Recent results on (a) metallicity dependencies and (b) double degenerate collisions

Frank Timmes
D. Townsley, A. Calder, A. Jackson, E. F. Brown, D. Chamulak
C. Raskin, E. Scannapieco, W. Hawley, S. Diehl, C. Fryer

Outline

1. Systematic dependencies from $^{22}\text{Ne}$: simple counting, simmering, & dynamics

2. Double-degenerate mergers: collision cases
The only sure way to know that you've got a supernova in your sights, especially shortly after an explosion, is to capture a diagnostic spectrum. Basically, supernovae come in two flavors: those that have hydrogen (Type II, from a very massive star that blows up) and those that don't (Type I, due to thermonuclear runaways in a less massive star).

Both types exhibit a wide variety of subclasses. Type Ia is of no interest because these stars don't emit neutrinos. Types Ib and Ic are thought to undergo core collapse like Type II supernovae and, therefore, should emit neutrinos.
A higher metallicity can reduce $^{56}$Ni, yielding a dimmer Ia.

$$M(^{56}\text{Ni}) = M(^{56}\text{Ni})_{Z=0} \left[ 1 - 0.057 \frac{Z}{Z_\odot} \right]$$

Roepke et al. 2005
Travaglio et al. 2004
Brown et al. 2004
Timmes et al. 2003
Neutronization during “simmering” sets a floor that could wash out the TBT03 metallicity effect for individual SNIa with $Z/Z_{\text{sol}} < 1/2$.

Piro & Bildsten 2008
Chamulak et al 2008

Correlations between O/H and $\Delta m_{15}(B)$ may be masked.
Recent observations leave the situation somewhat murky.

Constraining a $Z$ dependence is challenging in part because there appears to be a stronger dependence on mean stellar age.
Given the uncertainty, we continue to look for new metallicity effects.

We’ve now examined how $^{22}\text{Ne}$ influences rising of burning material and expansion of the star.

We use a suite of randomized initial conditions in 2d DDT models, whose $^{56}\text{Ni}$ masses and Si-group velocities have averages and ranges similar to those observed.
From 20 ignition conditions, systematic changes from expansion prior to detonation are too small to alter the TBT03 effect.

This points to ignition morphology as being the dominant driver of the $^{56}$Ni yield of the explosion for a fixed DDT density.
“To the extent that it’s possible, it is the isotopes that keep the theorists honest.”

David Arnett
2009 Hans A. Bethe Prize
We’ve started an NSF funded effort to examine double-degenerate mergers with Lagrangian and Eulerian toolkits.

\[ b = R \sqrt{1 + \left( \frac{v_{\text{esc}}}{v} \right)^2} \]  

\[ t_{\text{coll}} = \frac{1}{\pi b^2 v n} \]

Following Pfhal et al. (2009), for typical WD & globular parameters we find 1 WD-WD collision in globulars per year within 100 Mpc.

If there are blue stragglers, there are going to be grazing WD-WD collisions ...

... and Chomiuk et al. 2008 identify a SNIa remnant in a globular orbiting NGC 7457.
3D, all particle projection onto xy-plane, color shows speed in x-direction.

Raskin et al. 2009
Head-on collisions of $0.6 + 0.6$ Msun WD produce dim SNIIa with a somewhat unusual element distribution.

Raskin et al. 2009

3D, xy-plane slice,
blue = $^{56}\text{Ni}$
red = Si-group
green = C+O
0.6 + 0.6 Msun, 1 WD radii impact parameter, fails to yield an initial explosion.

3D, xy-plane slice, color shows temperature

Raskin et al. 2009
Questions and Discussion

$^{56}\text{Ni}$

$^{56}\text{Co}$

$q = 3 \times 10^{16} \text{ erg/g}$

$e^{-}$ capture $\tau = 6.1 \text{ d}$

$\gamma_{748 \text{ keV}}$

$\gamma_{812 \text{ keV}}$

$\gamma_{158 \text{ keV}}$

$^{56}\text{Fe}$

$q = 6.4 \times 10^{16} \text{ erg/g}$

$e^{-}$ capture $\tau = 77.1 \text{ d}$

$\gamma_{1238 \text{ keV}}$

$\gamma_{847 \text{ keV}}$