ACTIVITY OF CONTACT BINARIES

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We discuss observational results for indicators of elevated activity of contact (W UMa-type) binaries. References are made to results for fast rotating single and detached binary (MS) stars: they are discussed in the accompanying paper by Vilhu and Rucinski.

δ(u-b): The ultraviolet excesses δ(U-B) were discovered by Eggen (1967) who explained them by the lowered metallicity in older among W UMa systems. However, because of the properties of the U-band, it was not possible to disentangle effects of metallicity from any Balmer-continuum emission. The four-colour Strömgren photometry for 36 W UMa systems (Rucinski and Kaluzny 1981) which will be soon supplemented by results for 17 southern systems enabled to obtain the following results: The interstellar extinction corrected data (Fig. 1) show concentration of genuine ultraviolet (u-band) excess at the short period border of the period-colour relation. This can be interpreted by the Balmer continuum emission related to the period-activity connection; the latter must, however,

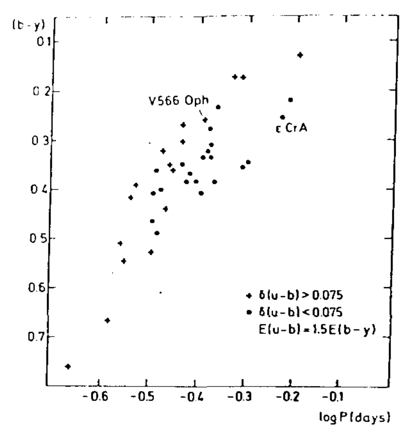

Fig. 1 Period-colour relation in the four-colour photometry

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differentiate between systems differing in periods by less than $\Delta \log P = 0.2$. Such a strong dependence is quite unexpected. Two systems, V566 Oph and ε CrA (mentioned further) having similar (b-y) but differing in δ(u-b) are marked in Fig. 1 for visualization of the ultraviolet excess effect.

The concentration of systems with ultraviolet excesses at the short period border in Fig. 1 can result to some extent from an improper removal of the interstellar extinction, especially if circumstellar extinction of unknown properties were to be present. A downward shift by E(b-y) should produce a 1.5 times larger (and positive) effect on (u-b) resulting in a decrease of δ(u-b). The "standard" value of δ(u-b) for contact binaries would correspond then to an excess > 0.075. It would be impossible to explain the whole morphology of the period-colour relation by effects of reddening but this possibility should be kept in mind, especially in view of the systematically too positive reddening-corrected (b-y) colours for earlier spectral-type systems.

f_{TR}/f_{BOL}. The summed fluxes for the transition-region (TR) lines observed with the IUE in SWP and normalized to the bolometric fluxes are surprisingly little dependent on the spectral type or period for the sample of 9 contact binaries (Rucinski and Vilhu 1982). Very rare fast-rotating giants seem to be even more active but for MS binaries there seems to exist a plateau in the TR activity for P < 3 days which continues into the contact binary domain (cf. Fig. 1 in the paper by Vilhu and Rucinski). We call this effect "saturation" of the TR activity. The origin is unknown but is related only to the period and it can be shown that it is not due to the transfer-of-radiation saturation effects in resonance lines.

f_{COR}/f_{BOL}. The normalized coronal (COR) fluxes, as observed by Dupree et al. (cf. Dupree 1981 for references) in soft X-rays with the Einstein satellite show strong dependences on period and spectral type (Fig. 2). The spectral type dependence is in the same sense as for detached binaries and single stars: more active are stars of later spectral types having thicker convection zones. However, the period dependence is quite unexpected showing decrease of coronal activity for shorter periods. It should be noted that the almost orthogonal dependence on period for contact binaries by Dupree (1981) resulted from overlooking the period-spectral type correlation; therefore, the contact systems must be split into spectral groups, as in Fig. 2, and then it is clearly seen that the strongest COR activity is observed for systems located close to the border between contact and detached binaries. This result has no obvious interpretation at present but a systematic decrease in loop sizes for very short-period systems seems to be a plausible interpretation. Notice in Fig. 2 locations of systems V566 Oph and ε CrA with identical (b-y) but with different δ(u-b).

f_{MgII}/f_{BOL}. The data for contact binaries are very fragmentary (Rucinski et al. 1982, Vilhu and Rucinski 1982) but suggest reduced MgII fluxes when compared with fast rotating stars, single and in binaries: W UMa itself seems to have similar MgII fluxes as that observed for the Sun. The total radiative losses (CHR, TR, COR) are difficult to estimate but might be roughly consistent with the $(\mathrm{Period})^{-1}$ dependence when comparison is made relative to the Sun.

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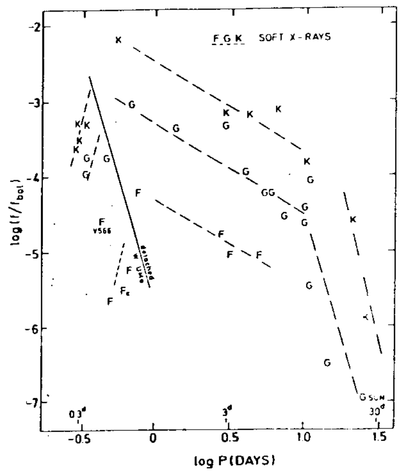

Fig. 2 Coronal activity - rotational period relation

Spots. The presence of spots on more massive components seems to be the best explanation of the W-subtype syndrome (Eaton et al. 1980, Hoffmann 1978, Stepien 1980). The spots must cover up to 20% of the primary's surface and be relatively smoothly distributed (e.g. small spots). Preference for more massive components can be plausibly accommodated into all presently considered theories of contact binaries: in the thermal-relaxation-oscillation and angular-momentum-loss theories, it would be due to the thicker convective zone of the primary component; in the contact-discontinuity theory, it would be due to difficulties for the magnetic field to penetrate the discontinuity. However, the W-subtype light curves can be obtained by assuming existence of belts of darkening extending to similar latitudes in both components. This non-magnetic darkening would result from the reduced efficiency of convection in equatorial regions and from different convection modes at different latitutes (like on Jupiter). This possibility, however, is difficult to incorporate into the light-curve-synthesis modelling because of unknown properties of such belts.

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DISCUSSION

Linnell: The model which you use to explain the W-type phenomenon using Mullan's suggestion of starspots, usually on the more massive component, seems to me to suffer from a fatal error. This is because it fails to account for the anomalous mass-luminosity relationship for the less massive components. How do you get energy transferred to the less massive component?

Rucinski: Can you explain your point a little further?

Linnell: It is this. You explain the occultation eclipse being the deeper one by reducing the surface brightness of the more massive star by putting dark spots on it. That does not provide an explanation of why the secondary, less-massive component is over-luminous for its mass.

Rucinski: No, but that is quite a separate problem.

Worden: The starspot models for W UMa systems are quite interesting. I have a comment and a question. It would seem that dynamo models for the generation of magnetic fields would be very much complicated by the dumb-bell-shaped convection zone. Are you aware of any models which predict what kind of convection zones could be expected in these stars?

Rucinski: No, I have no idea. My personal feeling is that there is no differential rotation because of the existence of something similar to meridional circulation. We might then have turbulence in very small cells and therefore more rigid rotation. Buth that is just a "handwaving" argument.

Budding: I have a comment about the A- and W-type systems which a lot has been made of. To my mind non convincing case has been made to show that all of the A-type systems are in contact. There are cases, for instance, RR Cen and ε CrA which may be close but detached systems. This is true for W-type systems although among those low-mass, cooler systems one cannot easily distinguish between W- and A-type and some change between the two types. So I wonder about the reality of this sub-division.

Rucinski: The answer to the first point would be that there is no way of transferring sufficient energy from one component to the other without contact. We observe that both stars have the same T_{eff} but different masses.

Budding: I do not think that is necessary. We observe different luminosities but there are not good spectroscopically determined mass ratios for many. We are using photometric mass ratios. RR Cen is an example where there is no spectroscopic mass ratio. The luminosities are different but because one star is quite a bit bigger than the other the T_{eff}'s work out comparable.

Rucinski: It was very nice to see this splitting in the case of ε CrA, which works out as predicted, in spite of the fact that no spectroscopic mass ratio was available. Tapi and Whelan just assumed something about the primary component.

Dupree: Yes and we saw the velocity separation giving the predicted massa ratio of 10:1.

Rucinski: Even in the case of AW UMa which has a very extreme mass ratio, the secondary component was recently observed and shown to have a very small mass.

Budding: In the case of ε CrA you have a mass ratio of 0.8 which is a long way from indicating a low-mass secondary.

Rucinski: Anyway to me the fact that they have equal temperatures and differ very much in the masses tells us that they must transfer immense amounts of energy from one component to the other and so that spots are a minor consideration. 20% spot coverage on one component or the other does not matter. Concerning your question about the division into A- and W-types, that it if one considers cooler stars they will all be W-type and if one considers hotter stars they will be A-type. In between there is certainly a group which switches from one type to the other.