TOI-1431b/MASCARA-5b: an ultra-hot Jupiter orbiting one of the hottest & brightest known exoplanet host stars

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TOI-1431b/MASCARA-5b: An **Ultra-hot Jupiter** Orbiting One of the **Hottest** & **Brightest** Known Exoplanet Host Stars

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Introduction

TOI-1431b/MASCARA-5b is an **ultra-hot Jupiter** on a **~2.65d orbit** [1]. Ultra-hot Jupiters are the **hottest** and most **irradiated** planets known with dayside temperatures **> 2200K** [2]. This planet was detected by the Multi-site All-Sky CAmeRA (MASCARA, [3]) between 2015 - 2018 and later by *TESS* [4] between Aug. & Oct. 2019 in Sectors 15 & 16.

- Radial velocities: SONG, SOPHIE, FIES, NRES, and EXPRES. K = 294.1 ± 1.1 m/s, **precise RV orbit!**
- Planet parameters from photometry + RVs in Allesfitter [5]:
  - Mass: $M_P = 3.14 \pm 0.19\ M_J$
  - Radius: $R_P = 1.51 \pm 0.06\ R_J$ ($16.9 \pm 0.7\ R_\oplus$)
  - Bulk density: $\rho_P = 1.2 \pm 0.2$ cgs
- Stellar parameters from Simbad & SED fit in EXOFASTv2 [6]:
  - Vmag ~ 8.1, **bright!**
  - Age: $0.29^{+0.32}_{-0.19}$ Gyr, **young!**
  - $T_{\rm eff} = 7690^{+400}_{-250}$ K, one of the **hottest** host stars (Fig. 1)!
  - $M_* = 1.90^{+0.10}_{-0.08} M_\odot$ and $R_* = 1.92 \pm 0.07 R_\odot$
  - Spectral type: Am (kA5mF2 [7]), usually in tight binaries.
  - vsini ~ 6 km/s, **very slow rotator!**

TESS photometry reveals the **planet's thermal emissions** from the **full phase curve** and **secondary eclipse** (Fig. 2), providing its dayside and nightside temperature as $\mathbf{T_{day}}$**=2983±68K** and $\mathbf{T_{night}}$**=2556±65K**, respectively. The nightside temperature is the **second hottest** ever measured (Fig. 3a)! The low day/night temperature contrast (~400K) suggests **very efficient heat transport** between the dayside and nightside hemispheres (Fig. 3b).

Analysis & Results

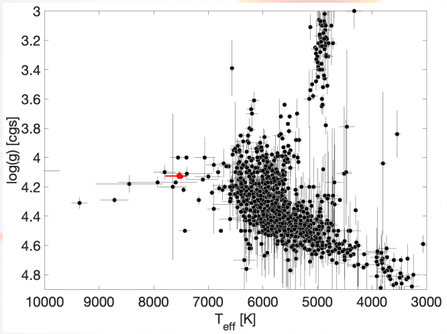


Fig. 1: Plot of stellar effective temperature versus surface gravity for planet hosting stars. TOI-1431 is plotted as the red point and shows that it is one of the hottest (top 1%) known planet hosting stars.

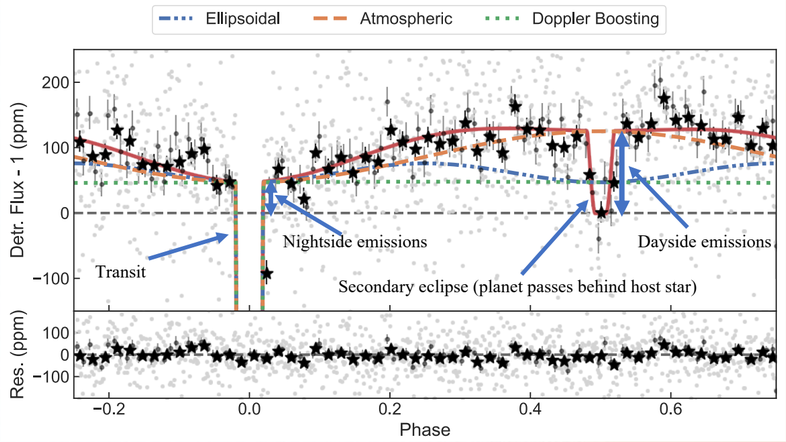


Fig. 2: The phase-folded *TESS* light curve, zoomed in to show the phase curve and secondary eclipse. The dark grey points are the binned photometry at a cadence of ~13 minutes and the black stars are the binned photometry at a cadence ~26 minutes. The grey dashed line represents no emission from TOI-1431b.

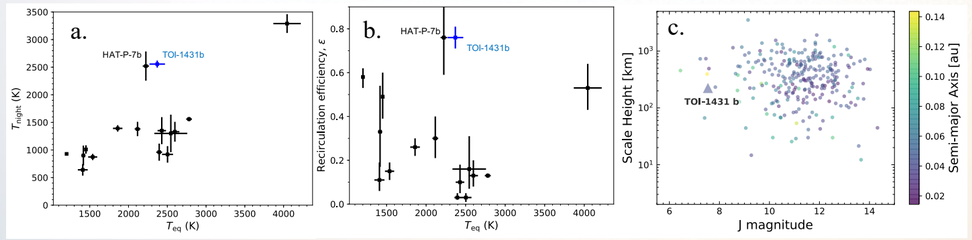
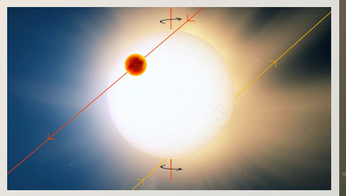


Fig. 3: **a**) Planet equilibrium vs nightside temperatures, comparing TOI-1431b to other hot and ultra-hot Jupiters. **b**) Planet equilibrium temperatures vs atmospheric recirculation efficiencies for the same sample of planets in a). **c**) Host star brightness in Jmag vs atmospheric scale heights of hot Jupiters, showing TOI-1431b orbits one of the brightest hosts.

Conclusions

- Planet's atmospheric scale height is H_p=220±30km (Fig. 3c), suitable for atmospheric characterization from space missions such JWST.
- The planet's **nightside temperature** of **~2600K** is the **second hottest** ever measured!
- The Rossiter-McLaughlin effect reveals that the planet is on a **retrograde orbit**, projected obliquity of $\boldsymbol{\lambda = -155^{+20}_{-10}}$° [8].
- The retrograde orbit for TOI-1431b suggests that it experienced **high eccentricity migration** shortly after formation, perhaps due to interactions with another planet or distant stellar companion.
- Lingering questions:
  - Is the planet responsible for star spin-down (via tidal braking) and transforming A star into an Am star?
  - If yes, for Am stars that don't have a close-in stellar companion host a hot/ultra-hot Jupiter instead?



Artist impression of TOI-1431b and its retrograde orbit. Video simulation can be found here (https://youtu.be/CO6r7676qR4).

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