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ARE THE PRECURSORS OF TYPE IA SUPERNOVAE DOUBLE DEGENERATE MERGERS?

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RESUMEN

Se argumenta que la evidencia observacional de fusiones enana blanca - enana blanca apoya el punto de vista de que dichos procesos producen enanas blancas ultra-masivas o estrellas de neutrones, mediante colapso inducido por acreción. Se discuten las implicaciones para las progenitoras de SNe tipo Ia.

ABSTRACT

I argue that the observational evidence for white dwarf-white dwarf mergers supports the view that they give rise to ultra-massive white dwarfs or neutron stars through accretion induced collapse. The implications for the progenitors of Type Ia SNe are discussed.

Key Words: **STARS: NEUTRON — STARS: SUPERNOVAE — WHITE DWARFS**

1. INTRODUCTION

The final fate of accreting white dwarfs is still highly debated and the precursors of Type Ia Supernovae (SNe Ia) have not been yet identified. There are two classes of models. One is the single degenerate model, where the white dwarf primary accretes material from a companion star and explodes, usually close to the Chandrasekhar mass limit. The other is the double degenerate scenario where two white dwarfs are drawn together by angular momentum losses caused by gravitational radiation. The SN explosion follows the merging of the white dwarfs.

In this paper, we will present some observational evidence that supports the view that following nuclear burning in merging white dwarfs, a collapse to a neutron star is more likely than a supernova event.

Possible observational evidence for double degenerate mergers, could be compact objects exhibiting some of the following characteristics. (i) Rapid rotation, (ii) Unusual masses; (iii) Unusual compositions (iv) Unusual magnetic fields.

2. SUB-CHANDRASEKHAR WHITE DWARF-WHITE DWARF MERGERS

Among the class of magnetic white dwarfs, there is one object that stands out as being peculiar under several different aspects. The white dwarfs EUVE J0317-854 is (i) Ultra-massive: ~ 1.35 M$_\odot$ (average white dwarf mass is ~ 0.58 M$_\odot$); (ii) Rapidly rotating: 725 seconds (average $\sim$ hours -days); (iii) Ultra-magnetic (up to 800 MG)and with a peculiar field distribution.

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In addition, the physical association of EUVE J0317-854 with the less massive (~ 1M$_\odot$) but older white dwarf LB 9802 causes an age paradox. EUVE J0317-854 is best explained as a merger (Ferrario et al. 1997).

We therefore have at least one example when the merging of two white dwarfs (probably two CO white dwarfs) did not lead to a SN event, even if the total mass of the merged white dwarf is very close to the Chandrasekhar limit.

This suggests that if white dwarf mergers lead to Type Ia SNe, they must result from super-Chandrasekhar mergers.

3. SUPER-CHANDRASEKHAR ACCRETION INDUCED COLLAPSE AND MERGERS

The compact object resulting from a super-Chandrasekhar white dwarf-white dwarf merger or accretion induced collapse (AIC) of a white dwarf must belong to the millisecond pulsars (MSPs) class. Observations of MSPs seem to give some "circumstantial evidence" to support the hypothesis that some members (if not most members) of this class could be the result of accretion processes. In fact, MSPs exhibit (i) much lower magnetic fields ($\lesssim 10^9$ G) than "normal" pulsars ($\sim 10^{11} - 10^{12}$ G); (ii) Rapid rotation (about one thousands that of normal pulsars) and (iii) low space velocities (~ 100 km s^{-1} instead of ~ 500 km s^{-1}), suggesting that there could not have been a substantial SN Type II velocity kick imparted to the neutron star at the point of its formation. Also, the problem associated with the discrepancy between the birthrate of binary MSPs and LMXBs, which are thought to be the progenitors of MSPs, could be alleviated if at least some MSPs could be the result of AIC (e.g. Bailyn & Grindlay 1990; Nomoto & Kondo 1991; Yi & Grindlay 1998).

Saio & Nomoto (1985) (among many others) simulated the merging of two CO white dwarfs as a rapid mass transfer from the less massive white dwarf to the more massive one at a rate of $10^{-5}\mathrm{M}_{\odot}\mathrm{yr}^{-1}$. They find that the fast accretion ignites an off-centre carbon flash. The carbon burning front propagates inward all the way to the centre of the white dwarf and the CO white dwarf turns into an ONeMg white dwarf *quiescently*. The result is *not* a SN Ia explosion induced by carbon deflagration but a collapse triggered by electron captures on ^{24}Mg and ^{20}Ne to form a single neutron star. Saio & Nomoto (1985) predicted that this class of neutron stars might produce the observed isolated millisecond pulsars (e.g. Bailes et al. 1997; Lorimer 2001). There is strong indication that this may indeed be the case since observations of isolated MSPs indicate that (i) they could not have been spun up in binaries (unless they ablated the companion, which is unlikely) and (ii) they exhibit lower radio luminosities than normal MSPs, thus suggesting that they may have had a different origin.

4. DISCUSSION

So we have circumstantial evidence that: (i) Sub-Chandrasekhar white dwarf-white dwarf mergers are unlikely to lead to SN Ia events (EUVE J0317-854 is a surviving example). (ii) Super-Chandrasekhar white dwarf-white dwarf mergers do not necessarily lead to Type Ia SNe (isolated MSPs may be very likely surviving examples). (iii) Not all super-Chandrasekhar accretors may lead to Type Ia SNe, since some binary MSPs could be the result of such an AIC.

Nomoto & Kondo (1991) calculations show that AIC for *both* ONeMg and solid CO white dwarfs is much more likely than explosion and give a range of masses and accretion rates for which collapse or explosion are expected.

They find that the most likely routes to SN Ia events appear to be either (i) helium shell detonation of sub-Chandrasekhar CO white dwarfs after they have accreted a critical mass of helium (edge-lit detonators), or (ii) detonation of CO white dwarfs ignited by carbon deflagration at their centre as they reach the Chandrasekhar mass limit. In either case, the accreted material could be hydrogen or helium. However, in the case of hydrogen, the accretion rate must be $\dot{M} > 10^{-9}\mathrm{M}_{\odot}\mathrm{yr}^{-1}$or the white dwarf would suffer from nova explosions which would not allow it to build up a helium layer through steady hydrogen nuclear burning.

ONeMg white dwarfs, whose masses are already very high ($1.1-1.37\mathrm{M}_{\odot}$), can grow for a much larger range of accretion rates. For these white dwarfs, collapse triggered by electron captures on ^{24}Mg and ^{20}Ne is far more likely than explosion.

The conclusion thus seems to be that if collapse for ONeMg and solid CO white dwarfs is much more likely than explosion, then a significant number, perhaps even the majority, of SNe Ia could arise from helium edge-lit detonations of sub-Chandrasekhar CO white dwarfs (see also the calculations of Livne & Arnett 1995). A range of masses in the precursors of SNe Ia, with the more luminous SNe corresponding to more massive progenitors, has the advantage of being able to explain some of the inhomogeneities observed in SNe Ia events. However, as Regös et al (2002) have recently pointed out, because of systematic effects they may not make good standard candles to study the expansion of the universe.

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