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Edge-lit double detonation in Subchandrasekhar-mass models for Type Ia supernovae

Ramon Forcada[1]

Dept. Física i Enginyeria Nuclear, Univ. Politècnica de Catalunya, and Institut d'Estudis Espacials de Catalunya (IEEC/UPC)
Barcelona, Spain
E-mail: `ramon.forcada@upc.edu`

Domingo García-Senz

Dept. Física i Enginyeria Nuclear, Univ. Politècnica de Catalunya, and Institut d'Estudis Espacials de Catalunya (IEEC/UPC)
Barcelona, Spain
E-mail: `domingo.garcia@upc.edu`

Jordi José

Dept. Física i Enginyeria Nuclear, Univ. Politècnica de Catalunya, and Institut d'Estudis Espacials de Catalunya (IEEC/UPC)
Barcelona, Spain
E-mail: `jordi.jose@upc.edu`

The explosion of a helium layer accreted on top of a white dwarf, leading to the subsequent explosion of the star (while the accreting dwarf is still below the Chandrasekhar mass limit) is an alternative model for some subluminous Type Ia supernova explosions. We present several calculations concerning these so-called sub-Chandrasekhar mass models for Type Ia supernovae, calculated in two dimensions. The usual assumption for this type of models is that the helium shell detonates first, leading to the off-center carbon detonation at the antipodes after a while. We explore the feasibility of a prompted detonation of the carbon lying just beneath the ignition point. To this end, we compare the initial carbon detonation mechanism for several models implying different white dwarf masses and initial helium ignition heights.

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Introduction

The standard model for Type Ia supernovae consists of a white dwarf in a binary system which grows to the Chandrasekhar mass by accretion from its companion, and subsequently explodes (see Röpke this volume). In contrast, the so-called Subchandrasekhar-mass models arise from the explosion of the helium layer accreted on top of the white dwarf, leading to the subsequent explosion of the whole star (while the accreting dwarf is still below the Chandrasekhar mass). This might be an alternative model for some Type Ia supernova explosions, especially for the subluminous subset [1]. We present some two-dimensional hydrodynamic calculations concerning these models, performed with an axisymmetric SPH code. The usual assumption for this type of scenario is that the helium shell detonates first, and the detonation propagates across the helium layer leading to an off-center detonation of the underlying carbon at the antipodes after a while ([2],[3],[4]). The sequence of events leading to the total disruption of the white dwarf is shown in *FIG 1* [5]. In contrast, we also explore the feasibility of a slightly different mechanism: in systems with higher densities at the interphase between the white dwarf and the accreted material, the initial helium hot spot might prompt the detonation of the carbon lying just underneath, leading to an edge-lit double detonation mechanism.

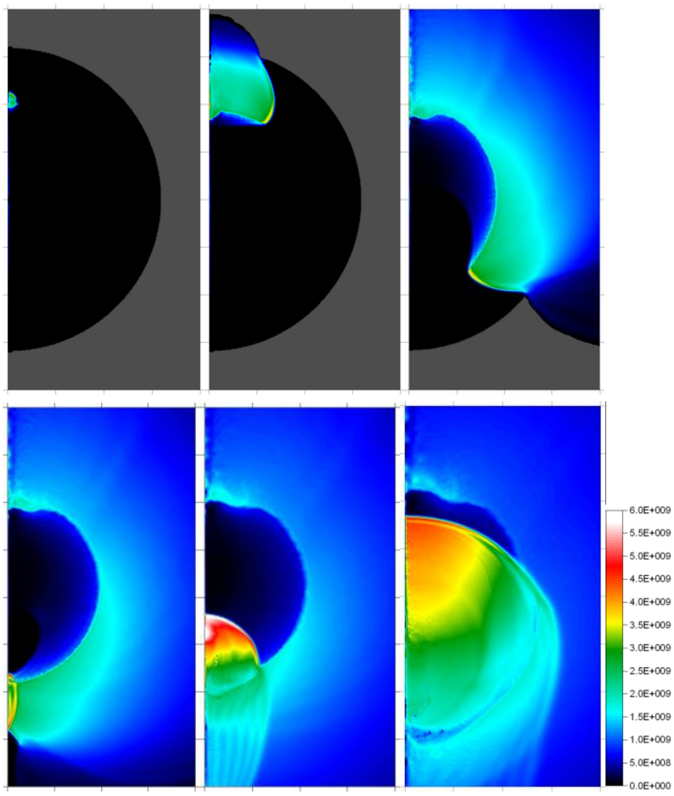

FIG 1 : Model: WD 0.7(core)+0.2(He)solar masses. Single point He-ignition and delayed (antipodes) detonation. Temperature plot at different times (left to right, up to down): t=0.06, 0.28, 0.89, 1.15, 1.38 and 1.71 s. Initial WD is plotted in black. Each box measures $8{\cdot}10^{8} \times 16{\cdot}10^{8}$ *cm. Temperature scale is shown at right*

Toy model in a wedge. Detailed study of the prompt mechanism

Different white dwarf and accreted layer masses (implying different ρ_{edge}) and ignition heights have been studied. Prompt (underneath) versus delayed (antipodes) induced carbon detonation is a function of carbon density at core edge and helium ignition altitude. Previous calculations in 1D showed that critical density was ρ_{edge} ~$6 \cdot 10^6$ gcm^{-3} [4]. In our calculations in 2D, dimensionality effects rise a bit this number to ρ_{edge} ~$8 \cdot 10^6$ gcm^{-3}. (see *TABLE 1* and *FIG 2*) For densities below this value, prompt ignition does not take place; therefore, the C-burning will not begin until the He-burning front converges at the antipode (see introduction). For densities above this value, prompt ignition is likely to happen as long as He is ignited at some height; and C-burning and He-burning fronts develop almost simultaneously (see box on the right in *FIG 2*).

More calculations of complete explosion models involving prompt C-detonations are in progress.

ρ_{edge} (10^6 gcm^{-3})	C-O prompt ignition	
	h~20km	h~200km
2	no	no
4	no	no
6	no	unclear
8	no	yes
10	yes	yes

TABLE 1: Prompt ignition (h=He ignition height)

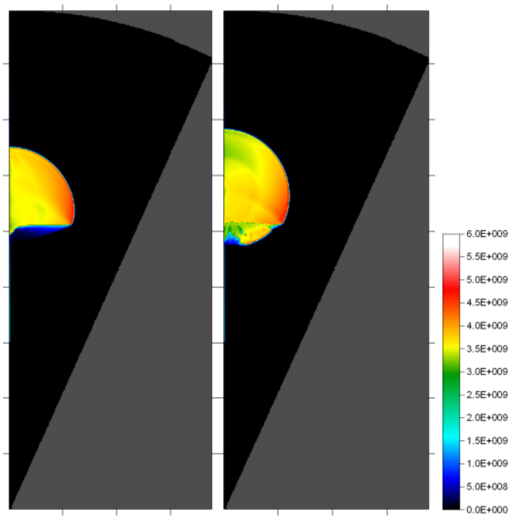

FIG 2: Model in a wedge: WD 088(core)+0.25(He)solar masses (ρ_{edge} ~$8 \cdot 10^6$ gcm^{-3}) . Left: temperature at t=0.054 s if He is ignited above the interphase. Right: temperature at t=0.058s if He is ignited 180km above the interphase. Each box measures $2 \cdot 10^8 \times 6 \cdot 10^8$ cm. Temperature scale is shown at right

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