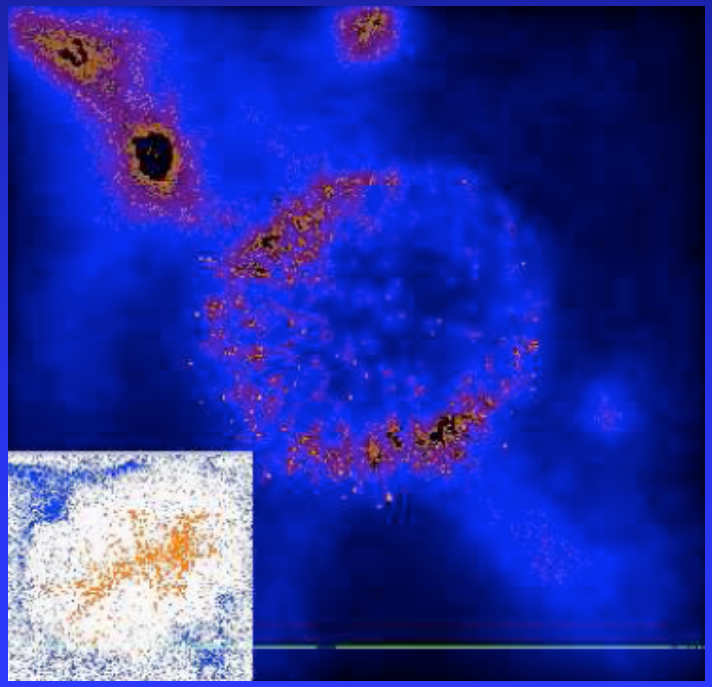
The Destruction of Cosmological Minihalos by Primordial Supernovae: Triggered Star Formation?

arXiv:0801.3698



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Brian O'Shea
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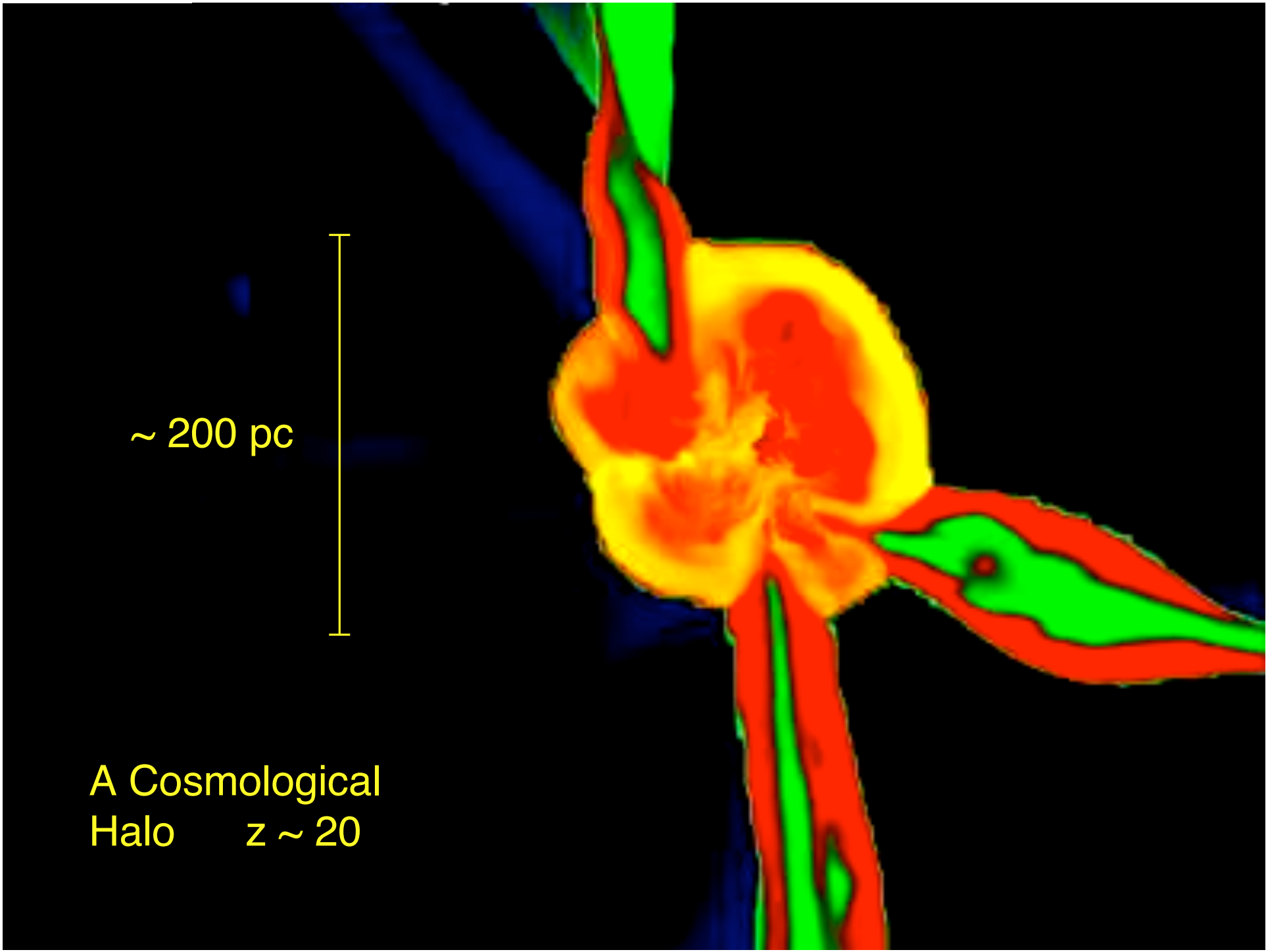
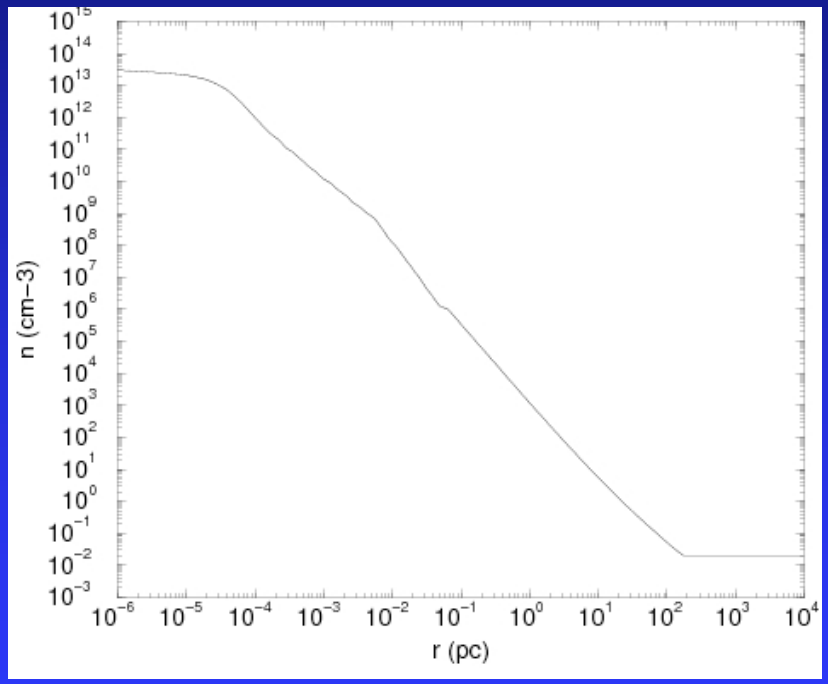
Los Alamos
NATIONAL LABORATORY
EST. 1943

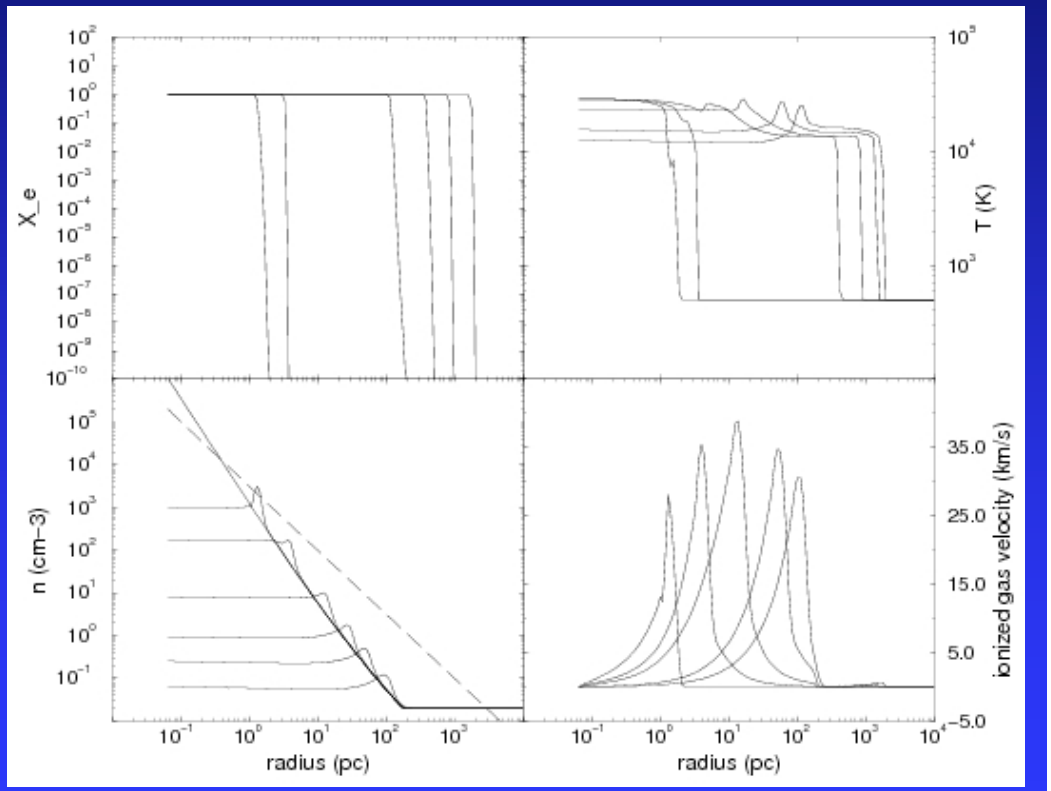

~ 200 pc
A Cosmological
Halo z ~ 20

Properties of the First Stars

- thought to be very massive (100 - 500 solar masses) due to inefficient H_2 cooling
- form in isolation (one per halo)
- $T_{surface}$ ~ 100,000 K
- *extremely* luminous sources of ionizing and LW photons (> 10^{50} photons s^{-1})
- 2 - 3 Myr lifetimes
- new results extend Pop III lower mass range down to 15 solar masses (O'Shea & Norman 2007, ApJ, 654, 66)

Transformation of the Halo

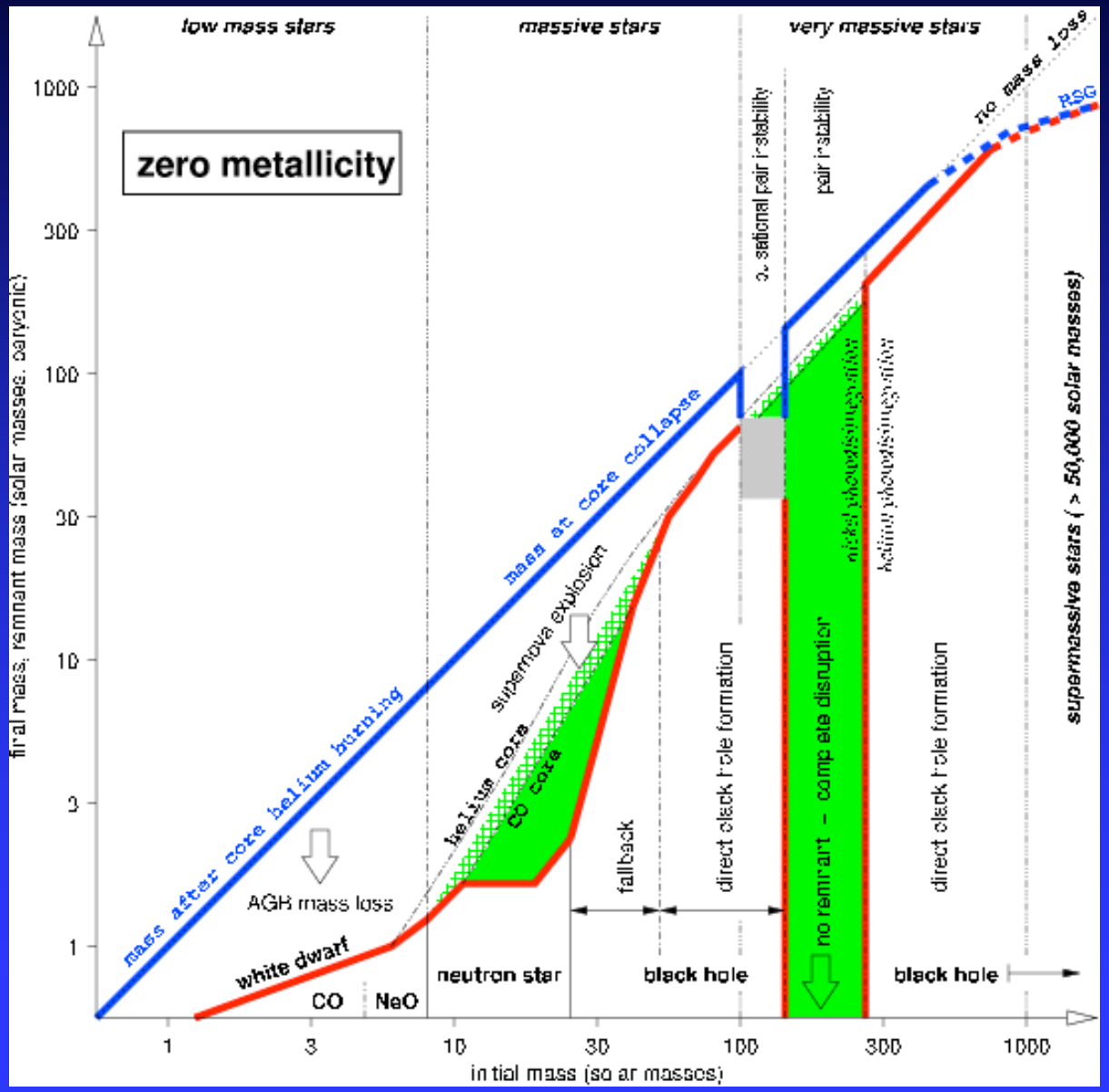




ZAMS

End of Main Sequence

Final Fates of the First Stars



Heger & Woosley 2002

What a Primordial Supernova Does to a Halo I: H II Region

- the remnant collides with the dense H II region shell and later grows to half the radius of the H II region
- metals preferentially permeate voids
- neither metals nor gas return to the halo in less than a merger time (~ 20 Myr)

Star Formation is Postponed!

Bromm, Yoshida & Hernquist 2003, ApJ, 596, 195L
Grief, Johnson & Bromm 2007, ApJ, 670, 1

What a Primordial Supernova Does to a Halo II: Neutral Halo

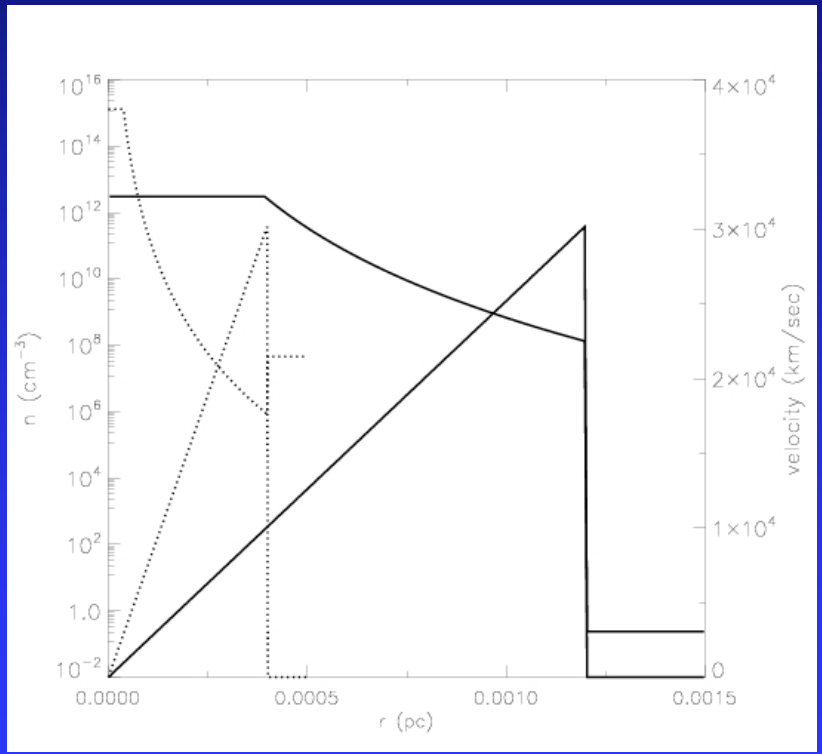
It Fizzles!

Yoshida & Kitayama 2005, ApJ, 630, 675

- temperatures skyrocket to 10^9 K at the center of the halo
- the hot, ionized, dense center emits intense bremsstrahlung x-rays
- the core radiates away the energy of the blast before it can sweep up its own mass in the halo

Recipe for an Accurate Primordial Supernova

- initialize blast with kinetic rather than thermal energy
- couple primordial chemistry to hydrodynamics with adaptive hierchical timesteps
- implement metals and metal-line cooling
- use moving Eulerian grid to resolve flows from 0.0005 pc to 1 kpc
- include the dark matter potential of the halo



Truelove & McKee 1999, ApJ, 120, 299

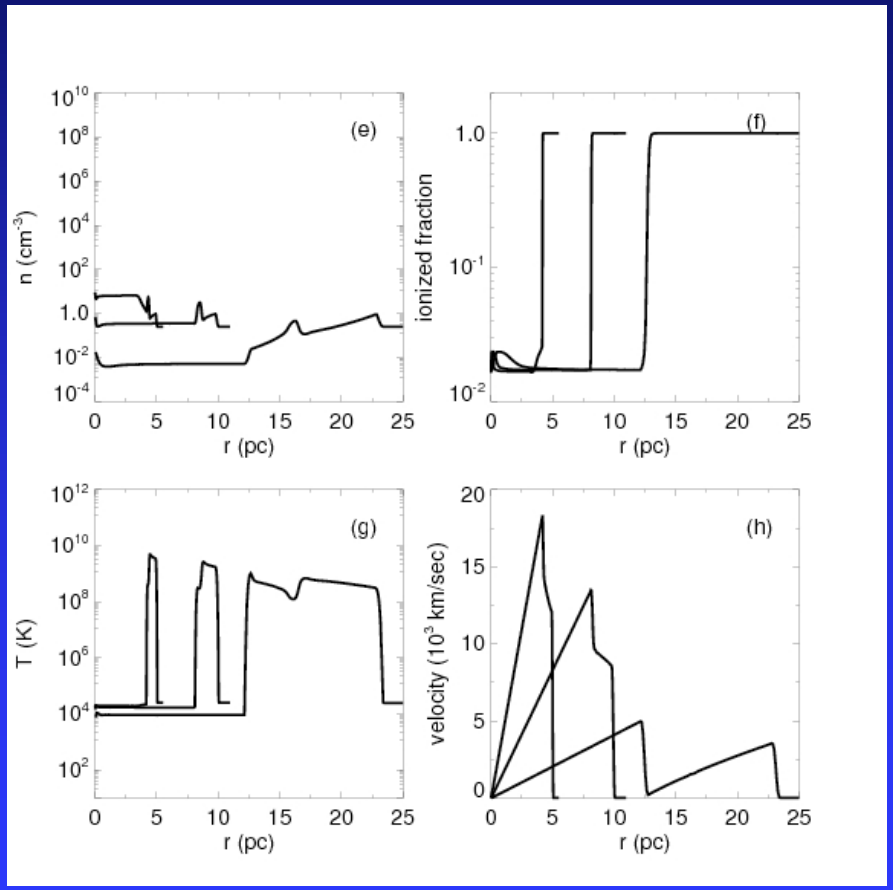
ZEUS-MP 1D Primordial Supernova: 9 Models

- Halos: 6.9×10^5, 2.1×10^6, and 1.2×10^7 solar masses
- Stars: 25, 40, and 200 solar masses (Type II, hypernova, and pair-instability supernovae)
- Stage 1: illuminate each halo for the lifetime of its star
- Stage 2: set off the blast and evolve the remnant for 7 Myr

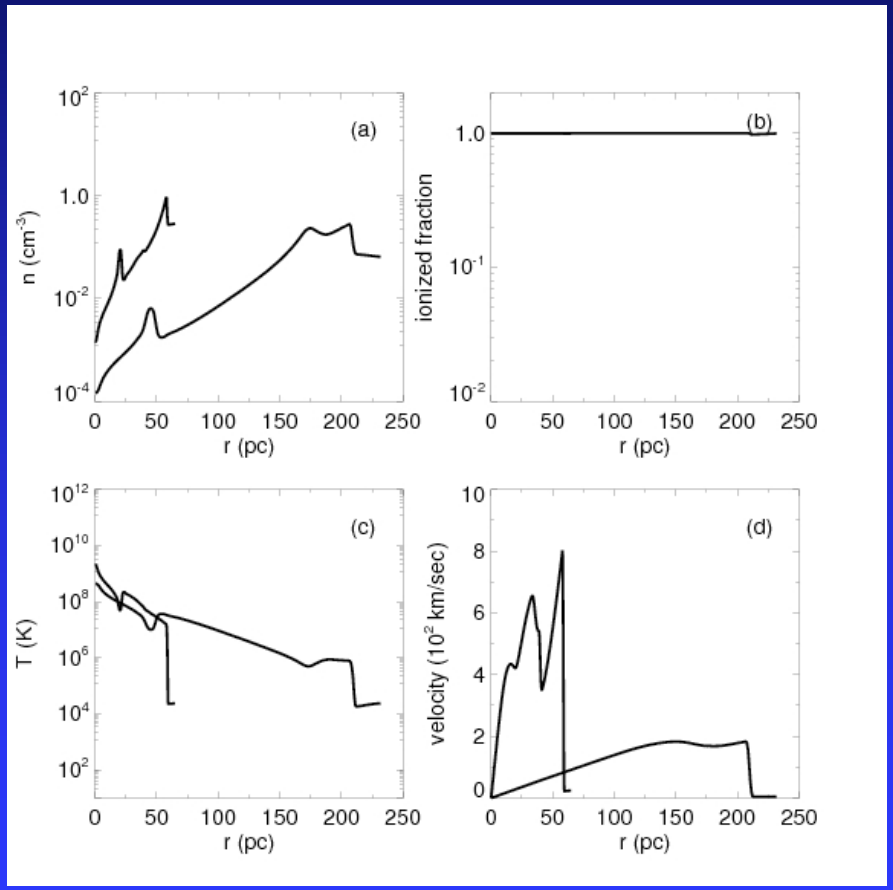
4 SN Remnant Stages in H II Regions

- $t < 10$ yr: free-expansion shock
- $30 \text{ yr} < t < 2400$ yr: reverse shock
- $19.8 \text{ kyr} < t < 420$ kyr: collision with shell / radiative phase
- $t > 2$ Myr: dispersal of the halo

Reverse Shock



Collision with the Shell

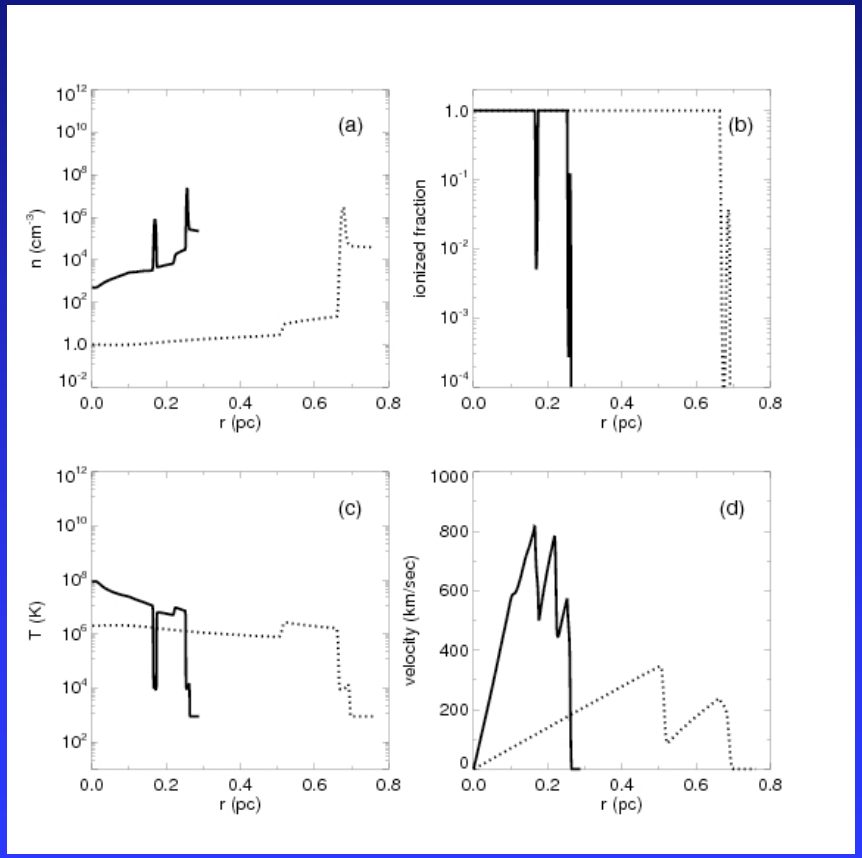


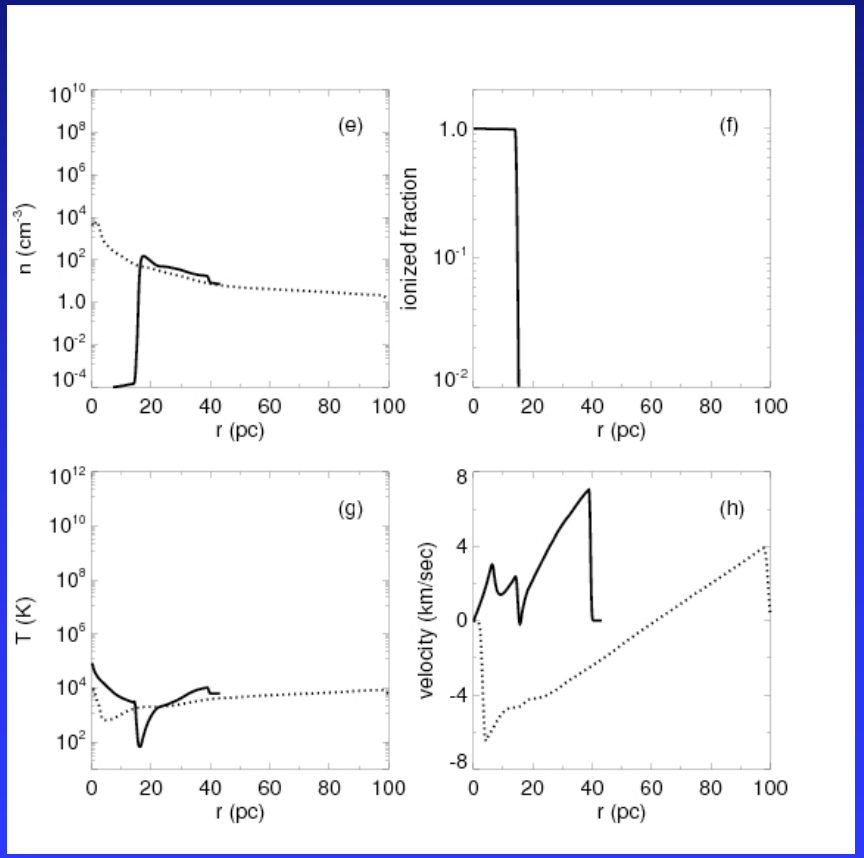
4 SN Remnant Stages in Neutral Halos

- $t < 1$ yr: free-expansion shock
- $t < 20$ yr: early radiative phase
- $100\ \text{yr} < t < 5000$ yr: late radiative phase
- $t > 1$ Myr: fallback

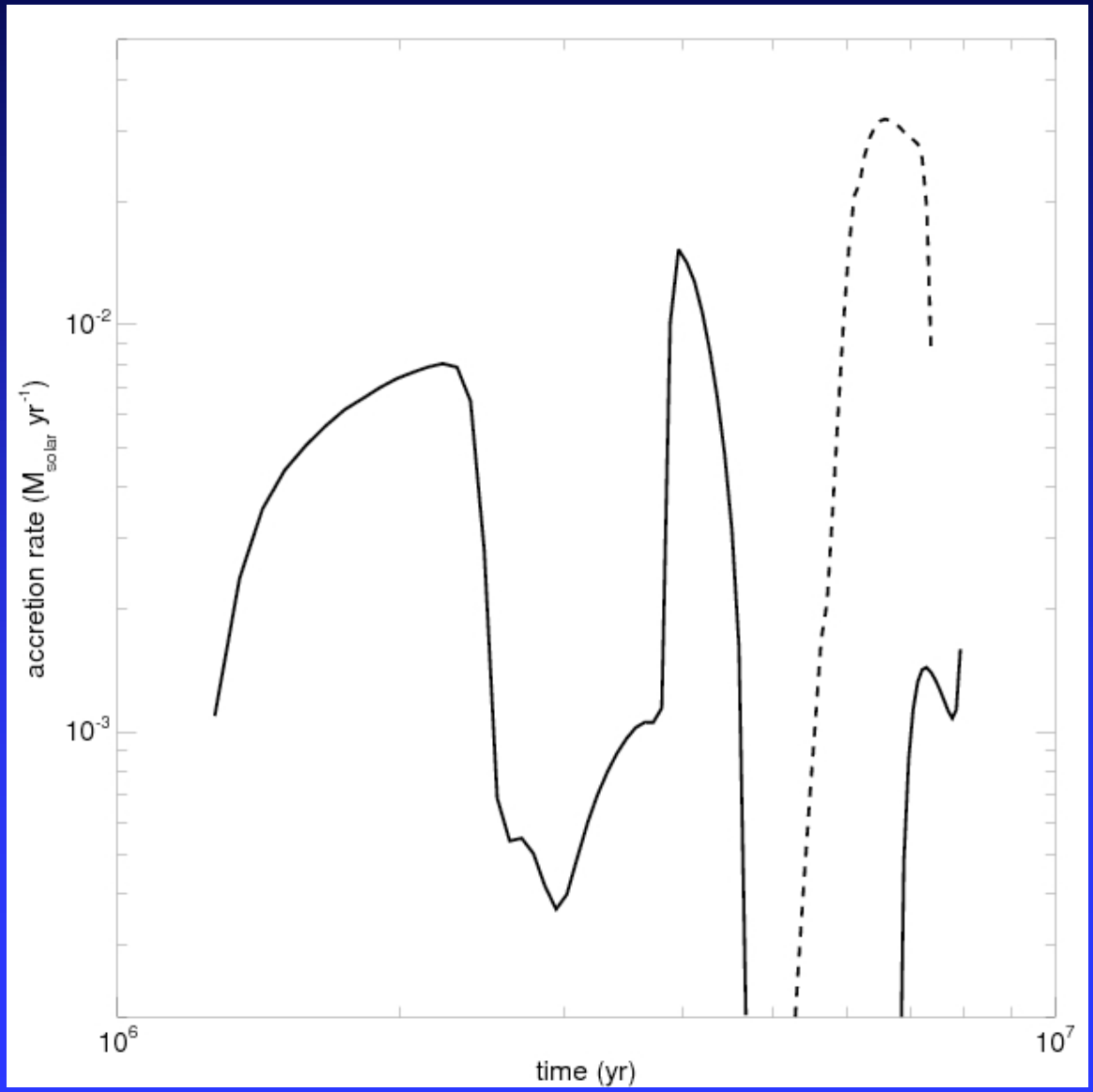
Late Radiative Phase

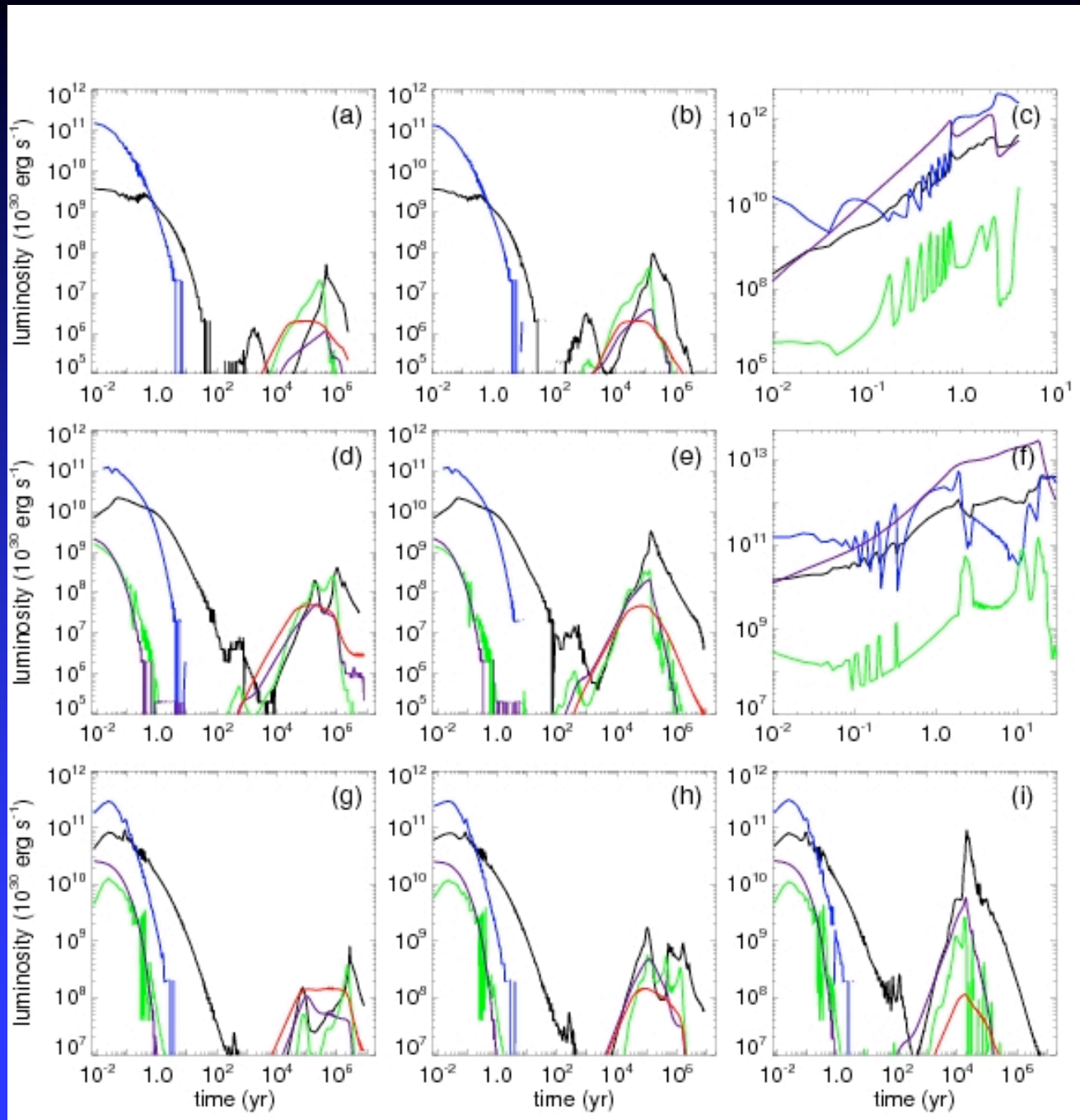
Fallback





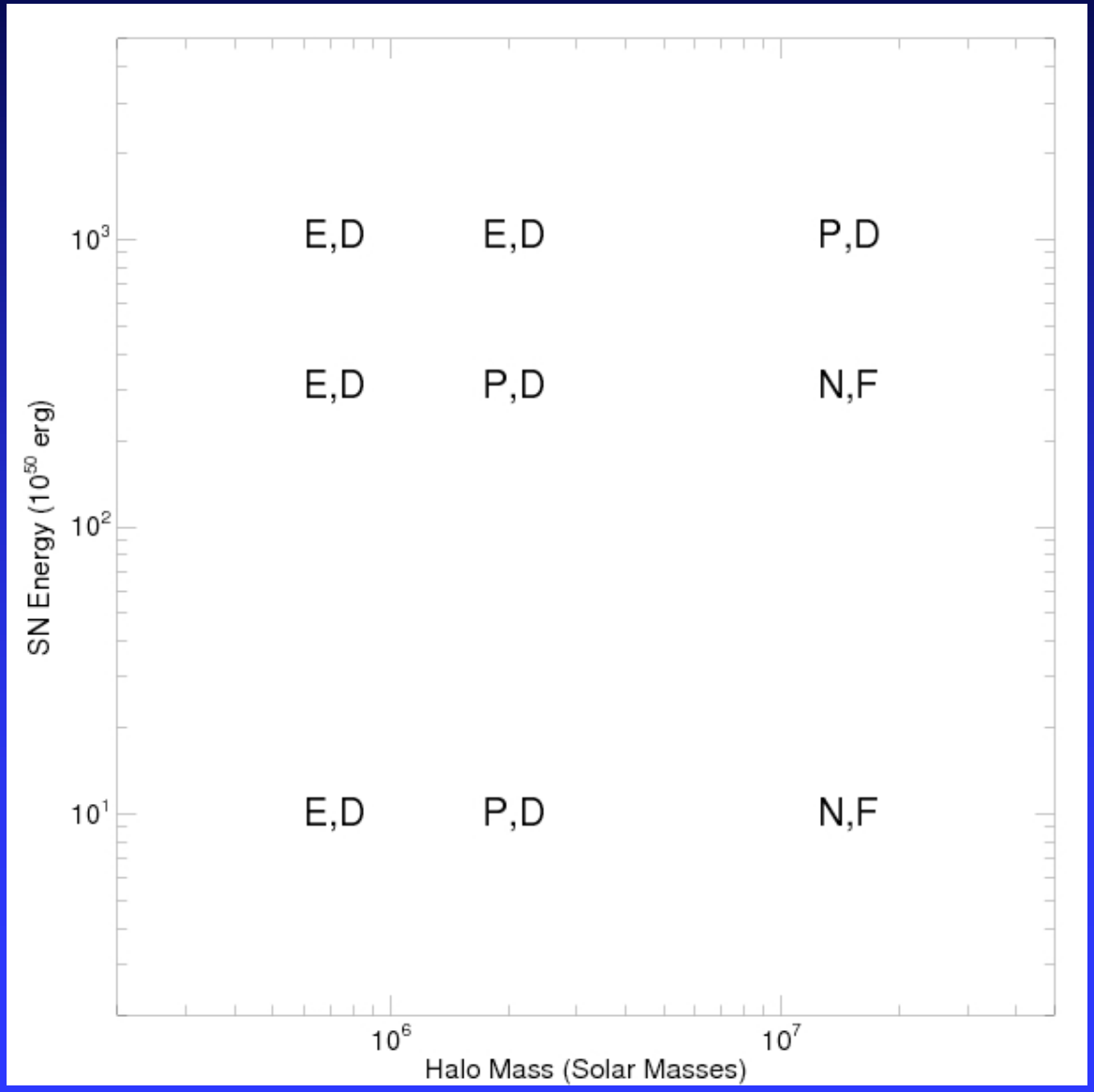
Enormous, Episodic Infall Rates During Fallback





Observational Signatures of Primordial Supernovae

Halo Destruction Efficiency



Conclusions

- if a primordial star dies in a supernova, it will destroy any cosmological halo < 10^7 solar masses
- supernovae in neutral halos do not fizzle--they seriously damage but do not destroy the halo
- primordial SN in H II regions may trigger a second, prompt generation of low-mass stars that are unbound from the halo
- blasts in neutral halos result in violent fallback, potentially fueling the growth of SMBH seeds and forming a cluster of low-mass stars

Thanks!