The not-so-extreme white dwarf of the CV GD 552

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Abstract. GD 552 is a cataclysmic binary which was previously believed to be composed of an M-star and a white dwarf, the latter having an extreme mass of 1.4 solar masses. In a recent paper we showed that this is not compatible with new observational evidence and presented an alternative model in which the white dwarf has a typical mass and the companion is a brown dwarf, making the system a likely member of the elusive group of CVs which have already evolved through minimum orbital period. Here we present additional spectroscopical evidence supporting this conclusion by means of skew mapping.

1. Introduction

GD 552 is a blue, high proper motion star (0.18″/yr) discovered by Giclas et al. (1970). It was first observed spectroscopically by Greenstein & Giclas (1978), who found that it is a cataclysmic variable star (CV). Up to very recently the main spectroscopic study of GD 552 had been carried out by Hessman & Hopp (1990). They measured the orbital period of GD 552 to be 102.7 min. They also measured the white dwarf’s projected orbital velocity to be \( K_1 = 17 \pm 4 \text{ km s}^{-1} \). This suggested a low inclination system, since for edge-on systems with orbital periods similar to GD 552 \( K_1 \) is typically \( 60 - 80 \text{ km s}^{-1} \). However, the emission lines from the accretion disc suggested instead a moderately inclined system as they display clearly separated double-peaks (which come from the outer disc, Horne & Marsh 1986) with velocities of \( \pm 450 \text{ km s}^{-1} \) which can be compared to typical peak velocities of \( \sim 600 \text{ km s}^{-1} \) for edge-on systems. Hessman & Hopp (1990) explained this by saying that the white dwarf in GD 552 is close to the Chandrasekhar limit. This allowed a low orbital inclination (\( \sim 20^\circ \)), a small \( K_1 \) value, and large disc velocities. This explanation suited well their assumption that the companion to the white dwarf had to be a main-sequence star. However, Unda-Sanzana et al. (2008) provided evidence supporting an alternative model in which the system is composed of a brown dwarf and an ordinary white dwarf. They used spectroscopic templates to estimate the maximum possible flux contribution
of an hypothetical main-sequence companion to the spectra of the binary. They estimated this to be 10% and thus were able to estimate the magnitude of the companion under that assumption. They showed that this was incompatible with a main-sequence star. In this work we carry out skew mapping of the spectroscopic data acquired for GD 552, offering an alternative means of estimating the contribution of a main-sequence mass donor to the flux of the system, which in turn allows to constrain the mass of the white dwarf.

2. Observations
The observations and its reduction are fully described in Unda-Sanzana et al. (2008). For the analysis in section 3 we use the dataset acquired in August 2001 using the 4.2-m William Herschel Telescope (Roque de los Muchachos) and the ISIS spectrograph.

3. Skew mapping
The aim of this section is to use an alternative means to put a limit on the contribution of the mass donor to the flux of the system. To try to detect the mass donor in our spectra we used skew mapping (e.g. Smith, Dhillon and Marsh 1998; Putte et al. 2003) with Gl 65A, an M5.5 star. A skew map is produced by applying Doppler map techniques (Marsh & Horne, 1988) to the cross-correlation functions of the CV data with a suitable template. If there is a consistent cross-correlation between the template and a pattern following the orbital motion of the binary system, then the skew map will show a spot at the velocity coordinates of the source of the pattern. For skew mapping we used the range 7850-8400 Å, which is devoid of emission lines. In order to preserve the relative line strengths along the spectrum we did normalise it carefully. First of all we fitted a constant to the continuum of both GD 552 and Gl 65A data (for scaling). Then we fitted a 5-knot spline to both continua (the number of knots set due to the complex shape of Gl 65A’s continuum). Dividing by these fits and subtracting unity, we obtained flattened continua. Then Gl 65A had to be prepared as a suitable template for a hypothetical mass donor present in the spectra of GD 552, accounting for both instrumental and physical effects. First we smeared the average spectrum of Gl 65A to account for its systemic radial velocity (Wilson 1953). In Figure 1 the grey scale represents the degree of cross-correlation between data and template, the blacker the shade of gray the better the cross-correlation. We normalized the scale of each panel so that white/black corresponds to minimum/maximum value in each skew map. In the figure, the top left panel is the skew map produced by cross correlation of GD552 with Gl 65A prepared as described above. There are no discernible peaks in this panel. We added percentages of Gl 65A to the original GD552 data, after applying a sinusoidal velocity factor to Gl 65A ($\gamma = -55$ km s$^{-1}$, $K_x = 0$ km s$^{-1}$, $K_y = 400$ km s$^{-1}$), using the orbital phases of the GD552 data. The top right panel of Figure 1 is the result of skew mapping the GD552 data + 10% Gl 65A; bottom-left panel with 20% Gl 65A and bottom-right panel with 30% Gl 65A.

\[ V_{\text{smear}} = \frac{2\pi KT_{\text{exp}}}{P}, \]  

where $K$ is the velocity of the moving object (160 km s$^{-1}$ assuming Hessman & Hopp (1990)’s parameters for GD 552), $T_{\text{exp}}$ is the exposure time (300 s in our case) and $P$ is the period (0.07134 d for GD 552). From this we obtained $\sim 49$ km s$^{-1}$ for the smearing to be applied. Also, we rotationally broadened this spectrum by 160 km s$^{-1}$, which is the velocity of the edge-on system (460 km s$^{-1}$) projected to the line of sight with Hessman & Hopp (1990)’s inclination of 20°. Finally, we shifted the Gl 65A spectrum by 29 km s$^{-1}$ to account for its systemic radial velocity (Wilson 1953).

In Figure 1 the grey scale represents the degree of cross-correlation between data and template, the blacker the shade of gray the better the cross-correlation. We normalized the scale of each panel so that white/black corresponds to minimum/maximum value in each skew map. In the figure, the top left panel is the skew map produced by cross correlation of GD552 with Gl 65A prepared as described above. There are no discernible peaks in this panel. We added percentages of Gl 65A to the original GD552 data, after applying a sinusoidal velocity factor to Gl 65A ($\gamma = -55$ km s$^{-1}$, $K_x = 0$ km s$^{-1}$, $K_y = 400$ km s$^{-1}$), using the orbital phases of the GD552 data. The top right panel of Figure 1 is the result of skew mapping the GD552 data + 10% Gl 65A; bottom-left panel with 20% Gl 65A and bottom-right panel with 30% Gl 65A.
Figure 1. Skew mapping of GD 552 and a template M star. The top left panel uses only GD 552 data for cross correlation. The other panels use a mixture of GD 552 and increasing percentages of the template star. See text for details.

We found that we could recover the position of the artificial mass donor by adding between 10% to 20% of Gl 65A to the GD552 data prior to cross-correlation and skew mapping. This is compatible with the conclusion reached by Unda-Sanzana et al. (2008) obtained by subtracting increasing amounts of Gl 65A to GD552 data until the features of the M star became distinguishable.

4. Conclusions
We estimated the maximum contribution of an hypothetical main sequence donor to the flux of GD 552. This was done by an alternative means to that used by Unda-Sanzana et al. (2008) but the result was nonetheless compatible with theirs. By considering either the distance $d \sim 70\, pc$ from Greenstein & Giclas (1978) or the value $d \sim 125\, pc$ from Unda-Sanzana et al. (2008) it is possible to set a limit on the absolute magnitude of the mass donor and on the mass of the white dwarf. Unda-Sanzana et al. (2008) show that for a 10% contribution the mass of the mass donor is $M_2 < 0.08\, M_\odot$ (a brown dwarf) and the mass of the white dwarf is $M_1 = 0.6\, M_\odot$, a rather average specimen.

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