STARS WITH VIGOROUS CONVECTION ENVELOPES AND RESULTS ON GENERAL MAGNETIC FIELD OBSERVATIONS

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ABSTRACT. Existence of the GMF on convective stars with vigorous convective envelopes confirms a conclusion that the GMF is a real phenomenon and reflects properties of a stationary global magnetic field, Origin Magnetic Field, of the Sun', convective star', radiative interior onto its surface. The presence of a variability of the longitudinal magnetic field measurements on ϵ Gem throughout the night is suspected.

Key words: stars: atmospheres, convection, activity; magnetic field

1. Introduction

The first results of the General Magnetic Field (GMF) measurements of the Sun as a star were published by A. Severny (1969). The value of the GMF of the Sun as a Star (GMFSS) varies with the period of sunspots cycle: maximal solar activity - maximal GMF amplitude; minimal solar activity - minimal GMF amplitude (Kotov et al., 1998). This picture represents, to first order, beating of two main neighbour frequencies, 1/26.93 and 1/27.14 (Plachinda, 2004b), which are produced by differential rotation of latitude belts with most contribution to the registered signal (equatorial and active region areas of the Sun). Using these frequencies one can calculate main prominent periods in the power spectrum for GMF of the Sun as a star including period of activity cycle (Table 1). One of the initial periods is due to a rigid rotation of radiative zone, and the second one is produced by differential rotation. Hence, Origin Magnetic Field of the Sun radiative zone is captured by moving matter of the convective zone and transported to the surface, where beating of two main frequencies produces observing picture. What mechanism of macro-organizing of the magnetic fields which are captured by moving matter and transported to the surface? Such possibility give us the law of parameter correlations of self-organizing structures of the open thermodynamic system: "In the thermodynamics of open systems, a star as a whole is a dissipative system of the greatest scale, in which global magnetic fields are self-organized due to the energy of rotation and convective motions, while dissipative systems are realized in small-scale structures due to the energy of the carrier of the deficit of photospheric radiation resulting in stellar flares and other local phenomena. Probably, this general synergetic approach will give a key to understanding the various manifestations of the solar-type activity on main-sequence stars." (Gershberg, 2005).

Computed result	Actual observation
$9.^y5$	$\sim 9.^y5 \div 10.^y5$
$13.^d62$	$13.^d62$
$9.^d02$	$9.^d03$
$27.^d42$	$27.^d42$
$27.^d70$	$27.^d72$
$28.^d14$	$28.^d14$

Table 1: Actual and computed periods for GMF of the Sun as a star

2. Observations

The program of systematic measurements of GMF on slowly rotating stars with convective envelopes was initiated at Crimea in 1989. The observations and data reduction were carried out using 2.6m Shajn telescope, Stokesmeter, coude spectrograph and "'Flip-Flop"' Zeeman Measurements Technique (Plachinda and Tarasova, 1999; Plachinda, 2004a).

In terms of Babcock' and Leighton' phenomenological magneto-kinematic model of the solar cycle and in terms of standard α-Ω dynamo theory, there are only two main components of large-scale magnetic field on the Sun: toroidal magnetic field and axisymmetric poloidal field. Both toroidal (strong) and poloidal (weak) fields change its polarity with a period of $\sim$22 ys. Toroidal magnetic field lies in the base of the convective zone and manifests itself when magnetic loops emerge on the surface in bipolar active regions, reaching peak values during maximum of spot activity. The axisymmetric poloidal field lies under the photosphere

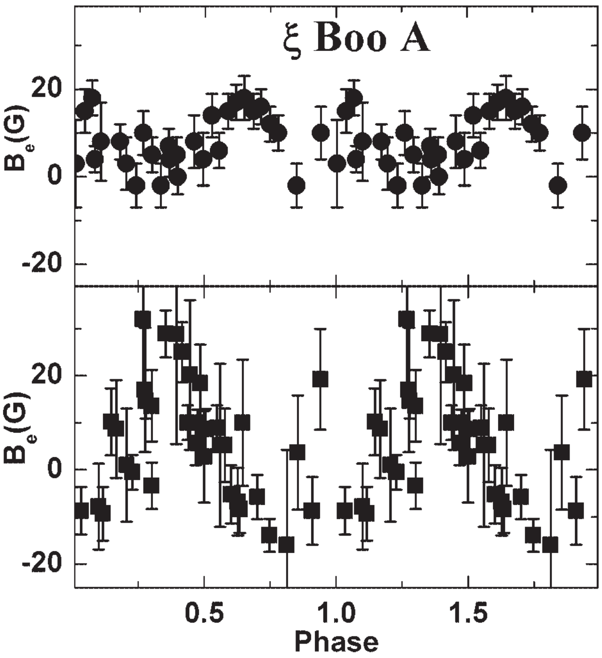

Figure 1: GMF of the ξ *Boo A*

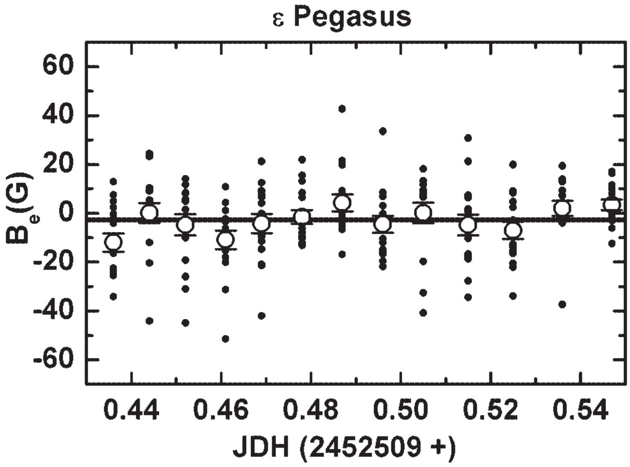

Figure 2: ϵ *Peg:* the example of absence of the significance discrepancy between different longitudinal magnetic field measurements throughout the night. The solid straight line represents magnetic field mean value B_e = -2.7 G.

and changes its polarity with a period of ~22 yr as well, but reaching peak values of about 1-2 G on rotation poles during minimum of spot activity. It is believed today that the underlying cause of the solar activity cycle is the interplay between poloidal magnetic field, differential rotation, and convection that is illustrated by the most developed Babcock' and Leighton' phenomenological model of the solar cycle. According to aforesaid, what is the origin of the GMF?

Today, the presence of weak general magnetic field (up to some dozen Gausses) for 21 convective stars (F9-M3 spectral types and I-V luminosity classes) is detected (Plachinda, 2004a; Plachinda, 2005). For two solar-like stars variations of the GMF as a function of the stellar rotation has been determined: for more active and more young star than the Sun ξ Boo A (G8 V) with P_{rot} = 6.198 d, and for old solar-like star 61 Cyg A (K5 V) with P_{rot} = 36.617 d. For ξ Boo A GMF variations as a function of rotational period was confirmed using MuSiCoS and Stokesmeter by Petit et al. (2005) (see Figure 1, where GMF variations are shown as a function of rotational period: first panel - Stokesmeter, MuSiCoS, Pic du Midi, 2003; second panel - Stokesmeter, Crimea, 1990; 1998-1999 and Multislit magnetometer observations (Brown and Landstreet, 1981; Borra et al., 1984). The bottom curve shows domination of the dipole component contrary to the top curve for 2003 year, which demonstrates the presence of quadrupole component. Analogue behaviour of the GMF on the Sun is present.

Owing to properties of GMFSS (Plachinda and Tarasova, 2000), especially because there is a balance of positive and negative magnetic fluxes, $\Phi_+/\Phi_- = 0.99$, in agreement with Maxwell equation $\vec{\nabla} \bullet \vec{B} = 0$, we suppose that the GMF is real nonaxisymmetric large-scale field on the Sun as on other convective stars.

The radius of stars increases as they evolve out of the main sequence. For convective giants the radii are tens of times the sun's radius and for convective supergiants hundreds of times. In the case of a dipole configuration when the star size increases the field can be decrease as the cube. In the convective giant stage the GMF as the global magnetic field of the radiative zone of a star will be reduced by a factor of $10^3 - 10^5$. In the case of supergiants, this coefficient will be even larger, $10^5 - 10^7$. If a giant is an evolved sun-like dwarf then the global field of the radiative zone beneath of the tachocline of the star would be less than a tenth of a Gauss and undetectable. In this case, as in the case of supergiants, we can suppose that the detected field on the stars surface is probably the product of the operation of dynamo mechanisms. On the other hand, if a giant is an evolved magnetic star with a high initial magnetic field at the poles (10^4 G) then its global field in the radiative core may reach tens of Gauss and can be detectable. In the case of supergiants the magnitude of the field of the former magnetic star in the radiative core is a small fraction of a Gauss and will be undetectable. Therefore, in most cases, the fields which have been detected on giants and supergiants is probably the product of the operation of dynamo mechanisms.

Figure 2 and Figure 3 for ϵ Peg and ϵ Gem illustrate of both the absence and presence of a variability of the longitudinal magnetic field throughout the night. In this case of ϵ Gem, probably, the process of emergence

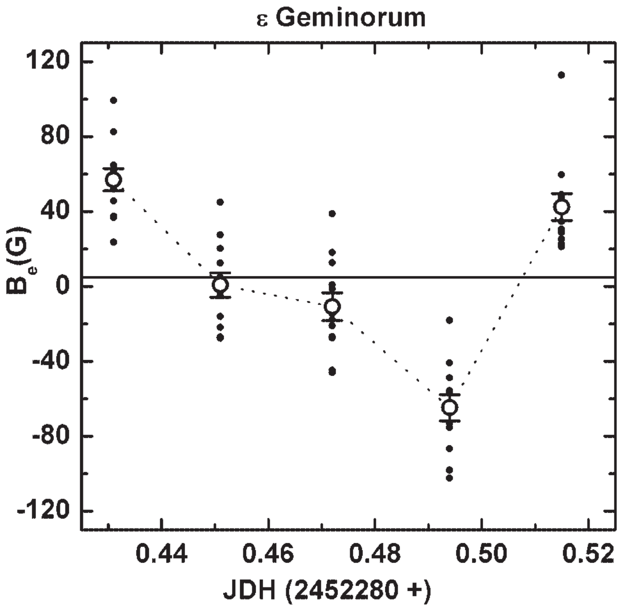

Figure 3: ϵ *Gem:* the significance discrepancy between different longitudinal magnetic field measurements throughout the night. The solid straight line represents magnetic field mean value $B_e = 4.9$ G.

of active region on the surface was registered as it was detected for 61 Cyg A (Plachinda, 2004b).

Existence of the GMF on convective stars with vigorous convective envelopes confirms a hypothesis that the GMF is a real phenomenon and reflects properties of a stationary global magnetic field, Origin Magnetic Field, of the Sun', convective star', radiative interior onto its surface.

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