Proceedings of 12th Cambridge Workshop on Cool Stars, Stellar Systems, & The Sun, 2003 University of Colorado.

Starspots Cycle Phase and Rotational Photometric Period Variations of Young Solar-type Stars: Different Patterns of Correlation

Sergio Messina[1], Edward F. Guinan[2]

Abstract. Very accurate values of the starspots cycle length and of the rotational photometric period have been determined for a sample of five among the most extensively observed young solar-type stars: BE Cet, κ^1 Cet, π^1 UMa, DX Leo and EK Dra.

The analysis of extended time-series of wide-band photometric observations have shown the existence of periodic or multiperiodic variations of the seasonal mean brightness level (starspots cycles) and periodic variations of the photometric period. The latter resulted to be correlated to the starspots cycle phase.

For a few stars (BE Cet, π^1 UMa, EK Dra) we see that the rotation period tends to decrease steadily during the course of each cycle, jumping back at a higher value at the beginning of a new cycle. This is indeed reminiscent of the sunspot cyclic behaviour, where the latitude of spot formation moves toward the equator, i.e., toward progressively faster rotating latitudes along an activity cycle, thus producing a decrease in the photometric period.

However, the remaining stars of the sample (κ^1 Cet, DX Leo) show an anti-solar pattern, where the rotation period tends to increase steadily during the course of each cycle, jumping back at a lower value at the beginning of a new cycle.

The newly determined cycle length values, the lower limit of the surface differential rotation amplitude ($\frac{\partial\Omega}{\partial\phi}$) and the clear evidence of the existence of such opposite patterns represent important observational constraints to the current models of generation and evolution of the stellar magnetic activity.

1. Introduction

In late-type stars the interaction of axial rotation with external convection determines a regime of differential rotation. This is believed to play a key role in the dynamo generation and amplification of magnetic fields and, consequently, in the generation of those phenomena better known as "stellar magnetic activity".

[1]Catania Astrophysical Observatory, Italy

[2]Dept. of Astronmy and Astrophysics
Villanova University, PA

Current models of magnetic activity generation predict the way the differential rotation depends on the global stellar parameters such as spectral type and rotation period (e.g. Kitchatinov & Rudiger 1999).

Analogue but empirical relations are needed to test the model predictions and/or to better constraint the free parameters they use. The sample of stars for which measurements of differential rotation are available is neither large nor homogeneous, but certainly increasing. Actually, only the stellar surface differential rotation (SDR), that is that latitude dependent, can be measured from observations. However, even the SDR put constraints to the value that the radial differential rotation should have.

Surface differential rotation can be currently measured from **a)** Doppler imaging maps (e.g. Donati et al. 1997) **b)** Line profile analysis (e.g. Reiners et al. 2001) **c)** *Rotation period variations* (e.g. present poster). The present poster concerns with this last technique. Although, this technique is the most indirect, however, it has so far provided us with the largest sample of SDR measurements. Rotation periods were determined using a Scargle-Press period search routine (Scargle 1982, Horne & Baliunas 1986). For each season of observation rotation period, its uncertainty (ΔP) and *false-alarm-probability* (FAP) of the peak frequency were derived. A search for secondary periodicities during each season has also been performed by filtering the primary frequency modulation from the data and recomputing a periodogram for the residual data according to the prescription of Horne & Baliunas (1986) and Baliunas et al. (1995). It is important to note that, in addition to the change of the spot rotation period, a factor which may produce variations of the photometric period is the growth and decay of the starspots. Using the method proposed Dobson et al. (1990) (the so-called *pooled variance analysis*) we found that the observed variance for time scales longer than the rotation period levels off and begins to increase significantly only at much larger value τ than which corresponds to the time scale of the active region evolution and activity cycles. Therefore, the interpretation of the changes of the photometric period of the analysed stars in terms of a variation of the rotation period of the starspots appears to be the most likely explanation.

Table 1. The analysed sample of stars

Catalogue number	Name	B−V (mag)	Period (day)	Cycle (year) primary	Cycle (year) secondary	corr. (+) (−)	SDR (%)
HD 1835	BE Cet	0.66	7.702-8.030	6.70	–	+	4.2
HD 20630	κ^1 Cet	0.68	9.045-9.406	5.91	–	−	3.9
HD 72905	π^1 UMa	0.60	4.543-5.385	2.14	12.98	+	17.1
HD 82443	DX Leo	0.76	5.345-5.476	3.206	–	−	2.4
HD 129333	EK Dra	0.61	2.491-2.886	10.91	> 30	+	14.7

2. Discussion

Magnetic activity centers in photoshere, as well as in chromosphere, induce periodic brightness and line width variations due to the stars axial rotation. Therefore, the modulation period marks the angular velocity of the mean latitude at which they are centered.

Time changes of the rotation period can then be interpreted as due to a migration of the center of activity towards latitude with different angular velocity, in analogy with the solar case where the activity belts migrate in time towards latitude with different angular velocity.

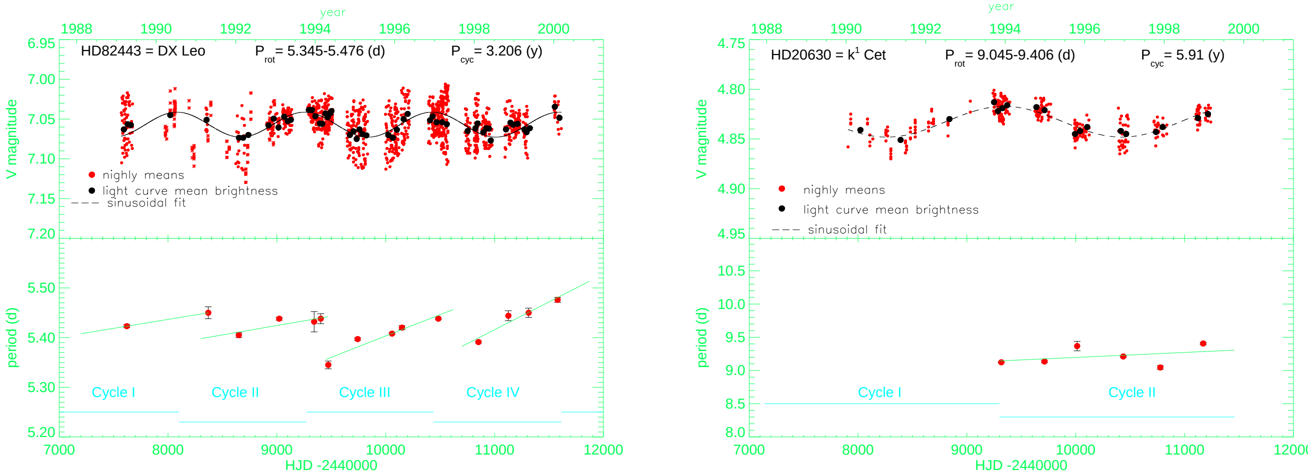
In our sample of single young solar-type stars two out of five show a solar pattern and two out five an anti-solar pattern. We have retrieved from the literature four more stars (HD160346, 15 Sge, 107 Psc, β Com) for which estimates of cycle length and seasonal rotation periods are available, which showed solar or anti-solar pattern. One more star (AB Dor) in the literature was found to show from Doppler images maps a solar pattern in the SDR.

Table 2. The total sample of stars

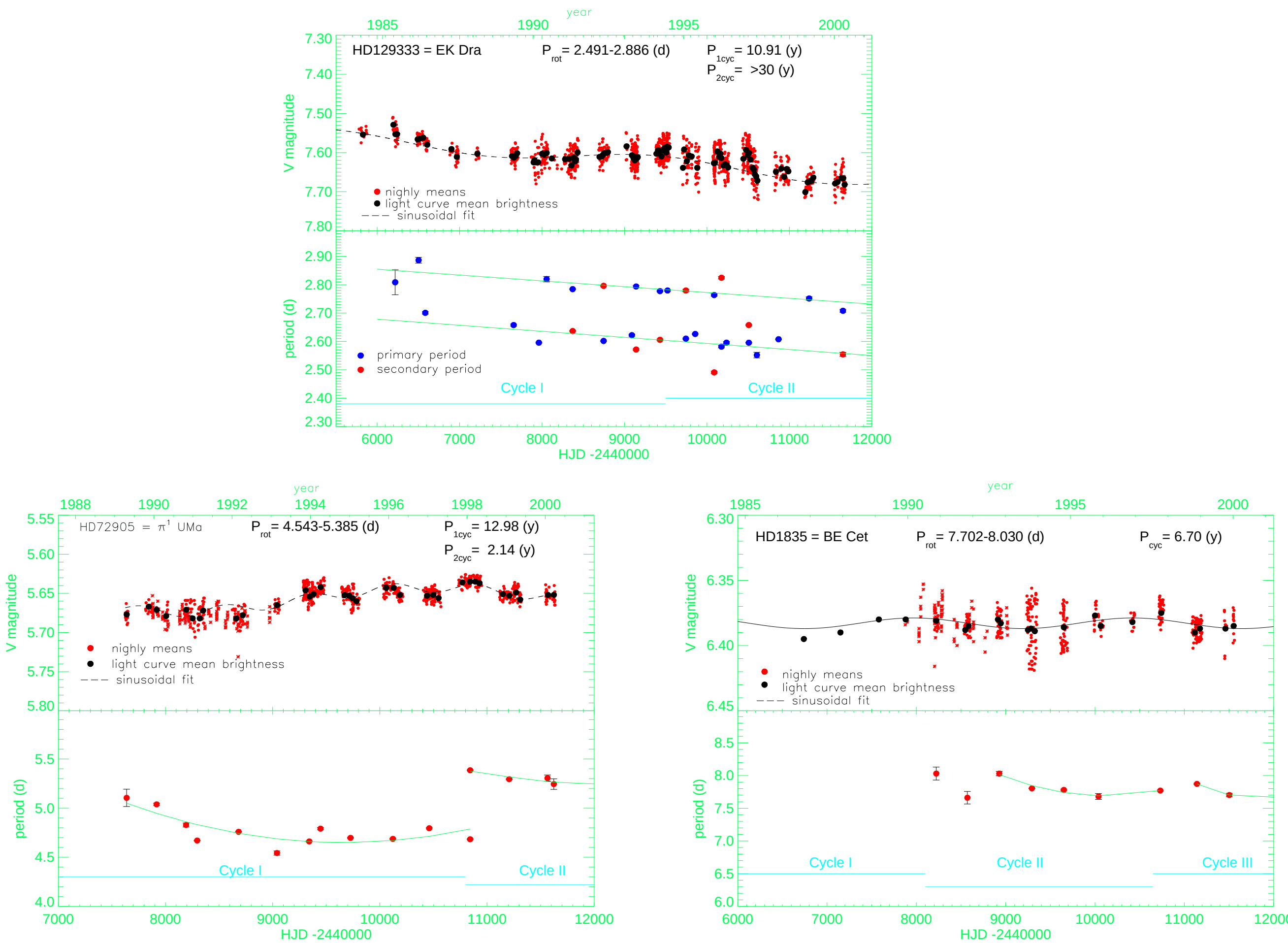
HD number	Name	Sp. Type	B−V	Period range (day)	cycle (year) primary	cycle (year) secondary	Nr	Ref.
				Solar pattern				
HD1835	BE Cet	G2V	0.66	7.702-8.030	6.70		0.609	a
HD36705	AB Dor	K0V	0.83	0.5132-5156	5.3		0.025	d,e
HD72905	π^1UMa	G1.5V	0.60	4.543-5.385	12.98	2.14	0.478	a
HD129333	EK Dra	G0V	0.61	2.491-2.886	10.91	> 30	0.269	a
HD160346		K3V	0.96	35.5-38	7	> 25	1.633	b,c
HD190406	15 Sge	G1V	0.60	13.7-15.3	2.6		1.533	g
				Anti-Solar pattern				
HD10476	107 Psc	K1V	0.84	34-38	9.6		1.745	b,c
HD20630	κ^1 Cet	G5V	0.68	9.045-9.406	5.91		0.672	a
HD82443	DX Leo	K0V	0.76	5.245-5.476	3.206		0.302	a
HD114710	β Com	G0V	0.58	12.35	16.6	9.6	1.546	f

a) present poster; **b)** Donahue 1996; **c)** Saar & Brandenburg 1999; **d)** Oláh et al. 2000; **e)** Donati & Collier Cameron 1997; **f)** Donahue & Baliunas 1992; **g)** Baliunas et al. 1985.

Anti-solar pattern



Solar pattern



3. Conclusions

The analysis of extended time-series of wide-band photometric observations has enabled us to obtain very accurate values of the starspots cycle length and of the rotational photometric period for an increasing sample of solar-type stars. Now, we are in the position to study the correlation between the phase of the starspot cycle and the rotation period variations and to investigate the causes for the existence of a solar or an anti-solar pattern for the SDR and which global stellar properties determine one of them.

References

Baliunas, S. L., Horne, J. H., Porter, A., 1985, ApJ 294,310

Baliunas, S.L., Donahue R. A., Soon, W. H., et al., 1995, ApJ 438, 269

Dobson A. K. et al. 1990, ASP Conf. Ser. vol. 9, p. 132

Donati, J.,-F., Collier Cameron, A., 1997, MNRAS 291, 1

Horne, J., H., Baliunas, S., L., 1986, ApJ 302, 757

Kitchatinov, L. L., Rudiger, G., 1999, A&A 344, 911

Oláh K., Kolláth, Z., Strassmeier, K. G., 2000, A&A 356, 643

Reiners, A., Schmitt, J. H. M. M., Kurster, M., 2001, A&A Letter in press

Saar S. H., Brandenburg, A., 1999, ApJ 524, 295

Scargle, J. D., 1982, ApJ 263, 835