The formation of type Ia supernovae: theory vs. 2 observations

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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 (cf. 2011 Nobel Prize)
- 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)?

1. 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?**

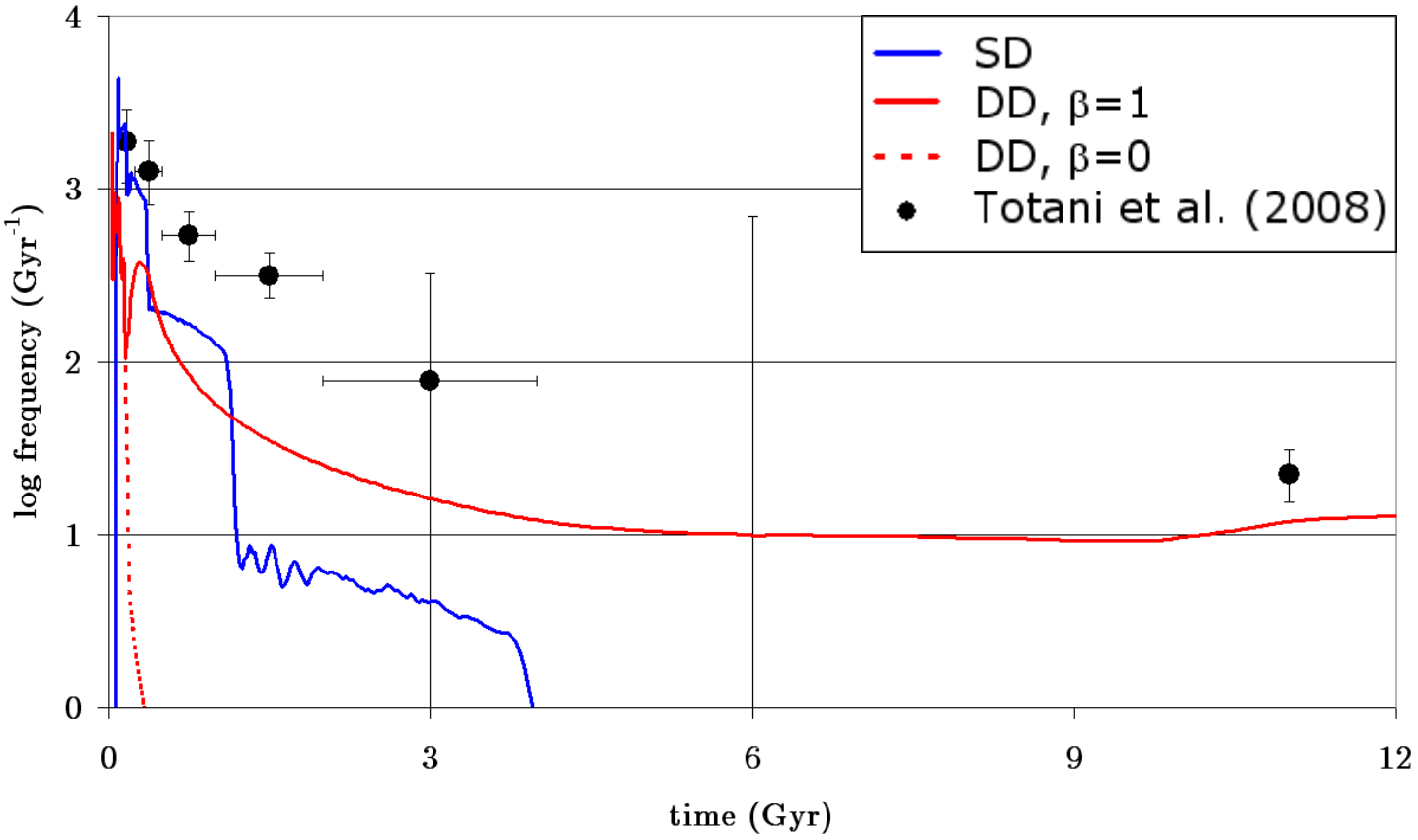
Assumptions

- Updated population number synthesis (PNS) code of De Donder & Vanbeveren (2004) with detailed binary star evolution
- SD progenitors: as given by Hachisu et al. (2008), including mass stripping effect with strength parameter $c_1 \in [0,10]$
- DD progenitors: every evolution resulting in (C-O) WD-merger exceeding (?) 1.4 M_{sun}

Parameter study

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

Delay times: $SD_{c_1=3}$ vs. DD



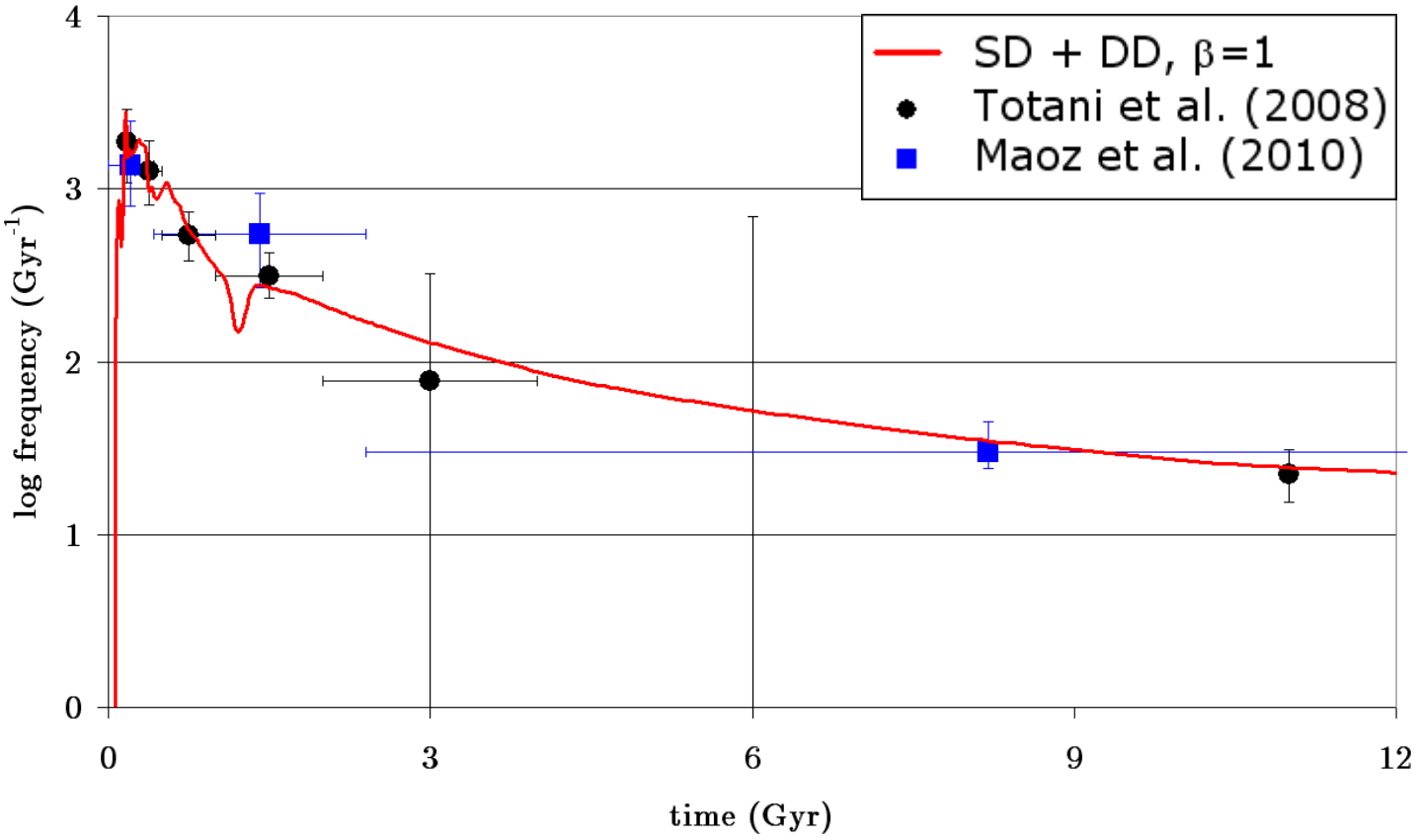
Important results

- 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

  → therefore: $\beta \approx 1$

Delay times: $SD_{c_1=1}+DD_+$



PNS comparison

When assumptions are homogenized → results for WD populations converge (Toonen et al. 2013)

Most important differences concerning SNe Ia due to

- Mass and angular momentum loss **assumptions**
- Common envelope model **assumptions**

Some (minor) disagreements remain

- Mostly caused by differences in "single star tracks" (e.g. Hurley et al. (2002) prescription vs. full evolution including accretion induced full mixing)

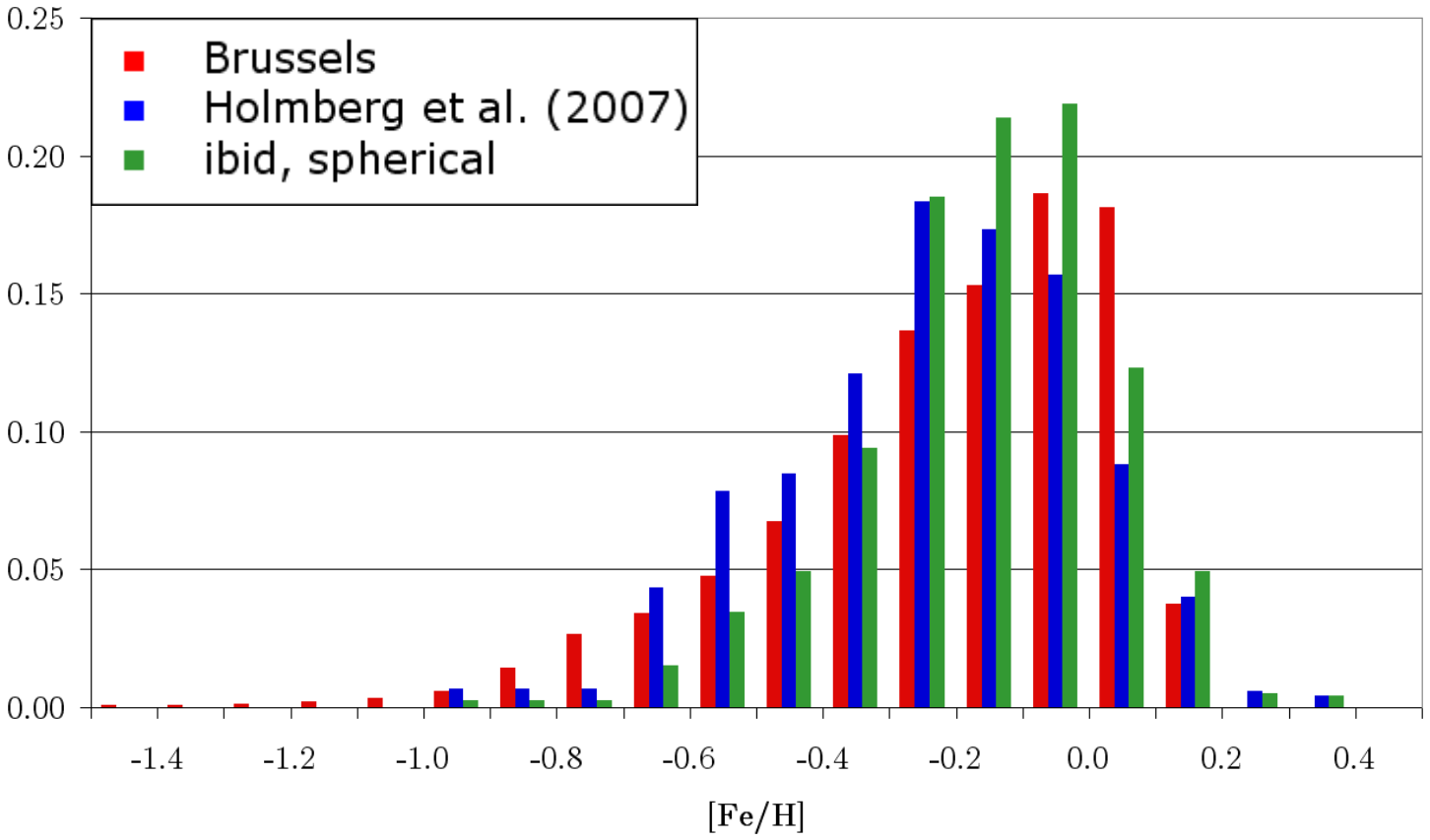
2. G-dwarf metallicities

- G-type dwarfs in Galactic disk: excellent indicators of chemical history
- Metallicity ([Fe/H]) distribution of these stars is critically affected by SN Ia rate, and thus by progenitor assumptions
- Observations for cylindrical solar neighborhood by Holmberg et al. (2007)

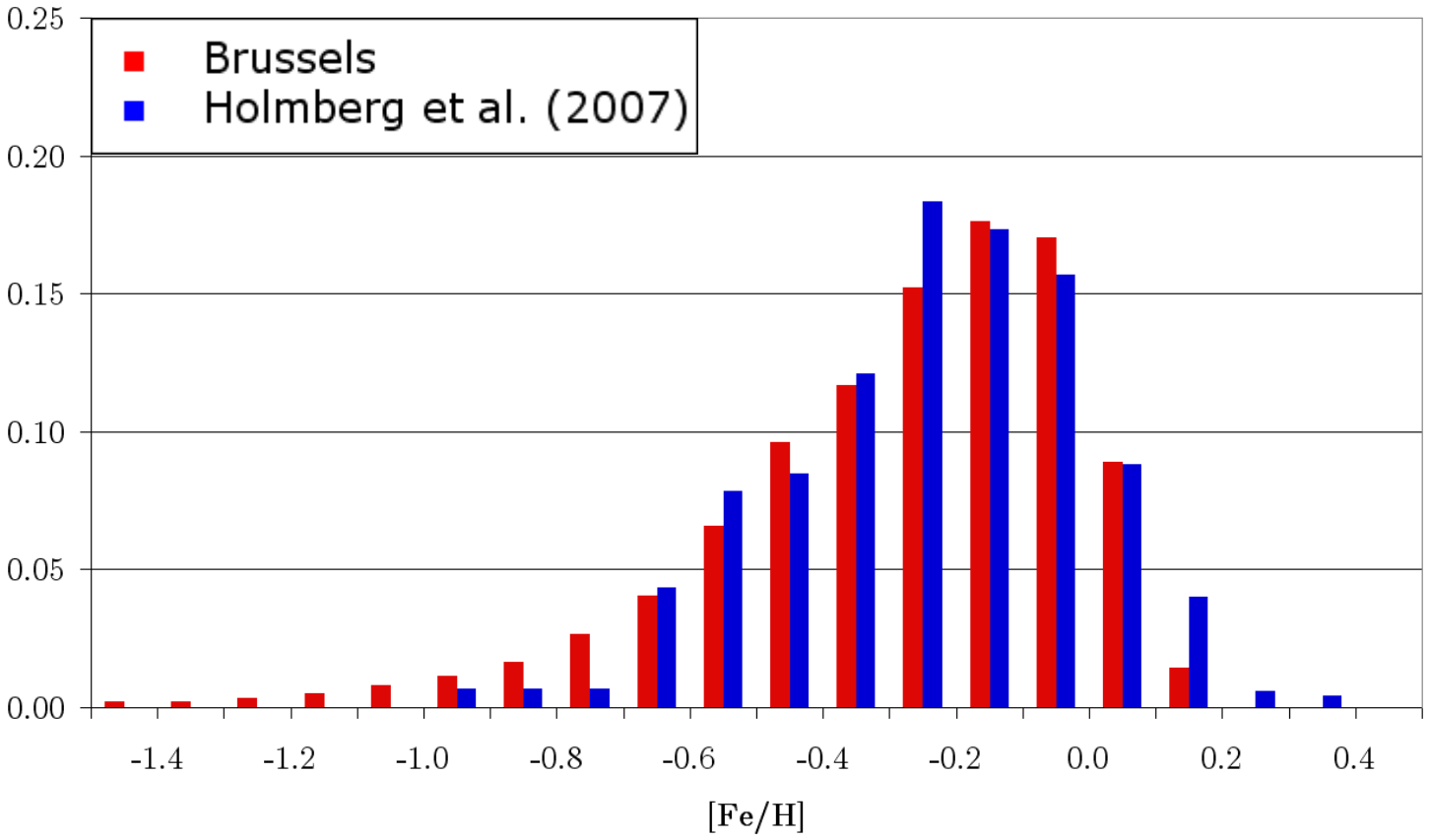
Chemical evolution model

- Update of De Donder & Vanbeveren (2004)
- Binary fraction = 70% (**required** to attain SN Ia rate)
- Galaxy formation:
  - Two-infall model
  - Flat star formation rate (SFR)

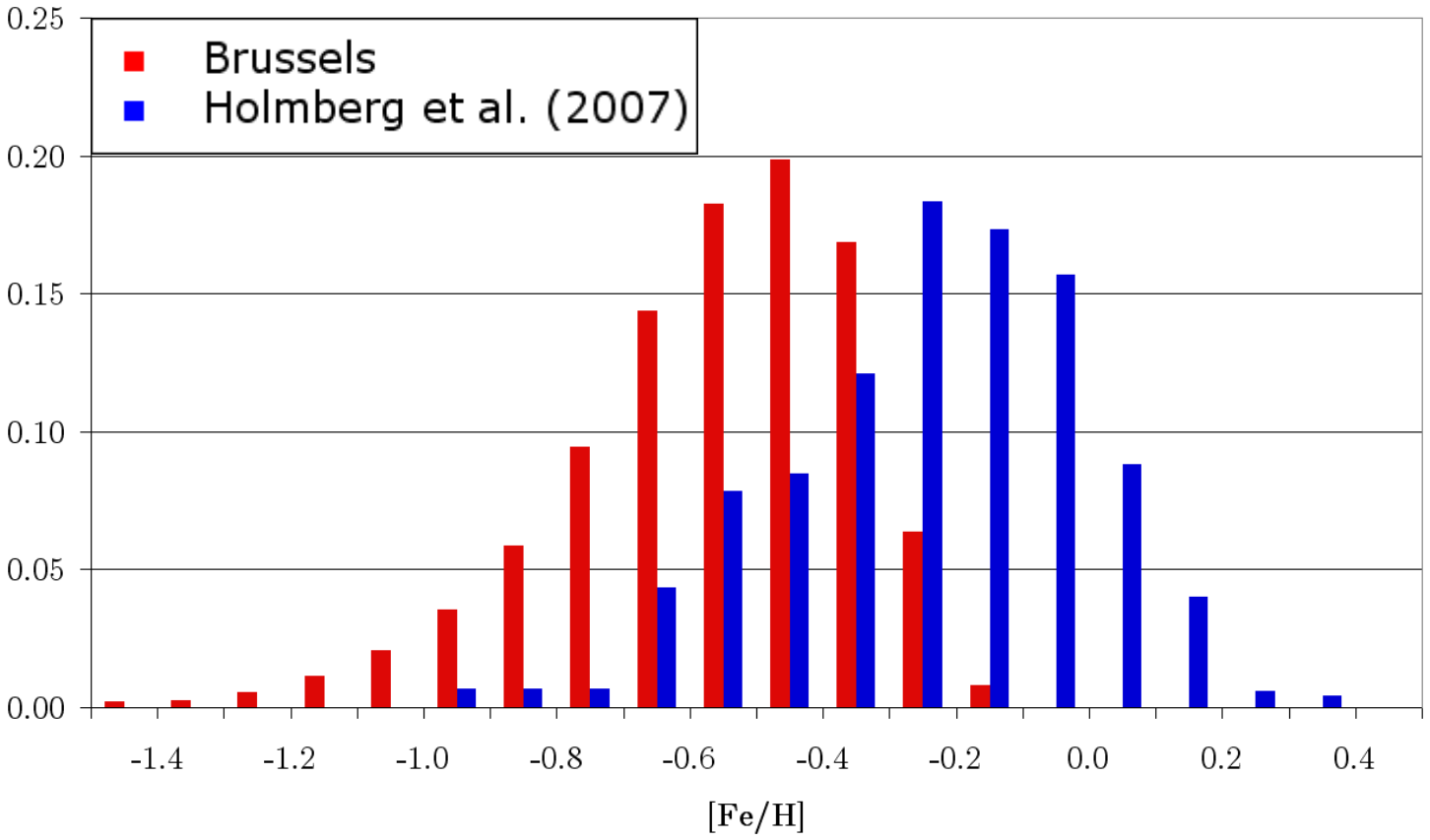
G-dwarfs: $SD_{c_1=1}+DD_+$



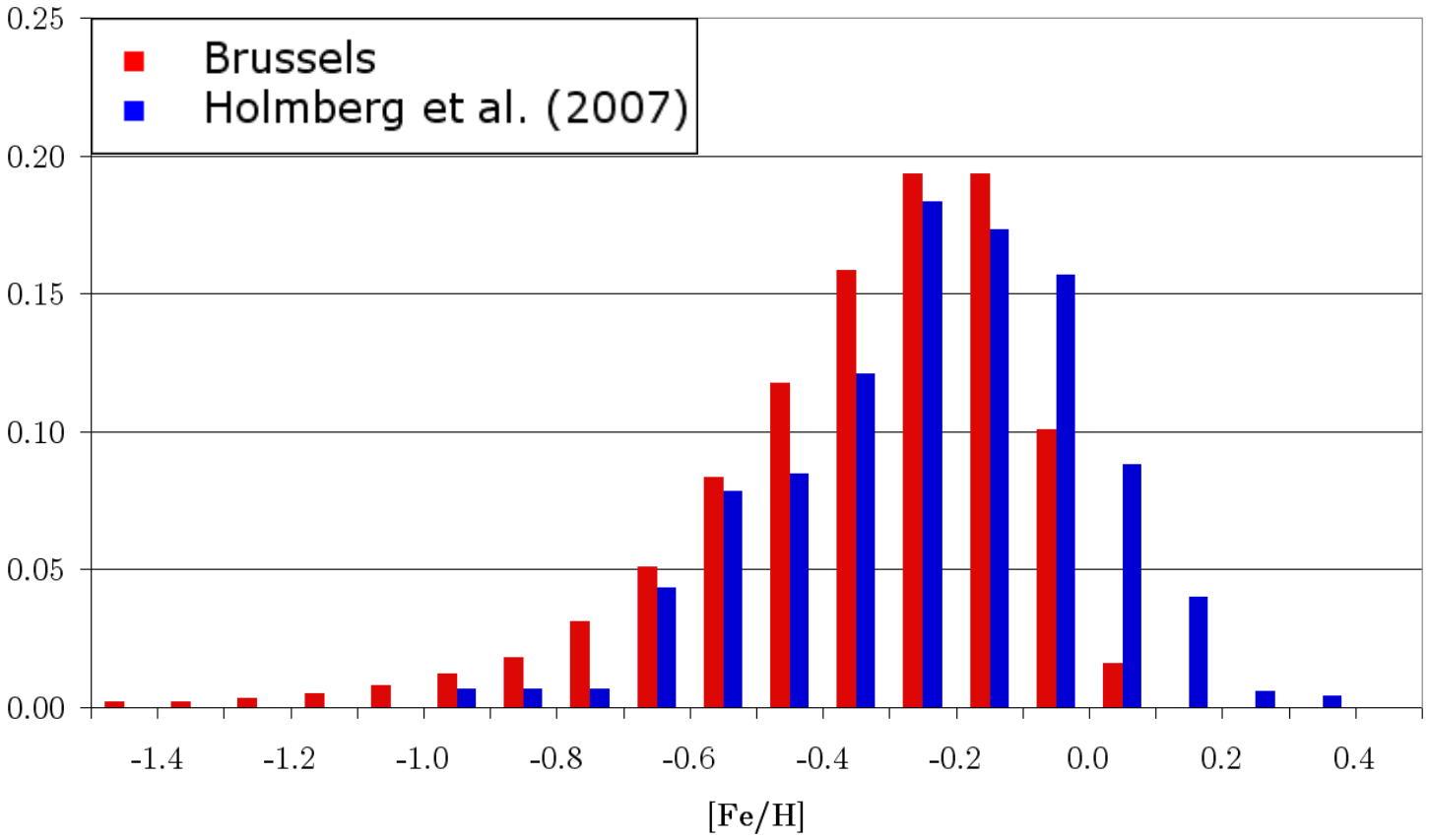
G-dwarfs: $SD_{c_1=1}+DD_+$ (flat SFR)



G-dwarfs: $SD_{c_1=3}$ (flat SFR)



G-dwarfs: DD_+ (flat SFR)



Important results

- Updated SN Ia yields, internally computed with full PNS model
- Supports previous conclusions that best match is obtained with SD + DD
- SD + DD model also reproduces observed [C/Fe] and [O/Fe] vs. [Fe/H] relations

Conclusions

- Delay time and G-dwarf metallicity distribution indicate **significant contribution by both single degenerate and double degenerate** (mostly through conservative RLOF + CE) scenario

- Critical dependence of distributions on binary evolutionary processes (=parameters in PNS) → ***way to find out more about these***

More info: Mennekens et al., A&A 515, A89, 2010 (arXiv:1003.2491)
Mennekens et al., submitted, 2013 (arXiv:1212.0313)