The role of Type Ia supernova feedback on the second generation formation in globular clusters

E. Lacchin [1,2], F. Calura [1] and E. Vesperini [3]

[1] INAF – OAS, Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, via Gobetti 93/3, I-40129 Bologna, Italy

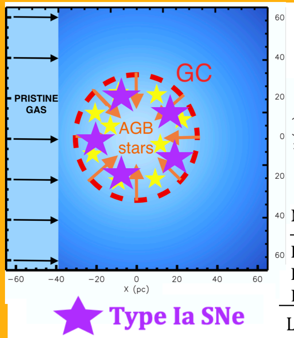
[2] Department of Physics and Astronomy, University of Bologna, via Gobetti 93/3, I-40129 Bologna, Italy

[3] Department of Astronomy, Indiana University, Swain West, 727 E. 3rd Street, Bloomington, IN 47405, USA

Abstract

Very little is known about the physical processes which determined the end of star formation in globular clusters (GC). By means of 3D hydrodynamic simulations, we study for the first time how the formation and the chemical properties of second generation (SG) stars in a massive proto-GC are affected by SNe Ia explosions belonging to the first stellar generation, one likely cause for the quenching of star formation in these systems. In our model, the formation of SG stars starts ~ 40 Myr after the cluster birth and is due to the retention of the fresh ejecta of first generation asymptotic giant branch stars plus accretion of cold, pristine gas. At the same time, SNe Ia start exploding, carving hot and tenuous bubbles in the interstellar medium. I have focused on SNe Ia effects on the iron and helium abundances and studied the role of various parameters in regulating the efficiency of SN Ia feedback. According to our results, SN explosions are able to halt star formation only if the pristine gas is tenuous (with density ~ 1cm^{-3}), whereas they have little effects if the pristine gas density is ~ 10 cm^{-3}. Finally, we show that gas from SNe Ia may produce an iron spread as found in Type II GCs, an anomalous sub-category of GCs.

INITIAL SETUP

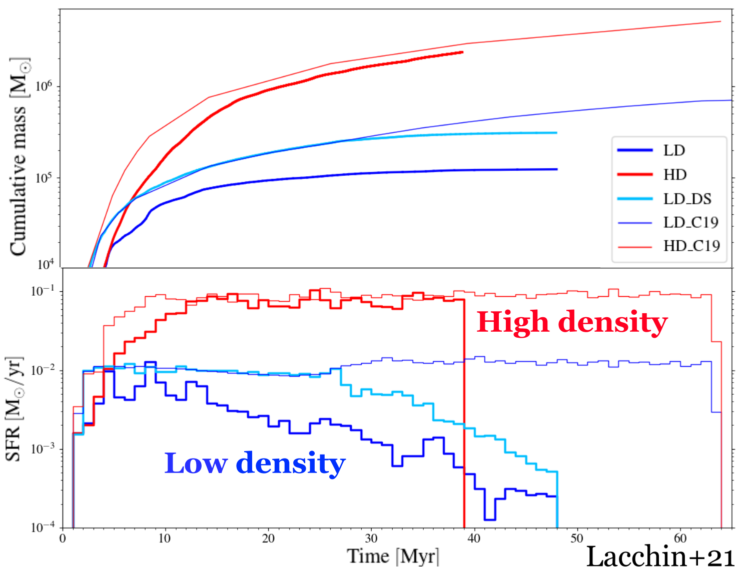


- AGB scenario
- $M_{FG} = 10^7 M_\odot$ and $a = 23$pc (Plummer profile)
- 10^3 SNe Ia (Greggio+05). Each SN injects:
  - $0.5 M_\odot$ of Fe
  - 10^{51}erg thermal energy

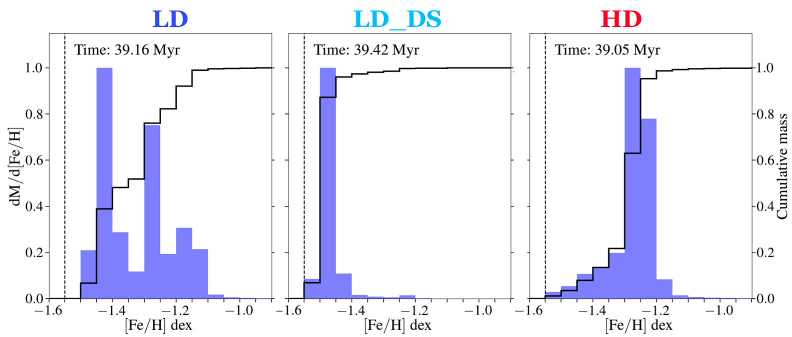
Model	Description	ρ_{pg} [g cm^{-3}]	t_{inf} [Myr]	t_{Ia} [Myr]
LD	Low density	10^{-24}	21	0
LD_DS	Low density with Type Ia SNe delayed	10^{-24}	21	25
HD	High density	10^{-23}	1	0
LD_C19	Low density without SNe Ia (Calura+19)	10^{-24}	21	-
HD_C19	High density without SNe Ia (Calura+19)	10^{-23}	1	-

EFFECTS ON THE SFR

In **low density models**, SN explosions lead to a significant **decrease of the SFR**. In the **high density model** SNe Ia have only **a minor effect on the SFR evolution**.

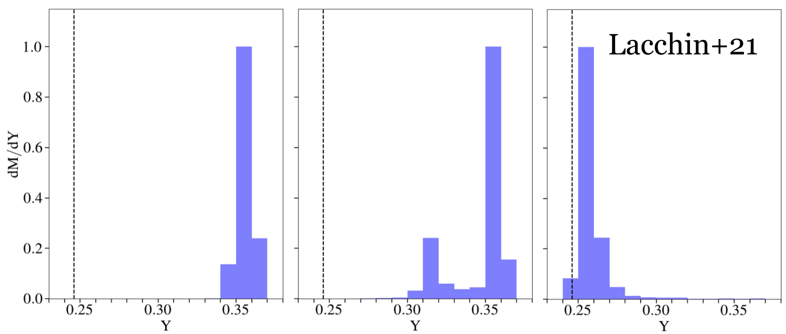


IRON & HELIUM DISTRIBUTIONS



$\sigma_{[Fe/H]} = 0.14$ dex — $\sigma_{[Fe/H]} = 0.07$ dex — $\sigma_{[Fe/H]} = 0.14$ dex

~ 20% of GCs show $\sigma_{[Fe/H]} > 0.05$dex (Type II GCs, Milone+17)



$\bar{Y}_{SG} = 0.355$ — $\bar{Y}_{SG} = 0.336$ — $\bar{Y}_{SG} = 0.258$

$\Delta Y_{FG-SG} = 0.11$ — $\Delta Y_{FG-SG} = 0.09$ — $\Delta Y_{FG-SG} = 0.012$

Observed $\overline{\Delta Y}_{FG-SG,obs} \sim 0.01$ (Milone+18)

CONCLUSIONS

1. *Low density* (10^{-24} g cm^{-3}) infall:
   - significant decrease of the star formation
   - the final stellar mass is reduced by Type Ia SNe by a factor of 5.4
   - **unobserved helium spread** between the two generations. Longer SN delay are needed to increase the contribution of pristine gas and therefore the extent of dilution.
2. *High density* (10^{-23} g cm^{-3}) infall:
   - negligible effect of Type Ia SNe on the star formation rate and on the helium enrichment
   - **large iron 1G-2G spread** observed in ~ 20% of Galactic GCs (Type II).

Given the observed correlation between iron enrichment and cluster mass, in the future we plan to explore the effects of Type Ia SNe in less massive clusters.

References:

Calura F. et al., 2019, MNRAS, 489, 3269

Greggio L., 2005, A&A, 441, 1055

Lacchin E. et al., 2021, MNRAS, 506, 5951

Milone A. P. et al., 2017, MNRAS, 464, 3636

Milone A. P. et al., 2018, MNRAS, 481, 5098

Feel free to contact me @ elena.lacchin@inaf.it