Type Ia Supernova Archaeology: Searching for the relics of progenitors past

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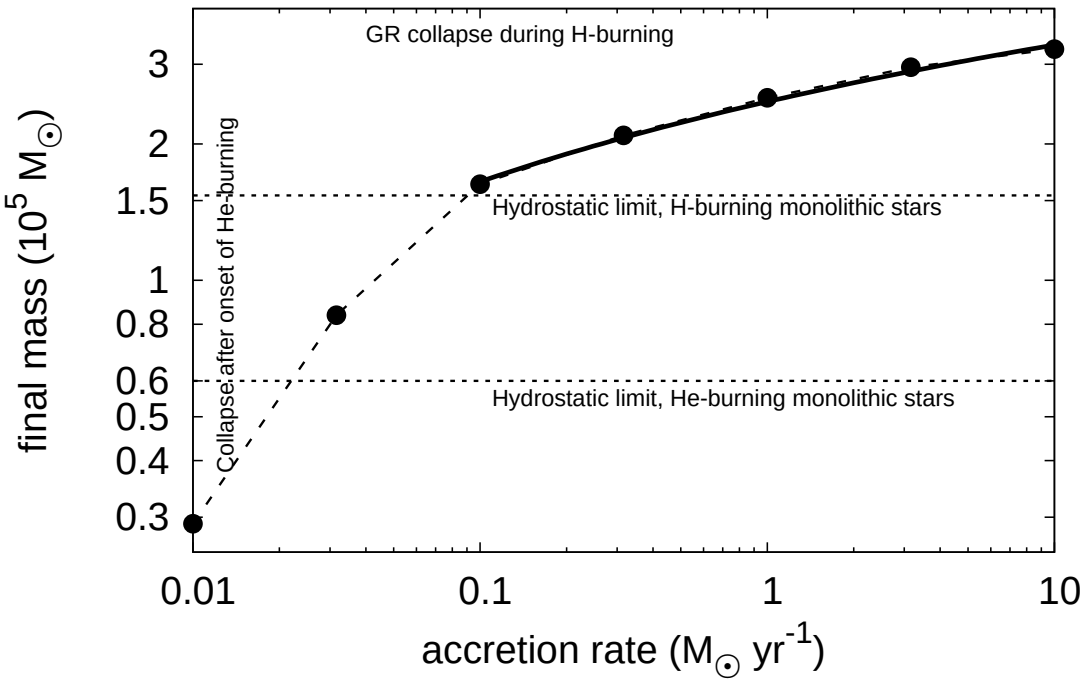
With Carles Badenes, Parviz Ghavamian, Armin Rest, Alejandro Clocchiatti, Marat Gilfanov, Lev Yungelson, Marc Sarzi, Hai-liang Chen, Jonas Johansson, et al.

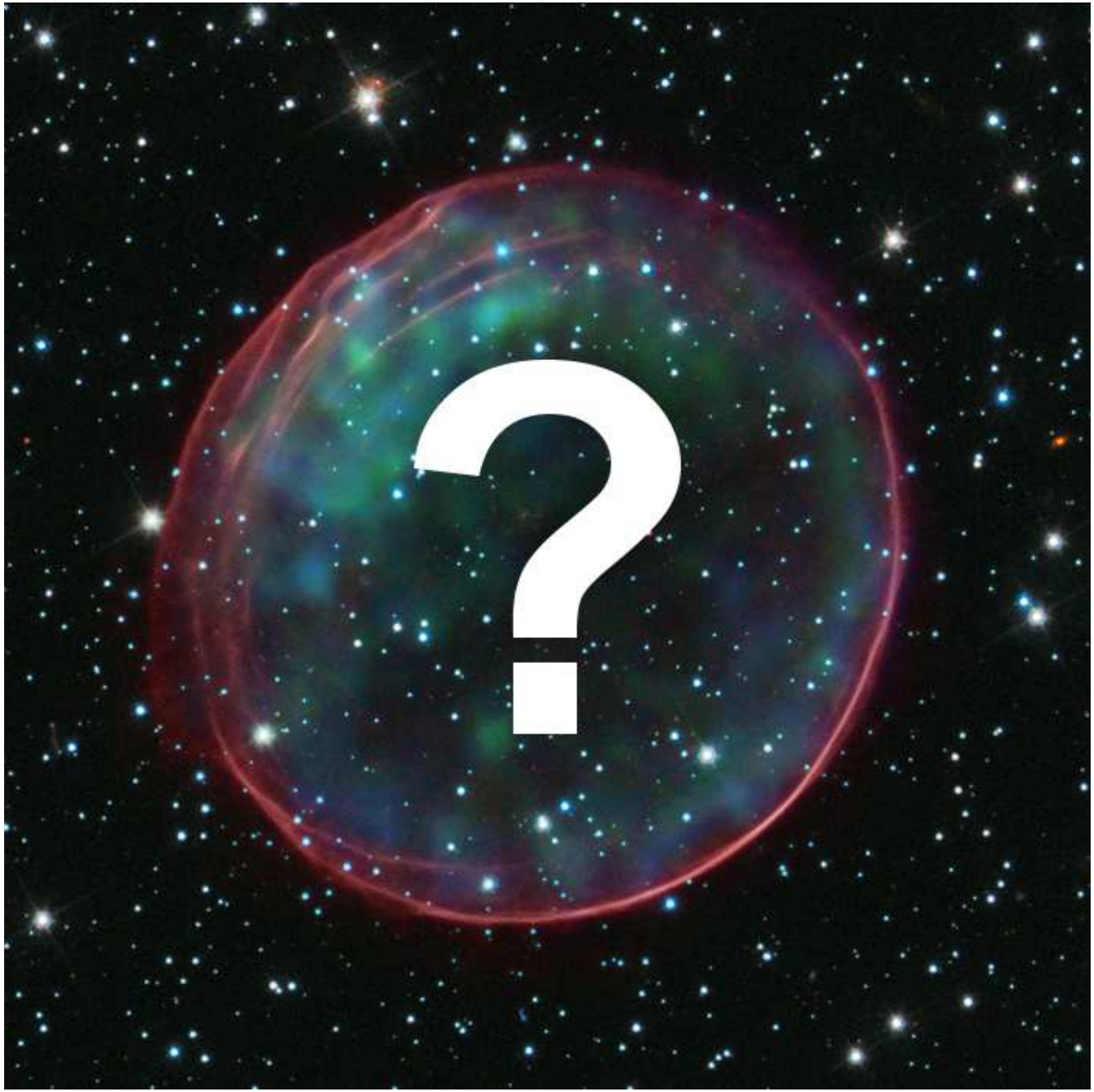
But first, something completely different!

Primordial Titans: Supermassive stellar seeds of massive, high-z quasars?

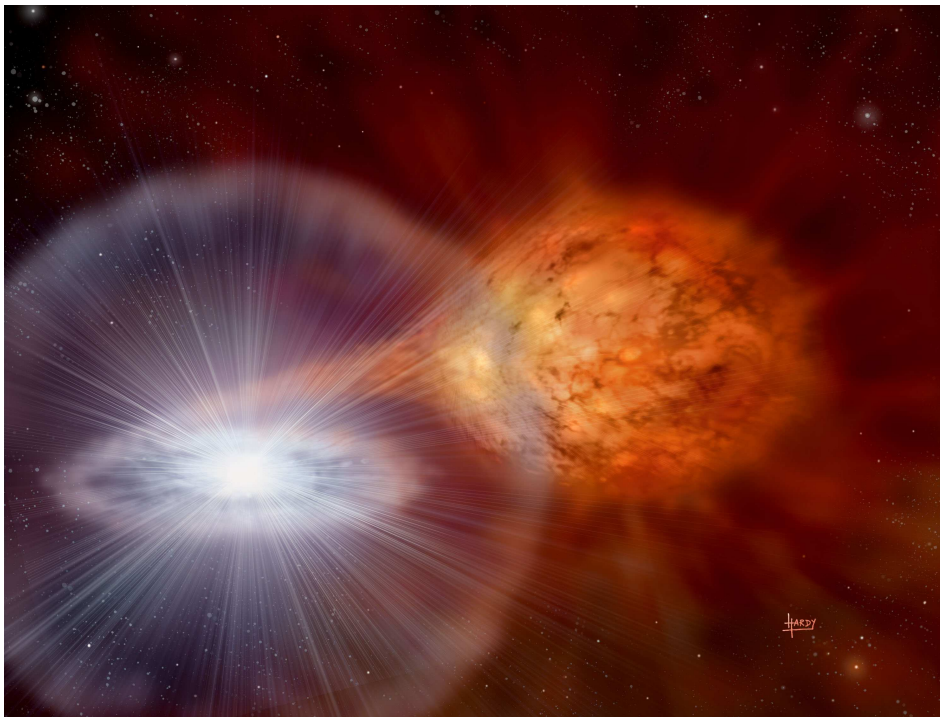
Together with Alexander Heger, Ralf Klessen, Lionel Haemmerle, and Daniel Whalen



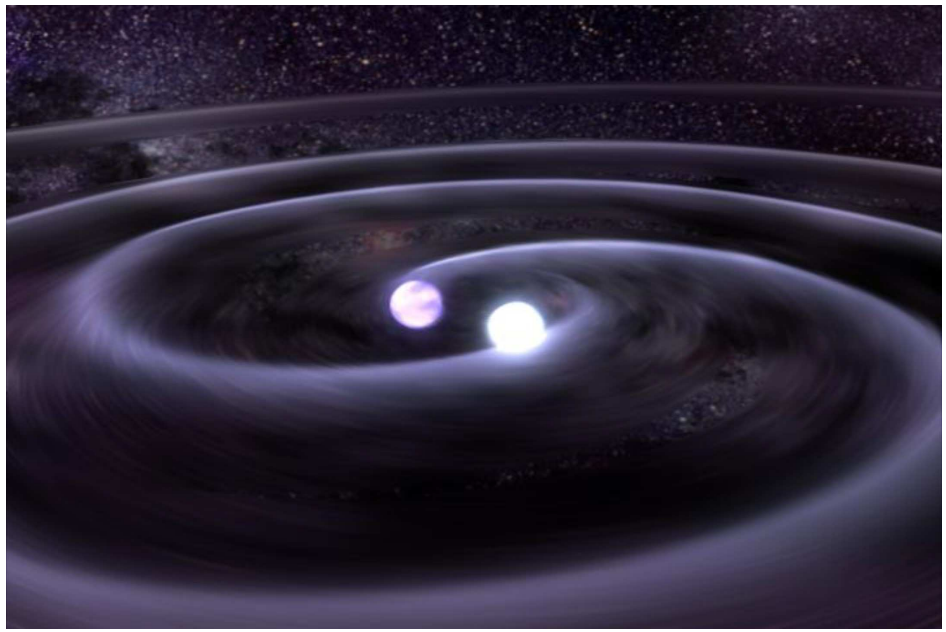
Woods et al. (2017); Haemmerle, Woods et al. (submitted)



What **could** be the progenitors of SNe Ia?



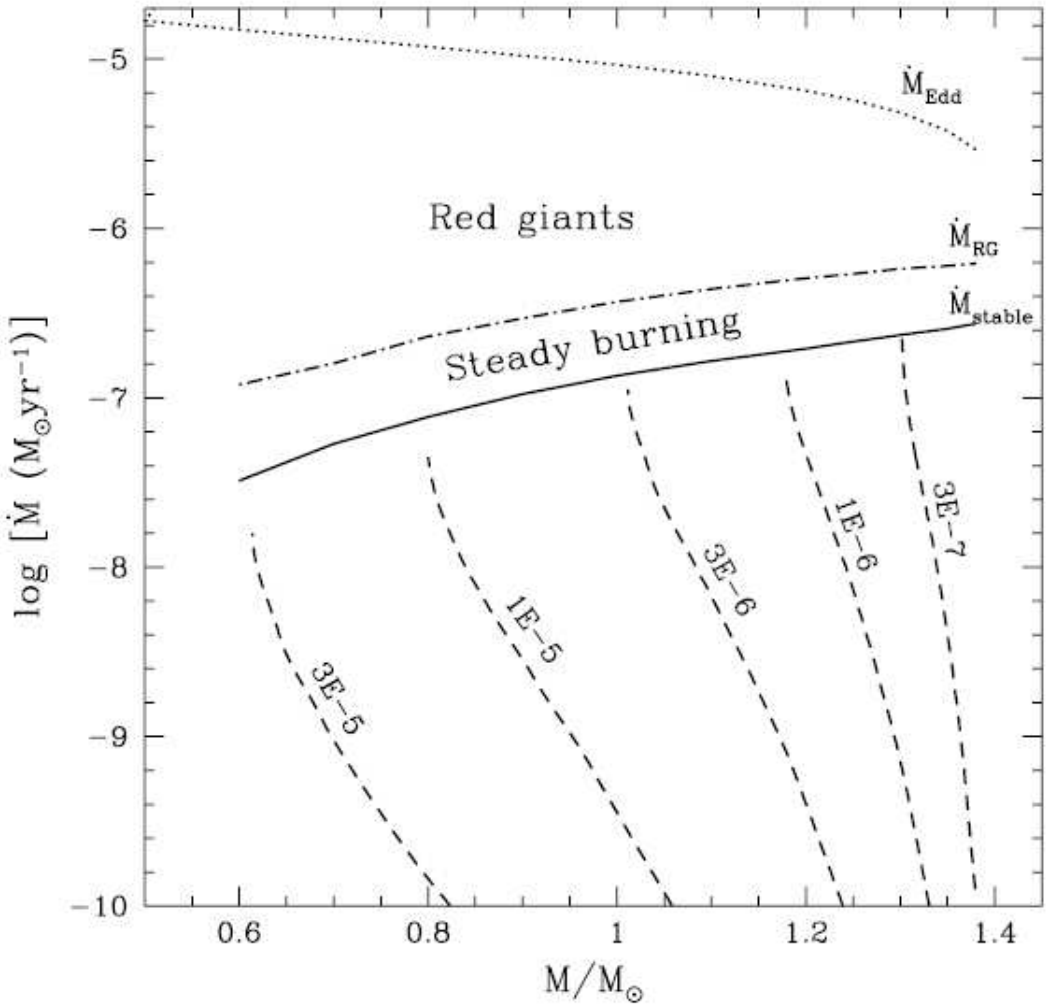
Single Degenerate (Accretion)



Double Degenerate (Merger)

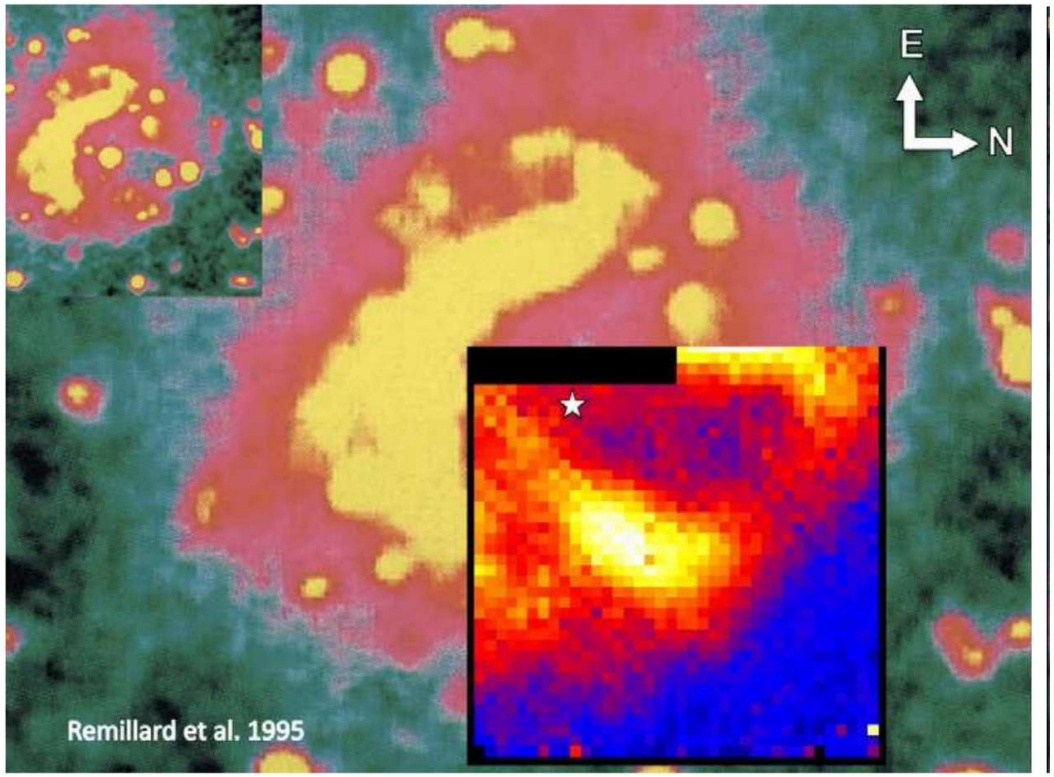
What **could** be the progenitors of SNe Ia?

Observational diagnostics



Progenitors of individual SNe Ia

- Should see strong He II 4686Å, [O I] 6300Å emission (Rappaport+ 1994, Woods & Gilfanov 2013, 2014)
- Individual sources can be difficult to detect, as most will lie in low-density ISM (Woods & Gilfanov, 2016)



[O III] 5007Å image of the CAL 83 nebula. Remillard et al. (1995), with inset from Gruyters et al. (2012). Image size: 15 $\times$ 20 pc.

SNe Ia progenitors at late delay times

The ionized gas in passively-evolving early-type galaxies

Passively-evolving galaxies with Low-Ionization Emission Line Regions (LIERs)

- Ellipticals with little to no star formation in the last $\sim$Gyr
- Have warm (T $\approx 10^4$K) ISM (e.g., SAURON, CALIFA)
- Extended (kiloparsecs) LINER-like emission
- Often in smooth, disky distribution (covering fraction $\sim$1/2, e.g., ATLAS 3D), although other morphologies seen as well

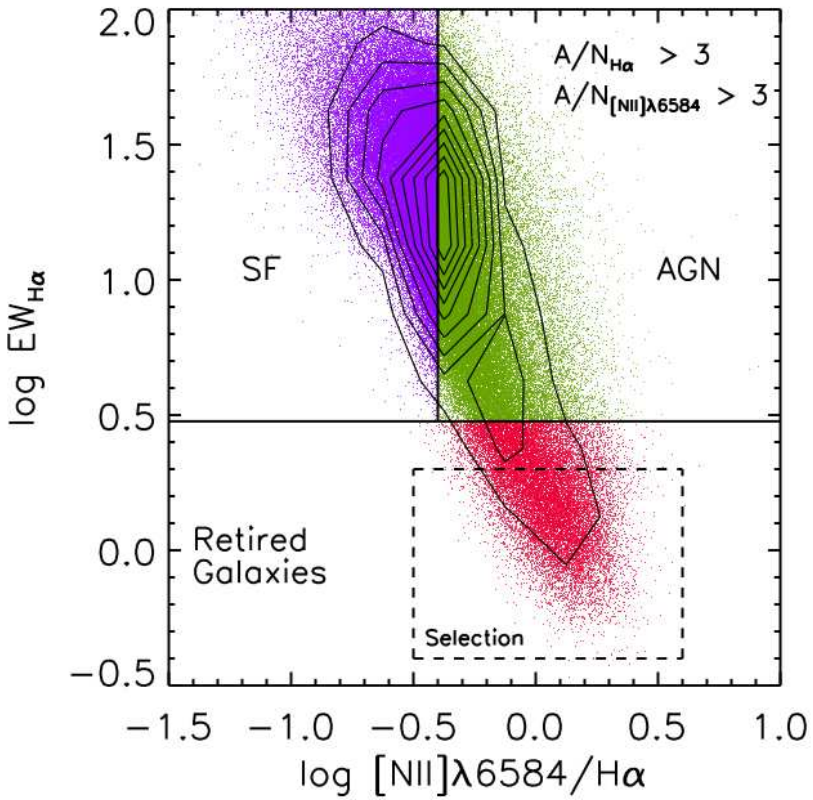
SN Ia progenitors at late delay times

The single degenerate channel as a population of ionizing sources

Johansson, Woods et al. 2014

Choose only retired galaxies in the SDSS (see Cid Fernandes et al., 2011)

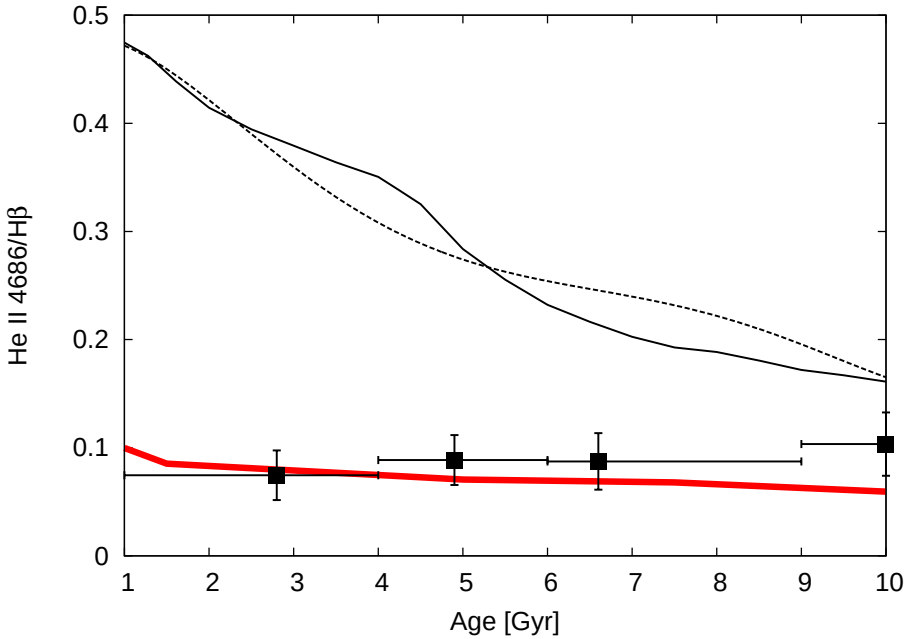
- $0.04 < z < 0.1$
- A/N > 3 (Hα & [N II] 6584Å)
- log(EW[Hα]) < 0.3
- -0.5$<$log[N II]/H$\alpha<$0.6

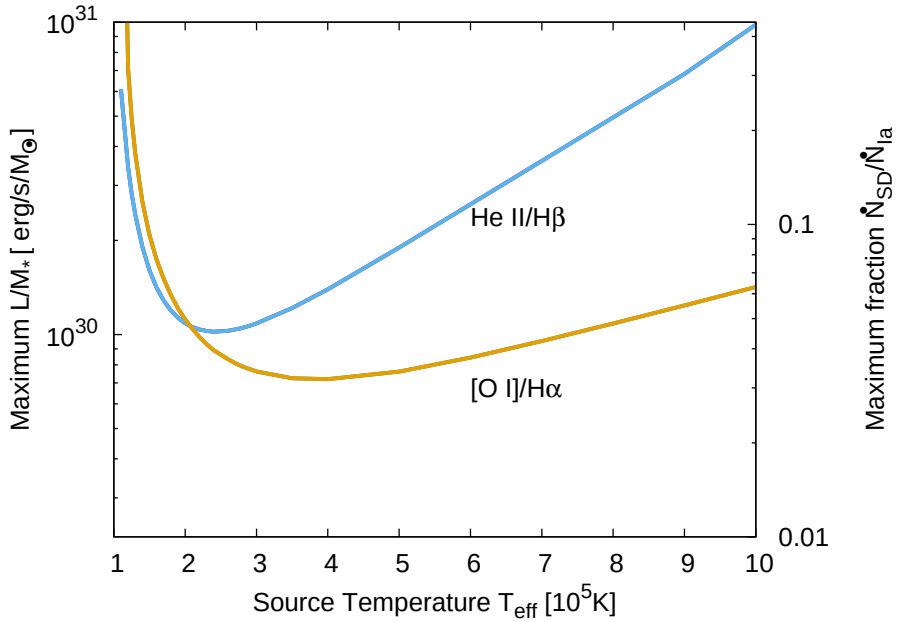


SN Ia progenitors at late delay times

No room for hot SN Ia progenitors at late delay times

At late delay times (e.g., 1 Gyr $< t <$ 4 Gyr), we exclude $\gtrsim$10% hot single-degenerate progenitors

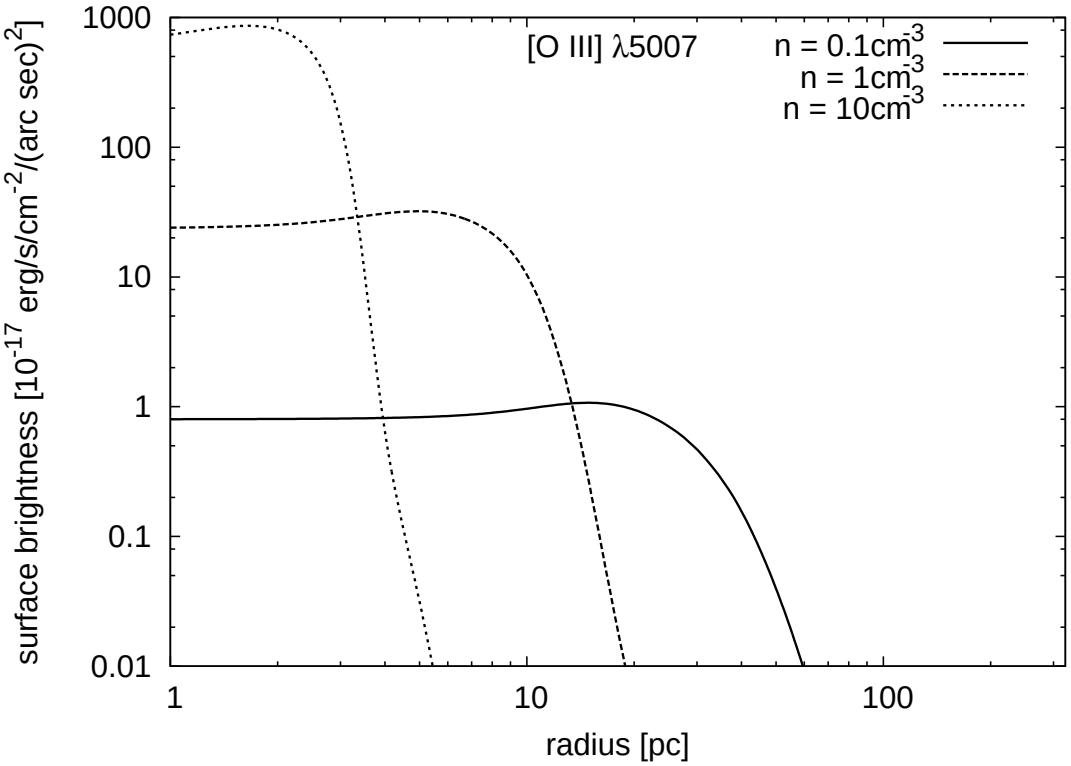




Woods & Gilfanov (2013,2014), Johansson, Woods, et al. (2014,2016)

SN Ia "Archaeology": Relic nebulae of past progenitors

- Can detect nebulae surrounding individual sources (if sufficiently dense ISM)
- True even after explosion of SN Ia! (for $\sim$recombination time, 10^5 years!)



[O III] 5007Å surface brightness profiles for acc. WDs. Woods & Gilfanov (2016)

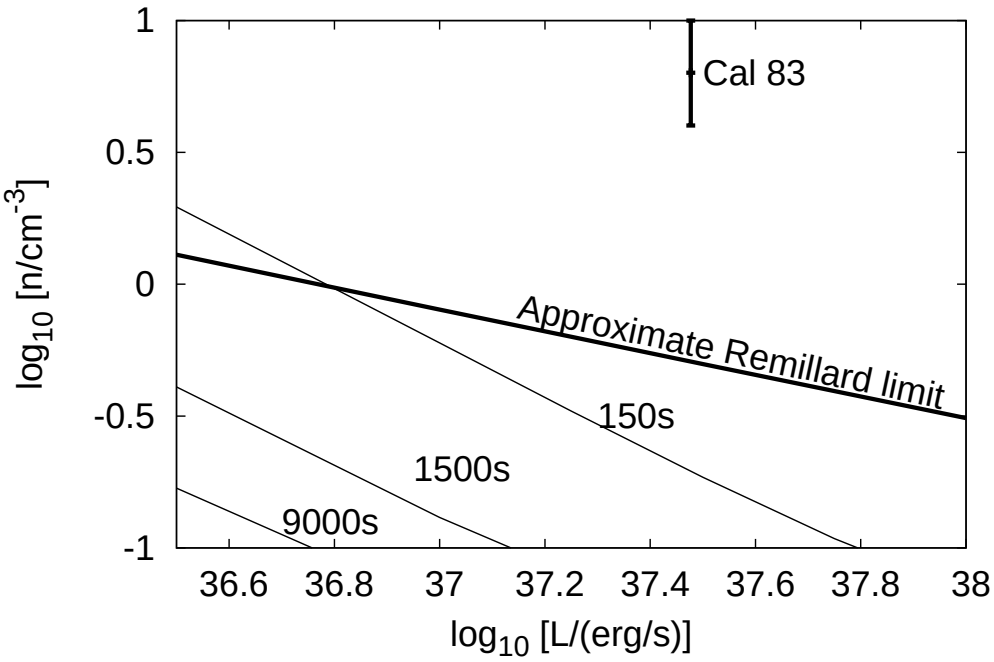
SN Ia "Archaeology": Relic nebulae of past progenitors

- Balmer-Dominated shocks reveal collision with neutral gas (e.g., Ghavamian+ 2001, 2003)
- Recombination time in ISM $\lesssim$ lifetime of remnant
- Constrains size of the nebula $\rightarrow$ ionizing luminosity of source!

$$\mathrm{R_S} \approx 30\mathrm{pc} \left(\frac{\dot{\mathrm{N}}_{\mathrm{ph}}}{10^{48}\mathrm{s}^{-1}} \right)^{\frac{1}{3}} \left(\frac{\mathrm{n_{ISM}}}{1\mathrm{cm}^{-3}} \right)^{-\frac{2}{3}}$$

SN Ia “Archaeology”: Relic nebulae of past progenitors

- Observations (with the Magellan Baade 6.5m telescope) of LMC acc. WDs, SN Ia remnants (PI: A. Clocchiatti)
- Important regardless of outcome!
  - No detections: No hot, luminous progenitor
  - Detection: Measure progenitor’s L,T!



Woods & Gilfanov (2016)

Summary

- Many models of SN Ia progenitors predict a hot, luminous phase prior to explosion – can be strong ionizing sources!
- No contribution from "hot" (10^5K $\lesssim$ T $\lesssim$ 10^6K) single degenerate channel at late delay times ($\lesssim$10% of total rate, or no more than $\lesssim 0.01 M_\odot$ accreted if all SNe Ia were single degenerate). We can use this to constrain other populations too (e.g., LMXBs?)
- We can constrain (or hopefully measure!) the temperature and ionizing luminosity of the progenitors of individual, nearby SNe Ia by searching for faint, extended emission-line regions – currently underway

`www.tewoods-astro.com`