Why galaxies care about SNIa progenitor scenarios?

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The importance of a correct treatment of the SNIa feedback

- main course of heavy elements (up to 0.7 M$_\odot$ of Fe)
- affects cooling rates and metal abundances
- reduces SF
- galactic fountains
- feeds IGM

Scientific motivation:
**The Single Degenerate Scenario (SD)**

Matteucci & Recchi (2001)

- a binary system
- Red giant + WD
- Chandrasekhar mass

The minimum time for the first system to explode is $3 \times 10^7$ yr
SN Ia Progenitor Scenarios:

**Theoretical Delay Time Distributions (DTD):**
- SD, Matteucci & Recchi (2001)
- Double Degenerate, Greggio (2005) [wide mode]

**Empirical DTDs**

**Power law DTDs**
- Pritchett et al. (2008) [l=-0.5 SNLS]
- Maoz et al. (2012) [l=-1.12, SDSSII]
  
  All equivalent to DD and to Totani et al. (2008) (l=-1 SXDS)

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How do the Delay Time Distributions (DTDs) look like?

\[ \log \left( \frac{\text{DTD}}{\text{DTD}_{\text{max}}} \right) \]

- SD
- DD
- Bimodal
- Pritchet's PL
- Maoz's PL

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Analytical model for the SD scenario
Matteucci & Recchi (2001)

Delay Time Distribution (DTD): is the rate of SN Ia produced by an instantaneous starburst

$$R_{\text{Ia}}(t) = A \int_{M_{\text{B,inf}}}^{M_{\text{B,sup}}} \phi(M_B) \int_{\mu_{\text{min}}}^{\mu_{\text{max}}} f(\mu) \psi(t-\tau_{M_2}) d\mu dM_B,$$

**free parameter**

**A**: the fraction of binary systems in the IMF with the right characteristics to become a SN Ia

**Salpeter IMF**

$$\phi(M_B) = C M_B^{-(1+\alpha)}.$$

the mass fraction of the primary and secondary star $M_2$ and its distribution function

SFR

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**Numerical Simulations**

- **Original Model**: Scannapieco et al. (2005, 2006)
- Tree PM/SPH-GADGET-2
- **SNIa events randomly distributed within** \([0.1, 1]\) Gyr.
- **NO DTD**
- **Rates according to observations of SNIa/SNCC**
New Implementations:

- TreePM/SPH–GADGET- 3
- SFR at high redshifts is in better agreement with observations

Theoretical DTDs:
- SD Matteucci & Recchi (2001)
- Double Degenerate Greggio (2005)

Empirical DTDs.

Power Law
- Pritchet et al. (2008)
- Maoz et al. (2012)
Fix the DTD to SD
and varying the A
• run 5 simulations of isolated galaxies with \( \sim 5 \times 10^{10} \) Mo with the same IC

• The free parameter A is chosen to reproduce the observed rates of S0 and bulge-type gxs. This rate is \( \sim 0.0026 \) SN per year (Li et al. 2011)

<table>
<thead>
<tr>
<th>Model</th>
<th>A</th>
<th>(&lt;\text{SFR}&gt;)</th>
<th>SNIa rates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>([\text{M}_\odot\text{yr}^{-1}])</td>
<td>([\text{N/yr}^{-1}])</td>
<td></td>
</tr>
<tr>
<td>SD-1</td>
<td>0.0015</td>
<td>83</td>
<td>0.002</td>
</tr>
<tr>
<td>SD-2</td>
<td>0.00015</td>
<td>60</td>
<td>0.0005</td>
</tr>
<tr>
<td>SD-3</td>
<td>0.0075</td>
<td>84</td>
<td>0.0080</td>
</tr>
<tr>
<td>SD-4</td>
<td>0.00075</td>
<td>76</td>
<td>0.0016</td>
</tr>
<tr>
<td>Original</td>
<td>0.008</td>
<td>44</td>
<td>0.0010</td>
</tr>
</tbody>
</table>

Fix the DTD to SD and varying the A
Star Formation Rate

SF history changes linearly with $A$

More SNIa leave less cold gas available for the star formation
Alpha abundances of the Galactic Bulge stars

First test for the model: is able to reproduce the observed knee in the \([\alpha/Fe]\) diagram?

The \([\alpha/Fe]\) ratios change linearly with A

Data from the Galactic Bulge by Gonzalez et al. (2011)
SuperNova Legacy Survey

The SFR is corrected for the last 0.5 Gyrs

This correlations does not seem to evolve within the range $0.05 < z < 0.25$
SuperNova Legacy Survey

The SFR is corrected for the last 0.5 Gyrs

This correlations does not seem to evolve within the range 0.05 < z < 0.25
Comparison with data from Smith et al. (2012) and Sullivan et al. (2006) and Mannucci et al. (2005)

The best model SD with $A=0.0015$ can reproduce the slope shown by the data!

Zero point shows variability when:

- is corrected by 0.5 Gyrs in the sSFR to mimic the data
- change the IMF
How can we explain this correlation?
SSFR = SFR / (galaxy mass)

SN Ia Rate / (galaxy mass)

evolving in time

SD with $A = 0.0015$

SD with $A = 0.0015$

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Comparison with data from Smith et al. (2012), Sullivan et al. (2006) & Mannucci et al. (2005)

Double Degenerate

Bimodal

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Can we reproduce the correlation with all the models? check the slopes

Original model

DD

Bimodal

Pritchet

Maoz

(Jimenez et al., in prep)
Can we rule out some of the models? (Jimenez et al., in prep)

Original model

DD

SD

Bimodal

Pritchet

Maoz
CONCLUSIONS

• We run isolated pre-prepared 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
  - $[\alpha/Fe]$ ratios

• The best model reproduces:
  - $[\alpha/Fe]$ 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!

For more info check arXiv:1402.4137, (submitted to MNRAS)
Third Workshop on Numerical and Observational Astrophysics: Linking the Local to the Early Universe

17-21 November 2014
Buenos Aires, Argentina

Invited speakers:
Michelle Cappelleri, University of Oxford, UK
Lisa Kewley, The Australian National University
Timo Anguita, Universidad Andrés Bello, Chile
Marteen Baes, Sterrenkundig Observatorium UGent, Belgium
Frank Bigiel, Heidelberg, Germany
Paula Coelho, Universidad de San Pablo
Nelson Padilla, Universidad Católica de Chile
Carlton Baugh, Durham University, UK
Felix Mirabel, IAFE, Argentina
Avila-Reese, UNAM, Mexico
David Algorry, Universidad Nacional de Cordoba
All the simulations include:

- Chemical enrichment and feedback from SNII (dependent with metallicity) and SNIa.
- SNIa yields are from the W7 model of Iwamoto et al. (1999)
- Multi-phase model for the gas component
- Metal-dependent cooling functions from Sutherland & Dopita (1993)
- The virial mass of the systems is $M_{200} = 10 \times 10^{11}$ Msun, 10% in form of baryons. The SFR efficiency is $c=0.1$
- Initially a high baryonic fraction (70%) distributed in the disc
- the formation of clumps which migrate to the inner regions, contributing to the formation of the bulge.