INTERACTING MAGNETOSPHERES IN RS CVn BINARIES - CORONAL HEATING AND FLARES

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ABSTRACT

Coronae and flares of RS CVn systems are interpreted as due to gradual and sudden releases of magnetic free energy which is built up throught the interaction of magnetic fields of stars in these close binary systems.

X RAY AND RADIO OBSERVATIONS

Recent observations of RS CVn binaries in soft X-rays (Walter et al 1980) and in radio wavelengths (Gibson et al 1978, Feldman et al 1978) indicate the presence of vigorous coronae and the occurrence of flares. These, combined with the starspot hypothesis based on the "Photometric Wave" (PW) in the light curves (Hall 1972, Eaton and Hall 1979), strongly suggest that these high temperature or high energy phenomena may be due to activated magnetic fields in the outer atmospheres of the component stars, as already found in the case of the Sun (e.g., Sheeley et al 1974, Sakurai and Uchida 1977). In the present paper, we look into this possibility by examining the magnetic field configuration and various distorting effects.

ACTIVE-LONGITUDE-BELT MODEL

In presenting our argument we first introduce a new aspect into the starspot hypothesis. We propose that the PW may correspond to the stellar analogue, in an extreme form, of an "Active-Longitude-Belt" on the Sun (ALB) in which active spot-groups are seen to emerge, drift across and disappear, rather than being due to a gigantic, long-lived starspot, or aggregate of spots. Introduction of the notion of an ALB relieves us of the somewhat unnatural, though very fascinating, assumption of a gigantic spot or aggregate of spots, staying almost fixed on

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the surface of a rapidly rotating star. The 8-10 year recurrence period of the PW means an extremely slow drift or migration of the spot on the surface! Much faster differential rotation may be expected even if the synchronization tends to suppress it. Thus, if we are freed from the restriction that the differential rotation is traced by the PW drift, we are allowed to assume a larger range of differential rotation on K and F stars about the average rotation which is assumed synchronous with the orbital revolution. Polar regions, with latitudes higher than the synchronous latitude, will be rotating retrogressively, while the equatorial regions rotate progressively with respect to orbital motion. The notion of an ALB is also better for interpreting some other observed features of the PW, like the presence of forward or backward drifts and the smooth reversal of the direction of drift in some systems. ALB's on the Sun are known to drift very much more slowly than the individual sunspots and the drift can be in either direction, or even change direction by a mechanism not yet understood (Bumba and Howard 1969, Gaizauskas et al 1982).

It is clear that the notion of an ALB introduces much dynamism into the picture. The size of the spot-pair may now be of the order of the depth of the convection zone rather than of the stellar radius and a much faster differential rotation of spot-pairs is now admissible. The possibility of differential motions of the footpoints of magnetic flux tubes (some of them connecting both stars) introduces a means of energizing the magnetic field, e.g. by induction of field-aligned currents by twisting or the formation of current sheets or in connections of spot-pairs, as well as pole-pole or pole-spot connections extending to the scale of the binary system.

By applying the method of Sakurai and Uchida (1977) to the present situation, we can calculate the magnetic field in the system. Since no direct measurement of magnetic field is yet avilable, we have to rely on an appropriately assumed set of photospheric magnetic field data for both the global and the starspot fields. The example shown in Figure 1 is for RS CVn itself (radii 1.9 $R_\odot$(F4V) and 4.1 $R_\odot$(K0IV), separation 16.8 $R_\odot$). Global magnetic fields are tentatively assumed to be due to dipoles with polar intensitied of 10 G (K star) and -100 G (F star), respectively, with four pairs of spots assumed in the ALB which as a 120° width in longitude on the K star. The spot parameters are: $a_p = 0.5\ R_\odot$, $B_p = 3000$ G (preceding spots); $a_f = 0.7\ R_\odot$, $B_f = -1350$ G (following spots), i.e. the area of the following spots are twice that of the preceding, and their fluxes are 10% less than those of the preceding ones as in the solar case.

HEATING OF THE CORONA

A mechanism for energizing the magnetic field is now introduced in

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our picture by the notion of ALB's. Winding up of magnetic flux tubes in pole-pole or pole-spot connections, due to differential rotation builds up currents in the corona (Sakurai 1979, 1981), and heating is expected as a result of their dissipation (cf. Kuperus et al 1981). An alternative mechanism is due to the interaction between pole-pole and pole-spot connection which execute a different mode of motion. Flux tubes are strongly disturbed and the setting-up of current sheets at the interface, sudden restoration of the distortion of flux tubes, etc., may take place (Uchida and Sakurai 1977), leading to the subsequent heating of plasmas.

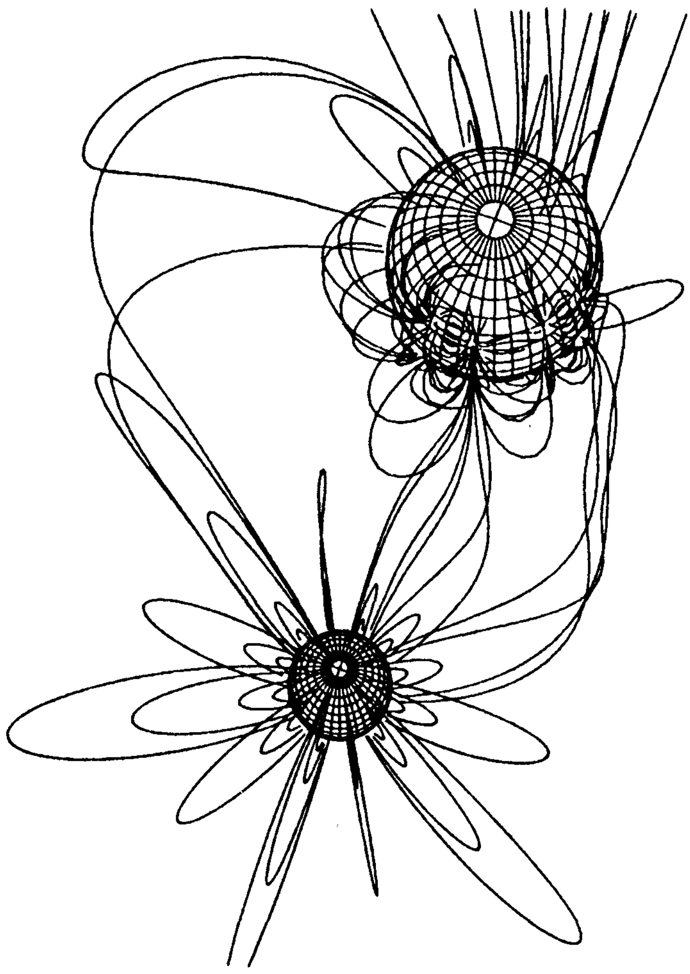

Figure 1. Possible magnetic field configuration in RS CVn system. For details, see the next.

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Convective shaking of flux tube footpoints may also result in Alvèn wave heating (e.g. Uchida and Kaburaki 1974) or heating due to current dissipation (Sturrock and Uchida 1981).

FLARES

We may, as an example, attribute the occurrence of flares to the drastic liberation of magnetically accumulated energy through reconnection (e.g., Priest 1982). As the spots drift in the ALB by differential rotation, the pole-spot connections are streched and interfere with other spot-spot connections. When reconnection takes place, e.g., as old spots disappear near the leading edge and new ones appear near the rearedge of the ALB, the stressed field can relax to a configuration of lower stress and the accumulated energy in the stressed field is liberated into dynamical or thermal modes of energy. In the solar analogy, such phenomena as i) the acceleration of electrons yielding radio and hard X-ray bursts, ii) the heating of magnetic loops to 10^8 K, iii) the ejection of hot gas into connections created by the reconnection (cf. Simon et al 1980) and so on, may take place vigorously through magnetic energy liberation.

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