SUBSTELLAR SECONDARIES IN ZERO-AGE CATACLYSMIC VARIABLES

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1. METHOD

Of necessity, we must be brief here in our description of this investigation. For a detailed description of this study and its results, we refer the reader to Politano (2004).

The population synthesis code developed by Politano (1988; 1996) to model the formation of CVs has been modified for the purposes of this study. For a complete description of the code, we refer the reader to the original paper Politano (1996), and here only discuss the modifications made.

(1) We have developed a Monte Carlo version of the Jacobian code used by Politano (1988; 1996), and have used the Monte Carlo code in the present study. The Monte Carlo code contains the same physics as the Jacobian code, except as noted below, and it has been calibrated against the Jacobian code.

(2) The birthrate calculations of Politano (1996) were modified to include a more realistic treatment of the radius of the BD as a function of mass and age. This treatment comes from cooling curves of BDs produced by I. Baraffe and co-workers (Baraffe et al. 1998; 2003).

(3) For the calculation of the present-day orbital period distribution of ZACVs with BD secondaries,
2. RESULTS

The results of the population synthesis calculations are shown in Figure 1 and Figure 2. In Figure 1, the present-day orbital period distribution of ZACVs is shown for the assumed choices, $\alpha_{CE} = 1$ and $g(q) = 1$. The subset of ZACVs that contain BD secondaries is shown in the dashed histogram. Our model predicts that CVs that are presently forming with BD secondaries occupy an orbital period range from 46 min to 2.5 hrs. We further predict that 18% of CVs that are present at the time are forming with BD secondaries. Of these, the majority (~80%) form below the orbital period minimum (78 min), with the remainder forming a tail reaching within the stellar domain. Thus, our model predicts that a significant fraction, ~15%, of CVs are forming at orbital periods shorter than 78 minutes at the present time.

In Figure 2, the fraction of ZACVs that contain BD secondaries is plotted as a function of $\alpha_{CE}$, the common envelope efficiency parameter, for three different IMRDs: $g(q) \propto q$, $g(q) \propto 1$, and $g(q) \propto q^{-0.9}$. Surprisingly, we find that even for very small values of the common envelope efficiency parameter ($\alpha_{CE} = 0.1$), the fraction of CVs that form with BD secondaries is not zero. Rather, for $\alpha_{CE} = 0.1$, this fraction ranges from ~3% to ~18%, depending on the IMRD chosen.

3. CONCLUSIONS

We summarize our key findings and conclusions below:

(1) CVs that are presently forming with BD secondaries are predicted to occupy an orbital period range of 46 min to 2.5 hrs. This result is in substantial agreement with the previous result by Politano 1996. For the assumed choices of $\alpha_{CE} = 1$ and a mass ratio distribution in the ZAMS progenitor binaries, $g(q) \, dq = 1 \, dq$, our model predicts that a significant fraction, ~15%, of CVs are forming with orbital periods shorter than 78 minutes at the present time.

(2) Assuming a constant CV birthrate throughout the Galaxy’s history, the fraction of CVs that are presently forming below the period minimum according to our model, 15%, represents an upper limit to the predicted fraction of all CVs with orbital periods less than 78 minutes at the present time. Of the ~500 CVs with known orbital periods, 15% represents 75 systems. The number of CVs with orbital periods less than 78 minutes is currently two, V485 Cen and 1RXS J232953.9+062814, and it is dubious whether these systems contained substellar secondaries at birth. Thus, even with the reconnis-
tion that 75 systems is an upper limit, the observed number of CVs in the period range 46 min–78 min is still considerably less than the number predicted by our models. It does not seem likely that the discrepancy is due to observational selection effects. The mass transfer rates and, hence, recurrence times, in CVs with BD secondaries below the period minimum should be very similar to systems like WZ Sge and AL Com (cf. Kolb & Baraffe 1999). Consequently, it is difficult to understand why we would not have observed outbursts in them.

(3) We have examined the dependence of the present-day formation of CVs with BD secondaries on the assumed value of the common envelope efficiency parameter, $\alpha_{CE}$. We find that even for values of $\alpha_{CE}$ as low as 0.1, CVs with BD secondaries are still able to be formed. A firm null result for the detection of CVs with BD secondaries having orbital periods less than 78 mins could therefore imply that the transfer of orbital energy into the common envelope is extremely inefficient for systems with very low-mass secondaries. Further, as it is unlikely that the CE process is that inefficient for the entire CV population, such a null detection would also then imply that the efficiency of the CE process is a function of secondary mass. If true, it would then seem extremely coincidental if $\alpha_{CE}$ decreases abruptly exactly at the substellar transition mass. Rather, one would expect that the decrease is smoother and begins in the stellar domain. Consequently, determining if there is a cutoff mass for the secondary, below which merger is inescapable, may have important implications for our theoretical understanding of the orbital period distribution in CVs below, and possibly within, the period gap.

(4) CVs that form with BD secondaries have evolved from progenitor ZAMS + BD binaries with primary masses in the range $\sim$ 1-10 $M_\odot$ and with orbital separations < 3 AU, for an assumed IMRD that is flat ($g(q) = 1$). Furthermore, 75% of these progenitor systems have primary masses $\lesssim$ 1.6 $M_\odot$, and therefore spectral types F or later. The orbital parameter ranges in primary mass and orbital separation for these 75% coincide with the so-called “brown dwarf desert.” Then observations of ultra-short period CVs may be able to provide important clues regarding the formation and distribution of BD + MS in binaries with orbital separations less than 3 AU.

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REFERENCES