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Amateur Spectroscopy of Hot Stars

Long term tracking of circumstellar emission

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The spectroscopic monitoring programs carried out by the Spectroscopy Group of the German "Vereinigung der Sternfreunde" are reviewed in light of current research. Potential benefits for the professional community in collaborating and obtain long-term monitoring data otherwise unaccessible due to telescope time restrictions are summarized. The contribution highlights results on specific objects of wide interest, such as the well investigated Be stars ζ Tauri or the S Doradus type variable P Cygni.

Keywords: Spectroscopy – Emission lines – Monitoring

1 Introduction

Spectroscopy of hot stars such as Be and WR types by amateur astronomy groups can be of large interest to the professional community. The main advantage is the telescope and instrument access not being limited by pressure factors and Time Allocation Committees, paired with the dedication and will to observe for an extended period of time. In the past couple of years the non-professional equipment has reached standards that allow contributions to contemporary research (see Pollmann, 1997, for a description of previous amateur Be star observations and Pollmann, 2002, for more recent data).

Spectroscopy is a specific sub-section of the "Vereinigung der Sternfreunde" of Germany with emphasis on stellar and solar spectroscopy. The Group was established in 1992. It currently has about 100 members, with a core of about 20 active observers. For the observations several telescopes of up to 45 cm diameter are available. With our various spectrographs we are able to obtain spectra of 7$^{\rm th}$ mag stars with about 0.5Å spectral resolution. The current main program is the long-term monitoring of profile and intensity variations of the Hα emission in Be-stars.

In the following, I will give a brief description of the equipment used by the group. In order to demonstrate the capabilities, I will present results achieved by the group and myself over the past ten years about the Be stars ϕ Per, ζ Tau, δ Sco, HR 2142, and the early B-type hypergiant and S Doradus variable P Cyg.

2 Telescopes and Instruments

Many the data presented below were obtained with a 20 cm telescope with a focal ratio of $f/4$ and a self-built spectrograph equipped with a CCD camera. The spectrograph is of slitless design. As a collimator, a telephoto lens of type Pentacon with a focal length of 135 mm and a focal ratio of $f/2.8$ is used. The dispersive grating of a size of $50 \times 50\,\mathrm{mm}^2$ has 1200 lines/mm. The spectrally dispersed beam is then focussed by a 200 mm $f/3,5$ telephoto lens on a CCD-camera of alpha Maxi type by the OES GmbH, Germany. The instrument is shown in Fig. 1 attached to the telescope.

The resolving power in this design is limited by the pixel size of the camera rather than by size of the stellar image in the focal plane, so that despite the slitless design the observational conditions do not restrict the resolution. With a dispersion of about 29Å/mm a spectral resolution of $R = \Delta\lambda/\lambda \approx 12\,000$ is reached. The spectral range is fixed to the Hα region and covers about 300 Å in total.

The location of the observatory permits observations towards the south west horizon down to declinations of $-25°$, which is important for long-term monitoring programs, that can not afford the observe objects only when they are close to culmination, but in order to extend the time-string also takes data as close as possible to the horizon. This was particularly important for the case of δ Sco.

Depending on stellar brightness the exposure time for an individual raw spectrum is in the order of 30 seconds. Data reduction is performed in a stan-

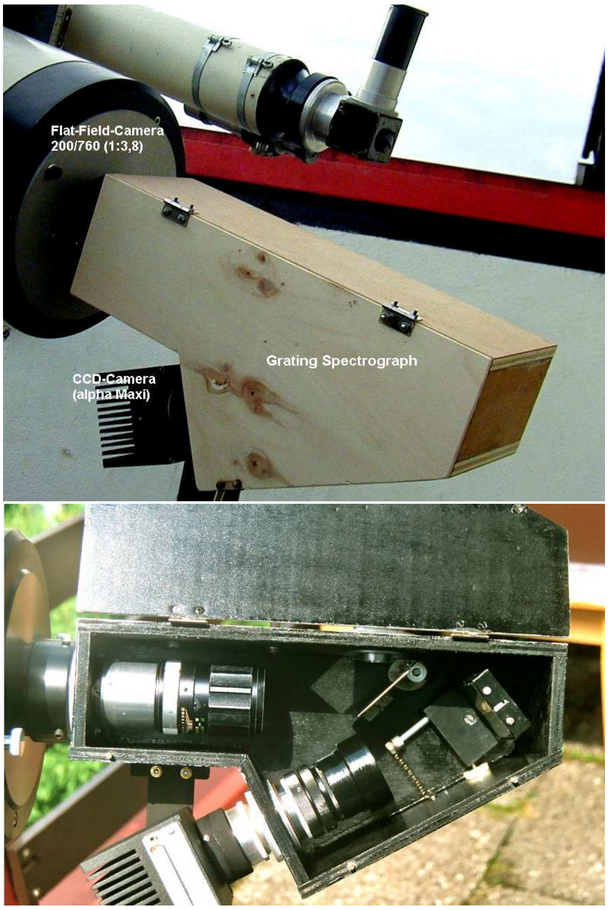

Figure 1: Telescope with spectrograph attached (top) and open instrument (bottom).

dard manner with bias correction and flat-fielding, but due to the slitless configuration wavelength calibration has to rely on telluric lines present in the object spectrum itself. Other CCD-equipped instruments available in the group have resolving powers of typically $R = 4000 \ldots 6000$.

A fiber-linked echelle spectrograph has been built and tested by group members, but requires further improvements in particular of the detector size before regular observations can be obtained.

3 Observational projects

3.1 ϕ Persei

This star was selected because it is known to show rather strong changes in Hα and Helium-line profiles. While most of these changes are phase locked to its orbital period of 127 d, there are also secular slow changes (see e.g. Božić et al., 1995; Štefl et al., 2000; and references therein).

Figure 2 shows the observed long-term behavior of

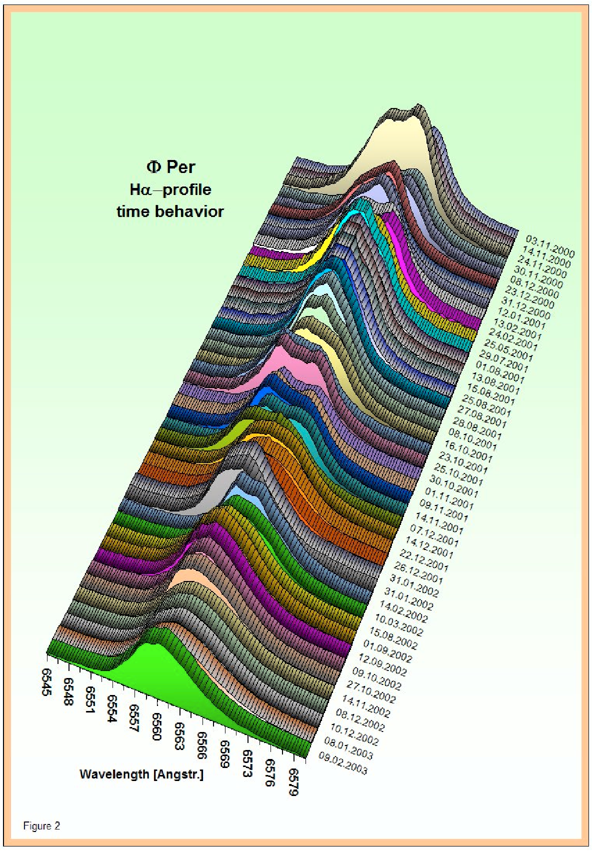

Figure 2: Hα profile behavior of ϕ Per.

the Hα profile variation of ϕ Persei between November 2000 and February 2003. In this campaign the dispersion of the spectrograph was 0.39 Å per pixel, which is not sufficient to resolve details of the line profile, as they are part of the orbital variations.

However, already with this dispersion I could al-

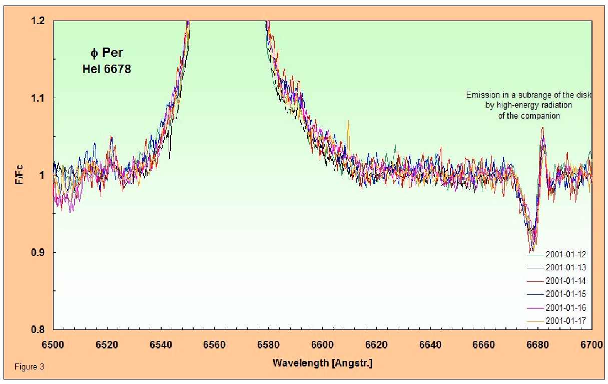

Figure 3: The phase-dependent He I 6678 emission of ϕ Per.

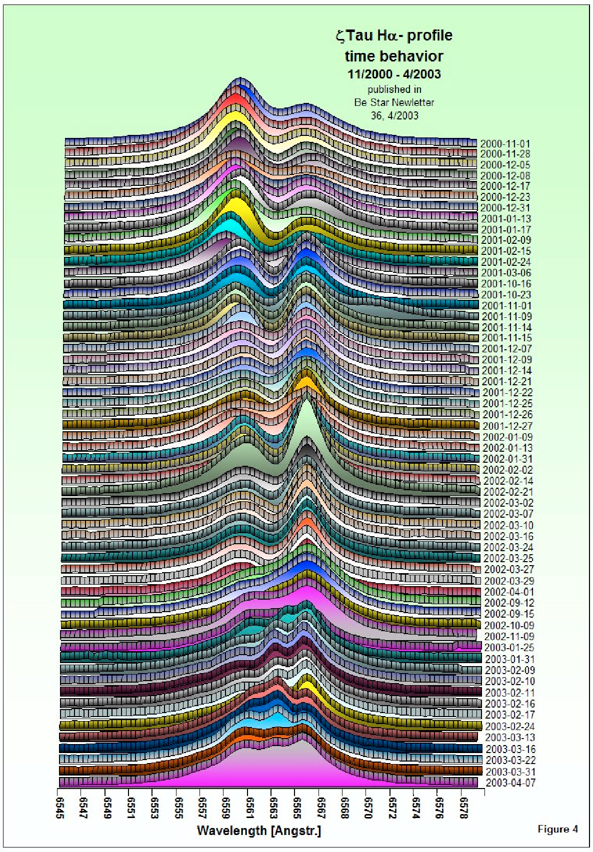

Figure 4: Hα profile behavior of ζ Tau between November 2000 and April 2003.

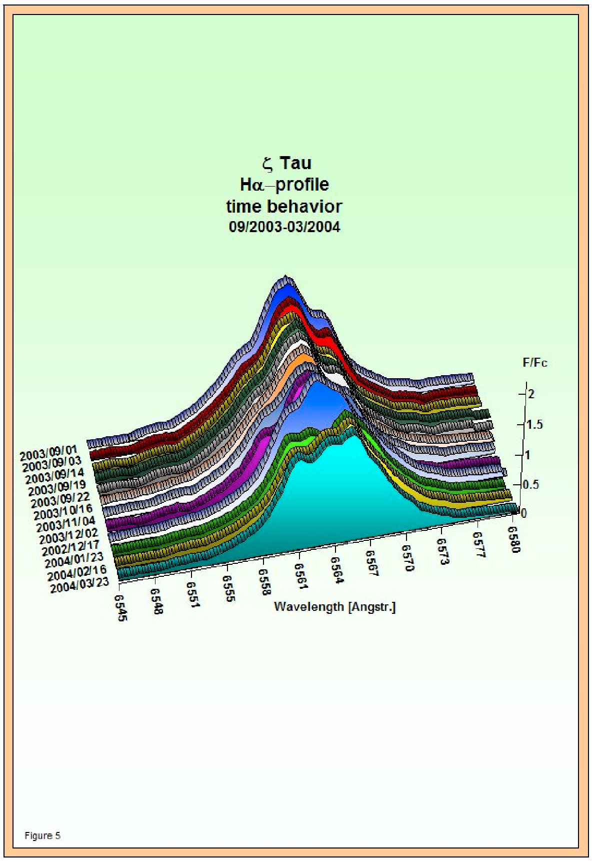

Figure 5: Hα profile behavior of ζ Tau between September 2003 and April 2004.

ready observe the evolution of the red HeI emission at 6678 Å between Jan 12 and 17, 2001 (see Fig. 3). This emission is thought to arise from the outer edge of the circumstellar disk, which faces the hot companion. This part of the disk is heated by the secondary star and thus the ionized disc material there has stronger emission than the rest of the outer disc (Hummel & Štefl, 2001).

The future monitoring of this star will be continued with a new instrument, which has a dispersion of 0.26 Å per Pixel and provides a resolving power of $R = 12\,000$.

3.2 ζ Tauri

The Hα profile variability was also the primary goal for ζ Tauri observations. While also this star is a binary with an orbital period of 133 d, its variations are dominated by the long-term changes (see Guo et al, 1995, and references therein for an overview of the observed behavior). Figure 4 shows the changes in the violet-to-red peak height ratio, the so called V/R-variations, between November 2000 and April 2003. These data were again obtained with a dispersion of 0.39 Å per pixel.

The Hα line profile usually shows two emission peaks separated by an absorption core. While the peaks usually just appear as "simply emission", they can have, at times, a rather complicated, asymmetrical appearance.

Starting in September 2003, I monitored the star again time (Fig. 5). The weak absorptions, giving rise to an unusual triple-peaked appearance, are again visible from about December, 2003 to February, 2004. With respect to the orbital elements of the binary, this corresponds to a phase range of 281.457 to 282.029. The detailed processes affecting the profiles and being responsible for this unusual behavior are still unclear. The more it is important to keep track the future evolution and to continue the monitoring observations.

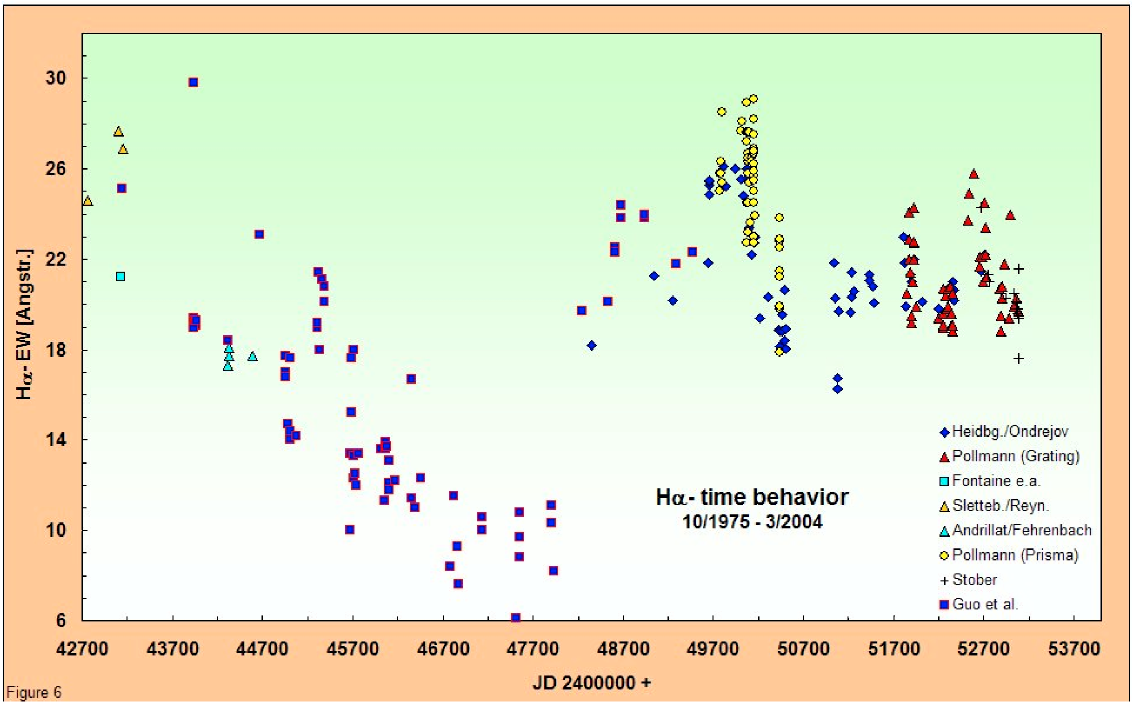

Figure 6: The Hα equivalent width of ζ Tau in the past decades, comparing also measurements made with professional instruments.

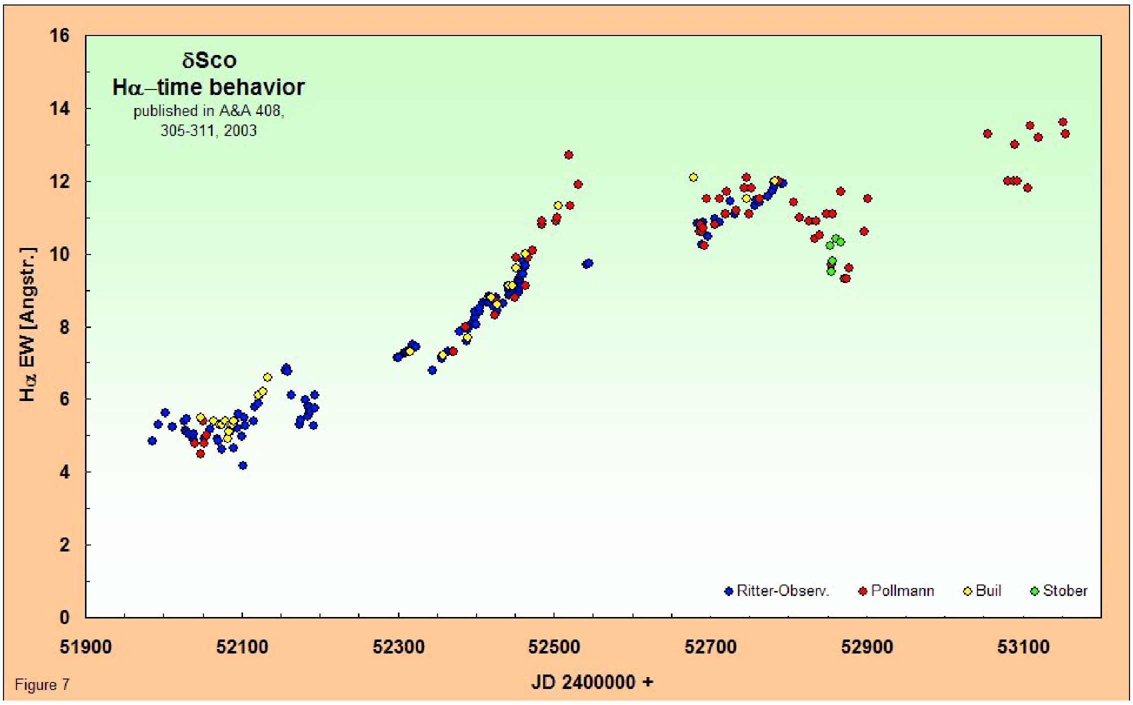

Figure 7: The Hα temporal behavior of δ Sco. Circles shown around JD 2 452 900 were obtained by B. Stober, also a member of our Spectroscopy group.

In a more general picture, the variations of the Hα emission show that the circumstellar disc is not in a steady state. The overview of the equivalent width presented in Fig. 6, spanning from October, 1975 to March, 2004 shows slow, but strong changes of the disc in density and/or volume. The data presented in this figure has been obtained both with a prism- and a grating spectrograph.In addition, data available from the literature has been collected and compiled into the figure, to provide comparison of the data quality achievable with a recent amateur-grade spectrograph. In particular such long-term monitoring can provide important data for the professional community. The interpretation of observations with a limited time base, as they are typically obtained with professional resources, may profit significantly from the knowledge of the disc state in the course of the long-term evolution.

3.3 δ Scorpii

Figure 7 shows results from the cooperation with Anatoly Miroshnichenko (Ritter-Observatory Toledo, Ohio, see also Miroshnichenko et al., 2003) for the observation of δ Scorpii, that only recently became a Be star. Faint emission had been reported about ten years ago already, which then vanished. It reappeared in an outburst in the year 2000, when the system, which is in fact an eccentric binary with a ten-year period, was close to periastron. Whether there is any relation, however, could not yet be ascertained.

Almost from the beginning of the outburst in 2000 I could observe the evolution of the disc until today. From August 2003 four measurements of our group member B. Stober are added (Fig. 7, green points). This is a good example for a fruitful cooperation between professional and amateur astronomers, that was was also worked into a refereed publication (Miroshnichenko et al., 2003).

3.4 HR 2142

Th. Rivinius and M. Maintz from the Landessternwarte Königstuhl in Heidelberg recently pointed out the need of observational data from the binary system HR 2142. It is believed to be similar to ϕ Per, but at also a nature as currently mass-transferring binary has been proposed. In order to observationally distinguish both hypotheses, further data was desirable. Between September, 2003 and April, 2004 I obtained 16 spectra, covering the different phases of the orbit relatively homogeneous (See Figs. 8).

Being in contact with the Heidelberg group during the observations, it became clear that tracking the phase-dependent variations of the V/R behavior in Be binary stars is a promising undertaking. Figure 9

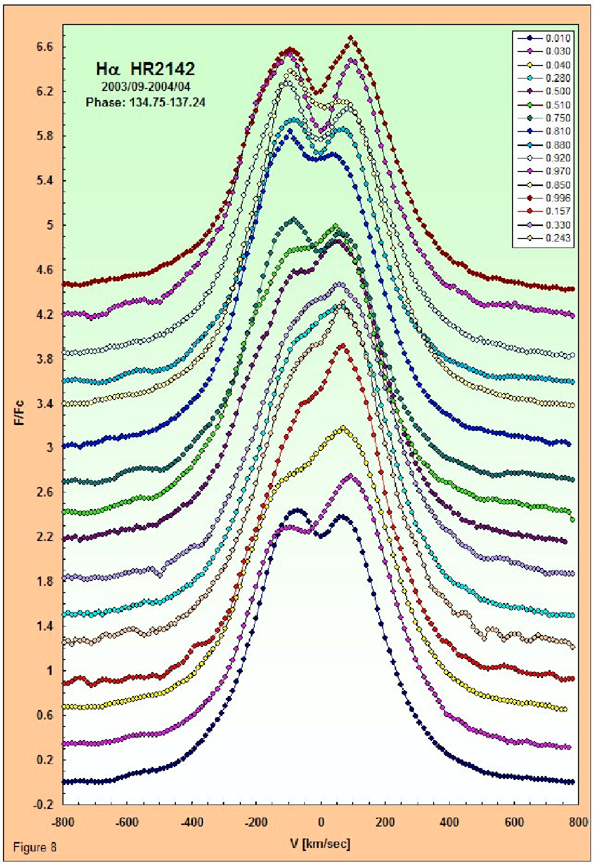

Figure 8: Hα profiles of HR 2142.

shows the V/R-data for the example of HR 2142. Between phase 0.9 and 0.1, the sudden V/R reversal, being typical for such sorts of binary systems, is easily seen.

3.5 P Cygni

As a final example, observational results from the dormant LBV star P Cygni are presented in Fig. 10. The observational timebase covered was from September, 1994 to May, 2004. In these almost ten years, the Hα equivalent width varied from 60 to 100 Å. Intermediate results have already been published in Pollmann (2000).

The data document the slow passage of the emission strength through a minimum in equivalent width. Superimposed a quasi-periodic micro-variation on time scales of weeks to months is seen. A few additional data taken from the literature are shown for comparison. These results encourage to continue the monitoring in the same way for some more years in order to be able to search for Hα variations in a much more extended and homogeneous data base.

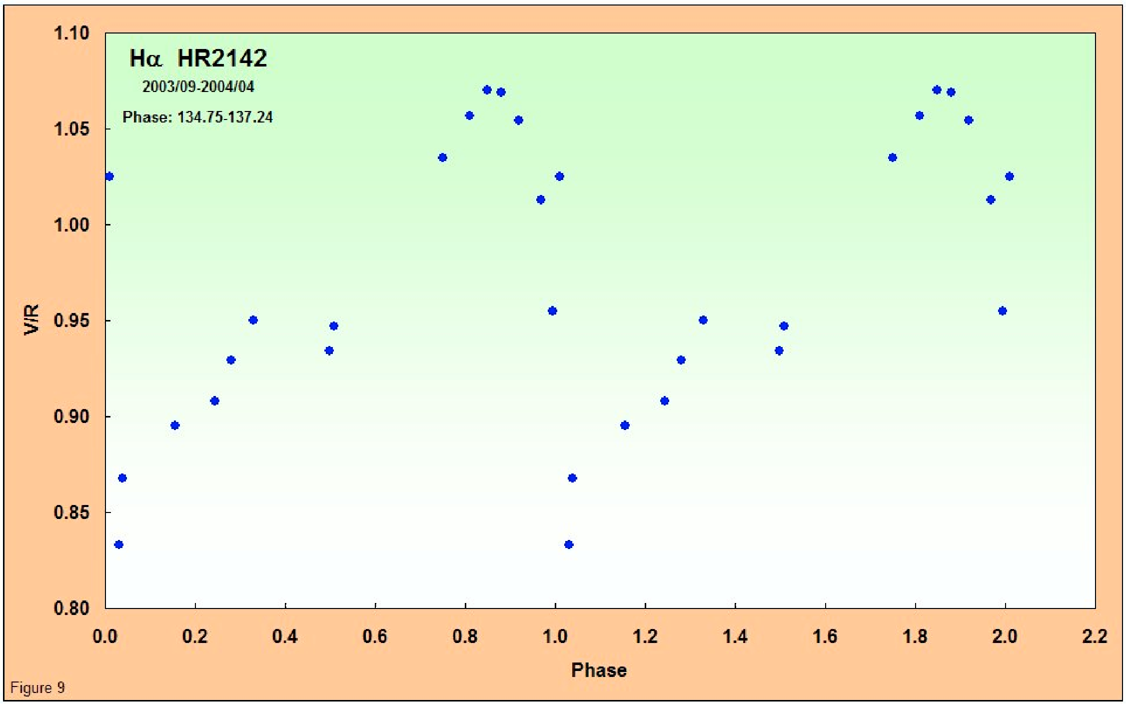

Figure 9: The V/R ratio of HR 2142 measured in Hα and phased with the orbital period.

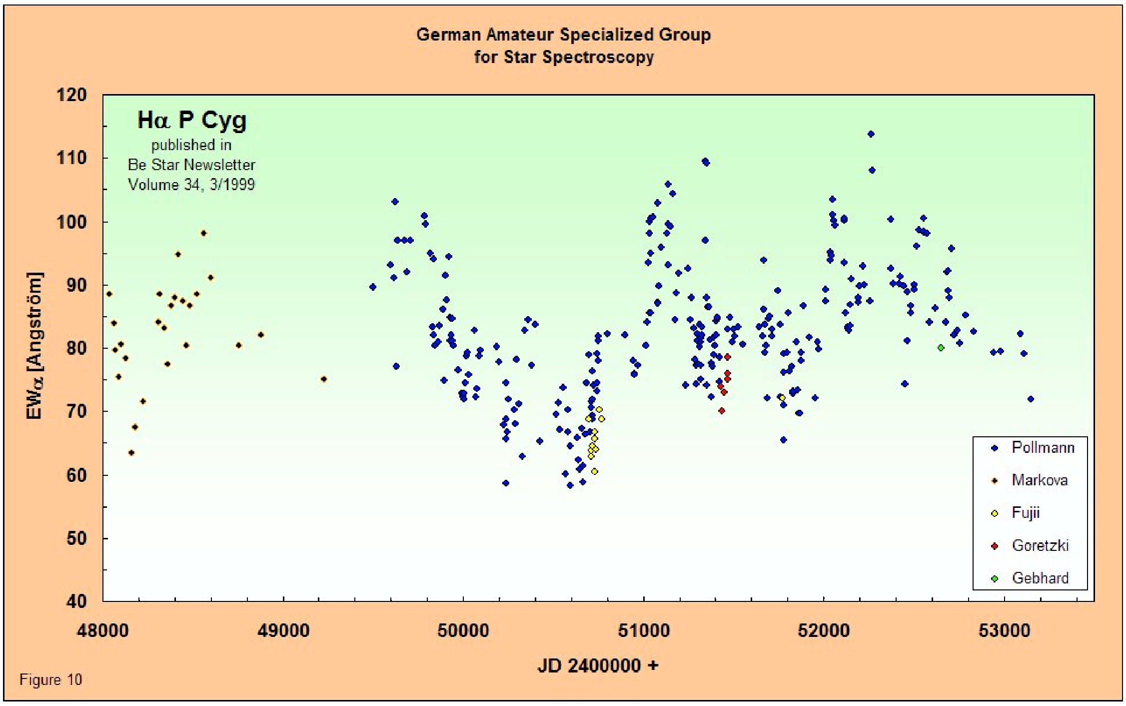

Figure 10: The Hα equivalent width long-term behavior of P Cyg.

4 Outlook

Next year we will start intense observations of Wolf Rayet stars in the Cygnus area. For this project a number of telescopes from 25 to 45 cm aperture are available. The motivation is to search for small-scale variations in the wind, but it has to be seen whether they will be detectable with our instruments.

But of course we will also continue our observations of Be stars. In particular, I would like to invite researchers studying relatively bright and Hα variable emission line stars to contact our group. More and up-to-date information is available from the homepage of the VdS-Spectroscopy Group at: `http://www.pollmann.ernst.org`. We are certainly looking forward to begin more collaborations such as the ones presented.

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