# RADIATION AND SUPERNOVA FEEDBACK FROM THE FIRST STARS

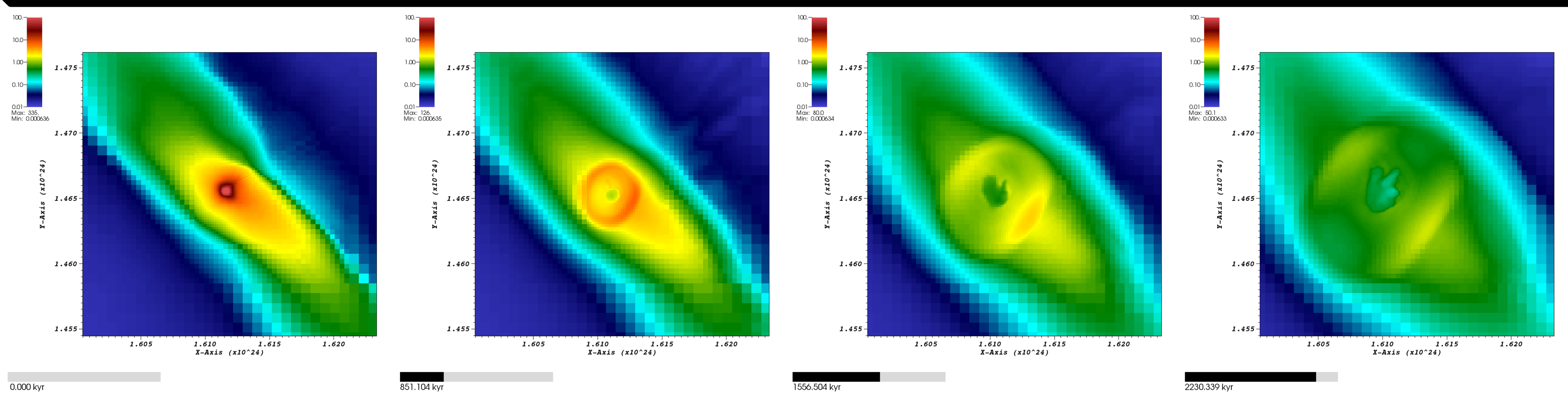
JEREMY S. RITTER, MILOS MILOSAVLJEVIC, AND VOLKER BROMM

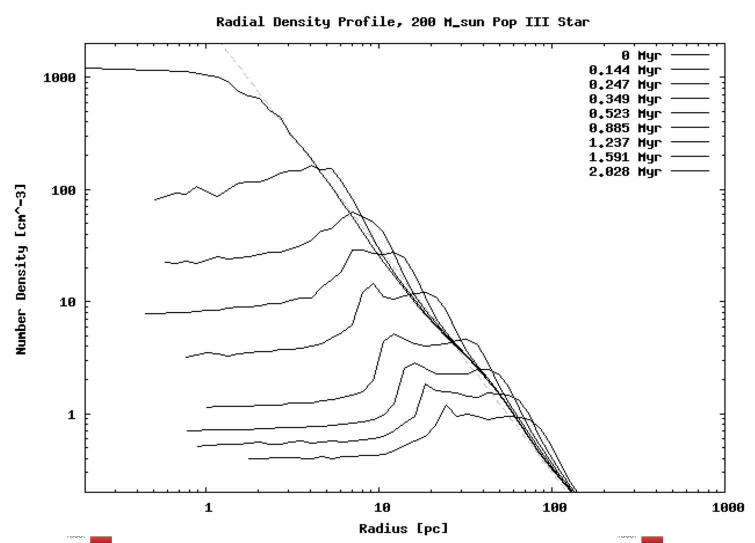
The University of Texas at Austin

## Population III Stars

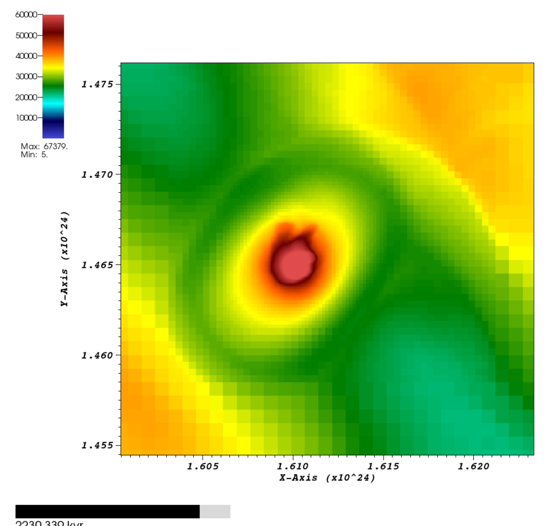
We have carried out 3D cosmological hydrodynamical simulations designed to investigate the evolution of a cosmic minihalo in the aftermath of the formation of the first, metal-free Population III star. In this study we assume that a moderate mass star explodes as a moderate-energy Type II-like supernova (SN), consistent with the recent downward revision of Population III stellar mass estimates. We analyzed the dynamics of SN ejecta and gas flow inside the minihalo. These can be compared to similar studies involving massive Population III stars exploding as highly energetic pair-instability supernovae (PISNe). Our main conclusions are detailed here and in: **Ritter, Safranek Shrader, Gnat, Milosavljevic, & Bromm (2012), ApJ, 761, 56**

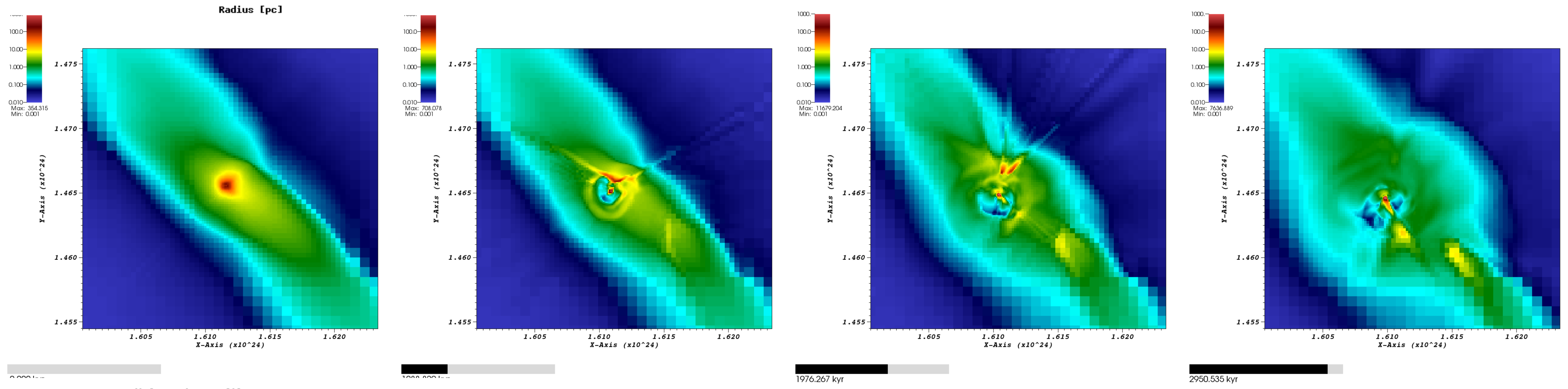
## HII Regions

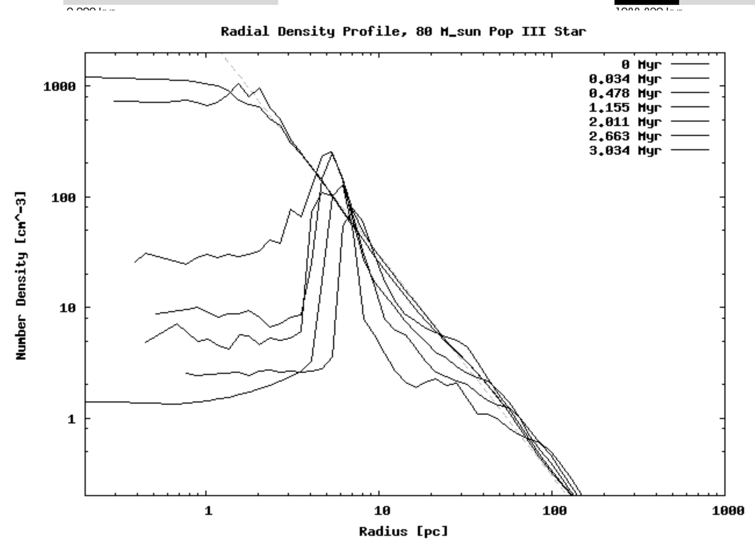





HII region simulation of a 200 $M_\odot$ star inside of a $10^6$ $M_\odot$ minihalo, as a time series of density slices (ABOVE), radial density profiles (LEFT) and pre-explosion temperature (RIGHT). An 80 $M_\odot$ star inside of the same minihalo (BELOW) was able to ionize only a portion of the gas inside the halo, leaving behind dense, neutral clumps.







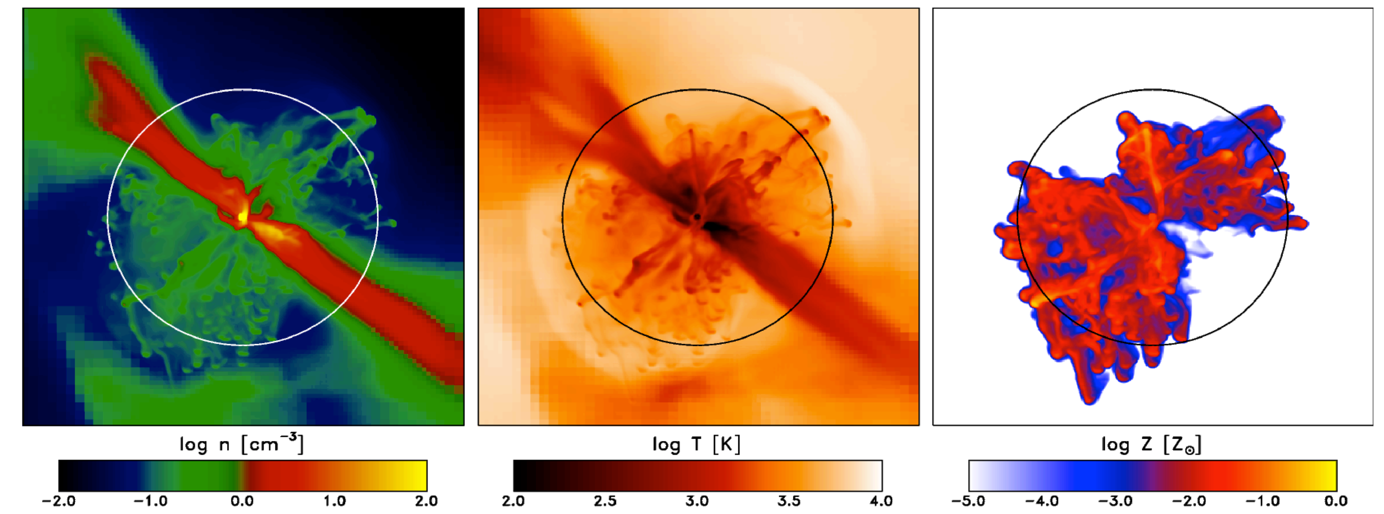

Simulations of a single 40 $M_\odot$ star (not pictured) only partially ionized the minihalo. The ionization front of a 25 $M_\odot$ star was completely unable to break out of the dense halo core.

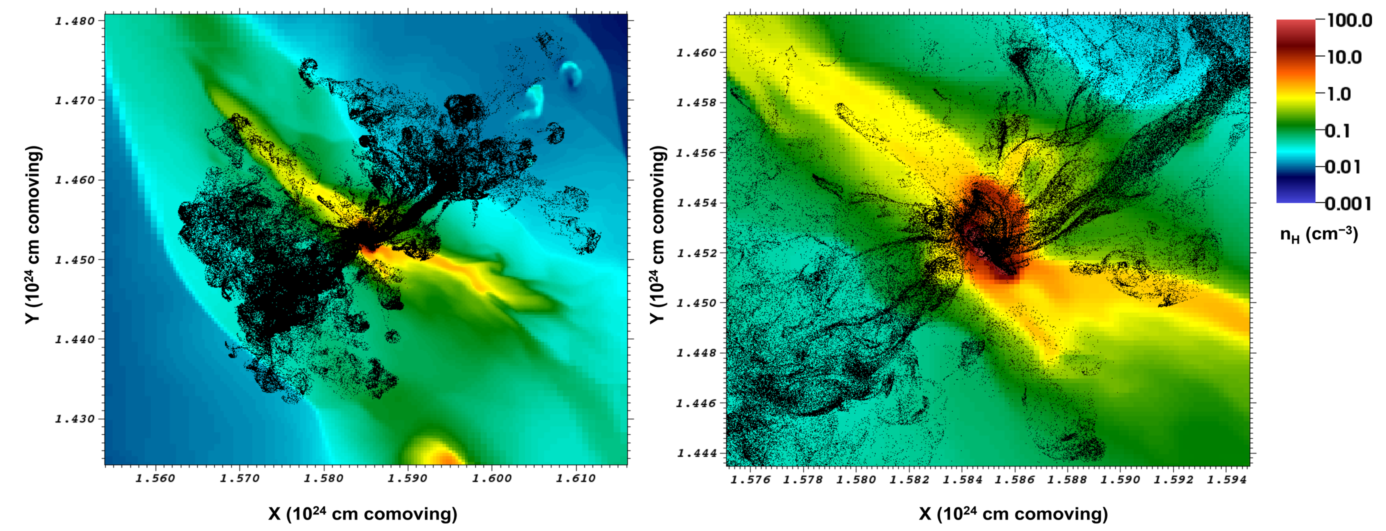
**A single moderate-mass star may only partially photoionize the host minihalo. The densest gas flowing from the filaments of the cosmic web into the star's parent cloud remains neutral and can drive renewed star formation on a short time scale.**

## Supernovae

RIGHT: Density, temperature, and metallicity projections 8.5 Myr after the explosion of a 40 $M_\odot$ star ($10^{51}$ ergs) inside of a $10^6$ $M_\odot$ minihalo at z = 19. Circle shows the virial radius of 180 pc.

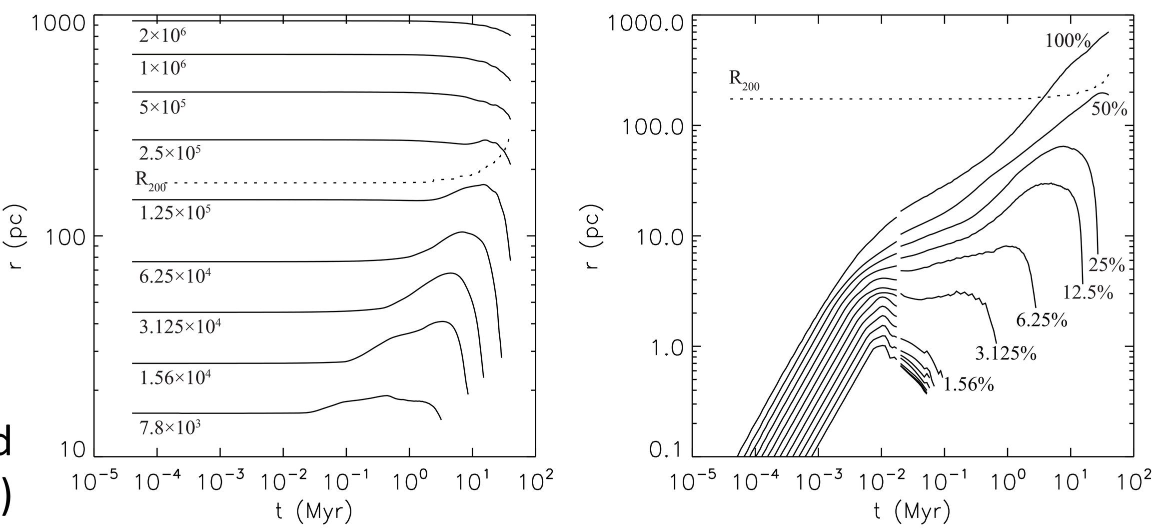
**The moderate-mass star and its supernova inflict significantly less damage on the host minihalo than a more massive star exploding as a PISN.**

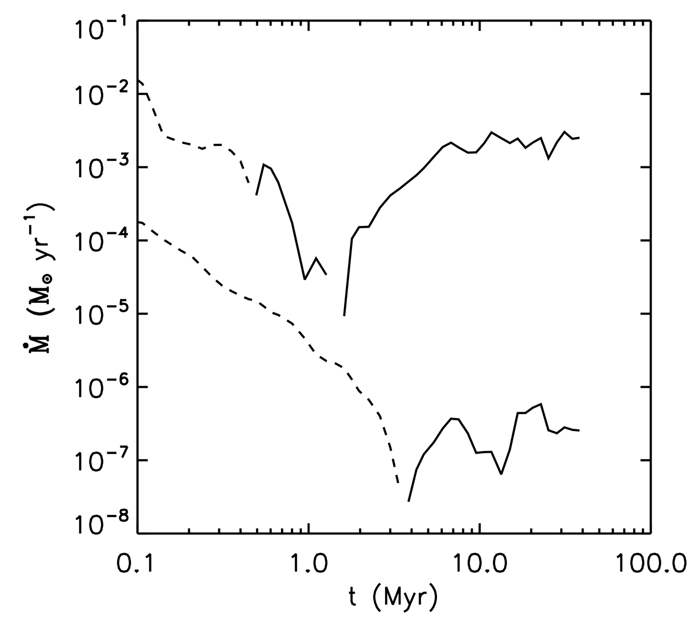


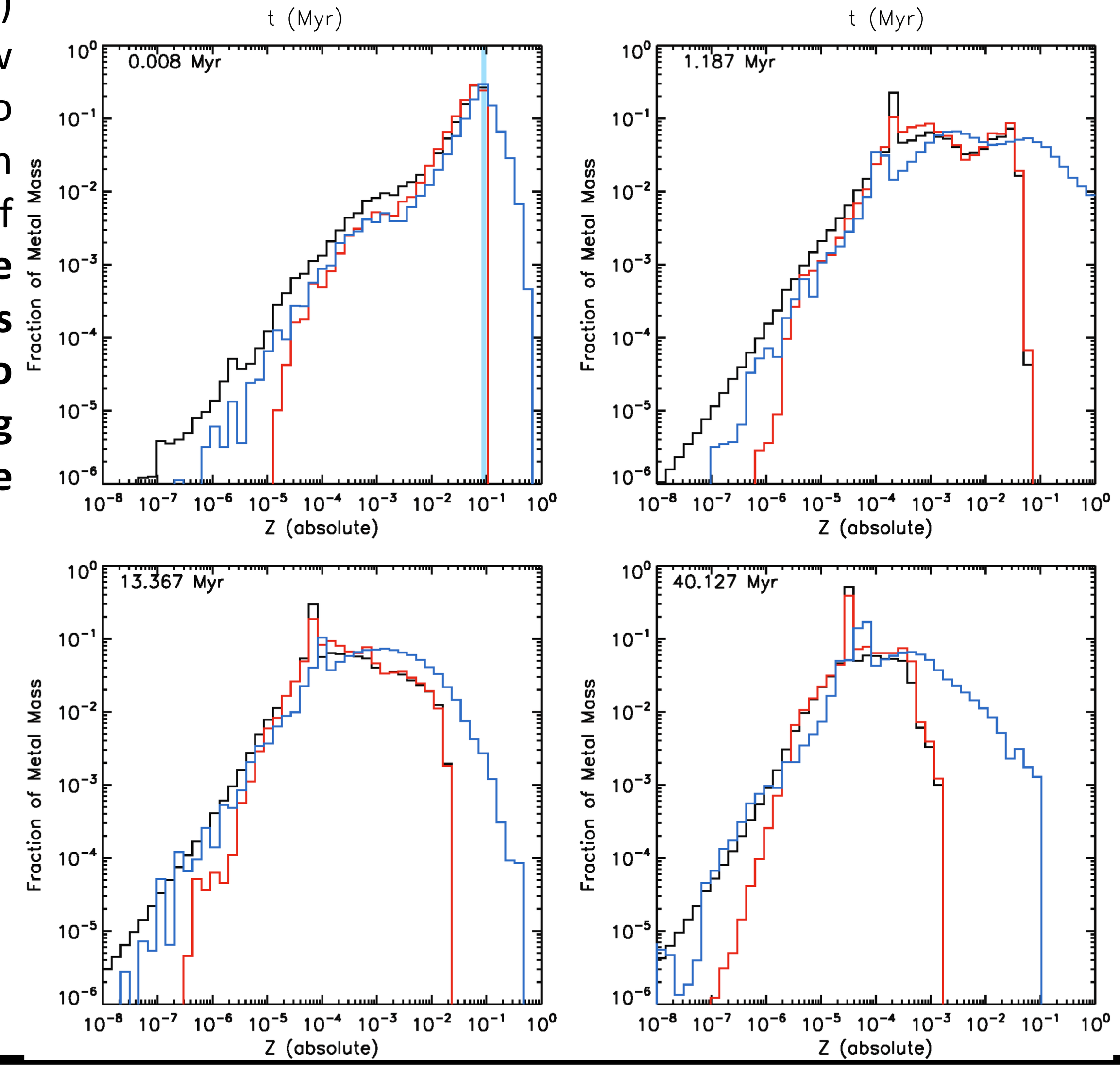

LEFT: Ejecta dispersal and fallback 40 Myr after the supernova (left 1.1 kpc wide; right 360 pc). Black dots show a projection of metal tracer particles and color is a slice of the hydrogen number density. **Instabilities in the blastwave lead to fragmentation in the ejecta, allowing for a portion of the ejecta to turn around and fall back into the halo center. The ejecta falling back are confined in thin sheets and filaments, having avoided complete mixing with the primordial gas.**

RIGHT: Radii enclosing total baryon masses (left panel; labeled in units of $M_\odot$) and supernova ejecta mass fractions (right panel). After 20 Myr, all spherically averaged baryonic mass coordinates are moving inward. **Less than half of the ejecta escape the virial radius; the escaping ejecta can be traced back to the outermost Rayleigh-Taylor fingers in the images above.**




LEFT: Metal (lower curve) and total baryon (upper curve) mass inflow (solid) and outflow (dashed) rates from the halo center. The fallback accretion rate reaches a steady state of 0.002 $M_\odot$ $yr^{-1}$ after 5 Myr. **The metallicity of accreting gas 0.001 – 0.01 $Z_\odot$ is sufficient to ensure that new stars forming in the central core will have lower characteristic masses.**




RIGHT: The total metal mass as a function of absolute metallicity calculated in three different ways: metallicity and mass from the fluid variables on the grid (black curve), metallicity from fluid variables and mass from tracer particles (red curve), and metallicity and mass from tracer particles (blue curve). The light blue column in the first histogram indicates the initial metallicity of the ejecta for scale. **The peak appearing at 0.001–0.01 $Z_\odot$ contains the supernova ejecta that have recollapsed in the unresolved dense cloud reassembling in the halo center.**

## Discussion

The possibility of prompt Pop III ejecta return brings into focus the prospect of metal-enriched star formation in minihalos and their immediate descendants. It shows that the early universe likely gave rise to a range of possible stellar population scenarios and that the onset of metal-enriched star formation is sensitive to the properties of the first, metal free stars, and to the hydrodynamics of metal transport in the first cosmic structures. Signatures of the processes revealed here should be detectable in local fossils of the first stellar systems, such as the ultra-faint dwarf galaxies and metal-poor globular clusters.

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