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PERIODIC BEHAVIOUR OF THE HeI 6678 Å EMISSION LINE IN γ Cas

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Introduction

The Be star γ Cas (27 Cas, HD 5394, HR 264) is a primary component of a spectroscopic binary and is the very first Be star known, discovered by Secchi (1866). Spectroscopically γ Cas has been investigated mostly in the Balmer lines, mainly in Hα. Recent studies considered He and Fe II lines as well as the kinematics of the circumstellar shell (Hanuschik 1994, Smith 1995). It is believed that a local density enhancement – a one-armed density spiral – is embedded in the disk of γ Cas. Precession of this density enhancement has been observed interferometrically by Berio et al. (1999). They found that this enhanced equatorial density pattern may be located at 1.5 stellar radii from the stellar surface. Stee et al. (1998) proposed that He excitation and ionization region, responsible for the emission in the HeI 6678 Å line, extend to 2.3 stellar radii. Thus, the HeI 6678 Å line has an important diagnostic value of activity close to the stellar surface. The time-dependent mass loss from the primary component of the γ Cas binary system assumes that both photospheric and disk density variations lead to the double peak profile variations of HeI 6678 Å. Recent investigations of Smith (1995), Harmanec et al. (2000), Harmanec (2002), Pollmann & Stober (2005) and Pollmann (2009) give detailed information about the long-term monitoring of the phase and time dependent radial velocities and equivalent widths of the HeI 6678 Å emission line. Further detailed and useful information of the known variations and their time scales, e.g. in context with the orbital period of 203.52 d reported by Harmanec et al. (2000), have been compiled by Miroshnichenko et al. (2002).

Many Be stars often show various periodic phenomena, which can be sometimes strictly periodic, however they can change that behaviour. The periodic V/R variations were explained by one-armed pulsations (Okazaki 1991, 1997), although this is not the only explanation. This V/R ratio is the ratio of the violet-to-red emission peaks that is used as one of the main characteristics describing the double-peak emission lines of Be stars as stated by Stefl et al. (2007).

A cooperative project of amateurs and professionals on π Aqr (Zharikov et al. 2013) shows that the V/R observed in the Hα line can be explained by a local density enhancement that revolves around the primary component of this binary system with the orbital period. Apart from the orbital period, which has been determined on the basis of radial velocity measurements of the Hα and HeI 6678 Å lines (Harmanec et al. 2000, Miroshnichenko et al. 2002, Nemravová et al. 2012), there is no information about the V/R periodicity of the HeI 6678 Å line in the spectrum of γ Cas. Since spectral lines may form in different places of a circumstellar disk, different V/R periods may be observed. Therefore we cannot a priori expect that these periods coincide with the orbital periods in binary systems. The observations of the V/R variability of the HeI 6678 Å line in the spectrum of γ Cas are presented here for the first time. We found that this variability has a period, which is not equal to the orbital one.

Results

The spectra with a resolution of $R \sim 17000$ were obtained with the Littrow grating spectrograph LHIRES III and the C14 Schmidt-Cassegrain telescope of the Vereinigung der Sternfreunde Köln (Pollmann, 41 spectra) and the Piera-Barcelona observatory Spain (Guarro, 4 spectra). The signal-to-noise (S/N) in the continuum near the HeI 6678 Å line was always higher than 1000 (> 1500 in most spectra). Fig. 1 shows an example spectrum of the HeI 6678 Å double peak emission in γ Cas. To achieve such a high S/N level, 5-10 single spectra with approx. 300 sec exposure time were summed.

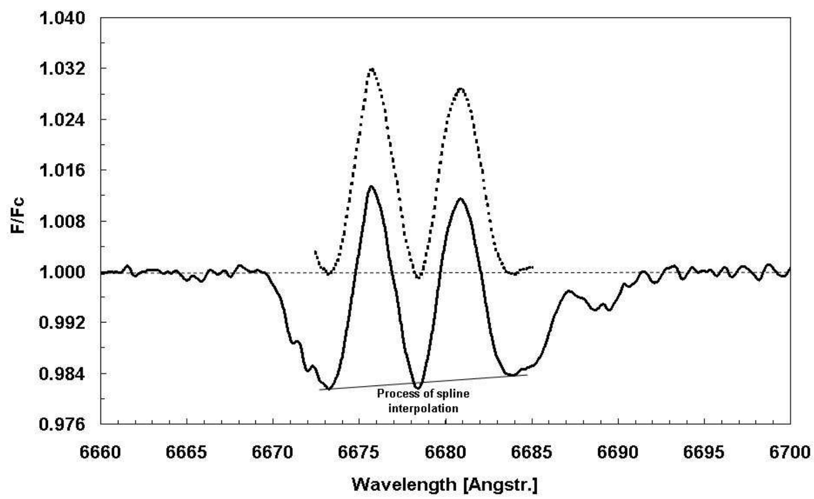

Figure 1. HeI 6678 Å spectrum of γ Cas (2014/02/04), S/N ≈ 2200, R = 17000. Solid line: sum spectrum; thin line: spline interpolation between the violet and red absorption minima; dashed line: the double peak emission after spline interpolation.

The accuracy of the V/R evaluation is determined by the S/N ratio and the accuracy of drawing the local continuum. It depends further on the definition of the line wing profiles and on the underlying photospheric absorption line profile. Therefore, as preparation for determining the V/R ratio, the division by a spline interpolation between the violet and red absorption minima serves as a normalizing basis with $F/F_c = 1$. The V and R intensities, separated in this way from the photospheric absorption profile, are then the values of the line maxima related to this basis (Fig. 1). The use of the data reduction program VSpec (`http://www.astrosurf.com/vdesnoux`) for that process and its tool for

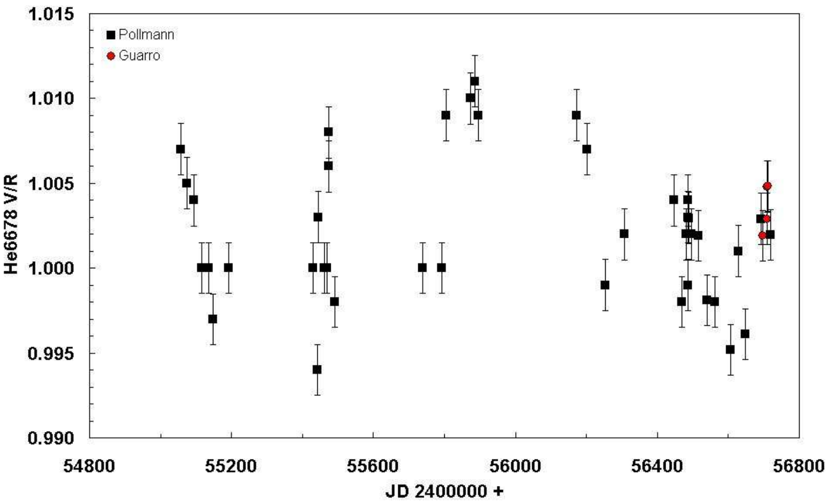

Figure 2. Time series plot of the HeI 6678Å V/R data from 2455058 to 2456719 (08/2009-03/2014).

spline filtering lead to a very precise spectrum normalization and a high level of accuracy of the V/R measurement of the order of approximately 0.2%.

Another way to separate the emission lines from the photospheric absorption profile, is the subtraction of a fitted theoretical absorption line profile. Comparisons of both methods with a same spectrum did lead to deviations to the spline interpolation process of approx. 0.01% in V/R.

As can be seen in Fig. 2, the variation in the V/R ratio of the HeI 6678 Å line is obvious. However the period of the observations (August 2009 through March 2014) covers only eight orbital periods of the binary. This result may motivate observers from different amateur groups (ARAS group for example; `http://www.astrosurf.com/aras`) to take part in this long-term study.

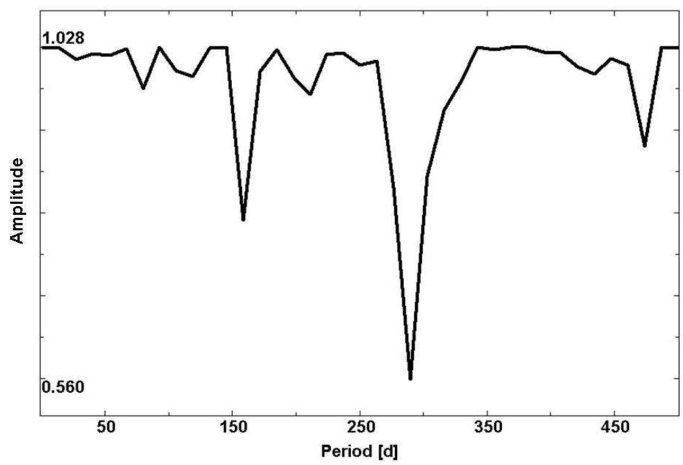

Figure 3. PDM (Phase Dispersion Minimization) periodogram (program AVE) of the data set shown in Fig. 2 points towards a period of 280 days.

The main peak in the PDM power spectrum (that corresponds to a period of 280 d) shown in Fig. 3 is very broad which makes the period evaluation uncertain. Definitely, more data are needed to constrain the period better.

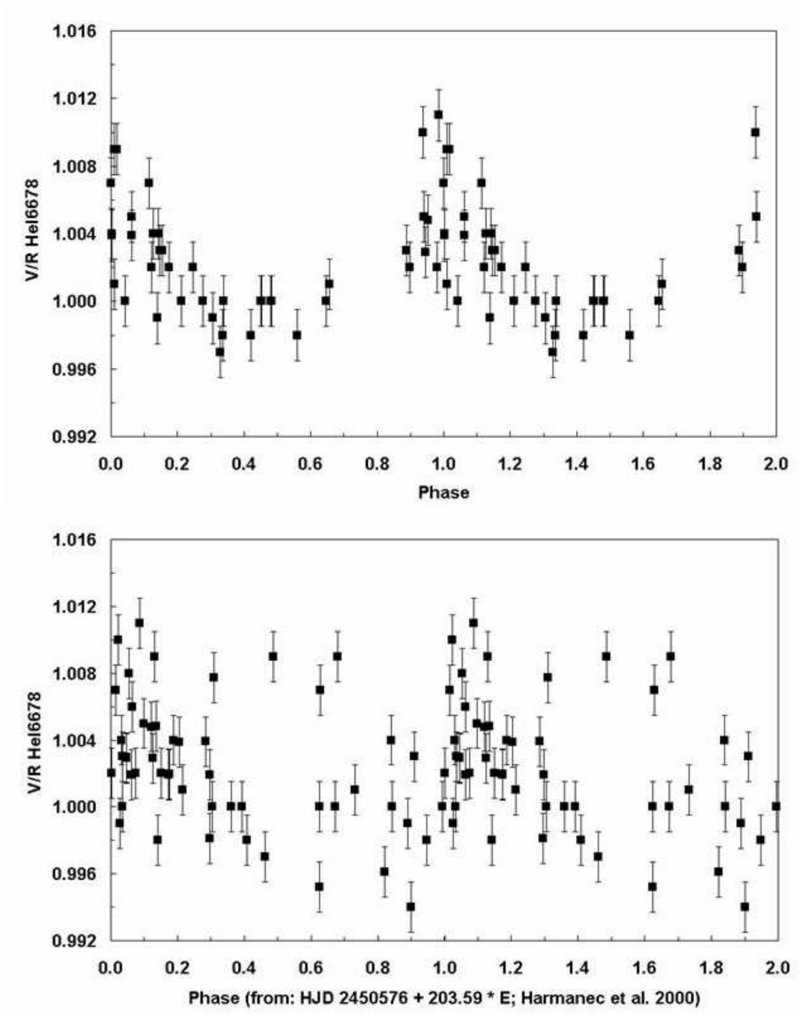

Figure 4. Top panel: phase plot of the V/R data from Figs. 2 & 3; Period: 280 ± 2.98 d; Amplitude: $0.00403 \pm 5.1 \cdot 10^{-4}$; T_0 [JD]: 24554969 ± 14.4; RMS: 0.00235. Bottom panel: phase diagram for the orbital period (203.53 d) by using the same data as in the top panel.

The top panel of Fig. 4 shows the V/R data given in Fig. 2 folded with a period of 280 days. The folding was performed with the program SpecTSA 2.0 by R. Buecke (Hamburg, Germany). In the bottom panel, these data are phased with the orbital period. There is a certain similarity of the V/R variability in the top and bottom panels due to the small difference between the periods of 280 and 203 d, respectively. However, it is clear that the observed variations in the V/R data are independent of the orbital period.

Searching for periodic phenomena (such as those found in π Aqr (Pollmann 2012, Zharikov et al. 2013) & ζ Tau (Pollmann & Rivinius 2008)) in the temporal behaviour of various lines in the spectra of many Be stars would allow us to better understand the structure of their circumstellar disks. Further long-term spectroscopic observations along with the data already stored in the BeSS database (Neiner et al. 2011; `http://basebe.obspm.fr`) will help to achieve this goal and can also result in finding new binary systems.

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