JOINT COMMISSION MEETINGS ON CLOSE BINARIES AND STELLAR ACTIVITY

(Commissions 10, 27, 40, 42, 44, 48)

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https://doi.org/10.1017/S1539299600004834 Published online by Cambridge University Press

A BAKER'S DOZEN: UNSOLVED PROBLEMS WITH THE RS CANUM VENATICORUM AND BY DRACONIS STARS

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The theme of this Joint Meeting of Commissions 10, 27, 40, 42, 44, and 48 is "Close Binaries and Stellar Activity". At the time this meeting was initially conceived, we took stellar activity to mean activity such as we observe on the Sun: spots, flares, chromospheric emission, variable radio and X-ray emission, coronas, winds, and so forth. That is why the series of seven reviews presented at this meeting will deal for the most part with convective stars, in particular with the RS CVn-type and BY Dra-type stars, which we know are active in so many of these ways.

It had been planned that Steven N. Shore would review briefly the situation from a theoretical viewpoint (briefly, I say, because theoretical treatment of the problem is still in the infant stages). Reference can be made, however to the contribution he presented at I.A.U. Symposium No. 88 in Toronto.

One way to open this meeting, I hope a useful way, is simply to list some unsolved problems. Those on my list may not be equal in importance or difficulty. Different problems would no doubt appear on someone else's list. It may even turn out that, after we have heard these reviews, a number of my unsolved problems have already been solved or soon will be, but that would be a pleasant surprise rather than a disappointment.

1. Though frequent reference is made to the RS CVn-type binaries and the BY Dra-type variables as they have been defined (Hall 1976, Bopp and Fekel 1977) on the basis of directly observable properties, we must force ourselves to probe beyond the boundaries of any formal definition in order to define the domains in which various types of activity occur. Only in this way can we gain a solid understanding of the physics at play.

Many are becoming convinced (Bopp and Espenak 1977) that rapid rotation is of major importance and that duplicity (occurrence of the active star in a binary) may be only indirectly relevant, as one means of achieving rapid rotation, by enforced synchronization with a relatively short orbit period. Crucial will be the search for presence or absence of activity in rapidly rotating stars demonstrated to be single (Bopp and Fekel 1977).

Patrick A. Wayman (ed.), Highlights of Astronomy, Vol. 5, 841–845.

Surely, though, rapid rotation cannot be the only relevant physical parameter. Depth of convection zone, for example, should be another.

Our understanding is so poor that we cannot even answer the audacious question: do the radio activity and the X-ray activity and certain other types of activity in Algol binaries (which, unlike the RS CVn binaries, are semi-detached) stem from the mass transfer process or are they more directly related to the cooler component, which, except for filling its Roche lobe, is remarkably similar in most other respects to the cooler component in the RS CVn binaries? Such a question was posed by Gibson at the recent Workshop on Radio Stars (Feldman and Kwok 1979).

2. It is generally believed now that large scale (dark) spot activity is responsible for producing the photometric variability in the RS CVn binaries and the BY Dra variables (Eaton and Hall 1979). Nevertheless, the case for spots is largely circumstantial or, at best, indirect. We should work to find sufficient direct evidence to convince the devil's advocate that such spots exist.

3. Why (assuming that spots do exist) are the spots so large or, if we are dealing with a large group of smaller spots, why are there so many? First steps towards the answer have been taken by Mullan (1979), Rucinski (1979), and Shore and Hall (1979).

4. Why do spotted regions persistently prefer one hemisphere? There is virtually no clue as to why, and certainly no theory. It is ironic to realize that spots covering much or even most of a star's surface but distributed *uniformly* in stellar longitude might have gone completely unsuspected for perhaps several more decades.

5. Can we actually determine uniquely the shape, size, location, and temperature of the spot groups, or are we doomed to play entertaining but not very instructive games with computer programs, which generate light curves by rotating stars on which we have placed one or more dark circles, rectangles, triangles, or tadpoles? Multicolor photometry over extremes of wavelengths promises to shed light on the temperature question. I also want to stress that *eclipsing* binaries are necessarily of far more value in this connection. First, the inclination of the rotational axis (assuming it is parallel to the orbital axis) is automatically removed as a free parameter. Second, since the spotted star is usually the larger, we have the spotted surface *scanned* by the smaller star during the transit eclipse and thus the promise of removing much of the problem's indeterminacy. Another way to approach the indeterminacy is for well-developed spot theories to make specific predictions as to what the spot distribution should be and then submit to testing by observation.

6. Are there spot cycles like the Sun's 11-year cycle? Wilson (1978) has already found evidence of similar ∿ 10-year cycles in nearby convective dwarfs, by looking at the H and K chromospheric emission intensity. Spot cycles in the RS CVn and BY Dra stars, if they exist, could manifest themselves clearly as a long-term modulation in the *amplitude* of the photo-

https://doi.org/10.1017/S1539299600004834 Published online by Cambridge University Press

metric wave. Possible cases of this have been found in RS CVn (Hall 1972), RT Lac (Haslag 1977), and SS Boo (Hall and Henry 1978, Vaucher 1979), but we need more good data to be sure: photoelectric light curves obtained once each year for a decade or two or three.

7. Can we get a reasonably good understanding of the orbital period variations, which are rather complex and can be occurring on several time scales? Hall, Kreiner and Shore (1979), and Hall and Kreiner (1979) have proposed a model in which the active star has a convectively driven wind constrained to corotate out to the Alfvén radius by a magnetic field assumed to be around 1 kG as a consequence of the supposed large scale spot activity. They emphasize, however, that the situation in reality is likely to be very complicated.

8. How are we to explain the puzzling irregular intrinsic light variations seen in around half of the systems? Often the mean light level in RS CVn binaries and BY Dra variables change from cycle to cycle and/or from season to season. One example is UX Ari (Hall 1977). In another system, SS Cam, it was shown that the star closer to the main sequence, *not* the supposedly spotted cooler subgiant, was responsible for the pronounced irregular intrinsic light variation (Arnold *et al.* 1979).

9. The apparent underabundance of heavy elements in the active component of RS CVn binaries, reviewed recently by Plavec and Polidan (1976), still, after its first report in 1966, has no satisfactory explanation. If it is not real underabundance, then what is the phenomenon?

10. Can we get direct observational evidence of the strong magnetic fields invoked to explain so many of the properties? To my knowledge only one paper has yet touched on this question. Anderson, Hartmann, and Bopp (1976) presented spectroscopic evidence which could imply a field of 40 kG in the active region of the primary star in BY Dra.

11. Although we believe now that virtually all of the RS CVn binaries are post-main-sequence before Roche lobe overflow (Popper and Ulrich 1977, Morgan and Eggleton 1979), can we find even one pre-main-sequence? K-type subgiants evolving towards the main sequence and those evolving away from it have most of the same physical characteristics. Two suspected pre-main-sequence RS CVn binaries are II Peg (Rucinski 1977) and W92 in NGC 2264 (Walker 1977).

12. We have yet to understand the synchronization problem in detail. There are many aspects to this problem.

First is differential rotation as a function of stellar latitude, such as occurs in the Sun. It may be occurring in other stars also and could be manifested as a variable photometric period when the starspots drift in latitude as they do in the solar "butterfly diagram".

Second is the action of the nearby companion star, which tends to synchronize the rotation. We see already (Hall 1978) that all RS CVn binaries with orbital periods less than ∿ 20^d do rotate synchronously but those with longer periods not necessarily so. Nevertheless, the tendency towards synchronism must not be strong enough to enforce completely rigid rotation, because the photometric period and the orbital period are never identical, and consequently the photometric wave migrates through the light curve.

Third, we know little about rotation in the interior of the stars. Conceivably, there could be differential rotation as a function of radial distance out from star center, and it could be that only the outer layers are synchronous.

Fourth is the difficult problem of understanding how rotation and synchronization evolve in time as the stellar components move onto and off of the main sequence, the orbital separation changes in response to the observed period changes, and the companion star tries constantly to enforce synchronization. DeCampli and Baliunas (1979) have made an important first step in tackling this complex problem.

13. The last problem is easy to state but will be hard to solve completely: describe to everyone's satisfaction the atmospheric structure of the RS CVn and BY Dra stars, starting with the unevenly spotted photosphere and ending with the anisotropic wind. Though strides in the right direction have been taken by Linsky and his coworkers, Dupree and her coworkers, and others, the goal has not yet been reached.

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