Chemical Evolution in the Earliest Galaxies in a Cosmological Context

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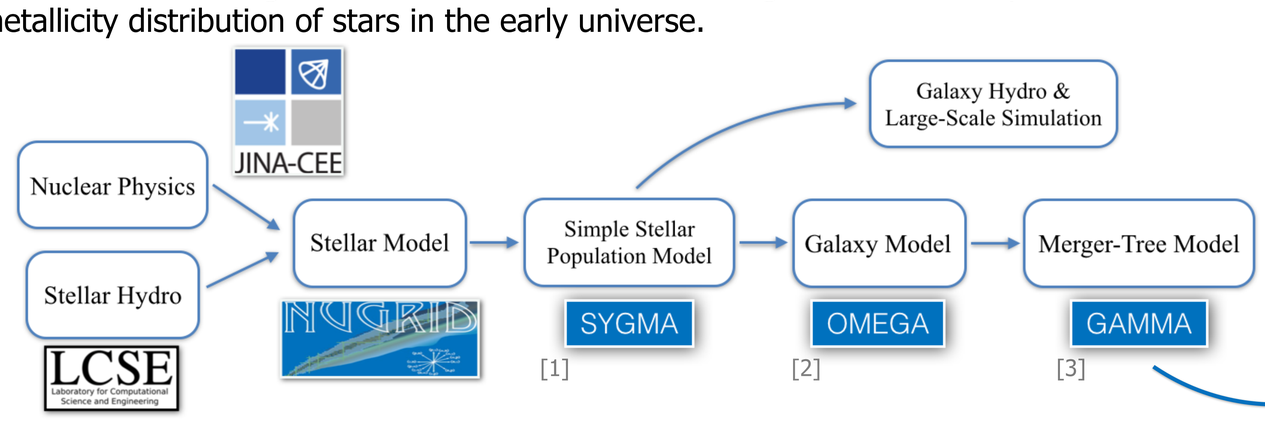
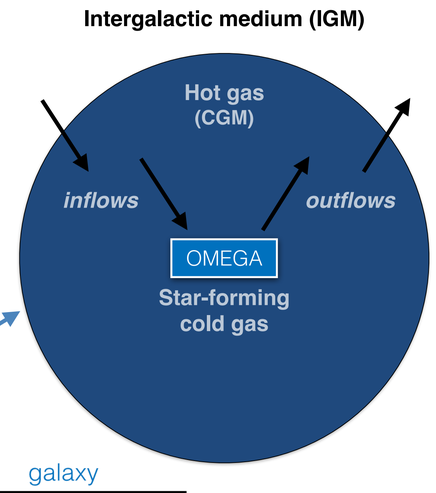
Overview

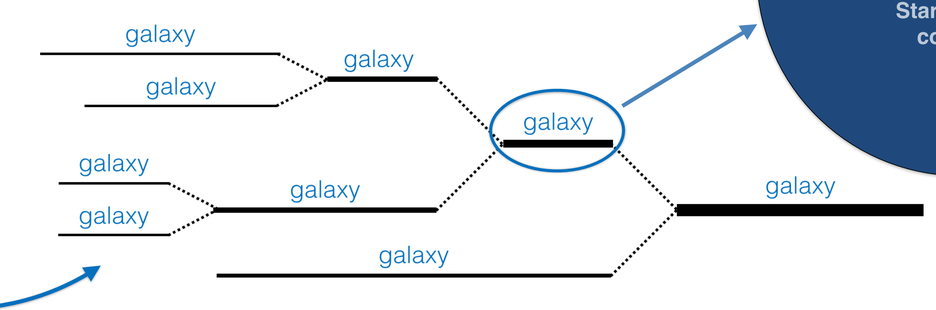
Our goal is to study the chemical evolution of high-redshift (z) galaxies in order to better understand the connection between galaxy formation and chemical abundances observed in metal-poor stars. Here we compare a semi-analytical model (SAM) with a hydrodynamic simulation to investigate the role of non-uniform mixing and stochastic processes on the metallicity distribution of stars in the early universe.



GAMMA

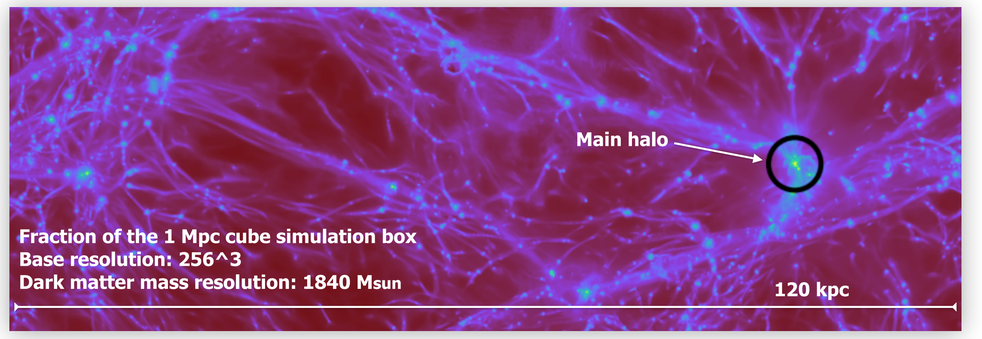
GAMMA is part of our JINA-NuGrid chemical evolution pipeline [4] and consists of a SAM that uses the merger trees extracted from cosmological simulations to account for the mass assembly history of galaxies during the chemical evolution calculation (can track 280 stable isotopes).

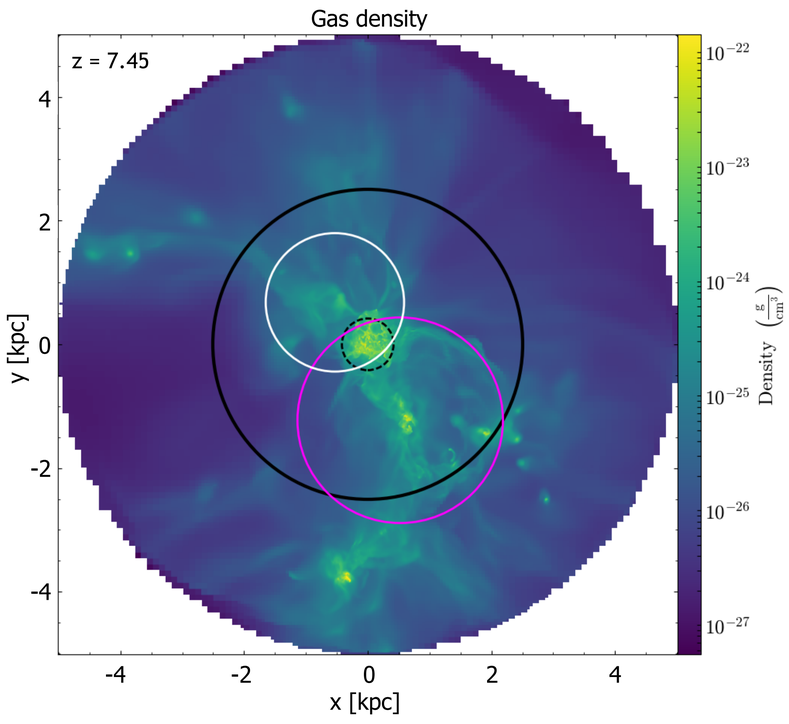




Hydrodynamic Simulation vs Semi-Analytical Model

We analyzed the most massive galaxy of the cosmological simulation of **Wise et al. (2012)**, calculated with the AMR code Enzo [5] for z = [130, 7], and extracted its merger tree to calculate a simplified version of its chemical evolution using GAMMA. The goal is to learn what new physical ingredients need to be included in GAMMA to better capture the early evolution of galaxies and the formation of metal-poor stars.

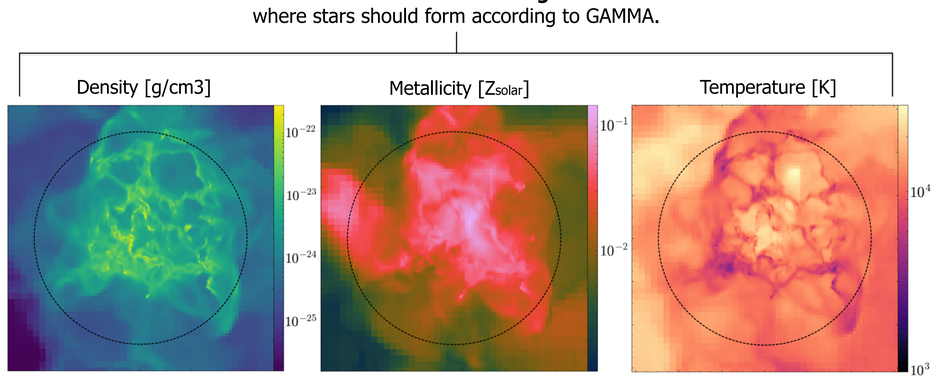




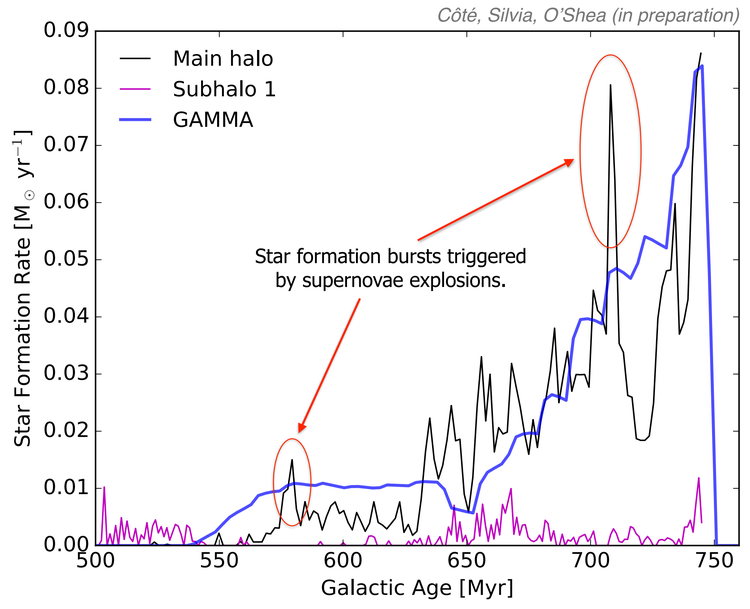
Black solid circle — Virial radius of the main halo (Mtot = 4.37e8 Msun).
Black dashed circle — Inner region of the main halo (1/6 x Rvir).
Pink circle — Subhalo 1 (Mtot = 1.27e8 Msun) that has not merged yet.
White circle — Subhalo 2 (Mtot=0.39e8 Msun) that has not merged yet.

Subhalos are not part of the merger tree, as the simulation stopped before they merge.

Zoom of the inner region
where stars should form according to GAMMA.

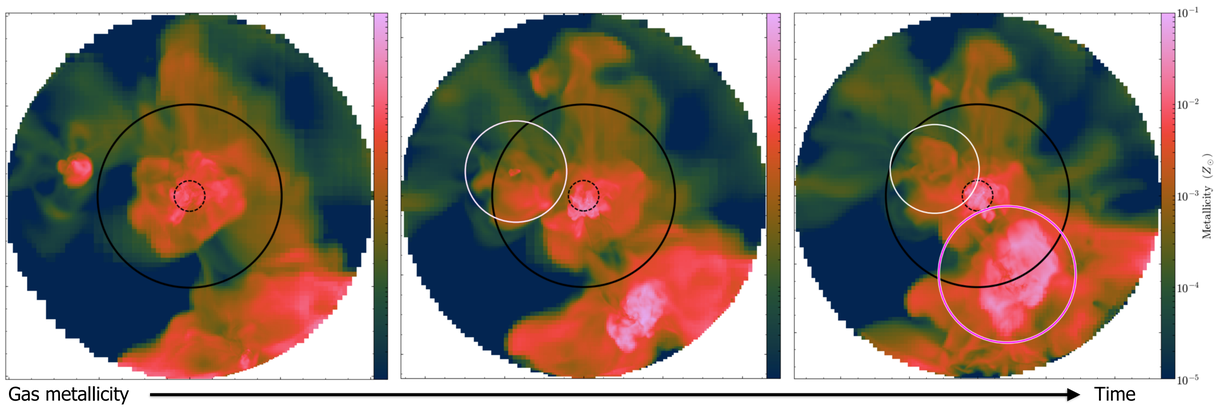


Côté, Silvia, O'Shea (in preparation)

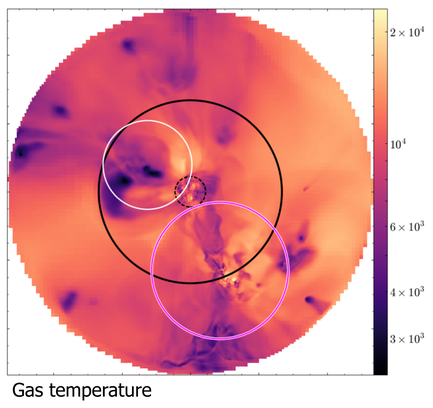


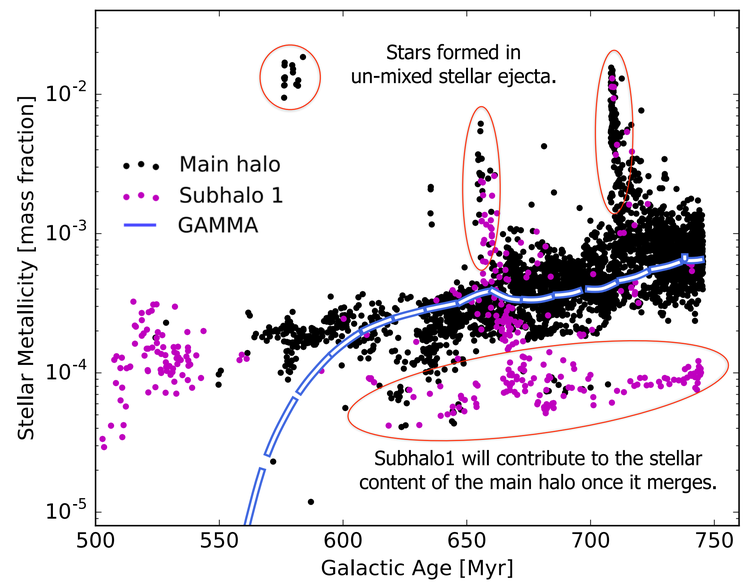
Evolution of Metallicity and Galactic Outflows

Subhalo stars explode in the circumgalactic medium (CGM) of the host galaxy during the merger process. The inward motion of subhalos and infalling gas overcomes the expansion motion of bubbles blown by stars, leading to a high metal retention.



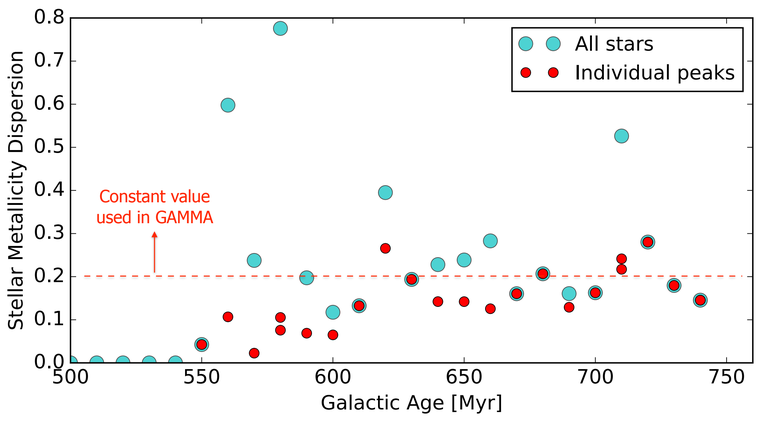
As opposed to GAMMA, the CGM is not a stable, well mixed, isothermal sphere.





Non-Uniform Mixing

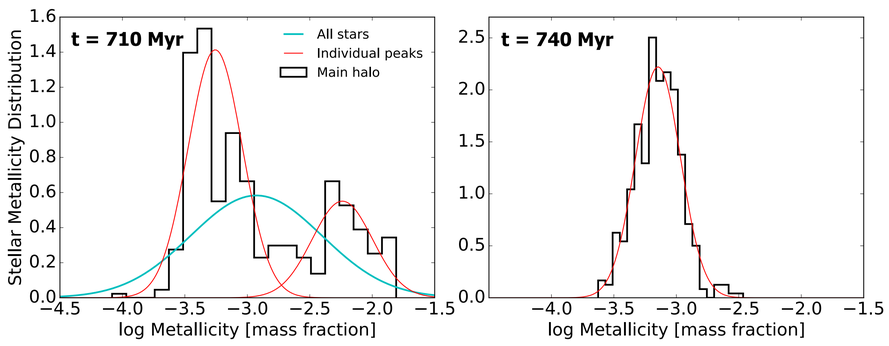
Currently, GAMMA can recover the global star formation and chemical evolution trends, but cannot capture the stochasticity of the hydrodynamic simulation.



GAMMA better matches the simulation when its metallicity distribution is convolved with Gaussian functions to mimic non-uniform mixing.

We fitted the metallicity dispersion of all stars formed in the hydrodynamic simulation with normal distributions (cyan).

The largest dispersions are composed of two main peaks (red) representing two stellar populations formed in different environments.



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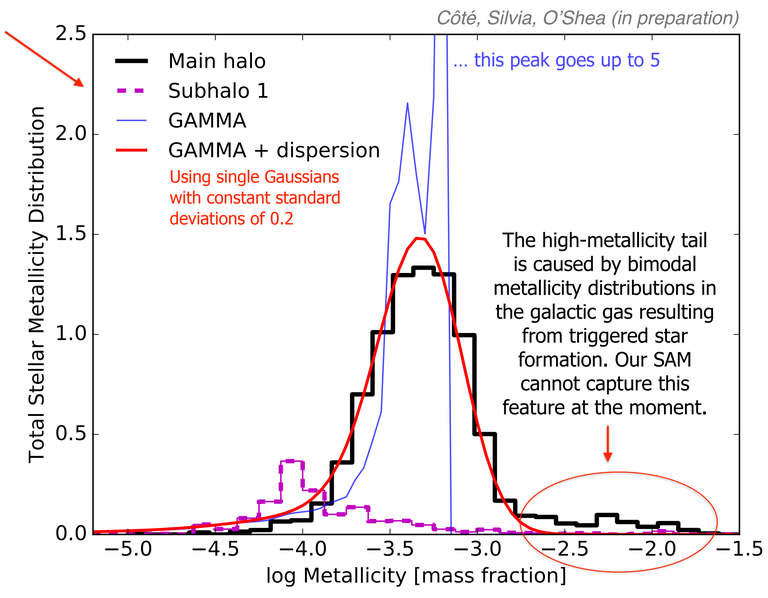

[1] **SYGMA** (**S**tellar **Y**ields for **G**alactic **M**odeling **A**pplications) Ritter et al. in prep.
[2] **OMEGA** (**O**ne-zone **M**odel for the **E**volution of **GA**laxies) Côté, O'Shea, Ritter, et al. 2017, ApJ, 835, 128
[3] **GAMMA** (**G**alaxy **A**ssembly with **M**erger-trees for **M**odeling **A**bundances) Côté et al. in prep.
NuPyCEE (**N**uGrid **P**ython **C**hemical **E**volution **E**nvironment, github.com/NuGrid/NUPYCEE)

[4] Côté, Ritter, Herwig, et al. 2017, NIC, 0203C
[5] Bryan, Norman, O'Shea, et al. 2014, ApJS, 211, 19
Wise, Turk, Norman, Abel, 2012, ApJ, 745, 50

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This material is based upon work supported by the National Science Foundation under Grant No. PHY-1430152.
(JINA Center for the Evolution of the Elements).