The A-Star Puzzle
Proceedings IAU Symposium No. 224, 2004
J. Zverko, J. Žižňovský, S.J. Adelman, & W.W. Weiss, eds.

DOI: 10.1017/S1743921305009786

On the rapid variability of the global magnetic field in γ Equ

V.D. Bychkov[1], **L.V. Bychkova**[1] **and J. Madej**[2]†

[1]Special Astrophysical Observatory, Russian Academy of Sciences, Nizhnij Arkhyz, Russia
email: vbych@sao.ru

[2]Warsaw University Observatory, Al. Ujazdowskie 4, 00-478 Warszawa, Poland
email: jm@alkor.astrouw.edu.pl

Abstract. We report the results of the search for rapid periodic magnetic variations in γ Equ. Observations were collected in August 1989 with the 6-m telescope of Special Astrophysical Observatory (Russia). We analysed a 3-hour series of 1720 rapid B_e measurements of γ Equ obtained with an average time resolution of 6.6 s. A power spectrum analysis shows a period of $P = 3.596$ min. That period differs from the well-known photometric period of rapid variability $P_{phot} = 12.44$ min. We do not confirm variations of the B_e field of γ Equ with the P_{phot}.

Keywords. Stars: magnetic fields, stars: individual (γ Equ), stars: variables: other

1. Introduction

Rapid oscillations in some Ap-stars were discovered by Kurtz & Wegner (1979) and Kurtz (1982). These oscillations are due to high-overtone p-mode pulsations, and appear as rapid periodic photometric variations in Johnson B and V. Periods of these oscillation are in the range 4–16 min with small amplitudes. Rapidly oscillating Ap-stars are often refered to as roAp-stars. This class contains 32 stars (Kurtz & Martinez 2000).

A search for the rapid variations of the radial velocity of γ Equ (A9p SrCrEu, $V = 4.7$ mag.) was begun by Bychkov (1987, 1988). Zverko *et al.* (1989) reported a search for the rapid variability of its magnetic field and radial velocity. These early investigations did not yield conclusive results due to their low accuracy. Now a few research groups are attempting to observe the rapid variations of its magnetic field. Of particular interest is its possible variability with the photometric period of pulsations. Leone & Kurtz (2003) reported the discovery of rapid variations of the stellar longitudinal (effective) magnetic field B_e with a period of 12.1 min. and an amplitude ofl 240 ± 37 G. Later Savanov *et al.* (2003) found variations of the magnetic field modulus with the period 12.53 min. with an amplitude 99 ± 53 G. These authors observed the variability of the distance between the resolved Zeeman components of Fe II λ6149.2.

But Kochukhov *et al.* (2004a) reported the absence of variations of the longitudinal magnetic field B_e in γ Equ. They obtained 210 spectropolarimetric observations with high time resolution. They found no B_e variations with amplitudes above $40 - 60$ G in the circularly polarised components of 13 Nd III lines. Such a limit represents their 3σ confidence level. Moreover Kochukhov *et al.* (2004b) showed that possible variations of the surface magnetic field in γ Equ do not exceed $5 - 10$ G in Fe II λ6149.25 and Fe I λ6173.34. Hubrig *et al.* (2004) searched for rapid variability of the longitudinal B_e field in several magnetic stars (observations in circularly polarised profiles of hydrogen lines). Unfortunately, their results for γ Equ are inconclusive due to the small number of

† Present address: SAO RAS, Nizhnij Arkhyz, 369167 Russia.

measurements, Recently Bychkov *et al.* (2004) found magnetic field variability in γ Equ with an amplitude ≈ 350 G.

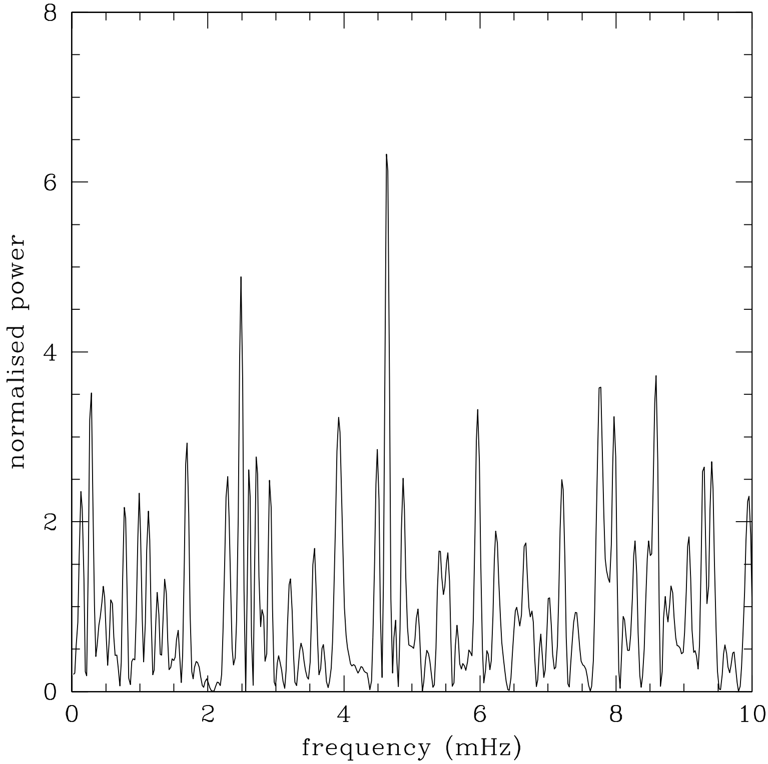

Figure 1. Normalised power spectrum of the series of 1720 $B_{\rm e}$ observations.

2. Instrumentation

We used the hydrogen line polarimeter (Bychkov *et al.* 1988, Shtol 1993) for measurements of the longitudial stellar magnetic fields $B_{\rm e}$. The polarimeter was placed at prime focus of the 6-m telescope to minimize instrumental effects from other optical elements.

3. Observations

Observations of the magnetic field $B_{\rm e}$ in γ Equ were performed during the night of 20/21 August 1989 for JD 2447759.414471 to .545842. The average time length of a single observation was 6.6 s. The time between the end of a previous exposure and the beginning of the following one did not exceed 0.05 sec. Thus the series of measurements was practically continuous.

We observed γ Equ for 189 minutes. We collected 1720 estimates of $B_{\rm e}$. Such a large number of $B_{\rm e}$ values in the single, uninterrupted series permitted us to compute reliable power spectra. Photon statistics implies some rough estimates of the error σ of a single magnetic field determination by Shtol (1993) $\sigma = 2925$ G.

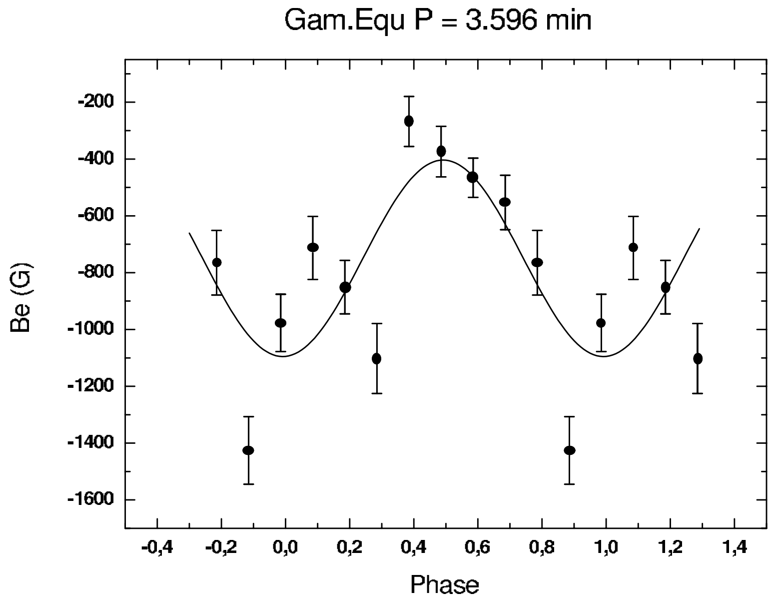

Figure 2. Magnetic sine phase curve best fitted to our $\langle B_e \rangle$ points with the period $P = 3.594$ min.

4. Magnetic phase curves and period determination

Standard Fast Fourier Transform subroutines were used to analyse these measurements of γ Equ. We have computed the power spectrum in the frequency range $0.185 - 16.67$ mHz, which corresponds to periods ranging from 90 min. to 1 min. Fig. 1 shows the power spectrum, which is rather noisy in this frequency range. The outstanding peak significantly exceeds the spectral noise level. Its frequency of 4.635 mHz corresponds to a period P = 3.596 min.

Numbers on the vertical axis of Fig. 1 denote the normalised power of our B_e series which is the ratio of the true power (square of the Fourier transform) in G^2/mHz^2, and its variance (cf. section II.b in Horne & Baliunas 1986). The value of normalised power at the peak of 4.635 mHz equals 6.327. The false alarm probability test predicts that the peak is real with a probability 66.7%.

Fig. 2 shows the magnetic phase curve computed for the $P = 3.596$ min., where the B_e points were averaged over the respective $0.1\,P$ bins. The value of $\langle B_e \rangle$ averaged over all phases equals -750 ± 22 G, and the amplitude of phase curve is 347 ± 31 G.

5. Discussion

Authors of most previous papers analysed observations of magnetic field in γ Equ in the metal lines. Consequently, their results could be affected by a nonuniform distribution of these elements over the stellar surface. Such a well known effect is common among Ap stars. Moreover, B_e measurements in the metal lines in principle may be distorted by other effects, e.g., complex blending of lines, and the cross-over effect.

The only exception is Hubrig *et al.* (2004), who obtained their B_e measurements in the wings of Balmer lines. Consequently their B_e data are free of the above effects, and seem to be more credible. Moreover, hydrogen line B_e data are of particular interest since they represent best the value of longitudinal component of magnetic field integrated over the stellar disc. They presented only 18 measurements of the longitudinal magnetic field

B_e of γ Equ. But, their observations are not inconsistent with the our period $P = 3.596$ min.

6. Summary

Fourier transform analysis of our B_e time series revealed rapid variations of the global magnetic field in γ Equ with the period $P = 3.596$ min. This period is different than the photometric period of rapid variations, $P_{\rm phot} = 12.44$ min., the latter is thought to represent pulsation periods. Power spectrum analysis reveals no signal at the frequenciy of pulsations. We found a confirmation of our period $P = 3.596$ min. by reanalysing the B_e measurements by Hubrig *et al.* (2004), and finding $P_{\rm Hubrig} = 3.54$ min. from their data.

A number of theoretical papers attempt to explain the existence of nonradial pulsations in Ap stars with very short periods, of the order ~ 10 min (Bigot & Dziembowski 2002). We believe, that the inclined pulator presented in the latter paper is the most relevant to interpret variations of the global magnetic field in γ Equ with a period as short as 3.6 min.

Acknowledgements

Our research is based on data compiled and posted in the SIMBAD, ADS, and CDS databases. We acknowledge support from the Polish Committee for Scientific Research grant No. 1 P03D 001 26.

References

Bigot, L., Dziembowski, W.A. 2002, *A&A* 391, 235
Bychkov, V.D. 1987, *Pis'ma Astron. Zh.* 13, 773
Bychkov, V.D. 1988, *Magnetic Stars (Leningrad: Nauka)* 197
Bychkov, V.D., Gazhur E.B., Glagolevskij Yu.V., El'kin V.G., Nazarenko A.F., Najdenov I.D., Romanyuk I.I., Chuntonov G.A., Shtol V.G. 1988, *Magnetic Stars (Leningrad: Nauka)* 12
Bychkov, V.D., Bychkova, L.V., Madej, J. 2004, *Proceedings of 49-th Sci. Conf. Stavropol University* 85
Horne, J.H., Baliunas, S.L. 1986, *ApJ* 302, 757
Hubrig S., Kurtz D.W., Bagnulo S., Szeifert T., Scholler M., Mathys G., Dziembowski W.A. 2004, *A&A* 415, 661
Kochukhov, O., Ryabchikova, T., Piskunov, N. 2004a, *A&A* 415, L13
Kochukhov, O., Ryabchikova, T., Landstreet, J.D., Weiss, W.W. 2004b, *MNRAS* 351, L34
Kurtz, D.W., Wegner, G. 1979, *ApJ* 232, 510
Kurtz, D.W. 1982, *MNRAS* 200, 807
Kurtz, D.W., Martinez, P. 2000, *Baltic Astronomy* 9, 253
Leone, F., Kurtz, D.W. 2003, *A&A* 407, L67
Savanov, I., Musaev, F.A., Bondar, A.V. 2003, *IBVS* 5468
Shtol V.G. 1993, *Bull. Spec. Astr. Obs.* 35, 114
Zverko J.,Bychkov V.D.,Ziznovsky J.,Hric L. 1989, *Contr. Astr. Obs. Skalnate Pleso* 18, 71