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POPULATION SYNTHESIS STUDIES OF WHITE DWARF BINARIES

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RESUMEN

Presentamos estudios de síntesis de población de binarias enana blanca – estrella de la secuencia principal, de variables cataclísmicas que son conducidas por discos circumbinarios y de binarias eclipsantes, en la búsqueda del tránsito de exoplanetas SuperWASP.

ABSTRACT

We present population synthesis studies of white dwarf - main-sequence star binaries, of cataclysmic variables that are driven by circumbinary discs, and of eclipsing binaries in the exoplanet transit search SuperWASP.

Key Words: **BINARIES: CLOSE — BINARIES: ECLIPSING — WHITE DWARFS**

1. INTRODUCTION

We use the BiSEPS population synthesis code developed by Willems & Kolb (2002) to study binaries with a white dwarf component. The code makes use of the analytic fits to the evolution of single stars by Hurley et al. (2000), and follows largely the scheme to treat the evolution of binary stars proposed by Hurley et al. (2002), but was independently developed. For details see Willems & Kolb (2002).

2. WHITE DWARF - MAIN-SEQUENCE STAR BINARIES

Willems & Kolb (2004) revisited the population of Galactic white dwarf (WD) main-sequence (MS) star binaries. Seven evolutionary channels have been identified, as summarised in Table 1. The comprehensive population synthesis serves as a basis for more detailed studies of subclasses and binaries that descend from WD-MS star binaries.

The ratio of systems that contain a helium WD to those that contain a C/O or O/Ne WD may act as a useful diagnostic for constraining the common envelope ejection efficiency α_{CE} (Fig. 1). If $\alpha_{CE} < 1$ this ratio is sensitive to α_{CE} but insensitive to the shape of the otherwise little constrained initial mass ratio distribution $n(q)$. For larger α_{CE} the ratio of WD types is affected by both α_{CE} and $n(q)$.

The observed WD type ratio will depend on observational selection effects. One of these is determined by the luminosity difference between the WD and its MS star companion. As can be seen in Fig. 2 the WD type ratio varies with the limiting luminosity ratio L_{WD}/L_{MS} that is necessary for a positive detection of the WD.

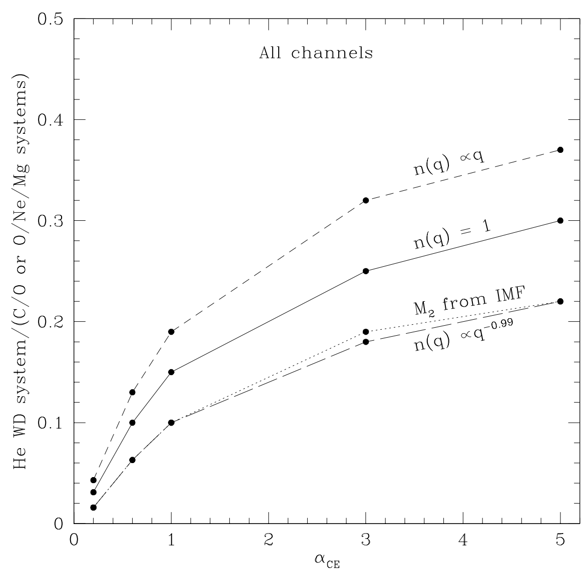

Fig. 1. Ratio of He white dwarf - MS star binaries to C/O or O/Ne WD-MS star binaries for different initial mass ratio or initial secondary mass distributions, as a function of the common-envelope ejection efficiency α_{CE} for WD-MS binaries forming through all considered formation channels.

For more details we refer to Willems & Kolb (2004).

3. CIRCUMBINARY-DISC DRIVEN EVOLUTION OF CVS

Spruit & Taam (2000) suggested circumbinary discs as a possible driver of cataclysmic variable (CV) evolution. Taam et al. (2003) presented the most refined numerical models of the evolution of

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TABLE 1

FORMATION CHANNELS OF WD-MS STAR BINARIES

Channel	nature of 1st RLOF	description	remnant WD	%
1	stable	Case A/B	He	5-15
2	stable	Case B, nHe	C/O, O/Ne	0.1-4
3	stable	Case C	C/O, O/Ne	0.1-3
4	unstable	Case B CE	He	35-40
5	unstable	Case B CE, nHe	C/O, O/Ne	0.1
6	unstable	Case C CE	C/O, O/Ne	50-55
7	non-interacting	-	C/O, O/Ne	C7:(C1-C6) = 7:3

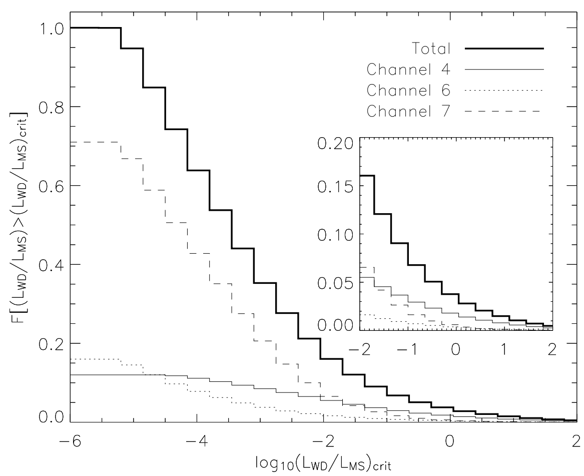

Fig. 2. The fraction F of systems for which the WD to MS star luminosity ratio is larger than the limiting ratio $(L_{\rm WD}/L_{\rm MS})_{\rm crit}$, in the case of a standard population synthesis model (see Willems & Kolb 2004 for details). The thick solid line represents the total for all systems forming through formation channels 1–7, while the thin lines distinguish between the contributions of channels 4, 6 and 7.

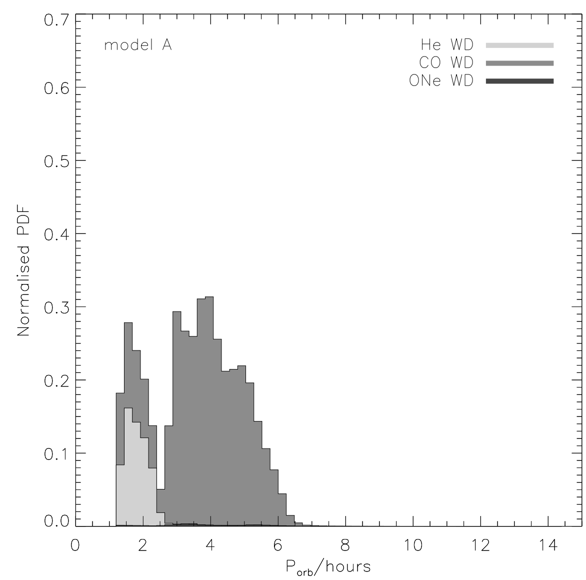

Fig. 3. Predicted orbital period distributions of CVs that evolve under the influence of a circumbinary disc.

CVs with circumbinary discs. In the light of continuing doubts of the validity of the standard disrupted magnetic braking model for the CV period gap (e.g. Andronov et al. 2003) we investigate if circumbinary disc-driven evolution can lead to a feature reminiscent of the period gap in the CV orbital period distribution. To do so we assume an ad-hoc continuous magnetic braking with a timescale of 10^{10} yr, while other parameters affecting the formation and evolution of CVs (such as α_{CE} and $n(q)$) are varied.

We make use of an extended grid of circumbinary disc-driven evolutionary sequences of CVs, a subset of which was published by Taam et al. (2003). The disc feeding parameter δ, the mass accretion rate into the circumbinary disc in units of the mass transfer rate, is assumed to be bimodal ($\delta = 0.0003$ for donor star mass $M_2 > 0.35 M_\odot$, $\delta = 0.0001$ for $M_2 < 0.35 M_\odot$).

Figure 3 shows the resulting orbital period distribution of a complete, volume-limited sample of CVs, for standard parameters as in Willems & Kolb (2002).

We find that a gap feature does appear only if δ is bimodal, and that in the intrinsic population the number of systems above and below the period gap region is about equal. Any likely observational selection effect would favour the brighter systems above the gap, so in order to reproduce the observed period distribution (e.g. Ritter & Kolb 2003) the intrinsic distribution should have a lot more power at short orbital periods. We attempted and failed to achieve this by varying standard parameters within reason-

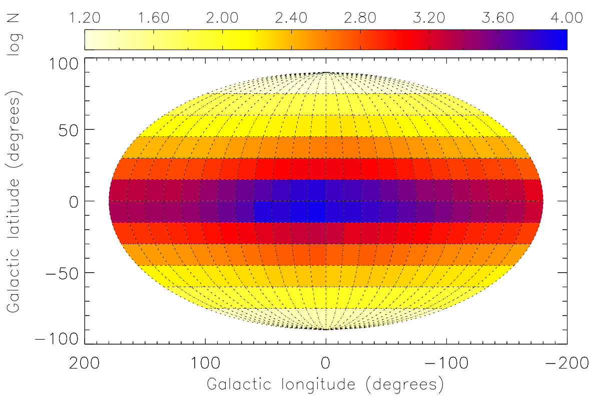

Fig. 4. Detectable number N of eclipsing binaries per $15^o \times 15^o$ field (N is on a log scale).

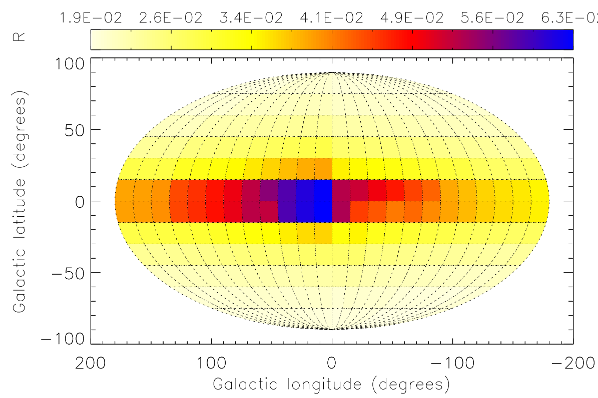

Fig. 5. Same as previous figure, but in units of the number of detectable single stars per field (linear scale).

able limits. This may make circumbinary discs a less attractive model for explaining the CV period gap. A full account of our numerical experiments will be published elsewhere (Willems et al. 2004, in preparation).

4. ECLIPSING BINARIES IN EXOPLANET TRANSIT SEARCHES: SUPERWASP

Exoplanet transit searches will inevitably also detect a large number of eclipsing binaries (EBs). The systematic nature and well-defined selection effects of some of the search projects will deliver a sample of EBs that lends itself to exploitation by population synthesis techniques.

We present preliminary calculations for the expected EB detection rate of SuperWASP (Kane et al. 2003, Street et al. 2003; see also http://www.superwasp.org), a wide-angle angle search for planets which is sensitive to transits with an amplitude in excess of 0.01 mag in the magnitude range $7 < m_V < 13$ in a combined field of view of about $15^o \times 15^o$. The first of several SuperWASP camera sets has just become operational.

We used the Galactic absorption model by Hakkila et al. (1997) to calculate the distribution of EBs as a function of Galactic latitude and longitude. For standard population synthesis parameters the resulting number of EBs per field of view are shown in Figs. 4 and 5, both in absolute terms and in units of the number of detectable single stars in the same field of view.

Using standard population parameters our simulations predict that SuperWASP should find about 5×10^5 EBs among a total of about 7×10^6 stars; up to 7% of stars in a SuperWASP field are expected to be EBs. The table spells out the expected frequency of major binary combinations.

TABLE 2

ECLIPSING BINARIES DETECTABLE BY SUPER-WASP

EB type	fraction	EB type	fraction
MS+MS	11%	AGB+MS	23%
HG+MS	15%	X+MS RLOF	11%
GB+MS	16%	X + WD	1%
HB+MS	11%		

For a detailed account of assumptions and the technique used to calculate the distributions shown on the figures, see Willems, Kolb & Justham 2004, forthcoming.

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