

# NEW PERIOD OF THE LONGITUDINAL MAGNETIC FIELD VARIABILITY IN Ap STAR $\gamma$ EQU

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**ABSTRACT.** We present an analysis of the secular variability of the longitudinal magnetic field  $B_e$  in the roAp star  $\gamma$  Equ (HD 201601). Measurements of the stellar magnetic field  $B_e$  were mostly compiled from the literature. We appended our new 33  $B_e$  observations which were obtained at the Special Astrophysical Observatory. All the available data cover the time period of 58 years, and include both phases of the maximum and minimum  $B_e$ . We determined that the period of long-term magnetic variations in  $\gamma$  Equ equals to  $91.1 \pm 3.6$  years. **Key words:** Stars: magnetic field; stars: individual: Gam Equ.

## 1. Introduction

The Ap star  $\gamma$  Equ (HD 201601, BS 8097) is one of the brightest objects of this class, with the apparent luminosity  $V = 4.66$  mag. Magnetic field of  $\gamma$  Equ was studied from over 50 years, starting from October 1946 (Babcock 1958). Longitudinal magnetic field  $B_e$  of this star does not exhibit periodic variations in time scales of usual stellar rotation, 0.5 – 30 days. Such a variability of  $B_e$  field was observed in most of Ap stars. The above effect is commonly interpreted as the result of stellar rotation (oblique dipole model).

The first measurements by Babcock (1958) showed, that the value of the longitudinal magnetic field  $B_e$  of  $\gamma$  Equ was positive in 1946–52, and approached +900 G. From that time on the value of  $B_e$  slowly decreased and even changed sign in 1970/71. One could interpret magnetic behavior of  $\gamma$  Equ either as secular variations, or variations caused by extremely slow rotation.

Behavior of the  $B_e$  field in  $\gamma$  Equ was investigated by many authors in the second half of the twentieth century. The previously determined period of secular magnetic variations,  $P_{sec} = 27027^d = 74.0$  years (cf. the extensive catalog by Bychkov et al. 2005a). This research and the analysis of a new, longer time series of  $B_e$  data is a major revision of the above magnetic

period of  $\gamma$  Equ.

We appended here our unpublished magnetic  $B_e$  measurements (33 points), which were obtained during the recent 7 years. All the new magnetic observations showed, that slow decrease of the  $B_e$  field in  $\gamma$  Equ apparently reached the minimum value in 1996–2002 and actually started to increase.

## 2. Observations and data processing

We have performed spectropolarimetric observations of Zeeman line splitting for  $\gamma$  Equ in the Coude focus of the 1-m optical telescope (Special Astrophysical Observatory, Russian Academy of Sciences).

## 3. Magnetic period of $\gamma$ Equ

The  $\gamma$  Equ exhibited slow and systematic decrease of the longitudinal magnetic field  $B_e$  starting from 1946, when the global magnetic field of this star was discovered (Babcock 1958). We have compiled the full set of 298 existing  $B_e$  measurements, which consists of the  $B_e$  data published in the literature and our observations obtained during recent 7 years (33  $B_e$  points). New magnetic observations, which were obtained at SAO in 1997–2004, include the phase when the effective magnetic field  $B_e$  in  $\gamma$  Equ apparently reached its minimum value over the recorded 58 years of observations. This fact is of extraordinary importance, because it allows one for a fairly accurate determination of the magnetic period and the amplitude of  $B_e$  variations in  $\gamma$  Equ.

1946–2004 (58 years), see Fig1 (Bychkov et al. 2005c). Assuming that the run of the observed longitudinal field  $B_e$  with time  $T$  can be approximated by a sine wave

$$B_e(t) = B_0 + B_1 \sin \left[ \frac{2\pi(t - T_0)}{P} - \frac{\pi}{2} \right], \quad (1)$$

we determined all four parameters and their errors simultaneously, using the least squares method.

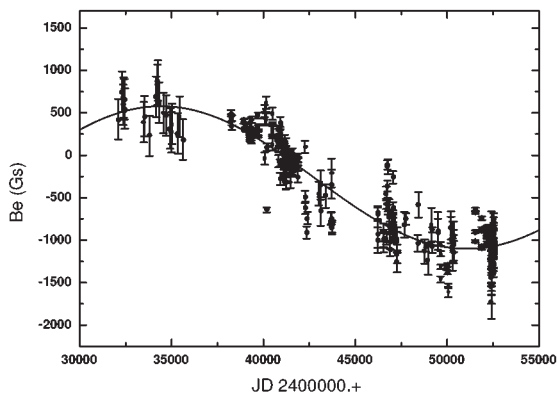


Figure 1: Longitudinal magnetic field  $B_e$  for  $\gamma$  Equ in years 1946–2004.

#### 4. Search for additional periods in $\gamma$ Equ

All the available data cover the time period of 58 years (1946–2004) and include both phases of the maximum and minimum  $B_e$ . Significant scatter of the observed points in the long-term run of  $B_e(t)$  in Fig. 1 suggests the search for short-term periodicities. We applied the strategy of prewhitening to the set of available  $B_e$  measurements, and removed the principal sine-wave variations from the data. Prewhitened data were then analysed with the method developed by Kurtz (1985), and with his Fortran code (Kurtz 2004). We have identified two additional periods of statistically low significance, see Fig.2:

$$P_1 = 348.07 \text{ days, amplitude} = 122 \text{ G}$$

$$P_2 = 23.44 \text{ days, amplitude} = 110 \text{ G}$$

Both peaks in the amplitude spectrum in Fig.2 exhibit low signal to noise ratio, with noise level at ca. 80 G. The period  $P_1$  is close to 1 year. Since most of the existing  $B_e$  observations for  $\gamma$  Equ were performed in months August–October, then the peak  $P_1$  in the amplitude spectrum represents a false period which most likely reflects the average 1-year repetition time in the acquisition of the existing magnetic measurements.

#### 5. Summary

Assuming that the secular variability of the  $B_e$  field is a periodic feature, we determined parameters of the magnetic field curve in  $\gamma$  Equ and give the value of its period,  $P = 91.1 \pm 3.6$  years, with the zero phase (maximum of  $B_e$ ) at  $T_0 = \text{JD } 2417794.9 \pm 62.7$ . Sine-wave fit to the  $B_e$  phase curve yields  $B_e(\text{max}) = +578$  G and  $B_e(\text{min}) = -1102$  G.

Spectral analysis of the 58-year long  $B_e$  time series essentially do not show the existence of shorter peri-

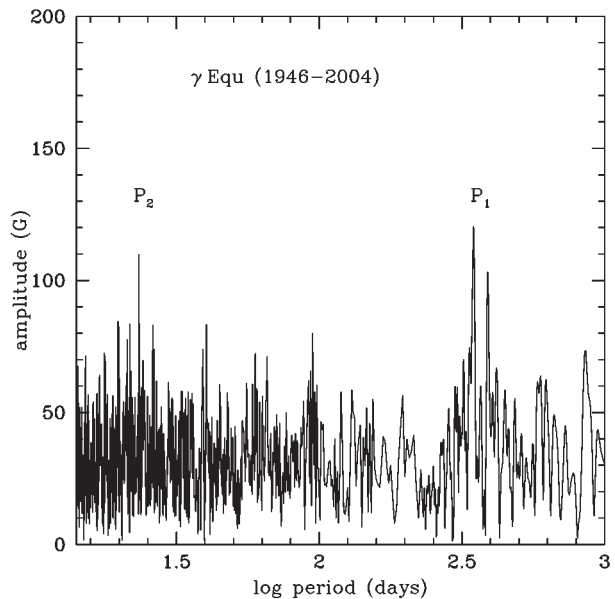


Figure 2: Amplitude spectrum of the  $B_e$  time series for  $\gamma$  Equ, years 1946–2004.

ods, down to trial periods of  $\approx 1$  day. More specifically, there are no real shorter periods in the run of the longitudinal magnetic field  $B_e$  with amplitudes exceeding the noise level of 80 G.

There exists a possibility that  $\gamma$  Equ exhibits periodic variability of its magnetic field  $B_e$  in time scale of the order 10 minutes (Bychkov et al. 2005b). Such a variability can be due to nonradial pulsations of this star.

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#### References

- Babcock H.W.: 1958, *Ap.J.S.* **3**, 141.  
 Bychkov V.D., Bychkova L.V., Madej J.: 2003, *A.&A.* **407**, 631.  
 Bychkov V.D., Bychkova L.V., Madej J.: 2005a, *A.&A.* **430**, 1143.  
 Bychkov V.D., Bychkova L.V., Madej J.: 2005b, *Acta Astronomica*, **55**, 141.  
 Bychkov V.D., Bychkova L.V., Madej J., Sarkisyan A.N.: 2005c, *Bull. GAISH*, **LXXVIII**, 76.  
 Bychkov V.D., Romanenko V.P., Bychkova L.V.: 1998, *Bull.SAO*, **45**, 110.  
 Bychkov V.D., Romanenko V.P., Bychkova L.V.: 2000, *it Bull.SAO*, **49**, 147.  
 Kurtz D.W.: 1985, *M.N.R.A.S.*, **213**, 773.  
 Kurtz D.W.: 2004, *personal communication*.