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

Tyrone Woods

with Marat Gilfanov, Jonas Johansson, Marc Sarzi, & Hai-Liang Chen

Introduction

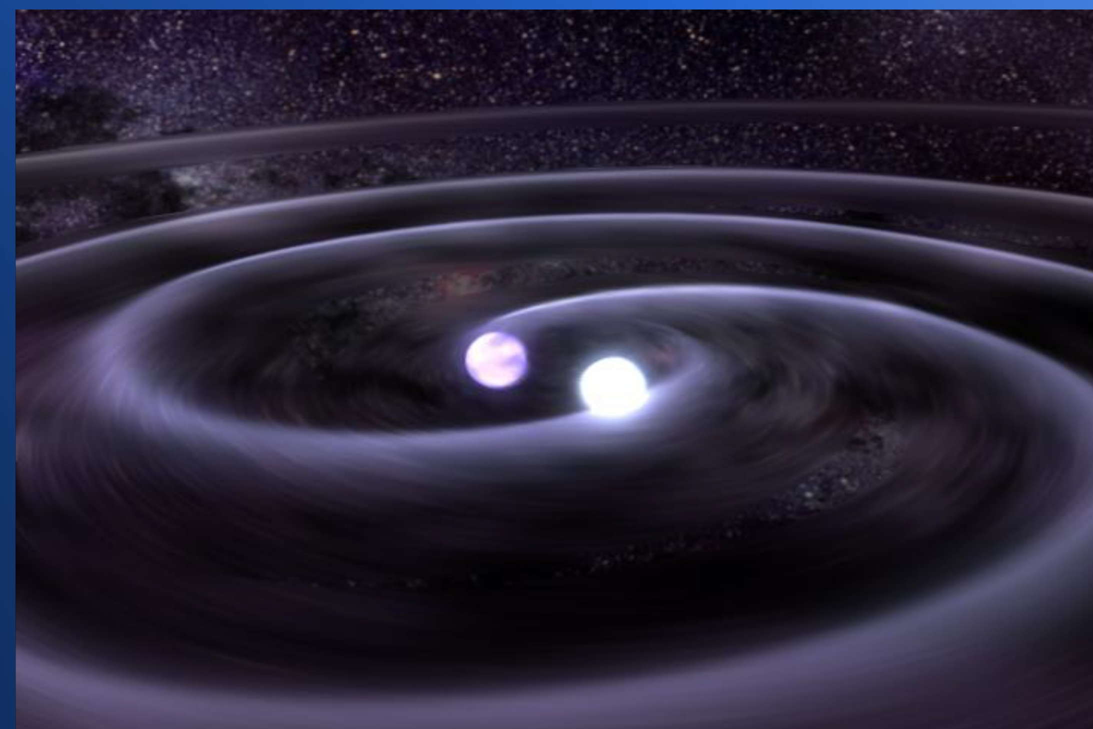
- Type Ia supernovae (SNe Ia)
  - “standard” candles → cosmological parameters
  - Important for chemical evolution
  - etc
- Alright, so how do you make a SN Ia?
  - A carbon-oxygen white dwarf undergoes a thermonuclear explosion...

… 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 K, $L \sim 10^{38}$ erg/s)

Introduction

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

$$L_{\rm tot,SNIa} \approx N_{progenitors} \cdot L_{nuc} = \epsilon_{\rm H} \chi \Delta M_{\rm Ia} \dot{N}_{\rm SNIa}$$

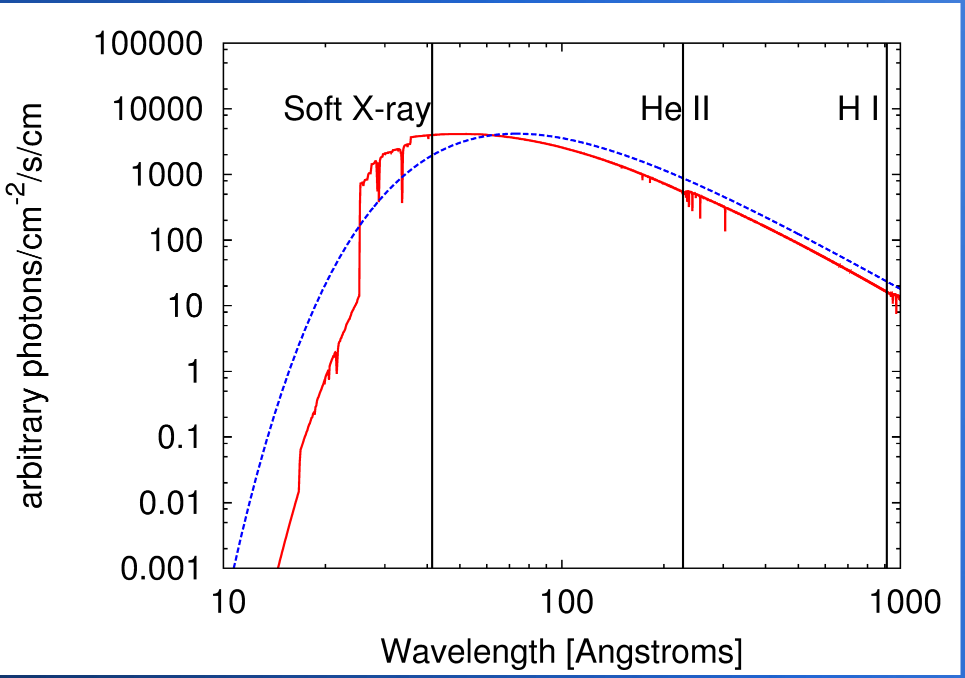
- But! Soft X-ray emission may be primarily absorbed near the source
- Photosphere may be inflated, pushing most emission to the EUV (T ~ 1 – 2 x 10^5, e.g. in accretion wind regime, Hachisu+ 2010)

Introduction

- 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

Introduction

- In general, for nuclear-burning white dwarfs $T \approx 10^5$K – 10^6K, spectra ~ blackbody
- In accretion-wind binaries, no break at He II edge (Woods & Gilfanov 2013)
- In elliptical galaxies, little to compete with...

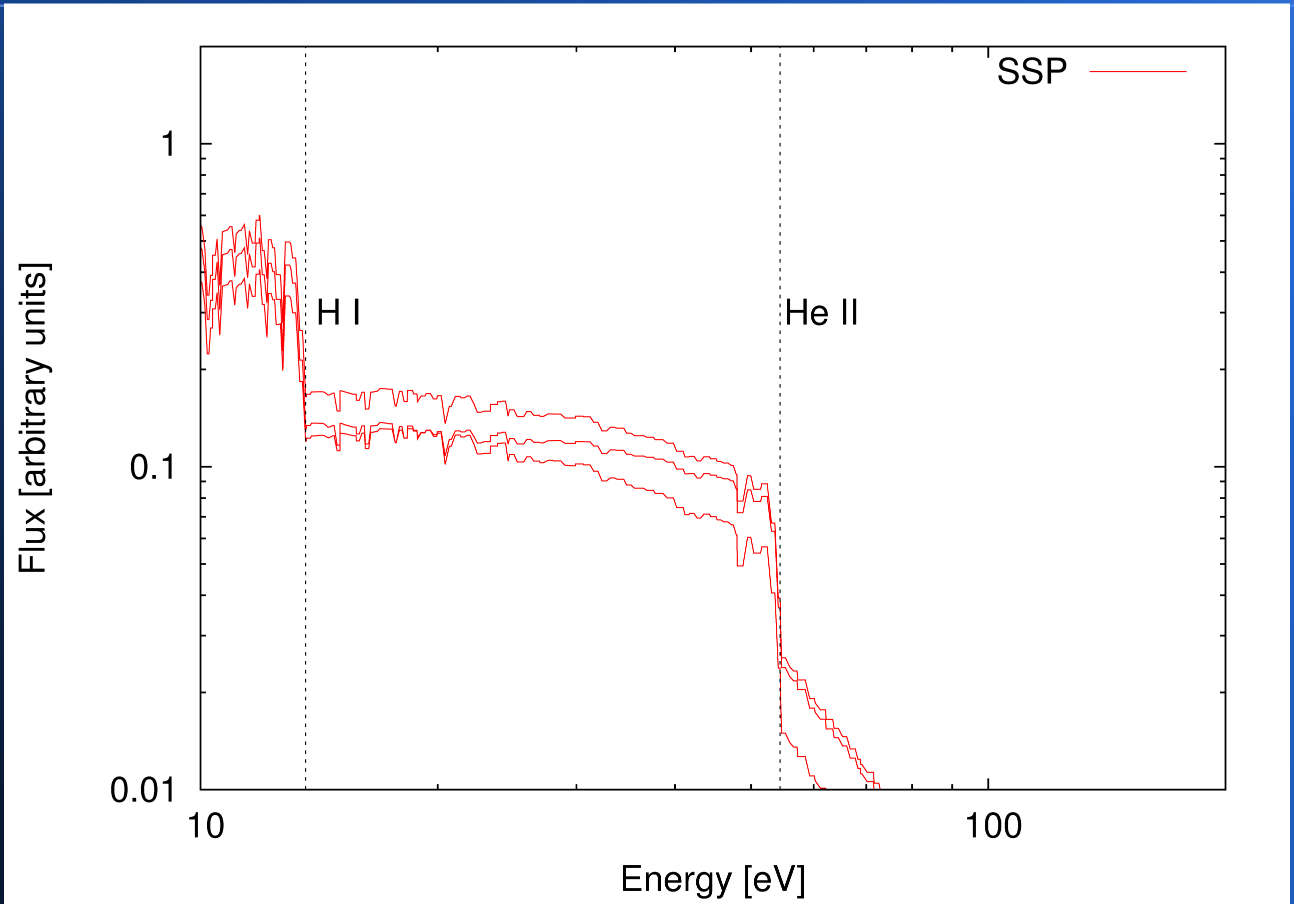


Rauch+ 2010 (red) and a simple blackbody (blue) for a $T = 5 \times 10^5$ K hot white dwarf.

Ionized Gas in Elliptical Galaxies

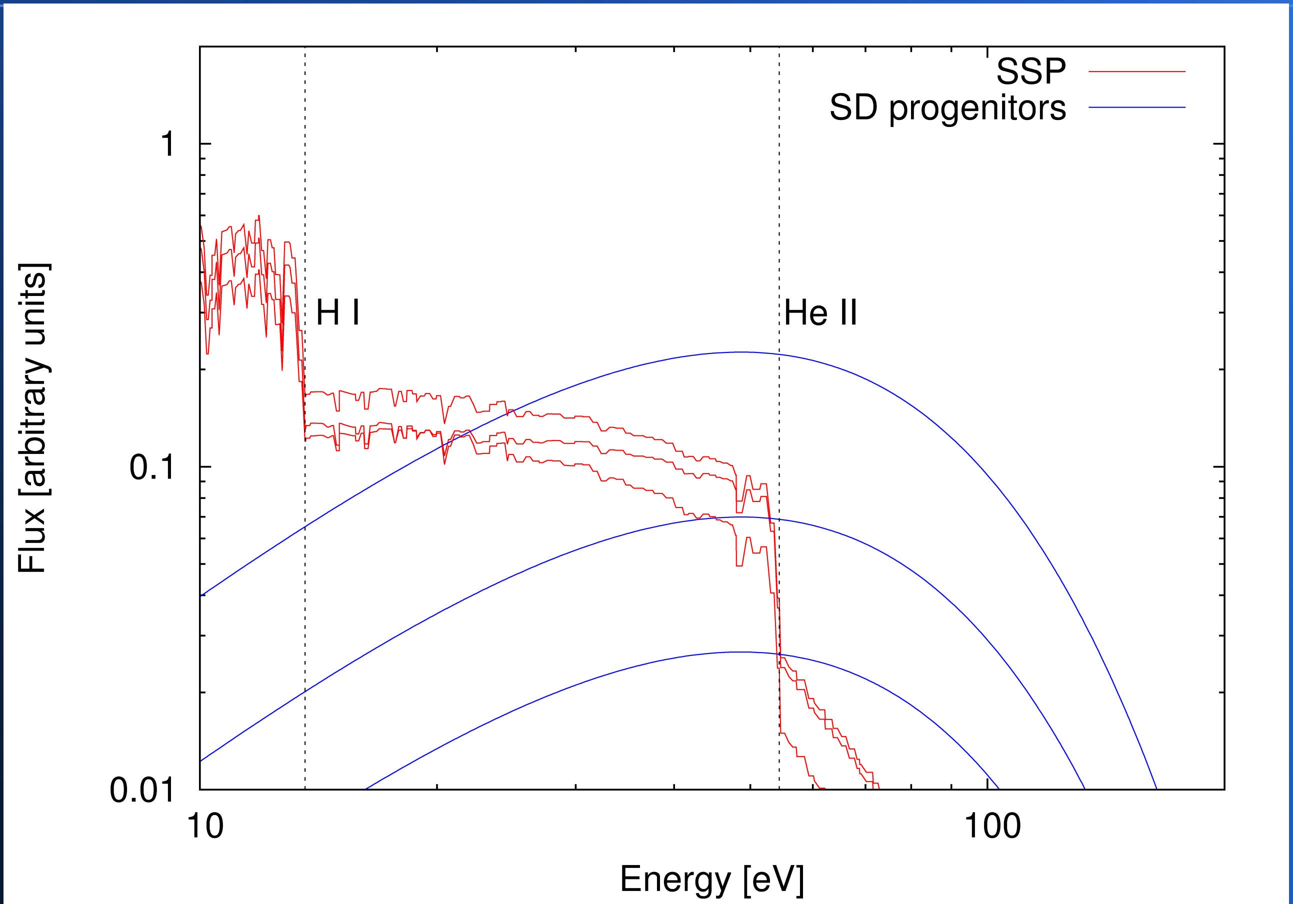
- Elliptical galaxies not without warm ($T \approx 10^4$K) ISM (see e.g. Sarzi+ 2006)
- Often in smooth, disky distribution (ATLAS 3D), other morphologies seen as well
- Primary ionizing source likely a component of the stellar population (e.g. Sarzi+ 2010, Yan & Blanton 2012)

Ionized Gas in Elliptical Galaxies



Bruzual and Charlot (2003)

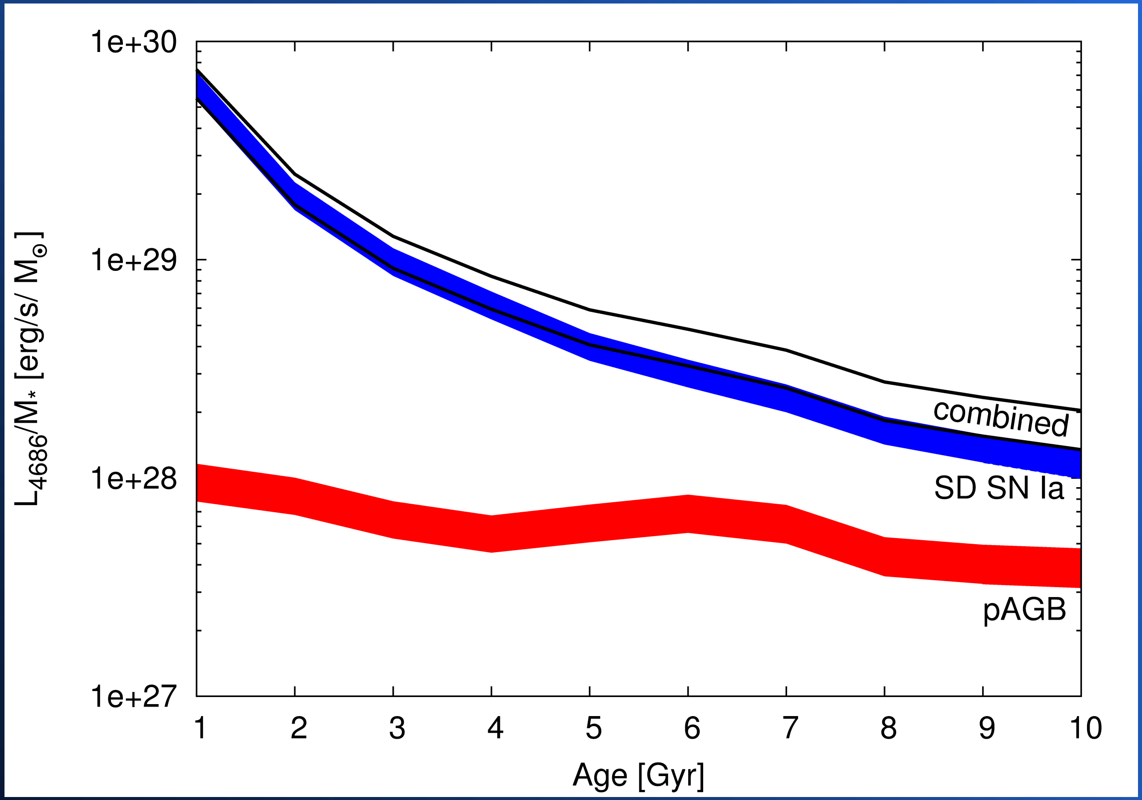
Ionized Gas in Elliptical Galaxies



Ionized Gas in Elliptical Galaxies

- SN Ia progenitors dramatically harden spectrum beyond He II photoionizing limit $\rightarrow$ 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

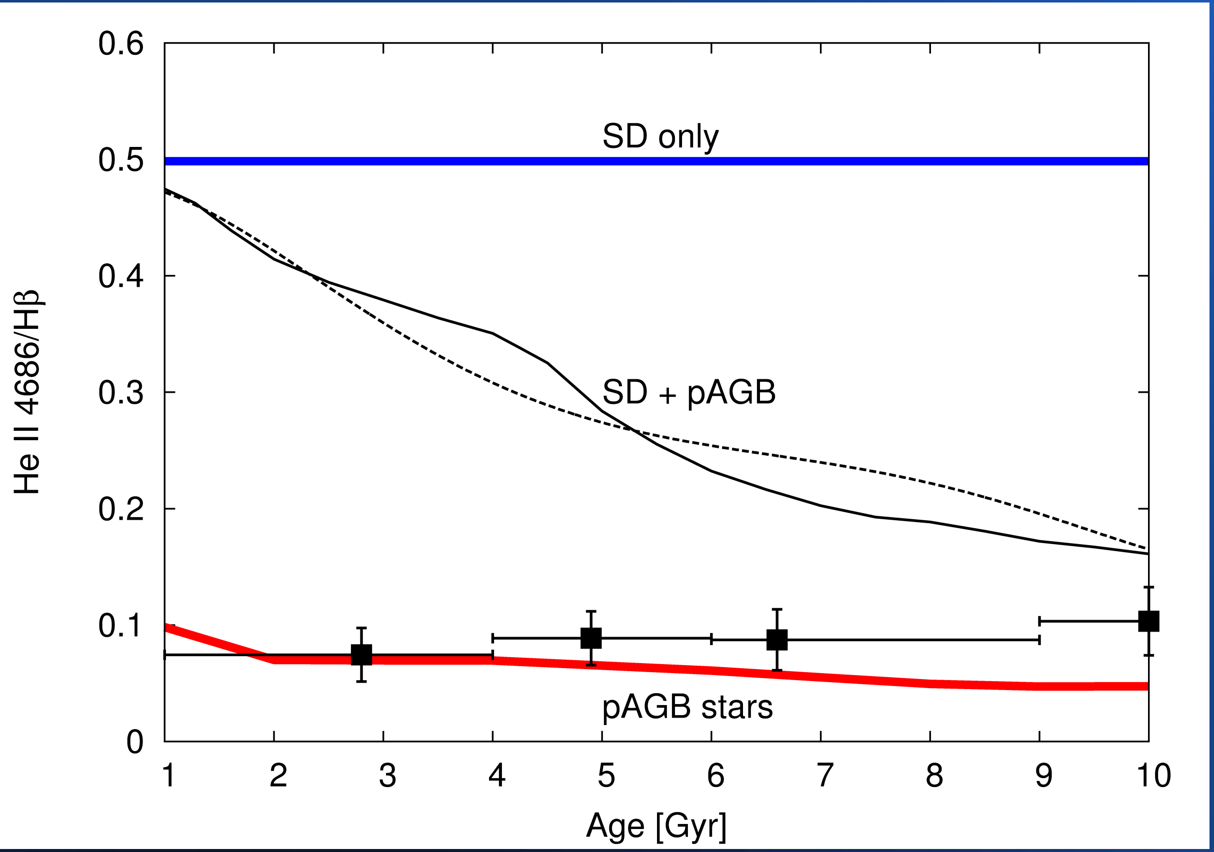
Ionized Gas in Elliptical Galaxies



$$L_{4686} \approx 1.4 \cdot 10^{40}\ t_{Gyrs}^{-1.7}\ T_5^{-1}\ f_c\ \frac{\Delta M}{0.3 M_\odot} \frac{M(t)}{10^{10} M_\odot}\ \mathrm{erg/s}$$

MAPPINGS III

Observations & Follow-Up



Stacked sample:
SDSS
1Gyr < t < 4Gyr

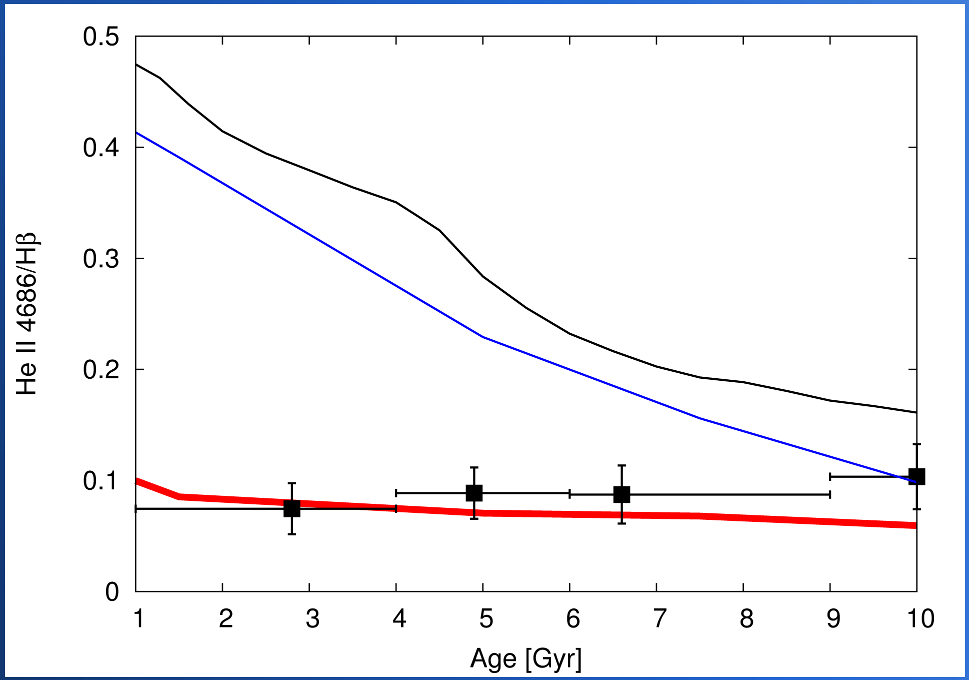
Select only "Retired Galaxies" using emission line criteria (Fernandes+ 2011)

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)

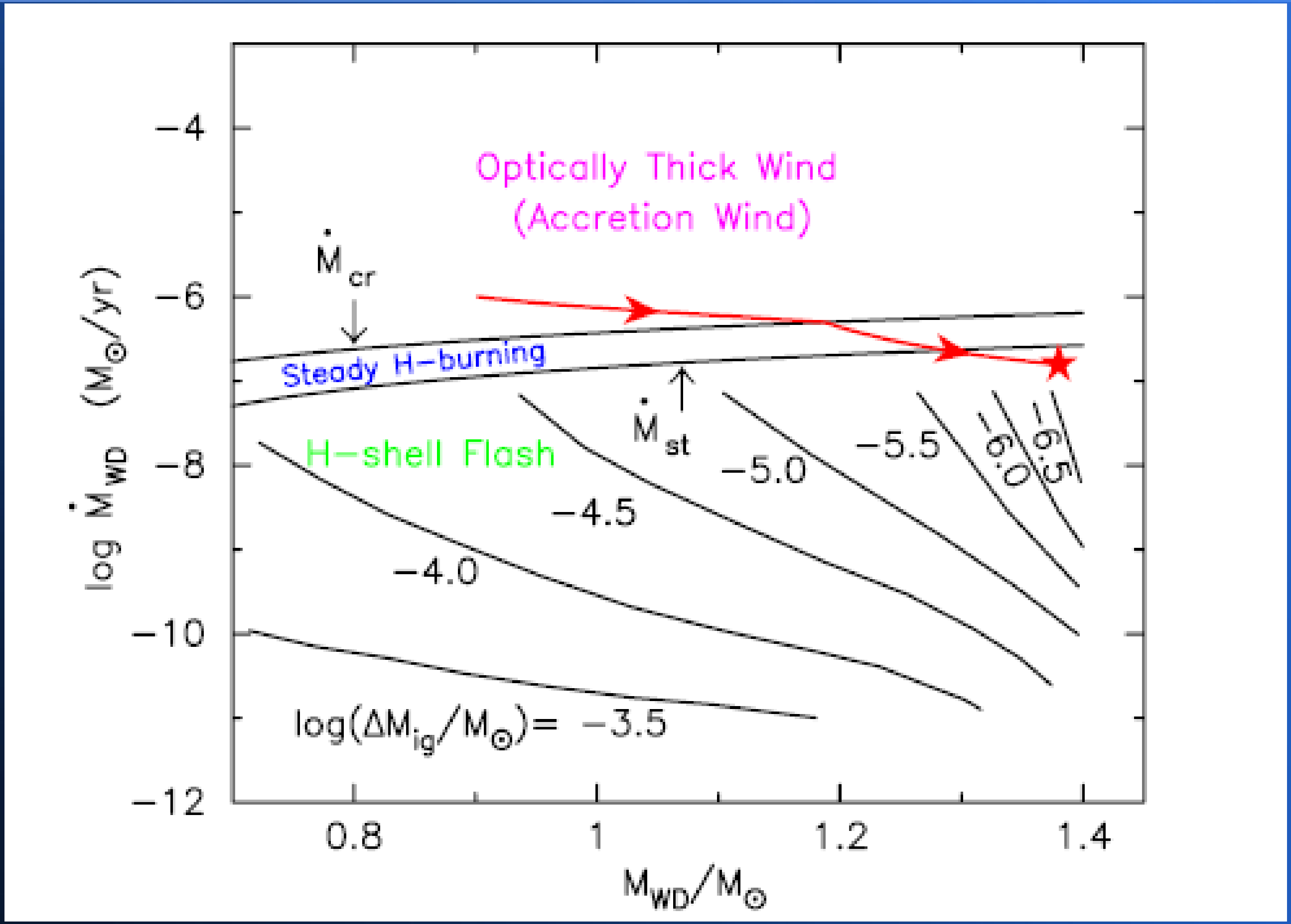


Chen, Woods et al in prep

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 <~10% of SNe Ia.
- “Normal” accreting WD population also problematic

Introduction



Hachisu+ (2010)

Observations & Follow-Up