

## A HOT SUBDWARF B STAR ECLIPSED BY A LOW-MASS WHITE DWARF IN TESS DATA

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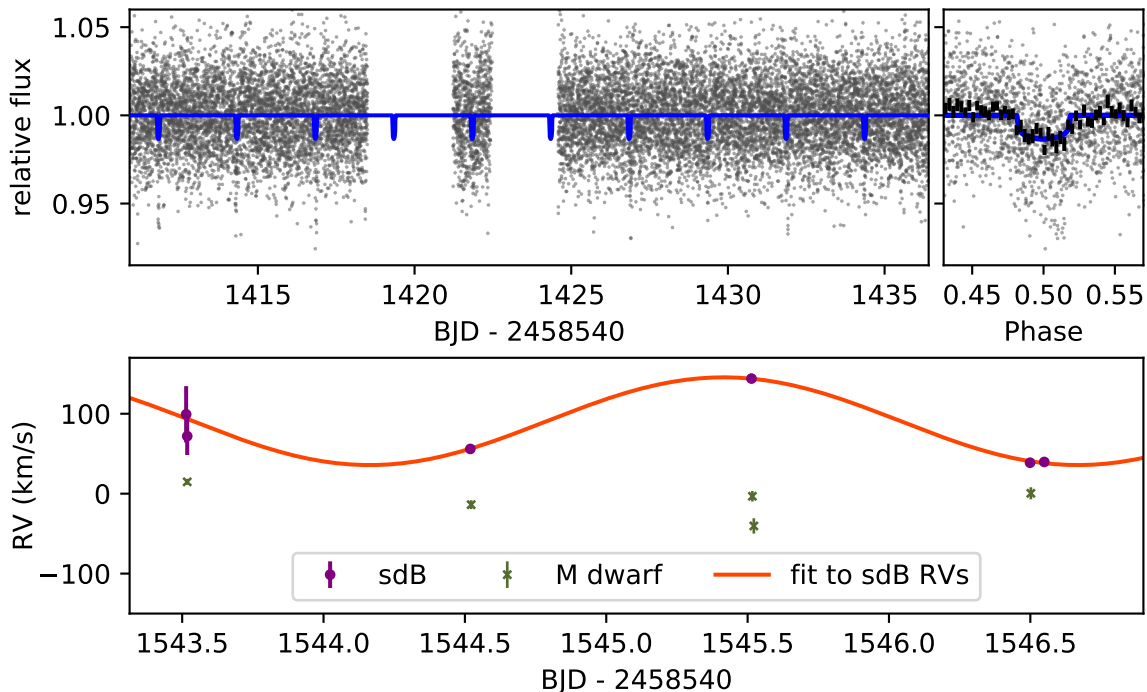
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*Keywords:* binaries: eclipsing — binaries: spectroscopic — stars: individual (PHL 1539) — subdwarfs

The Transiting Exoplanet Survey Satellite (TESS; [Ricker et al. 2014](#)) is obtaining 27 days of time series photometry in a sequence of sectors that will cover over 85% of the sky. 15,000 pre-selected targets in each Sector are observed with a 2-minute cadence. The TESS Asteroseismic Science Consortium Working Group 8 (TASC WG8) is coordinating the study of all photometrically variable evolved compact stars in the TESS data, whether from pulsations, binarity, or planetary systems. TASC WG8 has proposed for all known and likely subdwarfs and white dwarfs in each TESS sector to be observed with the 2-minute cadence.

The TESS Sector 4 light curve of the subdwarf B (sdB) target TIC 142875987 (PHL 1539;  $G = 14.0$  mag) exhibits regular dips that are reminiscent of exoplanetary transits. To date, no transits of subdwarfs have been detected, though other signatures of planets orbiting subdwarfs have been claimed: [Silvotti et al. \(2007\)](#) detected pulsation timing variations from V391 Peg consistent with planet-induced reflex motion (continued monitoring has deviated from this model; [Silvotti et al. 2018](#)), and [Charpinet et al. \(2011\)](#) and [Silvotti et al. \(2014\)](#) have attributed low-frequency signals in *Kepler* observations of two sdB stars to planetary reflection. Transits would provide the most definitive exoplanet detections, enabling the precise characterization of planets that survived or resulted from the formation of these hot, subluminescent stars, likely through mass transfer in tight binary systems (for a review, see [Heber 2016](#)).

We confirmed the subdwarf nature of TIC 142875987 by obtaining a spectrum with the Boller and Chivens spectrograph on the 2.3-m Bok telescope at Kitt Peak on 25 Feb 2019. A simultaneous fit of the Balmer and helium lines with a



**Figure 1.** TOP PANEL: full (left) and phase-folded (right, with 10-minute medians in black) TESS light curve of the eclipsing sdB target TIC 142875987 with the best-fit Transit-Least-Squares model (Hippke & Heller 2019). BOTTOM PANEL: RV measurements of the sdB target (absolute) and the nearby M dwarf, *Gaia* DR2 5054985505903099008, (relative) with the best-fit sinusoid to the sdB RVs overplotted. The spectroscopic data behind the figure are available online.

grid of non-LTE line-blanketed model atmosphere spectra (as used in Green et al. 2011) constrains the atmospheric parameters and helium abundance of the sdB to  $T_{\text{eff}} = 35,400 \pm 500$  K,  $\log g = 5.5 \pm 0.5$  and  $\log N(\text{He})/N(\text{H}) = -3.5 \pm 0.7$ .

We flattened the TESS light curve of TIC 142875987 with a 1-day, second-order Savitzky-Golay filter (Savitzky & Golay 1964) using LIGHTKURVE (Barentsen et al. 2019), iteratively clipping  $> 5$ -sigma outliers. We measure a period of  $2.504 \pm 0.012$  days with the Transit-Least-Squares algorithm (Hippke & Heller 2019). The best-fit model has transit depths of 1.34%, which is consistent with a terrestrial planet transiting a canonical  $0.15 R_{\odot}$  and  $0.47 M_{\odot}$  sdB star, though the 2.0-hour durations of this preliminary fit are slightly longer than expected. This model is plotted over the light curve in Figure 1.

The orbital period is close to TESS’s reaction wheel desaturation timescale, but corresponding quality flags do not coincide with the candidate transits. The 7.66-hour double-eclipsing binary system CD-31 1387 contributes flux to the TIC 142875987 target pixel file from  $160''$  away, but these eclipses also do not sync with the dips. Still, a  $G = 16.4$  mag M dwarf star (*Gaia* DR2 source\_id 5054985505903099008; Gaia Collaboration et al. 2018) positioned  $37''$  away could be the source if it is eclipsed.

To test whether the observed dips are caused by binary eclipses of either the subdwarf or the M dwarf, we obtained nightly spectra of both from 1–4 March 2019 with the Goodman spectrograph (Clemens et al. 2004) on the 4.1-m SOAR telescope. The radial velocity (RV) measurements are shown in Figure 1. The subdwarf exhibits significant RV variations on a timescale consistent with the photometric period, supporting that the dips in the TESS data are caused by eclipses of the sdB target TIC 142875987 rather than by planet transits or eclipses of the background M dwarf.

While the purpose of this note is to reject the transiting exoplanet hypothesis, TIC 142875987 is interesting in its own right. A fixed-period sinusoid fit to the RV data gives a semi-amplitude of  $54.9 \pm 1.1$  km s $^{-1}$ , implying a companion mass of  $\approx 0.3 M_{\odot}$ . We rule out that the secondary is an M dwarf from a lack of an observed reflection effect (Maxted et al. 2002) or an infrared excess in WISE (Wright et al. 2010). This matches the observed tendency of M dwarf companions to sdB stars to be in  $\lesssim 1$ -day orbits (e.g., Kupfer et al. 2015). This companion is instead a low-mass, likely helium-core white dwarf that also formed through mass transfer in a common envelope. This is the least massive white dwarf known to eclipse a hot subdwarf (followed by two systems reported by Green et al. 2004), and further analysis will guide our understanding of the physical processes and evolutionary scenarios that produce such objects.

The authors thank TASC WG8, especially Zs. Bognar, J. Debes, Z. Guo, J. J. Hermes, B. Kaiser, D. Kilkenny, T. R. Marsh, J. Reding, P. Sowicka, M. Uzundag, and W. Zong for helpful discussion. This paper includes data collected by the TESS mission. Funding for the TESS mission is provided by the NASA Explorer Program. Based on observations obtained at the Southern Astrophysical Research (SOAR) telescope (NOAO proposal 2019A-0134). GH acknowledges support by the Polish National Science Center (NCN) grant 2015/18/A/ST9/00578.

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