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Searching for the cycle period in chromospherically active stars

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Abstract. The detection and analysis of line emission of the CaII, H(396.8nm) and K(393.3nm) have confirmed the chromospheric activity of some single and binaries stars. This activity is associated to the presence of magnetic fields which in turn are produced by internal convective flows along with stellar rotation producing a long-term photometric cycle length related to the apparition and vanishing of superficial stellar spots. We present a photometric study of stars of the type RS CVn, Rotationally variable Star and BY Dra, that have shown evidence of chromospheric activity. The analysis of these measurements has allowed us to delimit periods of rotation. In addition, we have detected and measured the cycle length in some cases. It allows us to complement previous investigations and in some cases to determine for the first time the presence of a long photometric cycle, contributing to complement the link between rotation and magnetic cycles.

Keywords. Activity, binaries: eclipsing, spots.

1. Introduction

Chromospheric activity (CA) is an interesting phenomenon present in different types of stars such as RS Canum Venaticorum (RS CVn) and BY Draconis variables (BY Dra) which are one of the best and most complete astrophysical laboratories to study stellar activity according to Montes (1995). Since the latter are binaries (RS CVn), the phenomenon of synchronization between P_{rot} and P_{orb} is present due to its proximity, which at the same time generates a fast rotation.

Wilson (1978) was the pioneer in finding evidence of cyclic variation (P_{cyc}) by tracking spectroscopic indicators such as the emission lines of Ca II H (3968 Å) & K (3933 Å), and subsequent studies have allowed to establish that stars exhibit different levels of cromopheric activity. From this discovery and to establish the link between P_{rot} and P_{cyc}, the classification in the known $P_{rot}-P_{cyc}$ plane arises, in which two Active (A) and Inactive (I) sequences are present according to Saar & Brandenburg (1999).

The search for P_{cyc} has not only been addressed in the spectroscopic field, long term photometric missions such as those carried out by Phillips & Hartmann (1978) or Baliunas & Vaughan (1985) found evidence of cyclic activity in low mass stars. In addition, using a photometric analysis, authors such as Böhm-Vitense (2007) and Messina & Guinan (2002) find changes in the rotational period, associated with differential rotation.

Other variation in the light curve associate to the CA is the O'Connell Effect investigated by O'Connell (1951) this phenomenon is produced by asymmetries in the maxima of the light curve.

We present a new photometric study of 5 RS CVn and BY Dra stars, finding new cycle periods (not previously observed) and other indicators associated with CA, for example secondary peaks in the Fourier periodograms (associated with differential rotation) and morphological changes in the light curves.

Table 1. Results of the analysis of light-curves obtained, described in Villegas (2019).

Target	V_{ASAS} [mag]	P_{rot}(Pub.) [day]	P_{rot}(Med.) [day]	Error [day]	P_{cyc} [day]	Error [day]	P_{cyc}/P_{rot} -
YZ Men	7.770	19.58	19.401	0.009	∼827	-	43.54
CK Ant	8.506	29.83	29.5605	0.0049	3203.67	95.07	108.26
V1380	11.593	3.091	3.0921	0.0001	334.97	19.65	108.31
V1382	9.165	38.03	38.03	0.010	2623.1	38.6	69.84
YY CMa	11.262	11.22	5.625	0.010	-	-	-

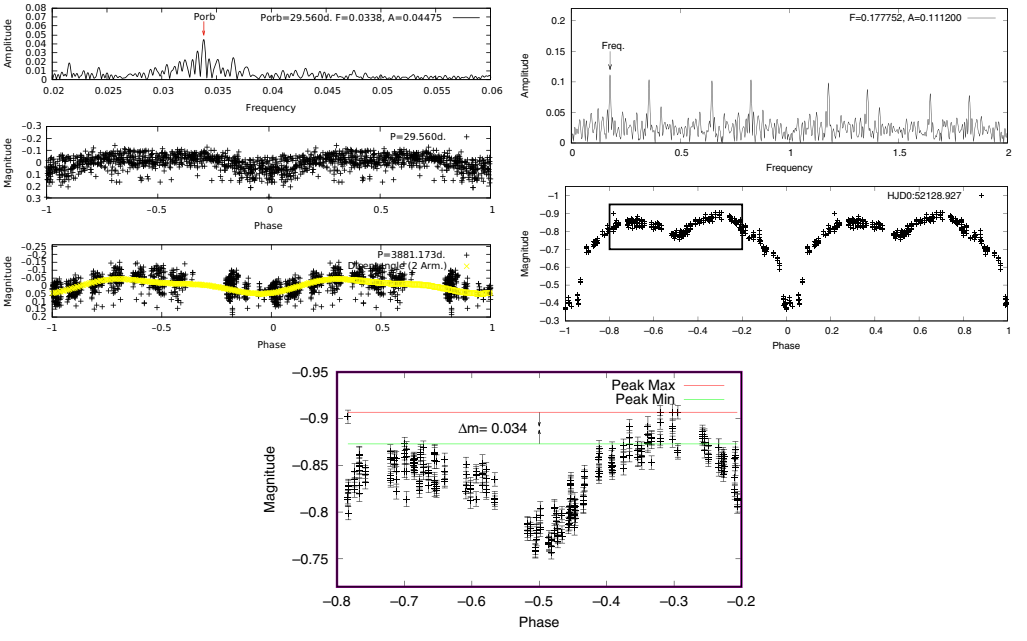

Figure 1. Up left the Periodogram (relation between the amplitude "A" of the light curve and the frequency "F"), rotational and long-cycle phase diagram obtained to the CK Ant star. (The yellow line represent the fit used to apply the disentangling) Top right: is similar but includes only the rotational phase and the periodogram to the YY CMa star, where is possible see secondary peaks associated with alias of the a frequency (for example 2F, 4F) and Down: is a zoom to the region where the O'Connell effect is identified.

2. Overview

Using photometric data, we obtained the final light curve from TAROT telescope, a 25-cm telescope located in La Silla Observatory, Chile with g,r,i and c filters, (data were reduced by a standard way using IRAF tasks ccdred and phot) and photometric observations provided by the All Sky Automated Survey described in Pojmanski (2003), these observations consist of simultaneous photometry in filter V through five apertures.

We disentangled the light curve into an orbital and long-cycle part with the aid of a Fourier decomposition algorithm described by Mennickent *et al.* (2012).

An overview of the five new long-cycle periods is shown in Table 1. The orbital and long-cyclic light curves for one system (CK Ant) are shown in Fig 1. In addition, the detection of O'Connell effect in YY CMa, indicator of Chromospheric Activity is also shown.

In the Figure 2, we include different published databases and the used fit, shown in Vida *et al.* (2013), Boro Saikia *et al.* (2018), Vida *et al.* (2014) and Oláh *et al.* (2016), incorporating our data we make a new adjustment shown with the blue line.

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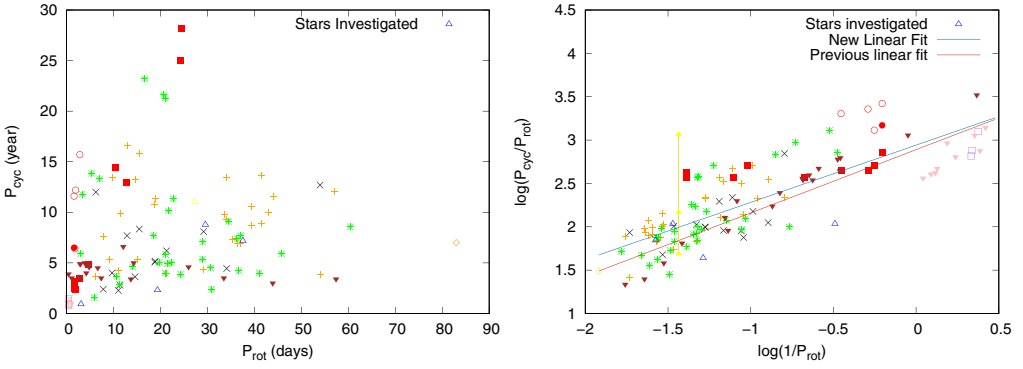

Figure 2. Different relation between orbital and magnetic cycle, using the database shown in Vida *et al.* (2013), Boro Saikia *et al.* (2018), Vida *et al.* (2014) and Oláh *et al.* (2016), the new fit is given by: $log(P_{cyc}/P_{rot}) = (0.66 \pm 0.04) log(1/P_{rot}) + (2.94 \pm 0.5)$.

3. Implications

• Using about 4500 CCD images obtained from our own TAROT observations and together with ASAS database, we find in 4 of the 6 stars analyzed, for the first time the presence of a long photometric cycle associated with chromospheric activity, for YY CMa confirm the activity through the presence of the O'Connell effect.

• When inspecting the $P_{cyc}-P_{rot}$ plane, unlike initially shown by Böhm-Vitense (2007), we observe the disappearance of possible I and A sequences.

• A lineal fit of the type $f(x) = ax + b$ was made including our new data, to determine the relationship between the magnetic and rotation period.

• We identify the presence of secondary peaks in the periodograms, showing possible signals related to stellar spots and the differential rotation.

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