

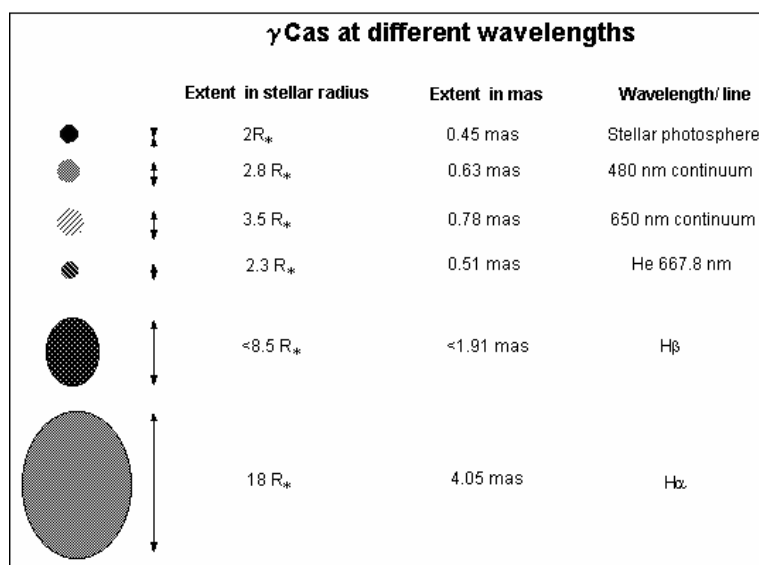
## H $\alpha$ and He6678 emission activities correlated with the Be star $\gamma$ Cas?

Long-term spectroscopy observations at time scales between years and decades will stay a strong domain in amateur astronomy. Especially with Be stars, several phenomena have been researched. These are the periodicity of the V/R ratio and the equivalent width (EW) of the H $\alpha$  emission line profiles. Candidates of research are  $\zeta$  Tau, 28 Tau,  $\delta$  Sco,  $\pi$  Aqr. This enumeration will not claim for completeness, however. The periodicity of the V/R ratio and EW of the H $\alpha$  emission line has been shown by insistent observations performed by single observers or groups of amateur astronomers. This is especially true for the star  $\gamma$  Cas, that is considered as the prototype of Be stars. The behaviour of the equivalent width of H $\alpha$  and also of the He 6678 line of  $\gamma$  Cas has been investigated earlier by the author [1, 2].

Tab.: Main parameters of  $\gamma$  Cas taken from [3]

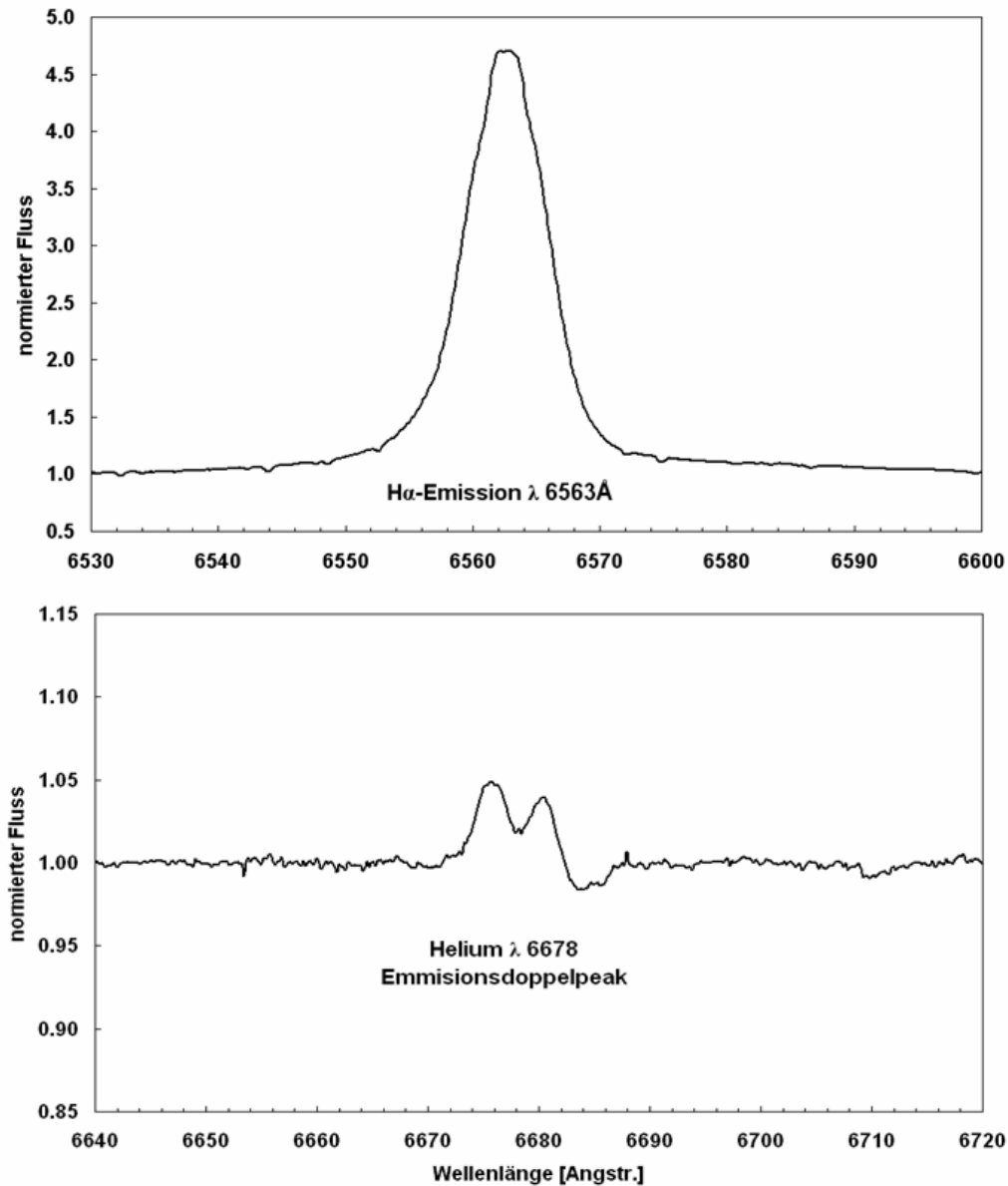
Spectral type	B0.5 IVe
Effective temperature	300000 K
Mass	16 solar masses
Radius	10 solar radius
Apparent angular diameter	0.45 mas
Luminosity	$3.5 \times 10^4$ solar luminosity
$V \sin i$	$230 \text{ km s}^{-1}$
Angle of inclination	$45^\circ$
Density of photosphere	$2.0 \times 10^{-11} \text{ g cm}^{-3}$

An international group of amateur astronomers collected data from long-term observations of  $\gamma$  Cas. Based on this material, this article will ask, whether there is a correlation of emission activities of H $\alpha$  and He 6678. Both, the H $\alpha$  and He 6678 line activities are originated in different regions of the stellar shell. While H $\alpha$  represents the total volume of the stellar shell, the He6678 emission is assumed to be originated closer to the surface of the Be star. Furthermore, the He6678 line is one of only a few lines, that are strong enough, not caused by hydrogen and not interfered by continuum radiation. From interferometric observations Stee et al. [3, 4] determined the diameters of the H $\alpha$  shell at 18 stellar radii and He6678 at 2.3 stellar radii.



*Fig. 1: The diameters of  $\gamma$  Cas in different wavelengths [4]: The wavelength dependent figures are projections to the sky plane. These are based on assumptions of symmetry, geometric flattening and inclination of the stellar shell.*

The observations of the international group of amateurs yielded spectra around the H $\alpha$  and He6678 lines in the observation time frame of this monitoring. The spectra have been obtained by slit spectroscopy at a spectral resolution  $R = \lambda/\Delta\lambda$  in the range between  $R=10000$  and  $R=20000$ . Figure 2 shows one of the sample spectra of H $\alpha$  and He6678 line respectively at a spectral resolution of  $R=18000$ .



*Abb. 2: Sample spectra of H $\alpha$  and He667; spectral resolution  $R=18000$*

Figure 3 shows the equivalent width EW for the H $\alpha$  and He6678 lines between 13. April 2003 and 24 December 2011 (Julian date: 2452743 – JD 2455920). The equivalent width EW has been uniquely derived at the wavelength intervals 653.0-660.0 nm and 667.0-668.5 nm for H $\alpha$  and He6678 respectively. The measurement errors for every single measurement are estimated to 2% for H $\alpha$  and  $\pm 5\%$  for the He6678 line. With two exceptions the measurements of the EW of He6678 are derived as a sum of the wavelengths at 667.5 nm and 668.0 nm.

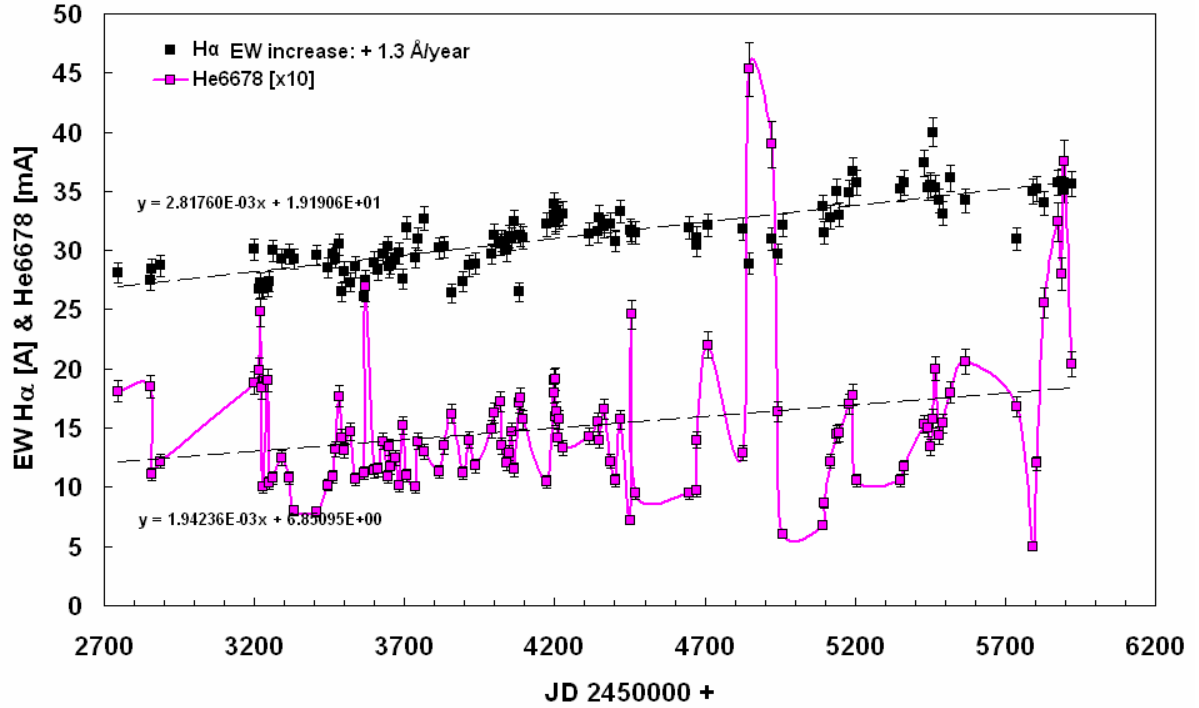


Abb. 3: The result of the long-term monitoring of the  $H\alpha$  and He6678 lines of  $\gamma$  Cas between 13. April 2003 and 24. December 2011

From Fig. 3 a steady growth of the EW of the emission line is found with both, the  $H\alpha$  and He6678 line. However, the He6678 emission is also interfered by short-scale fluctuations. In general, such fluctuations, as they are found with the measurements at dates JD 2454847-928 and JD 2455874-896, are connected with an eruption of the Be star, where an ejection of mass into the disk of the star occurred [5, 6, 7, 2].

It is assumed, that exo-photospheric events, which are caused by such outbursts, may only occur in the regions near the surface of the star. Here, excitation energy from radiation is high enough to result in the related emission line features of the helium atoms [7]. This is a main difference compared to the formation of the  $H\alpha$  emission, which is built up within the whole circum-stellar disk. Hence this leads to slower fluctuations of the  $H\alpha$  emission. Within the observing time frame the slope of the  $H\alpha$  equivalent width yields a value of  $2.82 \times 10^{-3}$  and  $1.94 \times 10^{-3}$  for He6678.

When comparing the slope of both graphs, the growth of the exo-photospheric mass outflow into the stellar disk of the Be star (with the He6678 emission as an indicator) lead to a growth of the  $H\alpha$  equivalent width in the order of  $1.3 \text{ \AA}/y$ . However, this result will not clearly indicate, whether the equivalent width of  $H\alpha$  and He6678 are really correlated in the way it is assumed in this work.

A time frame of about eight years of observation is not sufficient to clearly find certainty of the interpretation (in the opinion of the primary author). It is supposed that more years of continuing observation are necessary to get evidence. The author wants to encourage amateur astronomers to also enter this project and take part of the continuing spectroscopic monitoring of the Be star  $\gamma$  Cas. Such a work certainly is an important contribution to the general understanding of the processes of these stars and the stellar evolution.

Observer of the consortium:

R. Bücke, P. Fossanelli, Th. Garrel, J. Guaro, Th. Blank, P. Debreuil, St. Charbonnel, H. Kalbermatten, Ch. Netzel, E. Pollmann

References:

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E. Pollmann

Discussion in Be-Star-Mailinglist:

[https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=be-stars:](https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=be-stars)

Th. Rivinius (ESO, Chile)

I agree these outliers are physically real, indeed as expected for times of mass ejection/transfer into the disk. But the different formation locii of H $\alpha$  and He (As you say H $\alpha$  is emitted much all-over the disk, He only very very close to the star) have consequences for a potential correlation. Let me make an analogy:

H $\alpha$  is equivalent to the filling of a bathtub, while He is equivalent to how much the faucet has been opened. While the first is clearly related to the second, you would not expect a straightforward correlation between the two, but only that when H $\alpha$  has grown, He must have been there (or stronger) some time before. It may still be there, but equally might not, and as well a strong He can go without having an effect on H $\alpha$  if e.g. the strong He phase was short.

Pollmann

If I understand you correctly, an increase of the He-emissivity is to be expected. However it should manifest in a stronger rise? Is a continuous rise to be expected at all? Is the time base possibly even still too short, in order to derive a direct reciprocal effect?

Th. Rivinius (ESO, Chile)

Not really an increase on a long timeline: When mass is fuelled into the disk, more He emission is present than when not. The very inner part of the disk reacts to such changes in timescale of a few days at most, and likely less. The He-line basically only tells you high density close to the star vs. low density close to the star. H $\alpha$  forms out of a much bigger reservoir, here in a sense you see the entire mass of the disk, whatever is happening in the inner edge is not felt by H $\alpha$  directly, but H $\alpha$  smoothes over the changes at the inner edge with a fairly long time constant. For this reason, if you observe He very often, you can probably sort of integrate the estimated H $\alpha$ -evolution out of it, but not the other way around.

Pollmann:

Thank you so much, for the explaining descriptions of the complex. This makes very clear, that the further worth of my He6678 observation is rather the monitoring of its general behavior (mass-injection/transfer into the disk) in context with the further H $\alpha$  development (as you said: “the first is clearly related to the second”).