

HeI 6678 Emission Activity in γ Cas

(v. Ernst Pollmann; published in Be Star Newsletter Vol. 39, 2009)

I continue to monitor HeI 6678 emission in gamma Cas as described in BSN 38 (2007) and have now accumulated observations over six years. In this short paper I report on emission behavior from August 2005 to October 2008. I used the 0.4-m Schmidt-Cassegrain telescope at the observatory of the Vereinigung der Sternfreunde Köln. The slit spectrograph I used has a dispersion of $27\text{\AA}/\text{mm} = 0.245 \text{ Angstr./Pixel}$ with $R = 14,000$. Exposure times ranged from 30 to 40 seconds. I combined individual raw spectra with $60 < S/N < 80$ to achieve high S/N in summed spectra. In case of any cosmic ray appearance the respective spectrum has been rejected not to introduce artificial flaws within the nightly sum spectrum. The complete data reduction and equivalent widths measurement have been done according to a standard procedure as already described in Pollmann (1997). The accuracy of a EW measurement was determined in each sum spectrum according to the method of Chalabaev, and Maillard (1983). The size of the error bars of individual data points correspond to the maximum standard deviation of 6% in EW of He6678 and 2% in EW of Halpha. The S/N ratio was always between 400 and 1000.

Figure 1 identifies an episode of unusually strong emission in the red and blue wings of the HeI 6678 absorption profile. This plot compares the average F/Fc profile for the period November 2007 to August 2008 with individual observations during this event on 18, 21, and 26 September 2008. Figure 2 presents observed equivalent width for January 2003 through September 2008. Here, with two exceptions, equivalent width is a sum of emission peaks at 6675\AA and 6680\AA . For JD 2454728 and 2454731, or 18 and 21 September 2008, respectively, the equivalent width is a sum of emission in the wavelength range 6658\AA to 6695\AA to be consistent with the emission line profile on these dates in Figure 1.

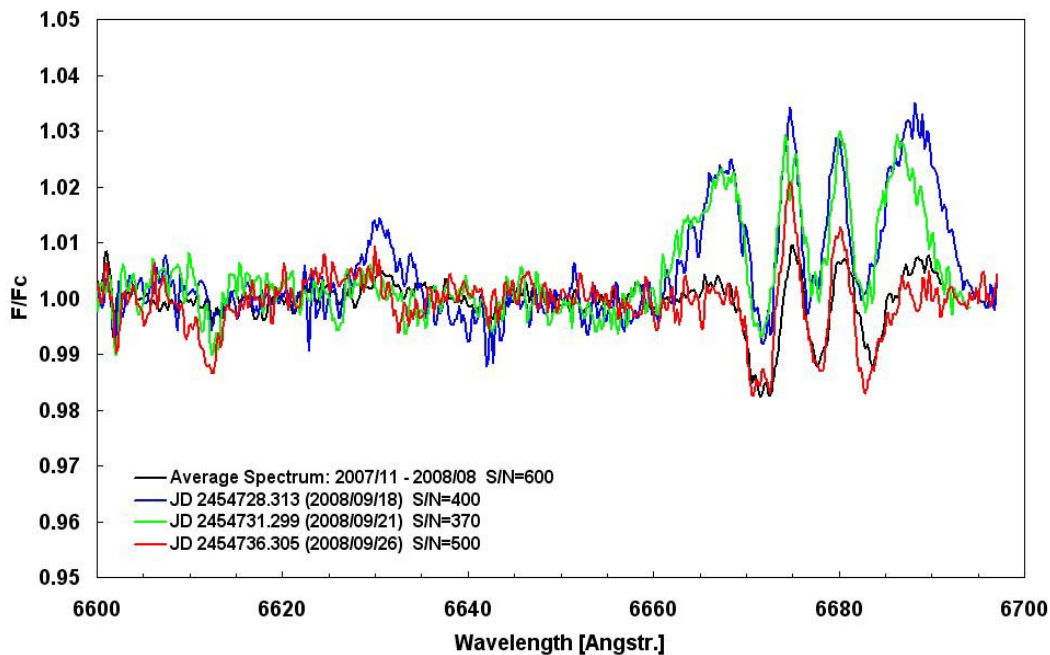


Fig. 1: Comparison of an average HeI6678-spectrum (2007/11 to 2008/08) to the HeI6678 "event-spectra" at 2008/09/18 and 2008/09/21

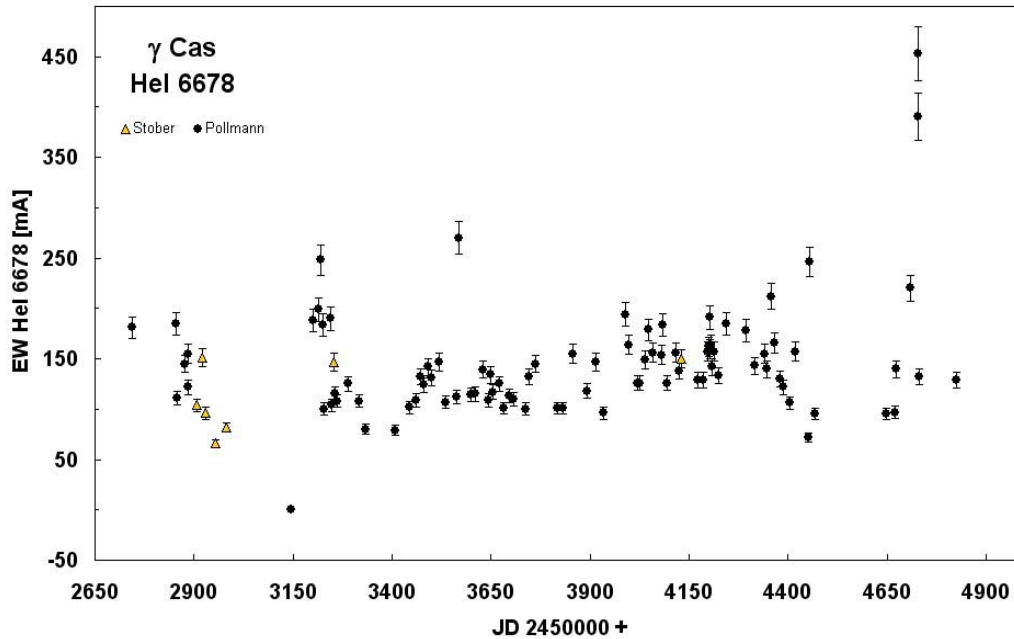


Fig. 2: Monitoring of the time behavior of the HeI6678-emission from JD 24542744 to JD 2454826

This sort of sudden activity has been observed by others. In gamma Cas, a “flare” with a duration of several minutes, appearing as additional emission at 6680Å in the He I 6678 peak, was observed by Smith (1995). Rivinius et al. (2001) found additional emission in HeI6678 at 6675Å and 6680Å during an outburst of mu Cen. They concluded that

. . . there can be little doubt that the bump patterns we described . . . are related to variations reported by investigations of numerous optical wavelength lines of gamma Cas. Doazan (1976) and Hutchings (1976) first reported variations in Hbeta, and Slettebak & Snow (1978) found similar but rapid variations in Halpha. These authors believed the variations to be associated with the emission components of the line arising from erratic activity in the circumstellar disk.

So-called migrating subfeatures, so far known, are almost certainly caused by absorptions from clouds locked into corotation by magnetic fields from the star are seen irregularly on most nights of intensive observations. The prototypical example is the magnetic active dKe star AB Dor. These features have been seen by several observers in the optical, beginning with Yang et al. (1998) and in the UV by Smith et al. (1998).

The outbursts reported herein are spectacular, particularly strong and rare and it’s likely that the small scale events have been formed near the star underlying the strong emission (something similar was reported by Hutchings). The timescale of the observations JD 2454728.313 to JD 2454732.299 (= 71.7 hr) is comparable to the orbital time of the inner region of the disk. It is possible (probably likely) that matter has been ejected into an unstable orbit close to the star's surface. Smith 1995 also reported on similar variations.

In case it may be relevant to this situation, Figure 3 is a lengthy history of changes in Halpha equivalent width as observed by myself and others. The arrow in the lower plot in fig. 3 marks the time when the HeI778-event occurred. Further it should be mentioned, since the Helium EW is monitored, no correlation or response is found to the EW of Halpha (see Fig. 4). Note that

the strength of H α in gamma Cas has been steadily increasing since the last minimum at approximately JD 2454230.

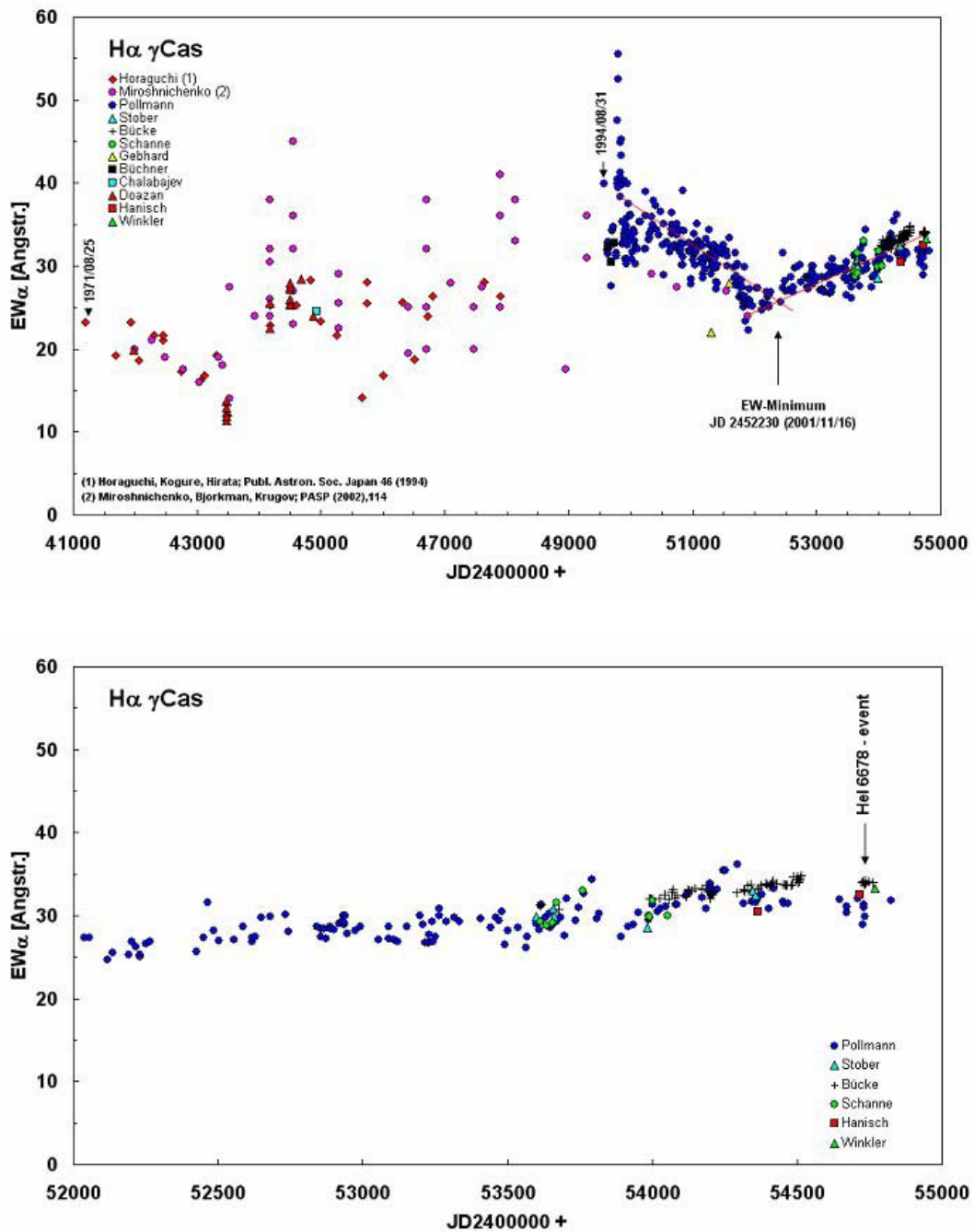


Fig. 3: Monitoring of the time behavior of the H α -emission with the marked position of the HeI6678 "event-spectra"

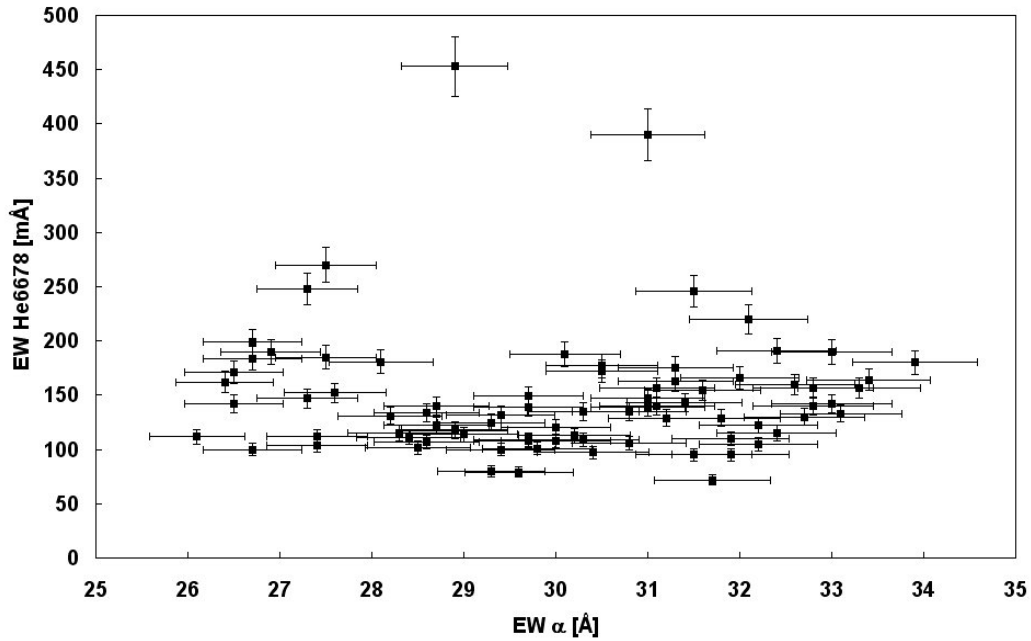


Fig. 4: Plot for evidence: there is no correlations between the strength of the H α - and the HeI 6678 emission

Acknowledgments:

I am grateful to Myron A. Smith, the referee, whose detailed and critical comments lead to major extensions and improvements of this work.

References:

- Chalabaev, A., Maillard J.P., 1983, *A&A*, 127, 279-288
- Doazan, V., 1976, *IAU-Symposium no. 70*, Dordrecht, Holland; Boston: D. Reidel Pub. Co., p.37
- Hutchings, J.B., 1976, *PASP*, 88, 911-916
- Pollmann, E., 1997, *Be-Star-Newsletter*, 32, 11
- Rivinius et al., 2001, *The Journal of Astronomical Data* 7, 5.
- Slettebak, A., Snow, T. P., 1978, *ApJ*, 224, L127-L131
- Smith, M. A., 1995, *ApJ*, 442, 812-821
- Smith, M.A., Robinson, R.D., Hatzes, A.P., 1998, *ApJ*, 507, 945
- Yang, S., Ninkov, Z., Walker, G.A.H., 1988, *PASP*, 100, 233-242

Supplementing comments of M. Smith und G. Peters

Myron Smith:

Migrating subfeatures (msf's), as they are known, are almost certainly caused by absorptions from clouds locked into corotation by magnetic fields from the star. The prototypical example is the magnetic active dKe star AB Dor. Only one other star is known to show this property, and that is the gamma Cas "analog", HD110432 (Smith & Balona 2006, ApJ, 640, 491).

These features have been seen by several observers in the optical, beginning with Yang et al. and in the UV by Smith, Robinson, Hatzes (1998, ApJ, 507, 945), but they have little do with with the kinds of outbursts seen by Smith, Peters, and Rivinius in gamma Cas, lambda Eri, mu Cen, and eta Cen.

The outbursts reported herein are spectacular and rare, whereas the msf's are seen irregularly on most nights of intensive observation of gamma Cas. In my opinion is likely that the small scale events reported by Hutchings are due to msf's formed near the star underlying the strong emission; Smith 1995 reported on similar variations.

Gerry Peters:

This paper is important because the Stromgren sphere for HeI 6678 (meaning the circumstellar region surrounding the star in which existing gas can ionize HeI6678 and recombine to form helium line emission) is small compared to that of hydrogen.

This argues strongly that the variations arise from matter present close to the star's surface, probably within 1-2 stellar radii (this is a guess), and possibly less.

Moreover, the double-peaked shape of the profiles when the emission is fully developed, together with the broad wings extending far from the line center(see footnote), argue that the matter is formed in regions which corotate with this rapidly rotating star.

Both arguments suggest that the emission is not formed in a Keplerian disk, in which the velocity law decreases with radius from the star. (Again, contrary to the speculation at the end of paragraph 4.)

The optical light curve of the star shows a period of 1.21 days (Smith, Henry & Vishniac 2007, ApJ, 647, 1375) and also has a peculiar waveform.

Photometric variations even from early-type B stars seem to have the same origin as on the surfaces of late-Bp and Ap stars, namely bound-free absorption edges of metals caused by peculiar abundance patches distributed across the star's surface.

This evidence, together with the existence of msf's argues strongly, in my opinion, that the Be star has multipolar (highly complicated) surface magnetic fields.

As a pure speculation it is possible that the events reported by Ernst are caused by a dissipation of magnetic energy stored in magnetic structures close to the star's surface.

I should add that the appearance of quasi-stable (over a few days) of 4 emission peaks is highly unusual in Be stars and suggests once again a complicated geometric picture.

It is too bad that the event was not caught earlier, but the subsiding of the event in 3-5 days gives valuable information about the dissipation processes.

(Note that this timescale is too long for material to have been ejected and returned to the star solely under the influence of gravity. This suggests that during the emission lifetime the material was suspended by another mechanism - either centrifugal force if one believes this is a free ejection, or by magnetic pressures preventing a free-fall return).

This article will not answer these questions by itself, but events like them, together from evidence from other observations will add to the final picture.

This event will become an important pieces that addresses the overall picture of short-term variations occurring in the "gamma Cas" (and possibly other Be) stars.

Footnote:

Typically, the emissions in the HeI 6678 line of this star extend to no more than $\pm 4A$ (200 km/s). These emissions extend out to perhaps $\pm 15A$, and the outer pair of peak are separated by about $20A$, suggesting blue and redshift velocities of about 500 km/s.

Interestingly, this velocity is comparable to the 550 km/s velocity determined by Hony et al. (2000, A&A, 355, 187) found in weak Brackett hydrogen line emissions and attributed to a "fast inner disk component" the star.

Opinion:

this suggests to me that the inner edge of the disk found by Hony et al. coincides with the outer limit of the structures responsible for the HeI6678 emissions found by Pollmann in this article, and would be in line with a discontinuity in the velocity gradient between an inner corotation region and an outer keplerian disk region at occurring within $1R^*$ of the star.