Massive Stars Near and Far
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Plaskett's Star: a fundamental revision of the architecture of the system

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Abstract. A century of study has characterized Plaskett's Star (HD 47129) as an evolved, massive, short-period, equal mass O+O binary system. The discovery of a magnetic field in the broad-line component by Grunhut et al. (2013) renewed interest in the study of this system and led to its establishment as the most rapidly rotating magnetic O-type star. Grunhut et al. (2021) observed the circular polarization signatures of the magnetic star to exhibit no radial velocity variations while the narrow-line star demonstrates radial velocity variations consistent with the established orbital period. This has raised fundamental questions about the architecture of this system and the nature of the magnetic star which have led to a major shift in our understanding of HD 47129.

Keywords. magnetic stars, massive stars, binary evolution

1. Introduction

Plaskett's Star was first discovered by Canadian Astronomer John Stanley Plaskett in 1922 (Plaskett 1922). It has been historically understood as a very massive ($M \approx 100$ $M_\odot$) double-lined, short-period ($P \approx 14.4$ d) spectroscopic binary containing two O-type components (see Linder et al. 2008). The broad-lined component was discovered to contain a magnetic field by Grunhut et al. (2013), establishing it as the most rapidly rotating known magnetic O-type star. Grunhut et al. (2022) have recently presented strong evidence against significant radial velocity variations in the magnetic star, which is supported by spectral disentangling analysis. These results are inconsistent with the near-equal mass binary model for this system and motivate a fundamental revision of our understanding of this system.

2. Observations

Spectroscopy of HD 47129 reveals a narrow-lined O8 component (NLC) and a broad-lined O7.5 component (BLC) (Linder et al. 2008) associated with a clear magnetic signature in Stokes V (Grunhut et al. 2013). The NLC is rich in nitrogen (16 $N_\odot$) and depleted in carbon (0.03 $C_\odot$), whereas the BLC is depleted in nitrogen (0.2 $N_\odot$) and rich in helium (1.76 $He_\odot$) (Linder et al. 2008). Plaskett's Star was recently observed extensively with the high resolution ESPaDOnS and Narval spectropolarimeters as reported by Grunhut et al. (2022). Analyzing these spectra, they found that substantially better fits to the Stokes V profiles were achieved assuming a constant RV for the magnetic star instead of the Linder et al. (2008) model. This is also reflected in the magnetic maps in each case, with the latter yielding an unrealistically complex magnetic geometry. This is further supported by direct measurement of radial velocities from disentangled Stokes I spectra. These results provide strong evidence against significant RV variability of the magnetic star that is required for the historical orbital model. This has motivated a fundamental revision of our model for the composition and structure of Plaskett's Star.

Plaskett's Star has been observed by both the Convection, Rotation, and Planetary Transits (CoRoT) satellite and the Transiting Exoplanet Survey Satellite (TESS) and demonstrates complex photometric variability (see Stacey et al., in prep.). The majority of this is attributable to modulation associated with the rotation of the magnetic star and its magnetosphere. The CoRoT data also present variability at the Linder et al. (2008) orbital period, and stochastic low-frequency variability (Blomme et al. 2011) is present in both datasets and qualitatively similar to the *O bright giant and supergiant* sample of Bowman et al. (2020).

3. Hypothesis 1: An unseen object

We consider a case where the NLC is in a close $P \approx 14.4$ d orbit with a third object, and the BLC is either dynamically unrelated or weakly dynamically bound (e.g. hierarchical trinary). The minimum mass of a companion based on the RV variations of the NLC is approximately 14 $M_{\odot}$ which is consistent with a potential black hole (BH) companion. There are several analogous examples in literature of O/B+BH systems that support the plausibility of this scenario (e.g. Cyg X-1; Brocksopp et al. 1999, MWC 656; Casares et al. 2014), nevertheless the strong winds expected of an O-type star as difficult to reconcile with the weak X-ray luminosity of HD 47129 ($L_X = 8.34 \times 10^{32}$ erg/s; Linder et al. 2006). Infrared interferometry reveals no targets from 1 to 8000 mas (subtending $\approx 1 - 8000$ AU) that are consistent with the luminosity of the BLC (Sana 2014). Therefore, this solution restricts the BLC to narrow ranges of orbital phase in a hierarchical configuration. Additionally, this solution does not address the rapid rotation of the magnetic star nor the system's chemical peculiarities.

4. Hypothesis 2: A stripped star

A second revised model under consideration for HD 47129 instead enforces the mass ratio as implied by the radial velocity models measured from the disentangled spectra. Assuming the BLC is a "normal" magnetic O star with a mass of (47.3 ± 0.3) $M_{\odot}$ (Linder et al. 2008), this requires a mass of approximately $1 - 2$ $M_{\odot}$ for the NLC. This component still demonstrates an O spectral type in the spectroscopic observations and comparable luminosity to the BLC. Therefore, we postulate the NLC may be a stripped sdO star (Götberg et al. 2018). This prescription addresses the radial velocity measurements of both components simultaneously with the anomalously high rotation rate of the magnetic star (through angular momentum transfer in the stripped material). The He/N enhancements and C/N/O depletions associated with these objects (Götberg et al. 2018) is also consistent with the Linder et al. (2008) abundances and apparent lack of oxygen lines in the system. Interpreting the NLC as a stripped sdO star currently appears to best address the outstanding issues with modelling Plaskett's Star while remaining consistent with existing observational results.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1743921322002198.

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