DOUBLE DEGENERATES FROM THE SUPERNOVA IA PROGENITOR SURVEY (SPY)

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1. Introduction

Close binary systems consisting of two white dwarfs (double degenerates – DDs) are considered possible progenitors of supernovae type Ia. The SPY project (Napiwotzki et al., these proceedings) surveys a large sample of white dwarfs for radial velocity (RV) variations. DDs are the result of close binary evolution, but the theoretical modeling of this evolution depends heavily on some not well known parameters (Nelemans et al., 2001). Therefore, an important way to calibrate these parameters is by comparison of observed system parameters such as periods and mass ratios of DDs with results of theoretical calculations. We present follow-up observations of four DDs found by the SPY project, which allowed us to derive radial velocity curves and system parameters. Two systems are of particular interest because they have double lined spectra.

2. Observations

Follow up observations carried out with the TWIN spectrograph at the 3.5m telescope of the Calar Alto Observatory, Spain (spectral resolution 1.0 Å) are combined with the discovery spectra taken with the UVES echelle spec-
trograph at the ESO UT2 telescope at Paranal, Chile (spectral resolution 0.3 Å).

3. Data analysis and results

For the analysis of our programme stars, we first computed the RV curves. We measured the RV of each spectrum by fitting the observed H line profile with a Gaussian for the line core and a Lorentzian for the wing plus a linear continuum. With respect to the center of the Gaussian we determined the RV. By fitting sinusoidal functions to a range of periods we obtained power spectra. These spectra indicate the quality of the sine-fits as a function of period. Combined power spectra were produced for the double lined systems by simply adding the χ² values of the two individual power spectra. In this way we got the most probable period of the complete system. Then, having fixed the period, we fitted the semi-amplitudes, the system velocities and the ephemerides using sine curves again. Results for the system HE 2209−1444 are displayed in figure 1.

HE 2209−1444: This is the first double lined system we analyzed. From the combined power spectrum we derived a period of 0.2769 days (see figure 1 and the following ephemeris). The Ephemeris for the time T₀ (defined as the conjunction time at which star A moves from the red to the blue side of the RV curve) is

\[ \text{He}l.\text{JD}(T₀) = 2,452,096.9010 + 0.2769 \times E. \]  \hspace{1cm} (1)

The periods derived from both individual power spectra agree within 0.8 sec. Results are provided in table 1. Also given are the semi amplitudes K_A/B and the system velocities γ₀. As can be seen, the ratio of the semi amplitudes is near unity, which means that the two WDs must have similar masses. Fitting observed Balmer line profiles simultaneously with a grid of synthetic spectra from NLTE model atmospheres we derive an effective temperature of 8450 resp. 7700 K and \( \log g = 8.07 \) for both components. By comparism with evolutionary calculations (Blöcker et al., 1997) we derived masses of 0.63 \( M_\odot \). We computed the merging time due to gravitational wave radiation to be 4.2 Gyr for this system, i.e. well below a Hubble time. The total mass is remarkably close to the Chandrasekhar limit, only 10% below it.

WD 1349+144: This is another double-lined system. Results from the single star analysis are given in table 1. The combined power spectrum shows a peak at a period of 2.2094 days, but some aliases with slightly different
Figure 1. Upper part: Combined power spectrum of the double lined system HE 2209+1444. Lower part: Radial velocity curve. The brighter component (filled triangles) is as well plotted as the fainter one (open triangles).

TABLE 1. Orbital parameters of the program stars

| System           | \(\gamma_0\) [km/s] | K [km/s] |
|------------------|----------------------|---------|
| HE 2209 - 1444   | A -12.2              | 108.2   |
|                  | B -13.5              | 103.3   |
| WD 1349 + 144    | A -18.2              | 74.5    |
|                  | B -10.3              | 66.9    |
| WD 1824 + 040    | 48.5                 | 59.5    |
| EGB5             | 69.6                 | 16.1    |
periods cannot be ruled out. The ephemeris of this system is

$$\text{Hel.} \text{JD}(T_0) = 2,452,096.7350 + 2.2094 \times E.$$  

(2)

The Balmer line spectra of both components are very similar and the mass ratio is very close to unity, thus we assumed identical stellar parameters for both stars. Fitting a spectrum taken near conjunction we derived an effective temperature of $T_{\text{eff}} \approx 16.600$ K and $\log g \approx 7.65$. The resulting masses are 0.44 $M_\odot$ for each component, which leads to a merging time of 2000 Gyr, much larger than a Hubble time.

**WD 1824+040:** The spectrum of this well known RV variable DA WD is single lined. The period derived from the power spectrum is 6.2663 days which is in perfect agreement with previous results from Maxted and Marsh (1999). The ephemeris is

$$\text{Hel.} \text{JD}(T_0) = 2,451,979.1918 + 6.2663 \times E.$$  

(3)

From the fundamental parameters $T_{\text{eff}} = 14795K$ and $\log g = 7.61$ (Bragaglia et al., 1995) we computed a mass of 0.44 $M_\odot$ for the visible component. If we adopt the most probable inclination angle of 54°, we derive a mass of 0.63 $M_\odot$ for the invisible component from the mass function. This system will merge within 24000 Gyr, again much larger than the Hubble time.

**EGB 5:** EGB 5 is a centre star of an old planetary nebula (PN G211.9+22.6). In addition to the Hα and Hβ lines HeI(4471Å) and HeII(4686Å) were available for RV measurements. From the power spectrum we found a strong peak at 1.1806 days, but there is a slightly weaker peak at 0.5505 days. Inspection of the RV curves for both periods cannot clearly favour one period over the other.

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