A Comparison of Type Ia Supernovae with C-O and Hybrid C-O-Ne White Dwarf Progenitors

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Abstract

Motivated by recent results in stellar evolution that predict the existence of hybrid white dwarf (WD) stars with a C-O core inside an O-Ne shell, we simulate thermonuclear (Type Ia) supernovae from these hybrid progenitors. We perform 2-D simulations in the deflagration to detonation transition (DDT) paradigm of Type Ia Supernovae from hybrid C-O-Ne progenitors produced with the MESA stellar evolution code (Denissenkov et al., 2015). We compare the results from these hybrid progenitors to previous results from C-O white dwarfs (Kruuger et al., 2012). We find that despite significant variability within each suite, trends distinguishing the explosions are apparent in their $^{56}$Ni yields and the kinetic properties of the ejecta.

Hybrid Type Ia Supernovae Progenitor Profile

[Image of Hybrid Type Ia Supernovae Progenitor Profile]

ZND Detonations for C-O-Ne Fuel

[Image of ZND Detonations for C-O-Ne Fuel]

Initialization of the Deflagration

[Image of Initialization of the Deflagration]

Delayed Core Detonation For Some Hybrid Realizations

[Image of Delayed Core Detonation For Some Hybrid Realizations]

Integral Quantities (e.g. $^{56}$Ni Mass) With Shading Showing the Range of Results Given By The Hybrid and CO Suites of Simulations

[Image of Integral Quantities with Shading]

Conclusions

- Type Ia Supernovae from hybrid white dwarf progenitors yield on average 0.1 M$_\odot$ less $^{56}$Ni than from C-O progenitors, suggesting they will be correspondingly dimmer. Exceptions may occur, however, given the large spread in possible $^{56}$Ni production among our hybrid realizations.
- Hybrid progenitors deposit an average of 21% less kinetic energy in their ejecta than C-O progenitors, indicating slower expansion velocities of the ejecta.
- We attribute lower average $^{56}$Ni production from hybrid progenitors to the lower binding energy released when burning $^{56}$Ne-enriched fuel compared to pure C-O fuel. Based on the comparable average mass remaining at high ($>2 \times 10^{32}$ g/cm$^3$) density at the DDT time for C-O and hybrid models, we conclude that the degree to which fuel is burned to Fe-group elements is not caused by differences in stellar expansion during the deflagration stage.

References


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