Atmospheric Evolution Around Evolved Stars

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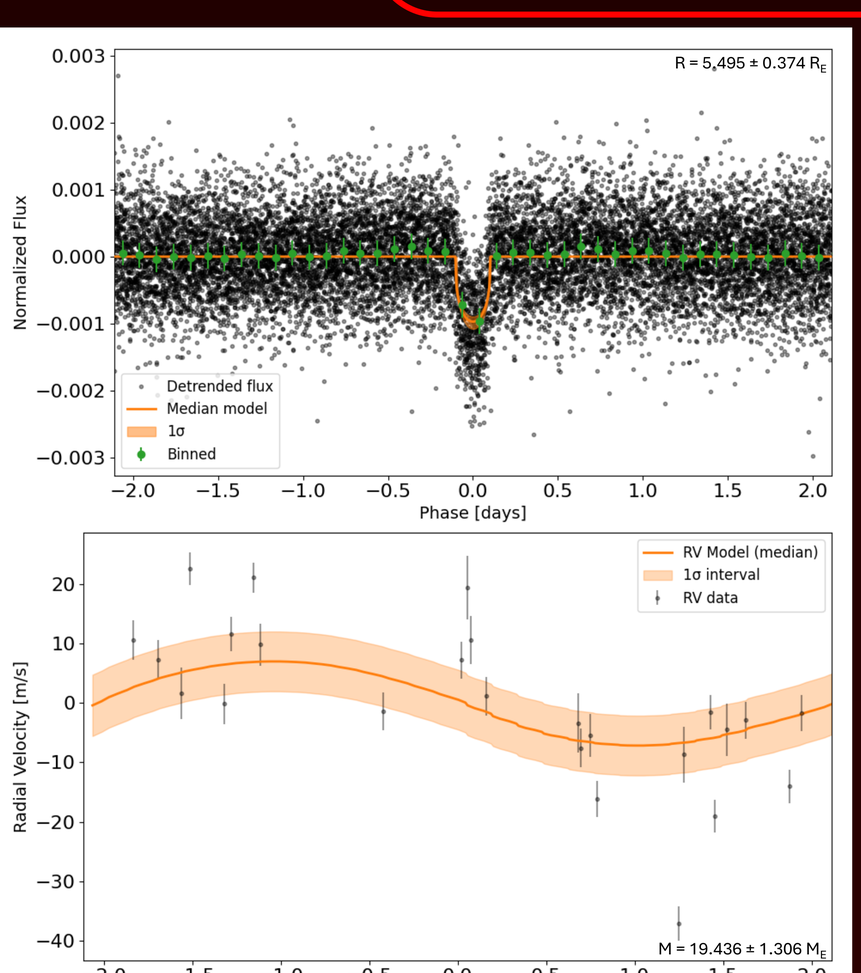
Key Points

- Here we present TOI 5965.01, a hot Neptune orbiting a subgiant star
- Hot Neptunes are rare due to their low masses making atmospheric retention difficult
- The low density and high incident flux of TOI 5965.01 suggest its atmosphere might have been reinflated

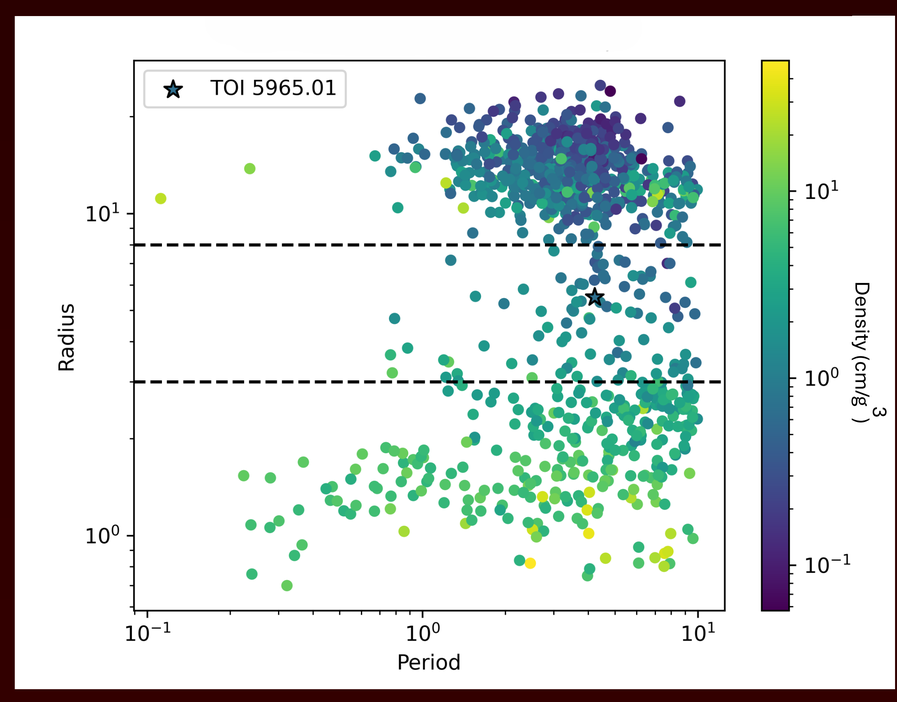


Top: Phase-folded light curve, centered on the transit of TOI 5965.01. Black points are TESS observations, green points show TESS data binned to 0.1 days, and the orange line shows the best-fit transit model. Bottom: All RV observations of TOI 5965.01 with the best-fit RV fit from the exoplanet model.

Identification and Characterization

TOI 5965.01 was first identified as part of the Giants Transiting Giants (GTG) Survey, which detects planets transiting red giants and other evolved stars[1]. Radial velocity (RV) measurements were later taken on the High Resolution Echelle Spectrometer (HIRES) spectrograph on the Keck I telescope.

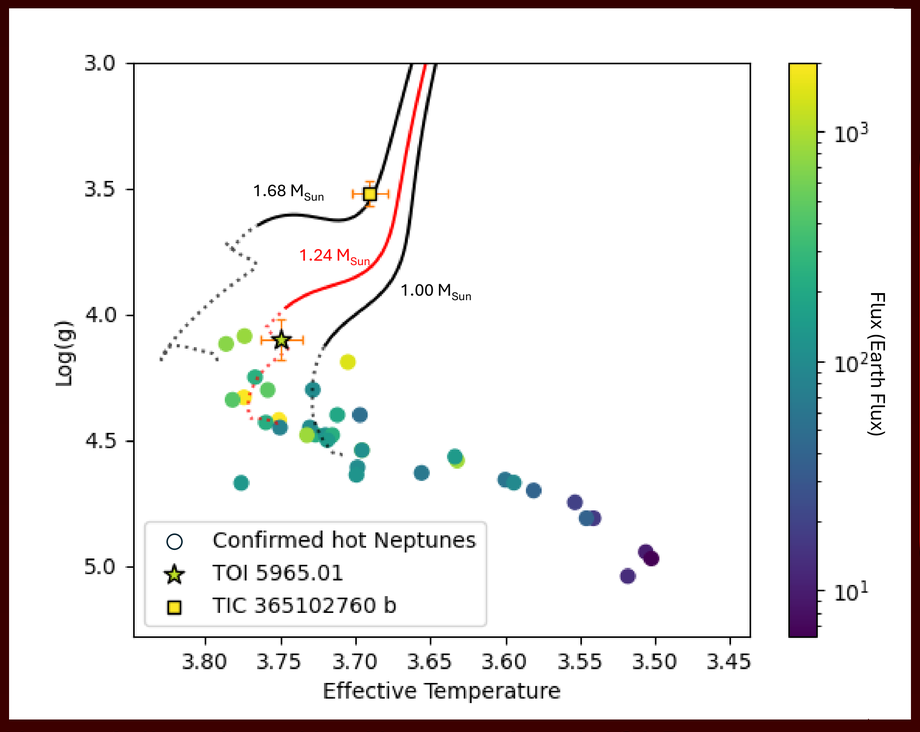
Planetary characteristics were determined using the python package `exoplanet`[2], which created a joint transit-RV fit. This resulted in a mass of 19.436 ± 1.306 M_E and a radius of 5.495 ± 0.374 R_E, orbiting with a period of 4.225 ± 0.01 days. The phase-folded transit and radial velocity curves from the exoplanet fit are shown to the left with TESS and HIRES data respectively. Additional RV measurements were recently taken and will be used to further constrain the mass value.



Planetary radius vs orbital period. Point color indicates the planet's density in cgs units. The upper and lower radius limits for Neptune-sized planets (3-8 R_E) are shown by the dotted lines. TOI 5965.01 can be seen to occupy the sparsely populated hot Neptune Desert.

A Rare Hot Neptune

The mass and radius of TOI 5965.01 place it in the category of hot Neptune. Hot Neptunes are rare[3-5], likely due to their low masses making atmospheric retention difficult[6-8]. To characterize TOI 5965.01's atmosphere further we estimate a density of 0.643 ± 0.061 g/cm^3 from the fitted mass and radius values, placing this planet in the bottom 19th percentile of all hot Neptunes.



Hosts of all confirmed hot Neptunes from NASA Exoplanet Archive on an HR diagram. We include stellar evolution tracks for 1.00, 1.24, and 1.68 M_{Sun} for reference, as well as TIC 365102760, another evolved hot Neptune system discovered by Grunblatt et al 2024[11].

A Re-inflated Atmosphere?

TOI 5965.01 is receiving a high amount of incident flux, with a TESS-determined value of 1118.057 F_E. This is high compared to hot Neptunes orbiting evolved stars, and extremely high compared to hot Neptunes orbiting MS stars. This combination of high incident flux and low density suggest that TOI 5965.01's atmosphere might have been reinflated following its star's transition off the MS[9,10]. Atmospheric modeling is currently underway to estimate lifetime mass loss and determine the likelihood of reinflation.

References: [1]Saunders *et al* 2022 *AJ* **163** 53; [2]Foremann-Mackey *et al* 2021 *JOSS* **6** 3285; [3]Szabò & Kiss 2011 *APJL* **727** L44; [4]Lundkvist *et al* 2016 *Nature Communications* **7** 11201; [5]Mazeh *et al* 2016 *AAP* **589** A75; [6]Lopez *et al* 2012 *ApJ* **761** 59; [7]Koskinen *et al* 2022 *ApJ* **929** 52; [8]Thorngren *et al* 2023 *ApJL* **945** L36; [9]Lopez and Fortney 2016 *ApJ* **818** 4; [10]Thorngren *et al* 2021 *ApJL* **909** L16; [11] Grunblatt *et al* 2024 *AJ* **168** 1