THE FORMATION OF THE FIRST SECOND GENERATION STAR

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GOAL

• Simulate the true conditions of the formation of the first metal-enriched stars.

Image: Nick Earl
THE SIMULATION

• Enzo: open-source, cosmological AMR + N-body.

• 500 kpc/h box, $z_i = 180$.

• $512^3$ root grid, 2 nested levels, 13 additional AMR.

• $\sim 0.19 \, M_\odot$ gas, $0.92 \, M_\odot$ dm mass resolution.

• Primordial chemistry with H, D, He species; metal cooling from Cloudy tables; dust cooling and $H_2$ formation on dust.

Image: Nick Earl
FORMING POP III STARS

• Insert a 40 M☉ Pop III at density $n = 10^7$ cm$^{-3}$.


• Supernova blastwave inserted at $r = 10$ pc from star ($E_{SN} = 3 \times 10^{52}$ erg, $M_{\text{metals}} = 8.6$ M☉).
CURRENT STATUS

• No metal-enriched star yet at $z = 16.1$.

• 3 Pop III halos:
  • $z = 20.04, M = 1.56 \times 10^5 \, M_\odot$
  • $z = 17.57, M = 2.89 \times 10^5 \, M_\odot$
  • $z = 16.37, M = 2.53 \times 10^5 \, M_\odot$ (3 stars: 66, 118 kyr after first)

• Metal fronts washing over 2 additional halos.
Our First Supernova
Halo 1
$M_{\text{vir}} = 4.50 \times 10^5 \, M_{\odot}$

Halo 2
$M_{\text{vir}} = 4.99 \times 10^5 \, M_{\odot}$
Halo 1: $r_{\text{vir}} = 92$ pc
Halo 2: $r_{\text{vir}} = 95$ pc
When are the metals coming?

Halo 1

Halo 2
EARLY STATEMENTS

• Pop III halos totally disrupted by SN blastwave.

• Pop III SN enrich nearby IGM to $Z \sim 10^{-4}$ to $10^{-3} \, Z_\odot$.

• First Pop II star will form in an externally enriched halo.

• Results depend on characteristics of Pop III stars and their halos.

Image: Nick Earl
HANG IN THERE
THANKS

The Enzo Community
enzo-project.org

The yt Community
yt-project.org

Matthew Turk
While the exact masses of the first stars are still unknown, it remains relatively well accepted that the Pop III initial mass function is not identical to that of stars forming today. This transition in star forming modes is due to the introduction of metals produced in the first supernovae. These metals enhance the radiative cooling efficiency of gas through fine-structure lines, molecular transitions, and thermal emission from dust grains. Simulations have made great contributions to our understanding of the ability of metals to induce fragmentation in collapsing gas, but little attention has been paid the actual conditions present when the Universe becomes enriched with metals for the first time. We present the results from a simulation of the formation of the first metal-enriched stars under realistic conditions. We simulate a Pop III star forming halo and assume the formation of a 40 Msun metal-free star. Using 3D radiation hydrodynamics, we then compute the evolution of the HII region and the blast-wave of the subsequent core-collapse supernova. We then follow the simulation until the first metal-enriched prestellar clouds collapse. We report on the true nature of the first Pop II stars, including their metallicities, masses, and orientation within the parent protogalaxy.