Populations of accreting, nuclear-burning white dwarfs and the origin of SNe Ia

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Introduction

- Type Ia supernovae (SNe Ia)
  - "standard" candles $\rightarrow$ cosmological parameters
  - Important for chemical evolution
  - etc

- Alright, so how do you make a SN Ia?
  - A carbon-oxygen white dwarf undergoes a thermonuclear explosion...

  … somehow …
Introduction

How do you make a SN Ia?

Single Degenerate (SD)  Double Degenerate (DD)
Introduction

- Problems exist with both models
- Double Degenerate:
  - May lead to accretion-induced collapse
  - However, violent mergers, sub-$M_{Ch}$ explosions may solve this...
- Single Degenerate:
  - Should be strong X-ray sources...
  - $T \sim 2 \times 10^5 - 10^6 \text{ K}$, $L \sim 10^{38} \text{ erg/s}$
Introduction

- We can estimate the total luminosity of a population of SD progenitors (as in Gilfanov & Bogdan 2010, Di Stefano 2010):

\[ L_{\text{tot,SNIa}} \approx N_{\text{progenitors}} \cdot L_{\text{nuc}} = \epsilon H \chi \Delta M_{\text{Ia}} \dot{N}_{\text{SNIa}} \]

- But! Soft X-ray emission may be primarily absorbed near the source

- Photosphere may be inflated, pushing most emission to the EUV (\( T \sim 1 - 2 \times 10^5 \), e.g. in accretion wind regime, Hachisu+ 2010)
Q: Is there some other way to detect/constrain the number/luminosity of SD progenitors?

A: Accreting white dwarfs should also be strong ionizing sources.
In general, for nuclear-burning white dwarfs $T \approx 10^5K - 10^6K$, spectra $\sim$ blackbody.

In accretion-wind binaries, no break at He II edge (Woods & Gilfanov 2013).

In elliptical galaxies, little to compete with...
Ionized Gas in Elliptical Galaxies

- Elliptical galaxies not without warm ($T \approx 10^4$K) ISM (see e.g. Sarzi+ 2006)

- Often in smooth, disky distribution (ATLAS 3D), other morphologies seen as well

- Primary ionizing source likely a component of the stellar population (e.g. Sarzi+ 2010, Yan & Blanton 2012)
Ionized Gas in Elliptical Galaxies

Bruzual and Charlot (2003)
Ionized Gas in Elliptical Galaxies
Ionized Gas in Elliptical Galaxies

- SN Ia progenitors dramatically harden spectrum beyond He II photoionizing limit → should see recombination lines
- Strongest observable line
  - $n = 3 \rightarrow 2$ transition (1640Å)
- Strongest optical line
  - $n = 4 \rightarrow 3$ transition (4686Å)
- So far, no observed He II recombination lines in ellipticals
Ionized Gas in Elliptical Galaxies

\[ L_{4686} \approx 1.4 \cdot 10^{40} t_{\text{Gyr}}^{1.7} T_5^{-1} f_c \frac{\Delta M}{0.3 M_\odot} \frac{M(t)}{10^{10} M_\odot} \text{ erg/s} \]
Observations & Follow-Up

Stacked sample: SDSS
1Gyr < t < 4Gyr

Select only “Retired Galaxies” using emission line criteria (Fernandes+ 2011)

Johansson+ 2014
Comparison with Population Synthesis

Compare with Binary Population Synthesis (Chen, Woods et al 2014)

- For ~100,000 systems, evolve using semi-analytic prescription (BSE)
- Follow accretion onto WD in detail using MESA (~10,000 tracks)

Chen, Woods et al in prep
Conclusions

- If most SNe Ia evolve through the SD channel, progenitors play a significant role in the ionizing background within early-type galaxies.
- Early-type galaxies (with warm ISM) would exhibit He II emission in their spectra, clear trend with mean stellar age.
- Not observed! Any high-temperature SD channel can only account for \(<\sim 10\%\) of SNe Ia.
- “Normal” accreting WD population also problematic.
Introduction

Hachisu+ (2010)
Observations & Follow-Up