Spectroscopic study of the extremely fast rotating star 44 Geminorum

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Abstract. Stars with extremely fast rotation represent interesting challenge to modern understanding of the stellar evolution. The reasons why such a spin-up process should occur during the evolution to otherwise normal star are still not well understood. Already in the beginning of the XX century Otto Struve proposed that fast rotation of the group of stars spectroscopically classified as Be could be the main reason for the formation of observed disks of circumstellar material around them. This circumstellar material is responsible for the emission lines observed in the spectrum of Be-stars as well as for the whole complex of spectral and photometrical patterns called in general Be-phenomenon.

Key words: stars: emission-line: Be - stars: variable - stars: fundamental parameters - stars:
individual : 44 Geminorum

1 Introduction

44 Gem (HR2659, HD53257, HIP34182) was often regarded as a fast rotating but otherwise 'normal' dwarf star of spectral type B8. The star has not been so far studied in detail and it was neglected until recently by the Be star researchers as spectral evidences of emission in its spectrum were scarce and controversial. It was reported by [Irvine(1975)] that the star shows a sharp absorption core in Hα. However, [Sletteback(1982)] noticed that 44 Gem has 'neither emission, nor shell lines visible' in spectra dated from 1980. Measured rotational velocities of the star vary from 365 km s^{-1} to 260 km s^{-1} (see [Abt et al. (2002)] and [Glebocki & Gnacinski(2005)]).

Although, the star has remarkably high rotational velocity up to now it was not connected with other evidences of the Be phenomenon where stars with high rotational velocities are the norm rather than the exception. There are photometrical evidences that the star goes through periods of significant decrease of its brightness. In classical Be stars such an activity is usually accompanied by significant spectral changes which were not reported so far for 44 Gem perhaps because of rare spectral observations.

2 Observations

A coordinated observational mini campaign was carried out in the beginning of 2011 at coudé-spectrographs of the Ondřejov and Rozhen Observatories in the frames of joint research project between astronomers from the Institute of Astronomy of Bulgarian Academy of Sciences and Astronomical Institute of the Academy of Sciences of the Czech Republic.

Spectral observations with the Coudé-spectrograph at Ondřejov Observatory were obtained using the 830.77 lines mm^{-1} grating and SITe 2030 x 800 CCD [Slechta & Skoda(2002)]. The slit width was set at 0.7 arcsec, projected on the sky, resulting in a spectral resolution of R = 13000 in the spectral region 6254 Å to 6763 Å. The Coudé-spectrograph of the 2m RCC telescope of NAO Rozhen was used in a configuration aimed to achieve resolution power of about R=30000 at Hα. 632 lines mm^{-1} Bausch & Lomb grating was used with a slit width set at 0.83 arcsec.

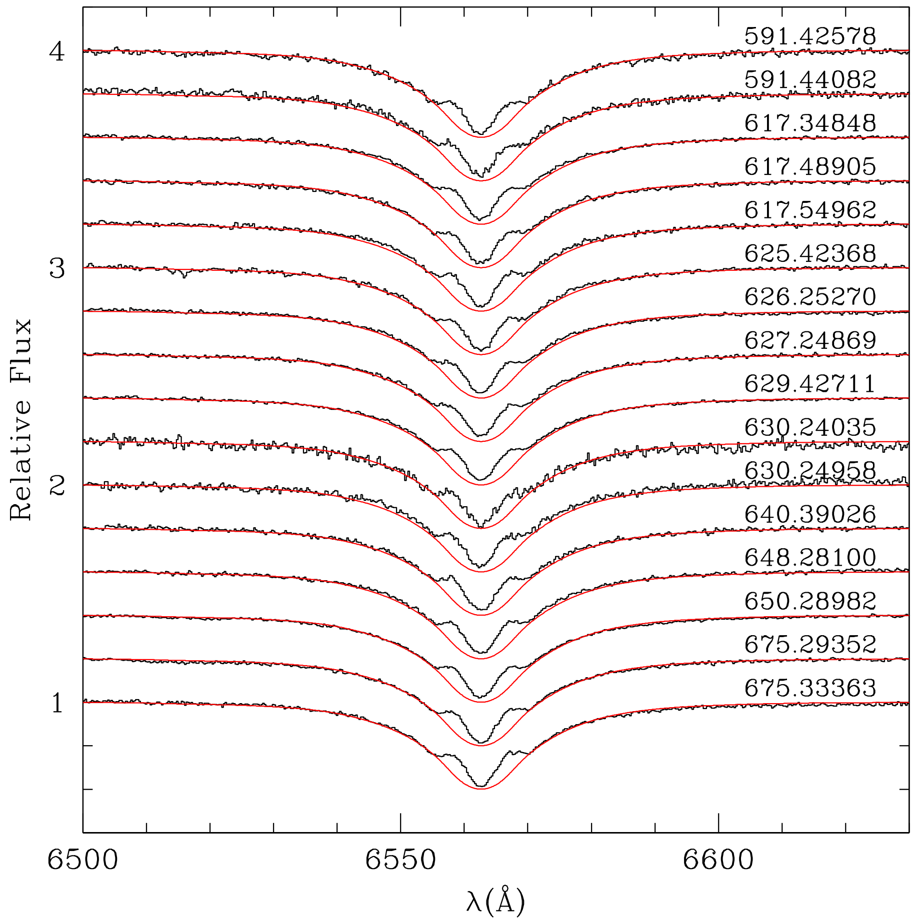

Fig. 1. Hα profiles of 44 Gem and model profile ($v \sin i = 260\,\mathrm{km\,s^{-1}}$).

All observations were done with Photometrics AT200 (SITe S1003AB 1024 x 1024) CCD camera. The dispersion obtained in this configuration is about 0.1 Å per pixel. Most of the observations were taken in the Hα spectral region. Some spectra were obtained also in the Hβ, Hγ and Hδ regions. ThAr comparison spectra were obtained before or after each stellar exposure.

3 Reduction, measurements and discussion of results

All spectral observation were reduced following standard procedures of IRAF and ESO-MIDAS astronomical software packages. Radial velocities of the central absorption core were obtained with fitting of a Lorentzian to the wavelength calibrated spectral frames. The results are summarized in Table.1.

Table 1. Moments of observations, observatory, spectral range observed and measured radial velocity in km s^{-1}.

HJD 2455000+	observatory	sp.range	RV core
591.42578	O	Hα	-6.42
591.44082	O	Hα	-11.49
617.34848	O	Hα	-8.9
617.48905	O	Hα	-9.15
617.54962	O	Hα	-4.18
625.42368	O	Hα	-3.74
626.25270	O	Hα	-6.43
627.24869	O	Hα	-9.42
629.42711	O	Hα	-6.14
630.24035	O	Hα	-4.22
630.24958	O	Hα	-10.17
640.39026	O	Hα	-9.59
646.41553	R	Hβ	-18.17
646.42520	R	Hγ	-17.58
646.43660	R	Hδ	-19.21
646.45126	R	Hα	-8.66
647.36537	R	Hα	-8.43
648.28100	O	Hα	-9.89
650.28982	O	Hα	-6.39
675.29352	O	Hα	-2.93
675.33363	O	Hα	-2.51
834.59976	O	Hα	-4.02
878.52154	O	Hα	-9.03
878.63391	O	Hα	-13.58
879.51815	O	Hα	-8.41
879.67136	O	Hα	-12.88
879.71253	O	Hα	-9.47

4 Spectral energy distribution of 44 Gem and its basic parameters

The Spectral energy distribution (SED) of 44 Gem was fitted with model spectrum under the assumption that $log\,\mathbf{g} = 4.0$. Models were taken from [Castelli & Kurucz (2003)]. They were built based on 10 data points obtained via ground based or satellite observations. Infrared photometry used for the modeling in JHK bands of 2MASS was obtained from [Skrutskie(2006)]. 4 band TD1 ultraviolet measurements of 44 Gem were taken from [Thomson et al.(1978)]. We applied χ^2 minimization techniques and obtained best-fitting parameters $T_{eff} = 10200$K and $E_{(B-V)} = 0.06$ at $log\,\mathbf{g} = 4.0$ (see Fig. 3). At $log\,\mathbf{g} = 3.5$ best-fitting parameters are $T_{eff} = 10400$K and $E_{(B-V)} = 0.07$.

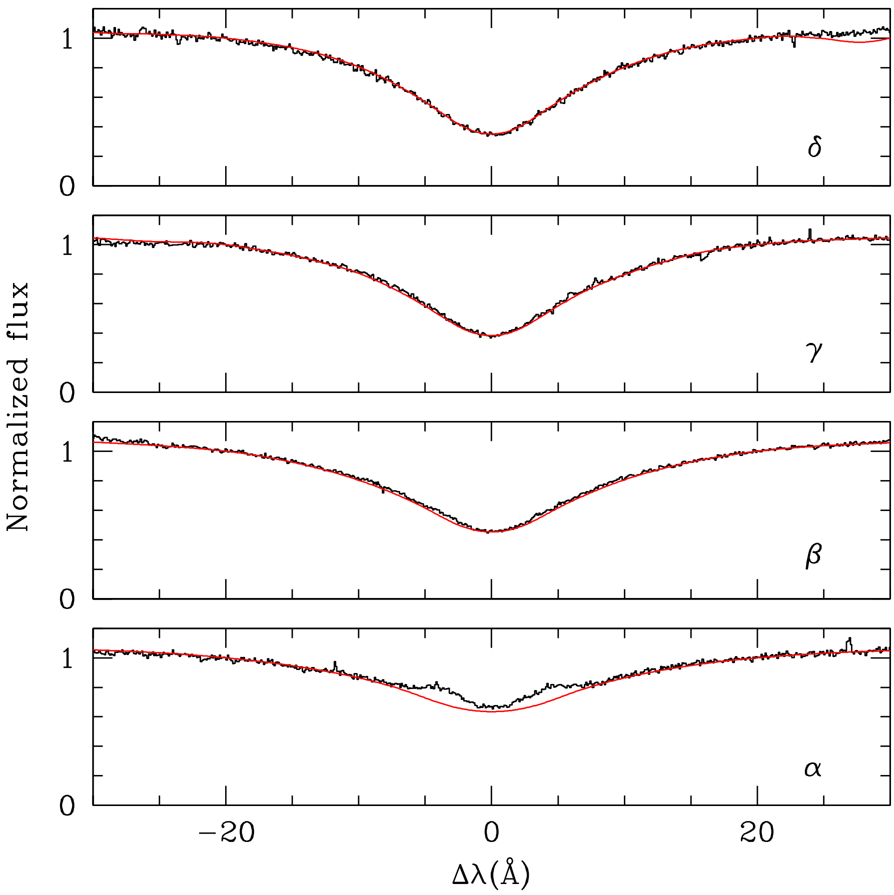

Fig. 2. Balmer line profiles in the spectrum of 44 Gem and model spectrum ($v \sin i = 260\,\mathrm{km\,s^{-1}}$).

The age and the mass of 44 Gem were determined by comparison with a set of evolutionary tracks taken from [Schaller et al.(1992)]. As can be seen from Fig. 4 the mass of the star could be estimated as 2.65 $M_{\odot}$ and the age as 250 Myr. The luminocity was estimated using Hipparcos paralax from [van Leeuwen(2007)] and bolometric correction BC = -0.29 corresponding to $T_{eff} = 10200$K was accepted.

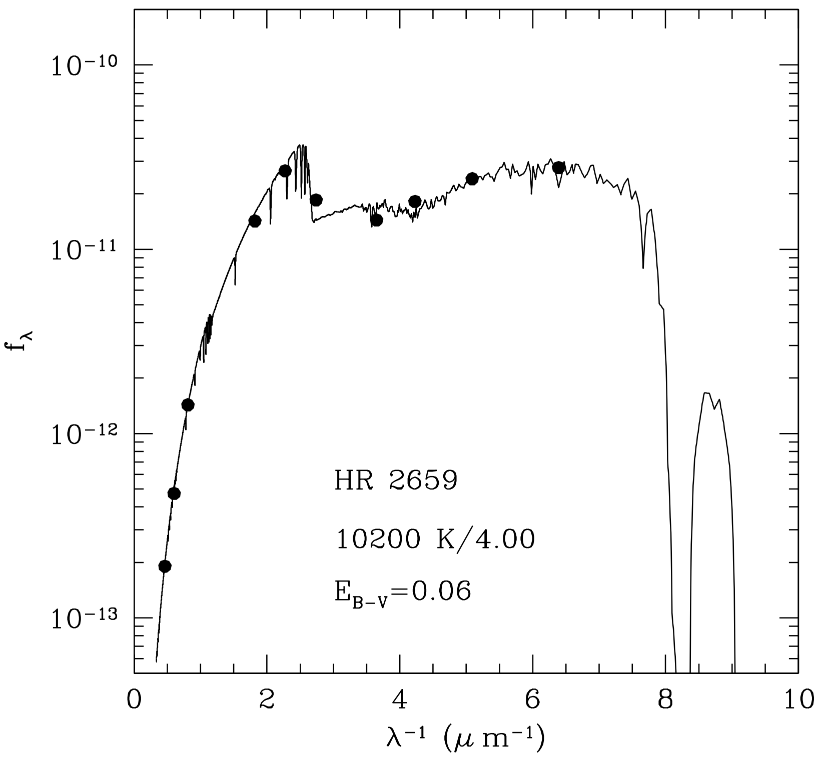

Fig. 3. Best fitting SED model for 44 Gem

5 Conclusion

Even preliminary analysis of 44 Gem spectral observations proves the fact that the star is in fact a Be star. Emission components in the Hα line are present on all spectra. However no significant emission was present on the profiles of Hβ, Hγ and Hδ. Rotational velocity was estimated to be 260 km s^{-1} (see Fig

2). All this together with the basic parameters of 44 Gem classifies the star as member of the group of 'classical Be stars'. Radial velocity measurements of Hα were performed by measuring the core of the central absorption (and of the emission components (if they were prominent enough)) with average $R_v = 7.72$ km s^{-1}. The scatter of the measurements was found to be about 3.12 km s^{-1} which is slightly larger than the estimated accuracy of the measurements. This allows to consider that 44 Gem is possibly a RV variable. Emission filling of the profile of Hα as well as eventual Balmer progression can explain the difference of radial velocities measured in other observed Balmer lines. We were not able to establish any type of periodicity, possibly because of the relatively short time interval covered by performed observations so far.

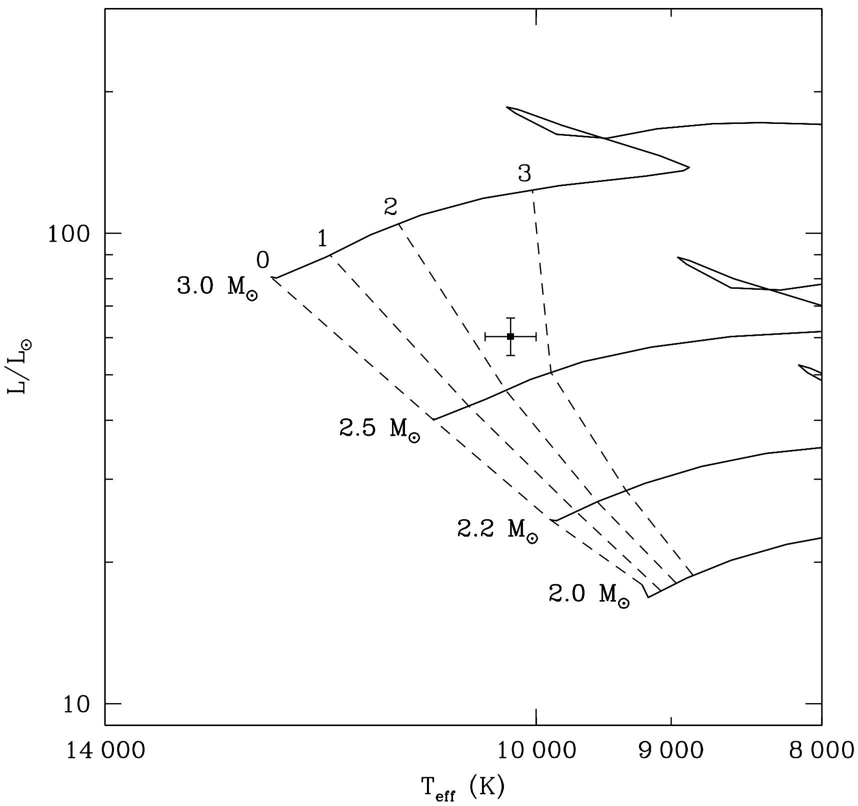

Fig. 4. Set of evolutionary tracks and the location of 44 Gem in a $T_{\rm eff}$ vs. L diagram. We adopted $T_{\rm eff} = 10\,500 \pm 500$ K and $\log L/L_{\odot} = 1.78 \pm 0.04$. Dashed lines in the graph represent positions of constant stellar age in 100 Myr units.

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