COMMENTS ON THE EVOLUTION AND ORIGIN OF CATACLYSMIC BINARIES

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ABSTRACT

Some aspects of the observational data on cataclysmic binaries are discussed and some possible correlations between type of behaviour and binary period are noted. A gap between 2 and 3 hours in the histogram of binary periods is estimated to be real. A numerical procedure for following the evolution of Roche-lobe-filling stars using simplified equations is described. This procedure is applied to white/red dwarf binaries for a variety of initial conditions, and of mass loss and angular momentum loss mechanisms. The results of these calculations, in which we ignore the short timescale behaviour of the systems, are classified into four modes of evolution: normal, nuclear evolution dominated, angular momentum loss dominated and hydrodynamical. The results are discussed in connection with cataclysmic binaries. The clustering in period below 2 hours is interpreted in terms of evolution following the hydrodynamical mode , and it is suggested that such systems contain low mass white dwarfs as well as low mass secondaries. These may be the most common type of cataclysmic binary. A possible explanation of the clustering of classical novae systems to binary periods of 3 to 5 hours is mentioned, and evolutionary scenarios for cataclysmic binaries are outlined. We suggest, following Ritter and Webbink, that the short period systems ($\lesssim$ 2 hrs) arise mainly from late Case B mass transfer in the original binary (original primary mass 1.5 to $3M_{\odot}$) and the longer period systems arise mainly from Case C mass transfer.

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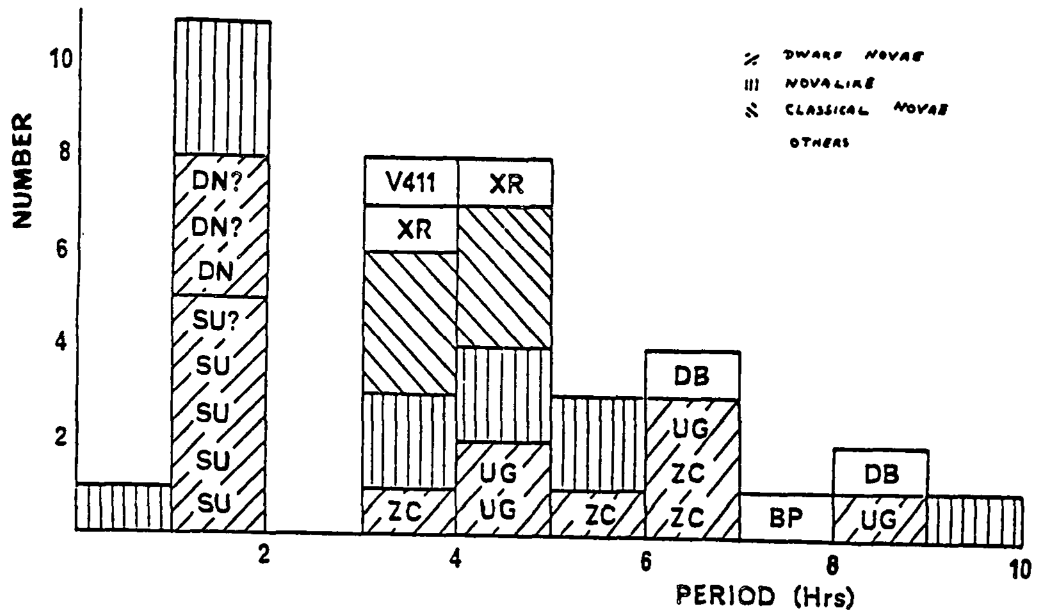

Figure 1 is a histogram of binary period ($<$ 10 hrs). There are a number of possible correlations between binary period and type of behaviour:

1) Lack of systems with binary periods between 2 and 3 hrs.

2) Clustering of systems below 2 hrs (and the predominace of SU UMa systems there).

3) Clustering of classical novae between 3 and 5 hrs.

To try and understand these correlations we have used a simple model of binary star evolution which is based on :

$$\tau' \frac{d\log R_*}{dt} + \log R_*/R_0 = \begin{cases} -\dfrac{\tau\lambda}{m}\log R_*/R_L & (R_* > R_L) \\ 0 & (R_* < R_L) \end{cases}$$

where R_0 is the equilibrium radius of the star, R_* is its actual radius ,R_L is the Roche lobe radius , m is the mass of the star, λ is a parameter which dictates the maximum mass transfer rate and τ and τ' are two stellar response timescales calibrated from detailed stellar evolution calculations. The models produced by this procedure were found to agree with detailed results to within a few percent.

The model was then used to explore the parameter field of white/red dwarf binaries. Four modes of behaviour were found.

(i) Normal Behaviour was such that the binary evolution was close to that described by the analytic results of Faulkner (1971).

(ii) Nuclear Evolution dominated behaviour was where the system evolved in response to nuclear evolution rather than gravitional radiation losses or angular momentum loss by other processes. (Fig 2) For some systems very little nuclear evolution was necessary before it dominated the evolution.

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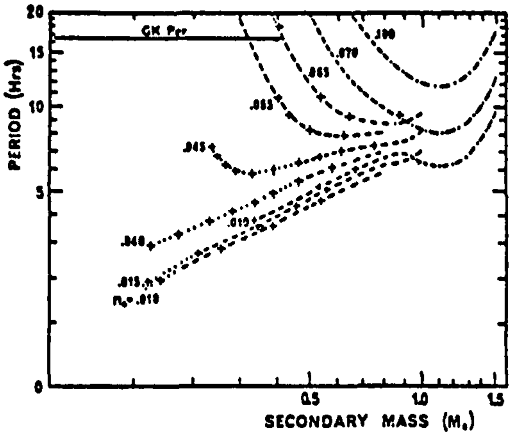

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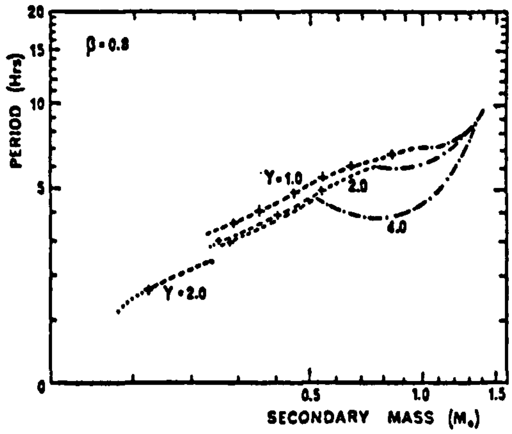

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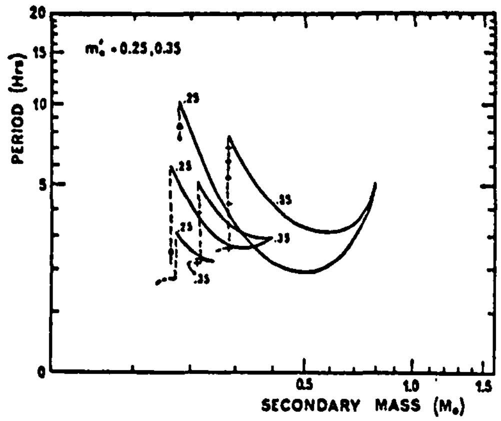

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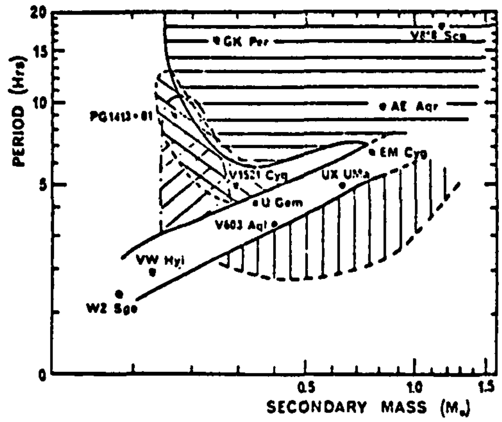

FIGURE CAPTIONS

In Figure 2 to 5 the following conventions are used. m_0', the initial mass of the white dwarf, is $0.7 M_\odot$; β, the fraction of mass lost by the secondary which is gained by the primary, is unity; γ, the relative specific angular momentum of the mass lost from the binary, is zero. Plus sign marks every 2.10^9 yrs and asterisks every 10^{10} yrs. In Fig 3 the numbers represent the mass (in $M_\odot$) of helium produced by nuclear burning

—— $|\dot{m}| > 10^{-6} M_\odot/yr$; —·—·— $5.10^{-9} < |\dot{m}| \leq 10^{-6}$;

--- $5.10^{-11} < |\dot{m}| \leq 5.10^{-9}$; ······ $0 < |\dot{m}| \leq 5.10^{-11}$;

~~~ $\dot{m} = 0$, i.e. detached

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(iii) Angular momentum (and mass loss) processes dominated the third type of behaviour where mass transfer rates tended to be much higher. (Fig 3)

(iv) Hydrodynamical Evolution resulted from either low mass white dwarfs or very efficient angular momentum loss and here mass transfer rates were very large ($\sim 1\ M_\odot$ /yr.) (Fig 4)

We can draw a number of conclusions from these calculations

i) Systems with low mass white dwarfs will undergo a period of very rapid mass transfer (which may rememble a short period version of the Bath-Webbink model for symbiotic variables), followed by a period of detached evolution before ending in a very long lived phase as a short period (SU UMa) type system. This process will remove systems with binary periods $>$ 2 hrs and when they again become semidetached their period will be $<$ 2 hrs.

ii) Nuclear evolution which leads to systmes with longer periods and lower mass transfer rates might be identified with U Gem systems while unevolved systems might be identidfied with classical novae (and possibly novalike) systems. Such systems would probably have transfered more mass and if any is accreted by the white dwarfs and is not lost during nova explosions they would have more massive primaries. Also the systems here will initially have more massive white dwarfs than those in (i) above.

iii) Angular momentum and mass loss is not very important in cataclysmic variables. Fig 5 summaries both our calculations and our suggested identifications of systems in the various modes of behaviour.

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