible channel: Time-varying star brightness (in visible band where stellar variability has high contrast)

IR channel: Time varying spectrum (in IR band where water is strong molecular absorber)

What do measurements provide?

Star spot and faculae brightness contrasts (from visible) and covering fractions (from Vis+IR) as a function of time & stellar rotation

What do we learn?

Stellar atmosphere contribution to planetary spectrum + deeper understanding of stellar heterogeneity → Star-corrected planet spectrum revealing composition of intrinsic planetary atmospheres (water, hydrogen, clouds)

Why are the data unique?

Pandora will produce the first long-duration dataset with simultaneous visible photometry and IR spectroscopy of exoplanets and their host stars.

Why Now?

Pandora will inform JWST exoplanet transmission spectroscopy analyses, and operate concurrently with JWST.