

Formation Channels of AM CVn SN Ia Progenitors



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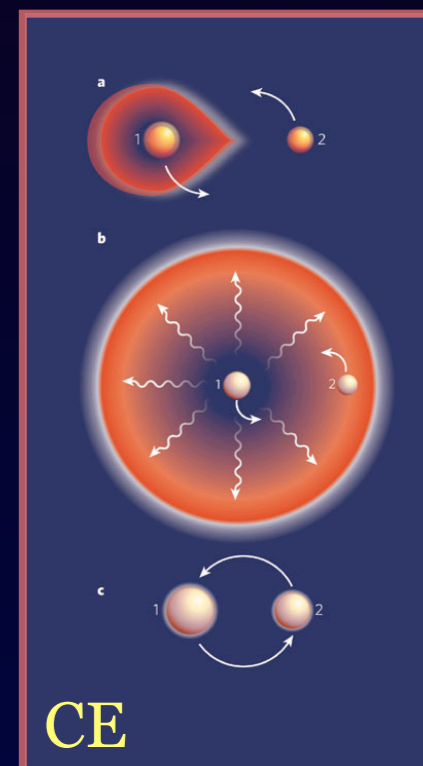
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Points to Address

- Population synthesis - good method of **evolving a stellar population** in order to determine statistical properties (e.g., **relative contributions** of certain binary types)
- **SNe Ia**: Important for cosmological distance scale/parameters, chemical evolution of galaxies, learn about binary evolution: **SNe Ia progenitors are UNKNOWN!** (nature of the donor?)
- SNe Ia: Favoured models are **Single Degenerate** (SD) and **Double Degenerate** (DD) scenarios; AM CVn not mentioned often (Solheim & Yungelson 2005; Ruitter, Belczynski & Fryer 2008 (submitted))
- **Chandrasekhar** limit ($1.4 M_{\odot}$) SNe Ia vs. **sub-Chandrasekhar** (will mention both in this talk)
- How do **rates** and **delay times** of SNe Ia from these channels (AM CVn) compare with other (SD, DD) channels, and the observed ones (rates)?

Binary Evolution: population synthesis model

- Use **StarTrack** population synthesis code (Belczynski et al. 2002, 2008) to evolve an entire stellar population (*e.g.*, a Milky Way-like Galaxy)
- Evolve **single and binary stars** incorporating analytical formulae for stellar evolution and most recent prescriptions for accretion onto WDs (*e.g.*, Nomoto et al. 2007)
- Initial conditions: common envelope (CE) evolution, mass transfer phases, magnetic braking, gravitational radiation, binary fraction (50%), IMF, SFR
- Calibration: use **Galactic stellar mass** ($6 \times 10^{10} M_{\odot}$)
- **AM CVn**: WD accretes stably from He-rich companion



Formation Channels of AM CVn with *StarTrack*

- 2 channels considered (He star, He WD)
- > 80% CO WD accretor \therefore will only consider these in detail (smaller contribution of He-He WD binaries)
- 75% CO + He-rich WD; 25% CO + Helium star
- most orbital periods 3 - 100 minutes
- mass transfer rates initially high ($10^{-7} M_{\odot} / \text{yr}$) then spend Myr-Gyr having low ($10^{-12} - 10^{-13}$) MT rates

Typical AM CVn evolutionary history (not to scale!)

$P=38$ yr $e=0.94$ $M=2.44$



$M=1.48$ $t=0$ Myr

$P=440$ d $e=0.0$

$P=96$ hr $M=2.39 \rightarrow M=0.58$
CO WD

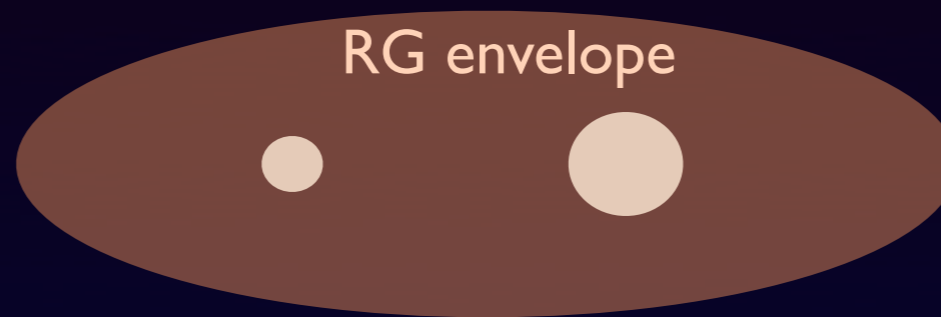


CE phase $t=853$

tides...

$P=59$ hr

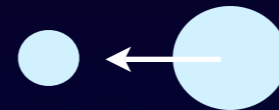
$P=7.5$ min



CE phase $t=3013$
 $M=1.47 \rightarrow M=0.19$
He WD

Grav. Radiation...

$P=4$ min



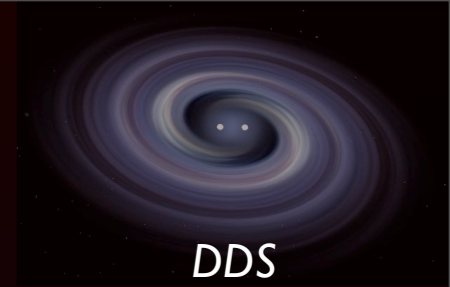
RLOF starts $t=3015$

$P=73$ min

$M=0.76$



calculation stops $t=5988$
 $M=0.01$



SN Ia Formation Channels

Above Chandrasekhar Mass

DDS: CO+CO, Co+He, WD-WD merge with $M_{\text{tot}} > 1.4 M_{\odot}$

SDS: CO/He WD + MS/Giant accreting binary (WD reaches $1.4 M_{\odot}$)

AM CVn: (CO) WD accretes to $1.4 M_{\odot}$ from He-rich companion (WD or helium star)

Sub-Chandrasekhar Mass

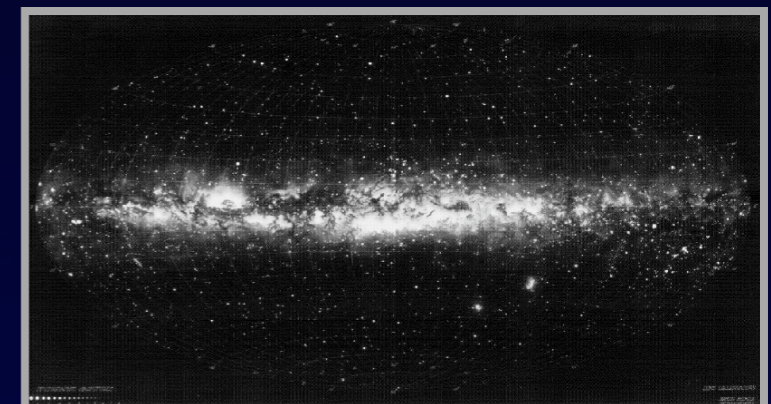
(Kato & Hachisu, 1999, 2004; Garcia-Senz, Bravo & Woosley 1999; Taam 1980)

AM CVn: CO WD accretes $0.1 M_{\odot}$ at low accretion rate from He-rich companion (WD or helium star)

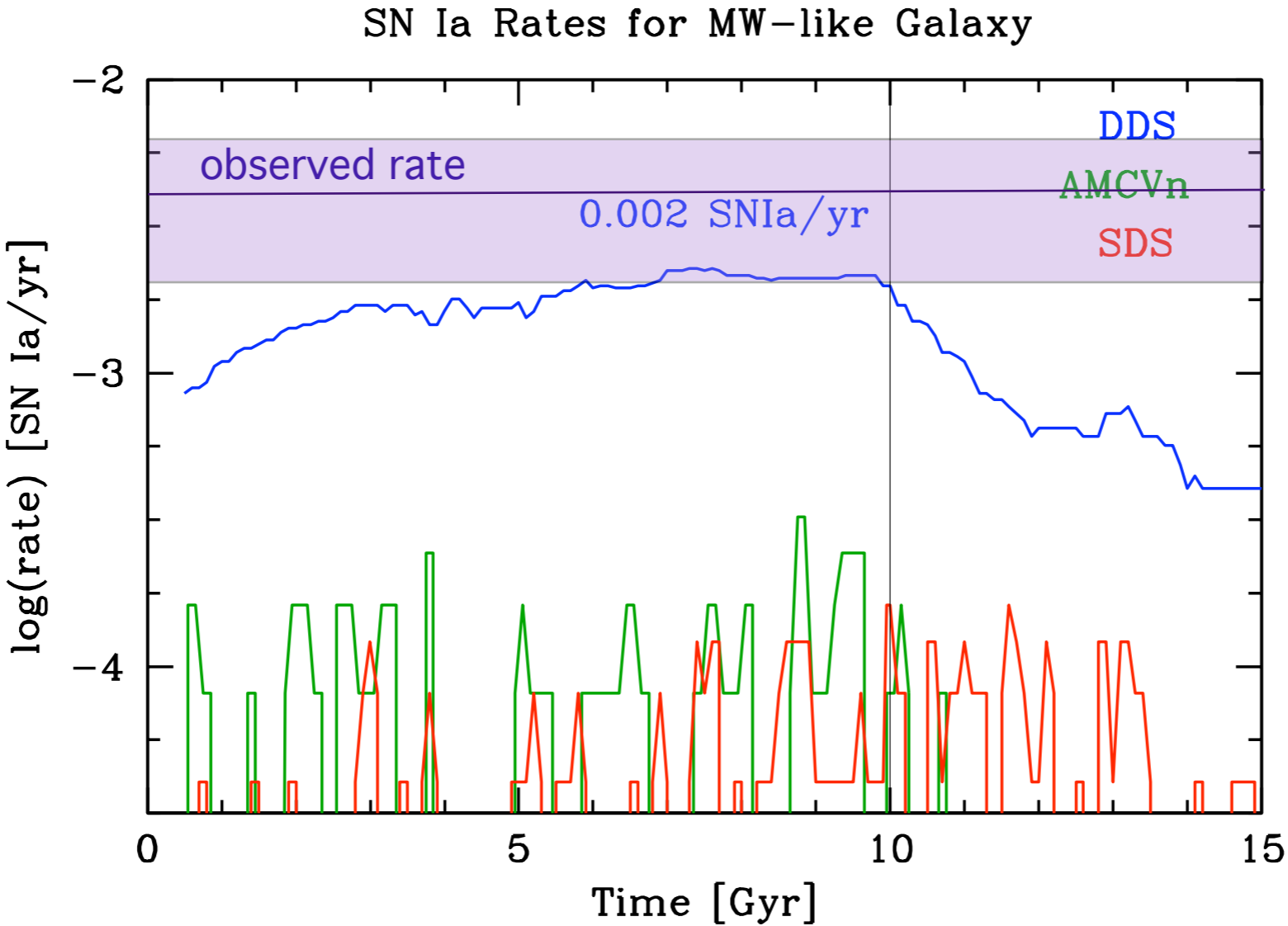


Galactic Rates of SNe Ia *calibration*

- Simple ‘spiral’ Galaxy with MW stellar mass ($6 \times 10^{10} M_{\odot}$)
- **Spiral Galaxy**: constant star formation history for 10 Gyr
- Kroupa IMF ($0.08 - 150 M_{\odot}$)
- Standard CE prescription $\alpha\lambda = 1$ (Webbink 1984)
- Initial mass ratio flat; initial separation flat in log, 50% binary fraction
- Check **rate of SN Ia/year** at current epoch (DDS, SDS, AMCVn)

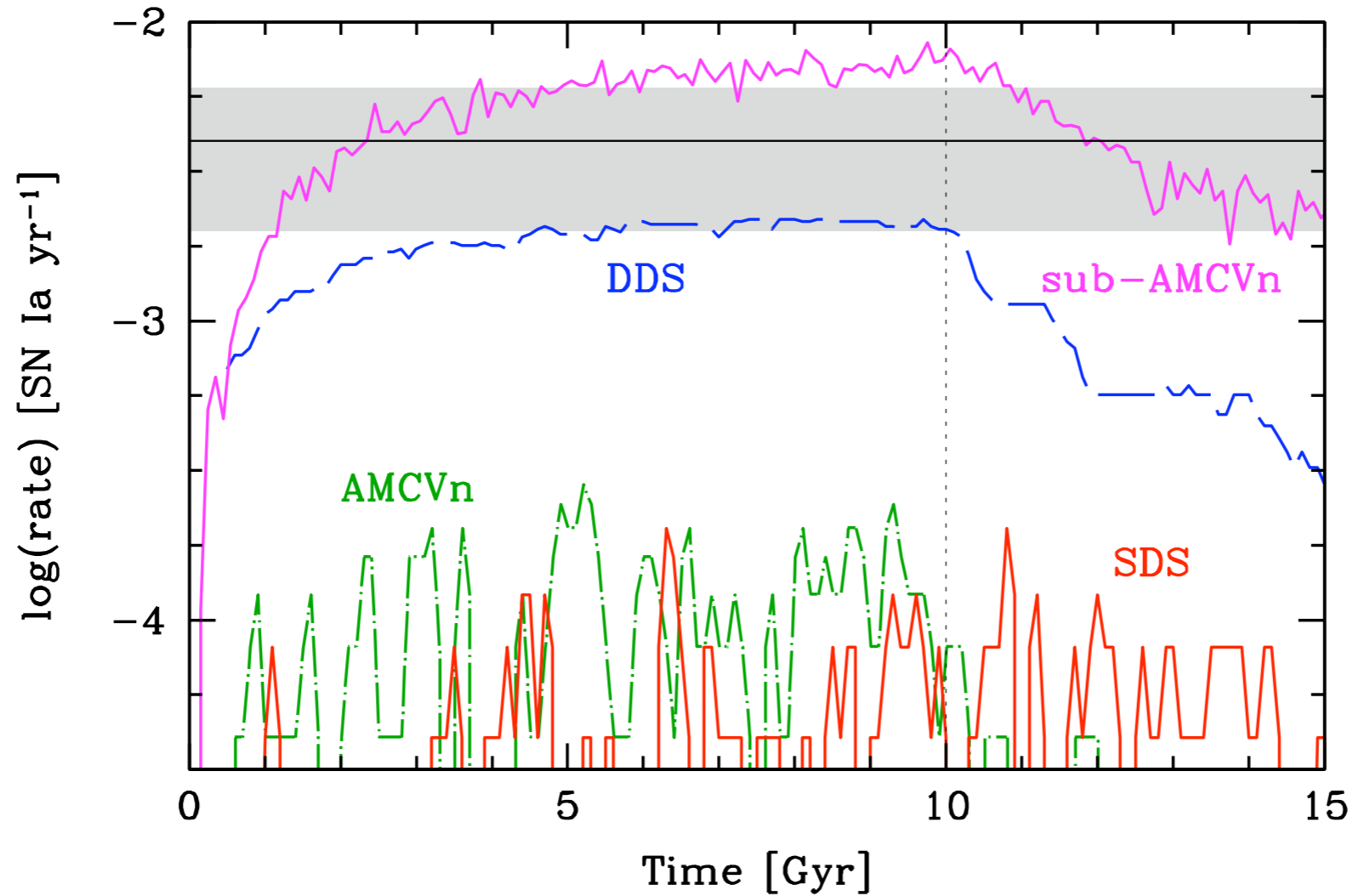


Chandrasekhar mass models



Observed Galactic rate: 0.004 ± 0.002 SNIa/yr (Cappellaro et al. 1999)
Chandrasekhar limit AM CVn SNe Ia cannot explain the rates...

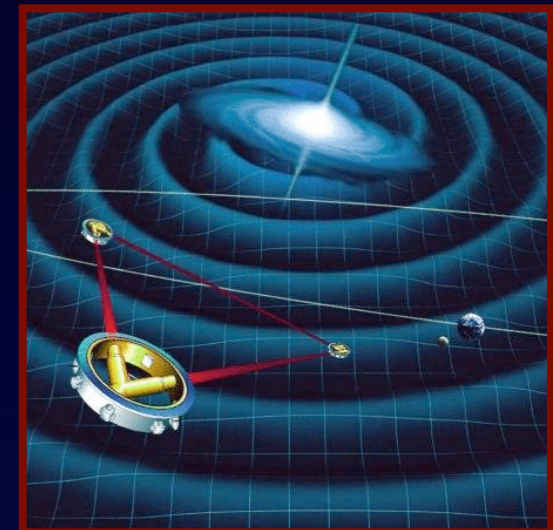
Include Sub-Chandrasekhar mass model



Observed Galactic rate: 0.004 ± 0.002 SNIa/yr (Cappellaro et al. 1999)
Sub-Chandrasekhar limit AM CVn SNe Ia can explain the rates! 0.007 SNIa/yr

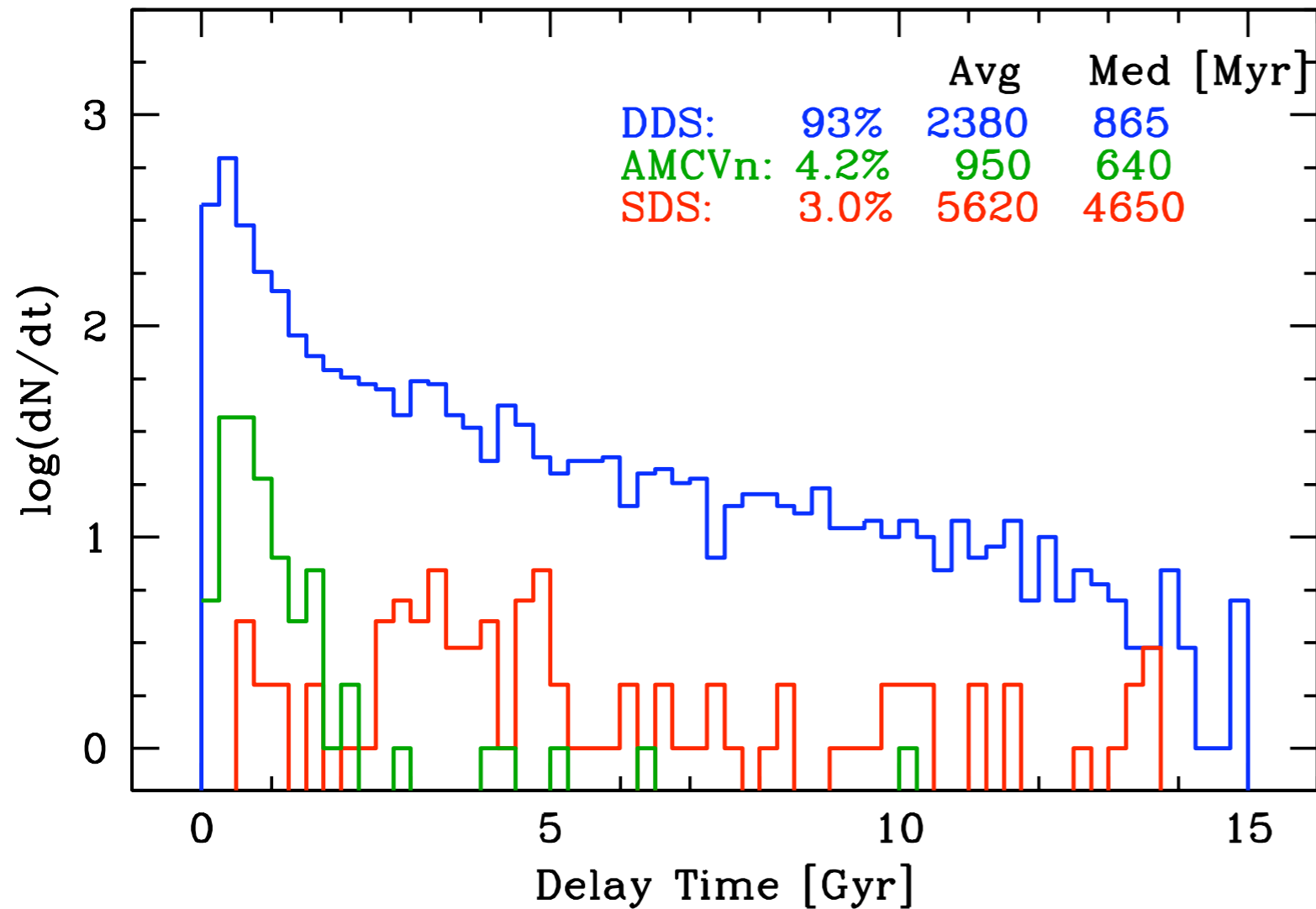
Discussion

- Here we have shown that the **Sub-MCh rates can explain** the SN Ia rates, however:
- Many in the SN Ia community do not believe sub-MCh model (it cannot explain observations/near max. spectra - **Standard Candles!**)
- If detonation does occur in a sub-population of AM CVns: what does it look like?
- Still to do: 'hot' AM CVn donors? (also: effects of rotation)?
- **LISA**: number of resolvable AM CVn systems ($\sim 10^3$ for CO-He WDs)
(Ruiter et al. arXiv:0705.3272)



Chandrasekhar mass limit model delay times

SN Ia Delay Times for Starburst



Dominant mechanisms:
DDS: GR timescale; Totani et al. 2008
CO-CO only; $DT_{\min} = 50$ Myr.
AMCVn: shortest DTD; GR drives
MT rates (small a).
SDS: mostly Giant-WD; MS-WD
have largest overall DT
take long time to accrete enough H.