THE ROLE OF SNIa IN GALAXY FORMATION

Noelia Jimenez (St. Andrews University) Patricia B. Tissera (Universidad Andres Bello / MAS) Francesca Matteucci (University of Trieste, INAF)

The nature of the Type Ia supernovae (SNIa) progenitors is a major issue for galaxy evolution models since both chemical and energetic feedback play a major role in the gas dynamics, star formation and therefore in the overall stellar evolution. The progenitor models for the SNIa available in the literature propose different distributions for regulating the explosion times of these events. These functions are known as the Delay Time Distributions (DTDs). We implement and analyse different DTDs in galaxies dominated by a rapid quenching of the star formation, displaying the majority of the stars concentrated in the bulge component. We find a good fit to both the present observed SNIa rates in spheroidal dominated galaxies, and to the [O/Fe] ratios shown by the bulge of the Milky Way using the Single Degenerate Mode (SD)l. Additionally, the SD scenario is found to reproduce a correlation between the specific SNIa rate and the specific star formation rate, which closely resembles the observational trend, at variance with previous works. All tested DTDs produce a correlation but not all of them follow the observational trends. Our results suggest that SNIa observations in galaxies with very low and very high specific star formation rates can help to impose more stringent constraints on the DTDs and therefore on SNIa progenitors.

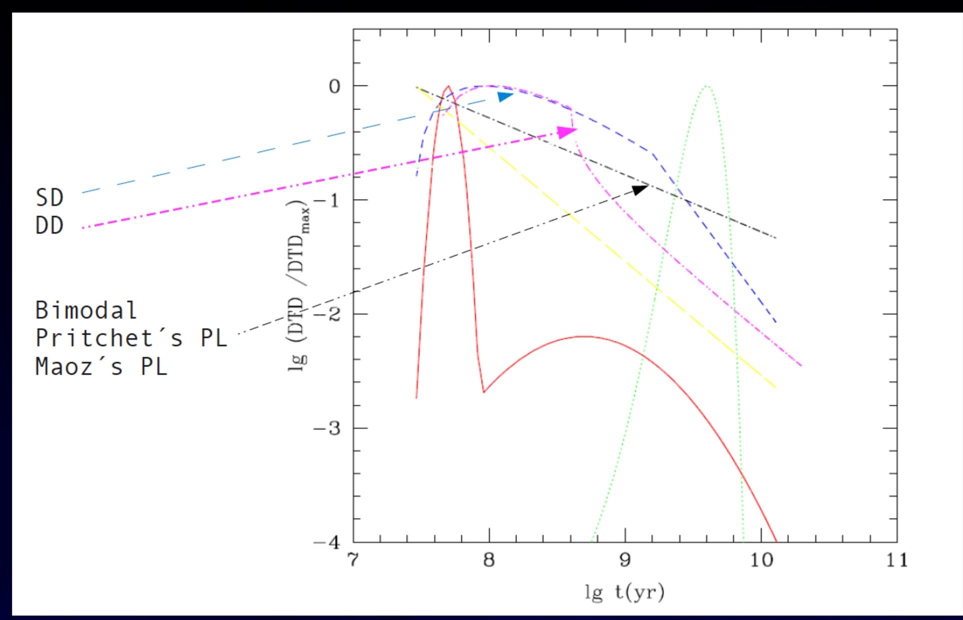


Figure 1 The DTDs tested: Single Degenerate (SD), Double Degenerate (DD), the Bimodal and those proposed by Maoz et al. (2012) And Pritchet et al (2008).

Simulations and Models:
We analyse the performance of the DTDs in simulations of pre-prepared galaxies in isolated dark matter haloes. This initial condition (IC) is simple enough to highlight the effects of the different DTDs without being distracted by additional processes such as mergers and gas infall, which complicate the picture in fully hierarchical scenarios for galaxy formation. This simple approach allows us to more easily test the influence of the free parameter of the implemented DTDs (see Figure 1).

The IC consists of a dark matter potential with an initial distribution following a NFW density profile (Navarro, Frenk &White 1994), which is let to evolve self-consistently with the baryonic component, with a concentration of c=9, an old stellar bulge with a Hernquist profile and a old stellar exponential disc. The virial mass of this system is 10^11Msun, with 10% of this mass in form of baryons. The adimensional spin parameter is λ=0.044

Initially, the gas component represents 65% of the total baryonic mass and is distributed in the disc component. The large gas fraction has been chosen to mimic a galaxy in its first stages of evolution in a simple way. The initial gas particle is 7e5 Msun while the dark matter particle is 9e6 Msun and the stellar mass particle, 3e5 Msun. The softening length for the gas particles is 200 pc and for the dark matter particles we adopt 450pc. The SFR efficiency is set at c=0.1. We follow the evolution of the systems until the gas to form stars is depleted and the star formation ceases. As the initial gas fraction is high (65%), this facilitates the formation of clumps which migrate into the inner regions contributing to the formation of the bulge component. This process has been extensively studied by Perez et al. (2013).

Results for the Single Degenerate Scenario

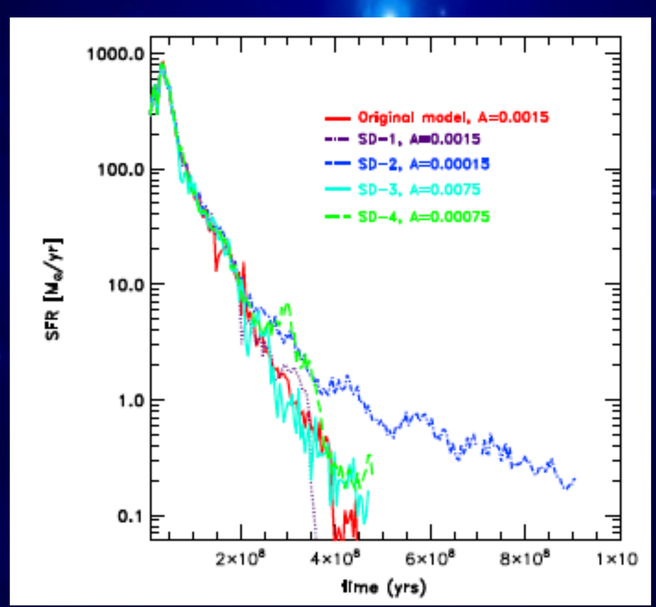


Figure 2 SFR for the SPH galaxies run with the same IC and varying the A values of the SD DTD.

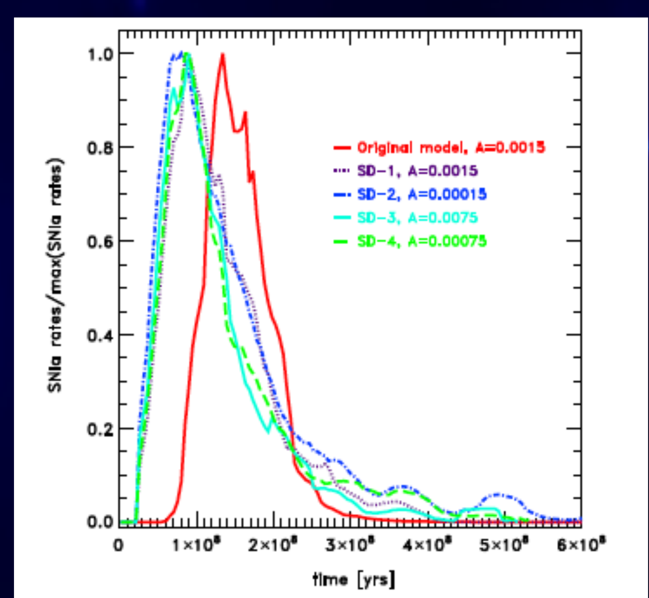


Figure 3
SNIa rates for the variations of A.

We use the SD scenario to compare with our original SNIa model where the lifetimes of the progenitors are taken at random in the range [1e8,1e9] yrs. In Fig. 2, 3 and 4, we show the star formation rates, SNIa rates and chemical patterns for the SD scenario, varying the free parameter A.
In analytical chemical models this parameter A is chosen for each time of galaxy to reproduce observational rates. However in our simulations, we can only chose a value of A which works at particle scales (see Jimenez et al. 2015).
Hence, the final trends are robust in the sense that they are determined by the evolution of the galaxies according to the history of assembly. It is also more challenging to obtain observational results for galaxies with different morphologies by using hydrodynamical simulations.

Table 1
Main Characteristics of the Simulated Galaxies Run with the SD Scenario and Varying *A*

Model	*A*	⟨SFR⟩ ($M_\odot\,yr^{-1}$)	SN Ia Rates (N/yr^{-1})
SD-1	0.0015	83	0.002
SD-2	0.00015	60	0.00006
SD-3	0.0075	84	0.0080
SD-4	0.00075	76	0.0016
Original	0.0015	53	0.0027

Note. The mean observed SN Ia rate for spheroidal-dominated galaxies of stellar mass ~3.5 × $10^{10}\,M_\odot$ is ~0.0017 SNe per year (Li et al. 2011).

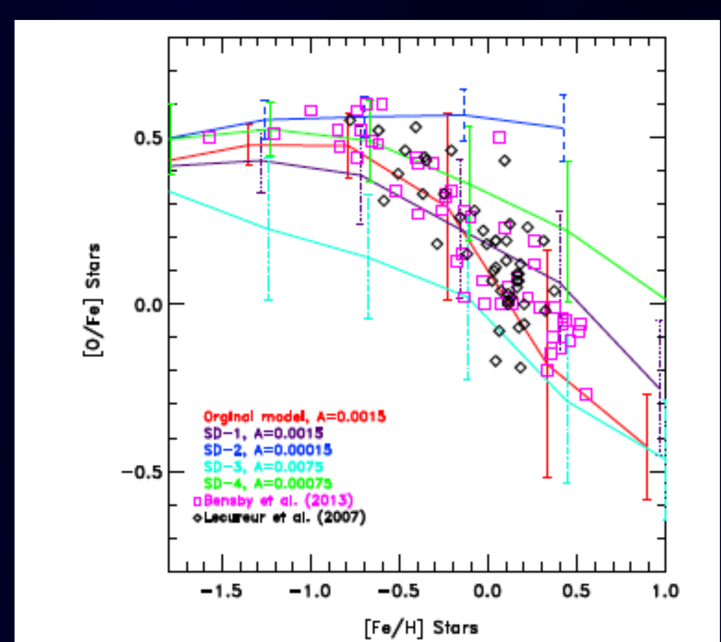


Figure 4
O/Fe] vs. [Fe/H] exhibited by the bulge stars in the SPH simulated galaxies with the SD scenario by Matteucci et al (2001) and varying A. These models are compared to observational [O/Fe] ratios for stars in the Galactic Bulge by Bensby et al. (2013) and Lecureur et al. (2007).

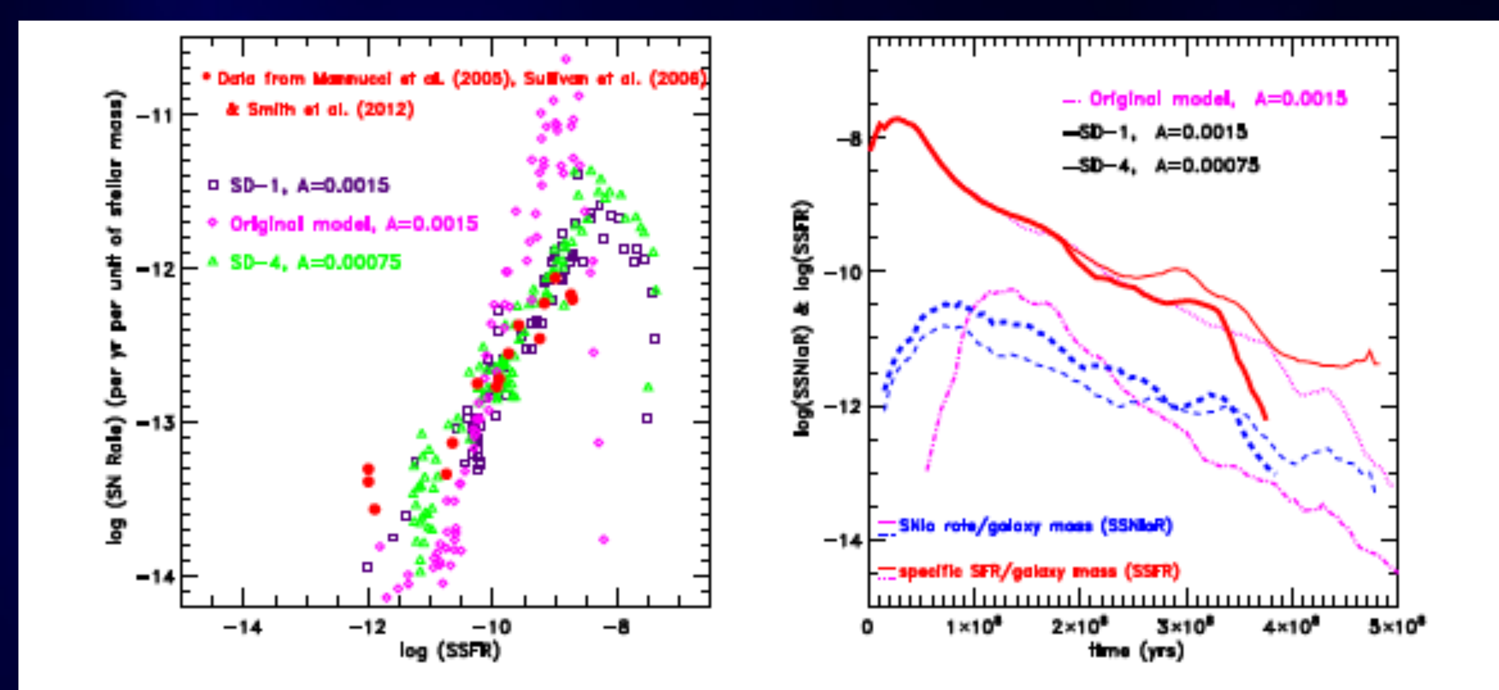
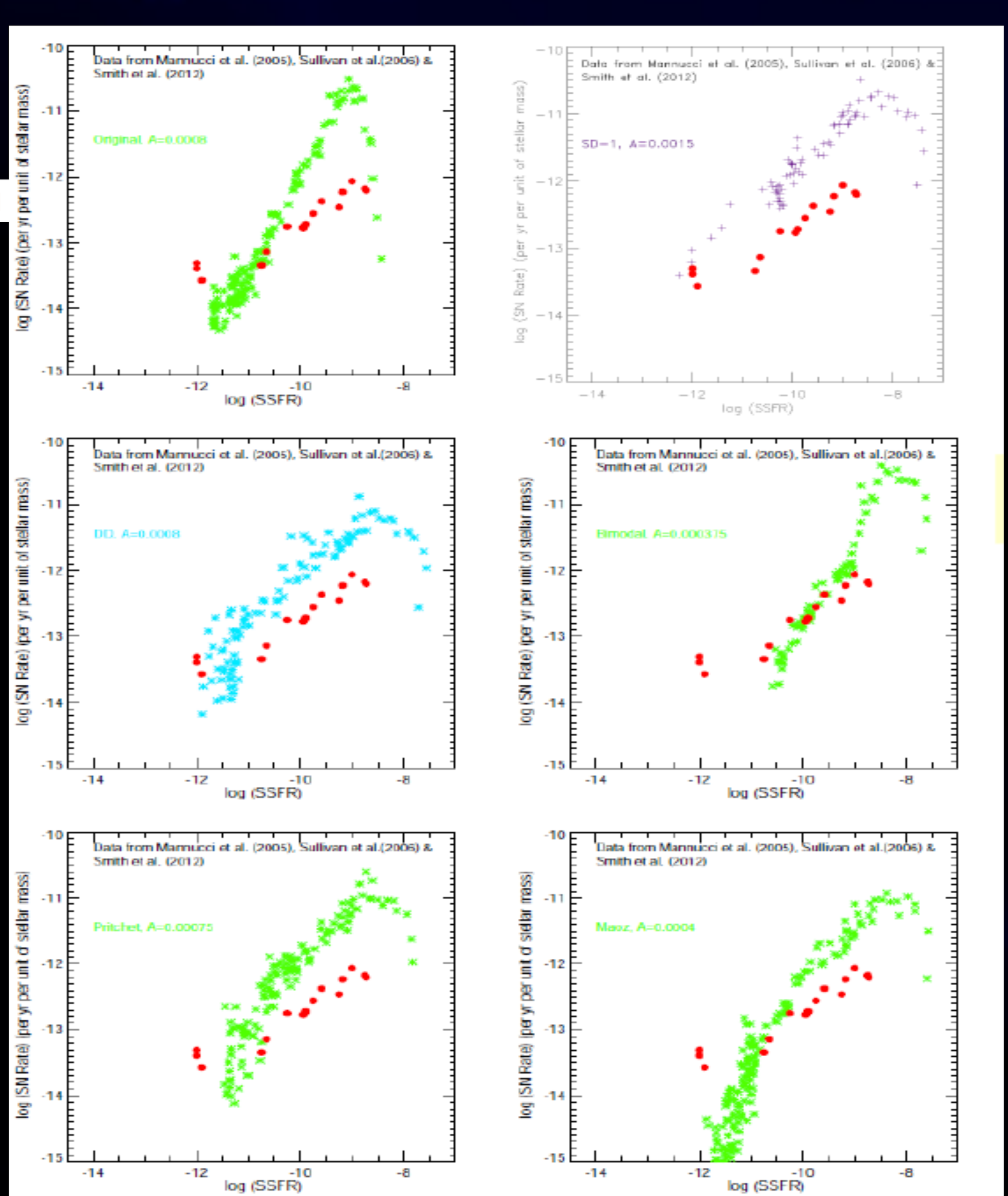
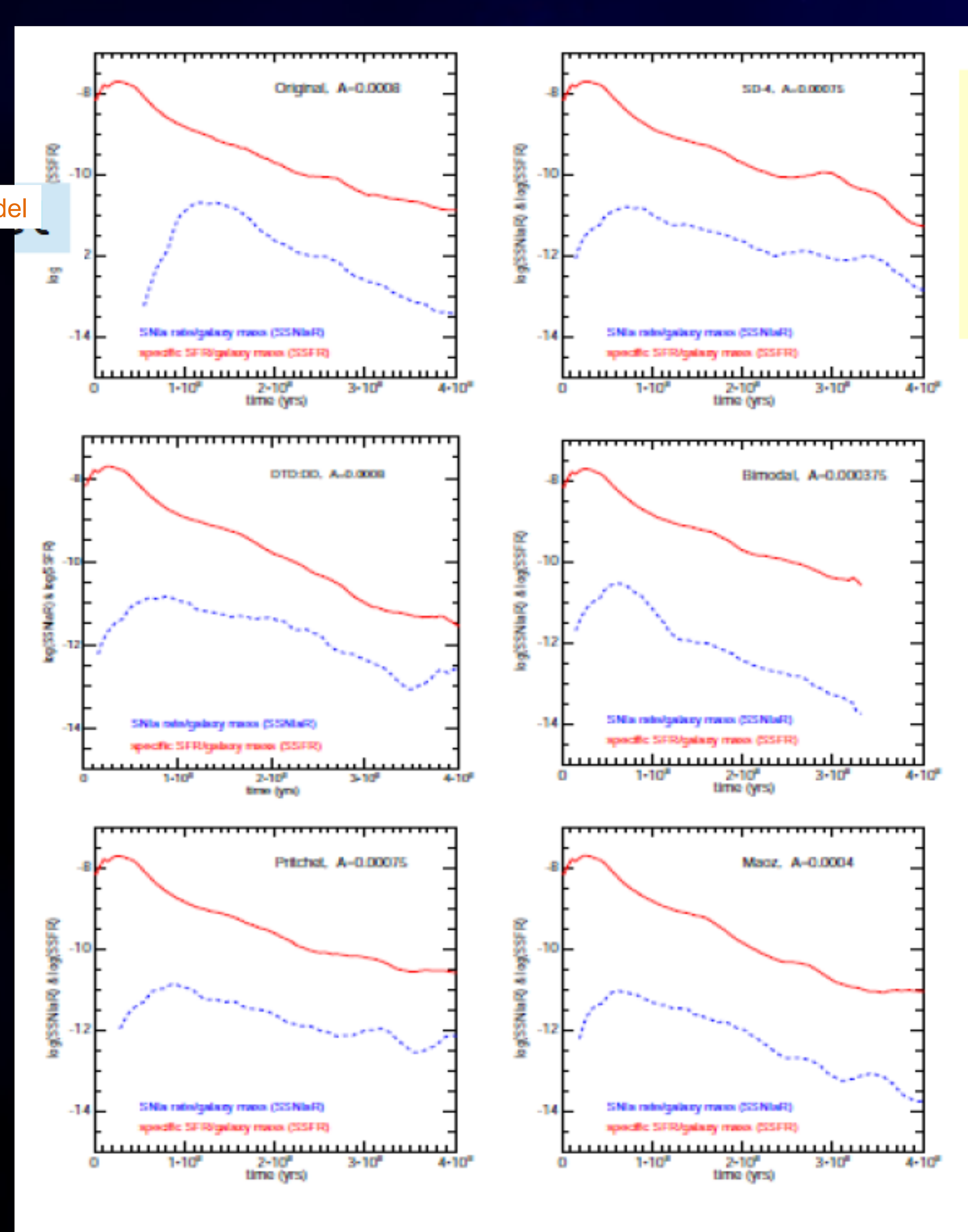


Figure 5 Specific star formation rate (sSFR) as a function of the specific SNIa rate (sSNIaR) for SD models (with different A parameters) and the original model (left panel). sSFR and sSNIaR as a function of time.

sSNIaR vs sSFR: the SNIa and their host galaxies





In Fig. 6 and Fig. 7 we show the relation between sSNIaR and sSFR of the host galaxies of the SNIa events for the different DTD scenarios tested in our work (Jimenez et al. In preparation).

In all cases both parameters determine a correlation but some of them do not follow the observed slopes. In Fig. 7 we plot both parameters as a function of time. We also note that for low sSFR the correlations is not longer present.

In this simple model for galaxy formation we are not reproducing a realistic variation of the formation histories and morphologies of galaxies. In order to do thi, we will run full cosmological simulation in the near future.

Conclusions

- We run isolated pre-preparated SPH galaxies to study the impact of SNIa feedback using different progenitor scenarios.
- Within the SD scenario, the free parameter A (number of SNIa), correlates linearly with:
  - -SFR
  - -[α/Fe] ratios
- The best model reproduces:
  - -[α/Fe] of the Galactic Bulge
  - -SNIa rates for elliptical and S0 galaxies
  - -the correlation SSFR- SNIa rates per unit mass
- The study of this correlation evolving in time could help to constraint the progenitors of SNIa (Jimenez et al. in prep.) We need data from SNIa rates and SSFR at high redshift!