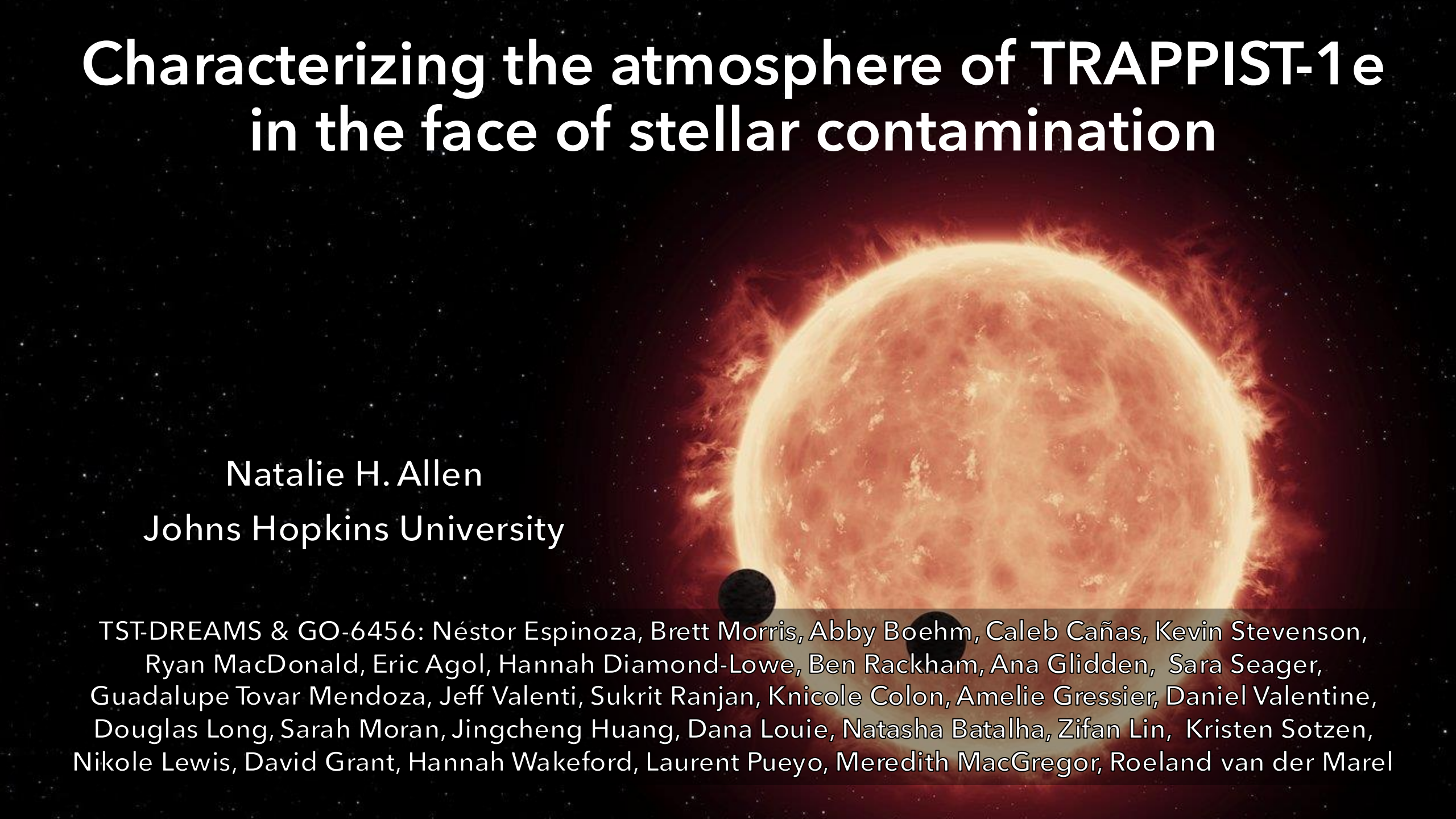
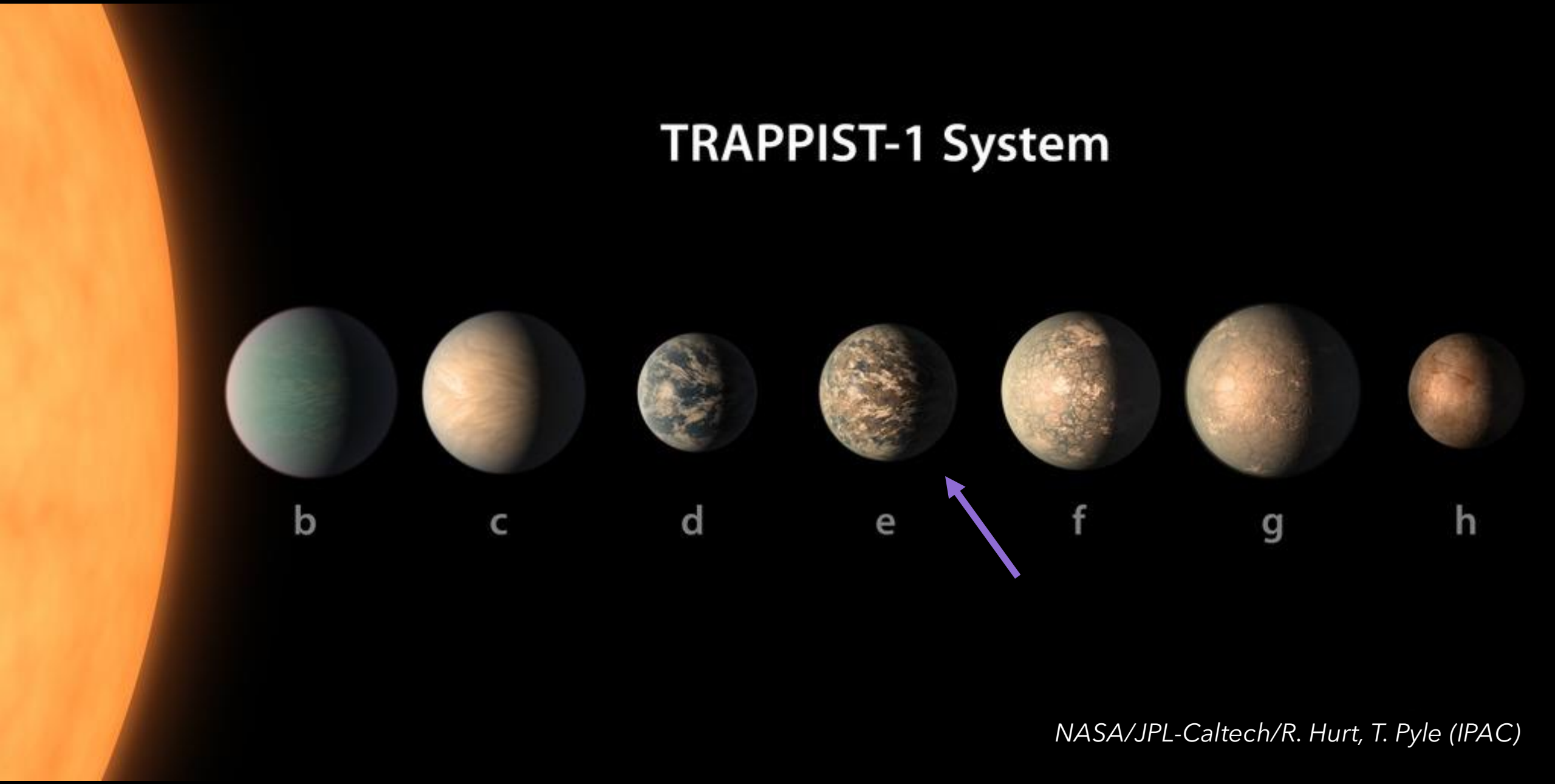
Characterizing the atmosphere of TRAPPIST-1 e in the face of stellar contamination



Natalie H. Allen

Johns Hopkins University

TST-DREAMS & GO-6456: Néstor Espinoza, Brett Morris, Abby Boehm, Caleb Cañas, Kevin Stevenson, Ryan MacDonald, Eric Agol, Hannah Diamond-Lowe, Ben Rackham, Ana Glidden, Sara Seager, Guadalupe Tovar Mendoza, Jeff Valenti, Sukrit Ranjan, Knicole Colon, Amelie Gressier, Daniel Valentine, Douglas Long, Sarah Moran, Jingcheng Huang, Dana Louie, Natasha Batalha, Zifan Lin, Kristen Sotzen, Nikole Lewis, David Grant, Hannah Wakeford, Laurent Pueyo, Meredith MacGregor, Roeland van der Marel

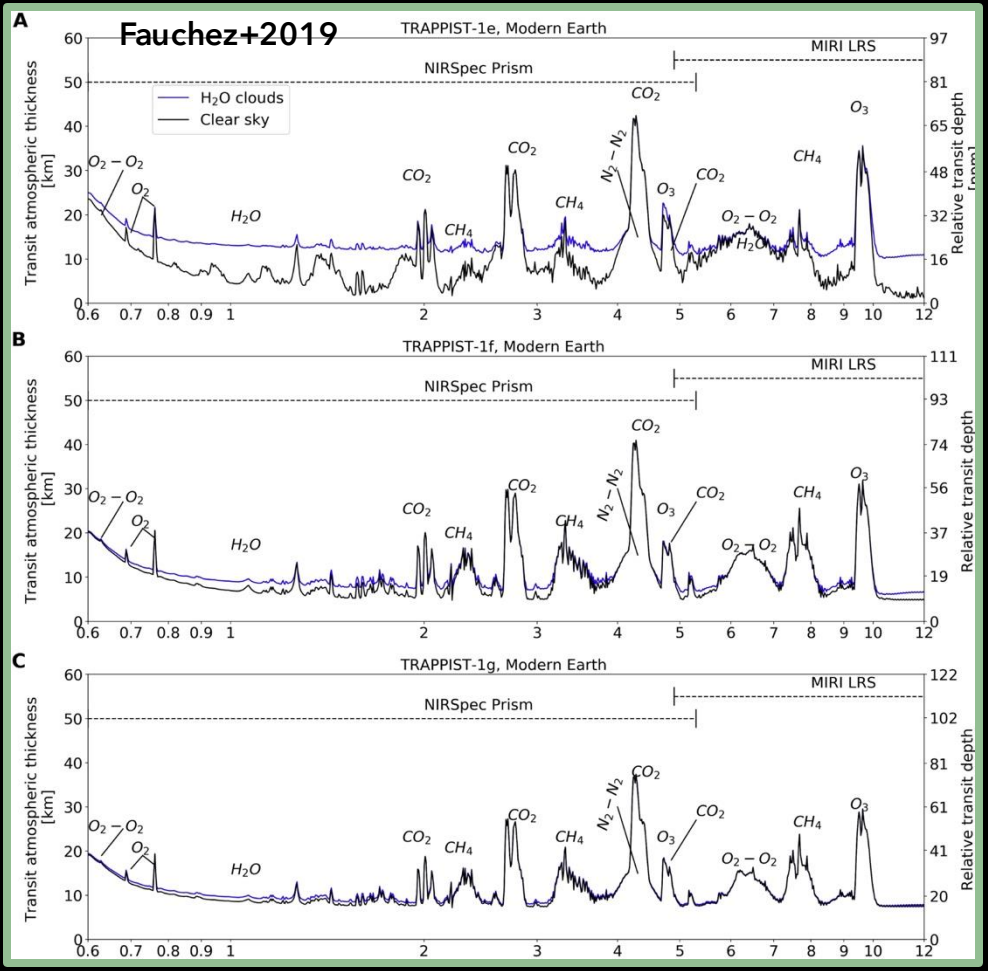


NASA/JPL-Caltech/R. Hurt, T. Pyle (IPAC)

ASA/JPL-Caltech/R. Hurt, T. Pyle (IPAC)

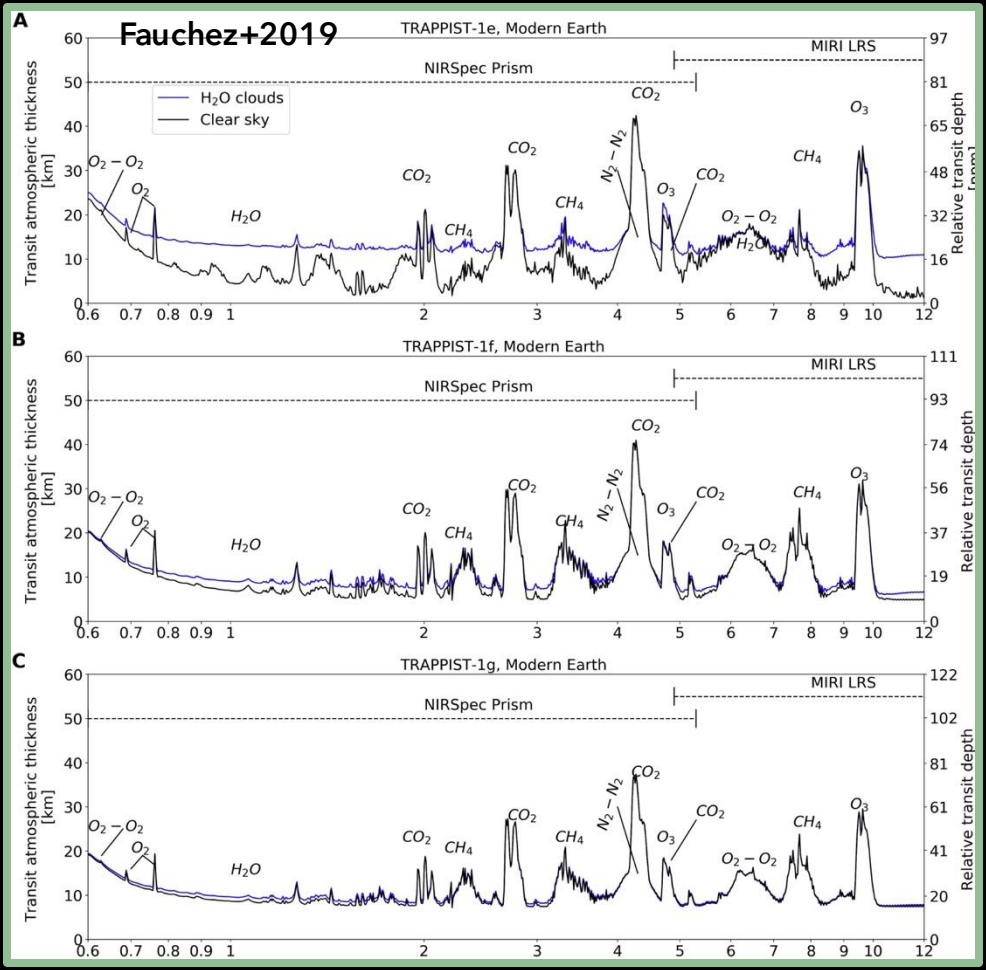
TRAPPIST-1 is our *best* chance to observe a habitable zone (temperate) terrestrial exoplanet with JWST

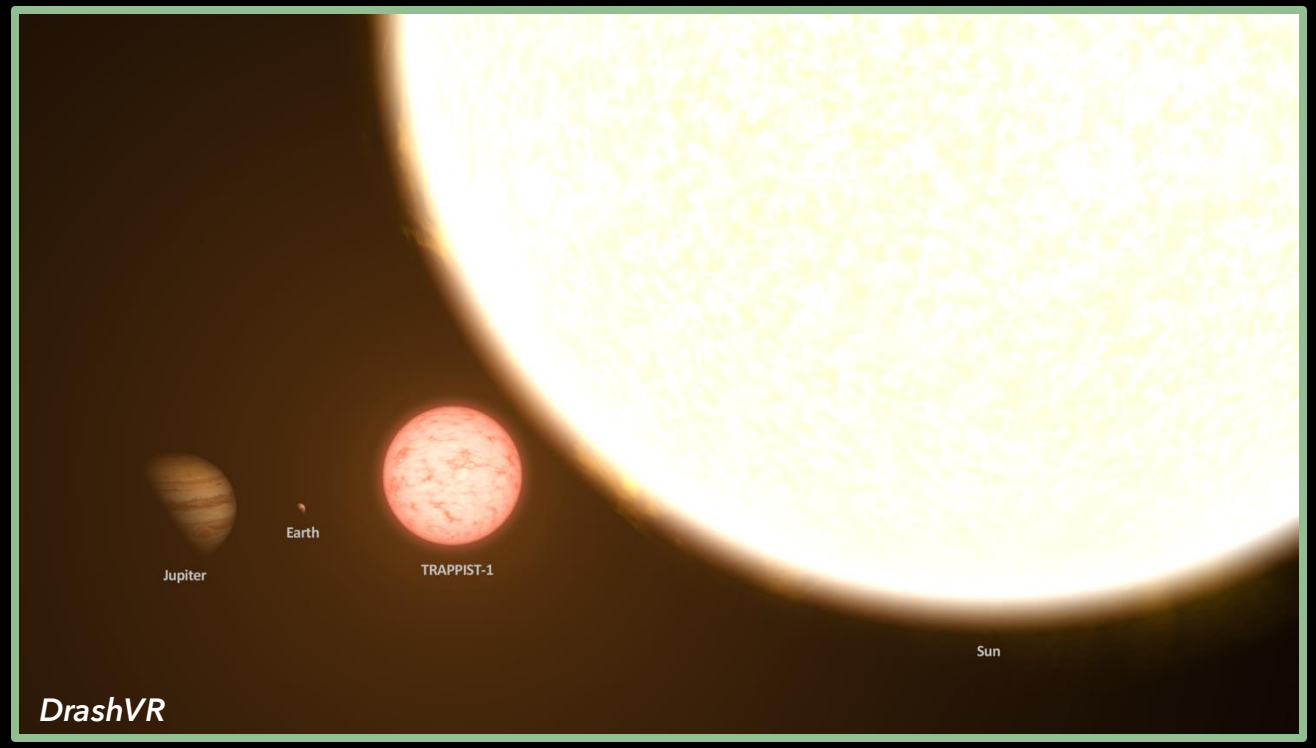
Predicted atmospheric features: ~10s to 100 ppm



TRAPPIST-1 is our *best* chance to observe a habitable zone (temperate) terrestrial exoplanet with JWST

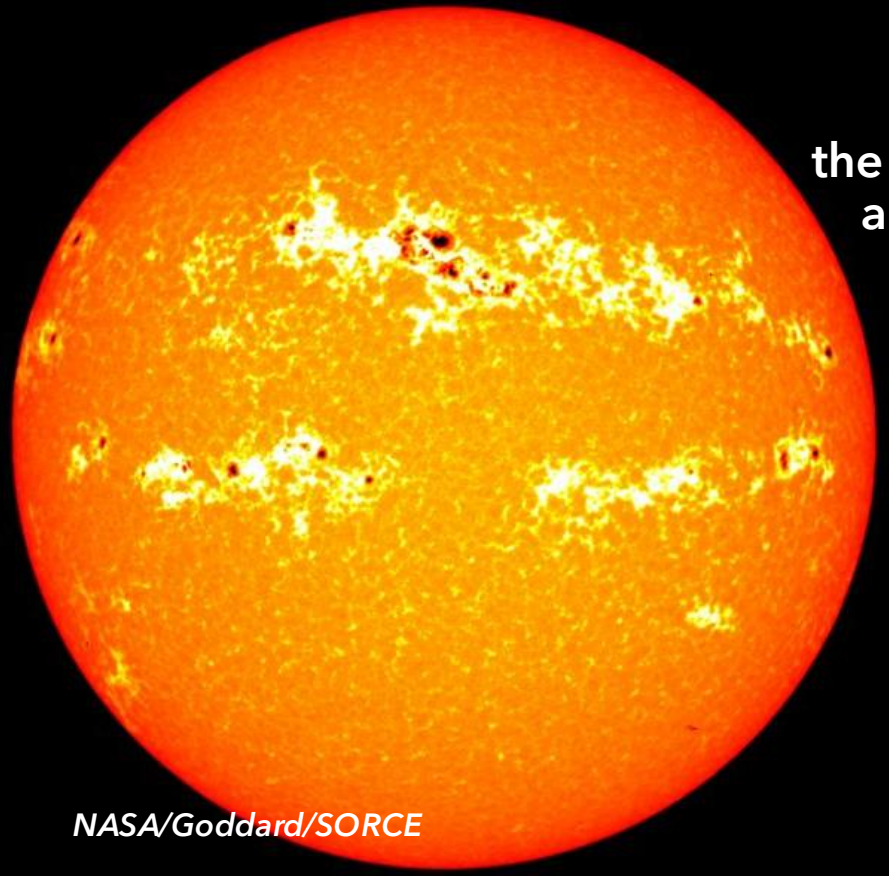
Predicted atmospheric features: ~10s to 100 ppm around the smallest possible star





TRAPPIST-1's small size is a double-edged sword:

Small stars = strong magnetic activity = strong surface features/flares = yikes
(and we have no idea what spots look like on M dwarfs)

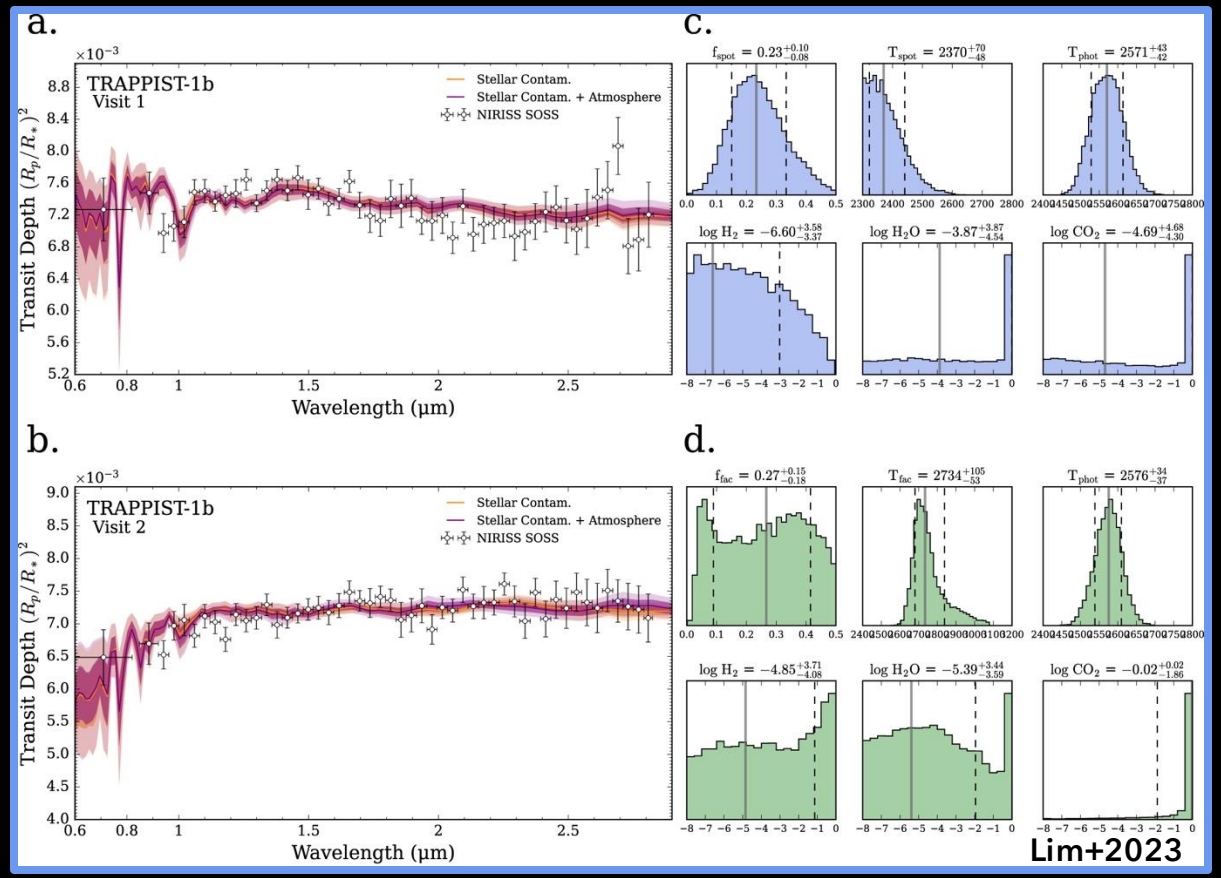


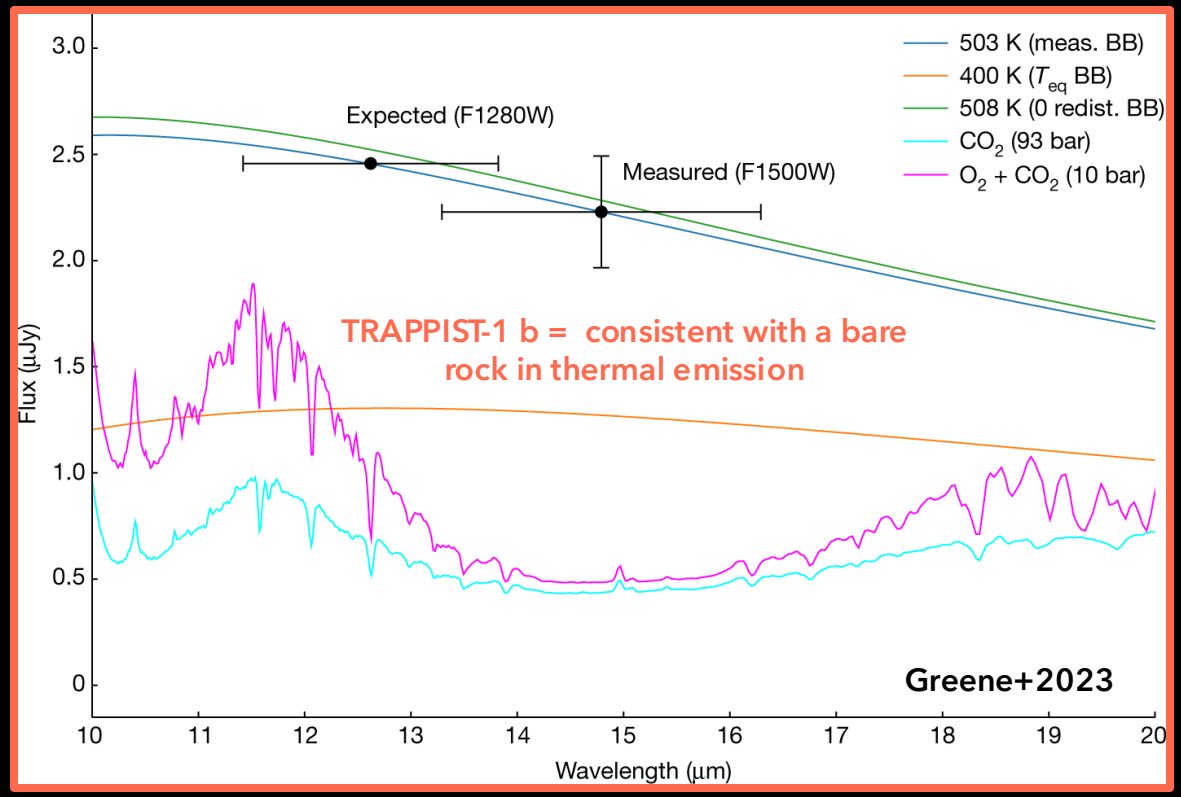
NASA/Goddard/SORCE

the sun is an *inactive* star
and still looks like this!

TRAPPIST-1's small size is a double-edged sword:

In early JWST observations, we see significant spectroscopic evidence of contamination across the optical-NIR





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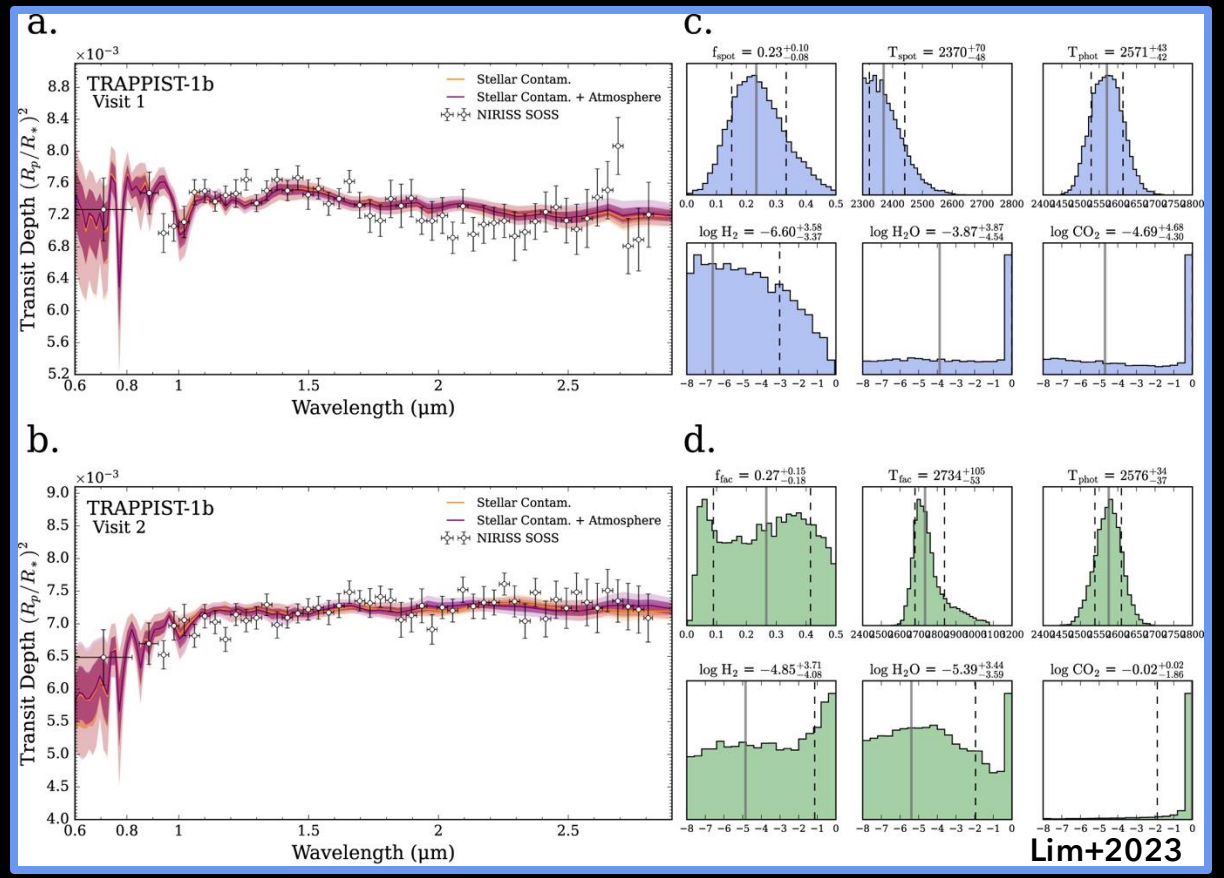
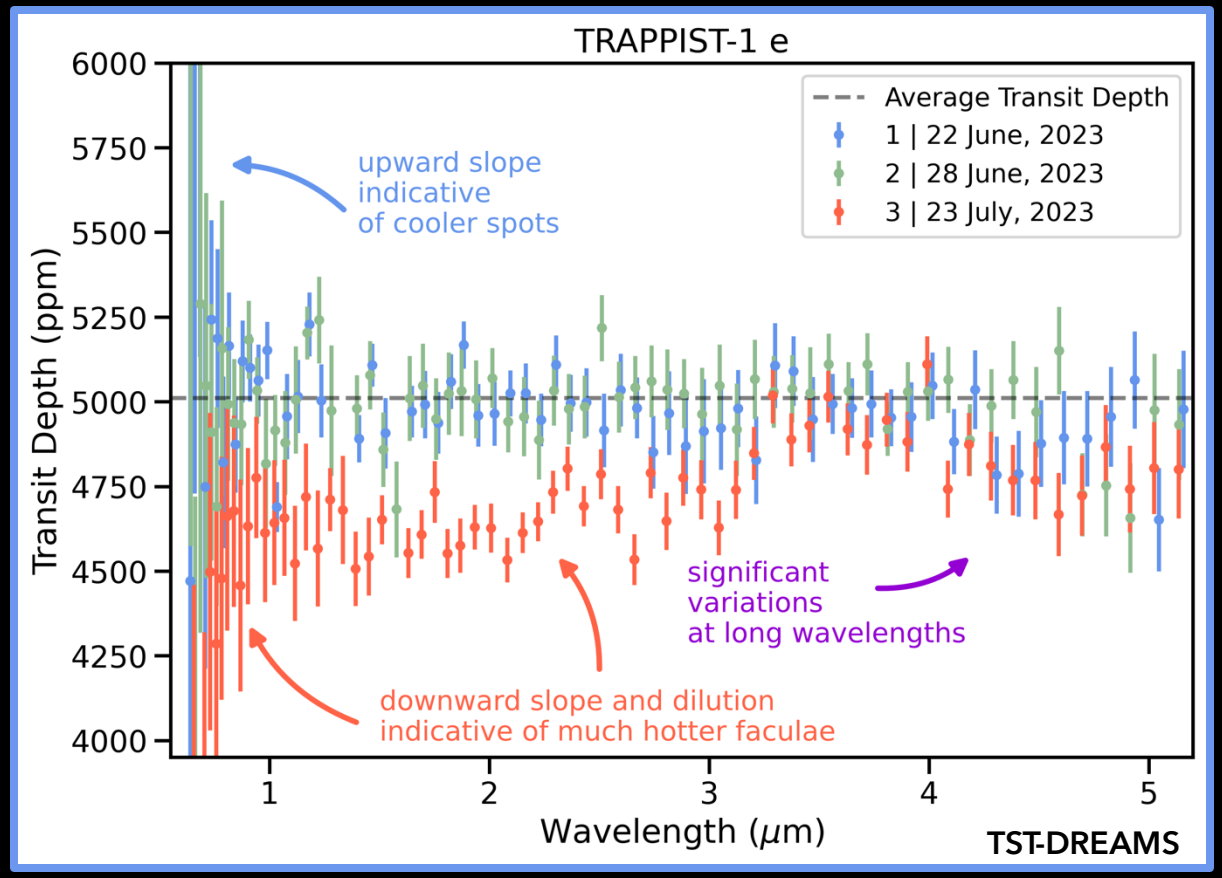
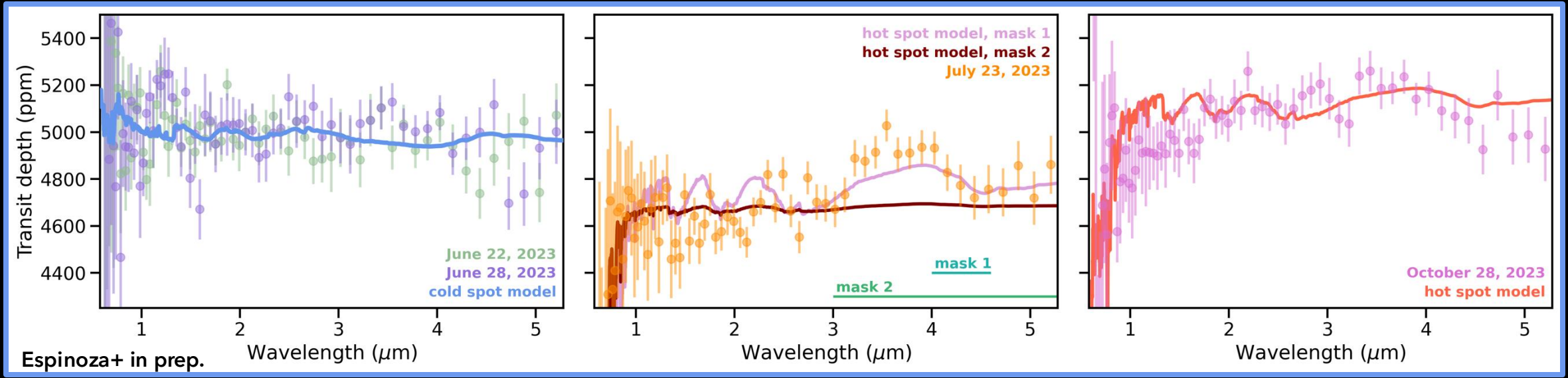




TRAPPIST-1's small size is a double-edged sword:

We are unable to model stellar contamination to the ~10s of ppm level needed to see atmospheric features across the whole wavelength range



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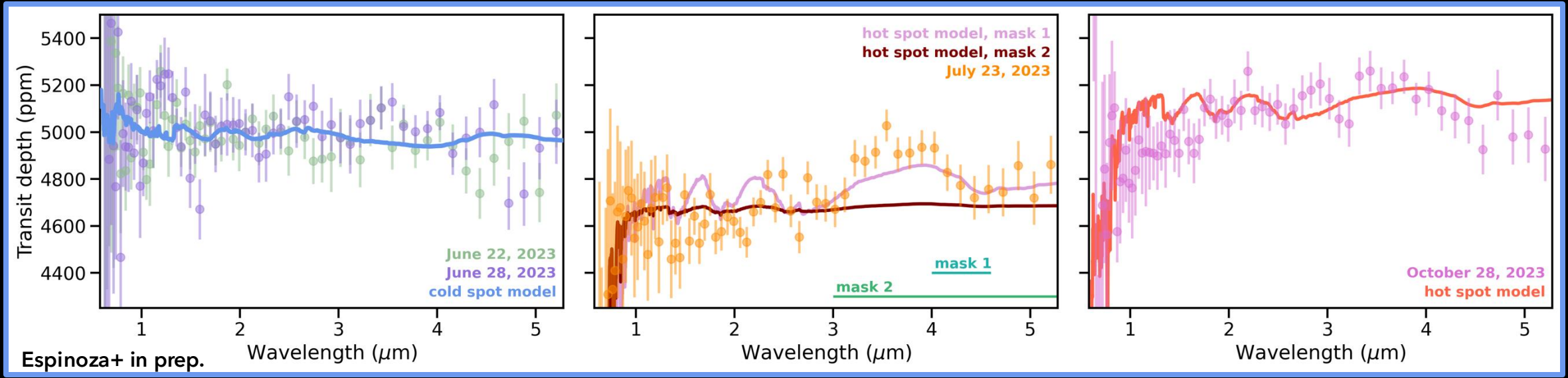

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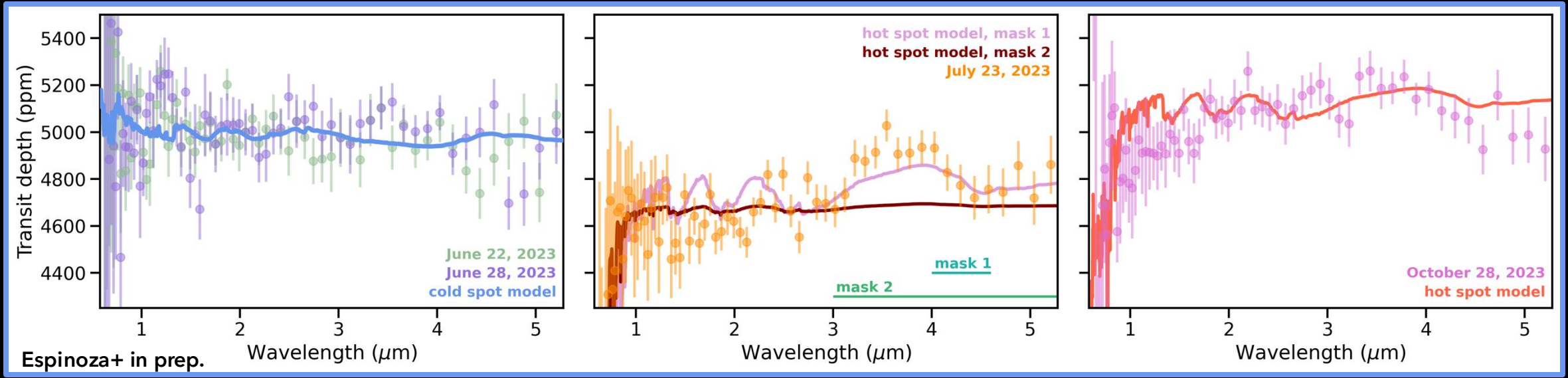

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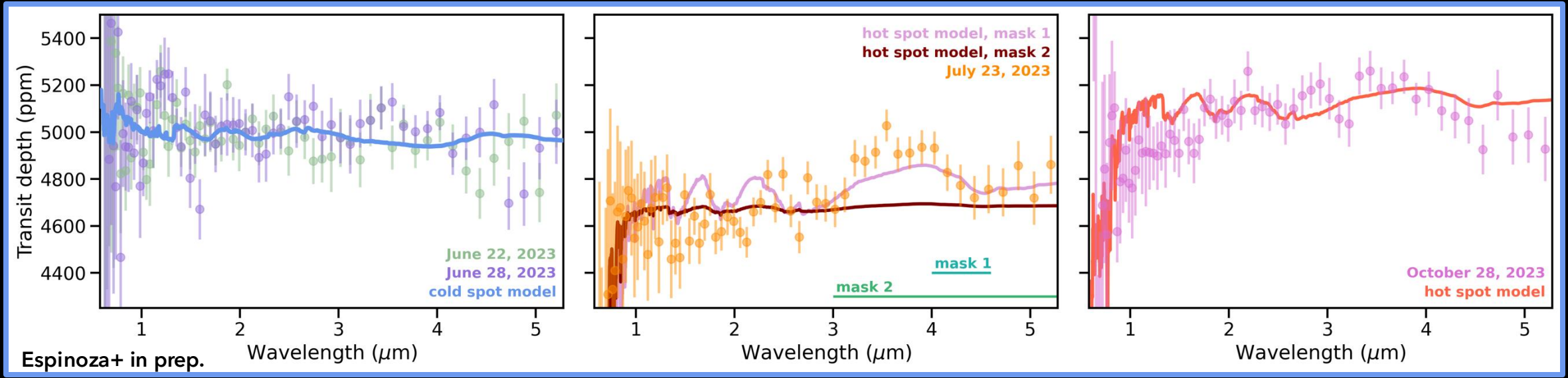

- Stellar contamination spans the entire NIRSpec/PRISM wavelength range
- The models cannot fit the 1-3 and 3-5 micron regions together
- Shortest wavelengths (i.e. NIRISS) cannot correctly infer the longer wavelengths

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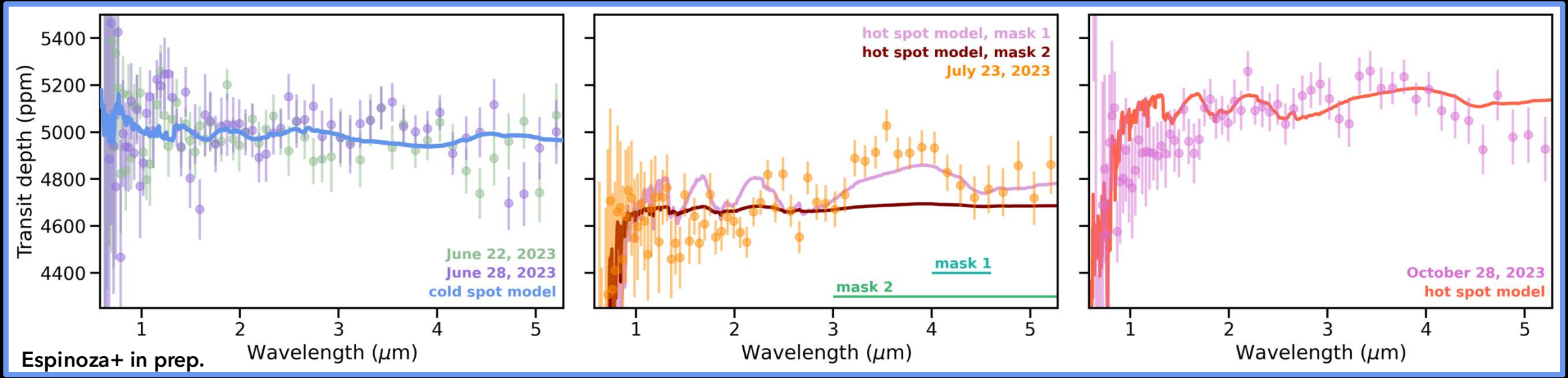

Our ability to correct for stellar contamination in the traditional method will *only ever be as good as our spot models*

Better models are being worked on! In the meantime…

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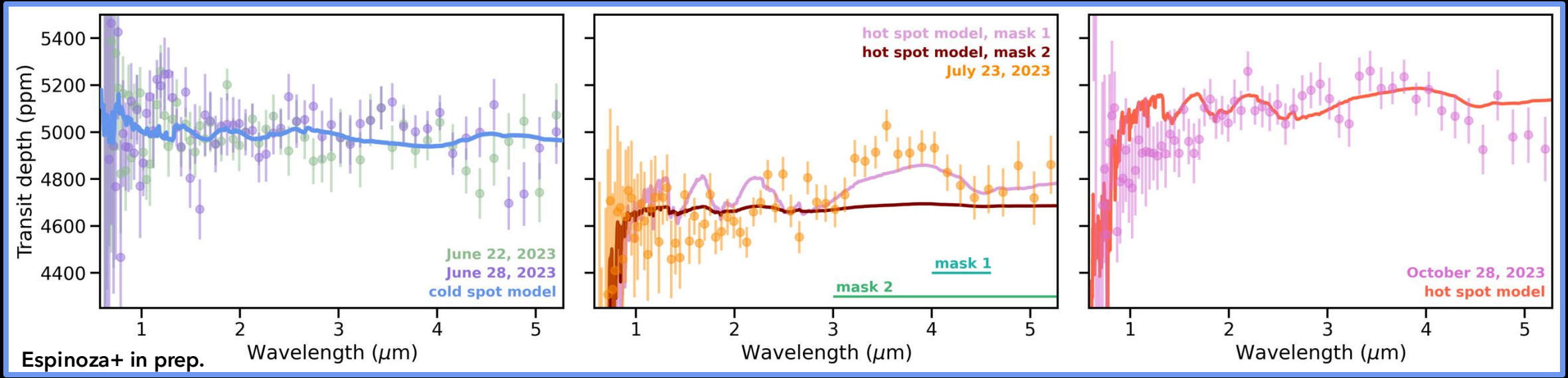

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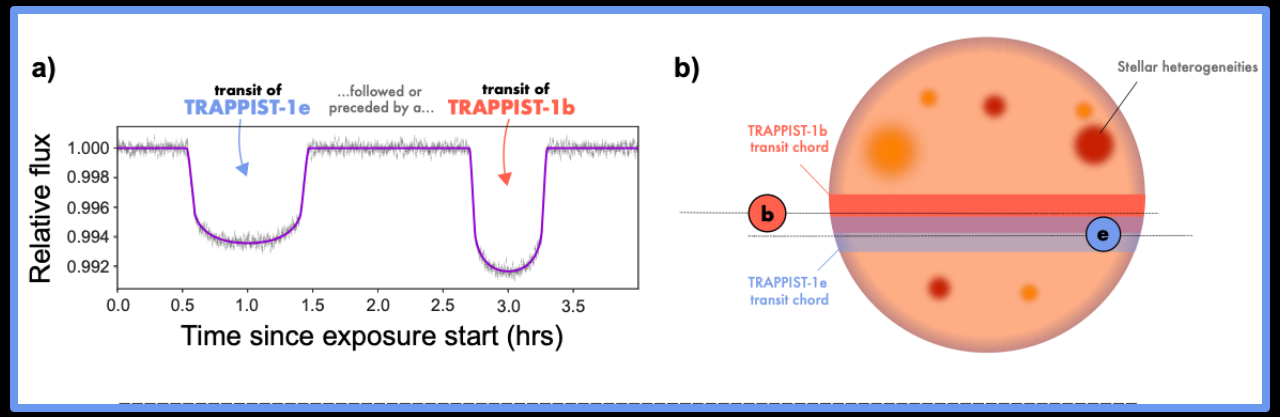
Check out Ana Glidden's poster (7.01) for atmospheric constraints from these observations!

Back-to-back transits to model-independently deal with stellar contamination



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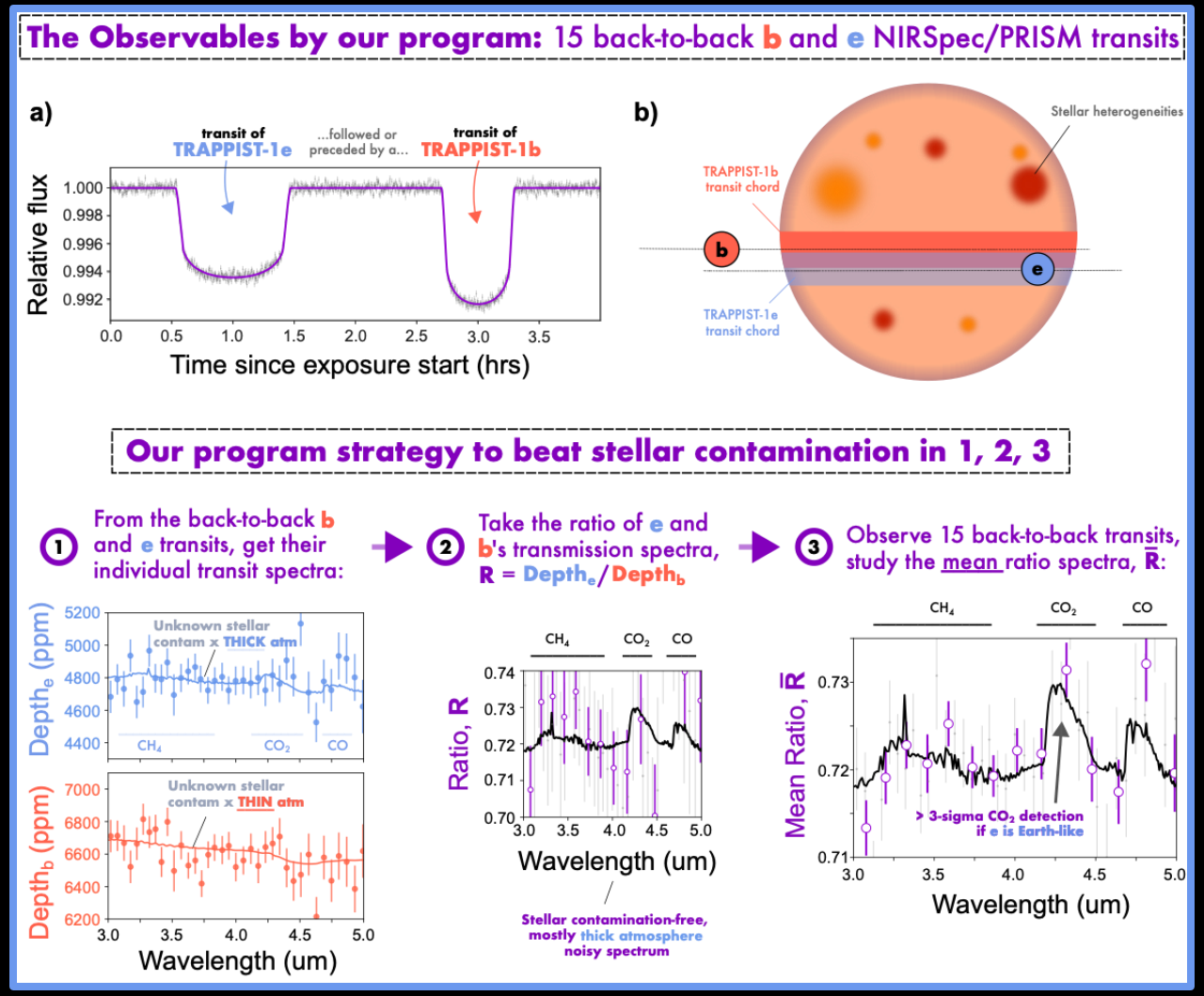
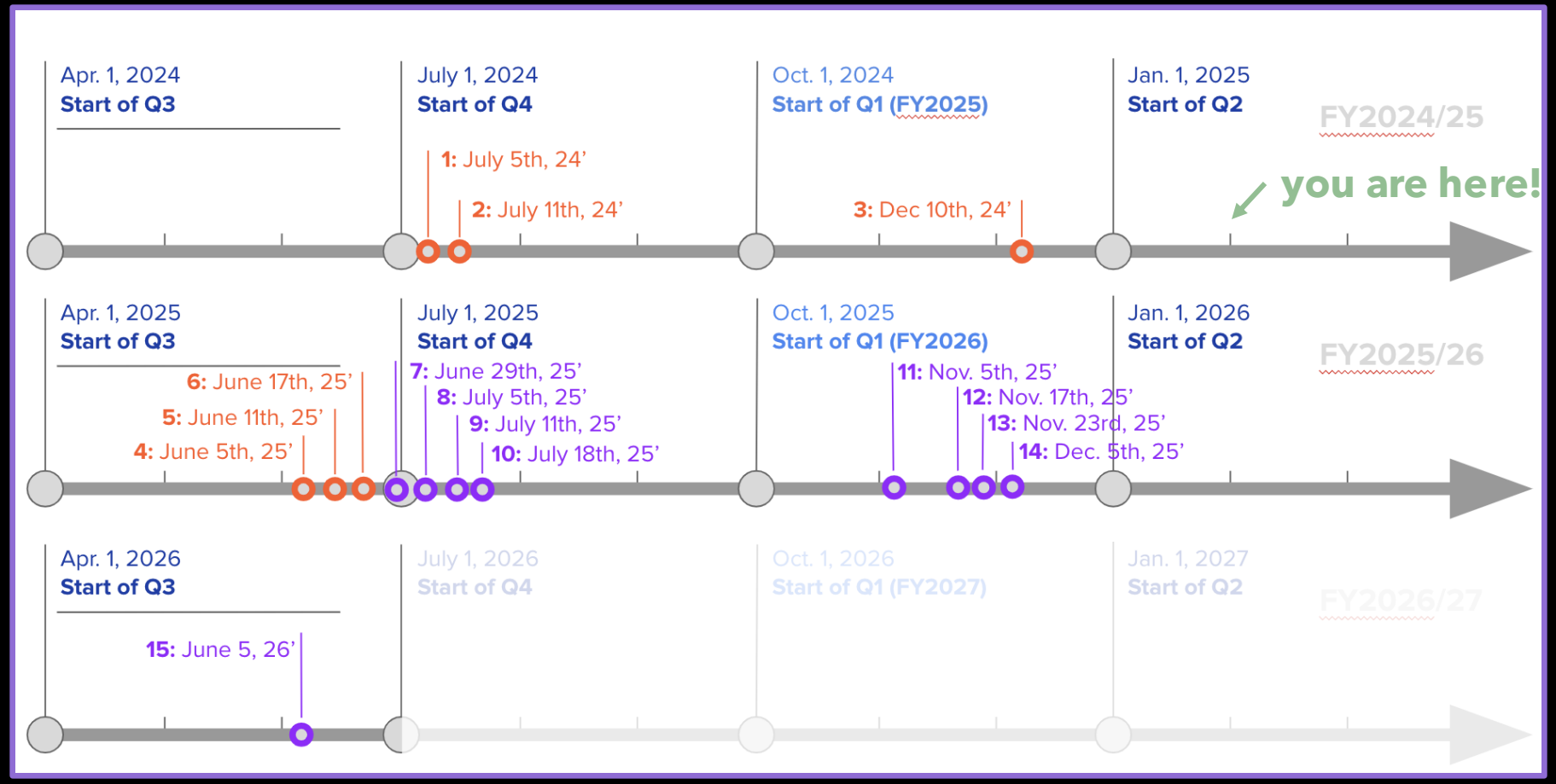
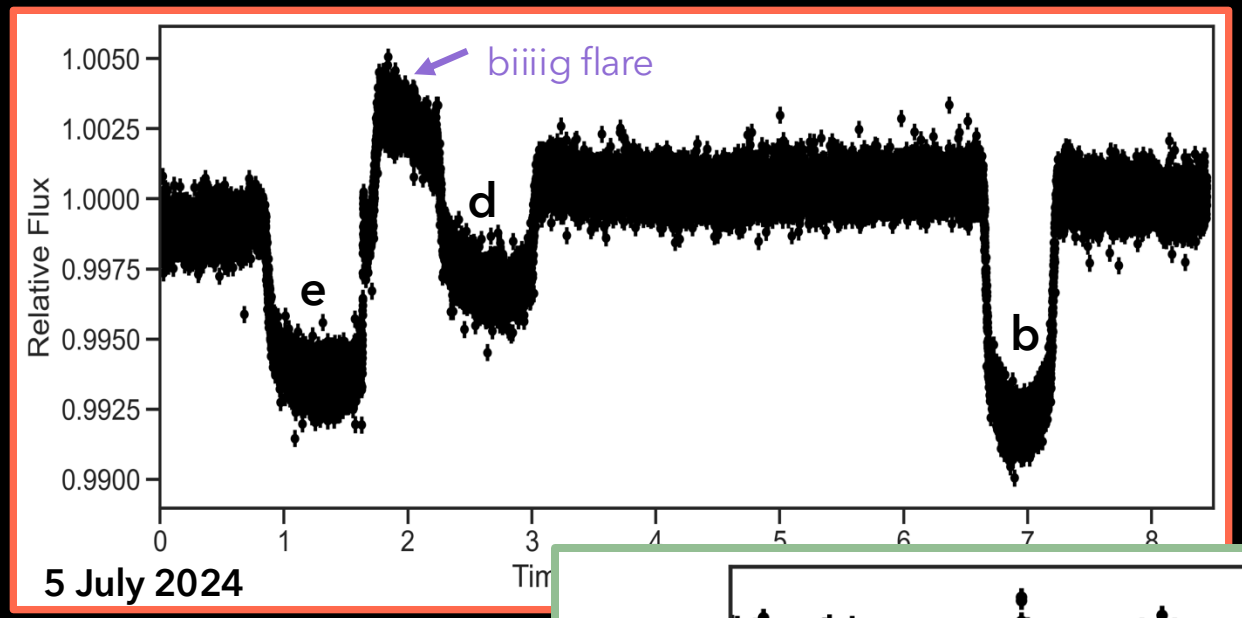


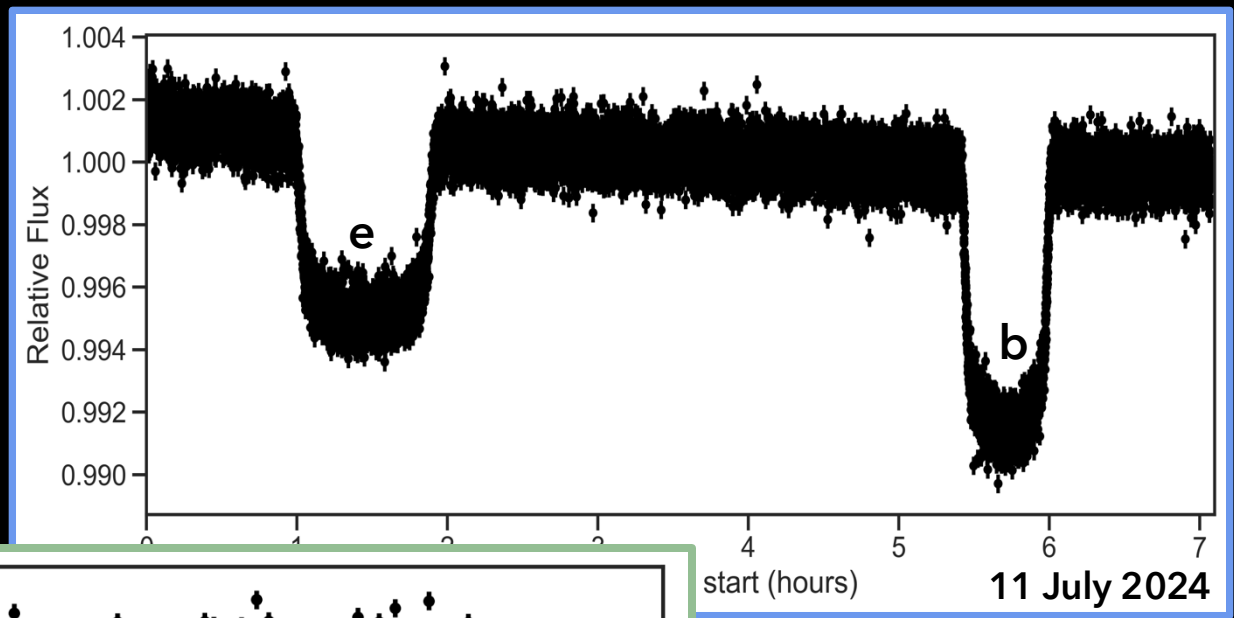
PIs: Natalie Allen and Néstor Espinoza, GO-6456

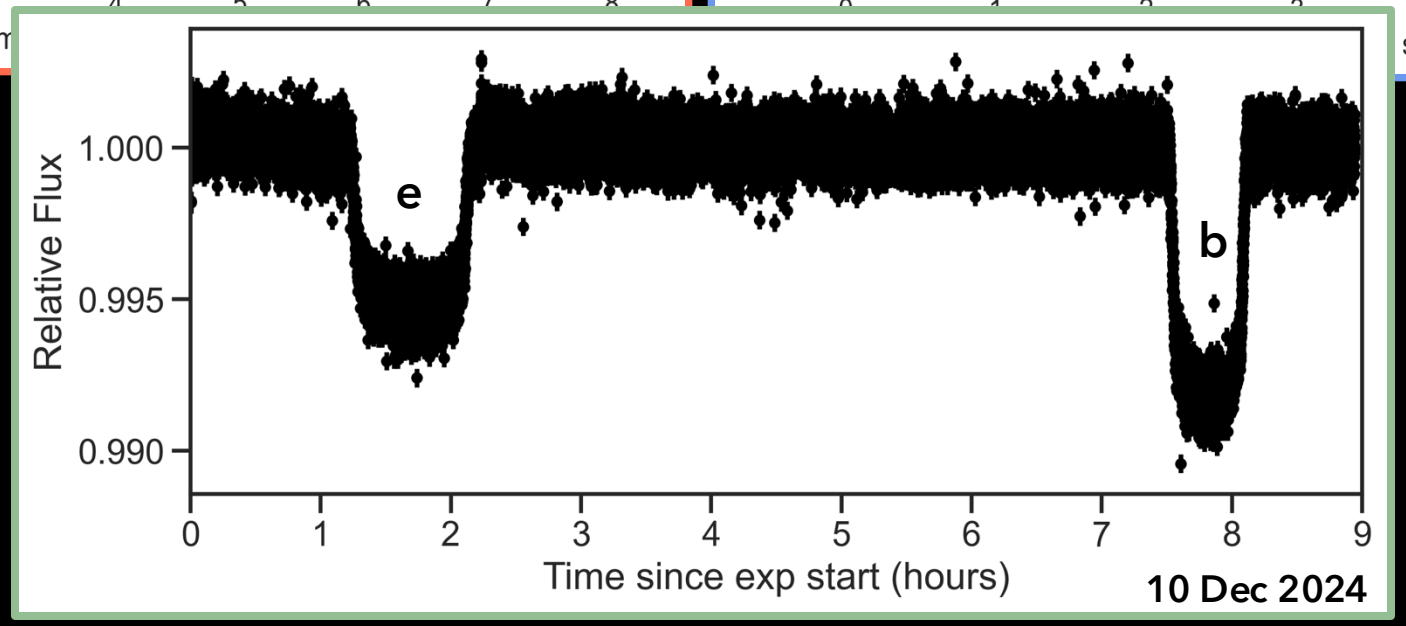
15 close transit observations over two years to figure out TRAPPIST-1(e)



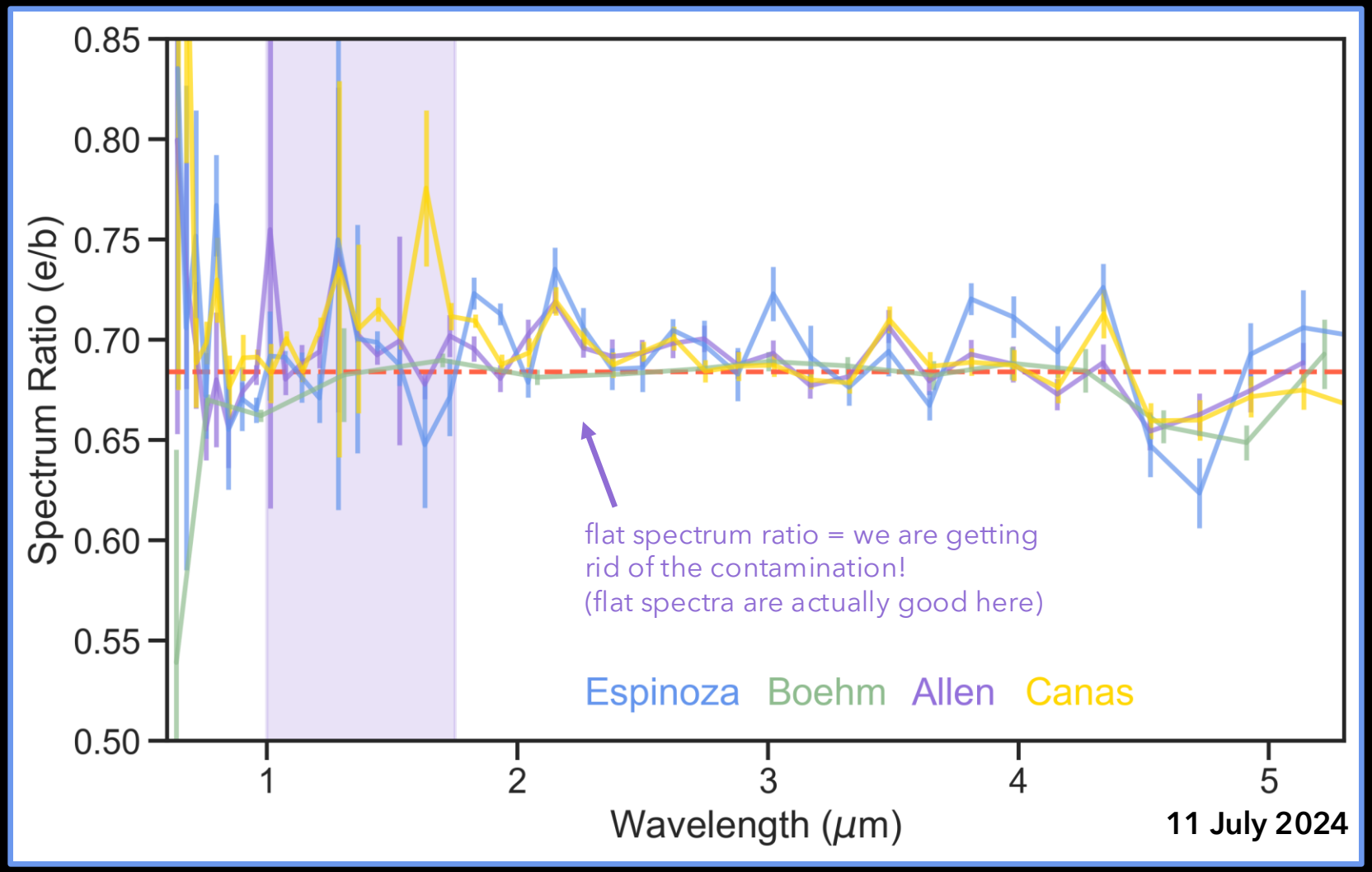
There's a lot going on in our first three observations:



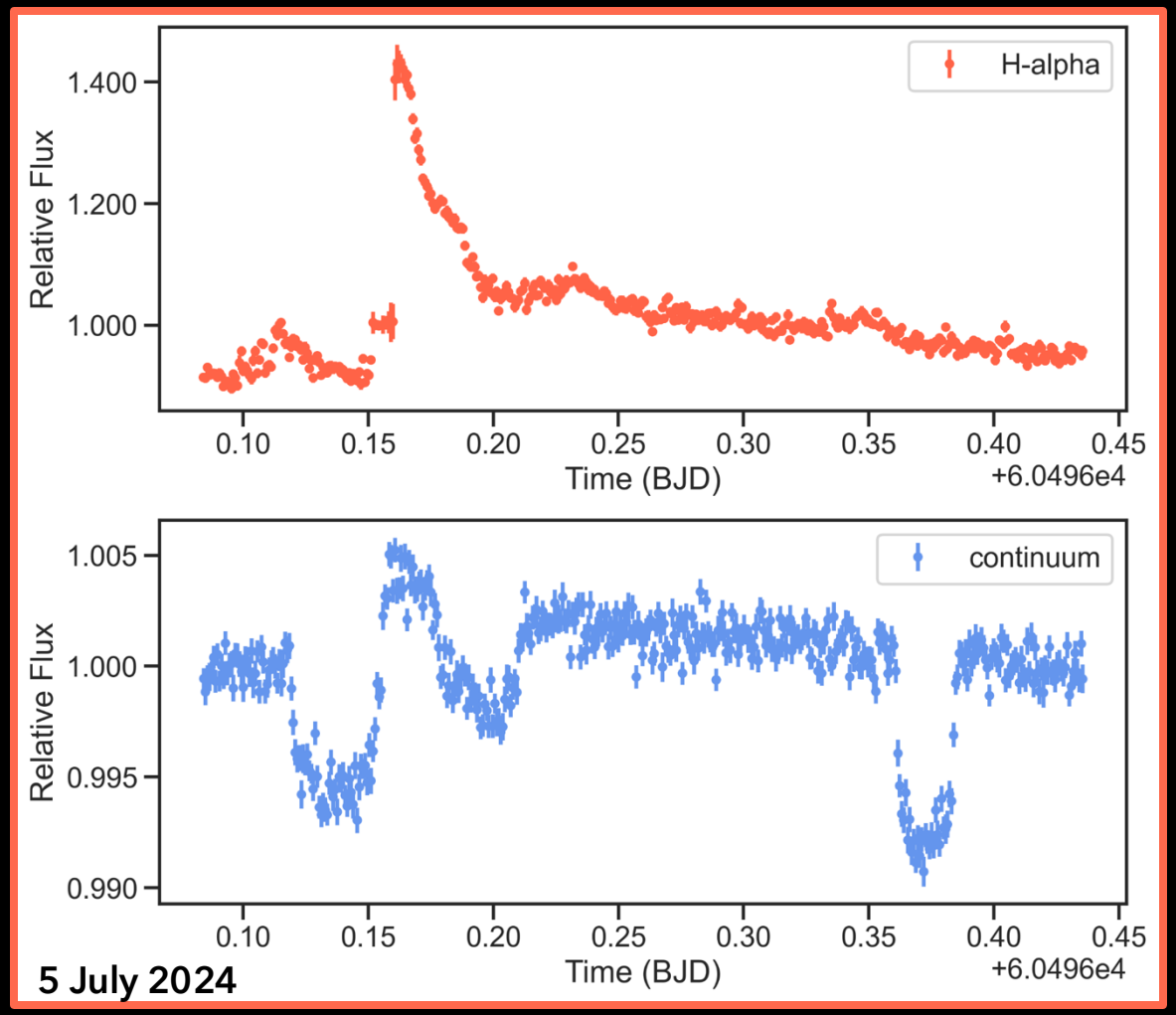


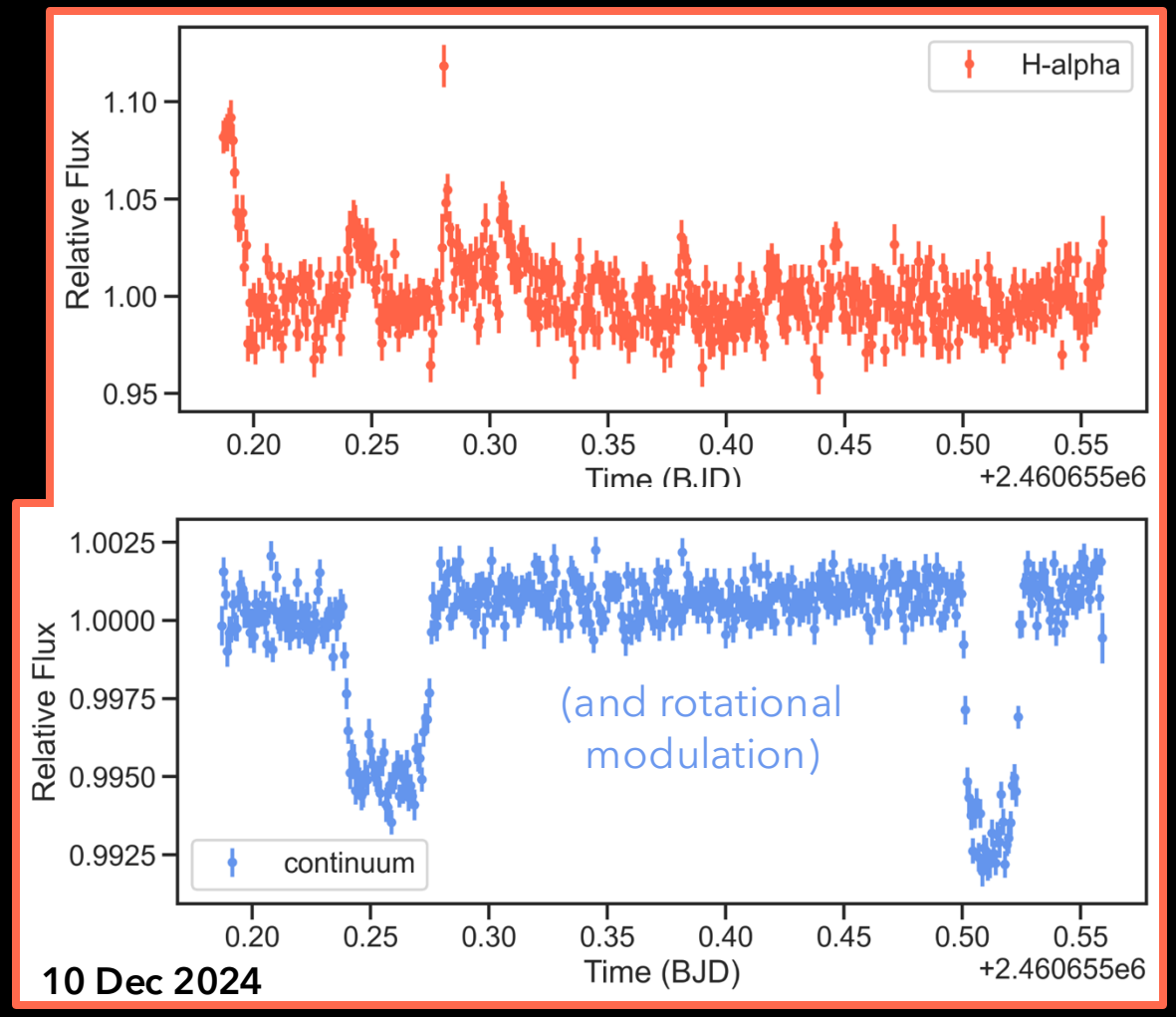


Our preliminary look at the ‘clean’ second visit spectra seem promising, showing the ability to correct for persistent surface features (spots/faculae)



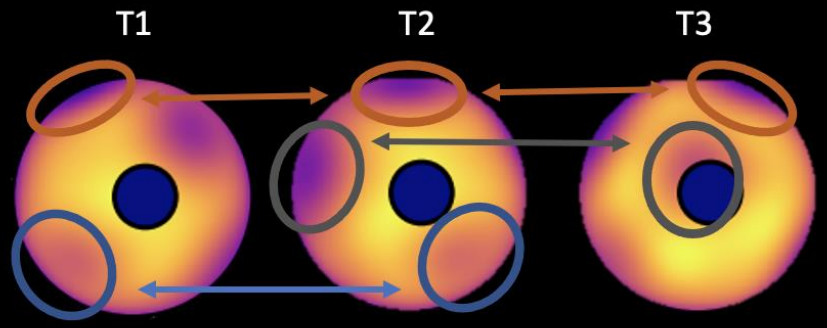
… but flares present a significant problem – not always obvious, but can change the stellar surface (on multiple timescales)

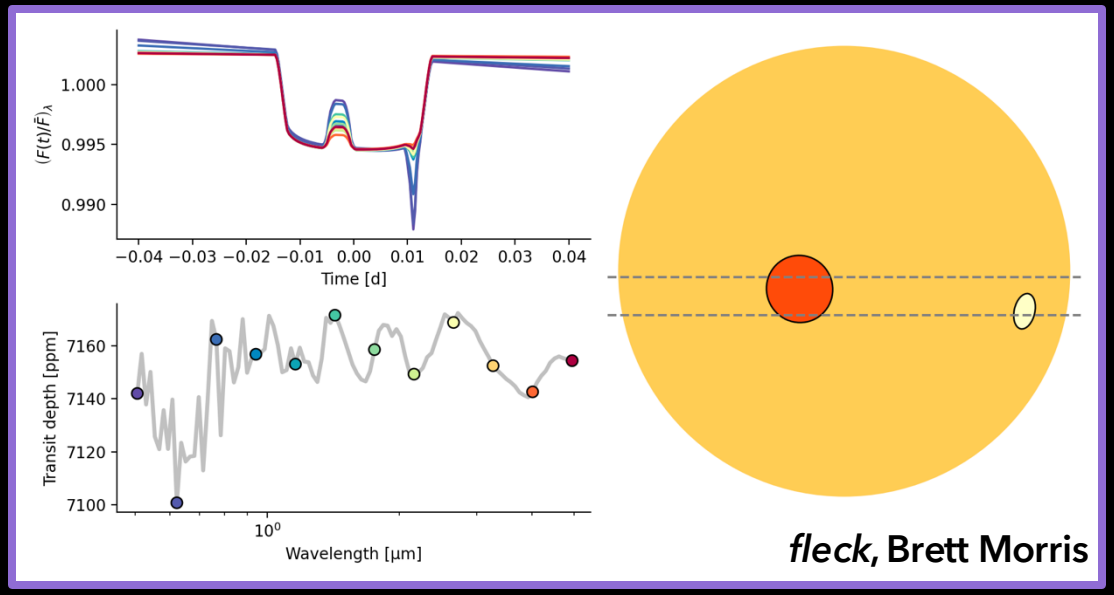




However, we are well prepared to analyze the observations if this method of stellar contamination transference doesn't work:

Model multiple observations using a persistent, evolving stellar surface at the light curve level

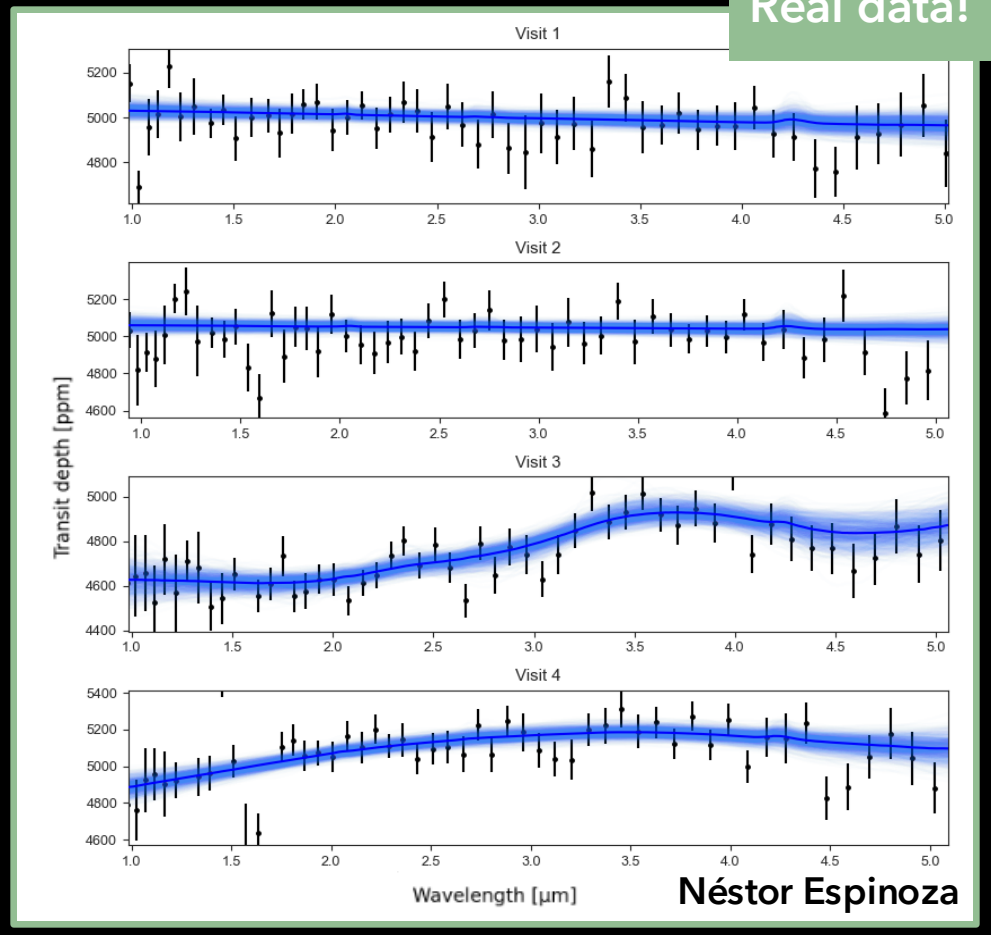




fleck, Brett Morris

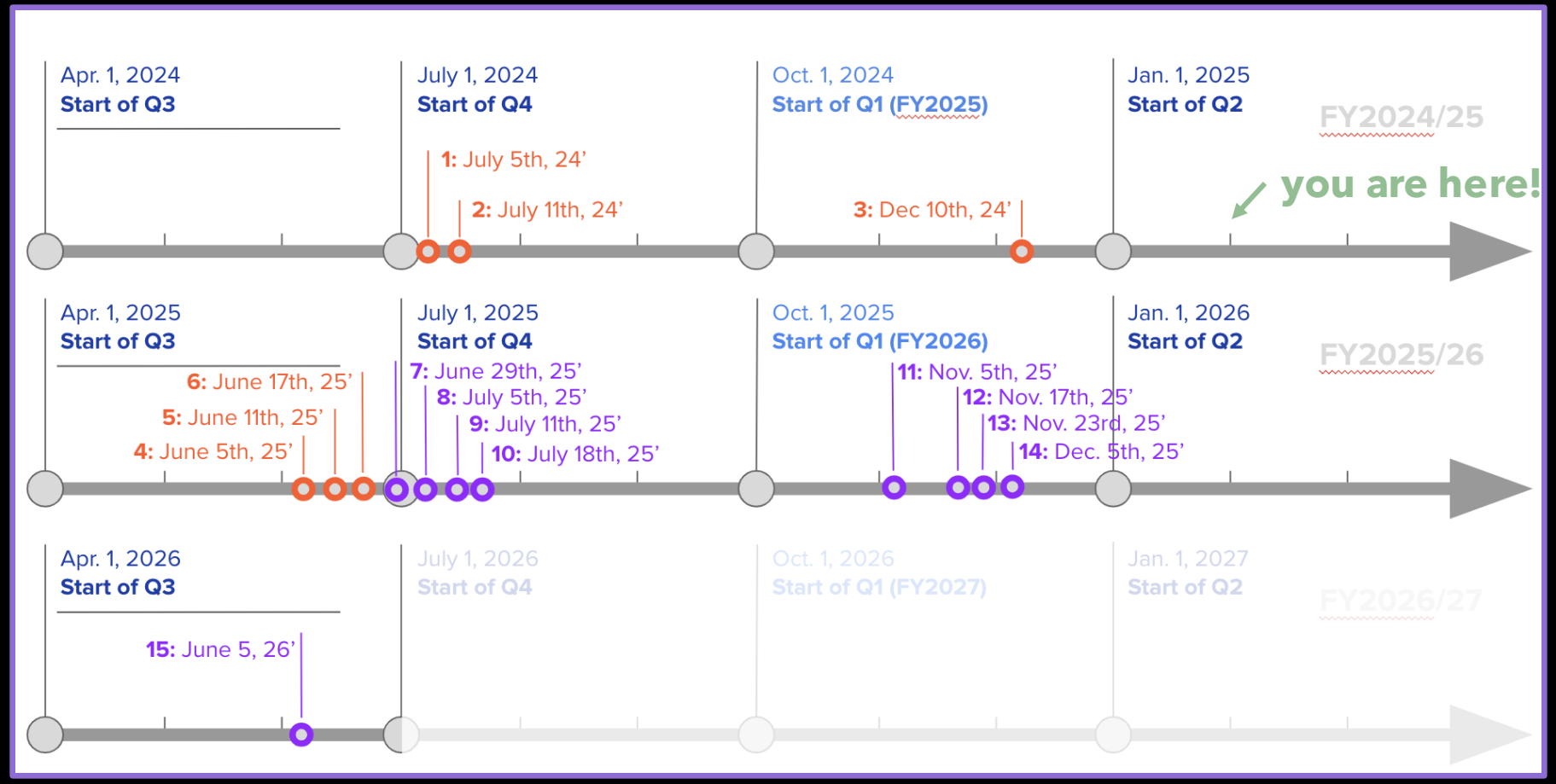
Stellar contamination as a gaussian process

Real data!



Néstor Espinoza

We have many more observations to go – please be patient for our final result! (and let us know if you're interested in helping with simultaneous observations)



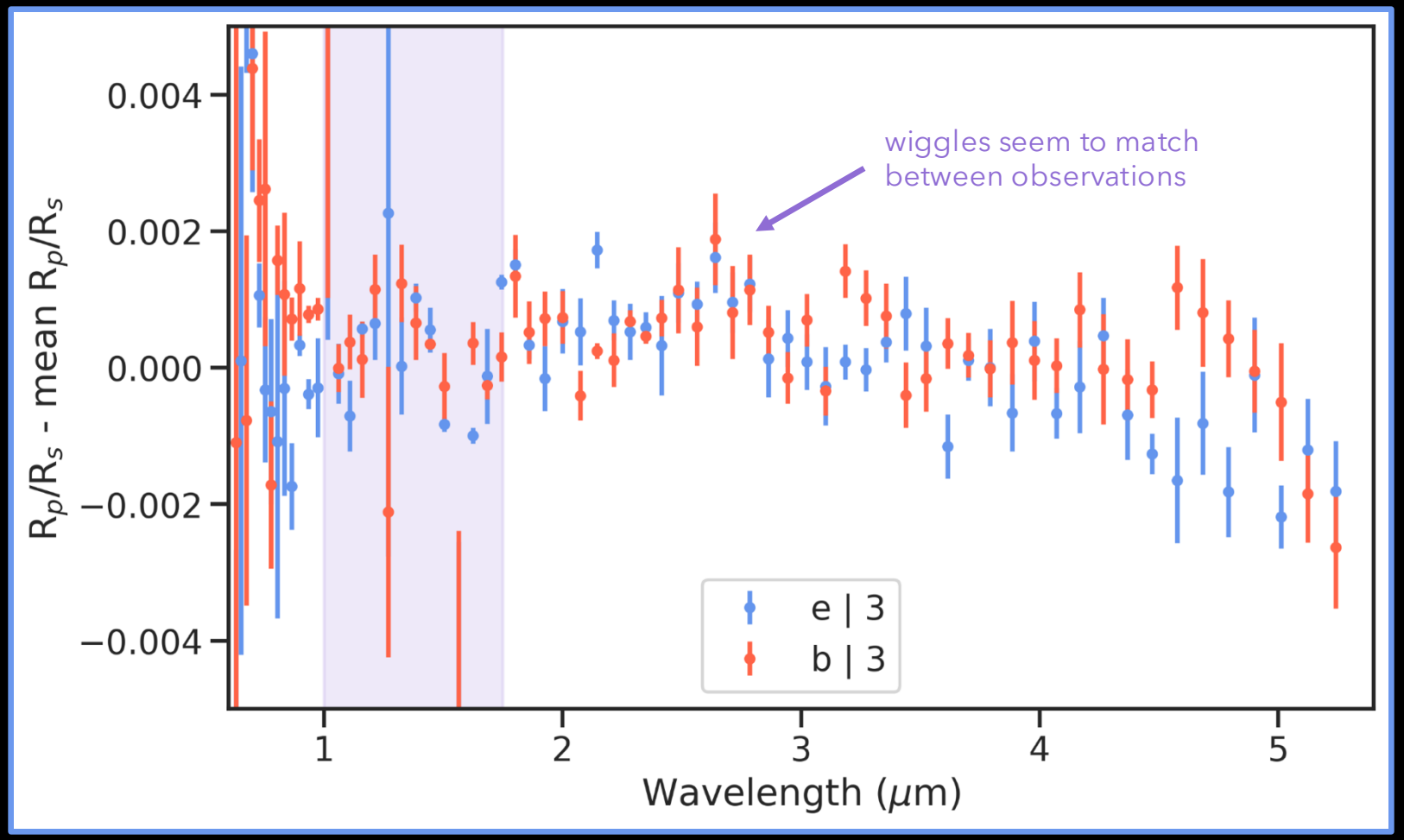
Takeaways:

1. Modeling of stellar contamination in transmission spectra with current stellar models is proving to be insufficient to get to the precision needed to detect terrestrial atmospheres
2. GO-6456 is obtaining close transits of TRAPPIST-1e and b to "model-independently" correct for stellar contamination and determine if TRAPPIST-1e is Earthlike or not
3. The first results are promising, but also show that the star will continue to be a problem even with this strategy
4. Even in the case of imperfect stellar contamination transfer, we have methods in the works to model the stellar contamination

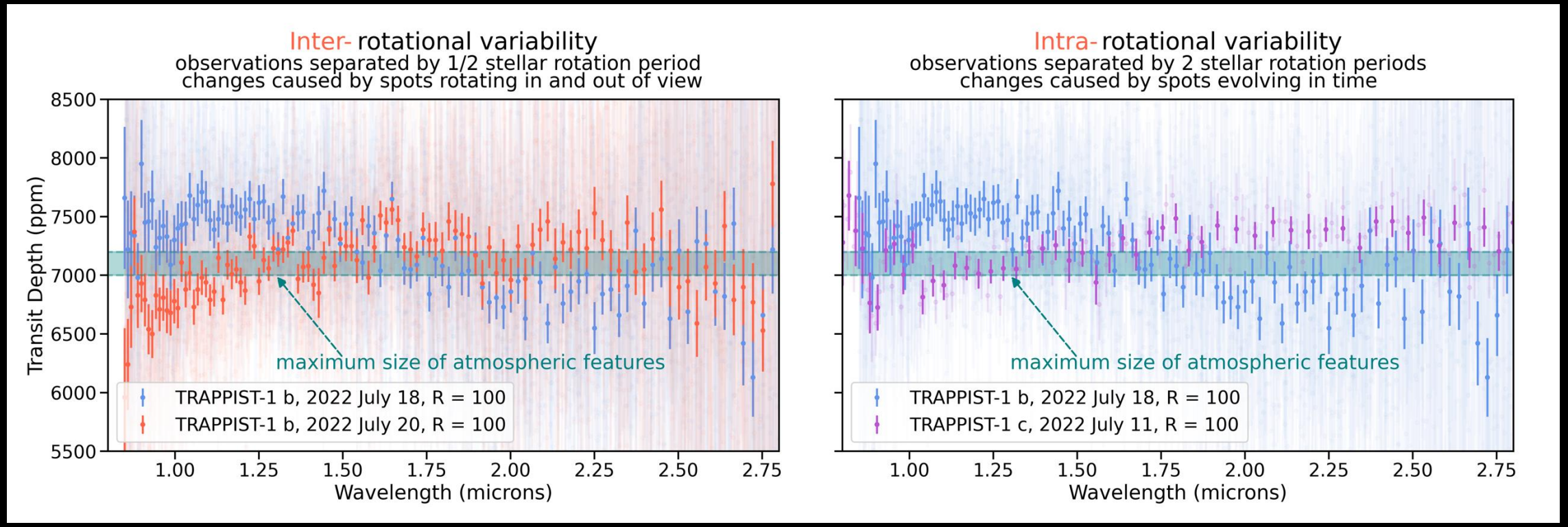
Stay tuned for more results from our TRAPPIST-1 study!

Natalie H. Allen | nataliehallen.com

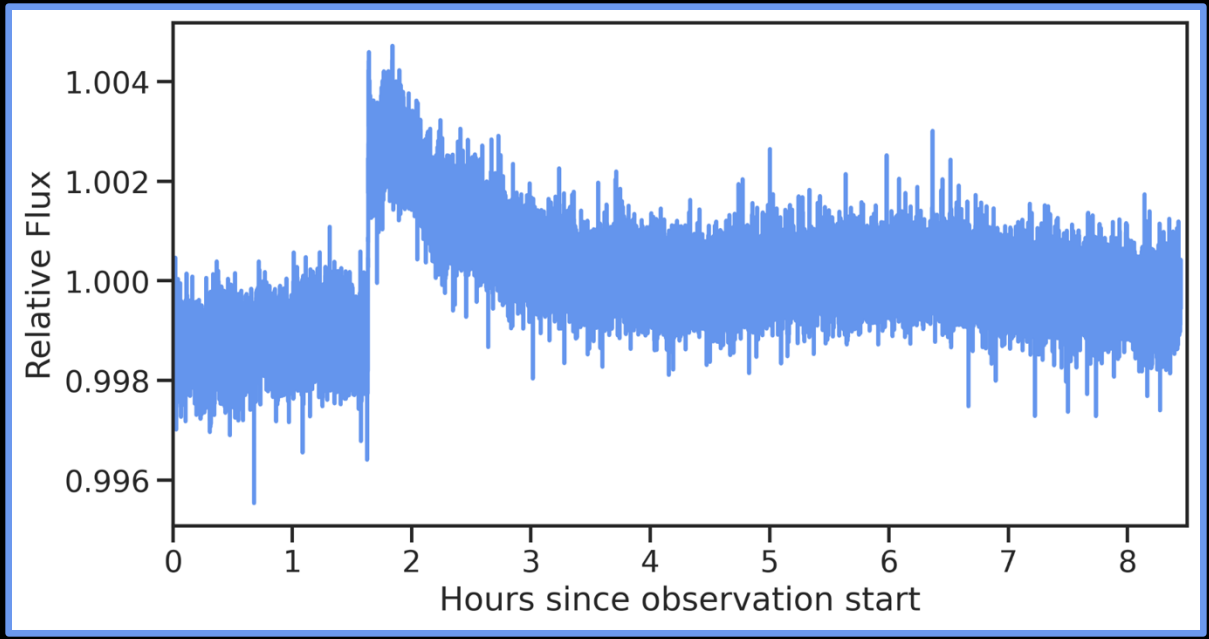
...and our preliminary look at the spectra seem promising, but complicated

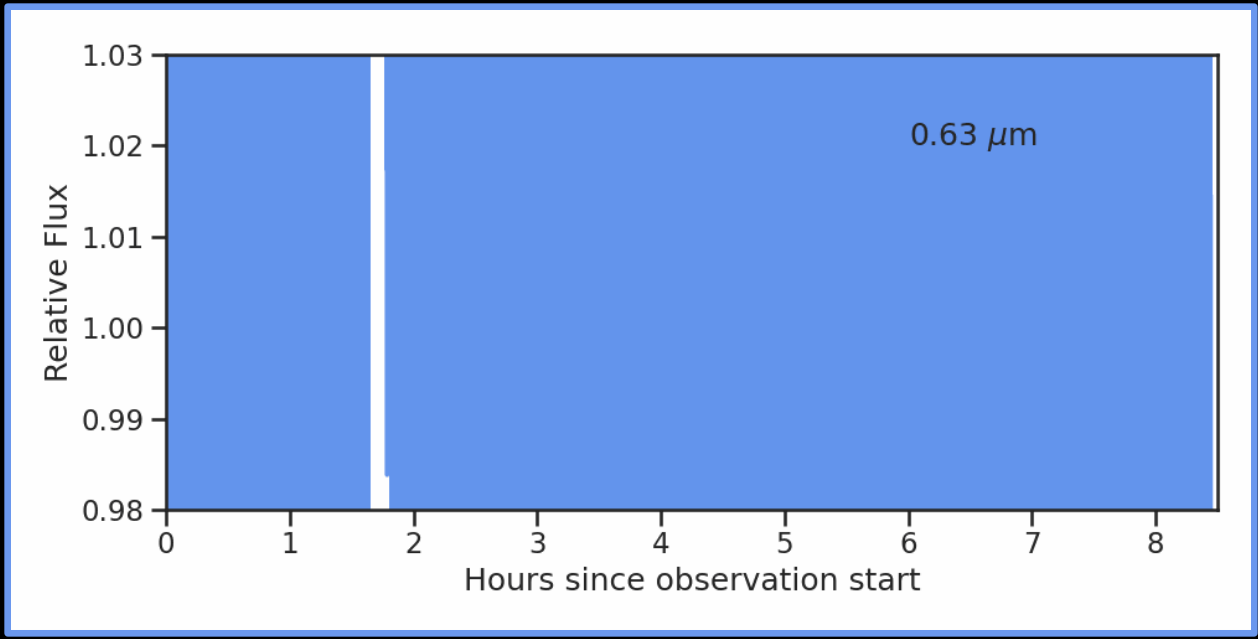


Backup: stellar contamination in observations of TRAPPIST-1 show the star switches between being spot or faculae dominated, evolves on short timescales

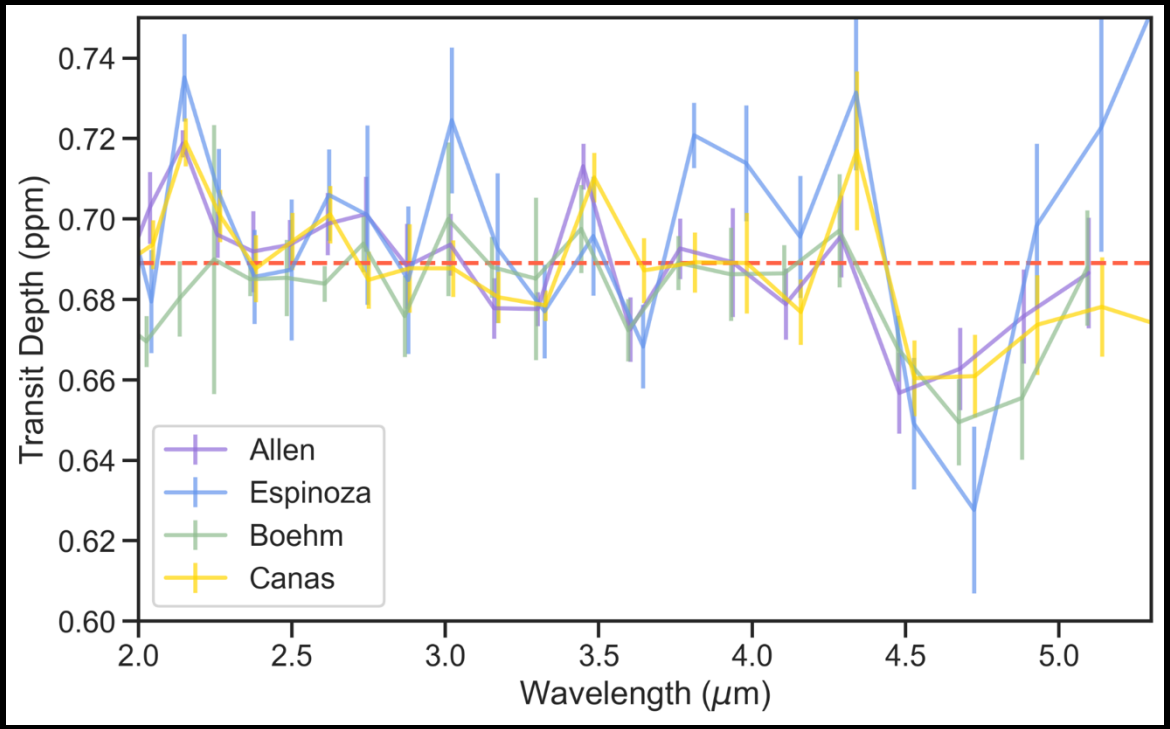


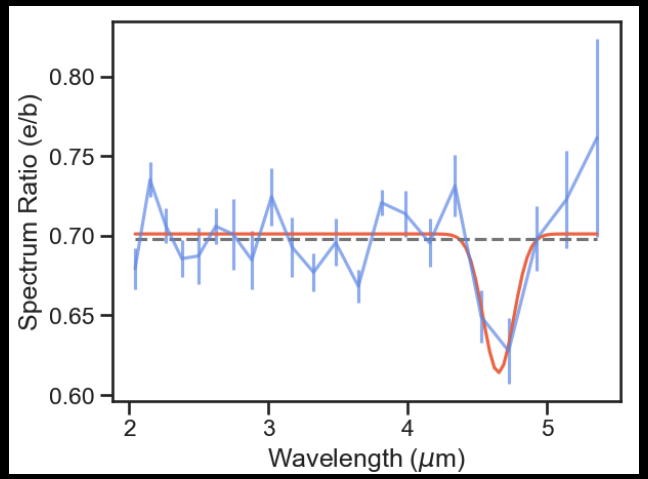
Backup: spectroscopic flare

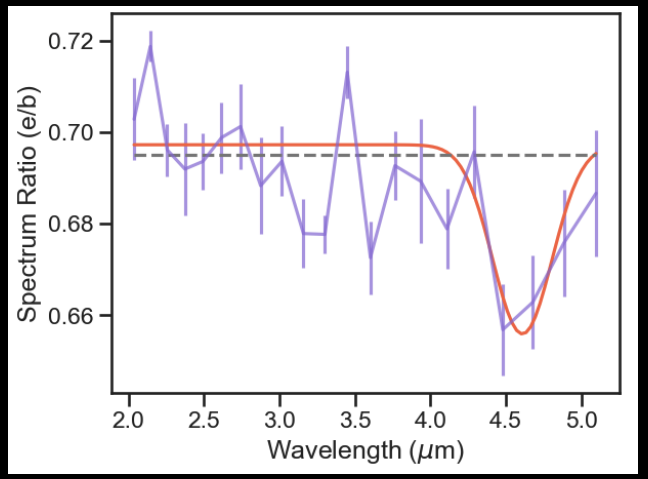


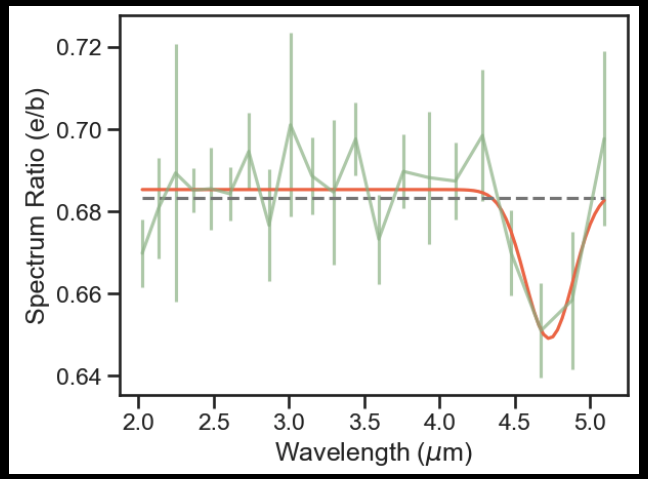


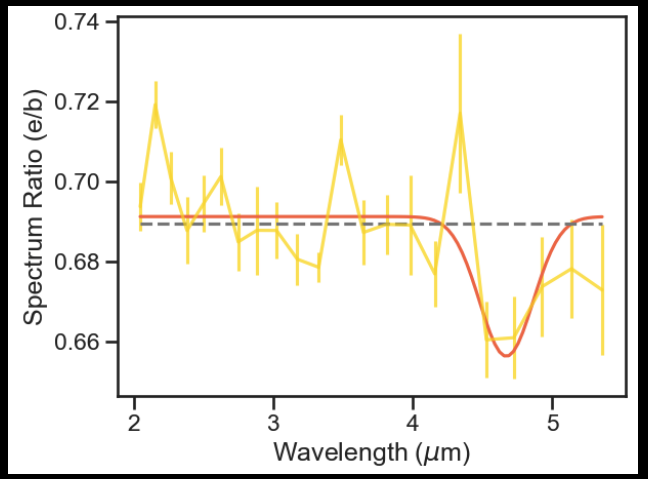
Backup: little bump :[











Backup: second observation H-alpha