PRESS RELEASE

AMERICAN ASTRONOMICAL SOCIETY

FOR RELEASE 09:20 AM PDT
JUNE 3rd, 2001

On the Theoretical Orbital Period Distribution of Galactic Novae

Lorne A. Nelson, Keith MacCannell, & Ernest Dubeau

Department of Physics, Bishop's University
Lennoxville, QC Canada J1M 1Z7

ABSTRACT

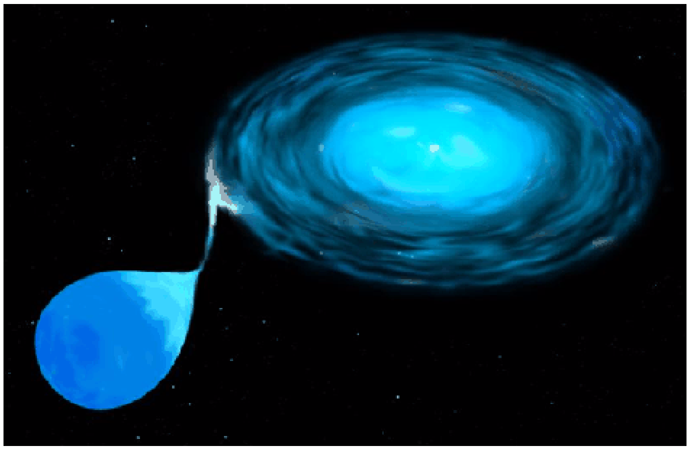
Using population synthesis techniques, we analyze the period distribution and properties of galactic novae. Starting with a primordial population of ten million binaries, we determine which systems will ultimately become cataclysmic variables and hence exhibit thermonuclear runaways. The evolution of these particular systems is then followed over the age of the Galaxy. We then compare the observed number of novae within a specific orbital-period range with that predicted by the population synthesis.

Depending on various assumptions, such as the birth rate function and the efficiency of the common envelope phase, we find that the frequency of nova events should be on the order of 50 events per year. This is in agreement with previous theoretical estimates and the observationally inferred rates (once selection effects have been taken into account). Moreover, the observed distribution of novae is in reasonably good agreement with the synthesis results. The drop-off in the number of novae in systems with orbital periods of more than 10 hours is interpreted as being due to mass-transfer instabilities. These instabilities prevent the formation of cataclysmic variables with higher mass donors and consequentially larger orbital periods. We'll also find that although there is approximately an order of magnitude more cataclysmic variables below the 2-3 hour period gap than above it, the number of novae above the gap should be at least a factor of three times more numerous. This result is also consistent with the observations.

This research was supported in part by an operating grant from the Natural Sciences and Engineering Council (NSERC) of Canada.

CATACLYSMIC VARIABLES

A Cataclysmic Variable is a binary system consisting of a white dwarf and a normal star (companion) that has an incredibly short orbital period (1 - 12 hours). These two stars are so close that the white dwarf literally cannibalizes its companion (see the artist's rendition below). The mass that is lost from the normal star generally (except for highly magnetic white dwarfs) forms an accretion disk around the white dwarf and the hydrogen-rich matter eventually settles onto the white dwarf’s surface. When a sufficient amount of gas has settled onto the white dwarf’s surface, a so-called critical mass is reached and a thermonuclear runaway ensues. This thermonuclear runaway is basically a very-rapid phase of nuclear burning that fuses hydrogen into helium. The explosion is usually so violent that most of the accreted matter is expelled from the binary system in what is referred to as a Classical Nova (CNe). An example of a recently obtained image of a CN using the HST is shown below.



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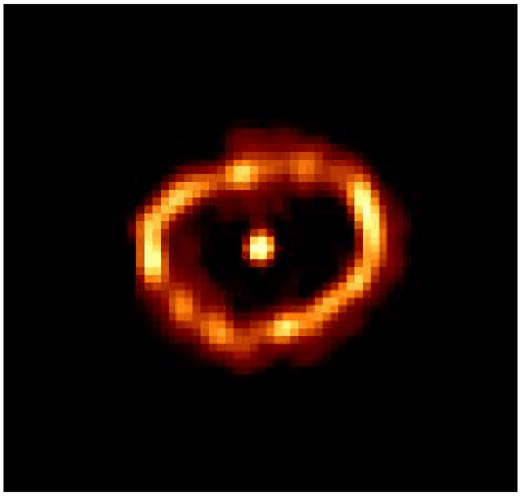
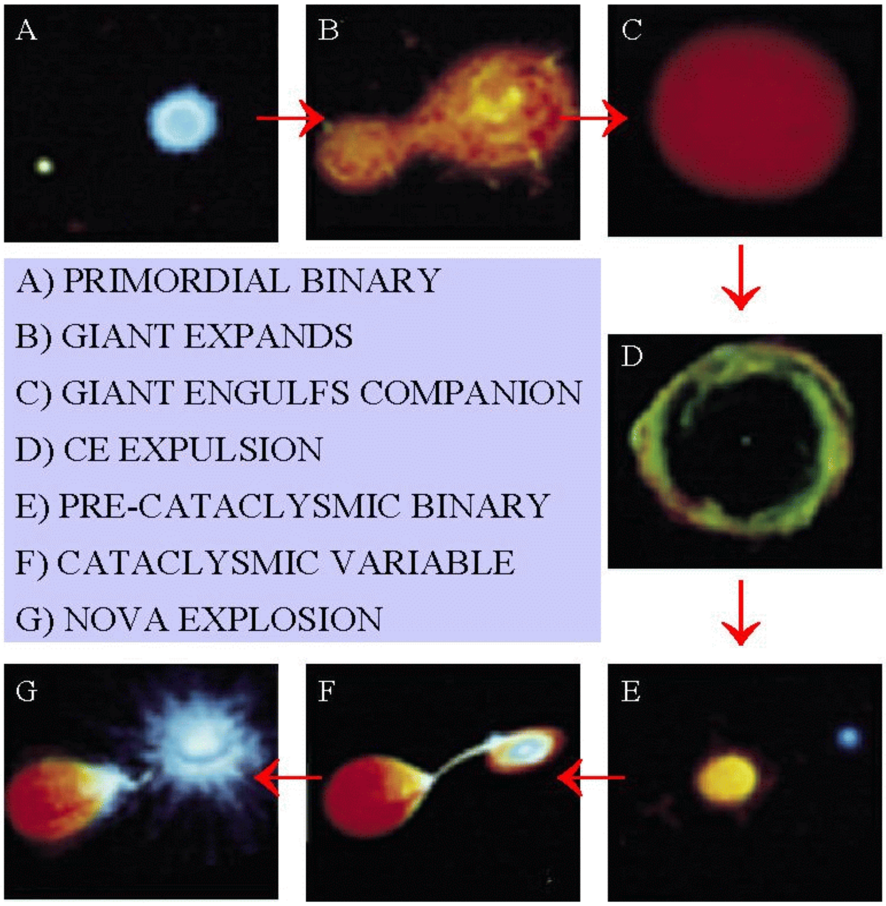


NOVA CYGNI 1992

FROM PRIMORDIAL BINARIES TO CV'S

Cataclysmic Variables are believed to have been formed as a result of a previous phase of mass loss in which a giant (the white dwarf's progenitor) interacted with the normal star (see the pictorial sequence of events on the next page). Nature does not favor the formation of binaries with separations as small as those of CV's. However, if the primordial binary that is originally formed has the correct range of orbital separations and if the mass of one of the stars is sufficiently large that it can evolve into a giant during the age of the universe, then it is possible that a CV can form. Assuming that the giant can swell to such a size that it engulfs the normal star, then a Common Envelope phase ensues. During this phase, the normal star spirals in through the envelope of the giant towards its burned out core (usually composed of a mixture of carbon & oxygen or sometimes helium). The energetics of the phenomenon require that the envelope of the giant be expelled (gravitationally) from the system as the normal star spirals inwards. What remains after the process is complete is a normal star that is in a tight (close) orbit with the core (now referred to as either a carbon-oxygen [or helium] white dwarf). If further angular momentum losses (due to a magnetic stellar wind or gravitational radiation) can bring the two stars close enough, then mass transfer commences and a Classical Nova can occur as a result of a thermonuclear explosion on the surface of the white dwarf star.

Formation of Cataclysmic Variables



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CONCLUSIONS

1) Based on our assumed BRF, we expect ~50 nova explosions per year in our galaxy (to within a factor of 5). This rate is in concordance with previous observational estimates that spanned the range of between 11 - 97 events/yr (Ciardullo et al. [1990], and Liller & Mayer [1987]). Similar theoretical estimates have been obtained by Yungelson, Livio, & Tutukov(1997).

2) The precise values of α (CE efficiency factor) and the assumed correlation between the primordial masses of the primary and the secondary can have a significant effect on the nova frequency distribution (see Figure 2). In particular, an independent correlation tends to produce more systems with low-mass donors (and concomitantly shorter orbital periods) than the $q^{1/4}$ case. Moreover, large values of u tend to produce many fewer TNR's at larger orbital periods (> 5 hrs). The exact conditions under which mass transfer instabilities occur also affect the numbers of systems that can form at large orbital periods (> 6 hrs) thereby changing the nova frequency rate.

3) Based on our models, the frequency-averaged WD mass ($<M_{WD}>$) undergoing TNR's ranges from ~ 0.7 to 1.2 M_{sun}. This range of values for $<M_{WD}>$ is in agreement with the observational estimate of 0.82 +/- 0.26 M_{sun} by Ritter and Burkert (1986) based on a sample of 26 CV systems, and a later estimate of 0.90 M_{sun} (Ritter et al. 1991). Systems containing He-degenerate dwarfs account for less than 10% of the integrated nova frequency rate. For some cases, their contribution can be as low as 1%.

4) The temperature of the accreting WD's has a significant effect on the estimated nova frequencies for systems in the orbital period range of 1 - 2 hours (i.e., below the period gap; see Figure 2). The frequency of nova explosions on the surfaces of hot WD's can be an order of magnitude larger compared to that for cold WD's. The temperature effect above the period gap is considerably smaller (~10 to 80%).

5) The ratio of the frequency of nova explosions above the period gap to that below the gap varies from approximately unity to 12. This is in general agreement with the observations for which the ratio is ~6.

6) The theoretical results tend to indicate that the observed frequency distribution is best matched by having systems with cold WD's below the period gap and having systems with hot WD's above the gap. Because systems born above the gap evolve very quickly (< 1 Gyr) compared to systems below the gap, their WD's are likely to be significantly hotter. The old WD's contained within the short-period systems would have had a substantial amount of time to cool.

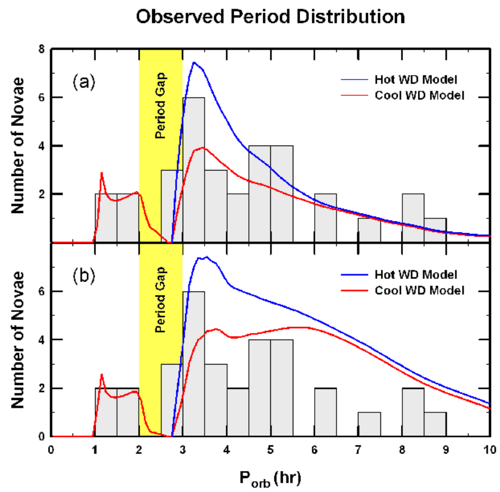

Figure 1. The observed orbital period distribution of novae is illustrated by the histogram (gray bars). The predicted distribution (arbitrarily normalized) is denoted by the red (cool WD) and blue (hot WD) curves. The position of the observed 'period gap' is also shown. Case (a) corresponds to an independent correlation (i.e., independent initial masses), and (b) corresponds to a $q^{1/4}$ correlation; $\alpha = 0.3$ for both cases.

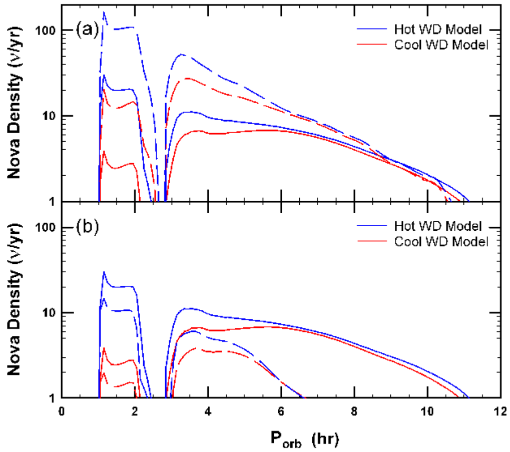

Figure 2. Theoretically predicted nova frequencies (densities expressed per hour of orbital period). Case (a): solid lines correspond to $q^{1/4}$ and dashed lines to independent ($\alpha = 0.3$ for both sets of curves). Case (b): solid lines correspond to $\alpha = 0.3$ and dashed lines to $\alpha = 1$ ($q^{1/4}$ for both sets of curves). As in Figure 1, the blue curves correspond to hot WD's and the red curves to cool ones.

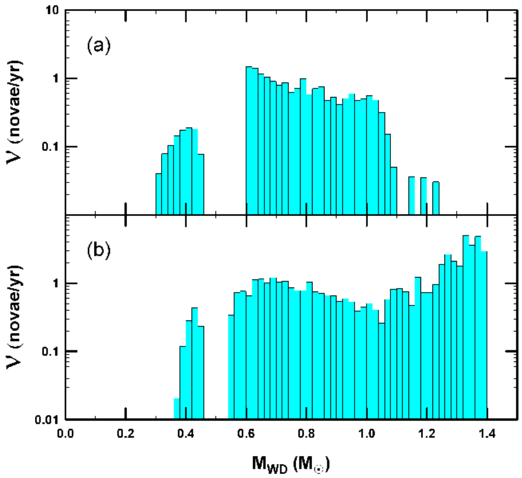

Figure 3. Histogram of the predicted nova frequencies (per 0.02 M_8 bin) as a function of the mass of the WD. Case (a) corresponds to $\alpha = 1$, and (b) corresponds to $\alpha = 0.3$; we have assumed a $q^{1/4}$ correlation for both cases. Note that as α gets smaller, the average mass of a WD undergoing nova explosions increases (see the adjacent table).