TIME-SERIES PHOTOMETRIC SPOT MODELING OF THE RS CVN BINARY HR 7275

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ABSTRACT We present a time-dependent spot modeling analysis of 15 consecutive years of $V$-band photometry of the long-period ($P_{\text{orb}} = 28.6$ days) RS CVn binary HR 7275. This baseline in time is one of the longest, uninterrupted intervals a spotted star has been observed. The analysis yields a total of 20 different spots throughout the time span of our observations. The observed, maximum lifetime of a single spot (or spot group) is 4.5 years, the minimum lifetime is approximately one year. If we assume that the mechanical shear by differential rotation sets the upper limit to the spot lifetime, the observed maximum lifetime in turn sets an upper limit to the differential-rotation coefficient, namely $0.04\pm0.01$. This would be differential rotation just 5 to 8 times less than the solar value and one of the strongest among active binaries.

DIFFERENTIAL ROTATION AND SPOT LIFETIMES

Most spots on HR 7275 can change their size and/or position on the stellar surface from one rotational cycle to the next (see Fig. 1). But most of the time there is more than one spot on the visible surface and separating the effects of the individual spots from the combined light in a time series is not straightforward and not unambiguous. Thus the determination of a spot's approximate lifetime helps to separate these effects and also supplies an important quantity for a starspot theory based on dynamo action.

Figure II is a plot of spot lifetime against maximum spot area of the 20 spots seen on HR 7275 over the past 15 years (Strassmeier et al. 1993). Either there is no clear correlation between lifetime and area of a starspot on HR 7275 or it is masked out by short-term variations. Hall & Busby (1990) computed upper limits of spot lifetimes based on the idea that large starspots will be disrupted by the shear of differential rotation. Figure II plots their predicted disruption time scales for three values of the differential-rotation coefficient $k = \Delta P/P = 0.02, 0.05$, and $0.10$ (note that the corresponding solar value is around 0.2). If we assume that the mechanical shear by differential rotation sets the upper limit to a spot's lifetime, the observed maximum lifetime in turn sets an upper limit to the differential-rotation coefficient, namely approximately $0.04\pm0.01$ according to Fig. II. This would be differential rotation just 5 to 8 times less than the solar
value and one of the strongest among active binaries.

Based on a large number of spots on 26 different spotted stars, including the Sun, Hall & Henry (1993) obtained a relation between spot radii and lifetime for a given stellar radius. For the K1 giant of the HR 7275 binary system these relations take the form

\[ \tau_{\text{empirical}} = 10^{0.13r_\text{spot} - 1.48} \]  \hspace{1cm} (1)
\[ \tau_{\text{disrupt}} = \frac{P_\text{rot}}{k} 0.285 r_\text{spot} \quad \text{if } r_\text{spot} < 20^\circ \]  \hspace{1cm} (2)
\[ \frac{P_\text{rot}}{k} (0.255 r_\text{spot} + 0.06) \quad \text{if } r_\text{spot} > 20^\circ \]  \hspace{1cm} (3)

where \( k \) is again the dimensionless differential-rotation coefficient, \( A_\text{spot} \) is the area of a spot as a fraction of the whole sphere, and \( r_\text{spot} \) is the spot radius in degrees. Note that the empirical \( \tau - A \) relation in Eq. (2) is valid only as long as \( \tau_{\text{empirical}} < \tau_{\text{disrupt}} \) and could be interpreted as the stellar analog of the fact that larger sunspots have longer lifetimes than smaller sunspots. Bumba (1963) and others already demonstrated that the slow decay of sunspot area is nearly constant in time and equal for a large number of studied cases.

**EVOLUTION OF THE STARSPOTS ON HR 7275**

Even though we have 15 consecutive years of photometry of a star with a fairly long rotational period (28 days), and thus good phase coverage, there seems to be no clear indication of any periodicity in the spot behavior. This result in itself is very interesting because it might be an indication that in overactive binary stars like HR 7275 the underlying dynamo is quite different from what we believe is the solar dynamo. Figure I clearly shows non-periodic changes of the visual brightness. So far, the faintest light-curve maximum occurred in 1987 and the brightest in 1981 with a difference of the peak magnitudes of 0.2 mag in \( V \). This large a variation can not be accounted for with the same spots that produce the rotational modulation and needs to invoke some other features,
FIGURE II  Spot lifetime versus spot area for the 20 individual spots identified on HR 7275. The dotted lines are the predicted disruption times $\tau_{\text{disrupt}}$ as a function of the differential rotation coefficient $k$ and the full line is the empirical relation of the observed (mean) spot lifetimes from a sample of 26 spotted stars. The dots are the observations of HR 7275. Arrows indicate lower limits.

e.g. a polar spot always in view or a symmetric spottedness all over the star or a changing average photospheric temperature due to facular contribution that would make the “unspotted” magnitude a function of time.

Spot cycles in evolved RS CVn-type photospheres are obviously not as straightforward to observe as emission-line cycles in main-sequence stellar chromospheres, as for example in many dwarf stars observed in the Mt. Wilson Ca II H & K project. This has primarily three reasons: first, the spot cycle period in evolved stars might be much longer than the time span of the observations (15 to 20 years is the best coverage with photoelectric photometry), second, there are large, superimposed, short-term light variations likely unrelated to a magnetic cycle and most likely due to the birth and decay of individual spots and, third, the light amplitude due to rotational modulation can be as large as the cycle amplitude or even larger.

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REFERENCES
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