LSS-GAC White Dwarfs

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White Dwarfs

- Most stars will end their lives as WDs
- Compact stars → electrons are degenerate:

  1) Gravitational collapse supported by the pressure of degenerate electrons

  2) Chandrasekhar mass limit → type Ia supernova

  3) Radius decreases with mass

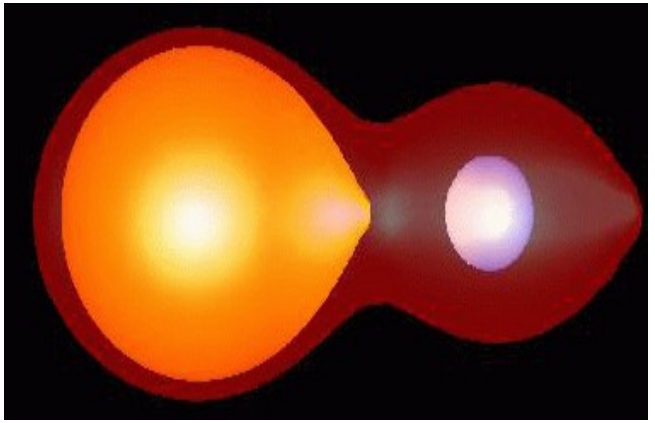
White Dwarfs

- Well understood cooling: well known ages

  1) Luminosity Function → age of the Milky Way

  2) Age Function → WD formation rate, local star formation rate

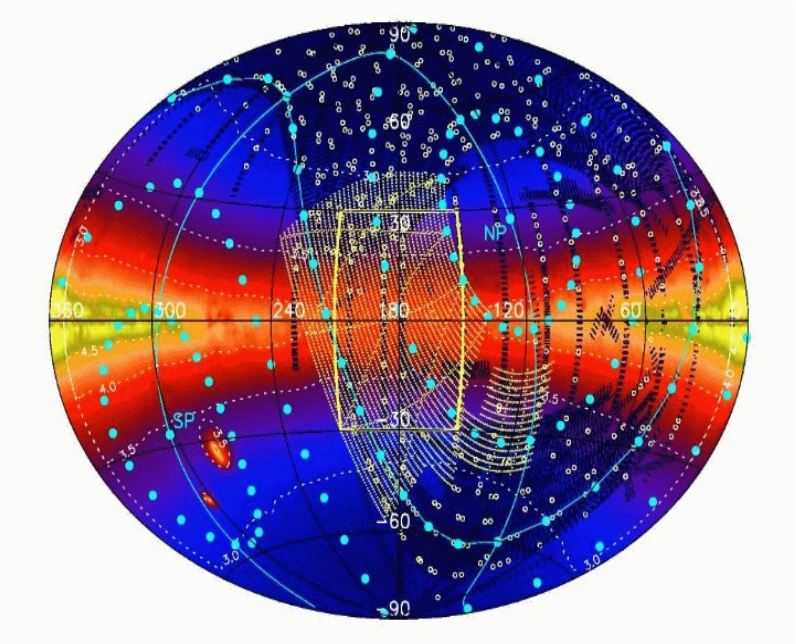
  3) Mass function → binary interactions



LAMOST-GAC (LSS-GAC)

Well-defined target selection criteria

Stars of all colours selected uniformly and randomly (Liu et al. 2014, Yuan et al. 2014)

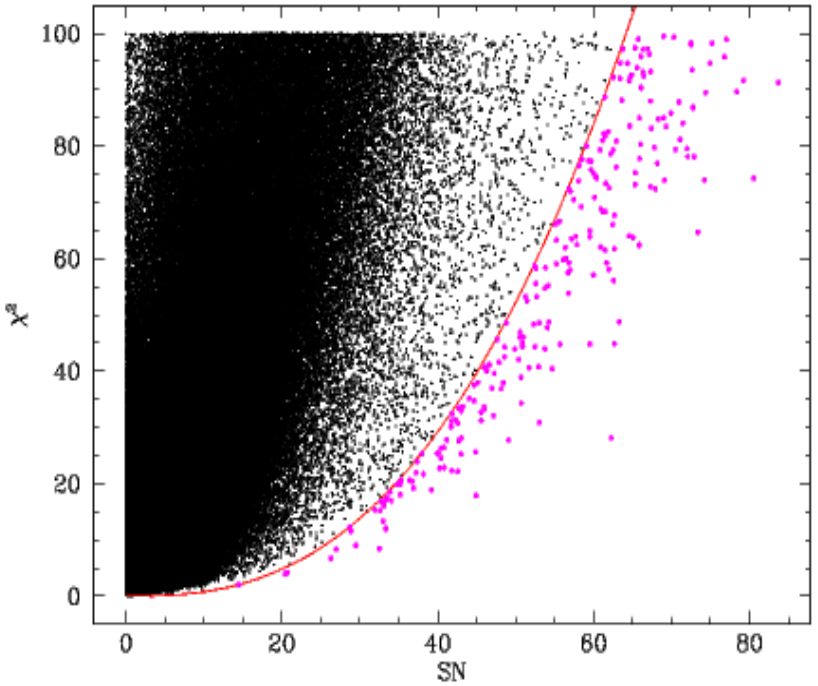


- *g,r,i* band, 14 < r < 18.5
- 150 < l < 210, -30 < b < 30

- Effective aperture = 4m
- R ~ 1800
- Covers ~3800-9000A
- 4000 fibres

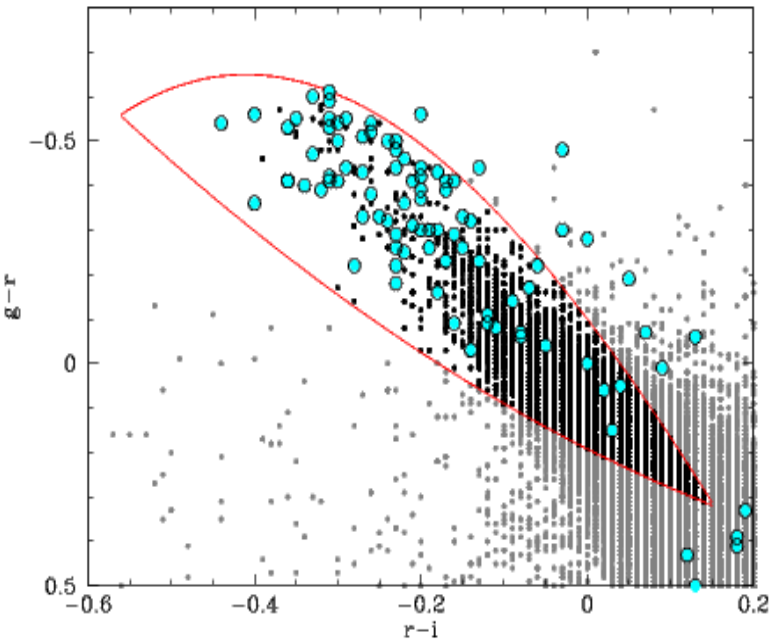
Observed Sample

LAMOST-GAC survey DR1 (2013): 306,600 spectra with SN > 5



Rebassa-Mansergas et al. (2010)

Two complementary methods:
χ^2-SN + colour selection



Girven et al. (2011)

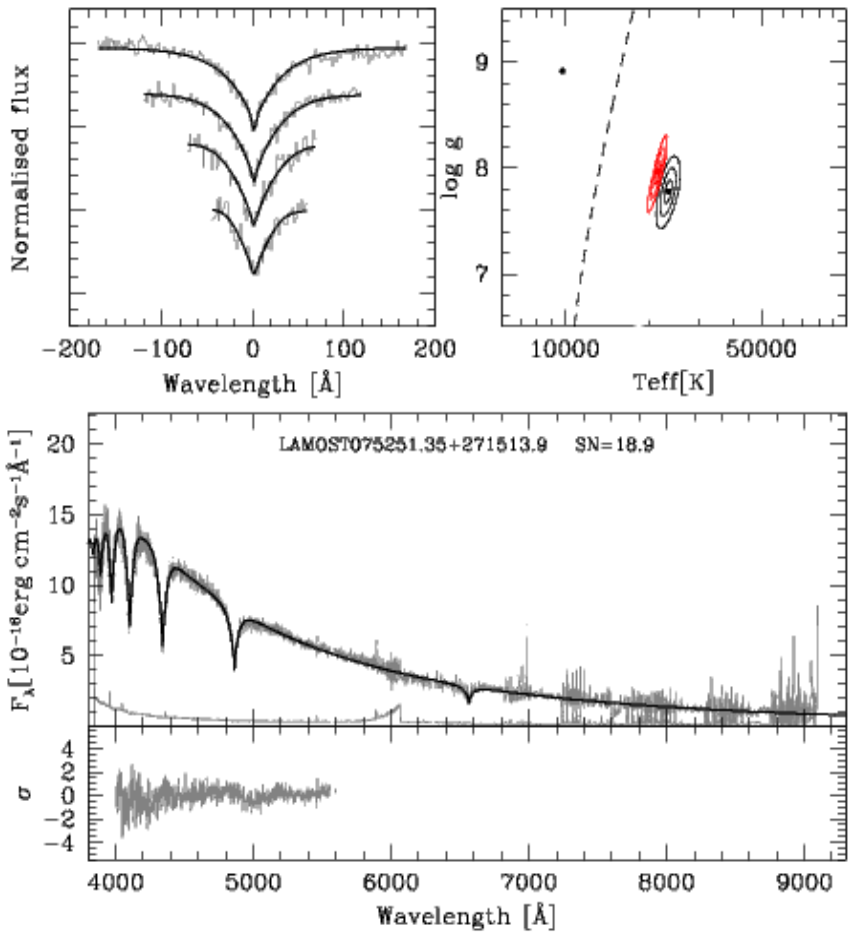
Estimated completeness ~ 95%

108 WDs
93 DAs

Stellar Parameters

- Teff, log(g) fitting the LAMOST spectra

  Rebassa-Mansergas et al. (2007)

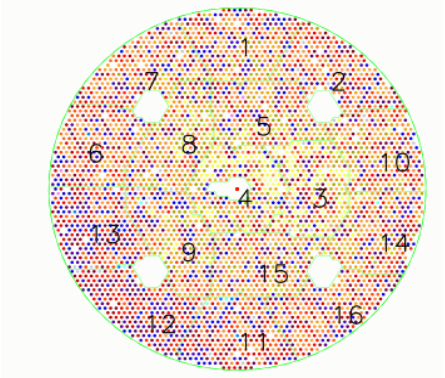


82 DAs with reliable fits

- Mass, tcool, UGRIZ, Mbol from Bergeron et al.'s tables
- Extinction from 3D map of Chen et al. (2014)
- Distance from distance modulus

Space Density

Space density obtained following the 1/Vmax method
Schmidt (1968), Green (1980)



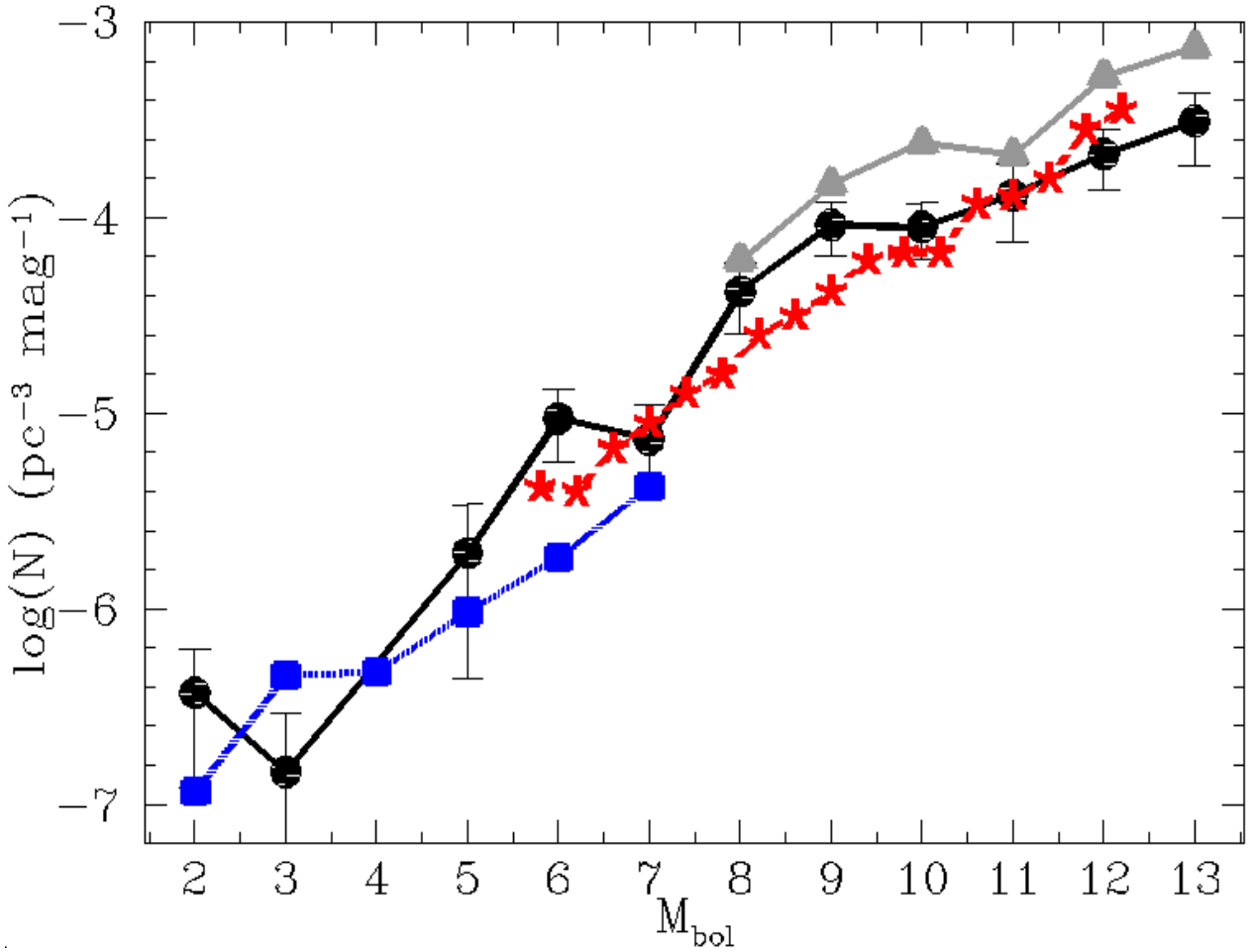
$$V_{WD} = V_{max} - V_{min} = \sum_{i=1}^{n_{spec}} \frac{\omega_i}{4\pi} \int_{d_{min}}^{d_{max}} e^{-z/z_0} \, 4\pi r^2 dr$$

Contribution from each specrograph in the survey, ωi = 1.2 deg2

Corrects non-uniform distribution of stars, Z0 = 250pc and z= d x sin(b)

Space density = Σ 1/(Vwd)
= 0.8 x 10^(-3) pc^(-3)

Luminosity Function



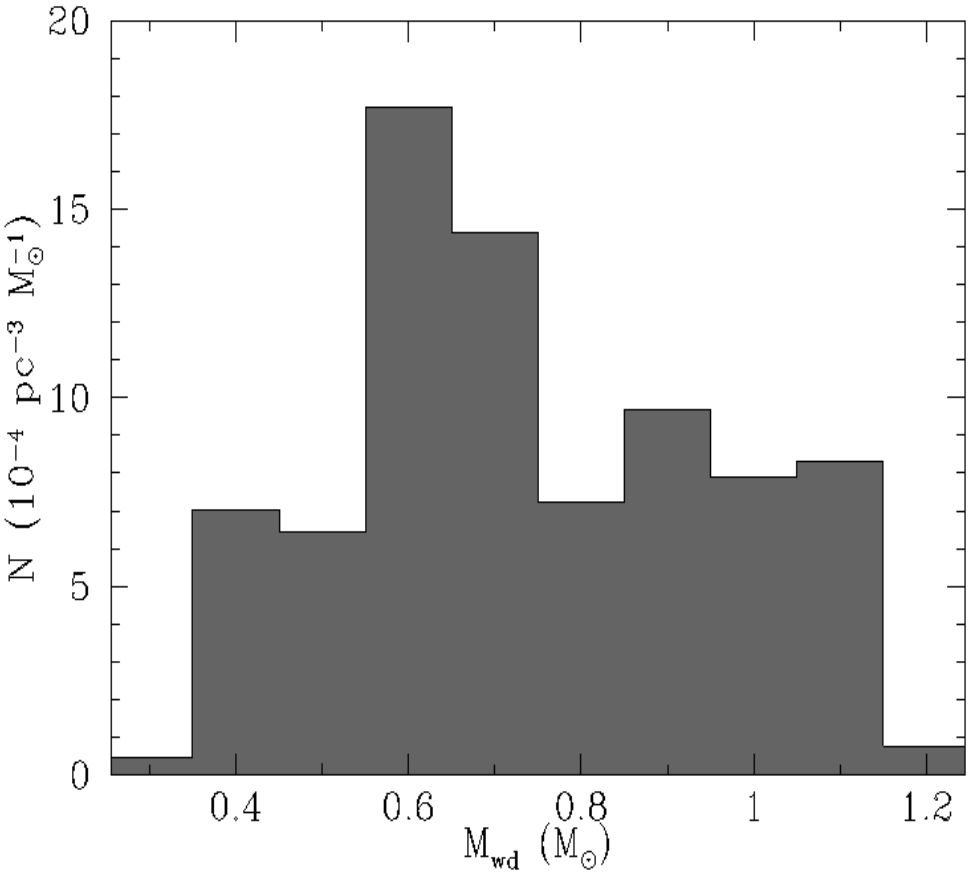
this work

Giammichele et al. (2012) (local)

Torres et al. (2014) (hot DA WDs)

De Gennaro et al. (2008) (SDSS)

Mass Function



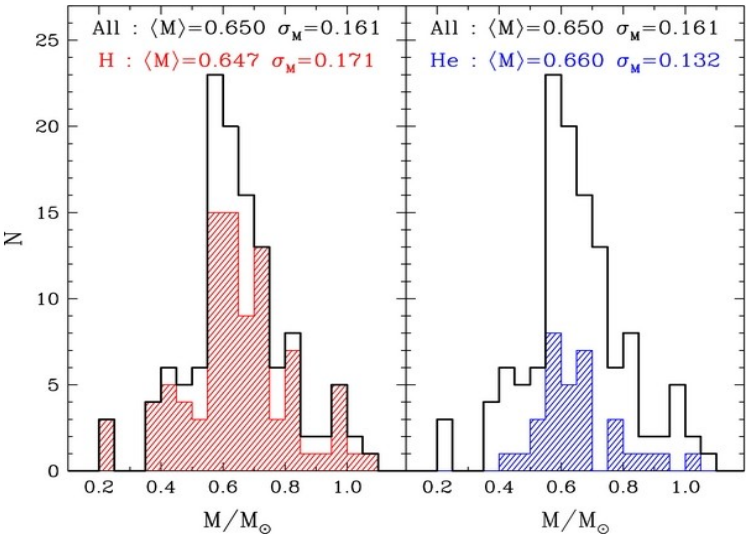
Large number of high-mass white dwarfs!

Excess also found in other magnitude limited samples.....

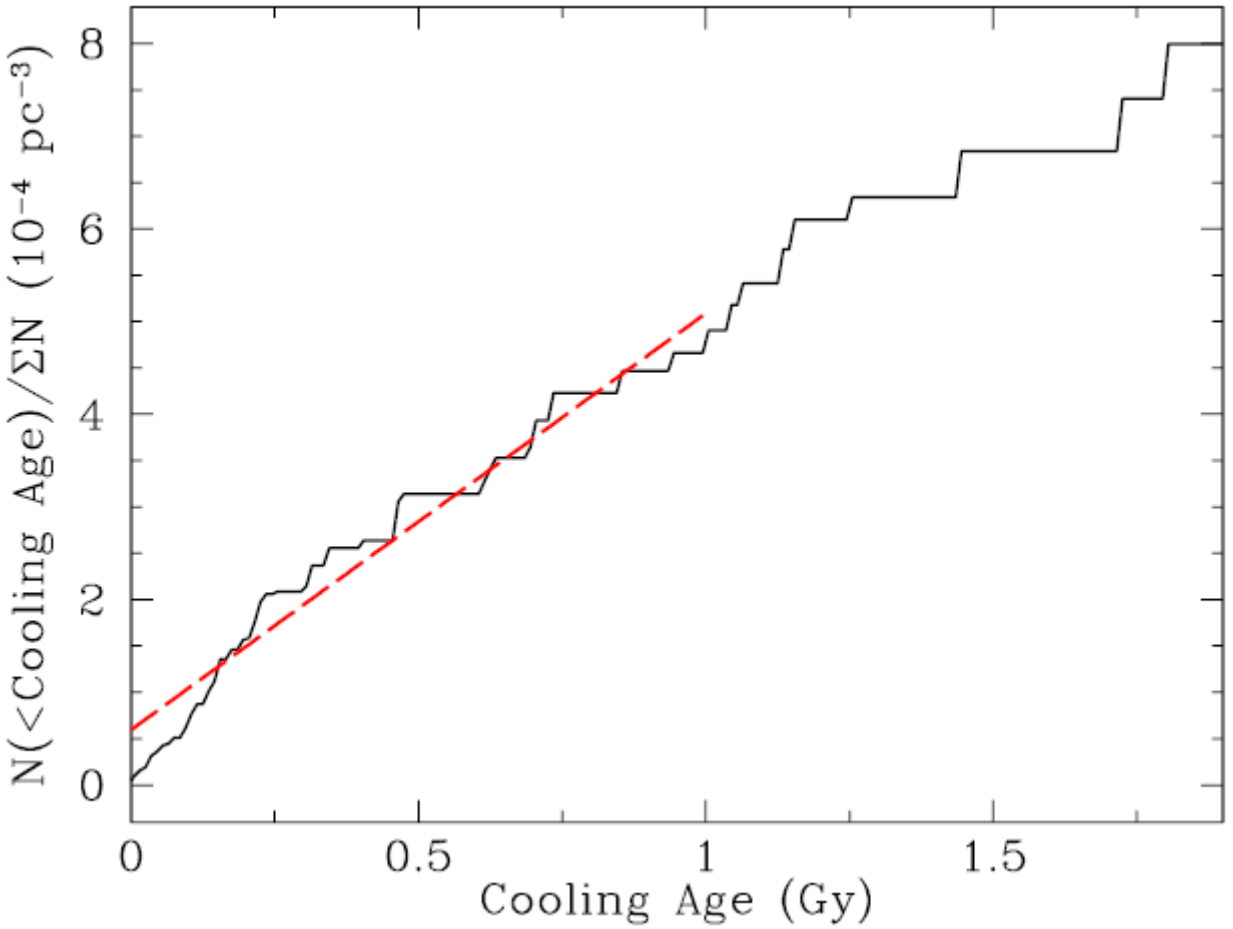
Hu et al. (2007), Ferrario et al. (2005) Liebert et al. (2005), DeGennaro et al. (2008)

...even in the local, volume limited sample

Giammichele et al. (2012)



Cumulative Age Function



Birt Rate = 4.5 x 10^(−13) pc^(−3) yr^(−1)

Simulated Sample

- Distance < 3.5 Kpc, within LAMOST-GAC survey limits
- Age thin disk 9.5 Gyr
- Position of each star: double exponential distribution
- IMF of Kroupa et al. (2001)
- SFR constant or bimodal (Rowell 2013)
- IFMR of Catalan et al (2008) or Ferrario et al. (2005)
- Cooling sequences of Althaus et al. (2007) and Renedo et al. (2010)
- Magnitudes in SDSS ugriz + extinction
- Stellar parameter + photometric errors taken into account

Garcia-Berro et al. (1999, 2004); Torres et al. (2002)

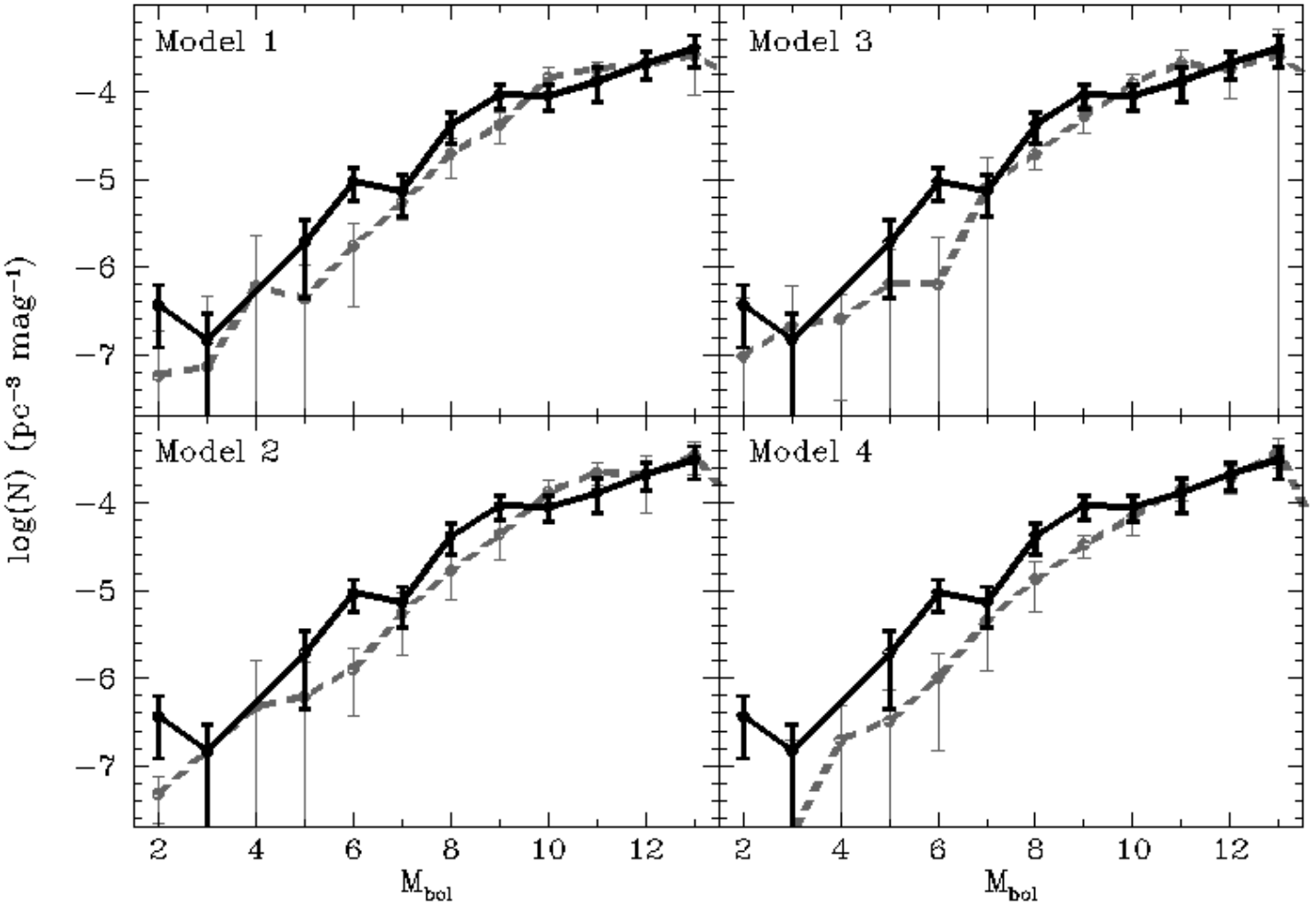
Models

Model	SFR	IFMR	Slope for the massive regime
1	constant	Catalán et al. (2008)	0.10
2	constant	Catalán et al. (2008)	0.06
3	constant	Ferrario et al. (2005)	0.10
4	bimodal	Catalán et al. (2008)	0.10

- Apply LSS-GAC selection criteria to the model populations (high success of selecting WDs, ~90% survive!; $14 < r < 18.5$)
- Consider WDs within the GAC plates satisfying the magnitude limits
- Evaluate the probability that SN > 5
- Take into account the completeness of the observed sample (~95%) and a probability for having a 'good fit'

  Final number of simulated WDs ~ size of observed sample

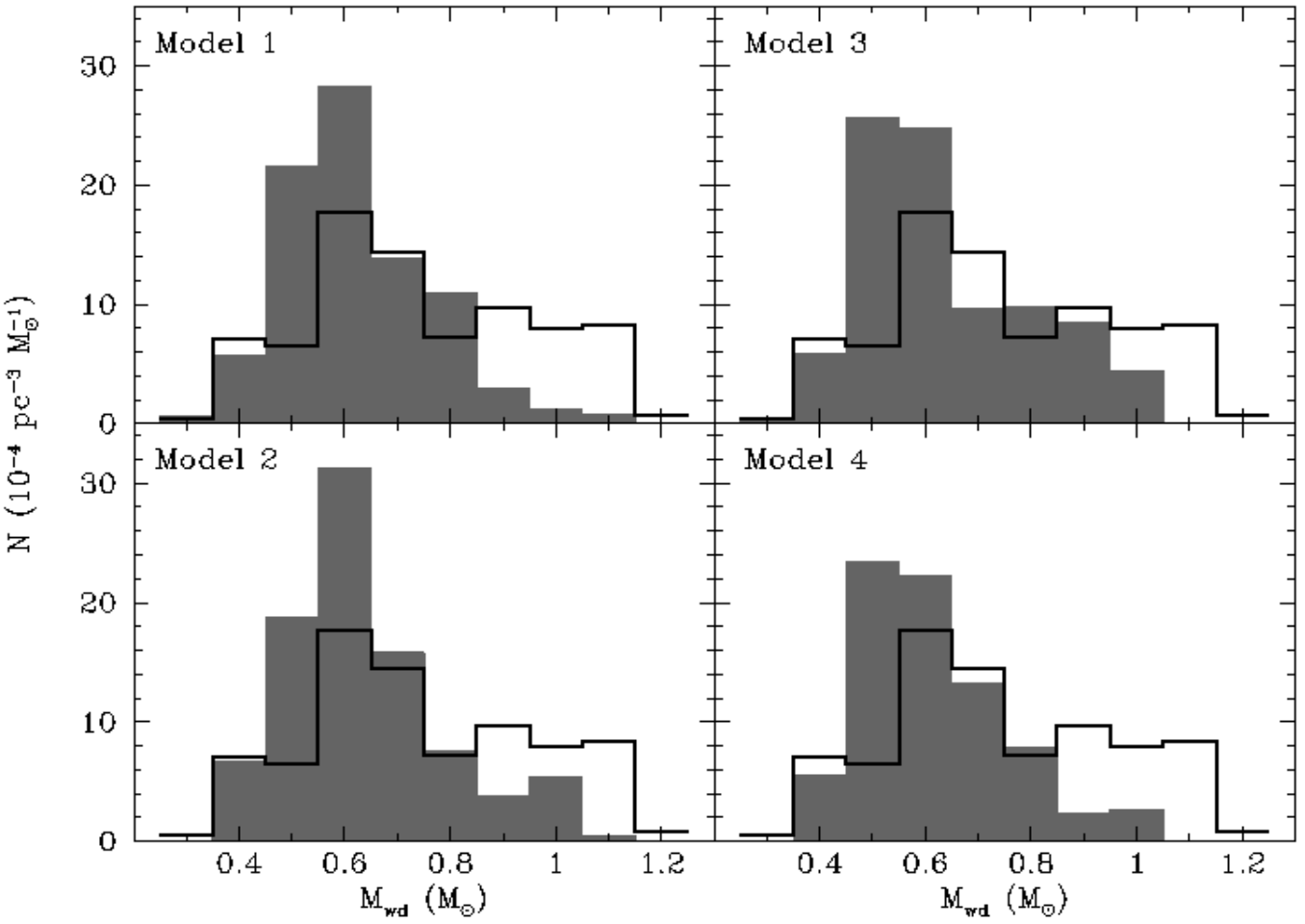
Observations vs Simulations



All models reproduce well the shape of the observed LF for 7 < Mbol < 12.5

Observations vs Simulations

No model invoking single star evolution can reproduce the excess of high-mass white dwarfs



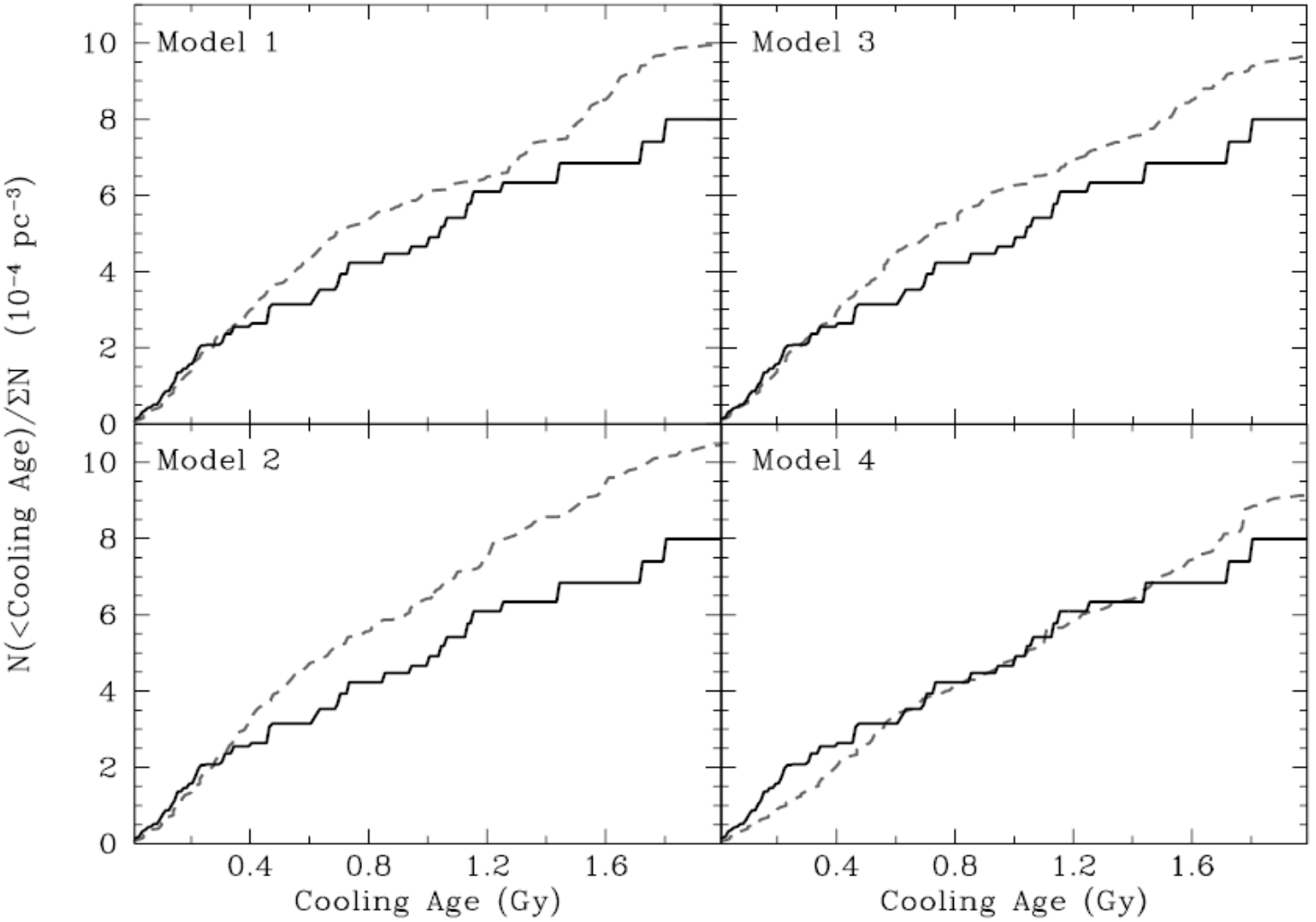
WD+WD mergers?

Marsh et al. (1997)
Vennes (1999)

Giammichele et al. (2012)

"And since we have a volume-limited sample, we are forced to conclude that the fraction of mergers in the Galaxy must be enormous„

Observations vs Simulations



Bimodal SFR fits better the data

Conclusions

- First well-characterised magnitude limited sample of DA WDs
- LSS-GAC selection criteria efficiently selects DA WDs
- Simulations reproduce the observations, however no model fits better the data (except bimodal SFR)→ dominated by the observational uncertainties
- Large number of massive WDs predicted that cannot be reproduced by any model

  WD+WD mergers is the most plausible explanation
- Space density of DA WDs ~ 0.8 x 10^(-3) pc^(-3)
- Birth rate of DA WDs ~ 4.5 x 10^(-13) pc^(-3) yr^(-1)
- Observed sample is small → forthcoming LSS-GAC releases will dramatically enlarge the sample