THE DEPENDENCE OF THE BY DRA–TYPE VARIABLE SPOTTEDNESS ON GENERAL STELLAR PARAMETERS

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Within the framework of the zonal spottedness model for red dwarf stars that was proposed and developed in Crimea, a spottedness of a star is approximated with two belts parallel to a stellar equator with a linear variation of darkness along the belt. Using $UBVRI$ observations of 25 stars for 342 observational epochs such models have been calculated for all these photometric data. Here we confront model parameters with global characteristics of stars under consideration – absolute luminosities, the Rossby numbers, rotational velocities. A set of good correlations is found, and the Sun fits to all of them.

In our papers (Alekseev & Gershberg, 1996ab) we proposed and developed a new approach to analyse the surface inhomogeneities of red dwarf stars based on the multicolour broad band photometry. Instead of trying to explain the observed photometric effects in the traditional way by estimating parameters of one or two – three large separate spots, we consider general characteristics of spotted regions on a star. We approximate the aggregate of stellar spots by two spotted belts located symmetrically relative to the stellar equator with variable linearly along stellar longitudes filling factor of the dark regions inside these belts.

This model can be described by four independent parameters: a distance of the belts from the equator $\pm\phi_0$, a width of the belts $\Delta\phi$, a lower limit of a range $(f_{min}, 1)$ for a filling factor into a belt and a spot/photosphere contrast β_V. The main advantage of our zonal model is a possibility to reproduce a spottedness picture similar to the solar one.

We used our algorithm to analyse all photometric observations of 25 red dwarf stars for 342 epochs (Alekseev & Gershberg, 1996c; Alekseev, 1998; Alekseev, 2000; Alekseev & Bondar', 1998; Alekseev & Grankin, 2001; Alekseev & Kozlova, 2000; Alekseev & Kozlova, 2001).

These stars occupy the wide ranges of spectral classes $(dG1e \div dM4.5e)$, luminosities $(M_V = 4\overset{m}{.}80 \div 12\overset{m}{.}24)$ and equatorial rotation velocities $(v_{rot} = 4 \div 25$ km/s). Therefore, we can draw preliminary conclusions about general regularities of the red dwarfs' spottedness.

It is known that the solar-type activity is determined by general structure and rotation of a star. The stellar structure primarily depends on its mass or on color index as an indicator of the mass. We compare our model parameters with the color index $V - I$.

Stellar rotation is characterized by its linear velocity v_{rot}, which can be determined from the observed period and stellar radius. The kinematics of stellar internal layers is determined by the Rossby number. Figure 1 presents comparisons of some zonal model parameters with these general stellar parameters $V - I$, v_{rot} and Ro. The vertical line in Fig. 1b corresponds to the range of spot latitudes on the Sun. The value $< \phi >= \phi_0 + \Delta\phi/2$ is a mean latitude of starspots.

The main results of the comparison of spottedness model parameters with general stellar characteristics are following:

– For all stars with $V - I > 1\overset{m}{.}5$, *i.e.*, with $T_{phot} < 4700\ K$, $\phi_0 = 0$ at all epochs. In other words, the two spot belts merge into a single equatorial belt. Such spottedness picture is directly confirmed for a single rapidly rotating star $LQ\ Hya$ studied by the Doppler Imaging (Rice & Strassmeier, 1998).

– The spotted belt width $\Delta\phi$ decreases to the hot end of the our sample. The hottest star of our sample $BE\ Cet$ of the same spectral class as the Sun has the lowest value of $\Delta\phi$, which is the closest to the situation on the Sun.

– The values $< \phi >$ show that starspots concentrate near the stellar equators on cool stars and near middle latitudes on the solar type stars. On latter stars the starspot latitude distribution is similar to the solar one. It should be noted that our algorithm did not impose any restriction on definable spot latitudes but in no case the latitudes $\phi_0 + \Delta\phi$ turned out to be more than 60°. Therefore, we did not found either very high latitude or

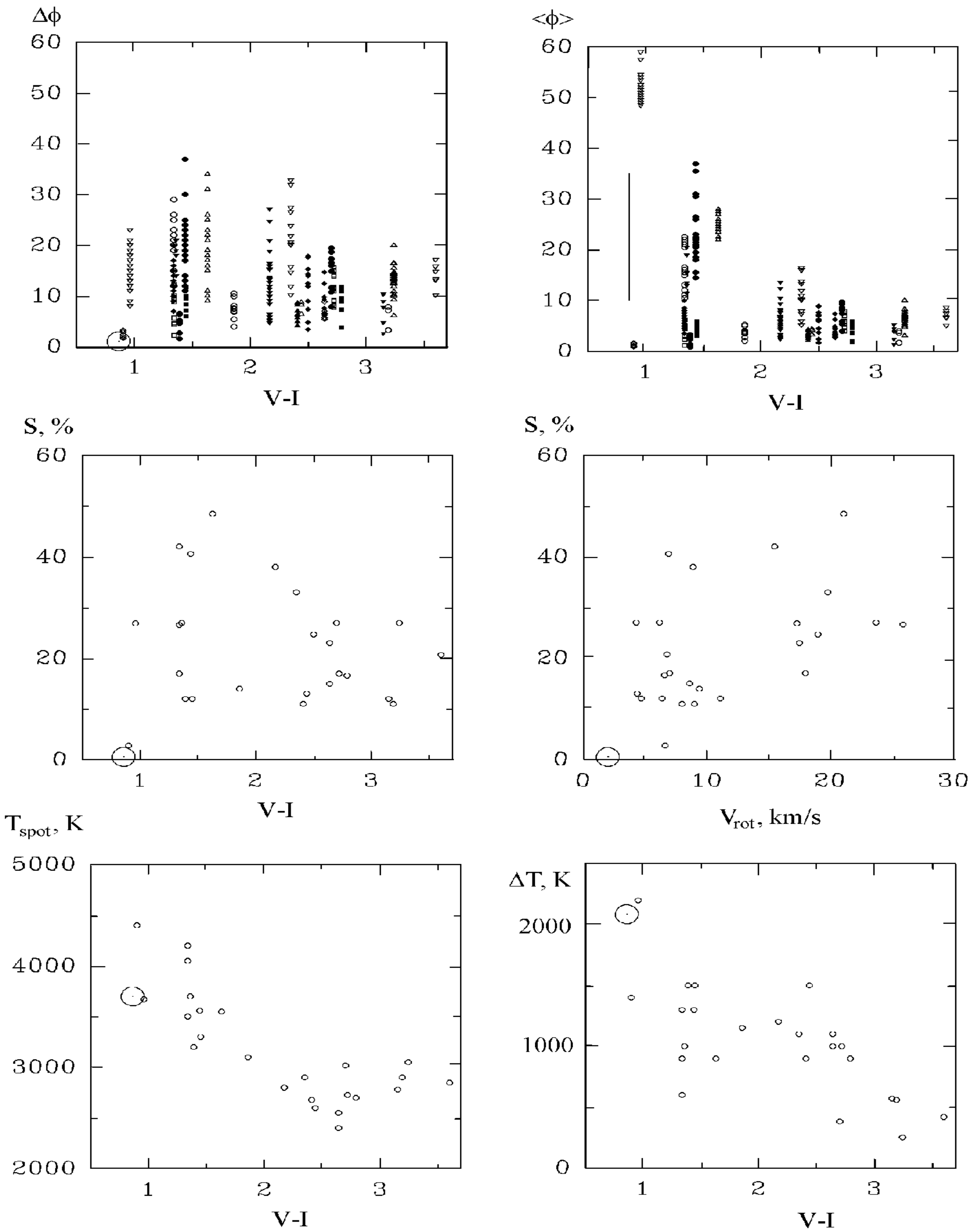

Figure 1: The comparison of model parameters with general stellar characteristics

circumpolar starspots.

– The coverage parameter f_{min} does not depend on any general stellar characteristics.

– The combination of ϕ_0, $\Delta\phi$ and f_{min} gives us the value of total spotarea S in each epoch measured in percents of the total stellar surface. The maximum S values for each star given in Figs. 1c, 1d demonstrate a tendency to increase S, when the rotation velocity grows. The largest spotarea values take place at the rotation velocity $v_{rot} \sim 15-20$ km/s. In this case spotted regions occupy up to 50% of the total stellar surface.

– The dependence of S on $V-I$ shows that the maximum spotarea takes place for stars with the spectral classes K. $BE\ Cet$, whose characteristics are the closest to solar ones, has the lowest spottedness degree approaching to the solar value.

– The mean starspot temperatures indicate well the defined statistical dependence: the coolest spots are on the coolest stars (Fig. 1e). The starspot temperatures are from 4000 K on solar-like G stars to $2500-3000$ K on the coolest M stars. The mean temperature difference ΔT between the quiet stellar photosphere and starspots is from 2000 K on the hottest stars to 300 K on the coolest stars (Fig. 1f).

– The sunspots fit to all these dependences.

In other words, we see a tendency for parameters of our models to match the characteristic parameters of solar spottedness. This matching leads us to believe that our zonal models indeed reflect fundamental properties of the red dwarf stars' surface inhomogeneities.

We intend to apply our model to the $T\ Tau$ and $RS\ CVn$ type variables, where the Doppler Imaging shows systematically an existence of high latitude or circumpolar starspots.

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