Staying star gamma Equ

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ABSTRACT

We determined rotational period of practically nonrotating Ap star gamma Equ and claim $P_{\text{rot}} = 97$ years. This period is about 35000 times larger than the average rotational period among stars of the same spectral class. Paper discusses possible mechanism explaining the origin of this phenomenon.

Key words: Stars: chemically peculiar – Stars: magnetic fields – Stars: individual: gamma Equ

1. Introduction

All stars rotate from the birthtime, that is, from the stage of protostars, to the last stages of evolution. Rotational speed plays an important role in star formation stage and in further processes (Tassoul 1982). Accurate value of the rotational period of a star can be determined if the star has a spotty appearance of the surface, on which exist areas of temperature and chemical inhomogeneities, as well as measureable magnetic fields. Such a situation was found e.g. in Ap stars or in spotty BY Dra stars.

Gamma Equ is a well known magnetic Ap star. Magnetic field of that star was studied from 68 years. Over the past 19 years longitudinal (effective) magnetic
field \( B_e \) of \( \gamma \) Equ was continuously studied at the Special Astrophysical Observatory (Russia). As the result, we collected the longest and homogeneous series of measurements, consisting of total 130 \( B_e \) points. Such a unique record of homogeneous observations, which was obtained with the same instruments and the same observers, allowed us to specify more precisely the period of rotation and parameters of magnetic variability of that object. We determined, that both rotational and magnetic periods of Gamma Equ, \( P_{\text{rot}} = P_{\text{mag}} = \) 35394 days. Note, that according to the average statistical relationships period of rotation for stars of this type should be equal to about 1 day (Bychkov et al. 2006; 2015).

2. **Analysis of observational data**

The average magnetic phase curve of \( \gamma \) Equ was shown in Figure 1. Based on that phase curve we derived the following parameters of the longitudinal magnetic field variations:

\[
\begin{align*}
P &= 35394.22 \pm 1171.5 \text{ days} = 96.97 \pm 3.21 \text{ years} \\
B_0 &= -266 \pm 6 \text{ G} \\
B_1 &= 851 \pm 8 \text{ G}
\end{align*}
\]

which implies the following values of parameters, according to Stibbs-Preston formalism (Stibbs 1950; Preston 1967):

- polar magnetic field strength, \( B_p = 11400 \text{ G} \),
- surface magnetic field strength, \( B_s = 7180 \text{ G} \),
- angle of inclination between the axis of rotation and the line of sight, \( i = 63^\circ \),
- angle between the magnetic dipole axis and the axis of rotation, \( \beta = 44^\circ \).

We prewhitened the observed 68-yr \( B_e \) time series from the long term period and using standard methods of spectral analysis obtained shorter period of the magnetic \( B_e \) variability, \( P = 6329.11 \pm 324.02 \text{ days} = 17.34 \pm 0.89 \text{ years} \) with the amplitude of 120 G. The corresponding phase curve with the period of 17.34 years is shown in Figure 2. This variability can be due to the precession of the rotation axis with that period.

3. **Discussion**

The most interesting problem is identification of the reason why Ap star \( \gamma \) Equ has incredibly long period of rotation. We believe that the very long period can be explained as due to braking interaction between the global magnetic field of the and surrounding circumstellar medium (Fabrika & Bychkov 1988). Braking of the rotation is result of the "propeller" mechanism (Illarionov & Sunyaev 1975). As
Figure 1: Long-term magnetic phase curve for the rotational period of 97 years.

Figure 2: Magnetic phase curve for the period of 17.3 years, which is not related to rotation.

was pointed out by Fabrika & Bychkov (1988), propeller mechanism effectively
works only if $R_G > R_A > R_C$, wherein the capture radius $R_G$ is defined as:

$$R_G = \frac{2GM}{\xi^2 v_0^2} \approx 2.0 \times 10^{14} m_0 \xi^{-2} v_{20}^{-2} \, \text{cm}$$  \hspace{1cm} (1)$$

alvenic radius, $R_A$ is

$$R_A = 2^{2/7} \mu^{4/7} M_3^{-2/7} (2GM)^{-1/7} \approx 1.8 \times 10^{14} \mu^{4/7} m_3^{-5/7} \xi^{6/7} v_{20}^{6/7} \, \text{cm}$$  \hspace{1cm} (2)$$

and corotation radius, $R_C$

$$R_C = \left( \frac{GM}{\Omega^2} \right)^{1/3} \approx 6.71 \times 10^{11} \times P_2^{2/3} \times m_3^{1/3} \, \text{cm}$$  \hspace{1cm} (3)$$

Change of the rotational period, $P$, proceeds according to the relation

$$P = \frac{P_0}{(1 - t/t_a)}$$  \hspace{1cm} (4)$$

where $t_a$ equals (in years)

$$t_a = 4 \times 10^{11} \mu_{37}^{-13/14} m_3^{-8/7} \xi^{-6/7} v_{20}^{-17/7} v_{20}^{18/7}$$  \hspace{1cm} (5)$$

Definition of variables were given in detail in Fabrika & Bychkov (1988).

As can be seen from these equations, effectiveness of the "propeller" mechanism is proportional to rotational period of the star and the density of surrounding medium. It turns out that relatively slowly rotating magnetic stars (slow rotators) can very effectively to lose angular momentum due to the interaction with the surrounding interstellar medium under specified conditions. Using the estimates of fundamental physical parameters of $\gamma$ Equ published in Perraut et al. (2011) and the formalism from Fabrika & Bychkov (1988), we find that the star $\gamma$ Equ could lose up to 90 time period of the order $10^7$ years.

It should be noted that this process is not linear and depends on a number of parameters. It should also be noted that slow magnetic rotators very effectively mix surrounding interstellar medium due to the action of "propeller" mechanism.

### 4. Concluding remarks

According to our opinion, such an unusually long period of rotation of $\gamma$ Equ is the result of braking (loss of angular momentum) caused by the "propeller" mechanism (Illarionov & Sunyaev 1975). I.e. that braking results from interaction of the global magnetic field of $\gamma$ Equ with the interstellar medium. This star represents probably the most striking example of a magnetic braking via "propeller" mechanism. The process was currently recognized among magnetic Ap stars.

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