ACCRETION WINDS FROM SN TYPE Ia PROGENITORS AND SUPERNOVA REMNANT EVOLUTION

Dan Patnaude (SAO)
INTRODUCTION

• Progenitors for Type Ia SNe have not been confidently identified (Hillebrandt & Niemeyer 2000)
• Type Ia’s are the result of a thermonuclear explosion of a C+O white dwarf that is destabilized by accretion from a binary companion
• Single degenerate is most promising, but requires 0.2 - 0.7 $M_{\odot}$ of material to be transferred to the white dwarf while avoiding unstable degenerate conditions on the white dwarf surface (Langer et al. 2000; Nomoto 1982)
Accretion Winds

- Models for SD-Ch scenarios predict outflows during the pre-supernova evolution.
- If these outflows are present, they will leave their imprint on the circumstellar medium.
- Prompt emission at radio/X-ray wavelengths has not been detected in Type Ia events (Panagia et al. 2006; Hughes et al. 2007).
ACCRETION WINDS

• Key parameter that determines whether a binary system will lead to a Type Ia SN is the accretion rate of the white dwarf

• Stable accretion depends upon the white dwarf mass, metallicity of the material, and rotation, but is generally:

\[ \dot{M}_{\text{stable}} = 10^{-7} M_\odot \text{yr}^{-1} \]
ACCRETION WINDS

- At higher accretion rates, the shell can puff up to red giant dimensions (Nomoto & Kondo 1991):
  \[
  \dot{M} = \dot{M}_{\text{Edd, nuc}} \simeq 6 \times 10^{-7} M_\odot \text{yr}^{-1}
  \]

- A solution was proposed whereby the luminosity from the shell nuclear burning drives an optically thick "accretion wind" from the white dwarf, such that the effective accretion rate is below \( \dot{M}_{\text{Edd, nuc}} \).
ACCRETION WINDS

- Hachisu et al. (1999a,b) modeled the evolution of these winds
- found timescales $\sim 10^5$ yr and mass loss rates $\sim 10^{-6} \, M_{\text{sun}} \, \text{yr}^{-1}$
- Observations of candidate Type Ia systems such as RX J0513.9-5961 show outflow velocities $\sim 4000 \, \text{km} \, \text{s}^{-1}$ and mass loss rates $\sim 2 \times 10^{-6} \, M_{\text{sun}} \, \text{yr}^{-1}$
COMPARISONS TO SNRs

- Remnants of Type Ia SN are typically thought to be expanding into a uniform CSM
- Accretion wind outflows will shape the CSM in a way similar to what is found around core collapse environments
- This should affect both the morphology and emitted spectrum of the remnant
Comparisons to SNRs

- Badenes et al (2007) compared Chandra observations of several Ia SNRs to models that include an accretion wind mass loss phase.
COMPARISONS TO SNRs

- Badenes (2007) parametrized accretion wind models
- Models either show accretion winds up to the Type Ia event or in some cases the enter a mass conservative phase
Standard models with fast winds ($\sim 10^3$ km s$^{-1}$) predict shocked wind densities of $\sim 10^{-4}$ cm$^{-3}$.

Lower outflow velocities predict higher shocked wind densities, and dense radiative shells at radii $\leq 10$ pc.

Lower limit on outflow velocity is set by WD escape velocity.
COMPARISONS TO SNRs

• CSM structures in the slow regime are hard to distinguish from the constant ambient medium models.

• Models for SNR evolution do not seem to agree with either the dynamics (i.e. the forward shock velocity) or observed X-ray emission of SNR Type Ias.
A new class of Ia’s has been identified with strong CSM interactions (2002bo, 2002ic, 2005gj, etc).

- have outflows $\sim 10^{-5}$ $M_{\text{sun}}$ yr$^{-1}$ and low wind velocities.

Lightcurve for SN 2002ic. The lightcurve resembles that of a core collapse SN. SN 1994D is also classified as a Ia.
Kepler’s SNR

- Has been classified as a Type Ia
- Has a dense CSM interaction in the north
- Thought to have a dense, slow outflow from progenitor system