PHOTOMETRIC SEARCH FOR AN ACTIVITY CYCLE IN THE YOUNG SOLAR ANALOGUE EK DRACONIS

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ABSTRACT

We have performed a long-term photometry of the young solar analogue EK Draconis (HD 129333) using 1030 blue-sensitive Sky-Patrol plates taken at Sonneberg Observatory from 1958 onwards. A secular dimming of 0.0057 ± 0.0008 mag/y beginning around 1975 has been found. Hence, the recent trend first observed with Automatic Photoelectric Telescopes (APTs) is confirmed and traced back to the mid-seventies.

Key words: Stars: activity; Stars: individual (HD 129333 = EK Dra); Stars: late-type; Stars: rotation; Stars: variables: other.

1. INTRODUCTION

Despite large sunspots, flares and coronal mass ejections in the solar maximum, the recent sun is not a really active star. There are other sun-like stars which are far more active. The reason for its only modest activity is its slow rotation. In the sequel the solar dynamo produces weak magnetic fields only. Accordingly, the sudden release of magnetic energy due to magnetic reconnection is moderate too, but nevertheless space weather is sometimes dangerous.

In former times the sun must have been more active. Since its days of infancy the sun has lost most of its angular momentum, having blown it away by a magnetized wind. It would be interesting, esp. for paleoclimate modelers, to know more about the faint fast-spinning young sun and its activity.

Because star formation has not yet ceased in a galaxy such as our own one may find among newly-born stars solar twins with the same mass and the same chemical composition as our sun, but rotating faster and being much more active. The most active among young solar analogues found so far is the star EK Draconis (Dorren & Guinan 1994, and references therein).

2. EK DRACONIS

HD 129333 (G1.5 V) is a probable member of the Pleiades moving group (age < 100 Myr). Due to its rapid rotation (2.7 d) it is very active with rotationally modulated short-term variability (BY Dra type). Flare activity and coronal X-ray as well as microwave emission are also observed.

The star, however, is not simply a spin-up version of our sun. It differs in a qualitative manner from the sun. For example Doppler tomography has revealed the existence of a persistent near-pole spot (Strassmeier & Rice 1998). Moreover, there seems to be an important difference between slow and fast rotators. While the sun exhibits a strong differential rotation fast rotators must rotate more rigidly. But then the α-effect, the source of the magnetic field, seems to be unable to produce an oscillating dynamo. At a glance there should no activity cycles at all. Producing oscillating magnetic modes in the absence of differential rotation is not a simple task (Elstner et al. 2002). It is this finding our interest in an activity cycle for EK Dra stems from.

3. OBSERVATIONS

UBV photometry obtained with robotic telescopes has already revealed a decline in mean luminosity over years (Strassmeier et al. 1997, 1999; Messina & Guinan 2001). Because precision photometry of this star is available only from 1994 onwards, we have performed a long-term photographic photometry on blue-sensitive Sonneberg Sky-Patrol plates taken between 1958 and 1995 (Fröhlich et al. 2002). The plates cover $26° \times 26°$ on the sky up to a limiting magnitude of $\approx 14^{\mathrm{m}}$. More than 1400 B-plates of the four patrol fields containing EK Dra were scanned by means of a CCD-line scanner with 15 μm resolution, corresponding to 12.4 arcsec/pxl.

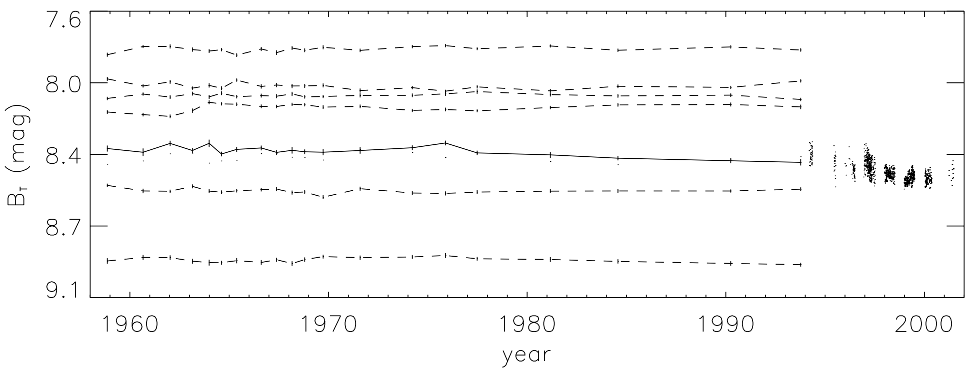

Figure 1. B_{T} light-curves for EK Dra (full line) and six comparison stars. Each time bin contains up to 52 brightness estimates. From 1994 onwards EK Dra has been monitored by robotic telescopes (Strassmeier et al. 1997, 1999, and yet unpublished measurements). These photo-electrically measured brightnesses, transformed into B_{T} and not averaged, are shown too.

4. OUTLINE OF THE METHOD

The photometric accuracy of a single measurement is $\simeq 0.07$–0.1 mag (Vogt & Kroll 1999). By averaging one can reduce (in the absence of any systematic errors) the photometric error of the mean. Rotationally induced short-term brightness variation is considered here as an additional random noise.

In order to cope with all the drawbacks inherent to such kind of study we rely only on the presumed constancy of six comparison stars (all but one belonging to spectral types A and F) with known Tycho-2 brightnesses, B_{T}, which were used for interpolation.

The plates are uncalibrated. After experimenting with a two-parameter representation of the characteristic curve which leads to a far too high mock accuracy and a strong correlation between the two parameters (gradation and a non-linear term) we decided to neglect any non-linearity and to fix the gradation, $\gamma = 1$, confirming Kroll & Neugebauer (1993) who claimed that this already yields, after background subtraction and integration within a centred aperture, satisfying photometric results.

In order to tie magnitudes into the Tycho-2 photometric system we have considered a colour equation, whose coefficients depend linearly on time (to allow for a drift in colour sensitivity). Moreover, a field error has been taken into account. For a given sky-patrol field altogether five free parameters remained to be fixed by constrained least-squares. (We have considered further effects too, as a scale error and the Purkinje effect, but the gain in goodness-of fit was marginal.)

5. RESULTS

A Friedman test certifies us that (at a five per cent level) the factor time does not affect the comparison star data. Repeating the analysis, with EK Dra being considered constant too, does not result in a satisfying fit.

In the upshot EK Dra's mean B-brightness faded significantly by 0.0057 ± 0.0008 mag/y beginning around 1975 (Figure 1). Hence the trend found by Messina & Guinan (2001) with means of APTs is confirmed and traced back to the mid-seventies. This trend of course hints at a very long activity cycle. (Using their empirical correlations between dimensionless cycle length and the inverse Rossby number, Saar & Brandenburg (1999) estimate for EK Dra a cycle lengths of 39 years, if EK Dra belongs to the so-called superactive branch.)

There are not enough plates to reveal an asserted 11-year activity cycle (Messina & Guinan 2001).

In the case of EK Dra the standard deviation from a bin mean exceeds the estimated mean photometric accuracy by a factor of ≈ 1.5. There is no indication that the strength of this spot induced rotational variability depends on time.

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