APSIDAL MOTION IN EVOLVED BINARY SYSTEMS

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The study of apsidal motions in eclipsing binaries has proven to be one of the best methods to check the internal density concentrations of the stars predicted by theoretical models. During the main sequence phase, we have found a good agreement between the observed apsidal motion rates and computer-constructed stellar models provided that a realistic consideration is made of the evolution between the lower and upper borders of the main sequence (Giménez and García-Pelayo, 1982). An obvious extension of this work is a throughout study of the more evolved evolved systems beyond the TAMS where theoretical models are less accurate and empirical data from different sources are largely needed (see review paper by Zahn in this volume). A preliminary report on such a study is presented.

In order to compare the available observations with the theoretical models, we have adopted those computed by Hejlesen (1980) which also include the values of the internal structure constants k_j (j=2,3, 4) for a wide range of stellar masses and chemical compositions (Hejlesen, 1982) and make use of the opacity tables by Cox and Stewart. In this evolutionary sequences we have found that: a) During the main sequence, log k_2 decreases smoothly for decreasing log g with a slope slightly dependent on mass (as it was empirically predicted by Giménez and García-Pelayo, 1982), b) After the consumption of the hydrogen fuel in the core, the inner density concentration continues to increase in a less pronounced way until a rapid grow of the dimensions of the stars is accompanied by a sudden increase in the log k_2 value, and c) For the range of masses of our interest, it is clear that a minimum value is theoretically predicted for log k_2 around -2.5 below which observational values are not expected to be found. Furthermore, variations in log k_2 are found to be small for different chemical compositions, within reasonable ranges, particularly with respect to the minimum value after the TAMS. Comparing the evolutionary sequences given by Petty (1973) with those by Hejlesen, we did not find significant differences.

The candidate systems to be compared with the theoretical models were selected according to the usual criteria (Giménez, 1981) but the following difficulties were found: a) Highly eccentric systems are not common among evolved binaries, b) To keep the system well detached

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even after the large expansion of the external envelope the orbital periods should be relatively long, thus making difficult an accurate determination of the apsidal motion period, c) The obtention of absolute parameters in these binaries is generally complicated due to the photometric variations found among most of them and d) As far as the mass ratio is not very close to unity, the rapid evolution after the main sequence implies a small luminosity ratio which makes the system to be a single-lined spectroscopic binary.

Anyhow, 10 candidates could be finally selected for which it was possible to make a reasonable estimation of the involved parameters (AR Cas, V346 Cen, V380 Cyg, GN Nor, δ Ori A, o Per, EO Vel, α Vir and HR 7551). The apsidal motion periods were taken from the literature except for V346 Cen which was deduced from our own observations. The absolute parameters were estimated mainly from the light and radial velocity curves but also spectral types, colour indices, etc. It should be noticed that, when the relativistic contribution is not important, the total mass of the system is not needed to compute log k_2 and that the main involved parameters are the relative radii far more accurate than their absolute values when derived from the light curve (i.e. changing the masses will move the points left or right in the log k_2-log g plane but not upwards unless the relative radii are changed). In case the radii are poorly known, it is possible to adopt minimum values from the models (e.g. on the TAMS) which will provide upper limits for log k_2.

From the comparison we could immediately deduce the following points: a) The less evolved binaries (close to the TAMS border like AR Cas, V453 Cyg and EO Vel) there is a good agreement within their mean errors with the models, b) For the remaining more evolved systems there is a clear tendency towards more centrally condensed configurations than theoretically predicted, c) This difference is too large to be easily explained in terms of observational errors or small modifications in the procedure to build up the models, d) The deviations are clearly systematic suggesting that either the actual structure of the stars is more highly centrally condensed or the radii of the components are too large (!). Moreover, the differences become larger for the more evolved systems with smaller surface gravities.

New observations and analyses are being carried out in order to increase the accuracy of the above sketched comparison and thus provide further background to our knowledge of stellar evolution. It seems that changes in the adopted opacities may modify the picture but also the existence of some kind of mixing in the stellar interior (Maeder & Mermilliod, 1981) leading to a significant widening of the main sequence or any physical mechanism producing changes in the orbital parameters which may bias the determined apsidal motion rates.

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