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Identification of a White Dwarf Companion in the V* HP Dra System

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Abstract

We present Gaia DR2 2144465183642117888, a previously unknown, wide white dwarf companion to the HP Dra eclipsing binary system. This companion was discovered through the Backyard Worlds: Planet 9 citizen science collaboration. It has separation of 14.″4 on the sky from the central eclipsing pair, translating to a projected separation of ~1140 au. We present a review of the orbit and physical parameters of all the components in this now triple system.

1. Introduction

The Backyard Worlds: Planet 9 (BYW; Kuchner et al. 2017) project considers if the theoretical Planet 9 (Batygin & Brown 2016), exists by searching the WISE images Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010). The same technique is also applied to identify previously unknown low-mass stars and brown dwarfs near the vicinity of the solar system, many of which are included in the recent full-sky census of Kirkpatrick et al. (2021). BYW: P9 has seen success with the discovery of exotic objects such as extreme T-type subdwarfs

(Schneider et al. 2020) and common proper motion companions to other stars (Rothermich et al. 2021). Here we present another area of expansion for the Backyard Worlds: Planet 9 project with the discovery of a white dwarf companion which was found to be associated with the HP Dra eclipsing binary system.

2. Historical Observations

HP Draconis is a well-known eclipsing binary (Milone et al. 2010) derived orbital parameters; P = 10.76152 ± 0.00019 days, a = 26.79 ± 0.04 $R_{\odot}$, e = 0.0367 ± 0.0009, and ω = 0.693 ± 0.037. HP Draconis was found to be a variable system in the Hipparcos mission data (HIP 92835). The initial period of variation reported for HP Dra was incorrectly reported as 6.67 days Kurpinska-Winiarska et al. (1999). Further work by Kurpinska-Winiarska et al. (2000) established the period of 10.76154 days and Milone et al. (2005) confirmed this result at 10.76152 days, with only minor discrepancies. The spectrum of the central pair is listed as G5 in the Henry Draper catalog. Further work by Milone et al. (2005) has resulted in both components being re-classified as F9V. Various other properties have been derived from the system. For example Feltzing et al. (2001) deduced a [Fe/H] metallicity of –0.24 from the *uvby* color indices.

Milone et al. (2010) investigated the system for additional optical companions, and found no conclusive evidence for any additional companions in the system.

3. Discovery of WDJ185454.97+511833.50

We identified a white dwarf companion co-moving with HP Dra. WDJ185454.97+511833.50 (DR2214446518364211788) was identified as having a similar proper motion and Gaia parallax (Gaia Collaboration et al. 2021) to the HP Dra system central pair at a separation of 14.″405 on the sky, indicating that they are likely associated.

Table 1. Properties of HP Dra Triple System

Parameter	HP Dra	WDJ185454.97+511833.50	References
Mass	M_1: 1.133 ± 0.005 $M_{\odot}$	0.45 ± 0.03 $M_{\odot}$	1
	M_2: 1.094 ± 0.007 $M_{\odot}$		1
Radius	R_1: 1.371 ± 0.012 $R_{\odot}$		1

Parameter	HP Dra	WDJ185454.97+511833.50	References
	R_2: 1.052 ± 0.010 $R_\odot$		1
R.A. (degrees)	283.72300282352	283.72918798268	1
Decl. (degrees)	51.30864577245	51.30967553575	1
ϖ (mas)	12.6153 ± 0.0516	12.4974 ± 0.0723	1
μ_α (mas yr^{-1})	23.234 ± 0.074	21.955 ± 0.100	1
μ_δ (mas yr^{-1})	83.306 ± 0.064	83.644 ± 0.098	1
$G_{\rm Bp}$ (mag)	8.111 ± 0.003	17.554 ± 0.022	1
G (mag)	7.826 ± 0.003	17.490 ± 0.003	1
$G_{\rm Rp}$ (mag)	7.369 ± 0.004	17.175 ± 0.022	1

References. (1) Gaia EDR3 (Gaia Collaboration et al. 2021).

WDJ185454.97+511833.50 has a 99% chance of being a white dwarf, with a $T_{\rm eff}$ = 7087 ± 205 K and log g = 7.73 ± 0.07, and M = 0.45 ± 0.03 $M_\odot$ if it is a DA white dwarf (Gentile Fusillo et al. 2018). The values are slightly lower, but within the errors if the white dwarf is a DB white dwarf. Although the white dwarf has a lower than average mass, the mass is high enough to suggest single star evolution.

Using WDWARFDATE (Kiman et al. 2021, in preparation) which combines the MIST isochrones with the Cummings et al. (2019) initial mass-final mass relation we determine the white dwarf cooling age to be $1.15^{+0.14}_{-0.11}$ Gyr, and the total age $5.91^{+4.11}_{-2.86}$ Gyr, with a likely initial mass of $1.29^{+0.44}_{-0.22}$ $M_\odot$, consistent with an earlier spectral type and higher mass than the common proper motion pair.

From this, calculations indicate that the wd is 1140au from the central HP Dra pair. Assuming a circular orbit and taking the mass of the central pair at 2.4 solar masses this would give an orbital period for the white dwarf of ~23,000 yr.

4. Conclusion

We present the discovery of white dwarf companion DR2 2144465183642117888 co-moving with the previously known eclipsing binary HP Dra. This has a wide projected orbital separation of ~1140 au. This system joins a growing list of recent discoveries from the Backyard Worlds: Planet 9 Citizen Science community. HP DRa is now a triple star system. With the white dwarf companion now being evolved past the main sequence stage it is expected that it had a higher original mass than the central eclipsing pair.

Considering the proper motions using the central pair as a baseline. The PMs of the central pair are given at: 23.234 R.A. masyr^{-1} ± 0.074 and 83.306 decl. masyr^{-1} ± 0.064. Proposed companion: 21.955 R.A. masyr^{-1} ± 0.100 and 83.644 decl. masyr^{-1} ± 0.098.

The R.A. shows a 5.5% difference and decl. 0.41% difference respectively between the components in this system. This high agreement within such tight margins between the central pair and the proposed companion would indicate that they are likely associated. The central pair and proposed companion are located at 79.13 pc and 79.90 pc from the solar system respectively. This would indicate that the companion is, at present, on the other side of its orbit around the pair as seen from Earth.

This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement, This publication makes use of data products from the Wide-field Infrared Survey Explorer, (WISE) which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, funded by the National Aeronautics and Space Administration.