The periodic behaviour of the HeI 6678 Å emission line in gamma Cas

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Introduction

The Be star gamma 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 (1987). Spectroscopically gamma Cas has been investigated mostly in the Balmer lines, mainly in Halpha. 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 gamma 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 star's 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 star's surface. The time-dependent mass loss from the primary component of the gamma 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 pi Aqr (Zharikov et al. 2013) shows, that the V/R observed in the Halpha 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 have been determined on the basis of radial velocity measurements of the Halpha 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 gamma Cas. Since spectral lines may form in different places of a circumstellar disk, different V/R periods may be observed. Therefore we can not 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 gamma 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~17000 were obtained with the Littrow grating spectrograph LHIRES III and the C14 Schmidt-Cassegrain telescope of the Vereinigung der Sternfreunde Köln (Pollmann, 43 spectra) and the Piera-Barcelona observatory Spain (Guarro, 6 spectra). The signal-to-noise (S/N) in the continuum near the HeI 6678 Å line was always higher than 1000 (higher than 1500 in most spectra). Fig 1 shows an example spectrum of the HeI 6678 Å double peak emission in gamma Cas. To achieve such a high S/N level, 5-10 single spectra with approx. 300 sec exposure time were summed.

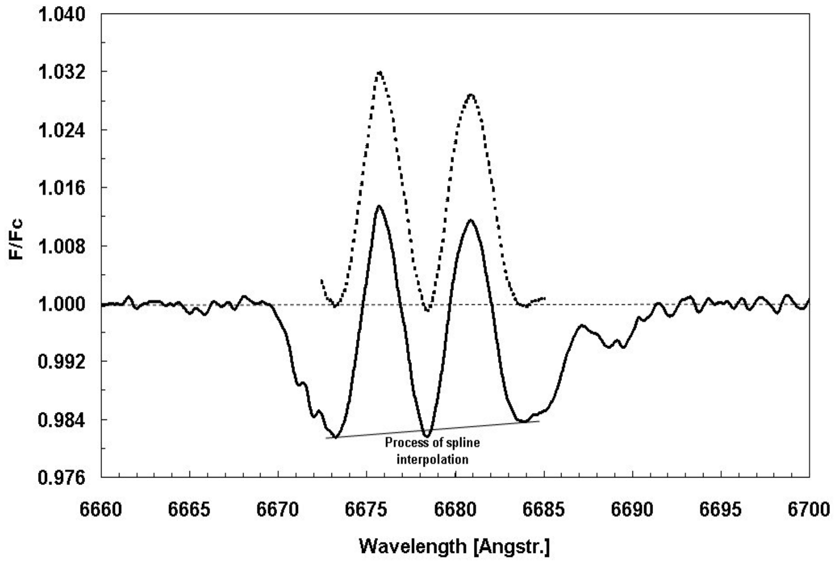

Fig.1: HeI 6678 Å spectrum of gamma Cas (2014-02-04), S/N approx. 2200, R =17000. Solid black: summed spectrum; thin line: spline interpolationbetween the violet and red absorption minima; dashed black line: the double peak emission after spline interpolation.

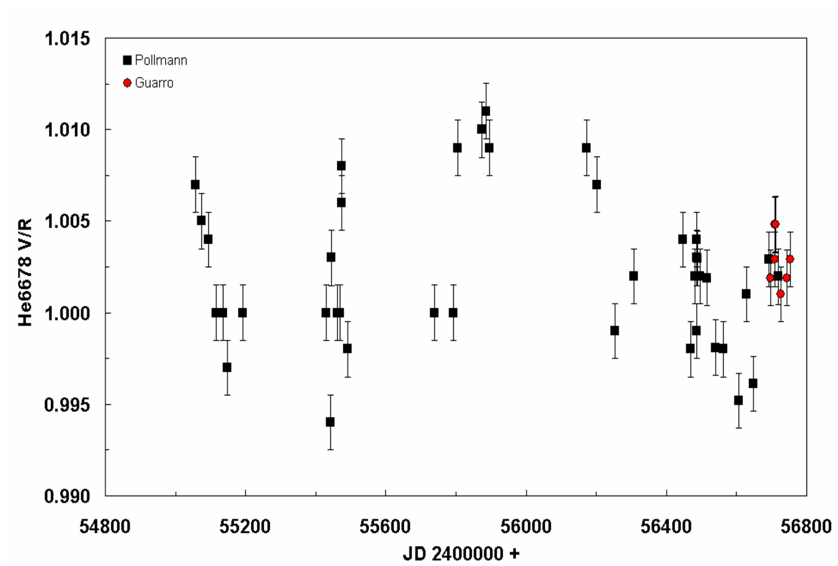

Fig.2: Time series plot of the HeI 6678Å V/R data from 2455058 to 2456746 (08/2009-03/2014)

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 photospherical 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/Fc = 1.

The V and R intensities, separated in this way from the photospherical 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 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 photospherical 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.

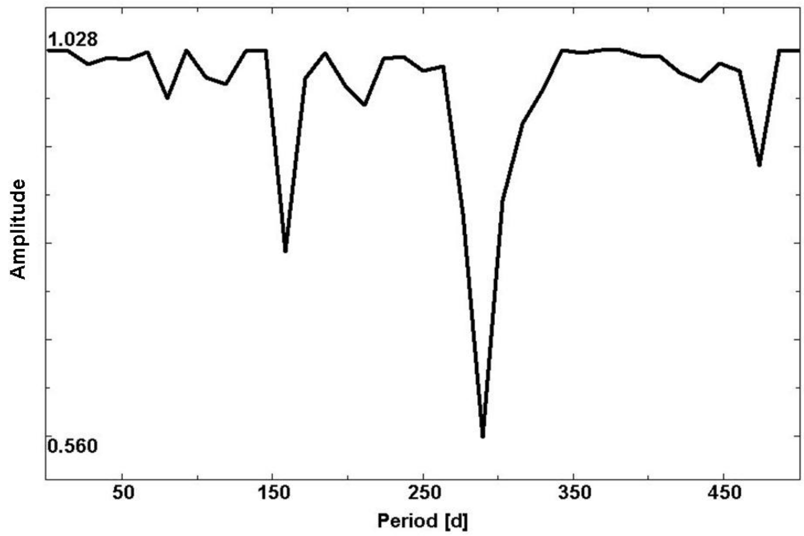

Fig. 3: PDM (Phase Dispersed Minimization) periodogram (program AVE) of the data set shown in Fig. 2 points towards a period of 280 days.

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

Fig. 4 shows in the top panel the V/R data shown in Fig. 2 folded with a period of 280 days. Folding was performed with the program SpecTSA 2.0 by R. Buecke (Hamburg, Germany). As the phase diagram in the bottom panel shows, there is a certain similarity of the V/R variability to the phase behaviour in the top panel, but due to the small distance of the periods of 280d to 203d. In spite of that, the top panel underlines impressive the clear orbital independency of the V/R period with 280 d.

Searching for periodical phenomena [such as those found in pi Aqr (Pollmann 2012, Zharikov et al. 2013) & zeta Tau (Pollmann & Rivinus 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.

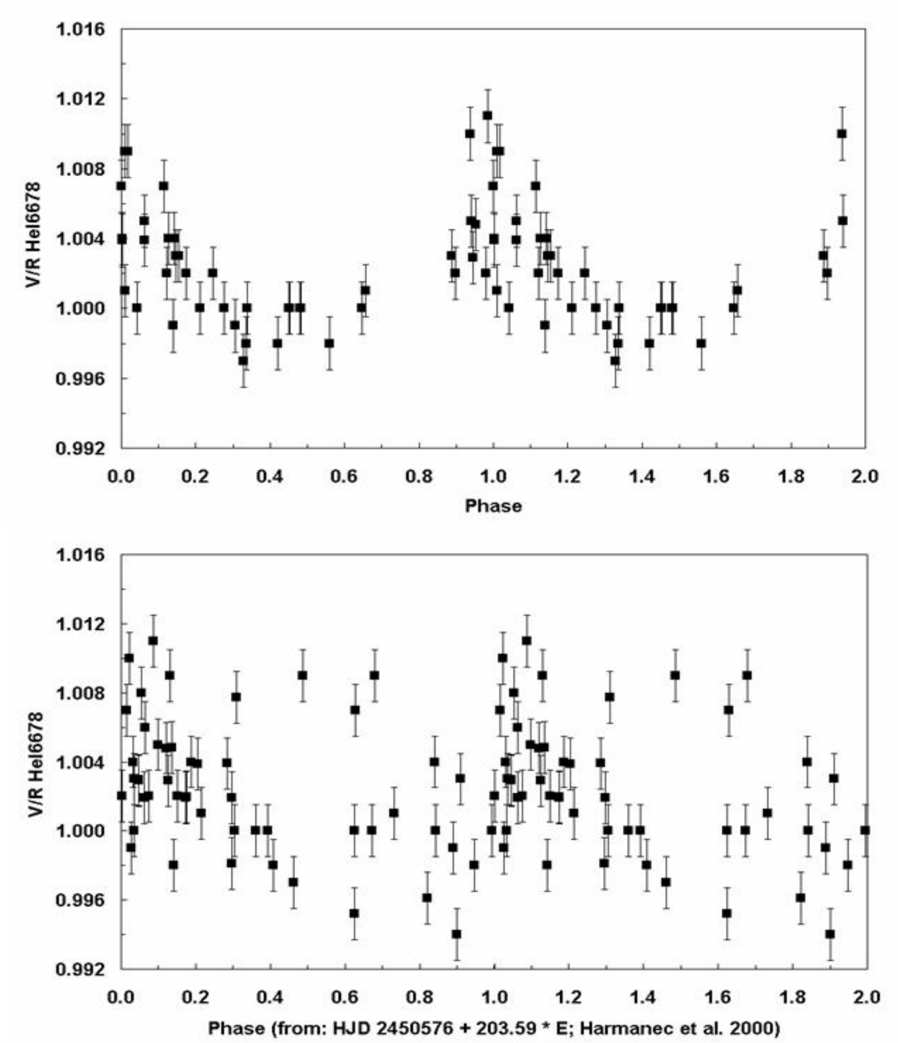

Fig. 4: Top panel: phase diagram of the V/R data from Fig. 2 & 3; Period [d]: 280 (±2.98), Amplitude: 0.00403 (±5.1x10-4), T0 [JD]: 24554969 (±14.4), RMS: 0.00235; bottom panel: phase diagram for the orbital period (203.53 d) by using the same data as in the top panel.

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