Light Curve Variations in Short Period EB Type Contact Binaries

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The structure and evolution of contact binaries is still very poorly understood. If two stars are so close together that they are physically touching, then it is to be expected that the normal equilibrium configurations of the single stars are heavily disturbed. Mass and energy transfer between the components can occur which makes the theoretical calculations on stellar structure and evolution extremely difficult.

The well-known and numerous W UMa type subgroup of contact binaries is characterized by the almost equal depth of the primary and secondary minima in their light curves. Consequently, the surface temperatures of both components must be nearly equal as well, regardless of the masses of the two stars. This posed a serious problem to theoretical astrophysics since the stars cannot be far from the main sequence. In 1968 Lucy (1) developed a theoretical model for contact binaries with a common convective envelope which allows a redistribution of the energy output over the whole common photosphere of the system, thus explaining the characteristic W UMa light curves. However, in 1971 Mauder (2) was able to show that this first model was in contradiction with the observations. In the meantime the model has been refined, and it has turned out that contact binaries cannot reach thermal equilibrium. Therefore, W UMa stars must be unstable on a thermal timescale. It was proposed that these systems undergo cyclic variations with alternating phases of true contact and semidetached, but almost contact, phases. During contact phases, the characteristic W UMa light curves should be observed while during the semidetached phases the surface temperatures of the two components should be different, thus producing Beta Lyrae (EB) type light curves. The cycles are also connected with mass exchange between the two components.

Another model for W UMa stars was proposed by Shu, Lubow and Anderson (3), where thermal equilibrium is possible. It is necessary in this case that a so-called discontinuity zone exists below the common convective envelope, which masks the physical properties of the underlying, less massive star. Thus, the structure of the whole photosphere is mainly determined by the more massive component.

Of course, it is interesting for the observing astronomer to look for systems which eventually may be relevant for a decision between the different theories, especially with respect to mass transfer and secular variations of the light curves. For these reasons the author started an observing campaign on several systems which seemed to have unusual properties. From eight systems originally chosen, the two stars FT Lup and V 1010 Oph turned out to be remarkably interesting. In Fig. 1 the V light curve of FT Lup is shown, where observations from 1980–1983 are combined. The light curve

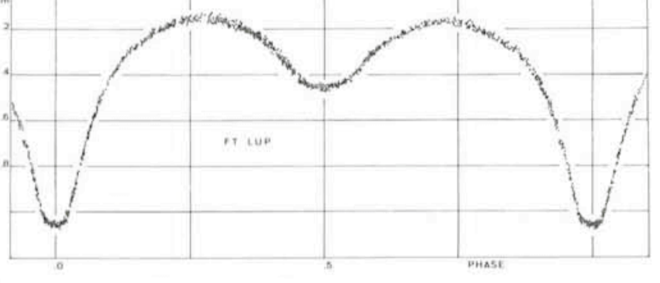

Fig. 1: *V light curve of FT Lup.*

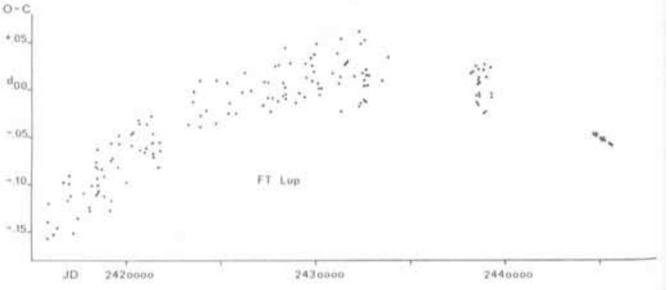

Fig. 2: *Difference between observed and calculated times of minima for FT Lup.*

is well defined and the solution showed that FT Lup is a contact system. However, the two minima are very different in depth, which means that the less massive component has a much lower surface temperature. Therefore, the energy exchange between the two stars in the common convective envelope is far from the expected equilibrium value which characterizes W UMa stars. The solution of the light curve showed that the degree of contact is still shallow. It could be, therefore, that the system is evolving towards a closer contact configuration. In this case, mass transfer should occur, which in turn causes variations of the orbital period. This is clearly seen in FT Lup (see Fig. 2). Here, all times of minima which are known back to 1890 are compared with the expected times of minima, calculated under the assumption that the period is constant. It is obvious that the period has steadily been decreasing since 1890. With the solution parameters of FT Lup, a mass transfer rate of 3.10^{-7} solar masses per year is suggested, consistent with the thermal timescale of the stars.

Even more dramatic variations are seen in V 1010 Oph. In Fig. 3 two light curves of this system are combined. The tiny dots show the V light curve obtained in 1983 at ESO, the circles are the points of the light curve observed in 1966 by Leung (4). In their light curve solution, Leung and Wilson (5) found V 1010 Oph to be a contact system, and again the degree of contact is rather shallow and the surface temperatures of the two stars are remarkably different. V 1010 Oph shows period variations which are very similar to those found for FT Lup, but even larger. But the most interesting feature is the variability of the light curve. Leung and Wilson (5) have found that their calculated light curve showed systematic differences compared with the observations in the phase interval 0.5 to 0.7: the observed points were all below the calculated values in this phase interval. The new observations of 1983 show that this difference vanished. At the same time the depth of the primary minimum decreased by almost 0.1 mag – the temperature difference between the two stars is therefore smaller now.

It seems to be a natural conclusion that the two systems are in a state of mass exchange during the evolution towards the W UMa stage of contact binaries, thus favouring the theory of cyclic variations. However, the scenario must be much more complicated. In the theory of cyclic variations as described above, the mass transfer during the contact phase is always from the less massive to the more massive component. During the semidetached phase the direction of mass transfer is opposite. V 1010 Oph and FT Lup are contact binaries, but the mass transfer was from the more massive component to the less massive one during the last 100 years. The decrease of the difference in surface temperature of the two stars in V 1010 Oph is evident, but is this really a secular evolution? Doubts

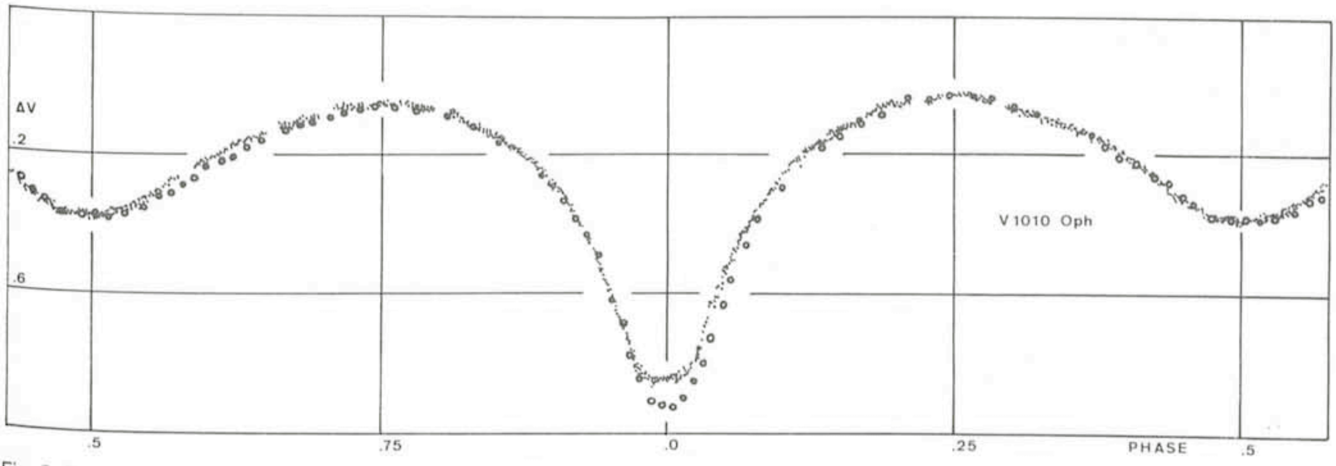

Fig. 3: *Two V light curves of V 1010 Oph. The tiny dots are observations from 1983, the circles are normal points of the 1966 observations by Leung.*

are appropriate since FT Lup showed an unexpected behaviour at the end of the observing run in 1981. In Fig. 4 the observations during primary minimum are shown. The dots are all observations between 1980 and 1983 as shown in Fig. 1, including observations from June 20, 1981. The circles are observations from June 26 and 27, 1981, only one week later, but unfortunately on the last nights of that run. In the next run, about one year later, the primary minimum was again at its lower value. Thus, the problem is still far from being solved. It is obvious that more extended observations are necessary to find out how these short-period, EB-type contact binaries are connected with the theory of the structure and evolution of W UMa stars.

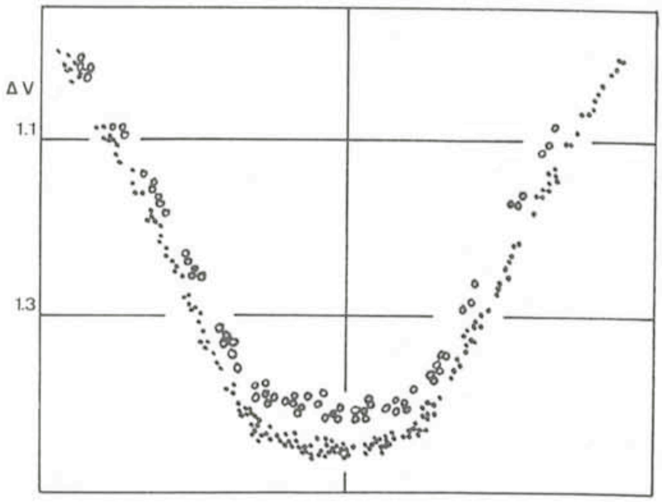

Fig. 4: *Primary minimum of FT Lup. The dots are observations between 1980 and 1983, the circles are the observations from June 26 and 27, 1981.*

References

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