Enabling JWST transmission spectroscopy in the presence of stellar contamination

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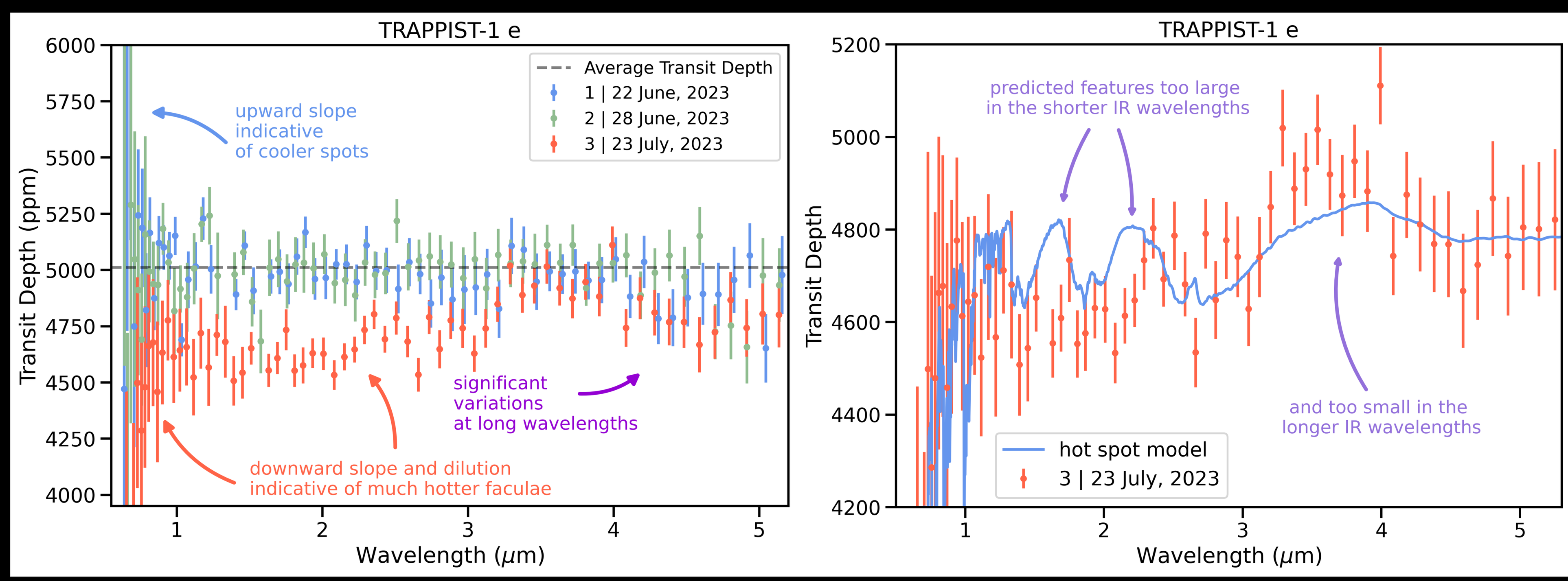
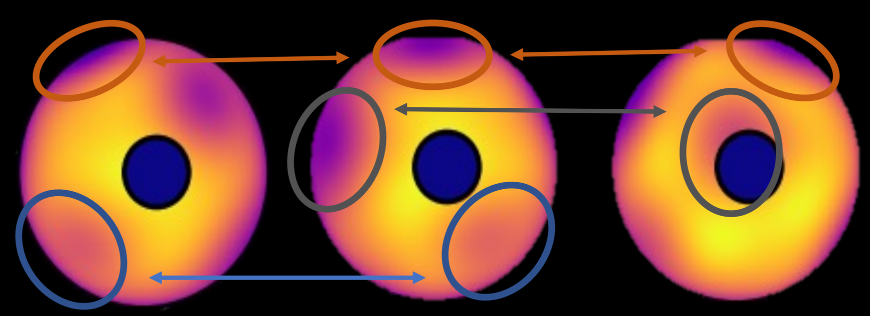
Stellar contamination, caused by hot and cold spots on the stellar photosphere during exoplanet transits, can cause chaos for our attempts to interpret the transmission spectrum of planets orbiting active stars. This is especially important when considering observations of small planets, which need repeated observations to build up enough signal to hunt for ~10s of ppm atmospheric signals, and M dwarf hosts, for which we have a poor understanding of the appearance of surface features.

Observations of TRAPPIST-1e from the TST-DREAMS team show that not only is activity clearly present, but the corresponding contamination signal can be vastly different between visits, and efforts to model the contamination are unable to satisfactorily match the observed features to the precision needed to allow a glimpse of the underlying atmospheric signal (~50 ppm). How can we tackle this problem?

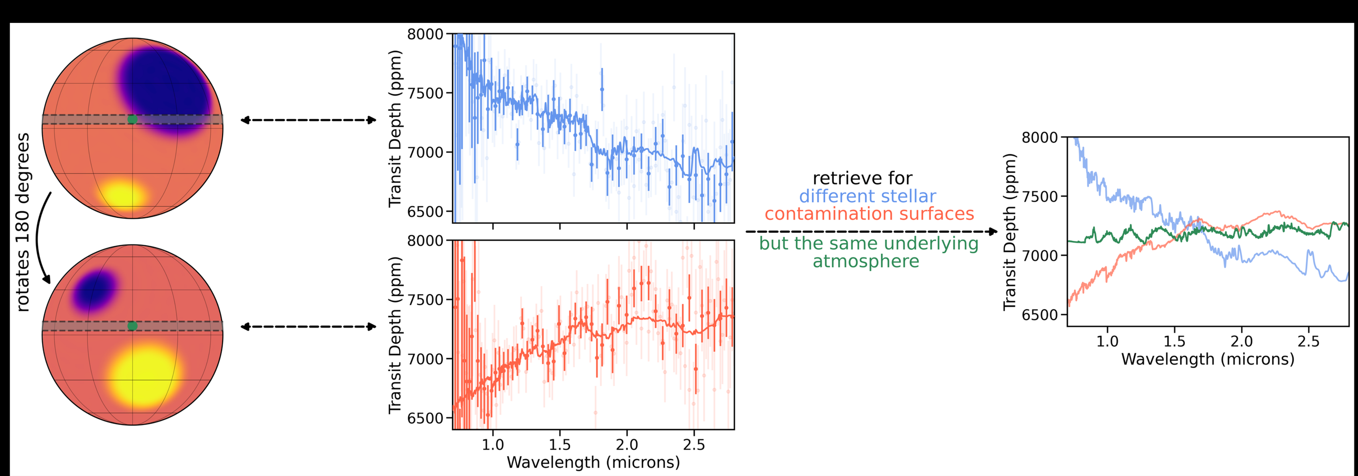


Model-dependent

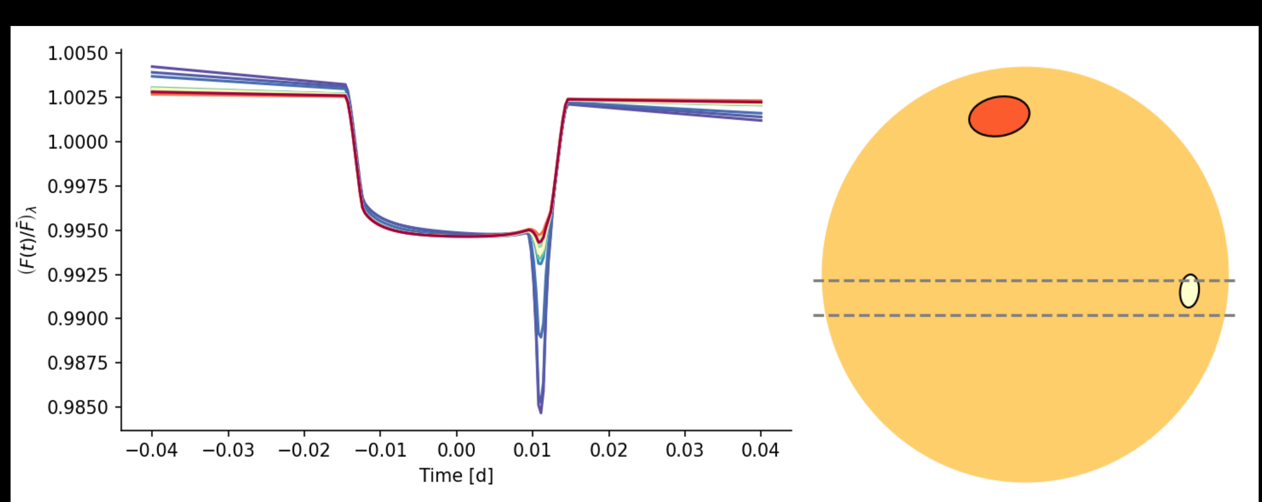
Observations close in either time or stellar rotational phase will have shared stellar information:



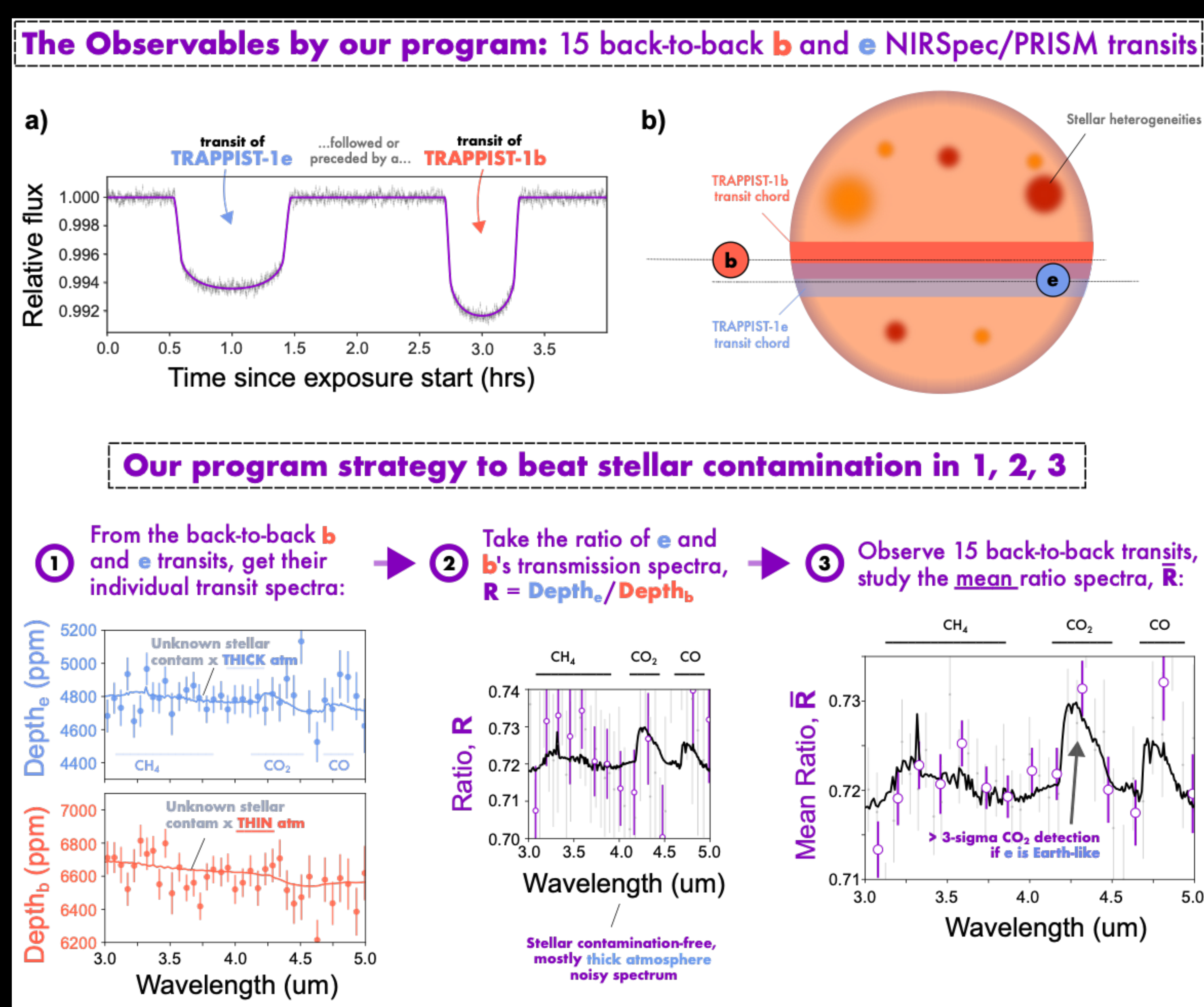
Therefore, we build a persistent stellar surface with *fleck* to phase and evolve in time to retrieve the stellar contamination signals for multiple observations simultaneously with an atmospheric retrieval of the underlying planetary signal.



By doing this modeling at the light curve level, we're able to maximize the stellar information we can glean from the data: rotational modulation from the out-of-transit slope, and transit depth variation due to center of disk surface features, as well as capture features like spot crossings.



Model-independent



We can use the fact that stellar contamination is *multiplicative* to our advantage: by observing back-to-back transits of the airless TRAPPIST-1b and the habitable zone TRAPPIST-1e, we can use the resulting ratio of transmission spectra to correct for the stellar contamination in a *model-independent* way. This is the basis of GO 6456 – a large multi-cycle JWST program to determine if TRAPPIST-1e has an Earthlike atmosphere.

Takeaways:

We can figure out stellar contamination! There are ways we can work towards disentangling the planetary and stellar signals on both the modeling and observational fronts. In addition, NASA's Pandora mission, slated for launch in early 2025, will be targeting observations specifically aimed at understanding the effects of stellar contamination. Solving the problem of stellar contamination is key to characterizing terrestrial planets around the most common stars in the universe.

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Hot Rocks Survey

Don't even want to think about the star? Check out our efforts to observe 9 planets around M dwarfs in eclipse with the Hot Rocks Survey!