Testing the white dwarf mass-radius relation

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Why are white dwarfs interesting?

- **Cosmochronology**: Using the temperature of a white dwarf to find its age, and the ages of associated stars.

- Potential to study the elemental composition of exoplanet systems.

- Natural laboratory for physics in a high gravity environment.

- The initial-final mass relation and chemical evolution of the galaxy.

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- Mass of star → IFMR → Mass of white dwarf
- Material returned to ISM
White Dwarf Cosmochronology: Using the temperature of a white dwarf to find its age, and the ages of associated stars.

The white dwarf mass-radius relation

Solid line = thick hydrogen layer, dashed line = thin hydrogen layer

3 Ways to Weigh a White Dwarf


Figure from Bergeron et al 1992 ApJ, 394, 228
The gravitational redshift effect
3 ways to weigh a white dwarf

The H alpha line is shifted to longer wavelength.
Why is the distance measurement so important?

Gaia: parallax - distance

\[ R = \sqrt{\left( \frac{D^2 \times \text{norm}}{1 \times 10^{-20}} \right)} \div R_{\text{sol}} \]

HST: redshift velocity

\[ M = \frac{v_{\text{gr}} R}{0.636} \]
How to distinguish between gravitational redshift and radial velocity?

Stationary high mass white dwarf

For a 1 solar mass white dwarf the gravitational redshift is equivalent to a velocity of ~80 km/s away from observer.

Low mass white dwarf with additional radial velocity

For a 0.6 solar mass WD the expected gravitational redshift is ~30 km/s

Both cases would result in a measured velocity of 80 km/s
The advantages of Sirius-like binaries

- Velocity of the binary towards or away from the observer. (gamma velocity)
- Orbital velocity of the white dwarf.
- Orbital velocity of the main sequence star.

Observer
The advantages of Sirius-like binaries

* Sirius-Like binaries consists of a main sequence star earlier than type M, and a white dwarf.

* Orbital parameters and the velocities of the stars are not known in many cases.

* These unknowns need to be resolved for us to be able to separate them from the gravitational redshift effect.

How radial velocity can help

Sirius A & B Radial Velocities

Figure from Jay Holberg
The mystery of the missing white dwarfs

Within 20 pc there are 11 known Sirius-like systems.

Each successive shell of equal volume should contain roughly the same number of systems.

However, in the next 3 shells only 1 SLS has been discovered so far.

Holberg et al 2013
342 Spectroscopic binaries have been identified in the Gaia- ESO survey (Merle et al 2017 A&A)

Unresolved Sirius-like binaries have excess flux in the UV due to the white dwarf.

Cross matching spectroscopic binaries with the GALEX catalogue of UV sources may identify many new Sirius-like systems.
The missing piece of the puzzle...
Conclusions and future plans

• Gaia and the Gaia ESO survey are providing the high precision distance measurements and RV measurements we need to make accurate measurements of the mass of WDs from the gravitational redshift.

• For long period binaries, we are still lacking precise measurements of the K velocity of the WD. This will require long term monitoring since these systems may have orbital periods of 100’s of years.

• For Sirius we have measured all binary system parameters very accurately and the WD K velocity is known.

• Gaia – ESO may help us to find some of the missing Sirius-like systems.

• White dwarfs can be used to determine ages of main sequence stars which could be useful for studies of the age metallicity relation.