Delay time distribution of type Ia supernovae: theory vs. observation

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Type Ia supernovae (SNe Ia)

- Only in multiple star systems
- Critical for understanding of galactic chemical evolution
- Standard candles: validation of ΛCDM cosmological model
- Thermonuclear disruption of white dwarf (WD) reaching Chandrasekhar limit

Progenitors: SD vs. DD

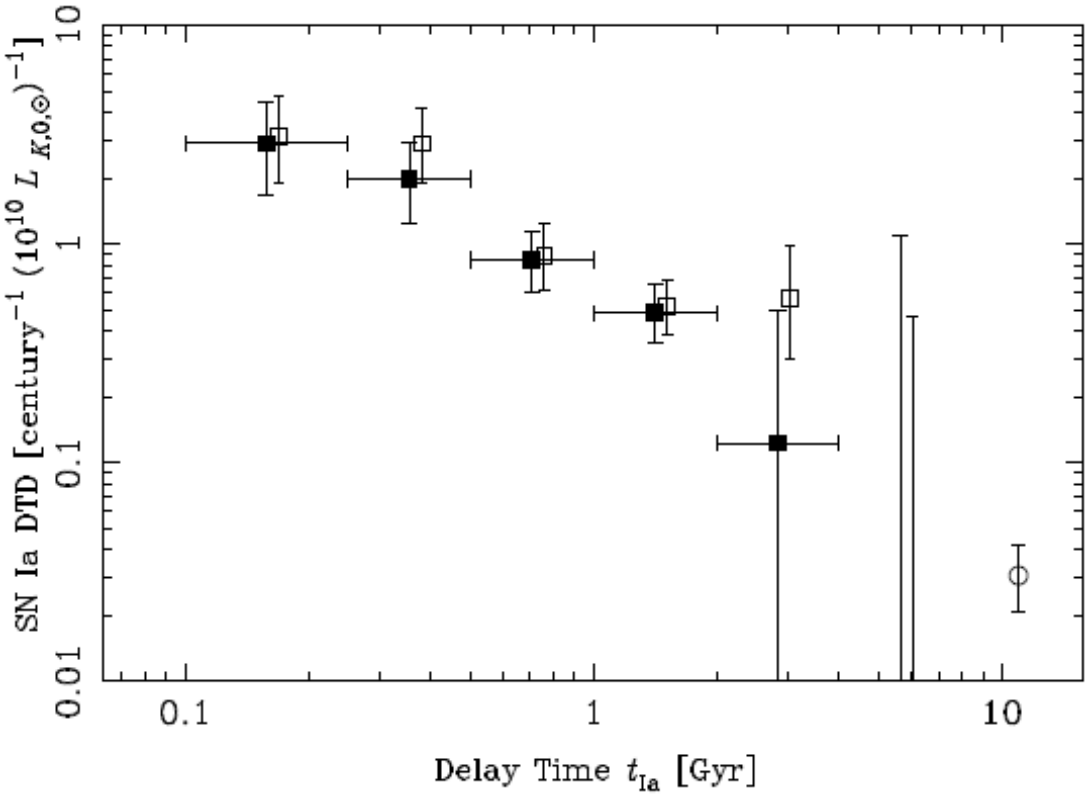
- **Single Degenerate**: WD pushed over Chandrasekhar limit by accretion from main sequence (MS) or red giant (RG) companion
- **Double Degenerate**: merger of two WDs after spiral-in due to gravitational wave radiation emission

Which is most dominant (or both)?

Delay Time Distribution

- DTD = number of SN Ia events per unit time, as function of time elapsed since starburst
- Measured by observations of elliptical (~starburst) galaxies at similar metallicity and different redshift, e.g. Totani et al. (2008) and Mannucci et al. (2005)
- Open question: **What is contribution of SD and DD in starburst galaxies?**

Delay Time Distribution



T. Totani, T. Morokuma, T. Oda, M. Doi & Y. Yasuda, PASJ 60, 1327, 2008

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Our work

- Previous studies by e.g. Ruiter et al. (2009), Hachisu et al. (2008), Han & Podsiadlowski (2004) and Yungelson & Livio (2000)

- **We investigate influence of mass transfer efficiency β during Roche Lobe Overflow (RLOF) in close binaries**

Assumptions

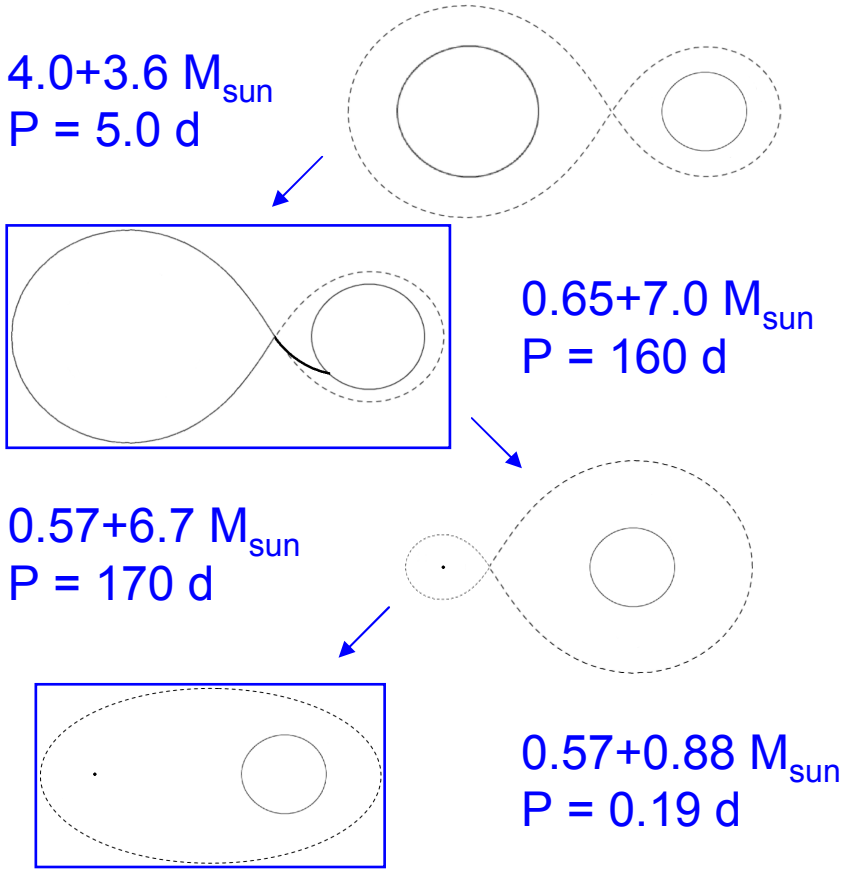
- Updated population code of De Donder & Vanbeveren (2004) with detailed binary star evolution
- SD progenitors: as given by Hachisu et al. (2008), including mass stripping effect
- DD progenitors: every evolution resulting in WD-merger exceeding 1.4 M_{sun}

Parameter study

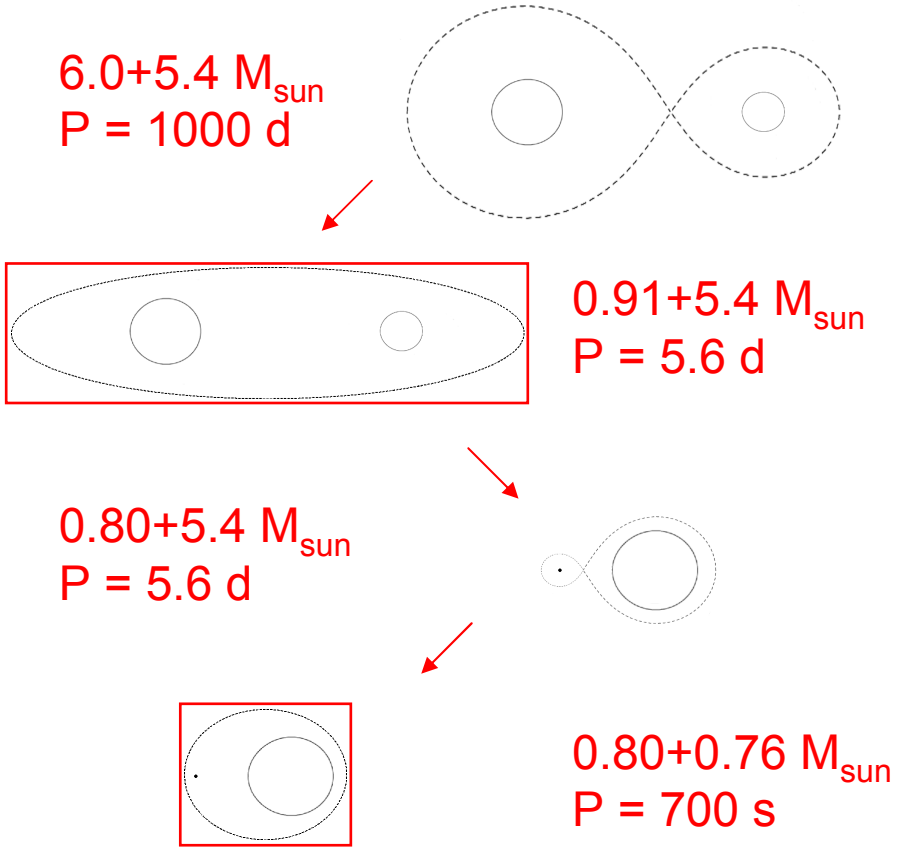
- **Fraction β of RLOF-material accepted by accretor**
- Lost matter leaves system with specific angular momentum of second Lagrangian point
- Energy conversion during common envelope (CE) phase: Webbink (1984)

Typical DD SN Ia evolutions

RLOF with β = 1 + CE (SN Ia at 3.4 Gyr)



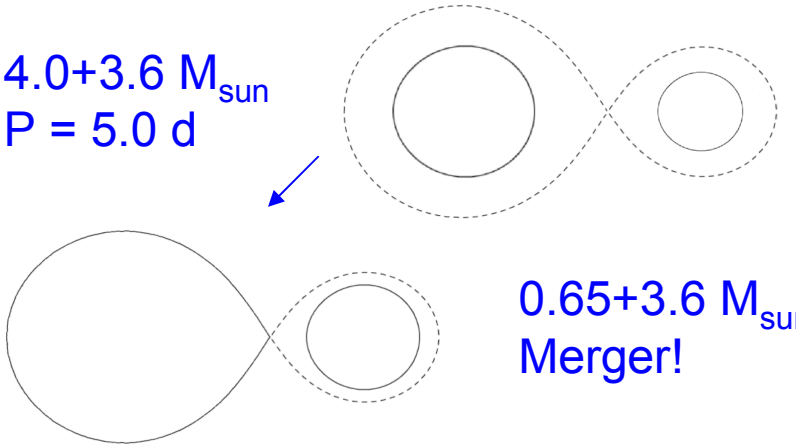
CE + CE (SN Ia at 97 Myr)



Typical DD SN Ia evolutions

RLOF with $\beta = 0$ (no SN Ia)

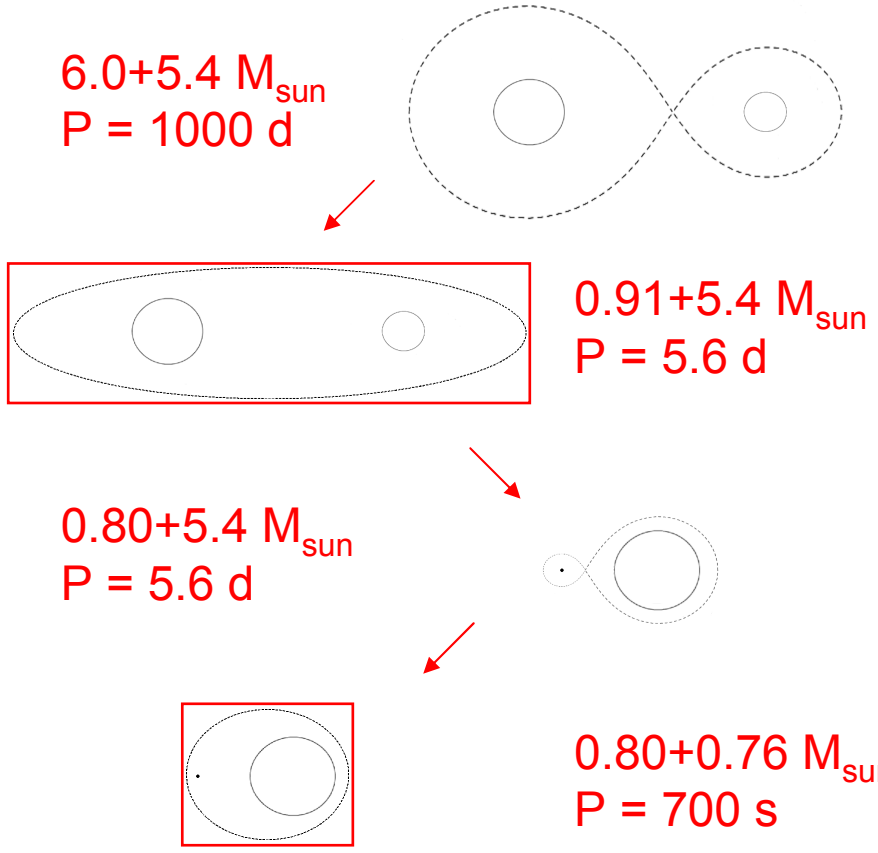
4.0+3.6 M_{sun}
P = 5.0 d



0.65+3.6 M_{sun}
Merger!

CE + CE (SN Ia at 97 Myr)

6.0+5.4 M_{sun}
P = 1000 d

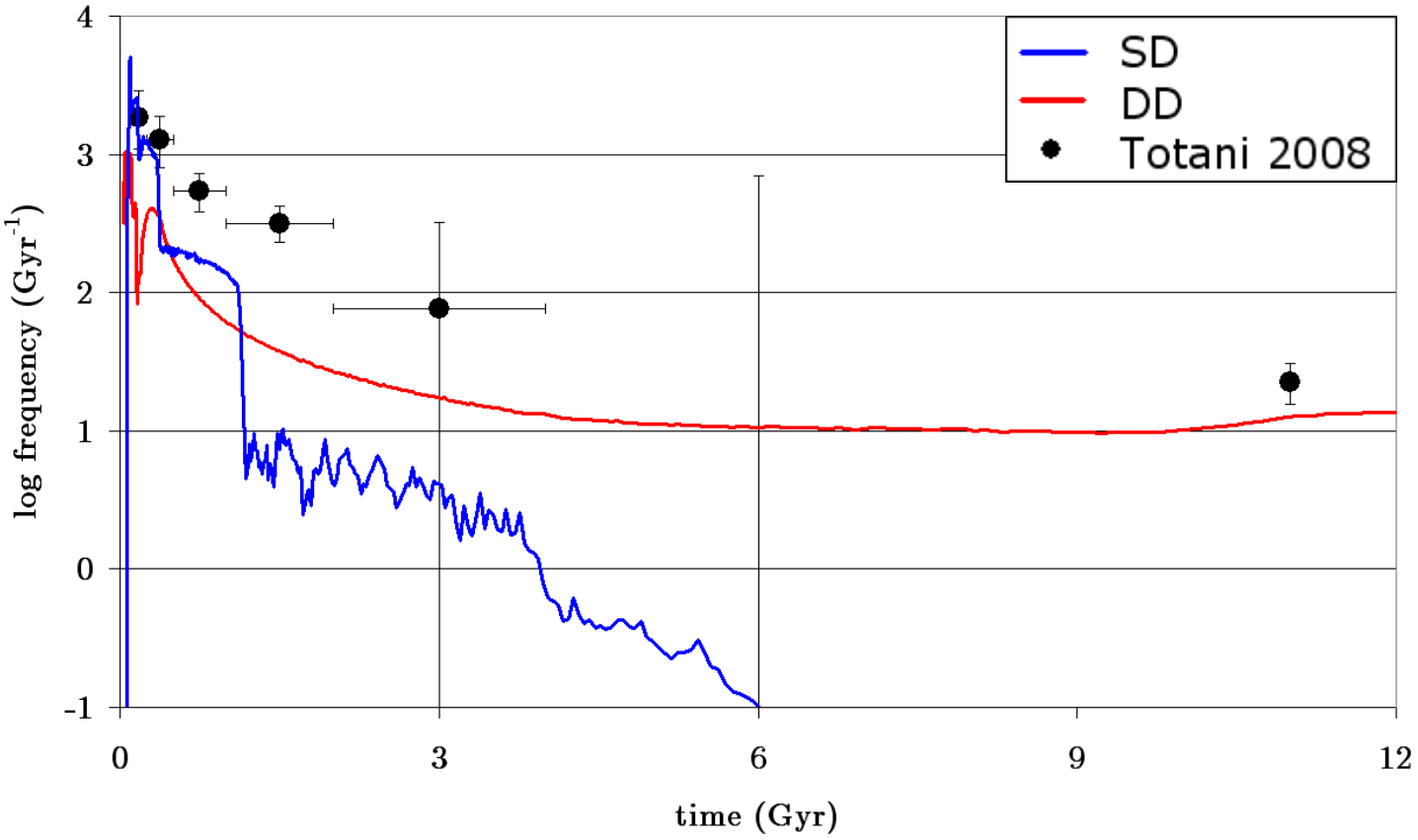


0.91+5.4 M_{sun}
P = 5.6 d

0.80+5.4 M_{sun}
P = 5.6 d

0.80+0.76 M_{sun}
P = 700 s

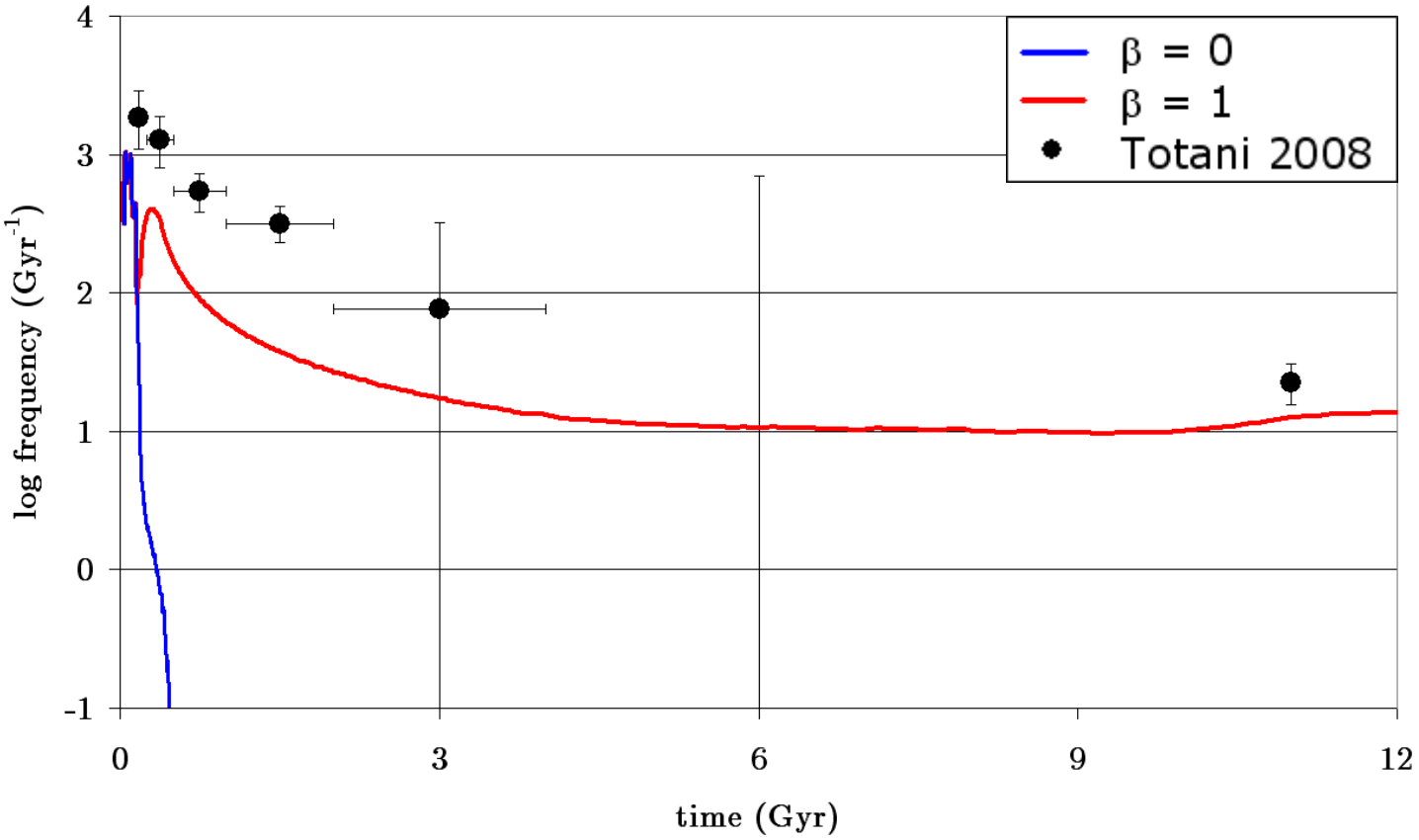
$\beta = 1$



Important results

- Most SD events created through WD+MS channel, not WD+RG
- Most DD events created through quasi-conservative RLOF phase followed by CE evolution, as shown by DTDs for different β

Double degenerate

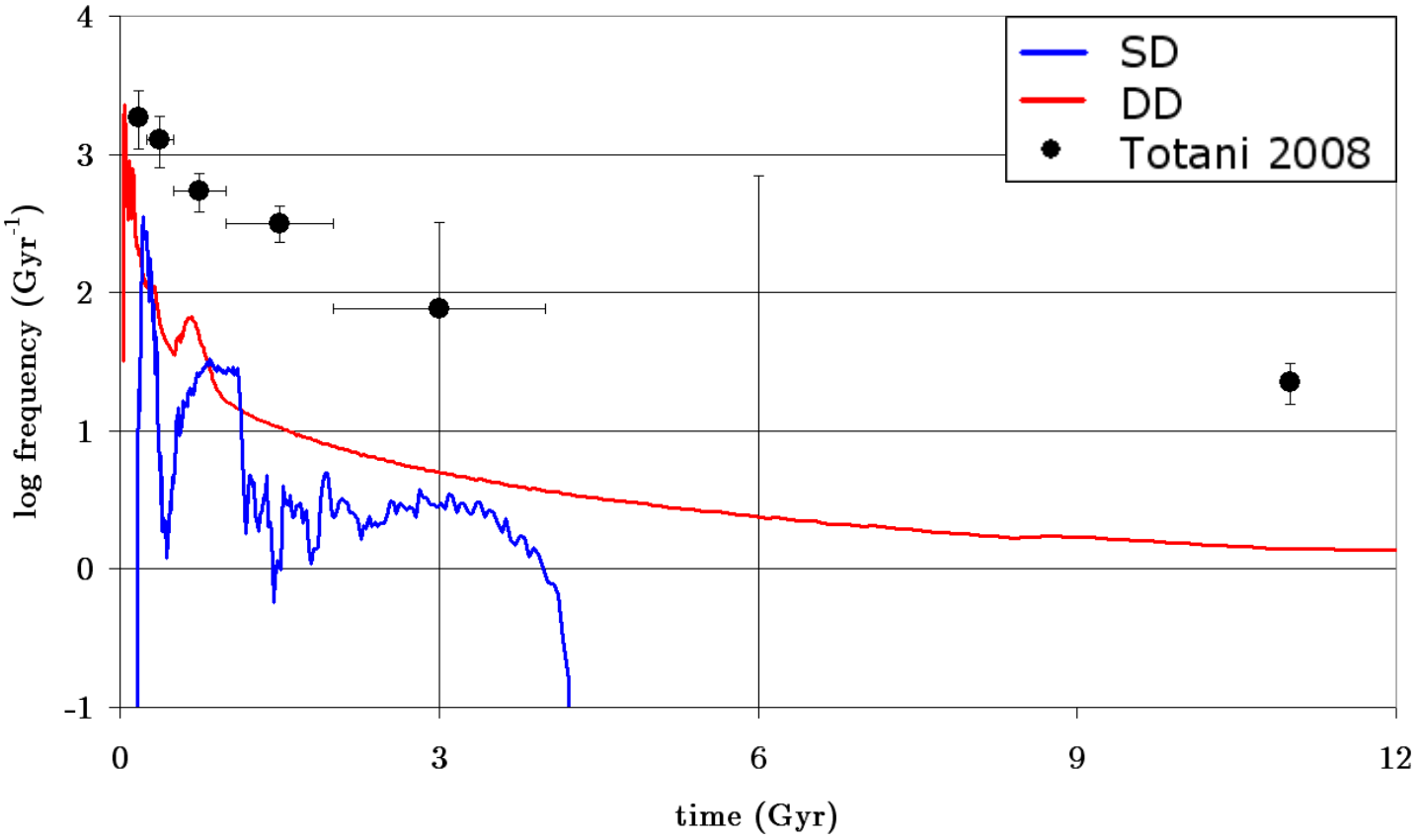


Influence of CE-scenario

DTD critically affected by description of CE-evolution:

- Alpha-scenario of Webbink (1984): balance of energy
- Gamma-scenario of Nelemans & Tout (2005): balance of angular momentum (for WD-binary evolution)

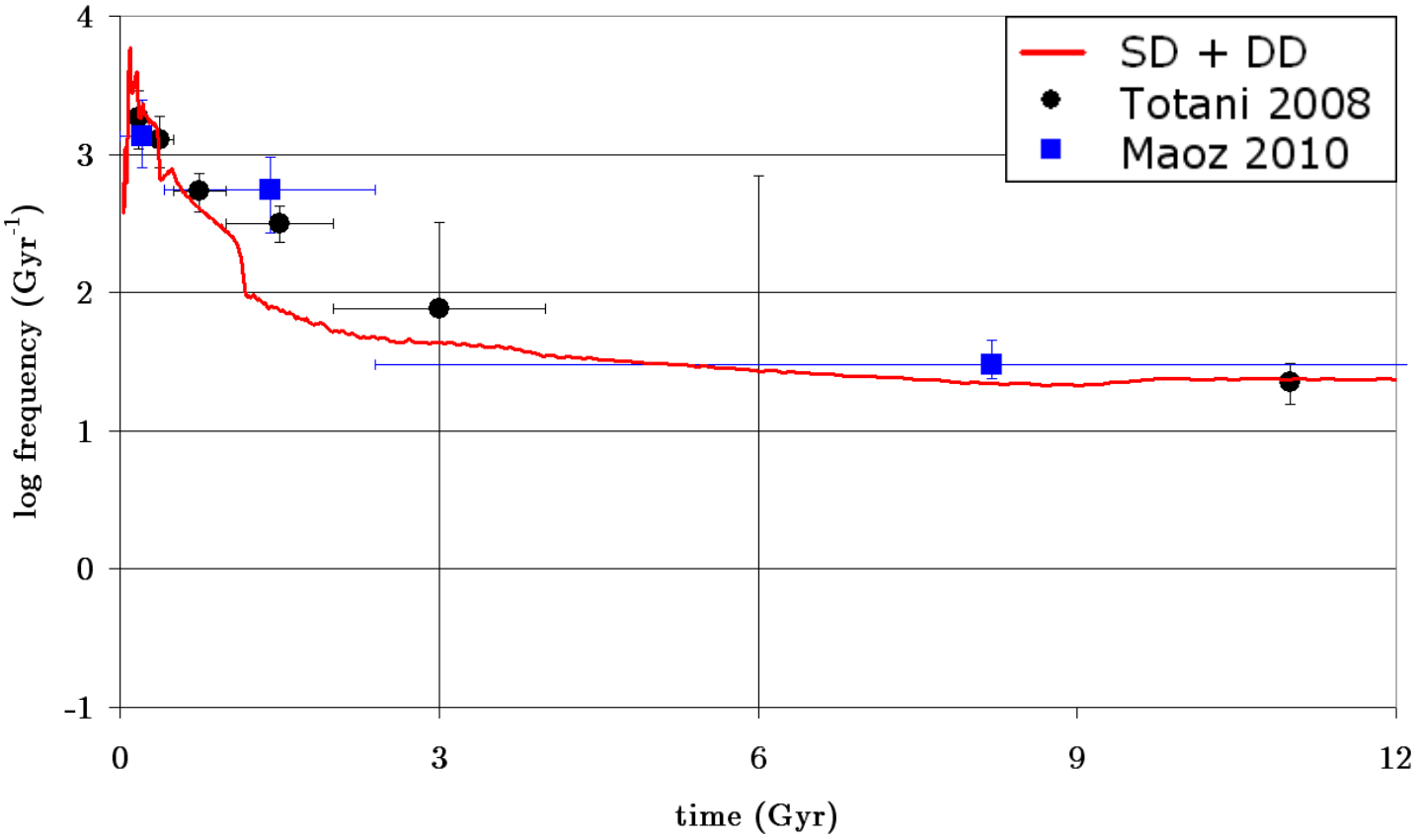
β = 1, gamma-scenario



Absolute number of SNe Ia

- Theoretical models underestimate observed rate by factor 2-3 at 11 Gyr
- May be partially caused by uncertainties on observational conversion factor
- Possible solution: faster-than-synchronous stellar rotation → heavier MS convective cores (CCs) → heavier WD remnants → more DD SNe Ia

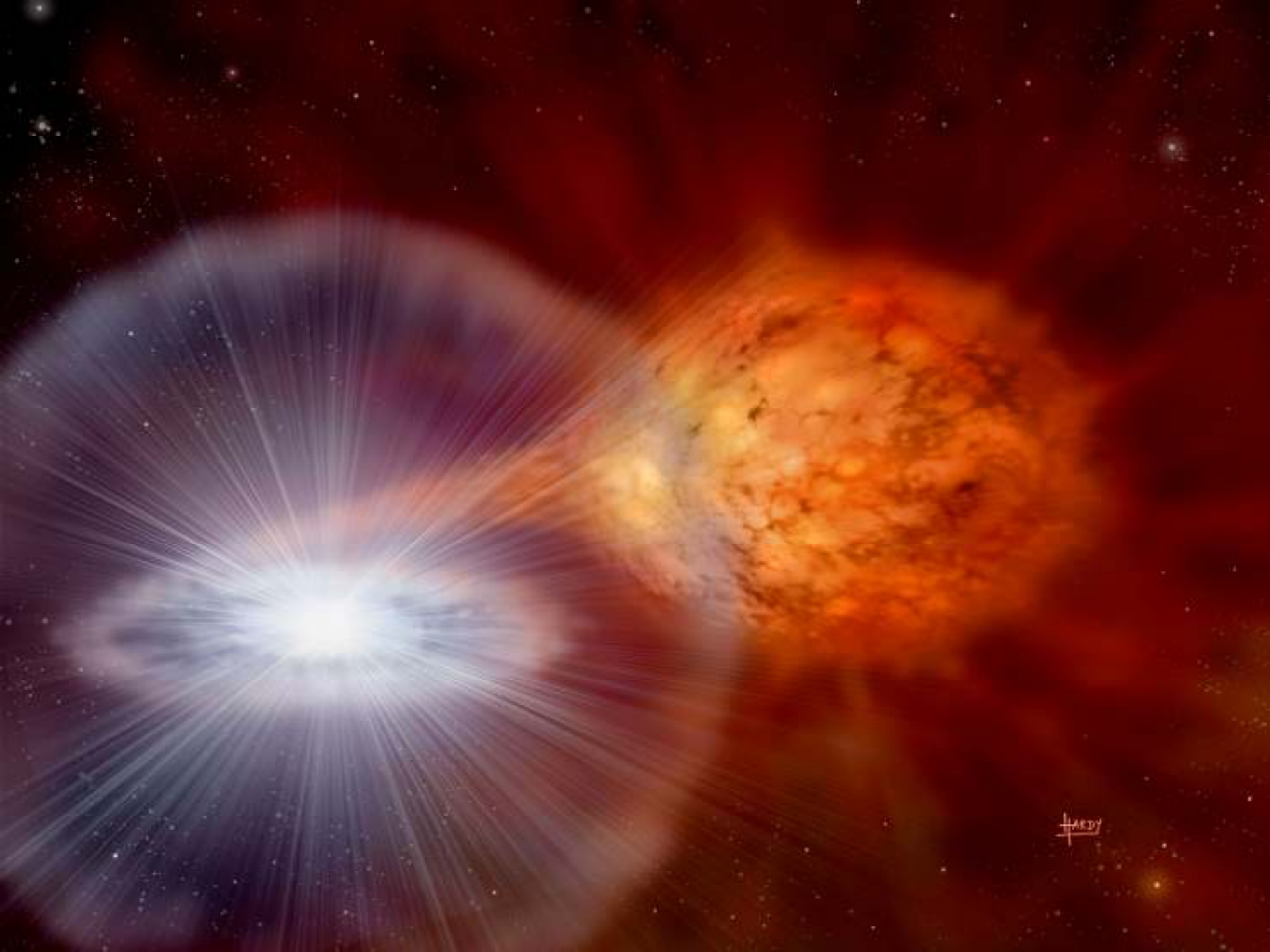
β = 1, CC mass +10%


SD + DD
Totani 2008
Maoz 2010
log frequency (Gyr^{-1})
time (Gyr)
4
3
2
1
0
-1
0
3
6
9
12

Conclusions

- SD alone incompatible with observations
- **Most DD SNe Ia created through quasi-conservative RLOF followed by CE**
- Critical dependence of DTD on mass transfer efficiency during RLOF and physics of CE
  → ***way to find out more about these processes?***

  More info: Mennekens et al., A&A 515, A89, 2010 (arXiv:1003.2491)


HARDY