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Constraining starspot properties by means of multiband photometric data

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Abstract. The photospheres of magnetically active stars are characterized by the presence of spotted regions. The stellar rotation modulates their visibility and determines broad-band and color variations because the spots are cooler than the unperturbed photosphere. The amplitudes of the light and color variations depend on the area and temperature of spots, and on their distribution over the stellar surface. We constrain the properties of the spotted regions by comparing the observed amplitudes of light and color variations with synthetic amplitudes obtained by means of Dorren's spot model (Dorren 1987) and computed for a grid of values of spot temperatures, areas and latitudes. Preliminary results of our analysis are presented.

Key words. Stars: Late-type – Stars: spots – Stars: photometry – Stars: AB Doradus

1. The test target: AB Doradus

The K0 single dwarf star AB Doradus (HD 36705) is here considered to test the validity of our approach of modelling simultaneously the light and color variation amplitudes of magnetically active late-type stars. It is a well known active star showing brightness and color variations attributed to the presence of dark spots. The short-term variability of the V magnitude and of the U−B and B−V colors is due to the stellar rotation that modulates the spotted region visibility, as the spot pattern is unevenly distributed along the stellar longitude. The long-term variability of the mean brightness is due to the intrinsic evolution of the spot pattern and a periodogram analysis suggests the existence of a starspot cycle of about 17.5 yr.

Our aim is to model the amplitude of such variations to derive information on spot area and temperature. In Fig.1, we display a sample of the light curves of AB Dor, whose amplitude variations are to be compared with the synthetic V magnitude and B−V color curve amplitudes. We point out that we are presently modelling only the light and color curve amplitudes and not their shape. The NextGen model atmosphere grid of Hauschildt, Allard, & Baron (1999) is adopted to compute synthetic stellar fluxes. The limb-darkening coefficient for either the unspotted and the spotted photosphere are from Diaz-Cordoves, Claret,

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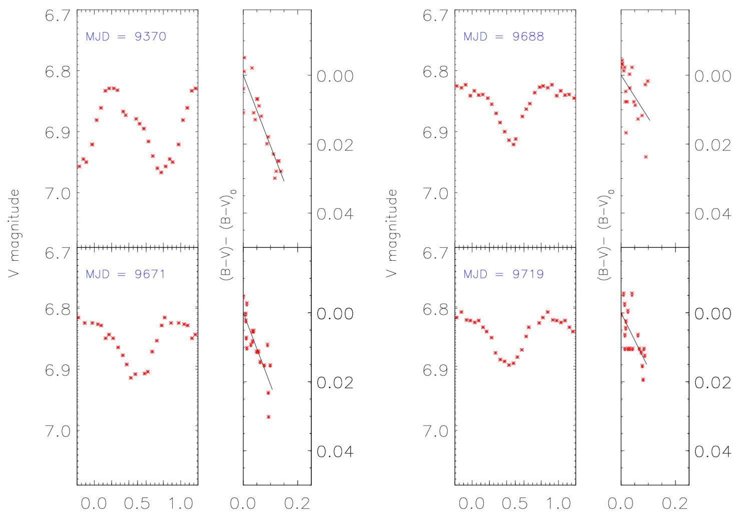

Fig. 1. *Left panels:* a sample of light curves of AB Dor: V magnitude is plotted vs. rotational phase, as computed adopting the ephemeris HJD= 2444296.575 + 0.51479 × E. *Right panels:* the B−V color variations are plotted vs. the V magnitude variations. V_0 and $B-V_0$ are the brightest magnitude and bluest color, respectively, at any given mean epoch.

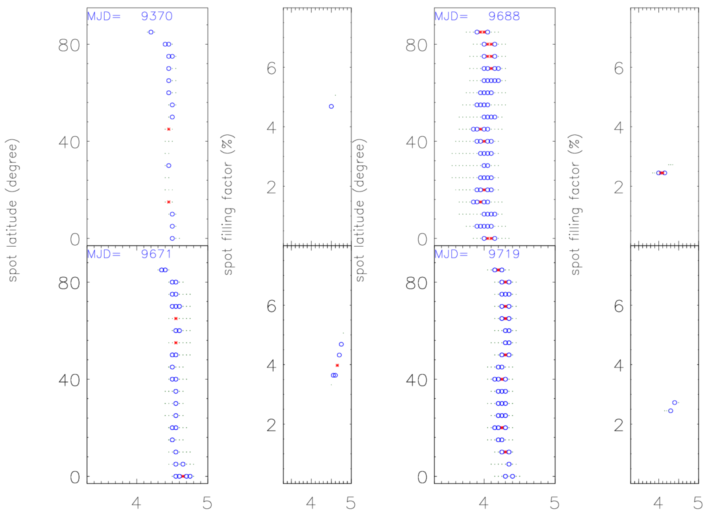

Fig. 2. *Left panels:* the chi-squares (χ^2) distributions of the fits to the observed V magnitude vs. B−V color variation amplitudes are plotted in latitude - temperature diagrams for the same mean epochs shown in Fig. 1. Dots, open circles and asterisks represent the best fit solutions for increasing chi-square values ranging,respectively, from χ^2=0.2 to χ^2=1.0. *Right panels:* the spot filling factor values (%) are computed with respect to the whole stellar surface. Symbols have same meaning than in left panels.

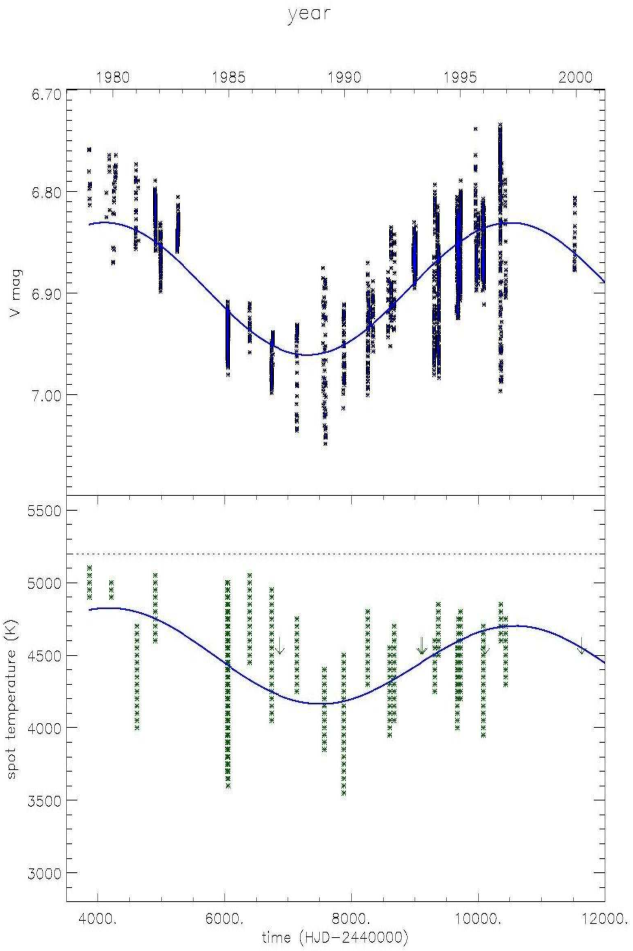

Fig. 3. *Top panel:* long-term sequence of V magnitudes of AB Dor. The continuous line is a sinusoidal fit to the data with a period of P_{cyc}=17.5 yr, which is the staspot cycle period. *Bottom panel:* the spot temperature, as derived from our analysis, is plotted vs. time. The average spot temperature seems to vary in phase with the starspot cycle. The downward arrows show the upper value for the temperature in those mean epochs when the spot temperatures are not well constrained.

& Gimenez (1995). The assumed parameters are the stellar effective temperature (T_{eff}), the inclination of the stellar rotational axis (i), the gravity log g and the unspotted stellar magnitude (V_{un}). We adopted the value of T_{eff}= 5200 K, the inclination i = 90°, the gravity log g = 4.5 cm s^{-2} and the unspotted magnitude V_{un}=6.756. Synthetic V and B−V curve amplitudes were generated for a grid of values of the spot temperature, radius and latitude.

2. Results

Fig. 2 shows, in latitude-temperature plots, the chi-square distribution of the fits to the V vs. B−V variation amplitudes as obtained from the analysis of the light curves in Fig. 1. As expected, solutions are not unique. However, they tend to cluster around a finite range of values of the spot temperature. As it is better shown in Fig.3, the spot temperature in a few epochs is found to vary significantly from the average value. Assuming the umbra/penumbra sunspot analogy, and assuming that either the umbral and penumbral components have a constant temperature in time, the inferred variation in the spot temperature can be very likely attributed to a variation in their areal ratio. In another reasonable scenario, we can image that active regions consist of dark spots and bright faculae, and the changing ratio of spot/plage is responsible for the observed average temperature variations.

References

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