STARSPOTS: AN UNCONVENTIONAL SOURCE OF VARIABILITY

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Abstract

Qualitative features of stellar variability produced by surface spots are discussed, and possible photoelectric observations are described.

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In Edward Pickering's day (Pickering 1880) starspots were a respectable source of stellar variability but they soon fell out of favor and remained so until recent years, when they seem once again to be invoked as the cause of every oddity in stellar variability.

They returned to favor following Kron's attribution of a peculiarity in the light curve of YY Geminorum to this cause (Kron 1952), and were reinforced by the discovery of the strange behavior of BY Draconis by Krzeminski and Kraft (1967) about 15 years later. I ran into CC Eridani about the same time (Evans 1971; Bopp and Evans 1973) and gradually became convinced that its variability was caused by spots. I believe the wider popularity of this phenomenon dates from this time, greatly helped by the work of my distinguished students, Bernard Bopp and Thomas Moffett.

I pointed out that any mathematical analysis must be entirely symmetrical as between the spot and the rest of the star, and likened this to the zebra problem (is this a white animal with black stripes or the other way around?), though a referee would not let me say so.

To produce any effect starspots must be large (up to even 30 percent of the star disk) but can usually cause no more than a few hundredths of a magnitude variation in brightness, rarely as much as two tenths, as the parent star rotates. For an equatorial view the shape of the spot is of little importance since it is highly foreshortened as it first appears and finally disappears from view. The total obscuration when the spot is fully in view is measured by the amplitude of the light variation, the longitudinal extent by the excess over the half-period in which any depression of the light is seen. If the spot is actually a pair made of a big and a small spot, the light curve will be asymmetrical, but otherwise the shape of the light curve is so insensitive to the detailed structure that little definitive information can be derived.

Stars like BY Dra and CC Eri which have good spectroscopic orbits can easily be shown from plausible estimates of masses to present not only their equatorial but also a polar area to our view (Oskanyan et al. 1977). A spot in the polar area will produce an almost constant depression of light, while an equatorial spotted area will produce in addition to this an oscillation giving the star's rotation period.

Spots on these red dwarf stars can last for months and can extend into the polar area. If a spot migrates over the pole we can get a sudden reversal of phase by 180 degrees, and this seems to have happened in the case of both BY Dra and CC Eri. BY Dra is exceptional in having an eccentric orbit with a spot period of 3.9 days and a spectroscopic period of 5.8 days, but the two periods do not seem to be phase locked. The photometric period is assumed to be the rotational period of the spotted star.

All these spotted red dwarfs are rapid rotators with equatorial speeds of between 4 and 40 kms^{-1}, and they often show transient emission lines of hydrogen as well as H and K of ionized calcium, and they flare. We have not been able to demonstrate a correlation between flaring rate and spottedness, in spite of much research in which Bjorn Pettersen has been very active. (Pettersen 1983; Pettersen et al. 1983).

The rapid rotation of a cool star with a convective atmosphere evidently sets up a dynamo effect which ought to lead to the generation of magnetic fields, but these have only recently been definitively found with strengths of ~2500G by Zeeman studies (Saar et al. 1985) in the near infrared. Some years ago polarization was detected at the level of some hundredth to tenths of a percent of the total starlight. (Koch and Pfeiffer 1976; Pettersen 1983).

Steve Vogt, who began his spot studies at Texas, has been able to determine the spot temperatures at some 800°K below the photospheric value, which explains why there is very little color change over the spotted star's rotation period. With great ingenuity Vogt has been able to plot spot shapes in detail in RS Canum Venaticorum stars from the distortions of spectral lines (Vogt 1982; Vogt and Penrod 1983). This is possible because the effects on the spectral lines are greatest near the limb, where photometry is powerless because of foreshortening, but demands the very high signal-to-noise ratios possible only from CCD spectroscopic scans.

An interesting question is why when some 80 percent of all red dwarf flare stars are binary, not all are. I mean by this close binaries, as for example, the classical flare star UV Ceti which is in an orbit with a companion in some 26 years.

Since the starspot flare star phenomenon seems to require rapid rotation I conjecture that a single flare star should suffer some braking action because of interaction of its magnetic field with the interstellar field. As the star spins down, the dynamo-driven magnetic field decreases so eventually it ceases to flare, whereas a star in a close binary will get into synchronism and maintain its rapid rotation.

It would be interesting for AAVSO members with good photoelectric facilities - required because the ranges are small and good accuracy is necessary - to observe single flare stars in hopes of detection of rotational period lengthening. Also interesting would be BY Dra, where period lengthening may be expected to be due primarily to tidal effects, though this will be very difficult to measure because the changes are expected to be very slow.

One should be careful to watch for the phenomenon of phase flipping, already mentioned in connection with BY Dra and CC Eri, which I have attributed to polar migration of spots, though it might conceivably occur if a dark spot were replaced by a bright one.

There is also the question of the possible existence of spot cycles analogous to those on the Sun. Olin Wilson in his studies of H and K emission in other red dwarfs came out with cycles of comparable length to the solar case, but the only estimate of spot cycle length I have heard of has been a 50-year value for BY Dra, which I am sure needs verification. Any spotted star would be suitable for this sort of study, the prime candidates being BY Dra in the north and CC Eri in the south both of which are quite bright - 9th magnitude - to say nothing of a host of fainter ones such as EV Lac, YZ CMi, FF And, and many more.

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