Modeling White Dwarf Binary Systems - A Hubble Space Telescope Project

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ABSTRACT:

White dwarfs are the final stage of stellar evolution for most stars–those less than about eight times the mass of the Sun. In these cases the star has ejected its outer layers, leaving a superheated core behind to cool. White dwarfs that are part of a binary system, or have a companion star, lead to many interesting astrophysical situations, and so are important objects to understand. In this study, we look specifically at binary white dwarf systems where the second object is a main sequence star. After the discovery of a binary system, it is necessary to create a working model to better understand the physical characteristics of the system. This is accomplished using data about the changing brightness of the system and measures of the speed of the stars toward and away from us as they orbit one another. We built preliminary models for two white dwarf binary systems–WD1136+667 and Gaia-DR2-3150–which we describe in this presentation. Both of these systems are part of a larger Hubble Space Telescope program studying very hot white dwarfs.

Background

White Dwarfs

- Leftover superheated core of a dead sun-like star after it ejects its outer layers
- Life cycle shown on the Hertzsprung-Russell diagram (Figure 1)
- Composed primarily of carbon and oxygen
- Mass limit of 1.44 $M_\odot$

Binaries

- One companion star (secondary) orbiting with another star (primary-white dwarf)
- Here, a white dwarf and a main sequence star in orbit with each other
- Primarily detected through variations in light

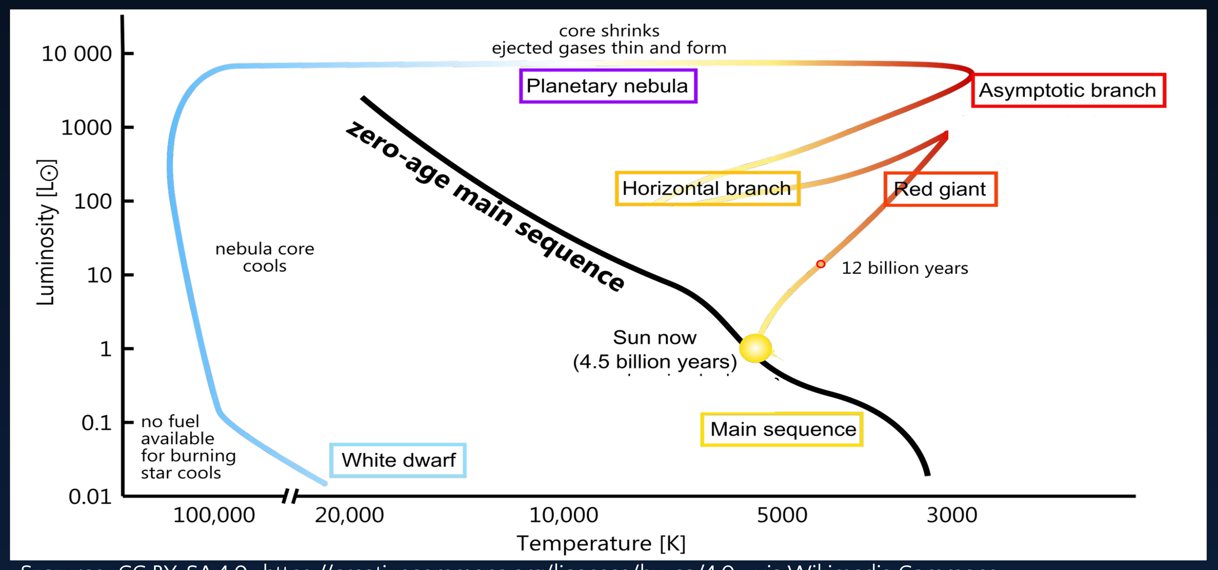


Figure 1: Hertzsprung-Russell diagram. Shows the life cycle of a sun-like star.

Method

PHOEBE
PHysics Of Eclipsing BinariEs
Eclipsing Binary Modeling Software

Prsa et al. (2016)

- Look for variations in brightness due to the binary system (light curves)
- Different types of variability include ellipsoidal, irradiation, and eclipsing
- Also get data of how fast the stars are moving towards or away from us (radial velocity curves)

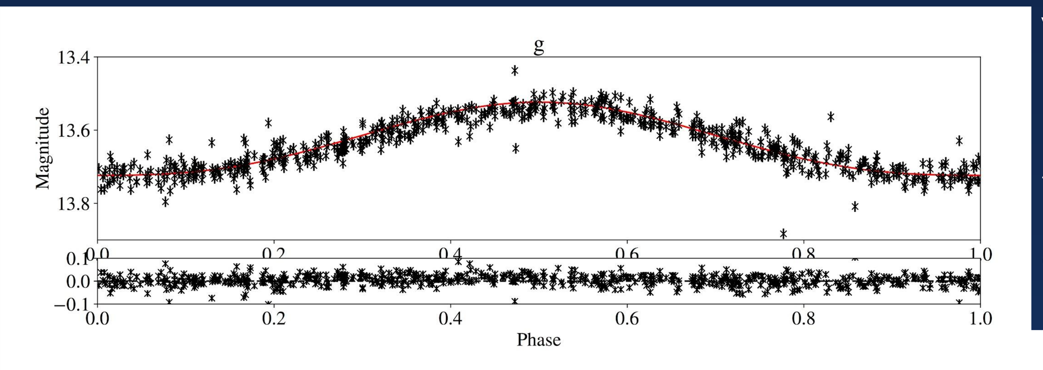
WD1136+667

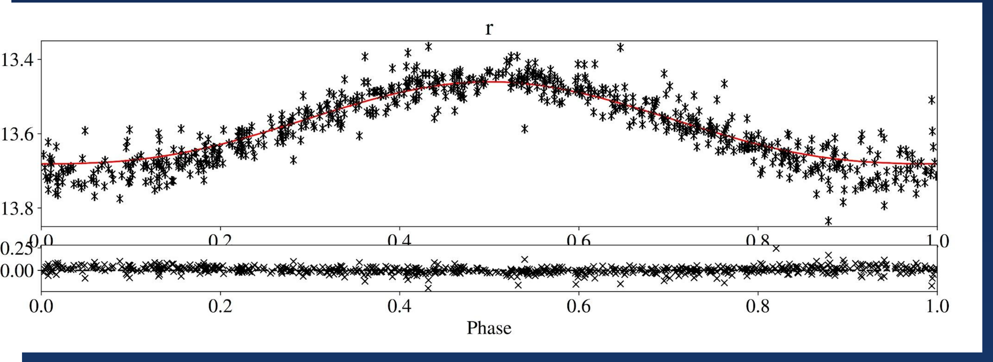
White Dwarf (Primary)		Main Sequence Star (Secondary)	
T1	80000 K	T2	3600 K
R1	0.30 $R_\odot$	R2	0.47 $R_\odot$
M1	0.65 $M_\odot$	M2	0.47 $M_\odot$
incl	65.0 °	A2	0.75

White Dwarf (Primary)		Main Sequence Star (Secondary)	
T1	50000 - 140000 K	T2	3600 - 6500 K
R1	0.01; 0.19 - 0.50 $R_\odot$	R2	0.38 - 0.75 $R_\odot$
M1	0.50 - 0.70 $M_\odot$	M2	0.38 - 0.53 $M_\odot$
incl	32.0 - 70.0 °	A2 (g, r)	0.15 - 0.70; 0.11 - 0.80

WD1136+667 (Gianninas et al. 2010).

We found that most of the ranges are consistent, except for R1, which is too large to be a true physical parameter. To shorten the ranges for the parameters and make the model more accurate, another light curve in a different filter should be added to this dataset.





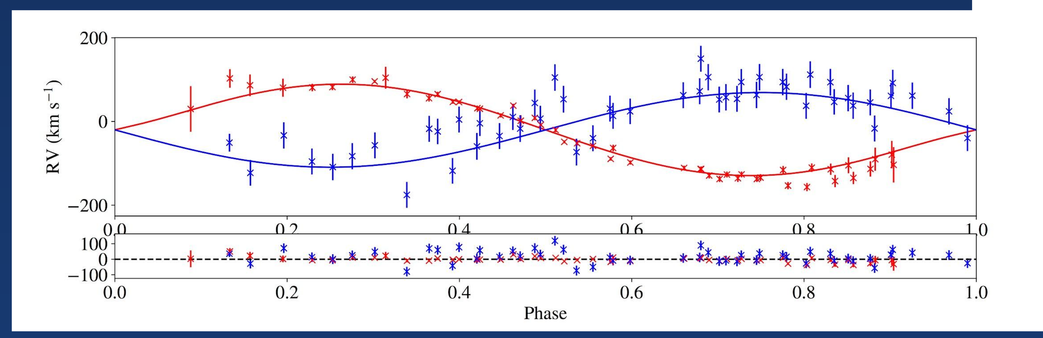


Figure 2: Light curves in g and r of WD1136+667, as well as the radial velocity of the two stars, with the blue for the WD and red for the companion star. The solid lines show the best fit models generated from PHOEBE.

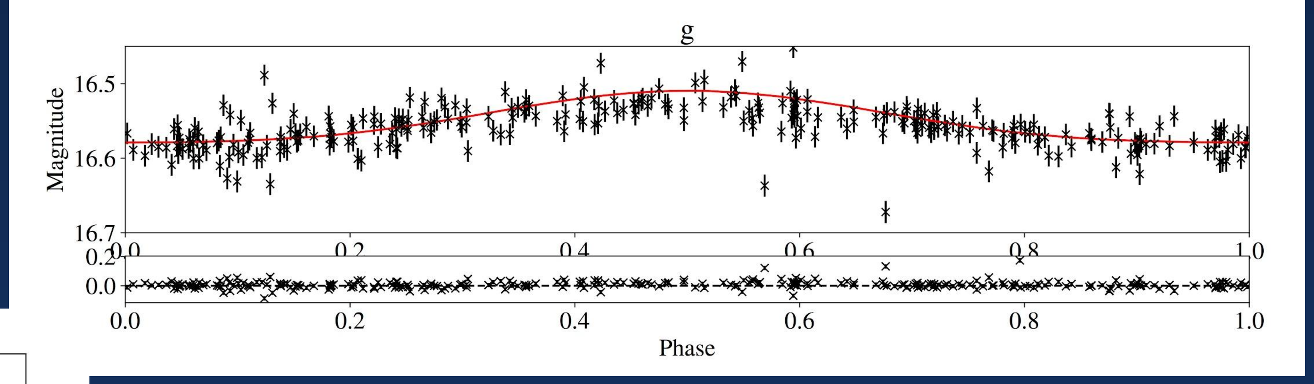
Gaia-DR2-3150708057532318208

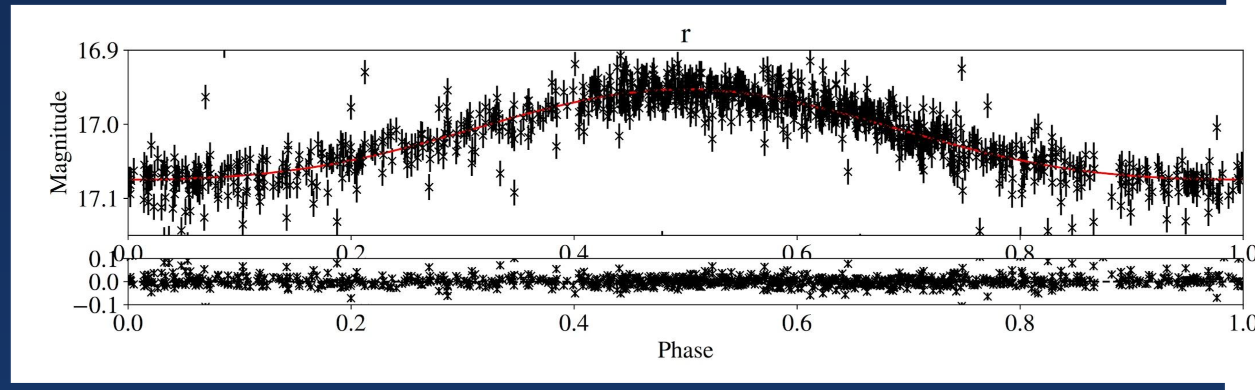
White Dwarf (Primary)		Main Sequence Star (Secondary)	
T1	30000 - 110000 K	T2	3600 - 4800 K
R1	0.01 - 0.12 $R_\odot$	R2	0.30 - 0.38 $R_\odot$
M1	0.50 - 0.70 $M_\odot$	M2	0.15 - 0.38 $M_\odot$
incl	10.0 - 70.0 °	A2	0.10 - 0.35

White Dwarf (Primary)		Main Sequence Star (Secondary)	
T1	47000 K	T2	4000 K
R1	0.08 $R_\odot$	R2	0.30$R_\odot$
M1	0.70 $M_\odot$	M2	0.15 $M_\odot$
incl	40.0 °	A2	0.15

Gaia-DR2-3150 (Gentile-Fusillo et al. 2019).

We found that these ranges are mostly consistent with the expected values. Since there is no radial velocity data for this system, the masses and inclination lie in a very large range. Radial velocity measurements are scheduled to take place in late summer or early fall.





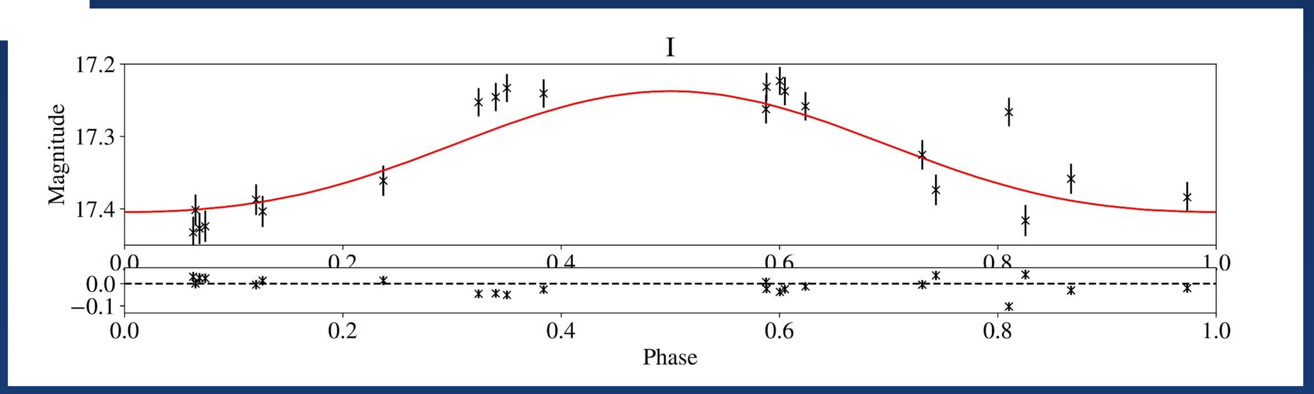


Figure 3: Light curves if g, r, and I of Gaia-DR2-3150. The data shows irradiation effects in all wavelengths. The solid red lines show the best fit model generated from PHOEBE.

References:

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-Gianninas, A., Bergeron, P., Dupuis, J., et al. 2010, Astrophysical Journal, 720, 581
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