Precise White Dwarf Masses and Radii from Eclipsing White Dwarf-Main-Sequence Binaries

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Outline

1. Determining precise masses and radii
2. Example - NN Ser
3. Current and future work
4. Summary

Determining Precise Masses and Radii

Kepler's third law gives

$$M_{\rm WD} = \frac{PK_{\rm sec}(K_{\rm WD}+K_{\rm sec})^2}{2\pi G \sin^3 i}$$

and

$$a = \frac{P(K_{\rm WD}+K_{\rm sec})}{2\pi \sin i}$$

we also know that

$$\frac{K_{\rm WD}}{K_{\rm sec}} = \frac{M_{\rm sec}}{M_{\rm WD}}$$

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Spectroscopy can give $K_{\rm WD}$ and $K_{\rm sec}$
Light curve can give $R_{\rm WD}/a$, $R_{\rm sec}/a$ and i

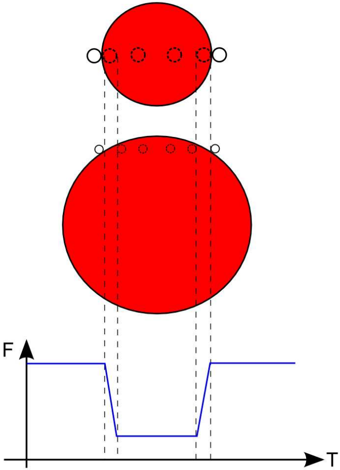
Determining Precise Masses and Radii

Cannot use the same method as for planetary transits because the primary eclipse is total.

For any given i there is a unique $R_{\rm WD}/a$ and $R_{\rm sec}/a$ from the primary eclipse.

Degeneracy between $R_{\rm WD}/a$, $R_{\rm sec}/a$ and i.

Need additional data to break the degeneracy.



Breaking the degeneracy

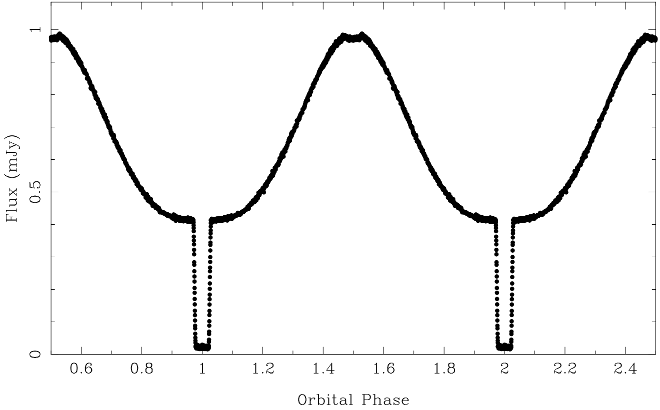
Most direct method is to measure the depth of the secondary eclipse.

Measurement of the eclipse depth gives $\left(\frac{R_{\mathrm{WD}}}{R_{\mathrm{sec}}}\right)^2$.

Combined with the primary eclipse give R_{WD}/a, R_{sec}/a and i.

The mass and radius of the white dwarf in NN Ser

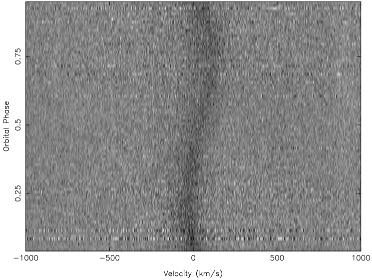
Hot white dwarf ($\sim 57,000$K) + low-mass M dwarf post common envelope binary (PCEB) with a $3^{\mathrm{h}}7^{\mathrm{m}}$ period.

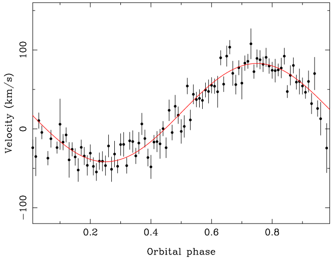


Haefner (1989); Haefner et al. (2004); Parsons et al. (2010)

The mass and radius of the white dwarf in NN Ser

UVES Spectroscopy gives $K_{\rm WD}$ and $K_{\rm sec}$

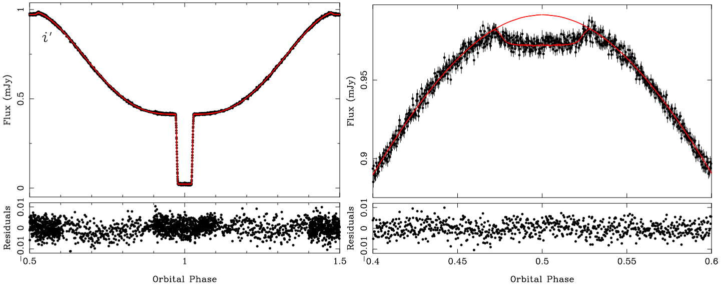




$K_{\rm WD}$ from HeII 4686Å absorption $\rightarrow 62.3 \pm 1.9 {\rm km\,s^{-1}}$

$K_{\rm sec}$ from a range of lines $\rightarrow 301 \pm 3 {\rm km\,s^{-1}}$

The mass and radius of the white dwarf in NN Ser

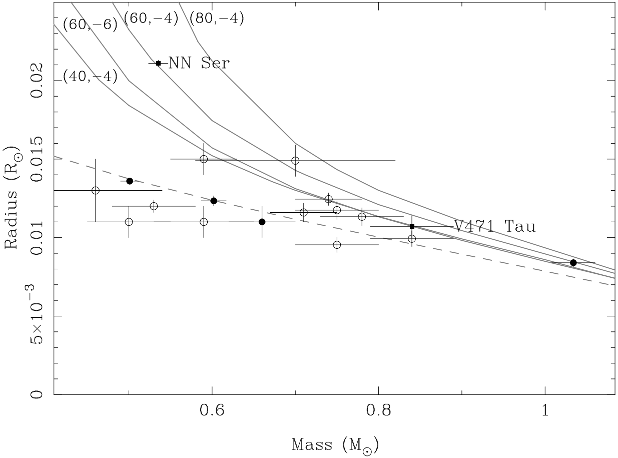


Fit to ULTRACAM u,g,r and i band light curves gives

$$R_{\mathrm{WD}}/a \rightarrow 0.0226 \pm 0.0001$$
$$R_{\mathrm{sec}}/a \rightarrow 0.165 \pm 0.001$$
$$i \rightarrow 89.6^{\circ} \pm 0.2^{\circ}$$

$$R_{\mathrm{WD}} = 0.0211 \pm 0.0002\mathrm{R}_{\odot},\ M_{\mathrm{WD}} = 0.535 \pm 0.012\mathrm{M}_{\odot}$$

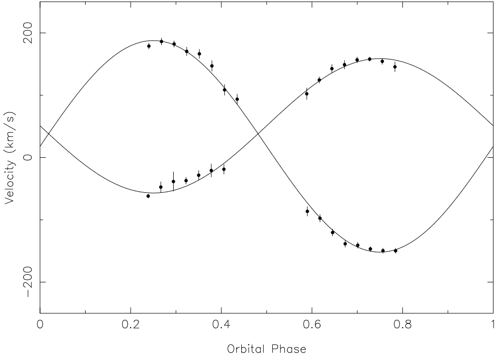
The mass and radius of the white dwarf in NN Ser



Data from Provencal et al. (1998), Provencal et al. (2002), Casewell et al. (2009) and O'Brien et al. (2001). Models from Holberg & Bergeron (2006) and Benvenuto & Althaus (1999).

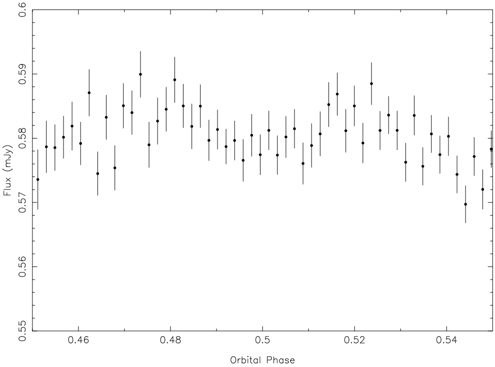
Current and Future Work

Use a combination of X-Shooter spectroscopy, ULTRACAM photometry and SOFI NIR photometry



SDSS J121258.25 − 012310.1 (Nebot Gómez-Morán et al. 2009)
K_{WD} and K_{sec} from X-Shooter spectra

Current and Future Work



SOFI J band secondary eclipse of GK Vir (Green et al. 1978)

Summary

Eclipsing PCEBs enable us to measure masses and radii of unrivalled precision and accuracy.

Secondary eclipse is the most direct way to break the degeneracy between the scaled radii and the inclination.

The mass and radius of the white dwarf in NN Ser are amongst the most precise for any white dwarf.

Future work looking at longer wavelengths is likely to produce more systems with precise parameters and will probe a large range of masses.

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