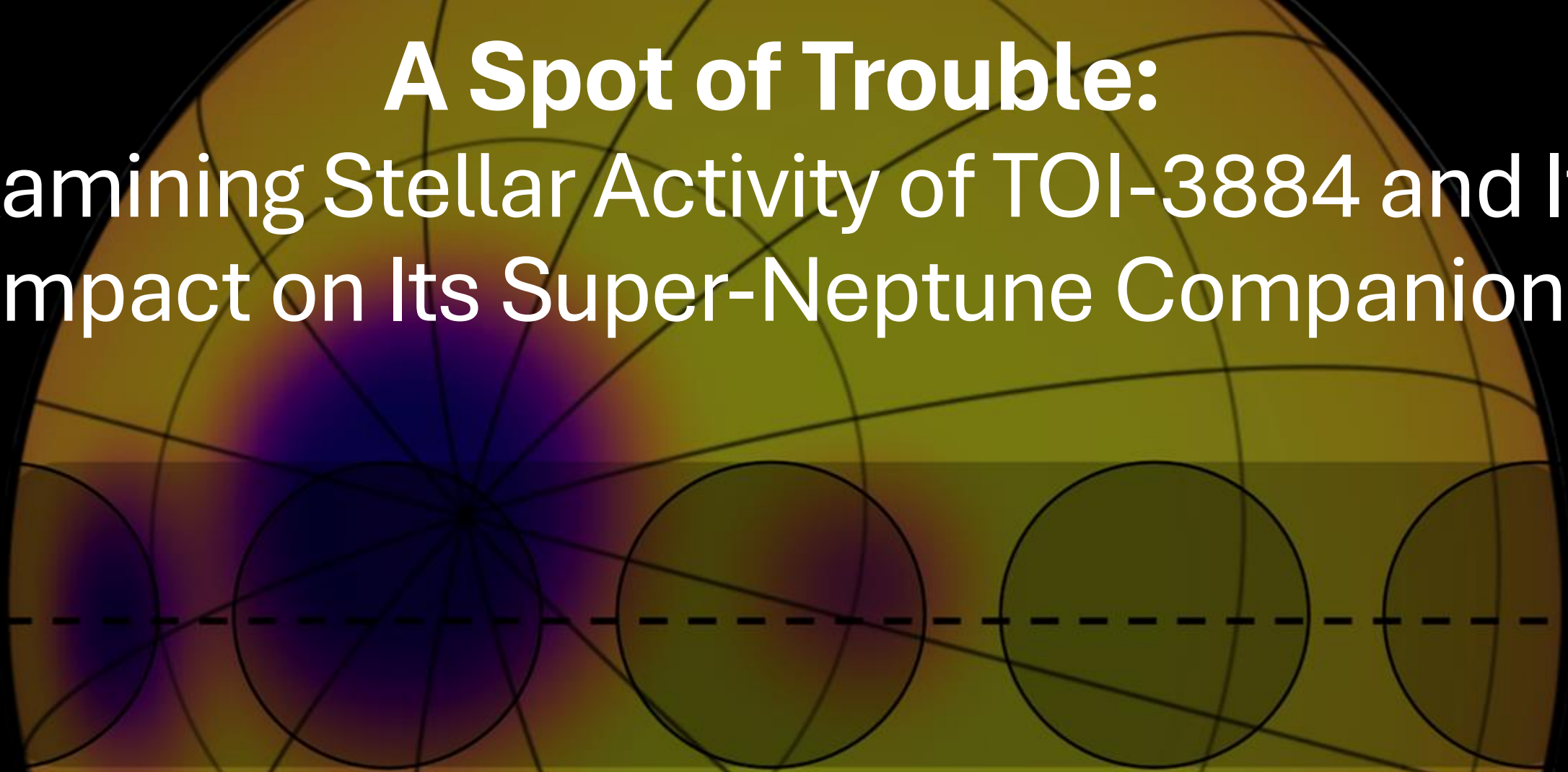
A Spot of Trouble:
Examining Stellar Activity of TOI-3884 and Its Impact on Its Super-Neptune Companion



Jessica Libby-Roberts

CEHW Postdoc Fellow (Penn State)

Know Thy Star 2

February 3, 2025

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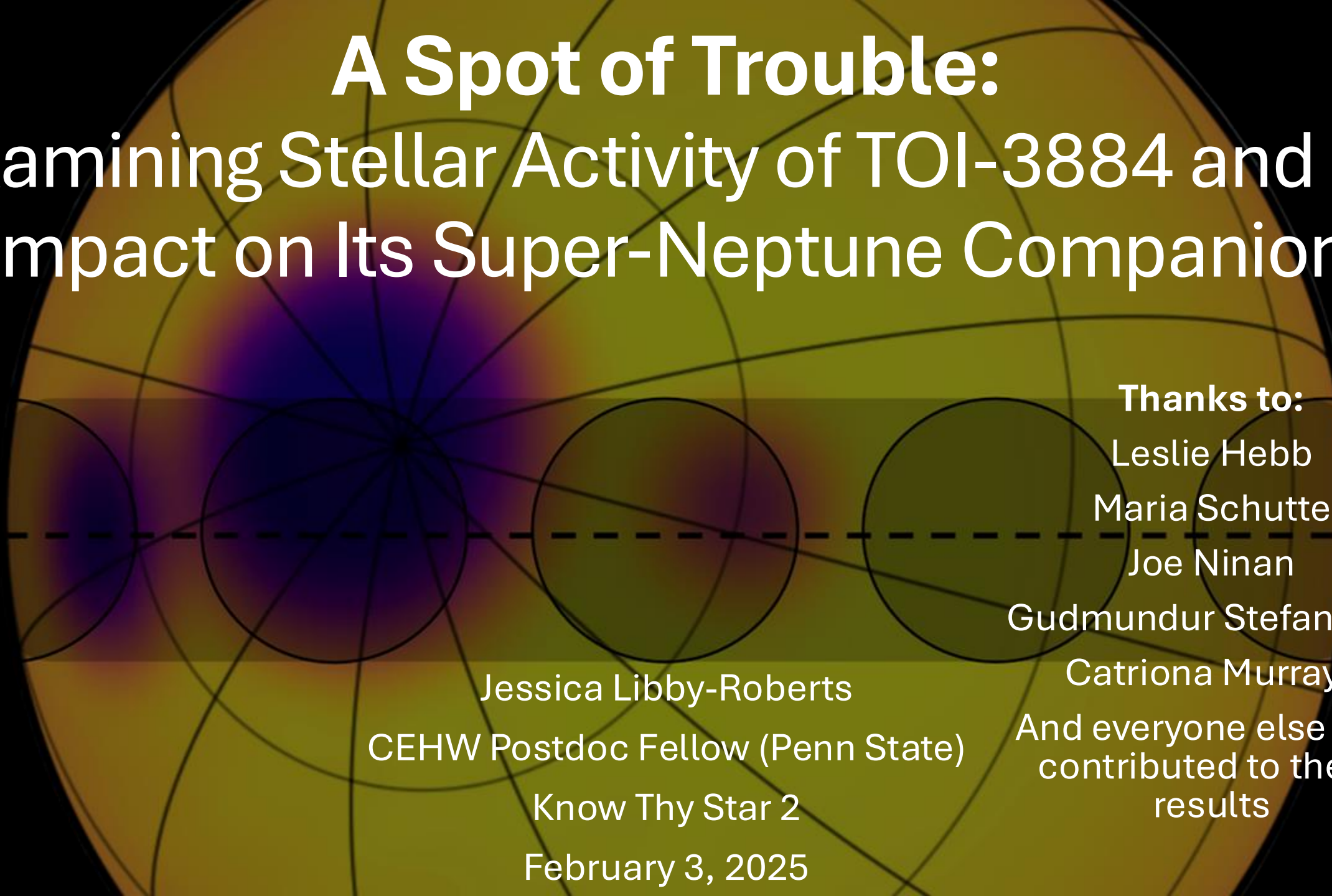

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Know Thy Star 2

February 3, 2025

Thanks to:

Leslie Hebb

Maria Schutte

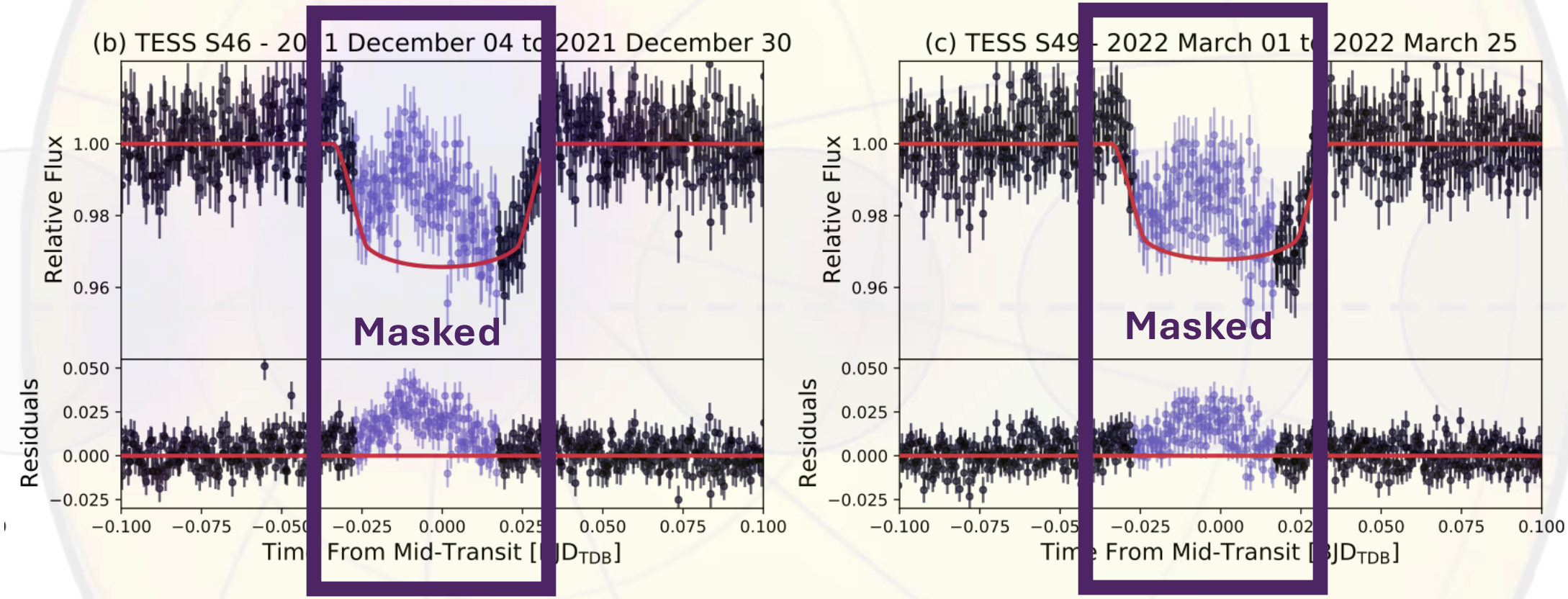
Joe Ninan

Gudmundur Stefansson

Catriona Murray*

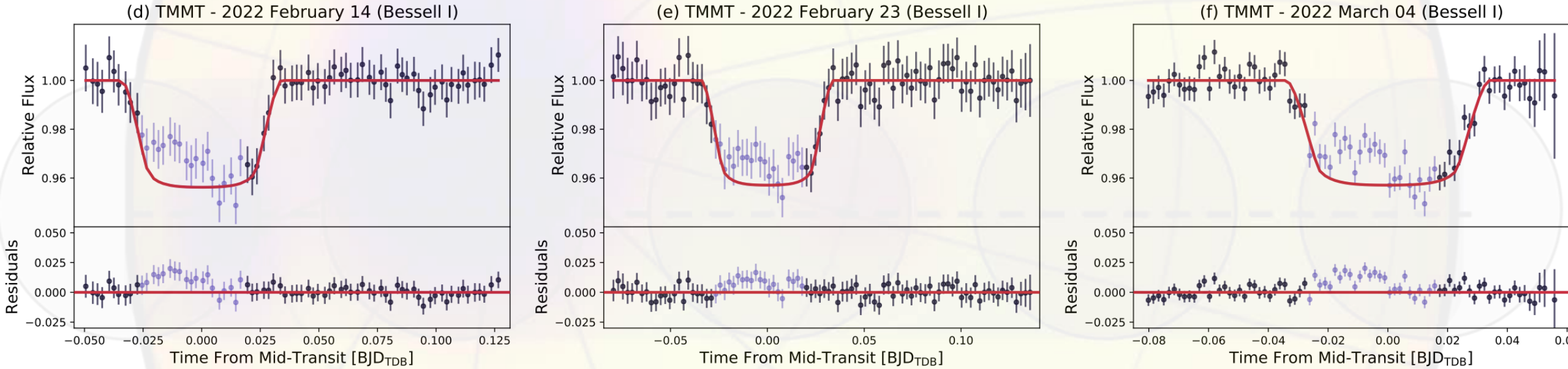
And everyone else who contributed to these results

Transit observations with **TESS** of TOI-3884b showed the same bump in EVERY transit



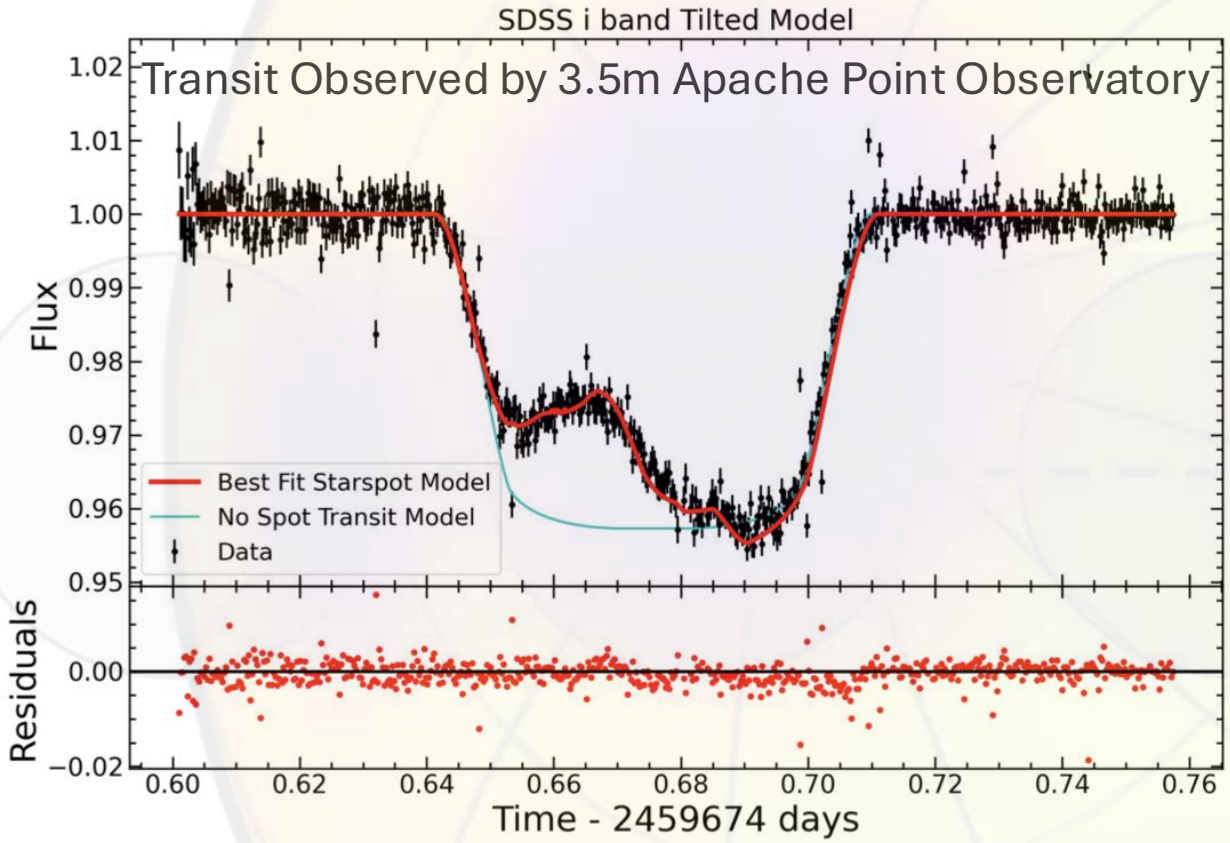
Libby-Roberts et al. (2023)

Transit observations from the **GROUND** of TOI-3884b showed the same bump in EVERY transit

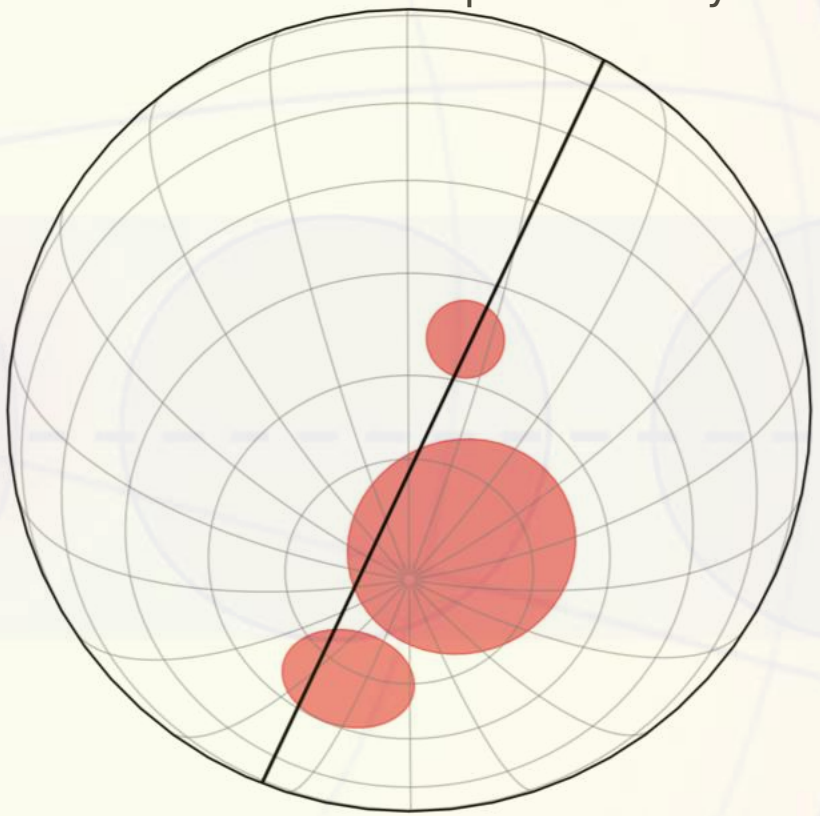


Libby-Roberts et al. (2023)

TOI-3884b is a 6 $R_\oplus$ planet on a polar orbit (4.5-day period) crossing the same pole spot

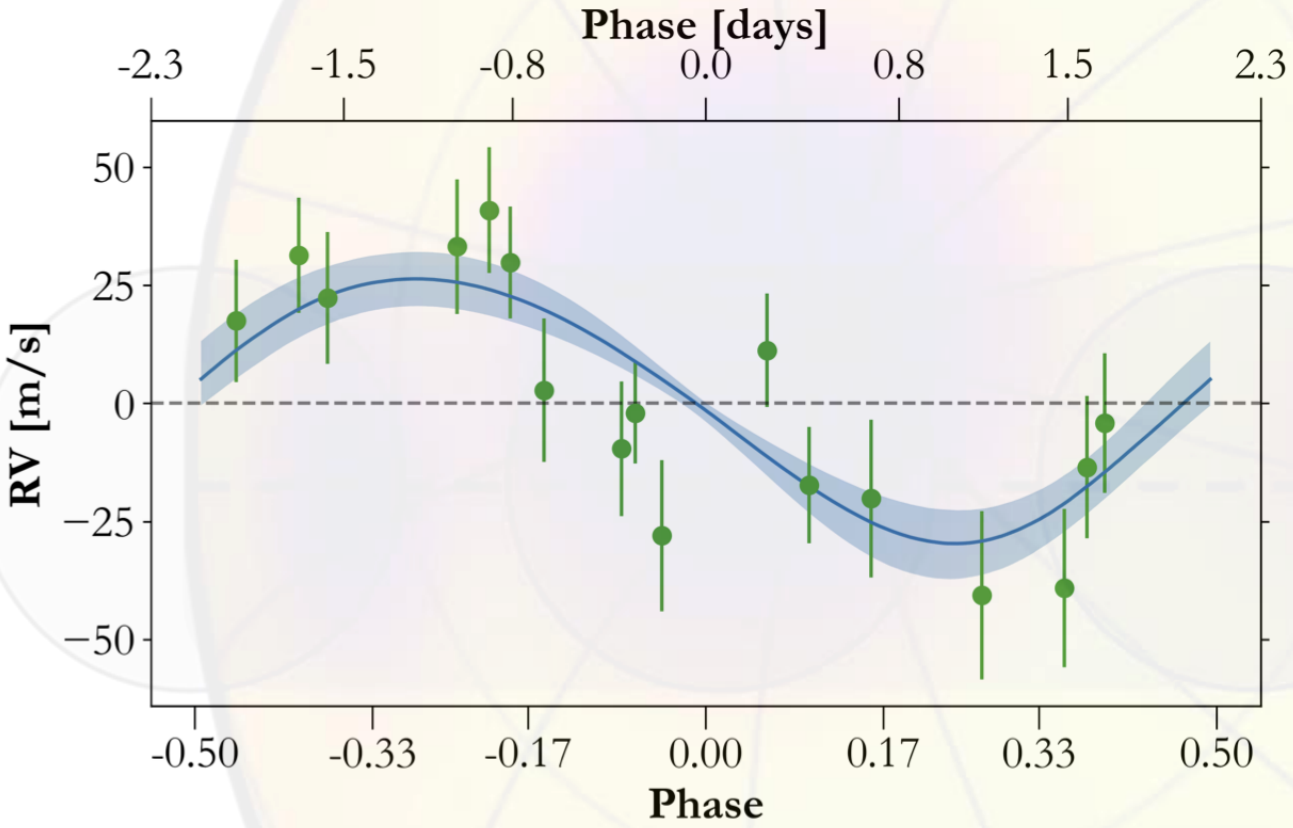


Spot Model By Maria Schutte



Libby-Roberts et al. (2023)

We measured the mass (32 $M_\oplus$) with radial velocities from the Habitable-zone Planet Finder



Derived Stellar Parameters:

Effective Temperature: 3200 +/- 100 K

Vsin(i): 3.59 +/- 0.92 km/s

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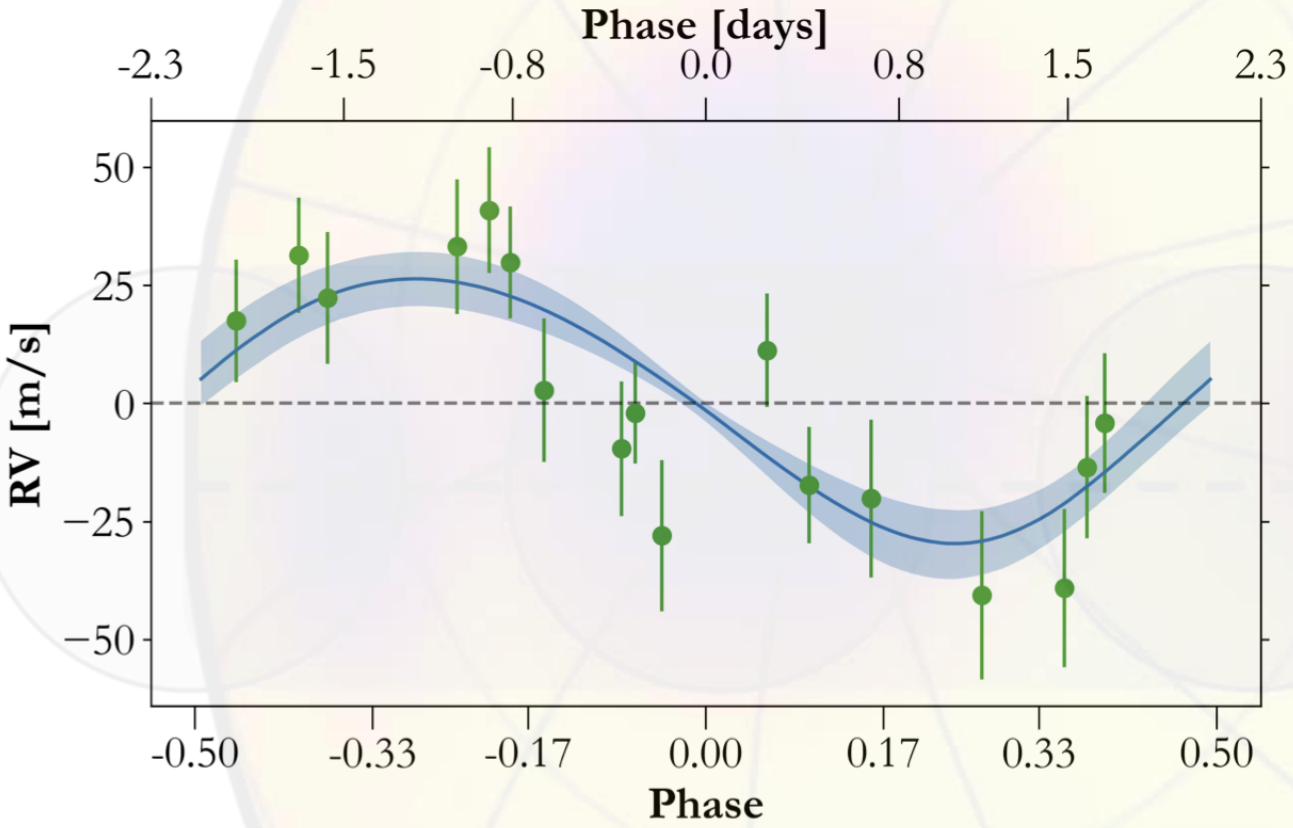

Derived Stellar Parameters:

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Vsin(i): 3.59 +/- 0.92 km/s

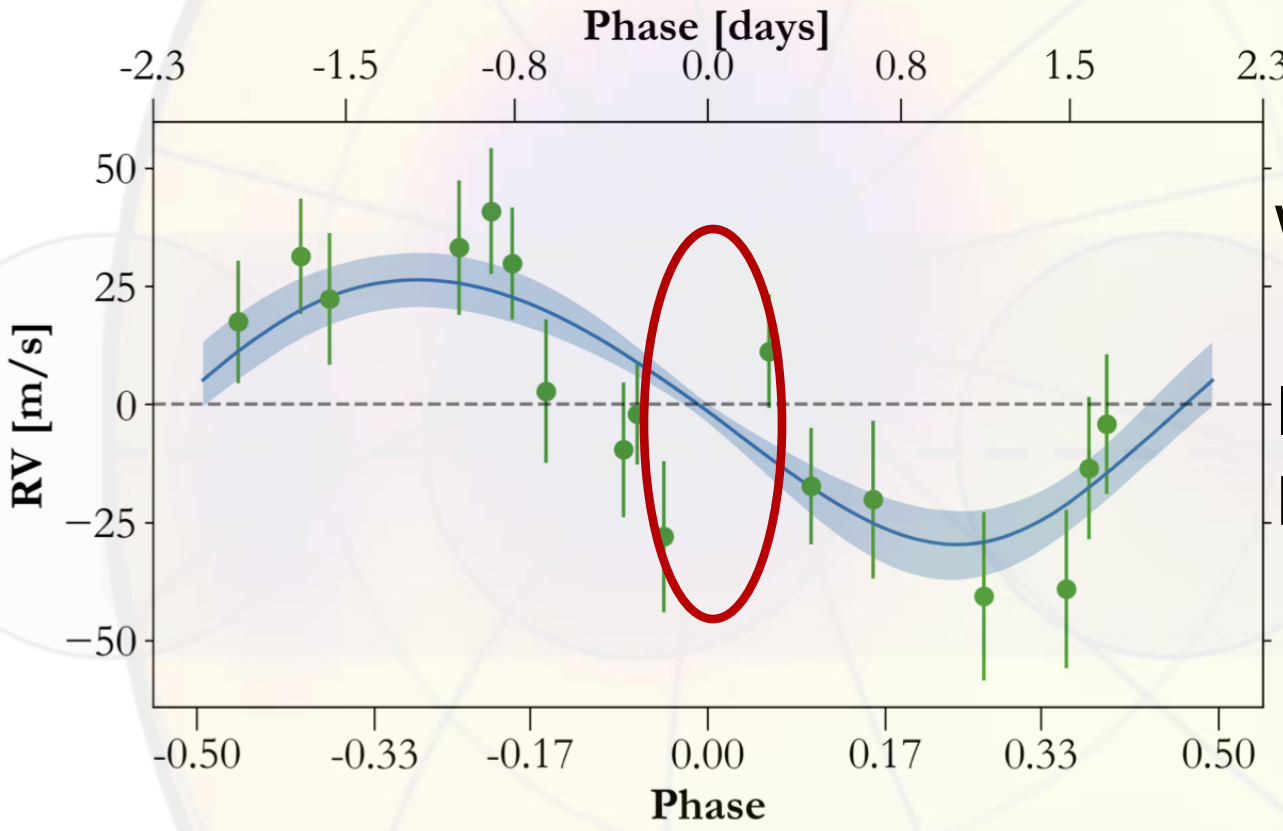
Stellar Mass: 0.30 +/- 0.02 $M_\odot$

Stellar Radius: 0.30 +/- 0.01 $R_\odot$

Age: < 1 Gyr

Libby-Roberts et al. (2023)

We measured the mass (32 $M_\oplus$) with radial velocities from the Habitable-zone Planet Finder

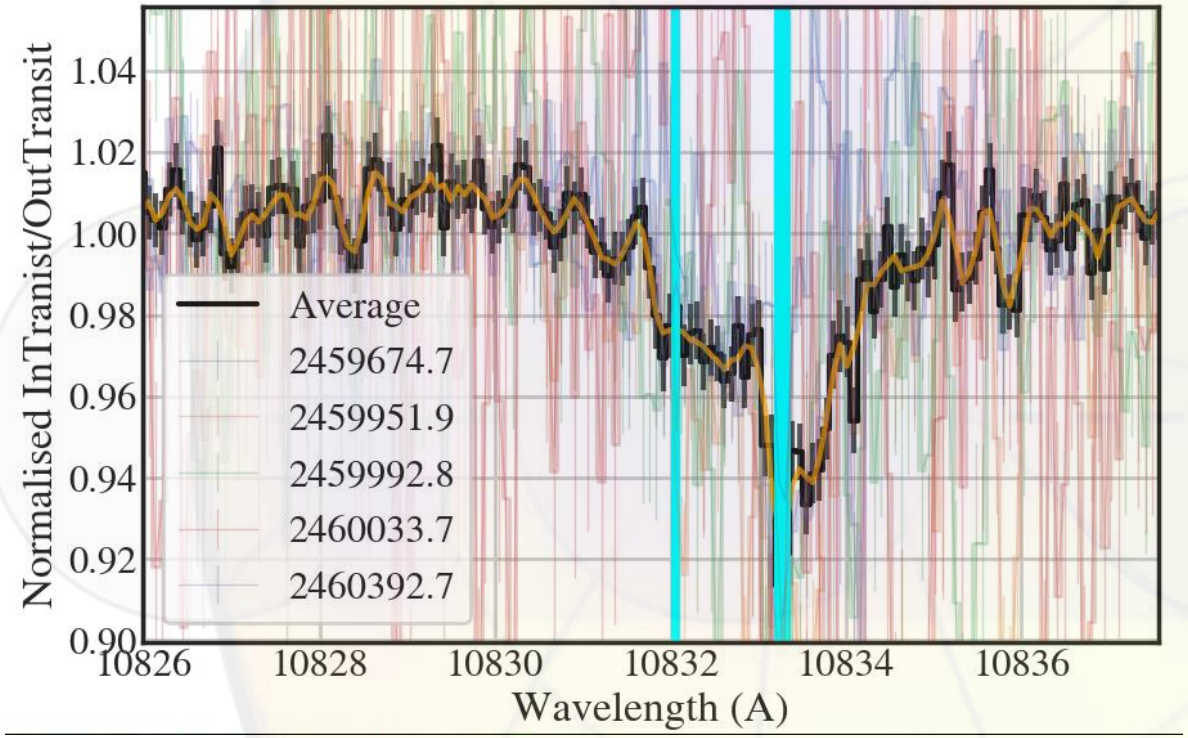


Wavelength Coverage: 810 – 1280nm

Including the 1083nm metastable Helium Triplet

Libby-Roberts et al. (2023)

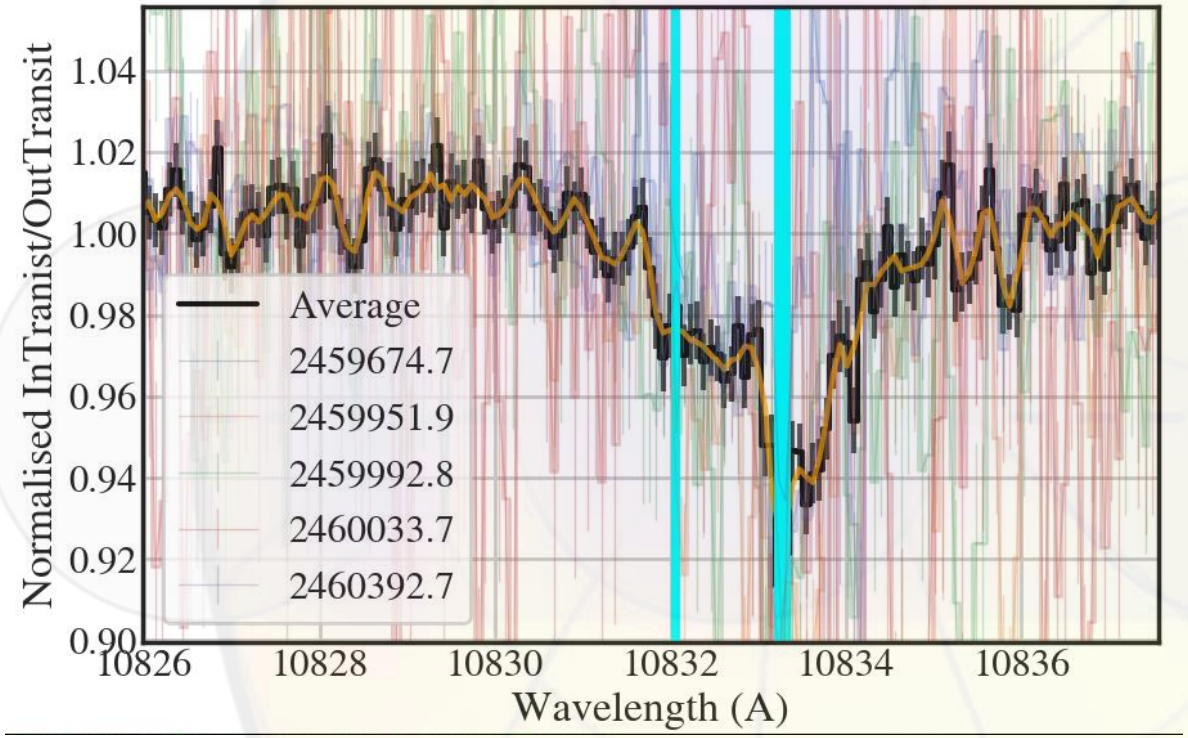
We observed a clear helium absorption feature during transit across multiple transits

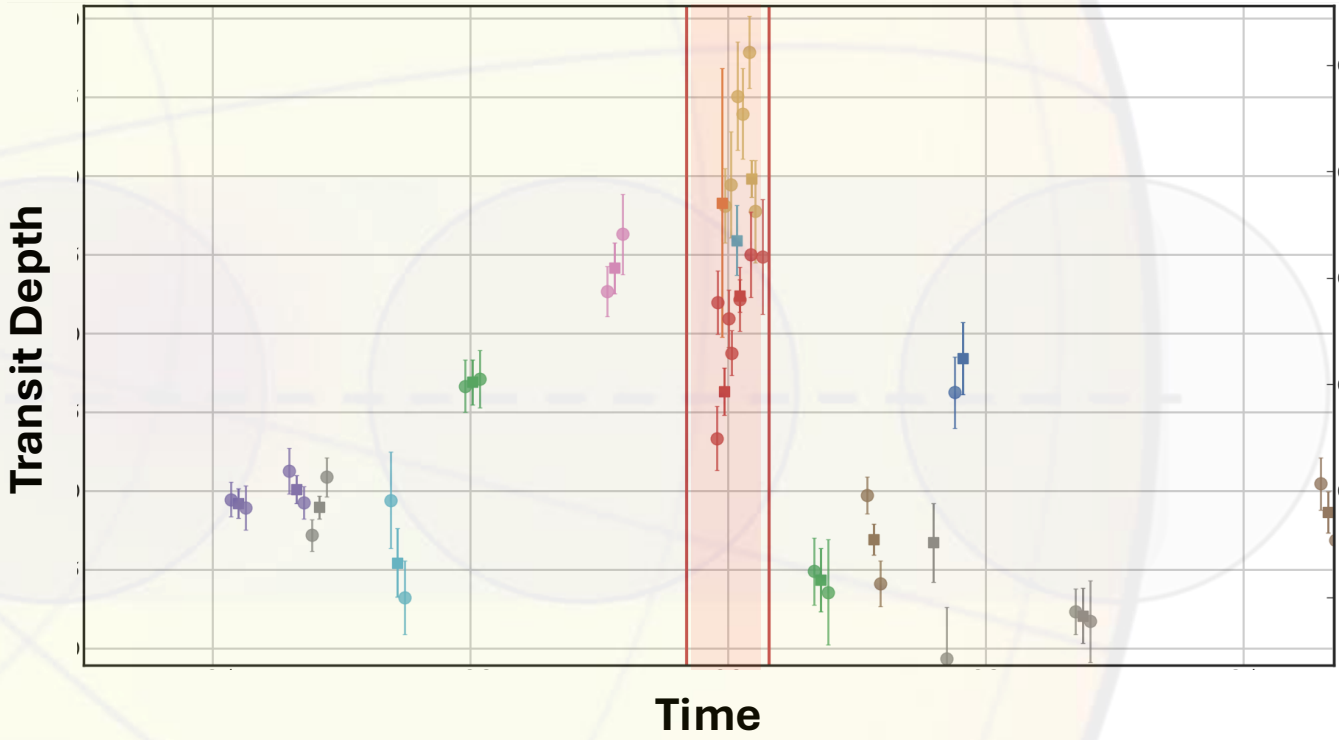


Helium analysis by Joe Ninan

Ninan, Libby-Roberts et al. (In Prep)

Follow-up with out-of-transit HPF observations show a 5-hour pre-transit helium tail





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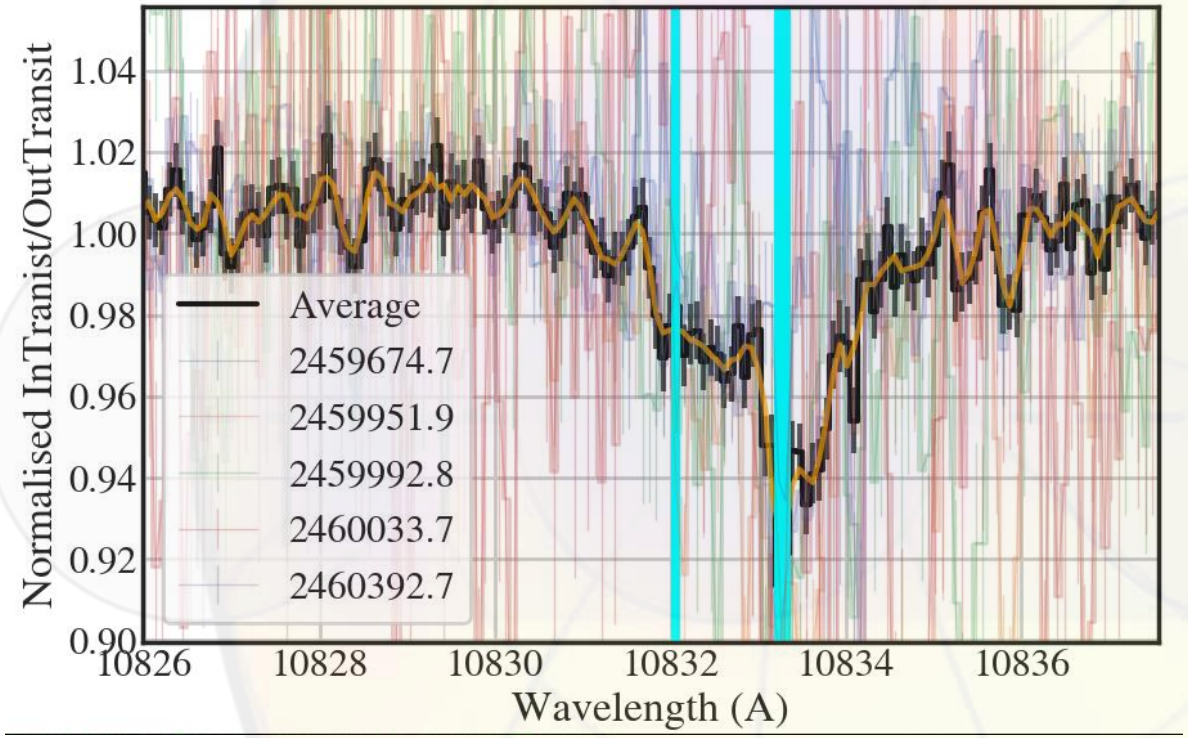

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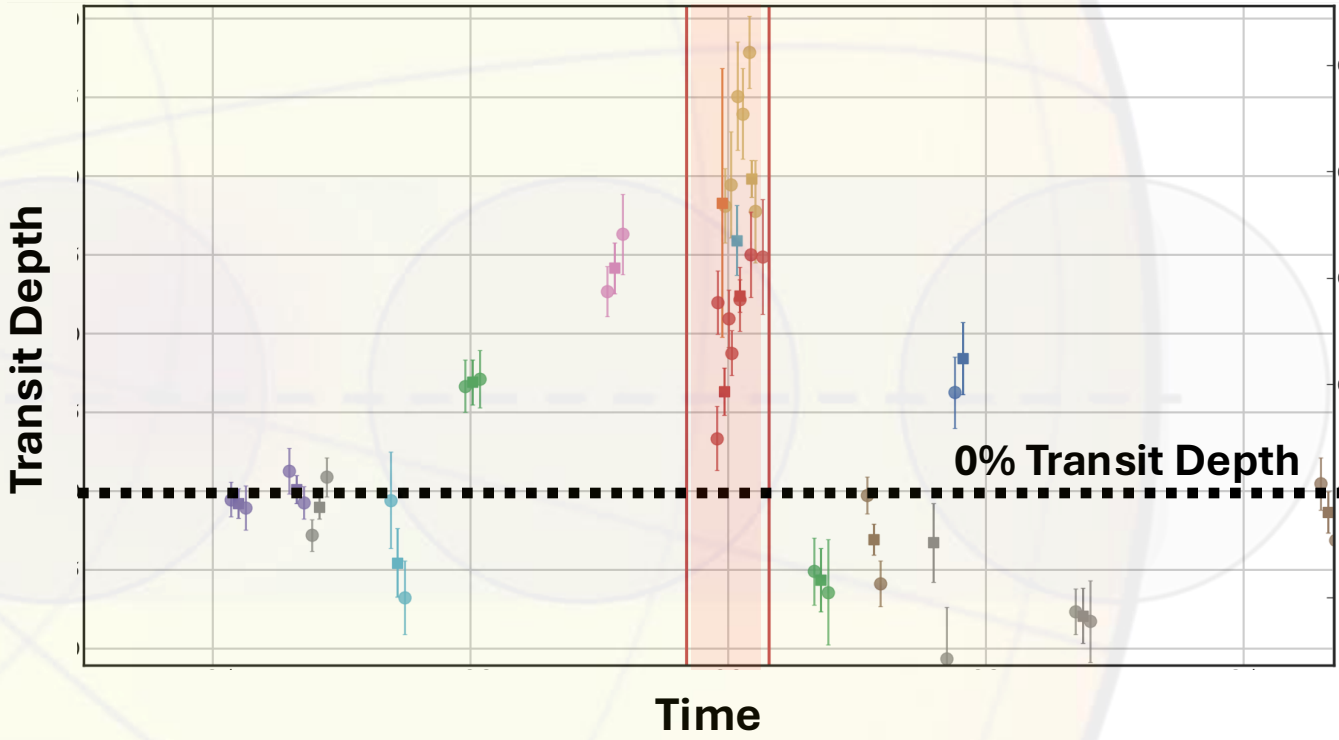
Transit duration ~1.5 hours



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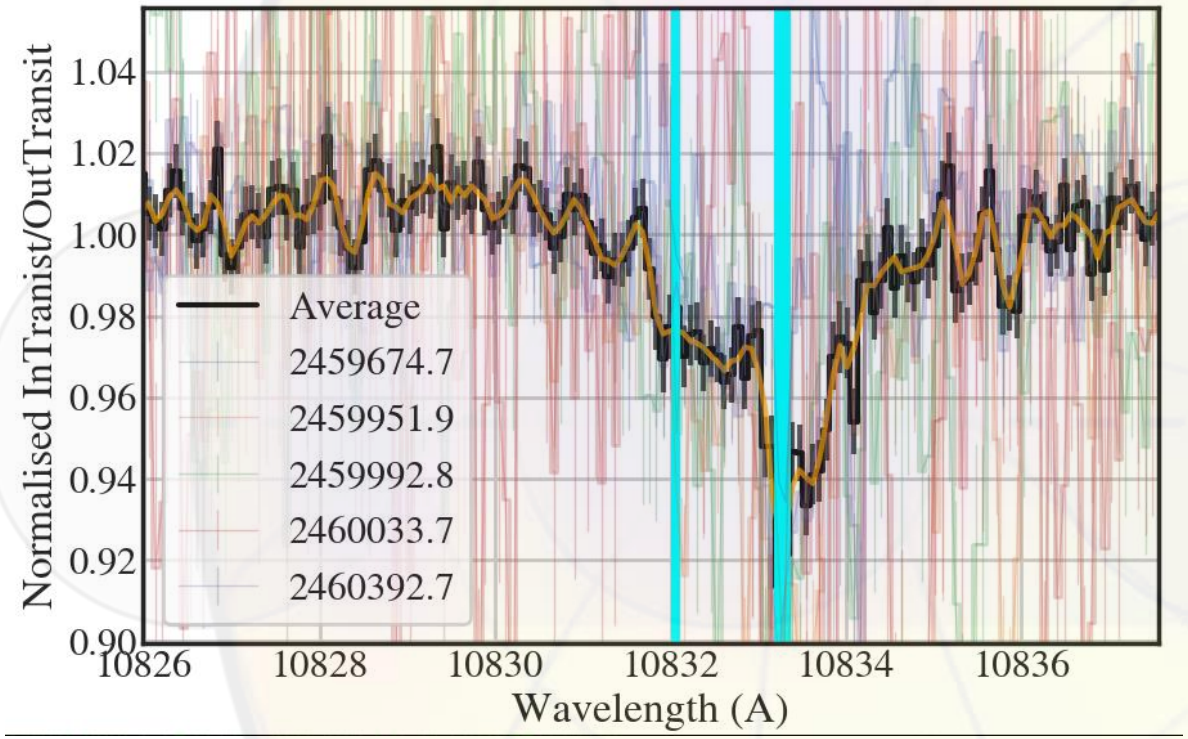

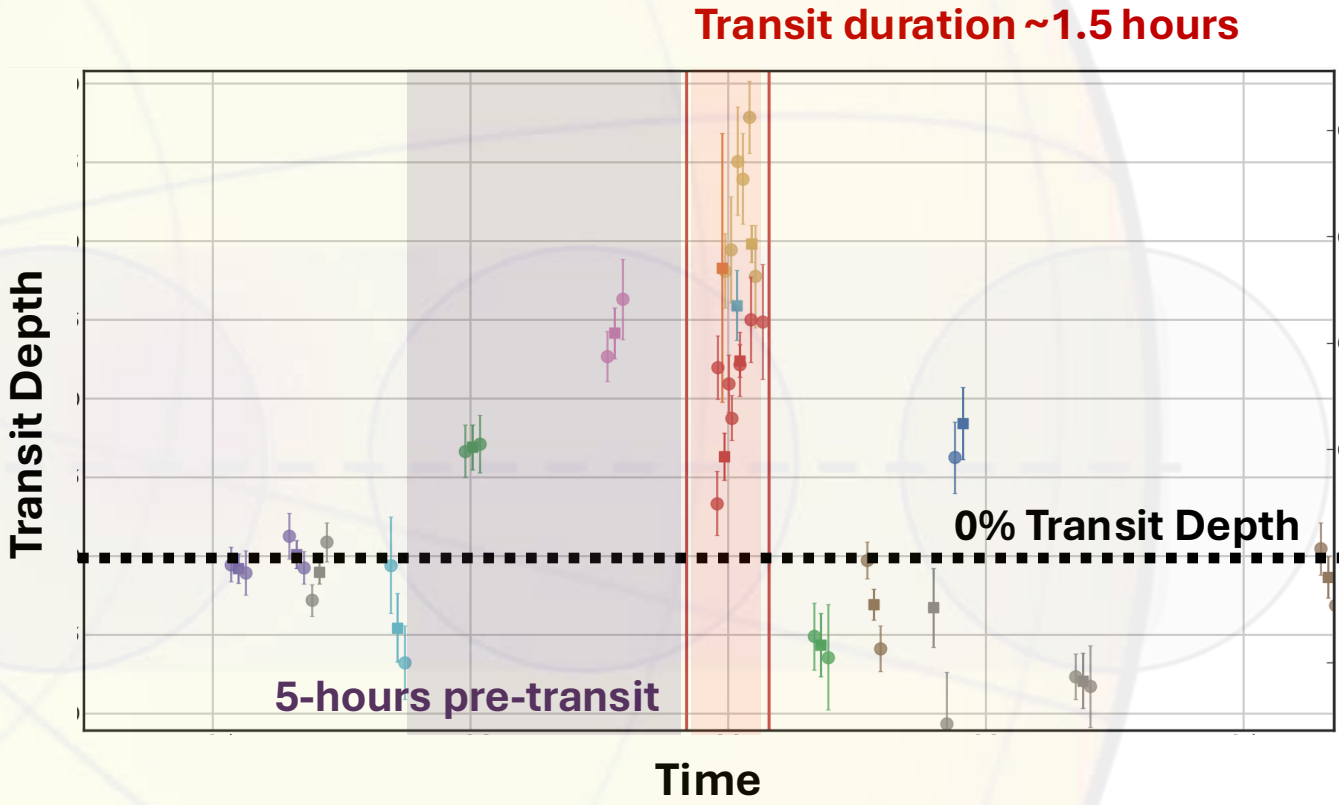

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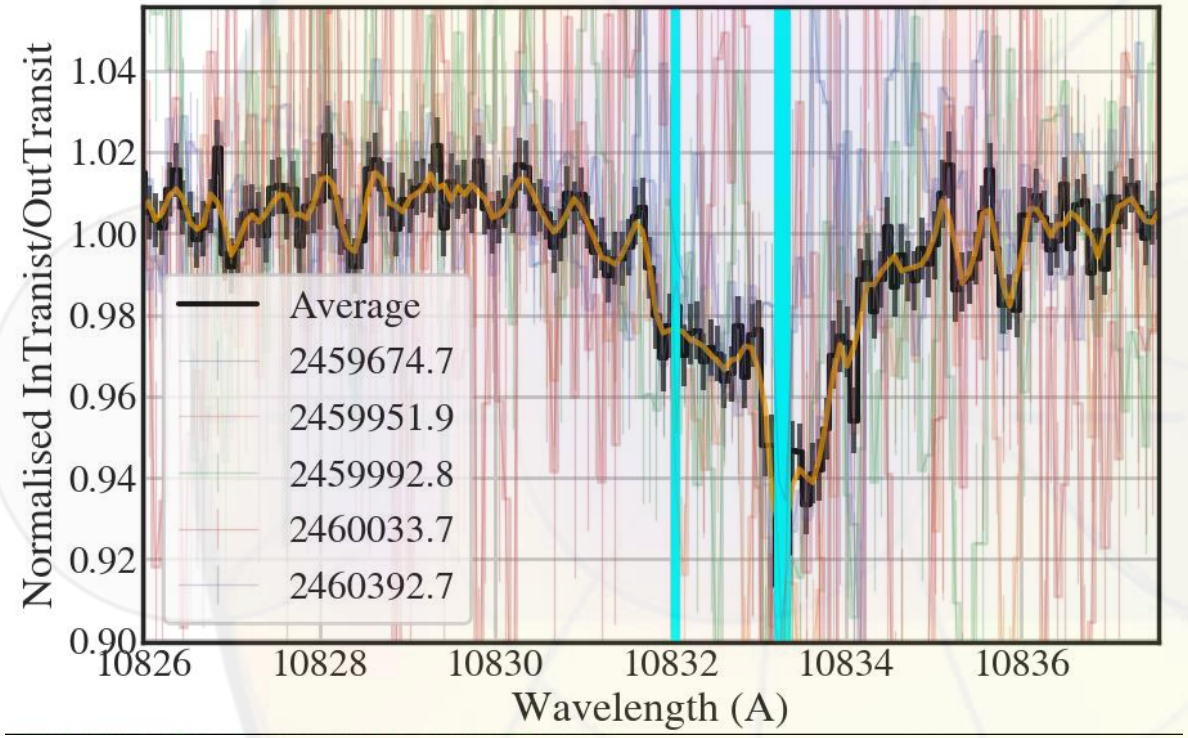

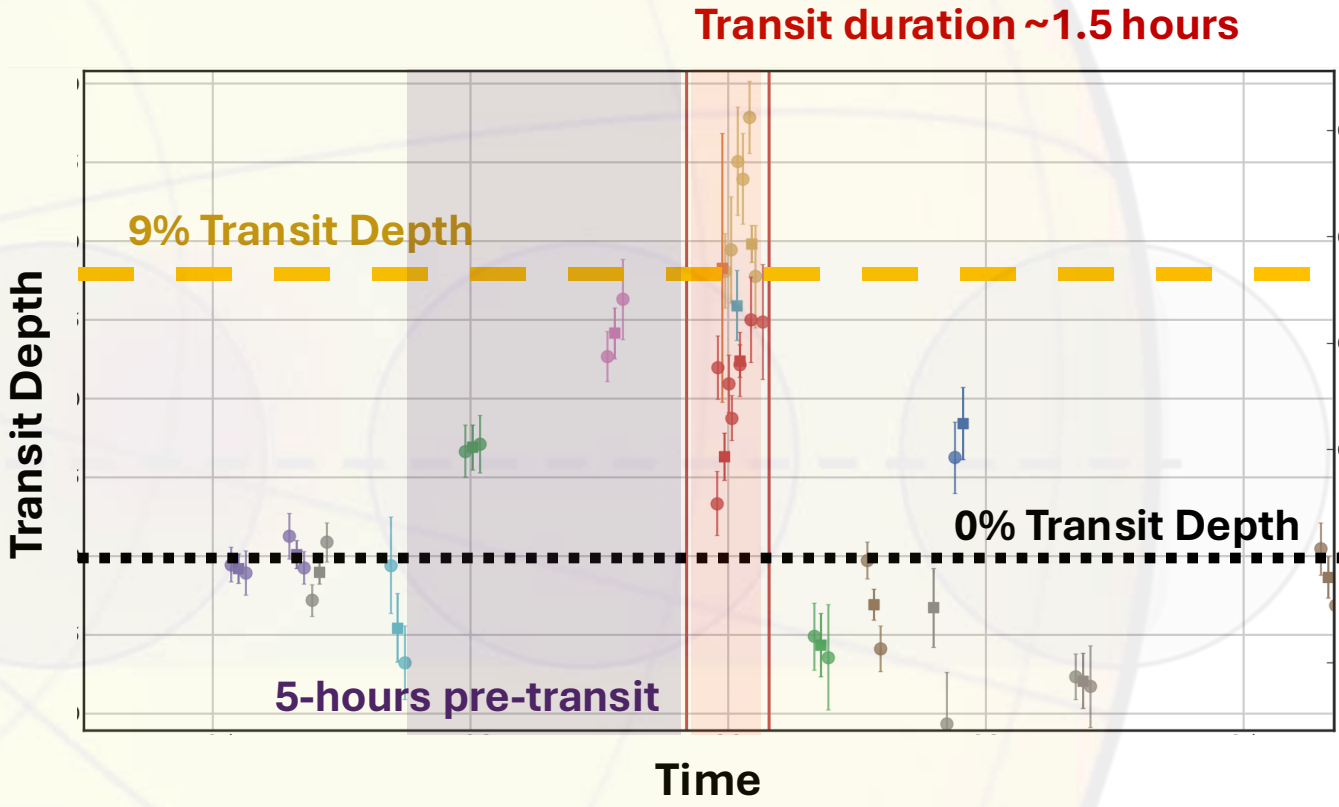

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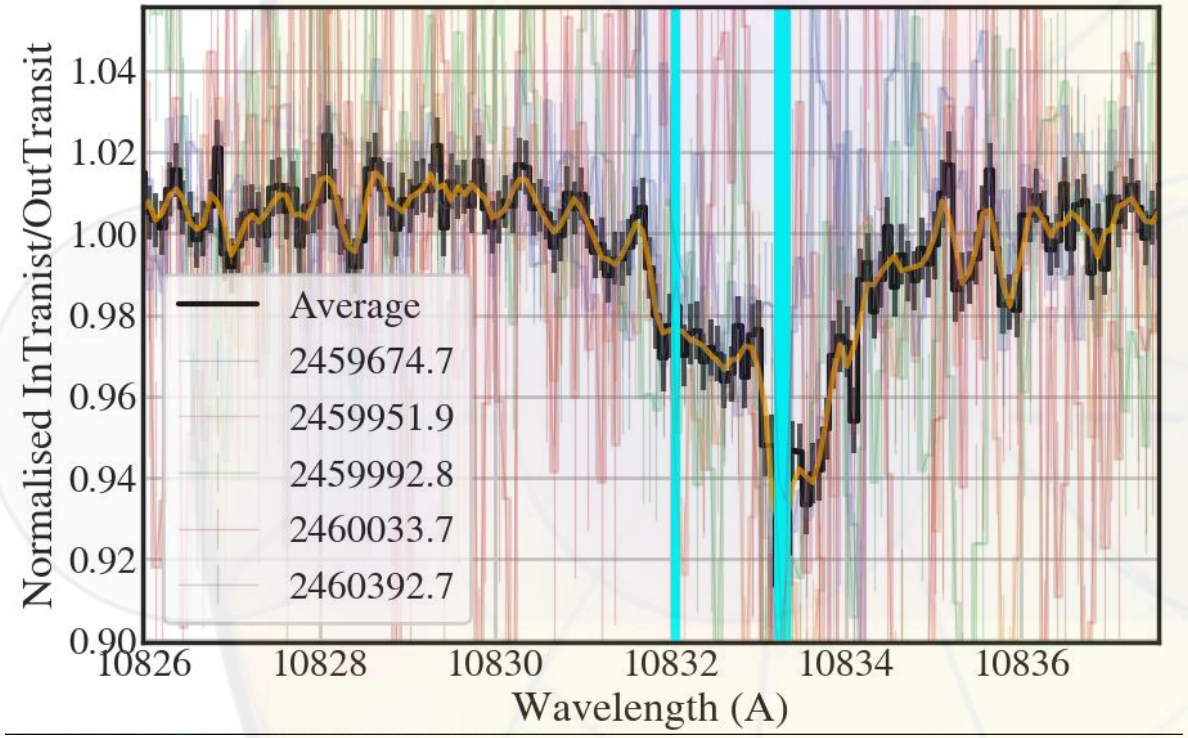

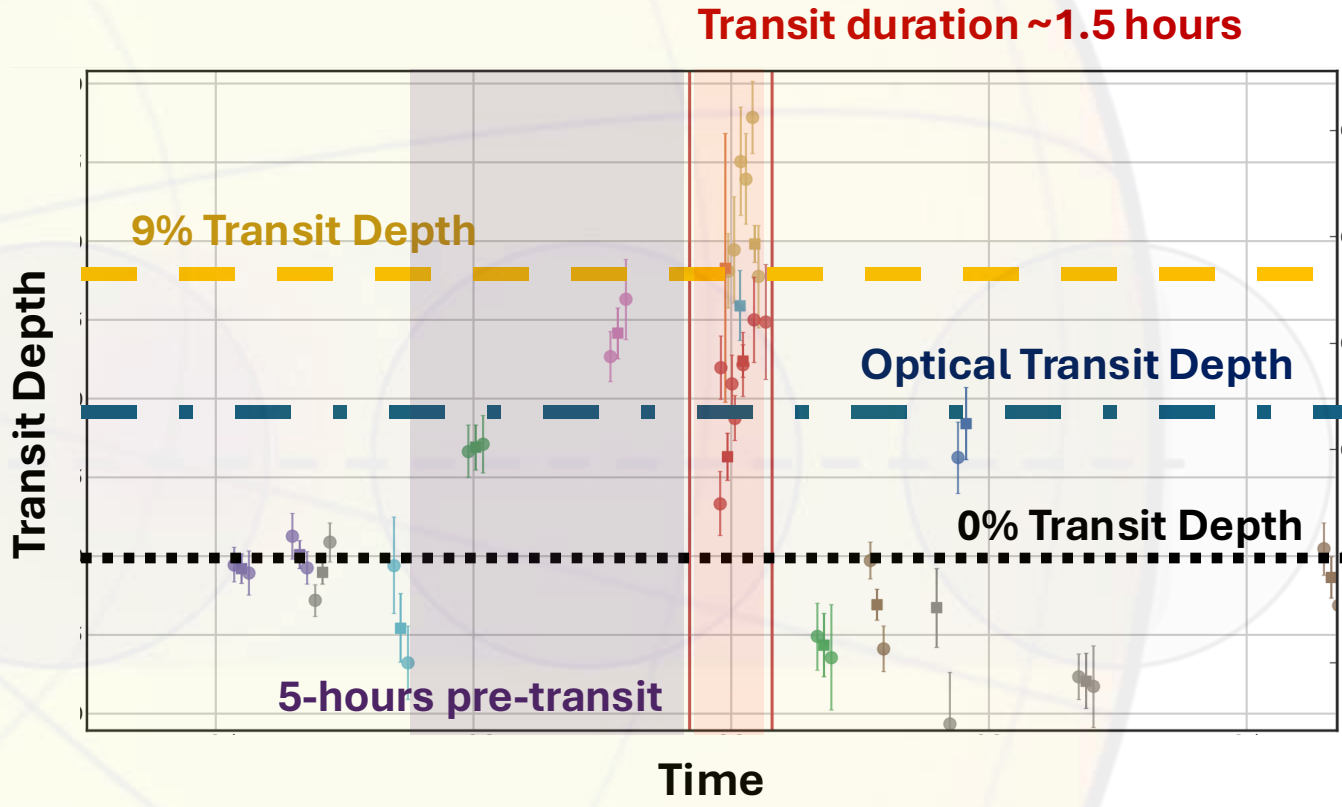

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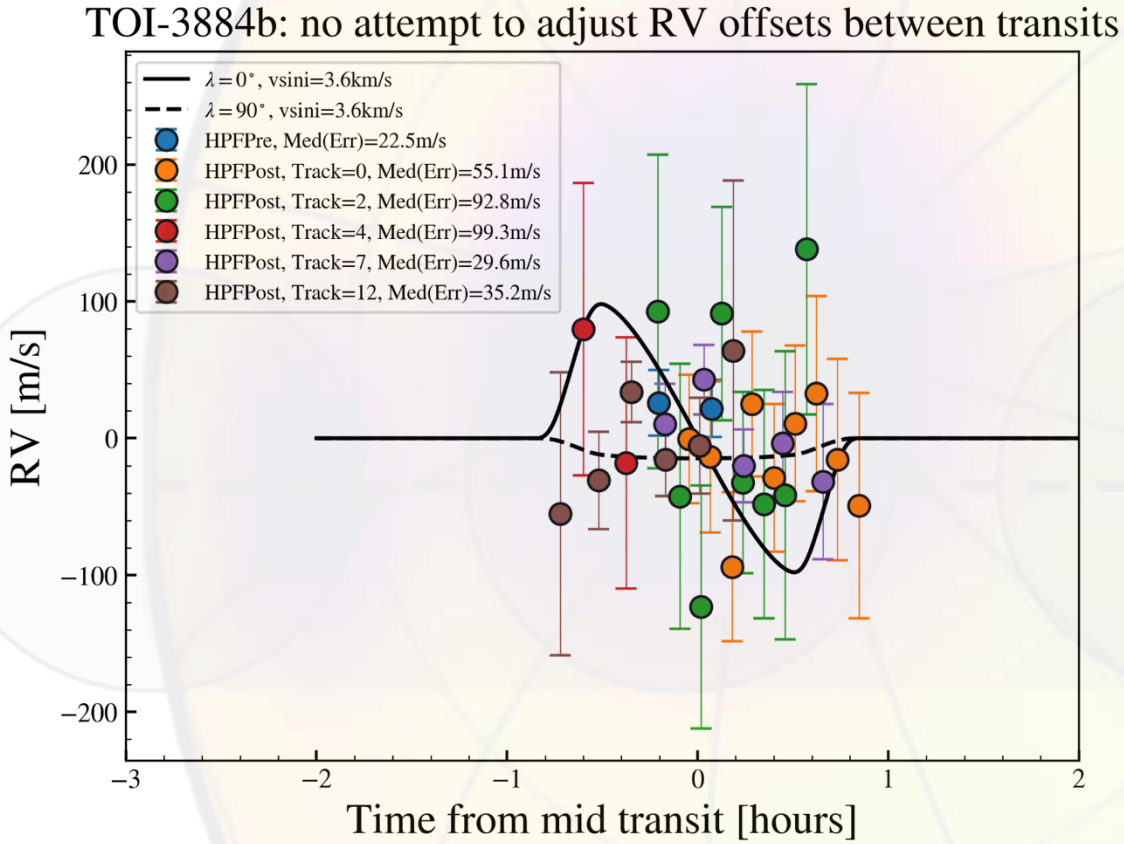
High-resolution observations with HPF also provide a tentative RM signal



RM analysis by Gudmundur Stefansson

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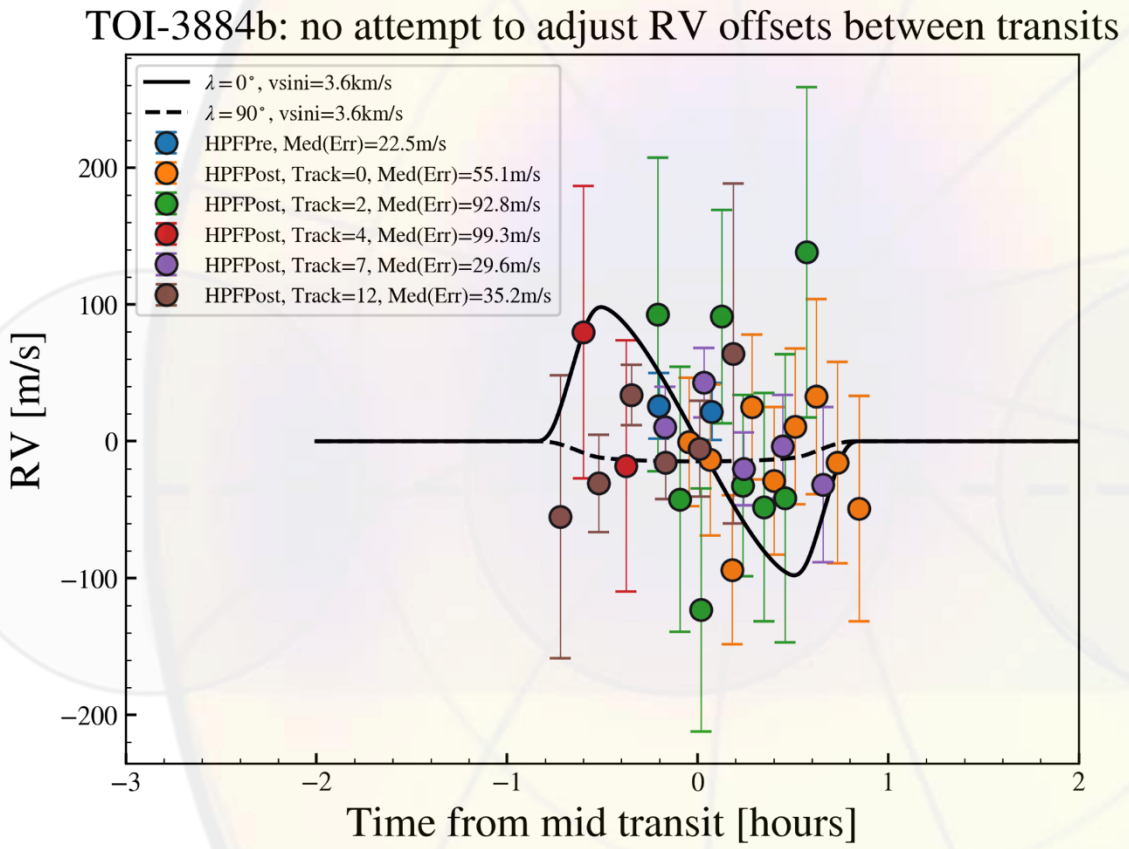

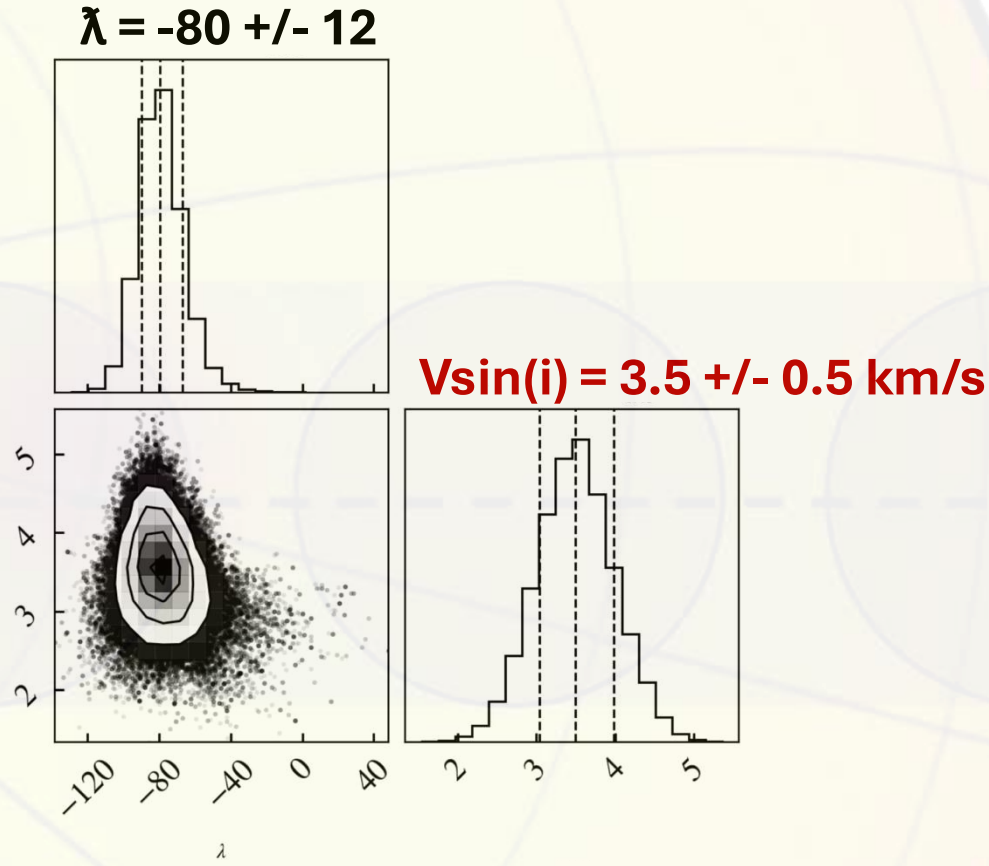

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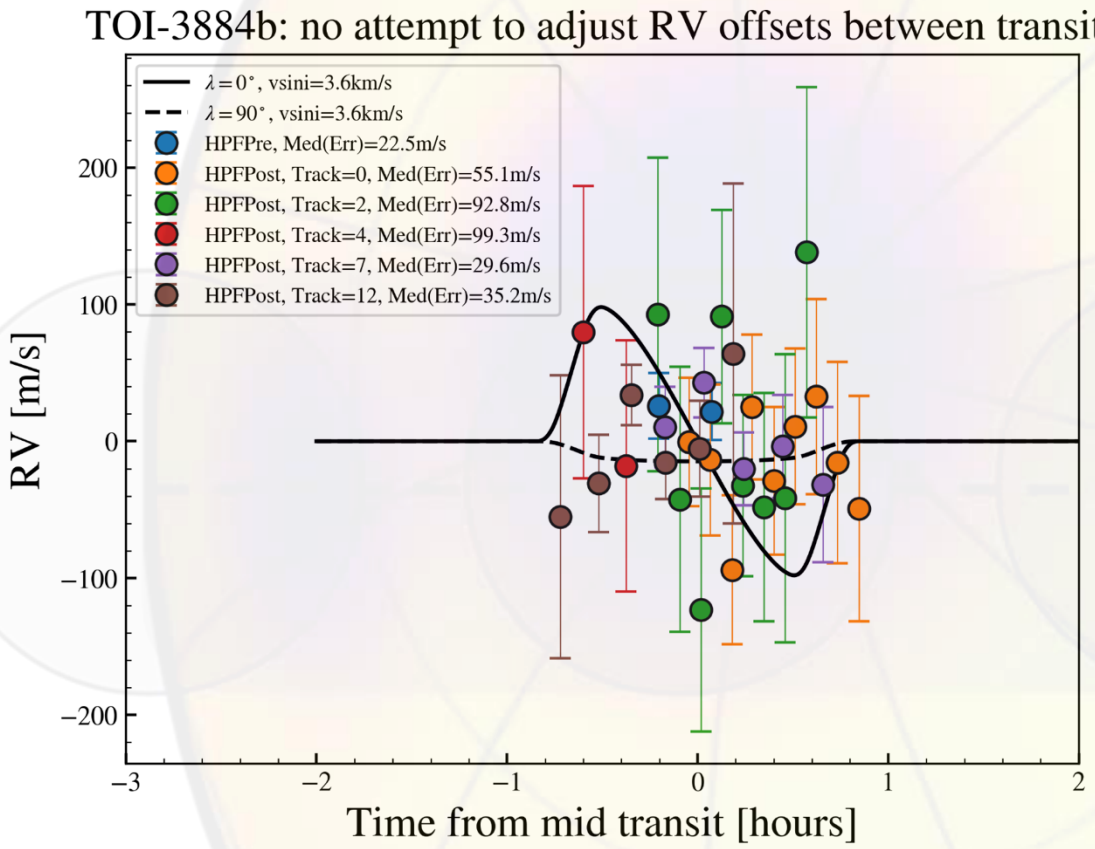
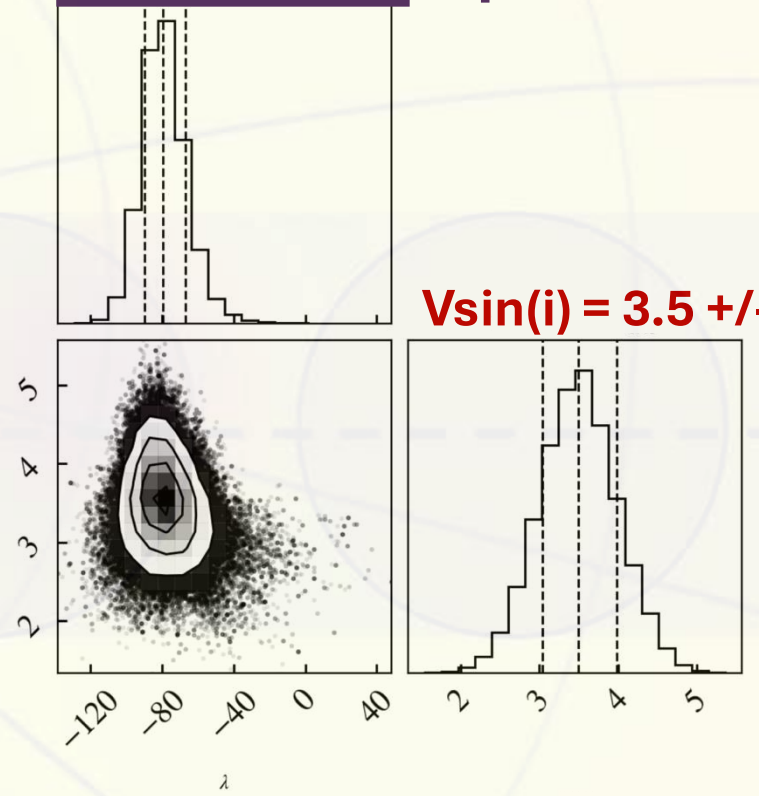


λ = -80 +/- 12

Spot Model: λ = -75 +/- 10

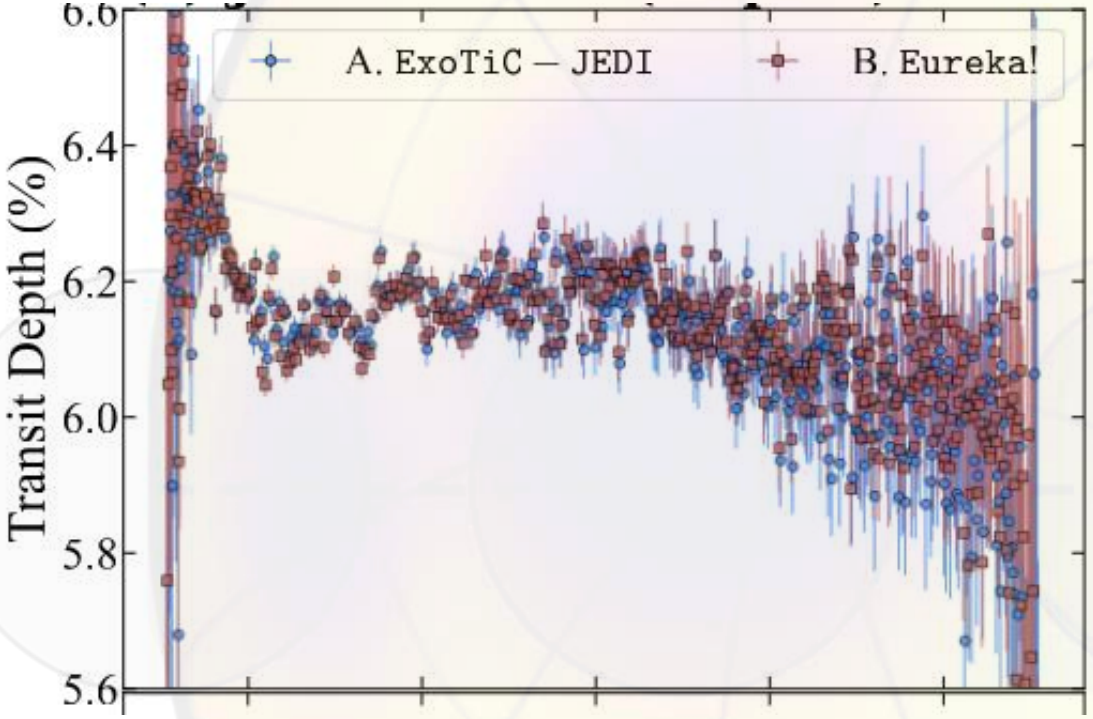


Vsin(i) = 3.5 +/- 0.5 km/s

RM analysis by Gudmundur Stefansson

Ninan, Libby-Roberts et al. (In Prep)

Know Thy Star -> Know Thy Planet



From JWST Observations of a Similar M4-Dwarf Star:

Avg Photosphere Temp: 3640 +/- 30 K
Avg Spot Temp: 3150 +/- 50 K
Avg Faculae Temp: 4260 +/- 130 K

Spot Coverage Fraction: 13 +/- 2%
Faculae Coverage Fraction: 1.5 +/- 0.5%

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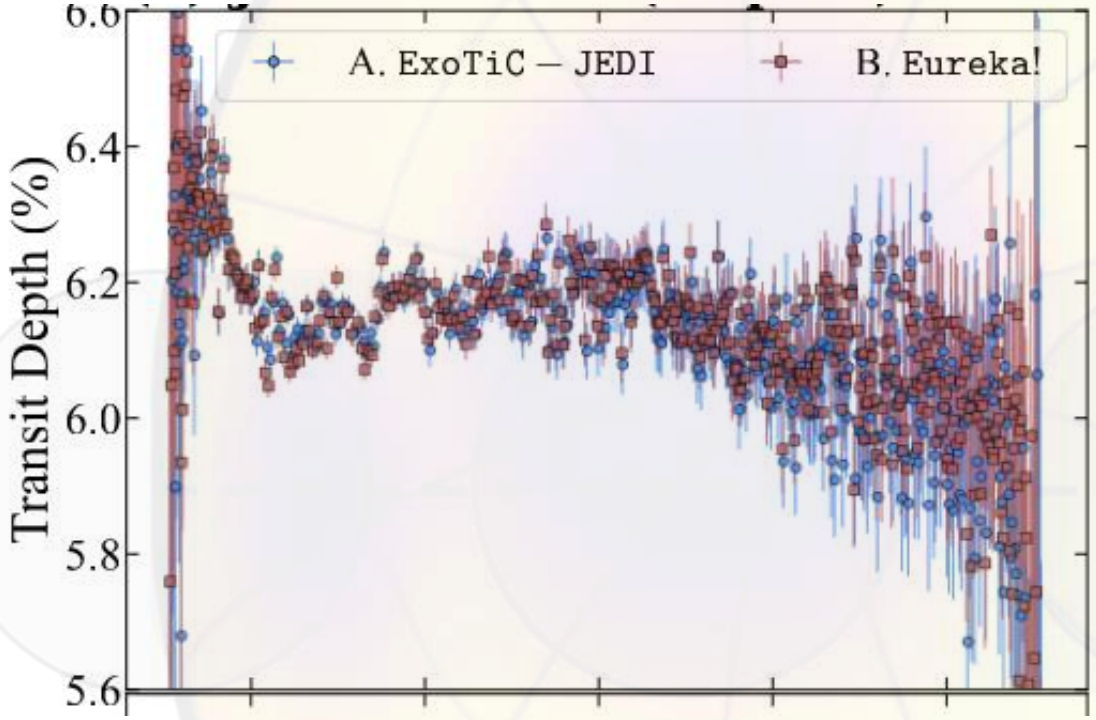

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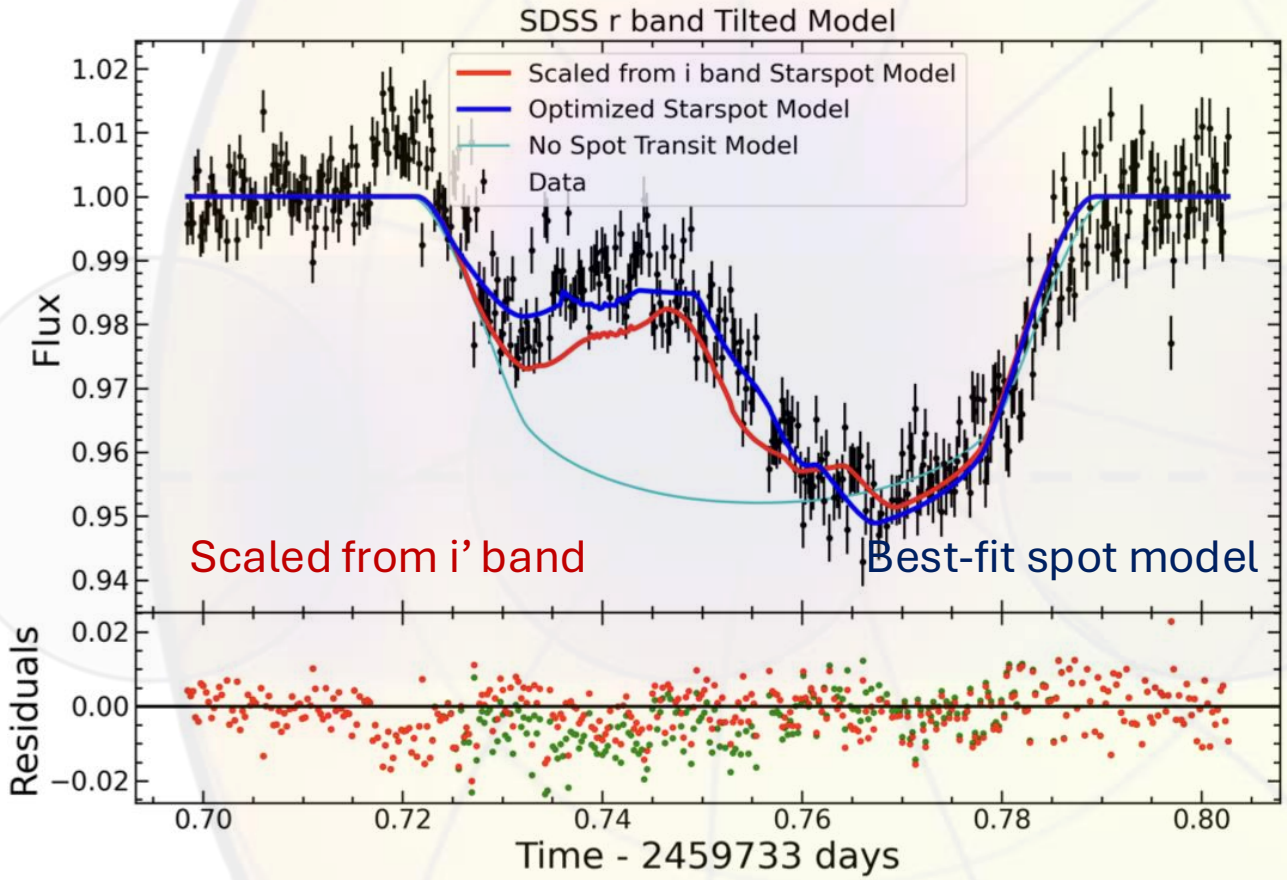
Reported spectroscopic derived effective temperature: 3430 +/- 50 K

Canas et al. (In Prep)

Broadband spot observations of TOI-3884b in different bandpasses show discrepancies



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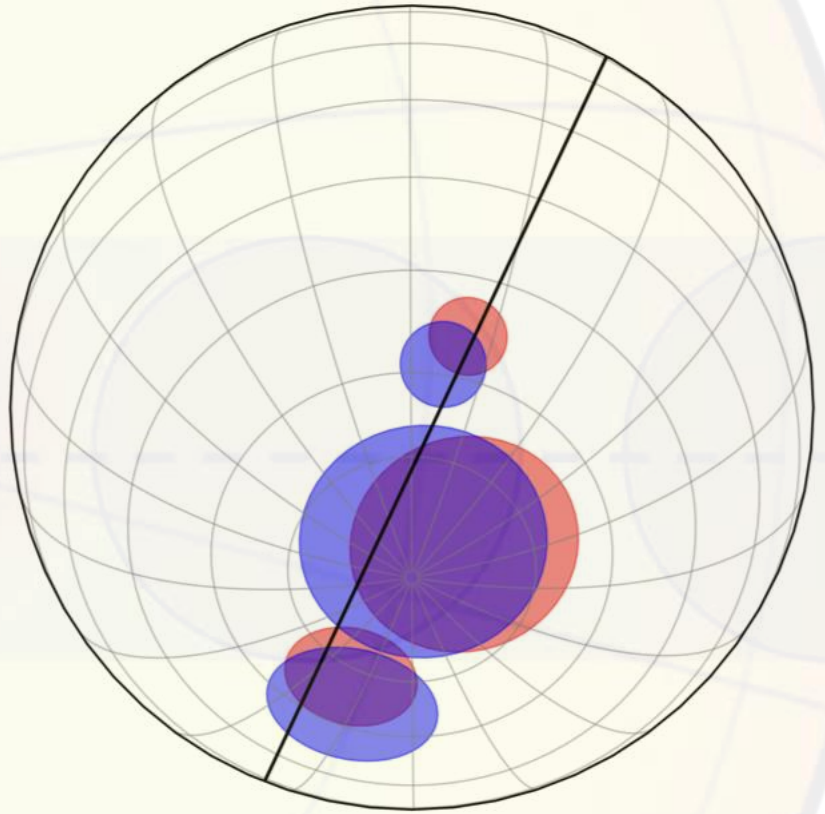
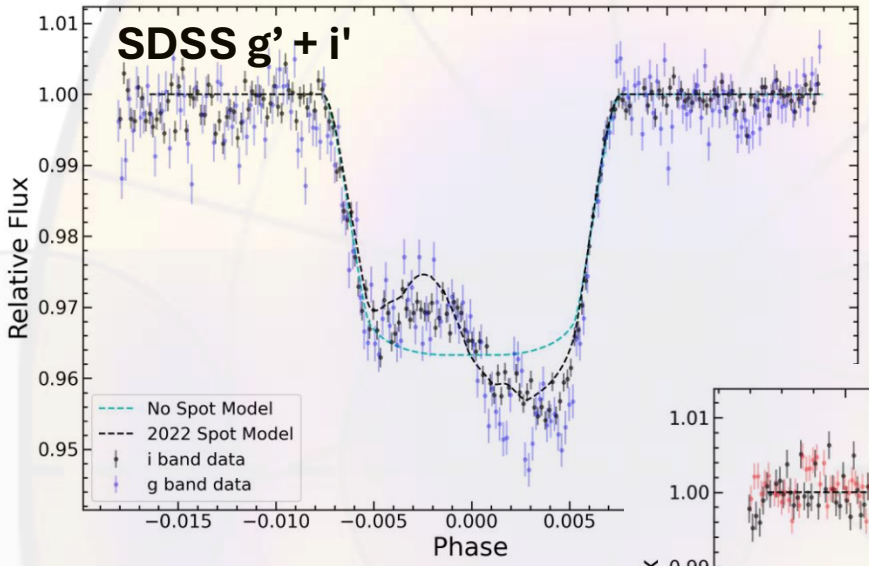
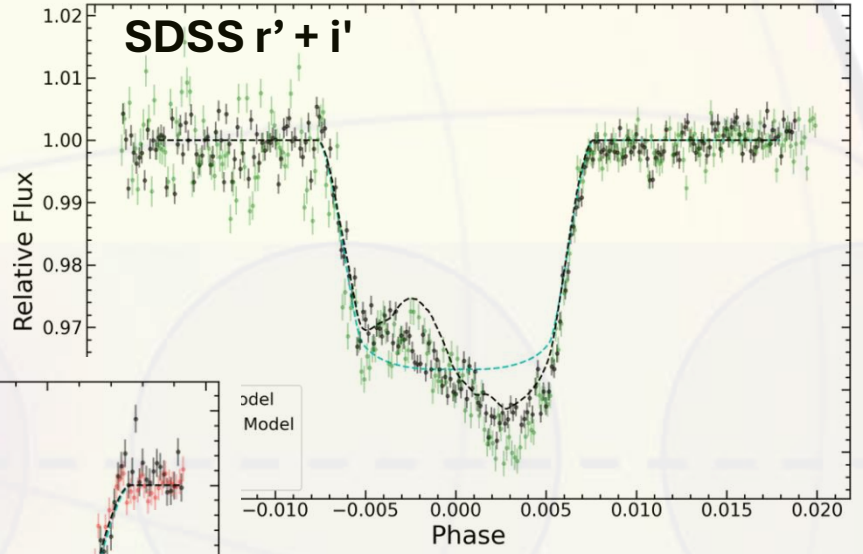
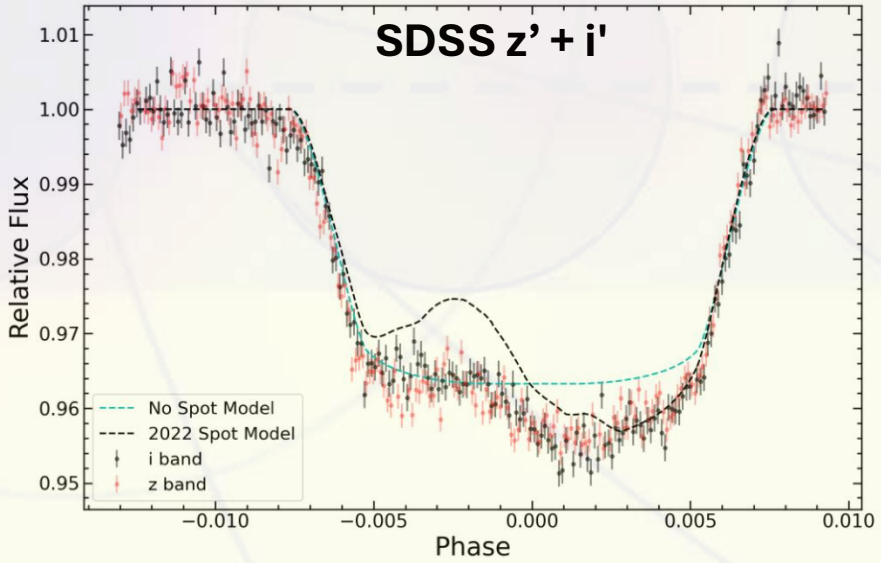


Libby-Roberts et al. (2023)

Follow-up with Apache Point using “filter-swapping” lead to a variety of transit shapes

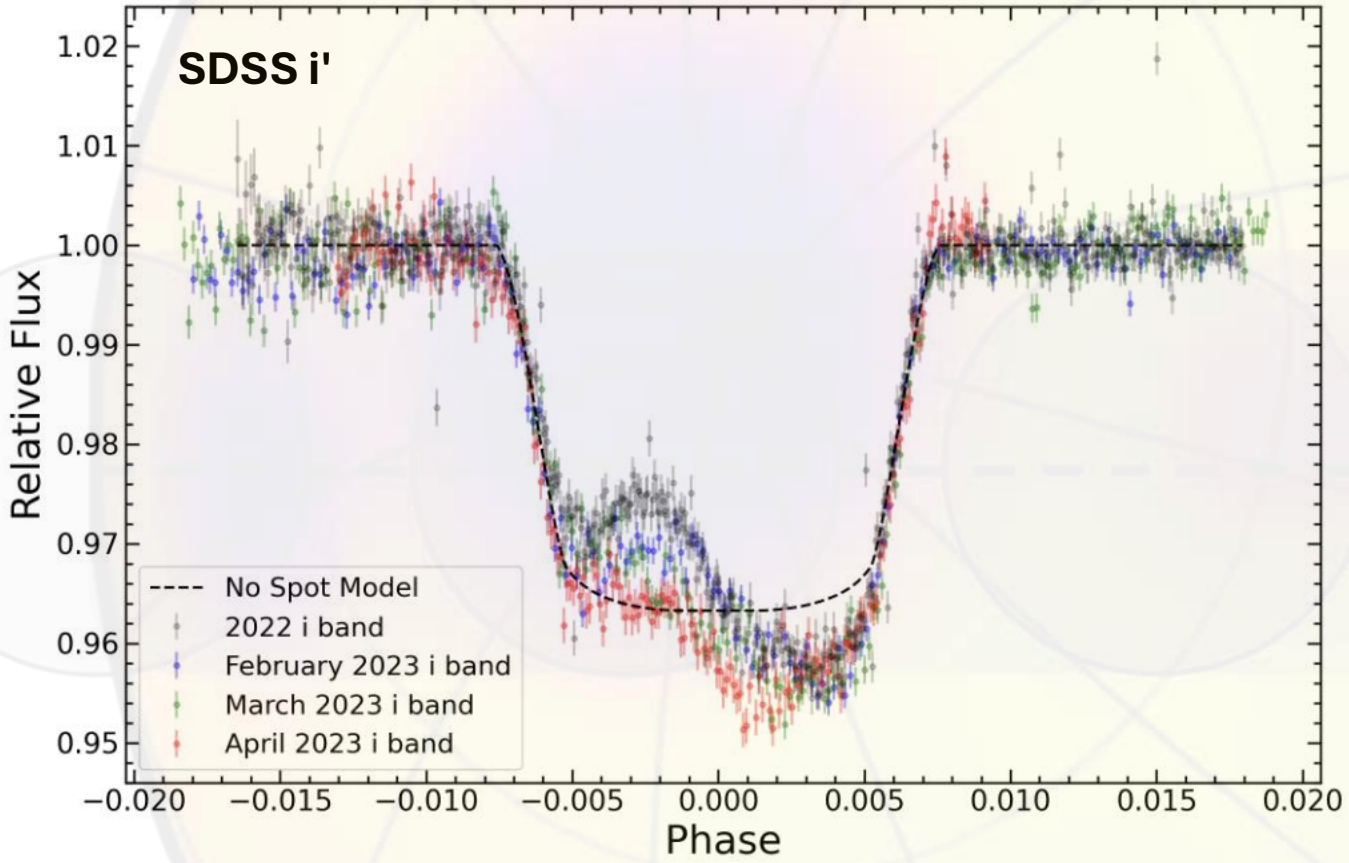






Hebb, Libby-Roberts et al. (In Prep)

A comparison of the transit in the same bandpass shows clear spot evolution on timescales < 1 month



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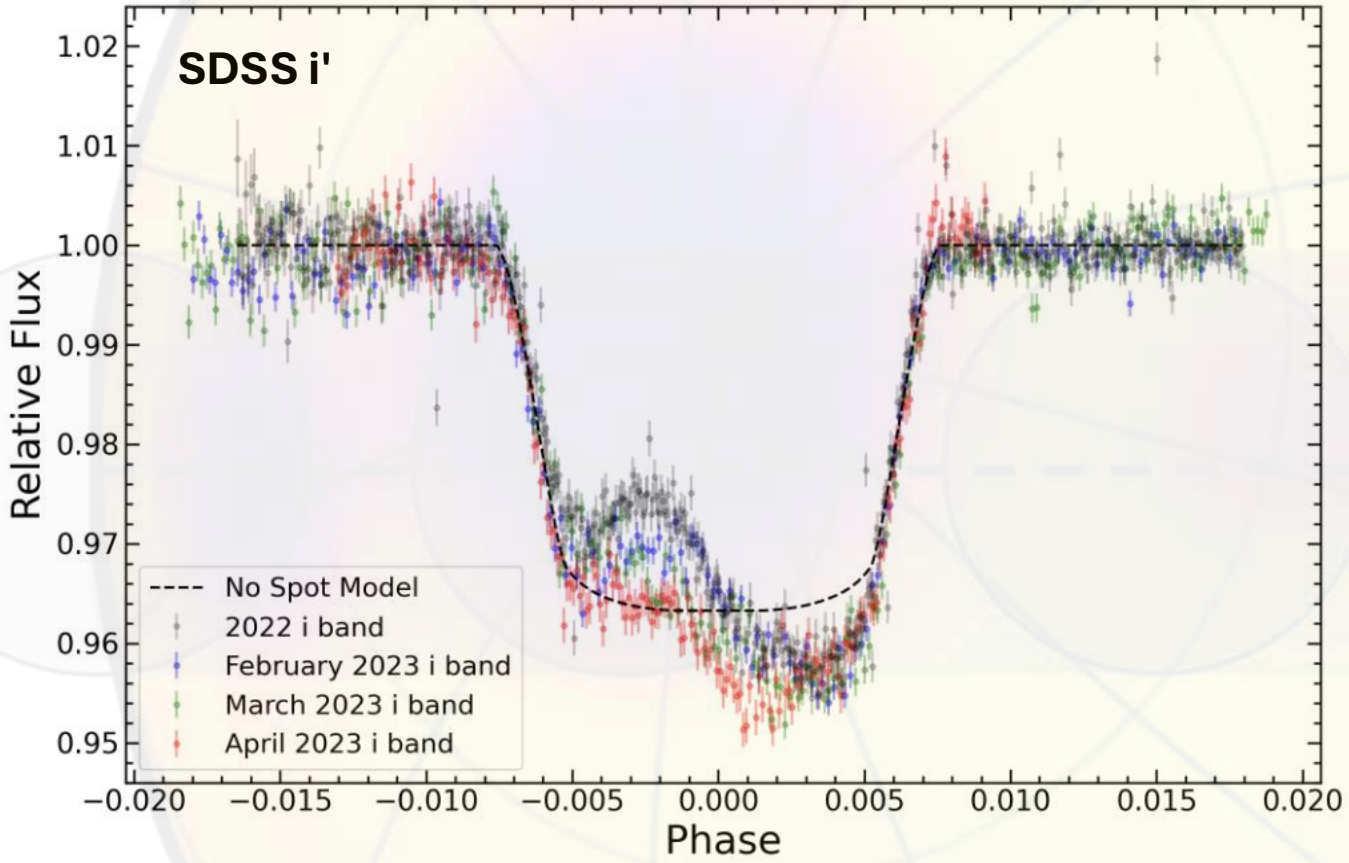

Each transit needs to be considered separately!

Hebb, Libby-Roberts et al. (In Prep)

Still leaves us with the challenge of retrieving stellar properties – JWST (please do not share)!

2 Transits with NIRISS

2 Transits with NIRSpec-G395M

PI: Catriona Murray – Murray et al. (in Prep)

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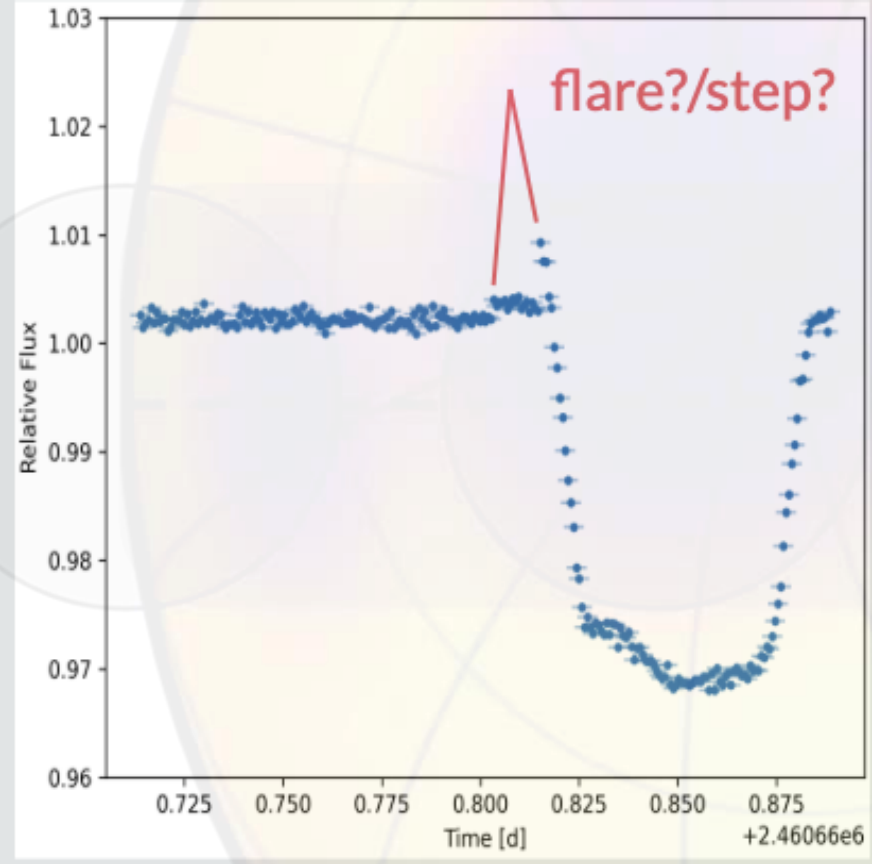
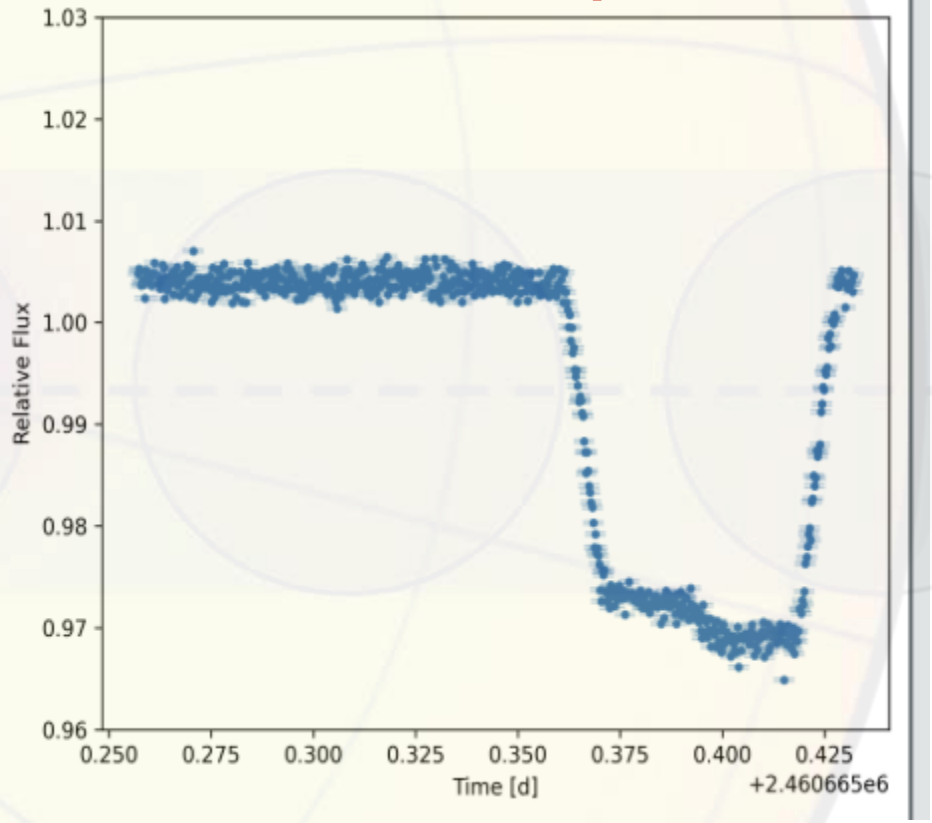


2 Transits with NIRSpec-G395M



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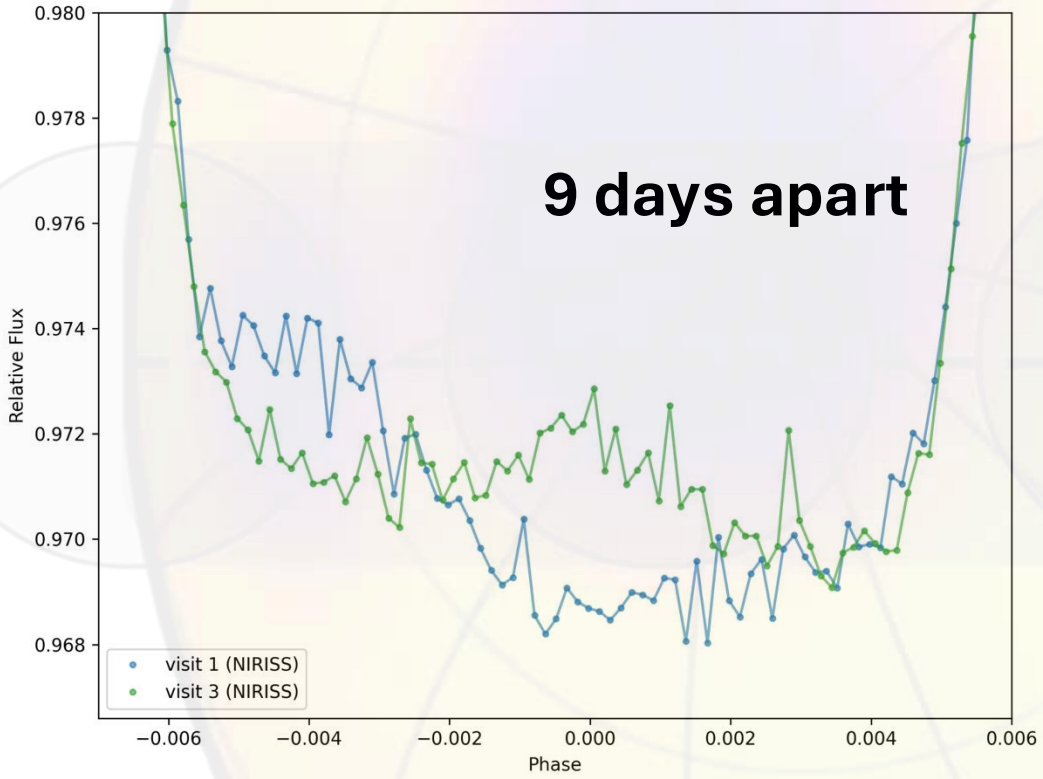

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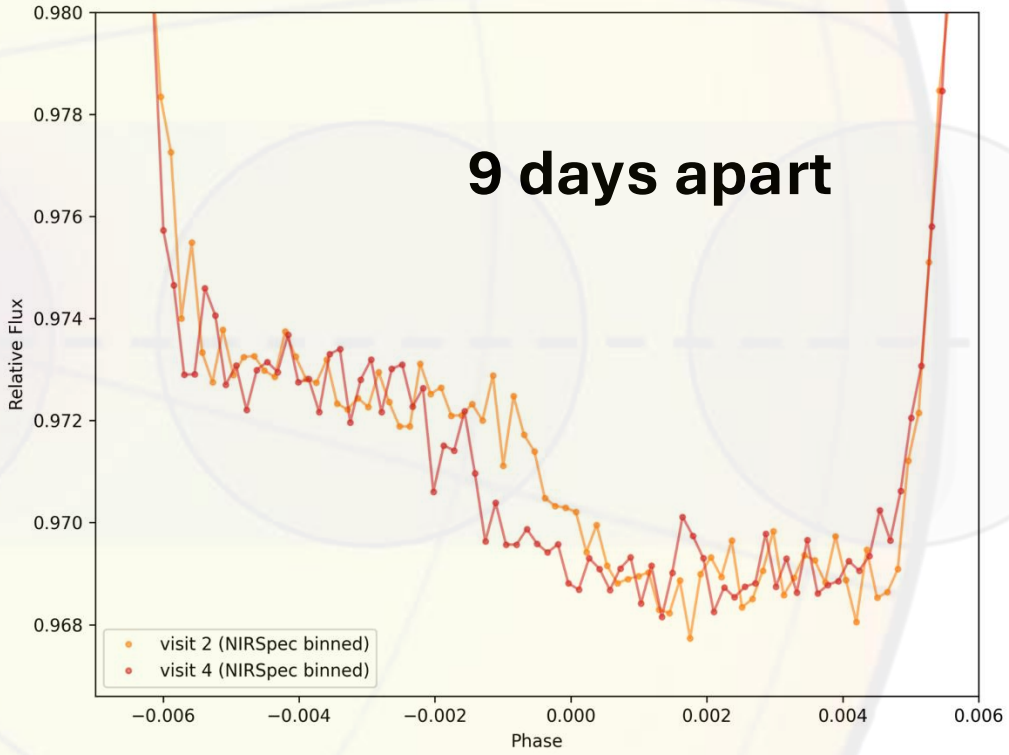
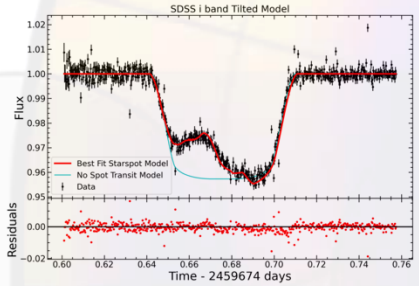
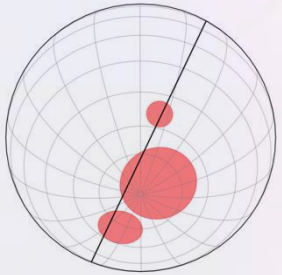


PI: Catriona Murray – Murray et al. (in Prep)

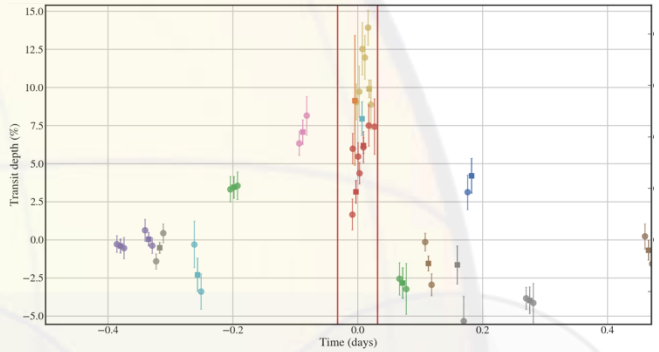
Conclusions:

TOI-3884b is a Super-Neptune on a polar orbit transiting the same pole spot on its M4-Dwarf

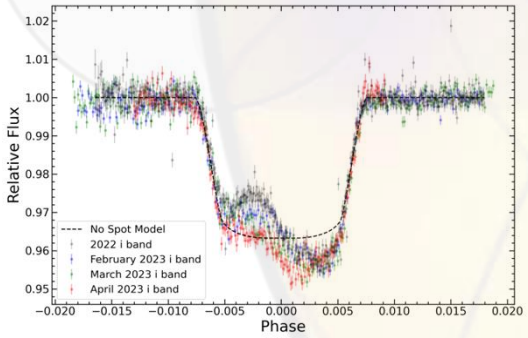




We detect a clear helium detection pre- and in-transit from atmospheric escape



New JWST observations will enable exciting insights into this unique system



There is clear spot evolution on the timescale of days