Progenitors of Type Ia Supernovae in early-type galaxies

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Accretion scenario predicts:

- **too large** (soft) X-ray luminosity of E/S0 galaxies, **inconsistent** with **Chandra** observations
(too many SSS – Di Stefano, 2010)

- **too frequent** Classical/Recurrent Novae explosions

Collective luminosity of accreting WDs

$$L_{WD,nuc} = \dot{M} X_H \varepsilon_H \sim 10^{37-38}\ erg/\sec$$

$$N_{WD} = \frac{\Delta M_{WD}}{\dot{M}} \times \nu_{SNIa} \sim 10^4$$

$$L_{tot} = L_{WD} N_{WD} = \Delta M_{WD} X_H \varepsilon_H \nu_{SNIa}$$

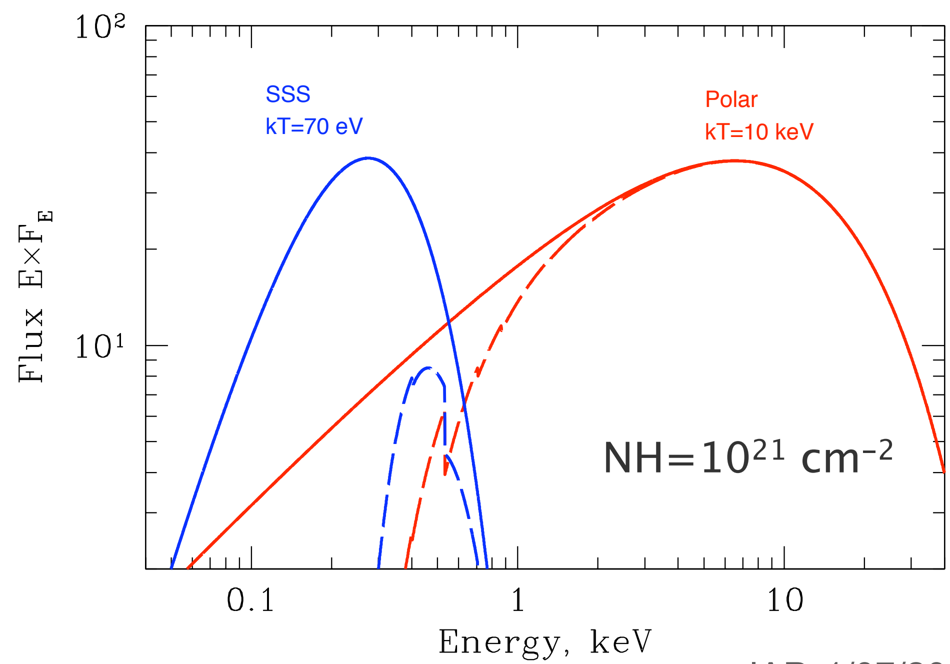
- compare with Chandra observations of nearby elliptical galaxies
  - ✓ Interstellar absorption
  - ✓ bolometric corrections
  - ✓ spectral energy distribution of accreting white dwarfs and its dependence on the white dwarfs mass

The effective temperature

$$T_{eff} \approx \left(\frac{L_{nucl}}{4\pi R_{ph}^2 \sigma_{SB}} \right)^{1/4} \sim 67 \left(\frac{\dot{M}}{5 \cdot 10^{-7} M_{\Theta} / yr} \right)^{1/4} \left(\frac{R_{ph}}{10^{-2} R_{\Theta}} \right)^{-1/2} eV$$

R_{ph} – **photospheric radius**

The role of the interstellar absorption:



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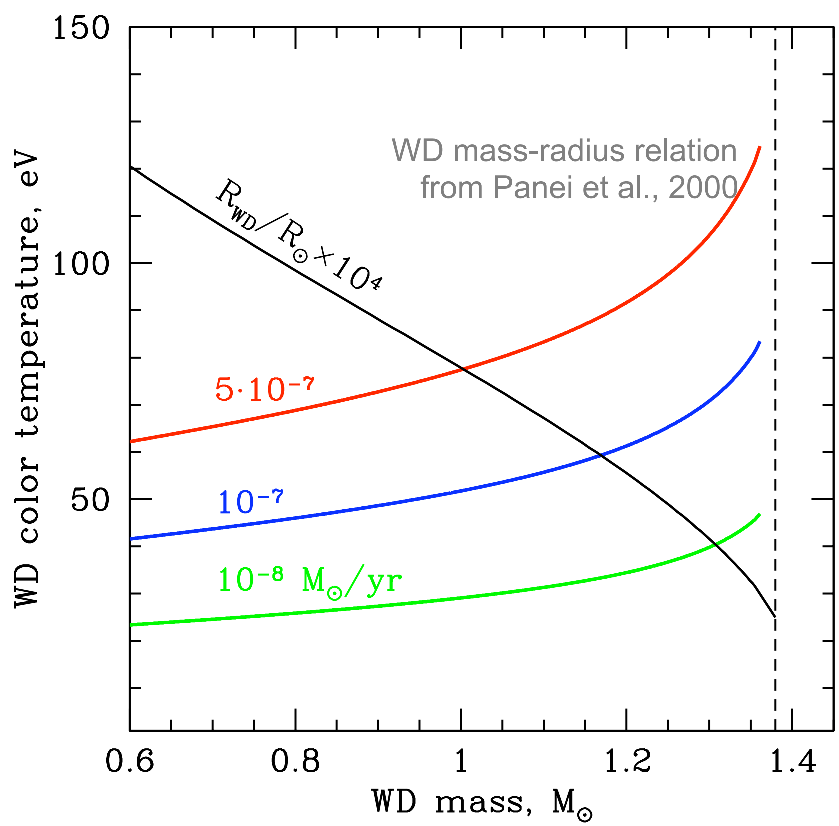
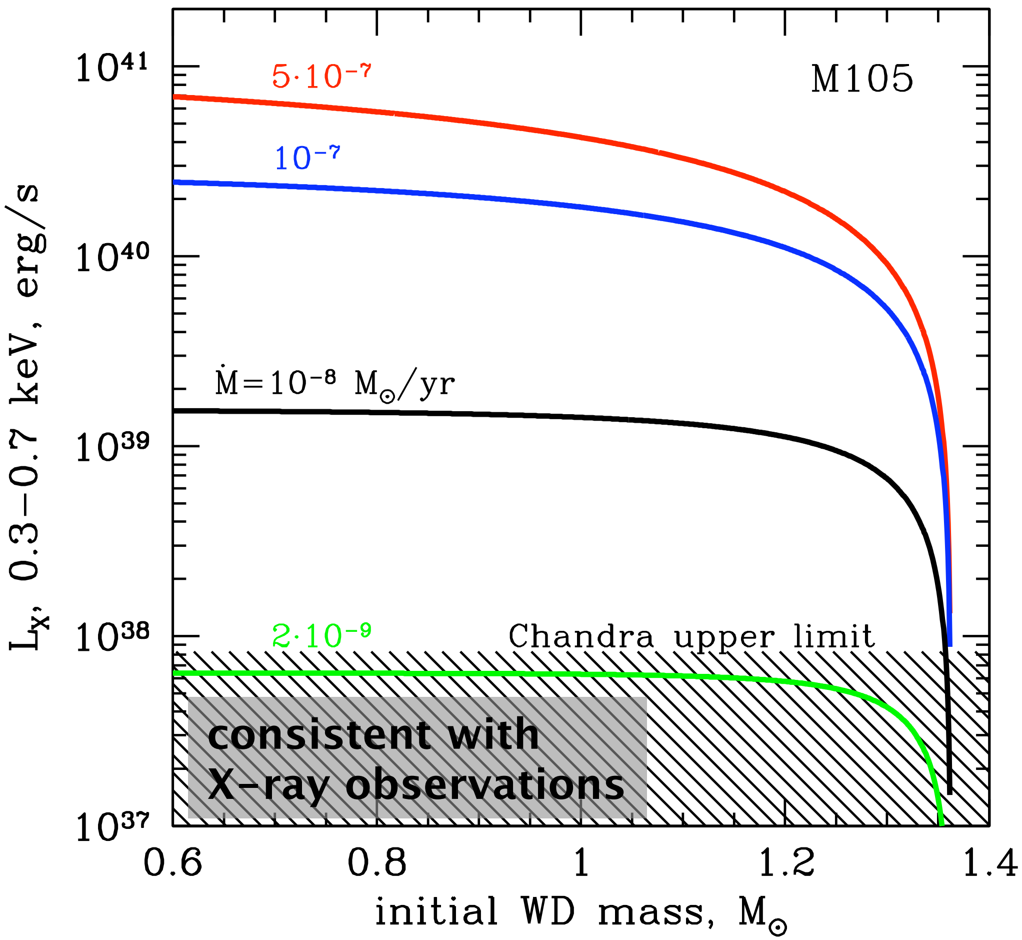
R_{ph} – **photospheric radius**

- photospheric radius ~ WD radius
- WD radius decreases with mass
- color temperature increases with WD mass



Luminosity of SNIa progenitors

combined luminosity of all SNIa progenitors in M105 predicted in the single degenerate scenario



Comparison with Chandra data

Name	L_K	L_x erg/s observed	L_x erg/s predicted	NH 10^{20} cm^{-2}
M32	$8.5 \cdot 10^{8}$	$1.5 \cdot 10^{36}$	$7.1 \cdot 10^{37}$	6.3
NGC3377	$2.0 \cdot 10^{10}$	$4.7 \cdot 10^{37}$	$2.7 \cdot 10^{39}$	4.2
M31 bulge	$3.7 \cdot 10^{10}$	$6.3 \cdot 10^{37}$	$2.3 \cdot 10^{39}$	6.7
M105	$4.1 \cdot 10^{10}$	$8.3 \cdot 10^{37}$	$5.5 \cdot 10^{39}$	2.8
NGC4278	$5.5 \cdot 10^{10}$	$1.5 \cdot 10^{38}$	$7.6 \cdot 10^{39}$	1.8
NGC3585	$1.5 \cdot 10^{11}$	$3.8 \cdot 10^{38}$	$1.4 \cdot 10^{40}$	5.6

predicted L_X: initial WD mass 1.2 $M_\odot$, mass accretion rate 10^{-7} $M_\odot$/yr,
intrinsic and interstellar absorption taken into account

predicted L_X exceeds observed L_X by a factor of 30-50

Comparison with Chandra data

Name	L_K	L_x erg/s observed	L_x erg/s predicted	NH 10^{20} cm^{-2}
M32	[illegible]	[illegible]	[illegible]	[illegible]
NGC3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
M31 b[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
M105	[illegible]	[illegible]	[illegible]	[illegible]
NGC4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NGC3585	$1.5 \cdot 10^{11}$	$3.8 \cdot 10^{38}$	$1.4 \cdot 10^{40}$	5.6

Contribution of super-soft sources to the SNIa rate <2-4%

predicted L_X: initial WD mass 1.2 $M_\odot$, mass accretion rate 10^{-7} $M_\odot$/yr, intrinsic and interstellar absorption taken into account

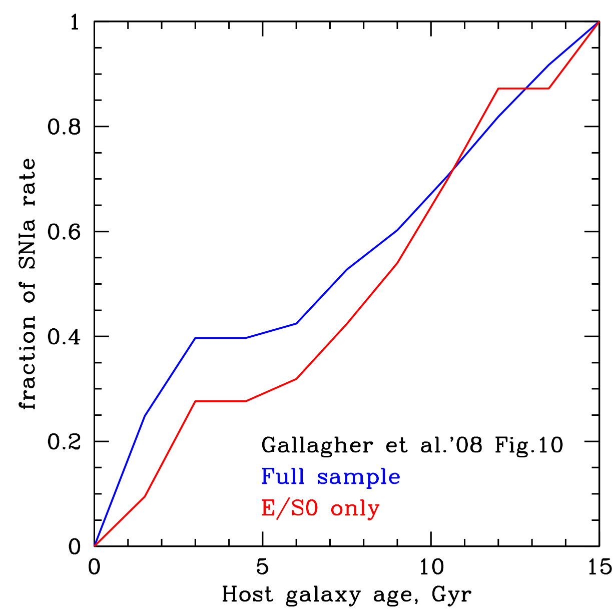
predicted L_X exceeds observed L_X by a factor of 30-50

Why early type galaxies?

- low intrinsic absorption, log(NH)≤20
- old stellar populations, age>5 Gyrs
  lack of massive donors (M_{donor}<1.1-1.2 $M_{\odot}$) requires high mass accumulation efficiency by the WD

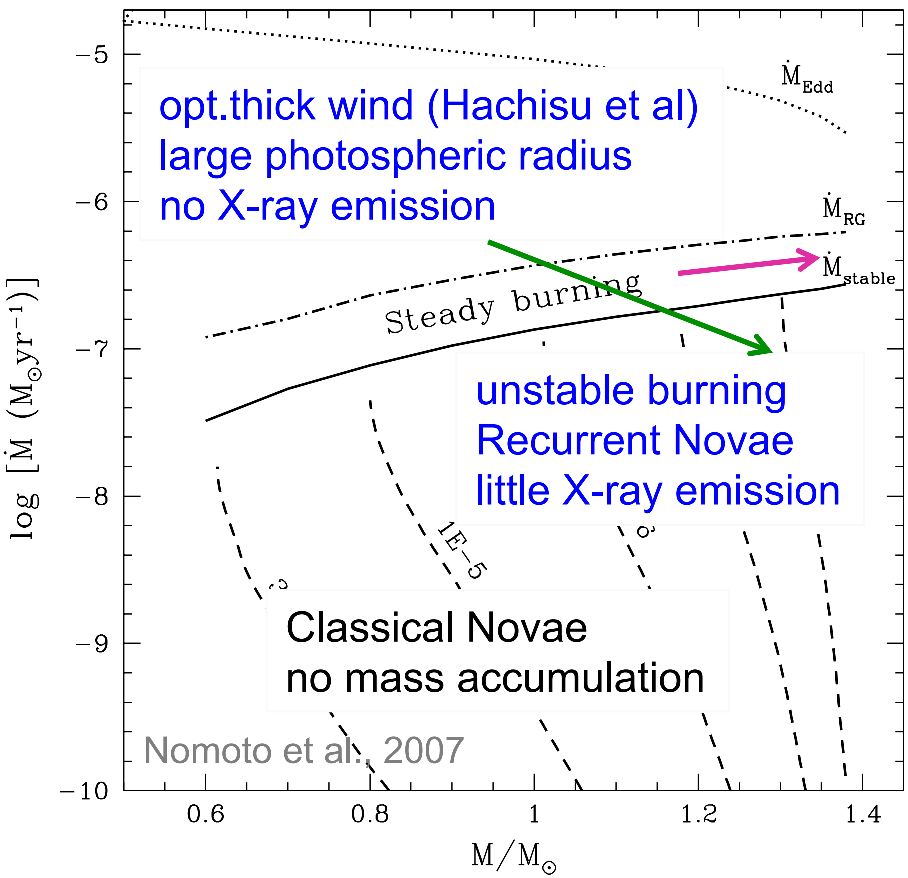
age pre-selection of the sample is taken into account by reducing the SNIa rate for E/S0 galaxies (Mannucci et al) by half

$$\nu_{SNIa} = \frac{1}{2} \times \left(4.4 \cdot 10^{-3}\ \mathrm{yr}^{-1}\ \mathrm{per}\ 10^{11}\ \mathrm{Msun}\right)$$



Marat Gilfanov

Population synthesis context



previous calculations assumed 100% of time in the steady burning regime

plausible binary evolution tracks spend ~moderate or ~small fraction of time in the steady burning regime

Wind regime

- low mass accumulation efficiency ≤1/3 (Hachisu et al) ≥2/3 of material leaves the system with the wind

- available mass budget:
  M_{donor}<1.0-1.2 $M_{\odot}$
  $M_{He\ core}$~0.3 $M_{\odot}$
  M≤0.2-0.3 $M_{\odot}$ are available for the WD growth

- the initial WD mass ≥1.1-1.2 $M_{\odot}$ is required in order to reach the Chandrasekhar mass in the wind regime ~exceeds the maximum initial mass of CO WD

Recurrent/Classical Novae

in the accretion scenario Nova rate ~ SN rate

$$\Delta M_{CN} \dot{N}_{CN} \sim \Delta M_{SNIa} \dot{N}_{SNIa}$$

$$\Delta M_{CN} \sim 10^{-6} - 10^{-5} M_{\Theta}; \quad \Delta M_{SNIa} \sim 0.3 - 0.5 M_{\Theta}$$

$$\dot{N}_{CN} \sim 10^{5} - 10^{6} \dot{N}_{SNIa}$$

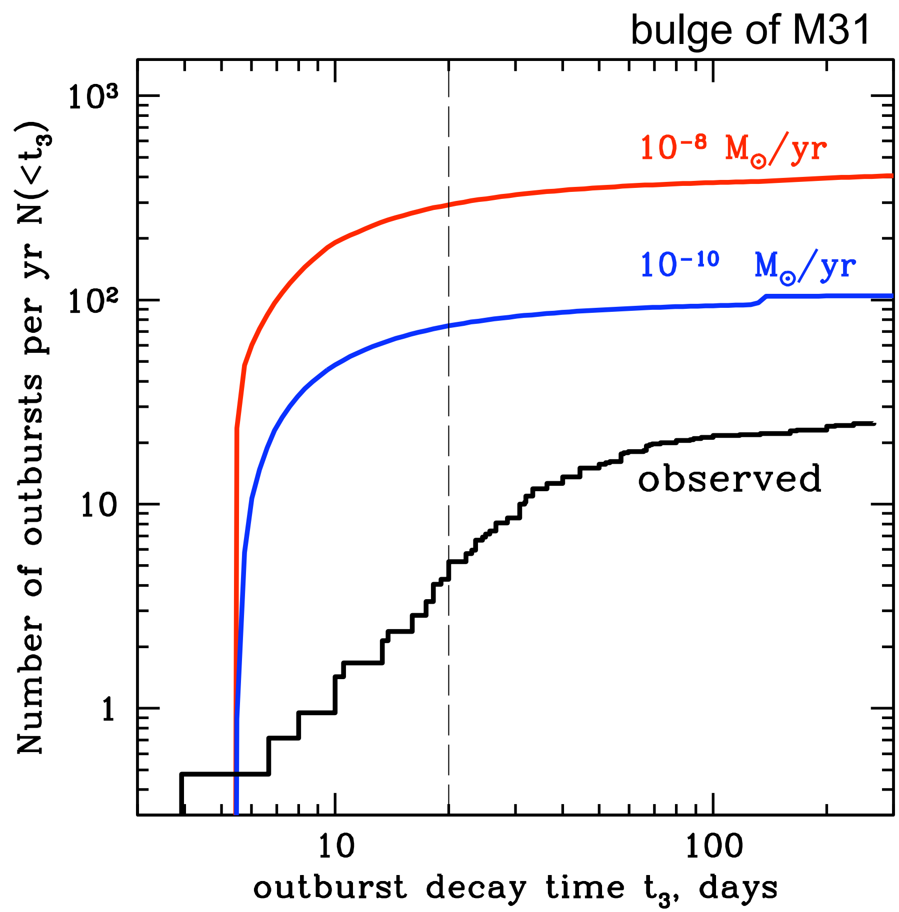
more precisely: $\dot{N}_{CN} \approx \int \frac{dM_{WD}}{\Delta M_{CN}(M_{WD}, \dot{M})} \dot{N}_{SNIa}$

Recurrent/Classical Novae

frequency of fast Novae **predicted in the accretion scenario** for the bulge of M31 ≥300-500 per year

observed: 5.2±1.1 per year

extensive Nova searches in M31 (e.g. Arp, 1956)



theory is based on Prialnik, Kovetz et al.
observations: Arp; Capaccioli et al.

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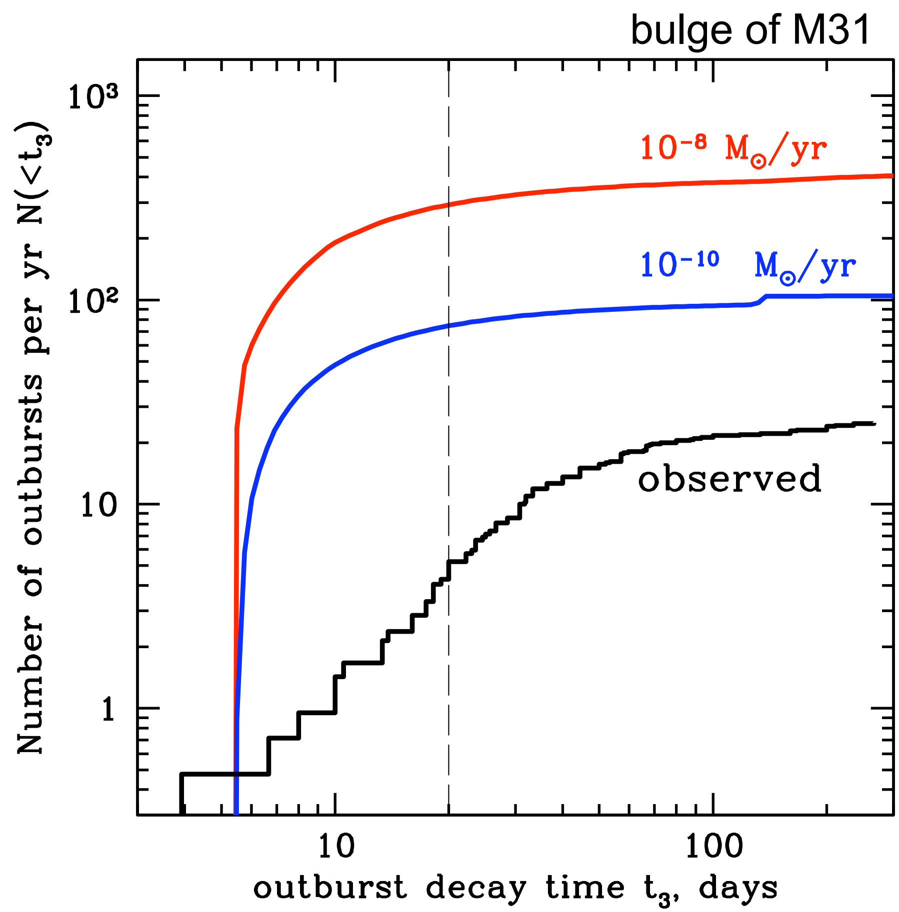
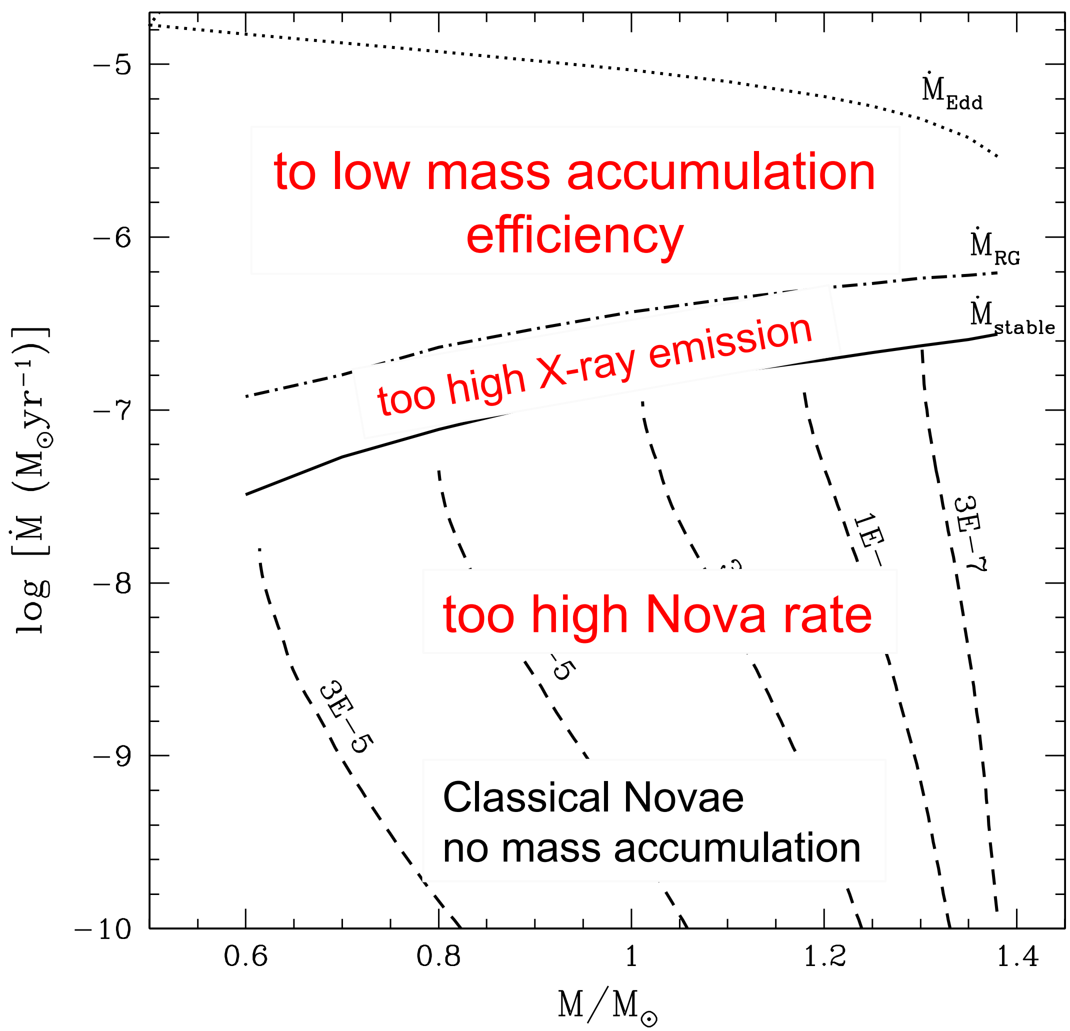


contribution of RNe to the observed SNIa rate

<1-2 %

Population synthesis context



Conclusion

- No more than ~5% of SNIa in elliptical galaxies are produced by white dwarfs accreting in binary systems and detonating at the Chandrasekhar mass limit
- alternatives:
  - white dwarf mergers
  - explosions of sub-Chandrasekhar white dwarfs
- unless our understanding of accretion and nuclear burning on the WD surface are fundamentally flawed
- this applies to early type galaxies; SNIa in star-forming galaxies may be different

Thank you!