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Orbital Effects in VLT–UVES Spectra of AA Dor and NY Vir

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Abstract. We analyse VLT/UVES spectra of two eclipsing subdwarf binary systems NY Vir, a rapidly pulsating subdwarf B primary with an M5 companion and AA Dor, an sdOB primary with a degenerate dwarf companion. We report the detection of the Rossiter-McLaughlin effect in the radial velocity curve of NY Vir, as previously seen in AA Dor. Reexamining the AA Dor spectra and simulating the amplitude of the Rossiter-McLaughlin effect, we find it to be in the accordance with the amplitude seen in the radial velocity residuals. In addition to the Rossiter-McLaughlin effect we observe clear radial velocity deviations in the Balmer lines at phases where the contribution from the secondary is greatest in both AA Dor and NY Vir. After careful subtraction of the contribution from the AA Dor primary we clearly detect both emission and absorption features originating from the superheated surface of the secondary. This allows us for the first time to estimate K_2 and the masses of the primary and secondary star in the AA Dor system.

1. Introduction

The two eclipsing subdwarf systems NY Vir and AA Dor are both post common envelope binaries, with low-mass companions of very low luminosity. They both show strong reflection effects – representative of a binary systems comprising of a very hot primary, 31 300K (NY Vir) and 42 000K (AA Dor) and much cooler unseen dwarf secondary of 2 000-3 000K. The two close binary systems ($a \sim 0.8R_\odot$ for NY Vir and $a \sim 1.2R_\odot$ for AA Dor) are orbiting synchronously and due to this one side of the secondary star (the one facing the hot primary) is constantly being heated. The atmosphere of such an irradiated side of the secondary star is very different to that of a normal dwarf. Studies of the model atmospheres for irradiated stars in pre-CV systems (Barman et al. 2004) find large temperature inversions and synthetic spectra show a number of emission lines. However, several attempts to detect spectral signatures of the irradiated face of the secondary in AA Dor (Hilditch et al. 2003; Rauch 2004) failed.

2. Exploring the RV Residuals

While examining the orbit subtracted RV residuals in the UVES spectra of NY Vir in light of simulating the detected RM effect (see Vučković et al. 2007) we have noticed an apparent redshift-blueshift distortion just prior to the secondary

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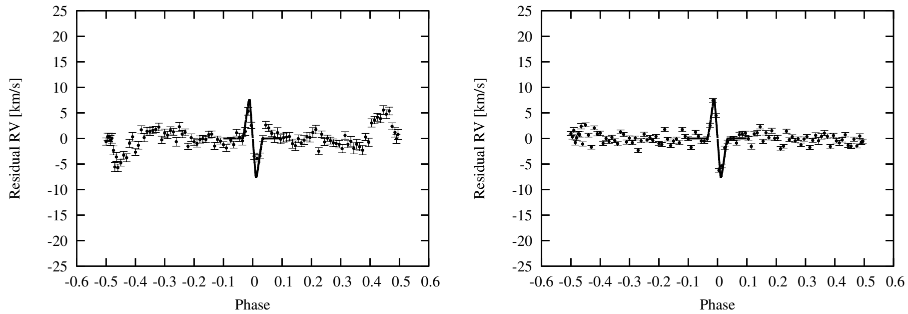

Figure 1. The orbit subtracted RV residuals (dots) with their corresponding errors. Left: H_δ, H_γ and H_β lines only. Right: HeII at 4685.79Å and three metal lines only O III at 3759.87Å, Si IV at 4088.86Å and Mg II at 4481.23Å. The solid line around phase $\Phi \sim 0$ is the simulation of the RM effect with the parameters given in Rauch (2000).

minima. This puzzling feature is arising right where the contribution of the secondary star is at its maximum and therefore could be an artifact of reflected light or a fingerprint of the heated face of the secondary. Unfortunately, the S/N of the NY Vir spectra didn't allow us to make any firm conclusions other than confirming the orbital solution as described in Vučković et al. (2007). To investigate this further we resort to the higher S/N UVES spectra of the only other eclipsing subdwarf star where the RM effect has been reported, namely AA Dor (Rauch & Werner 2003). We have retrieved the AA Dor UVES spectra from the ESO archive and reduced them using the UVES reduction pipeline. The radial velocities were determined in the same way as for the NY Vir (see Vučković et al. 2007) except that we were able to use not only Balmer lines, as was the case for NY Vir, but also some metal lines (O III, Si IV and Mg II) and He II.

We have simulated the amplitude of the RM effect in the radial velocity curve of AA Dor using the analytical description of RM effect given in Giménez (2006). The simulated RM amplitude is in accordance with the RM amplitude seen in the RV residuals. Fig. 1 shows the orbit subtracted RV residuals of the highest S/N Balmer lines (left) and of three metal lines + He (right) separately. While both RV residuals show the RM effect at the phase $\Phi \sim 0$, with the simulated RM amplitude (solid line) fully compatible with the observed RM amplitude with the orbital parameters given in Rauch (2000), only the Balmer RV residuals show the apparent blueshift-redshift bump just before the phase $\Phi \sim 0.5$. This is exactly what we had expected after having seen the distortion in NY Vir spectra, but with a higher significance level. The fact that this occurs only in Balmer lines (Fig. 1 left) and not in metal or He lines (Fig. 1 right) clearly rejects the reflected light hypothesis.

3. Irradiated Face of the Secondary

To search for any traces of spectral lines coming from the heated face of the secondary, we first subtract the contribution of the hot sdO primary. Therefore,

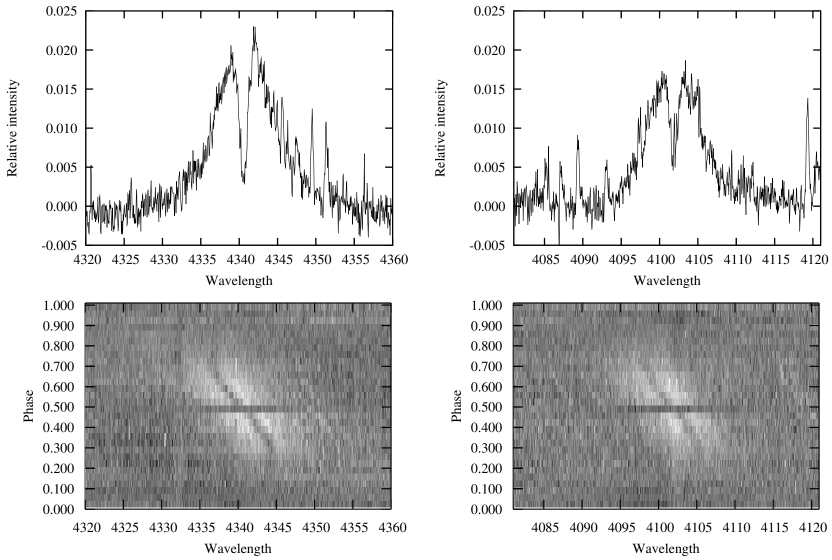

Figure 2. *Top:* the residual spectrum in the rest frame of the secondary after the contribution of the primary has been removed. The broad H_γ *(left)* and H_δ *(right)* emission with the narrow core absorption are clearly seen. *Bottom:* trailed and phase-binned residual spectra in the rest frame of the primary for the same wavelength interval.

we constructed the mean primary spectrum by taking the spectra with minimal contamination from the secondary, i.e. phases from 0.04 to 0.22 (about 36 spectra) when the heated hemisphere of the secondary is pointing away from us. We subtracted this mean primary spectrum, corrected for K_1 of 39 km/s (Rauch 2000) and finally the residual spectra were coadded in 30 phase-bins to produce the trailed spectra shown in the bottom of Fig. 2 and 3. As we have subtracted the spectrum of the primary the only lines left in the residual spectrum have to be coming from the secondary. The residual spectra show several very broad Balmer emission lines with a narrow absorption in the line cores. This can be seen in the gray-scale trailed spectrum (bottom of Fig.2). Summing the residual spectra in the reference frame of the secondary star gives us the spectrum of the secondary star (top of Fig. 2 and 3) where we can clearly see the broad Balmer emission followed by the narrow core absorption. In addition to the broad Balmer emission lines (Fig.2) we detect more than 20 narrow emission lines mainly of CII and OII. The strongest emission line detected is CII at 4267.40 Å shown in Fig.3 (right). Shifting to the rest frame of the center of the irradiated light gives us an estimate of the K_{irr} of 230 km/s, which puts a lower limit on K_2. Having both K_1 and a low limit on K_2 allows us to calculate the low limit masses for the AA Dor system by using the Kepler's laws. For $K_1 = 39$ km/s and $K_2 = 230$ km/s we get a typical EHB mass for the sdO primary $M_1 = 0.45 M_\odot$ and the secondary that is just above the substellar limit, $M_2 = 0.076 M_\odot$.

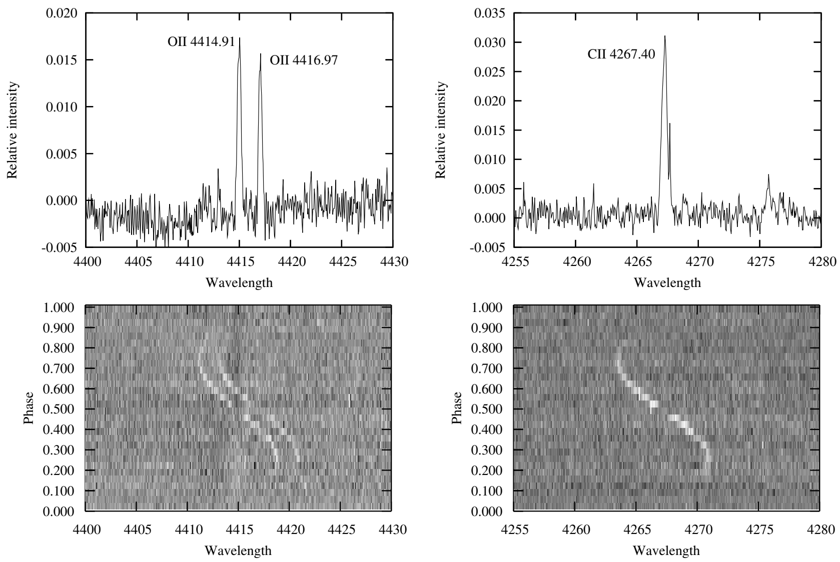

Figure 3. The same as in Fig. 2 showing the oxygen doublet at 4414.91 Å and 4416.97 Å *(left)* and the strongest emission line from the secondary star *(right)* CII at 4267.40 Å.

4. Conclusion

We have simulated the RM effect in the eclipsing binary systems NY Vir and AA Dor and obtained an independent confirmation of the orbital parameters from the RM effect. We have detected clear spectral signatures from the irradiated face of the secondary component in AA Dor UVES spectra. More than 20 narrow emission lines, mainly CII and OII and broad Balmer emission lines with core absorption have been detected. We have estimated the lower limit on K_2 of 230 km/s and the consequent masses of AA Dor system $M_1 = 0.45M_\odot$ and $M_2 = 0.076M_\odot$. Therefore, the primary must be a regular EHB star and the secondary a regular low mass M dwarf, contrary to the result of Rauch & Werner (2003).

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