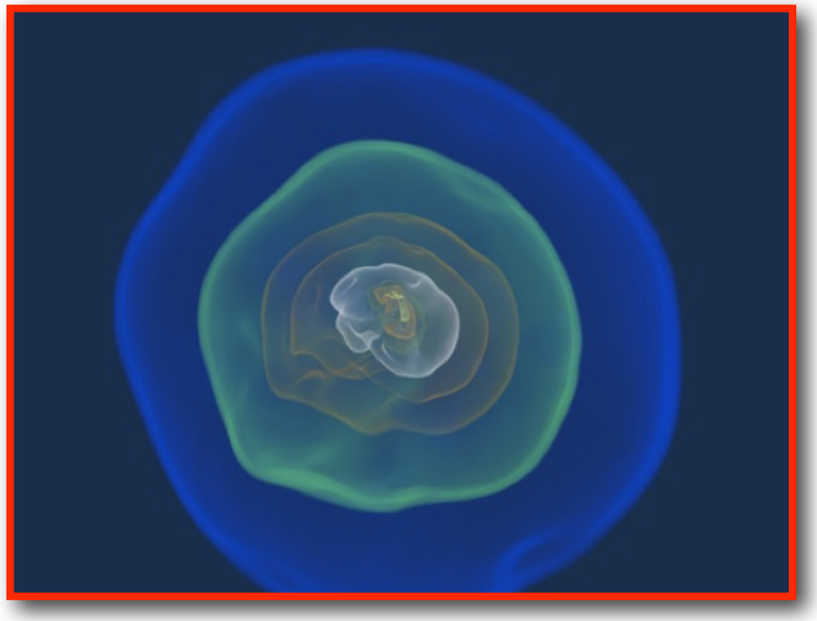
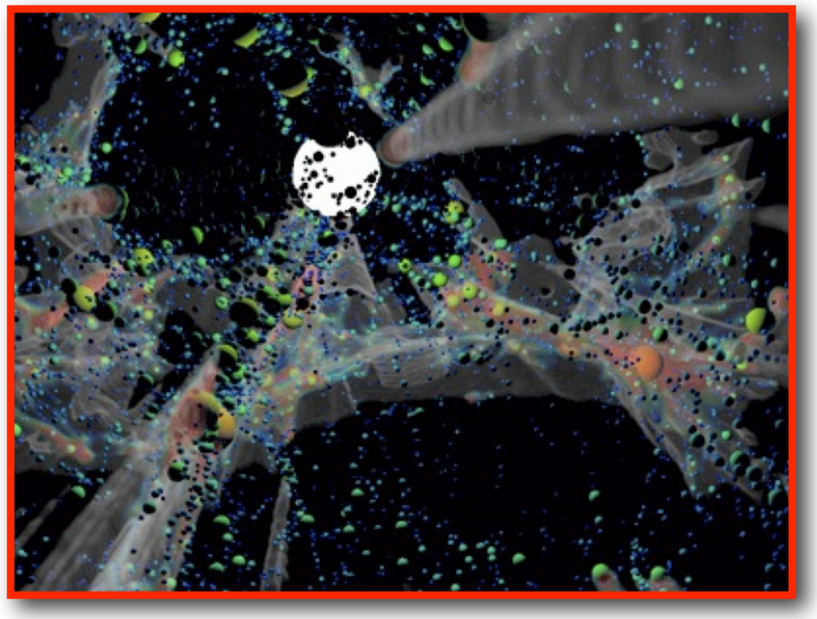
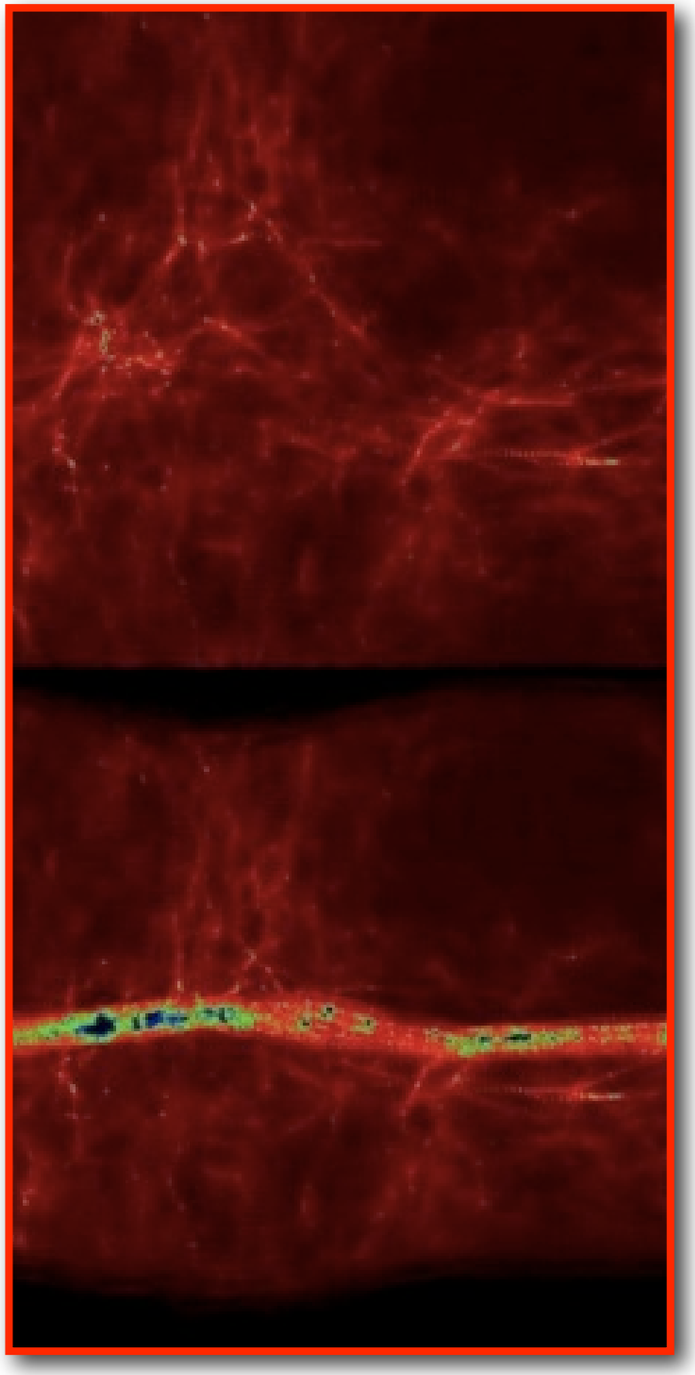


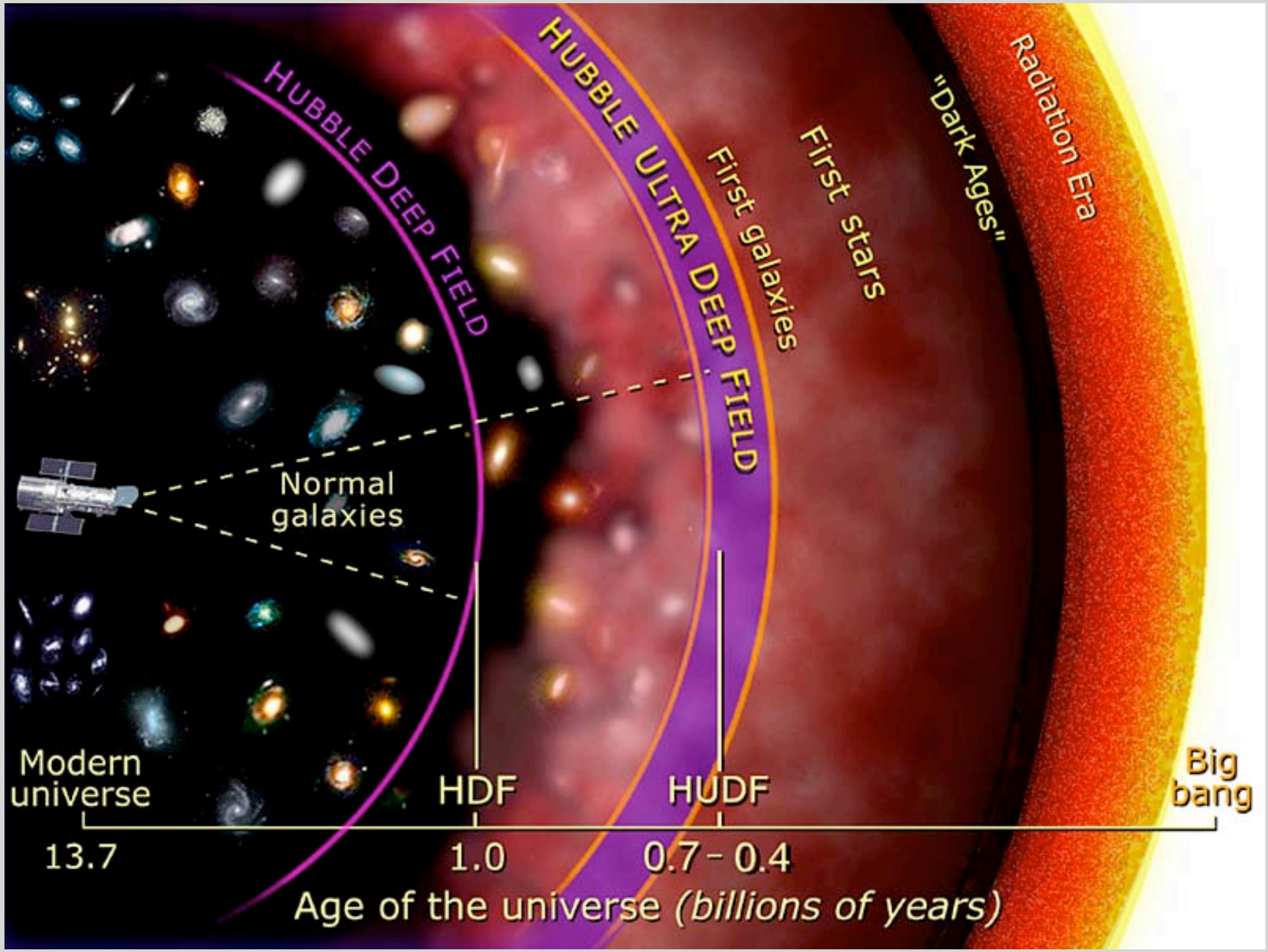




Computational Cosmology at KIPAC

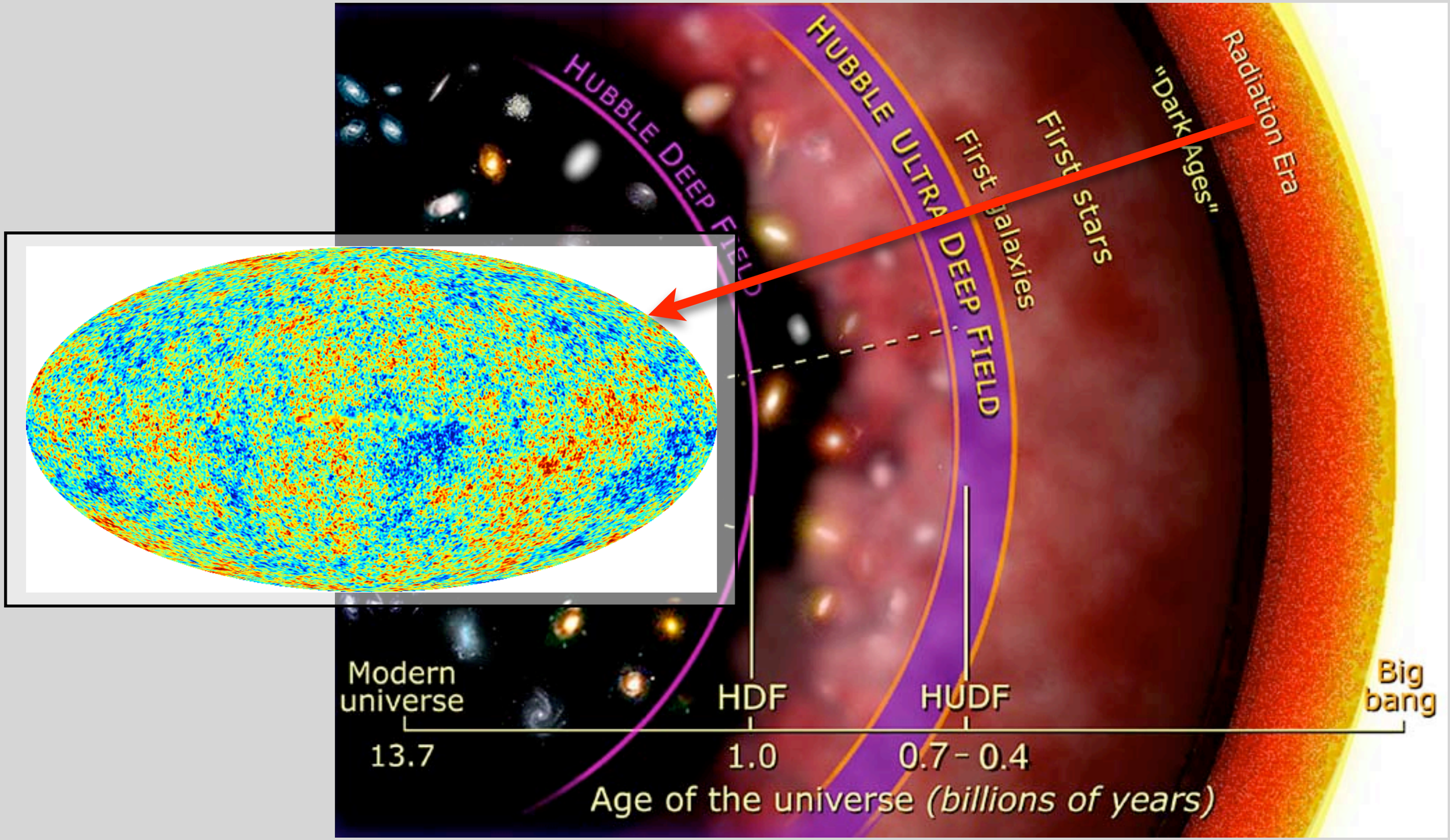
Tom Abel, Risa Wechsler

Marcelo Alvarez, Ji-hoon Kim, Matthew Turk, Peng Wang, John Wise, Fen Zhao



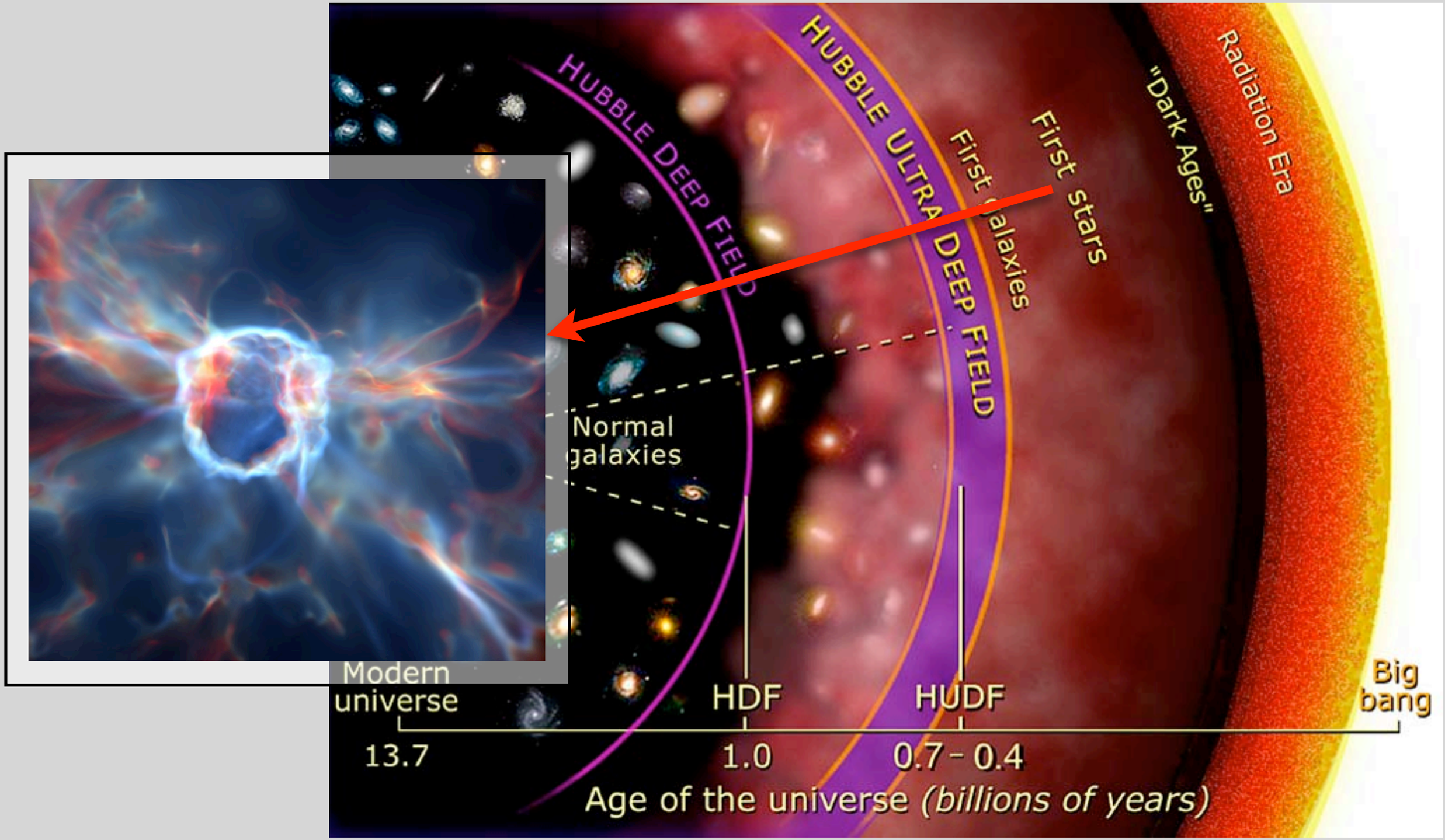
Cosmological Timeline

Credit: NASA and A. Feild (STScI)



Cosmological Timeline

Credit: NASA and A. Feild (STScI)



Cosmological Timeline

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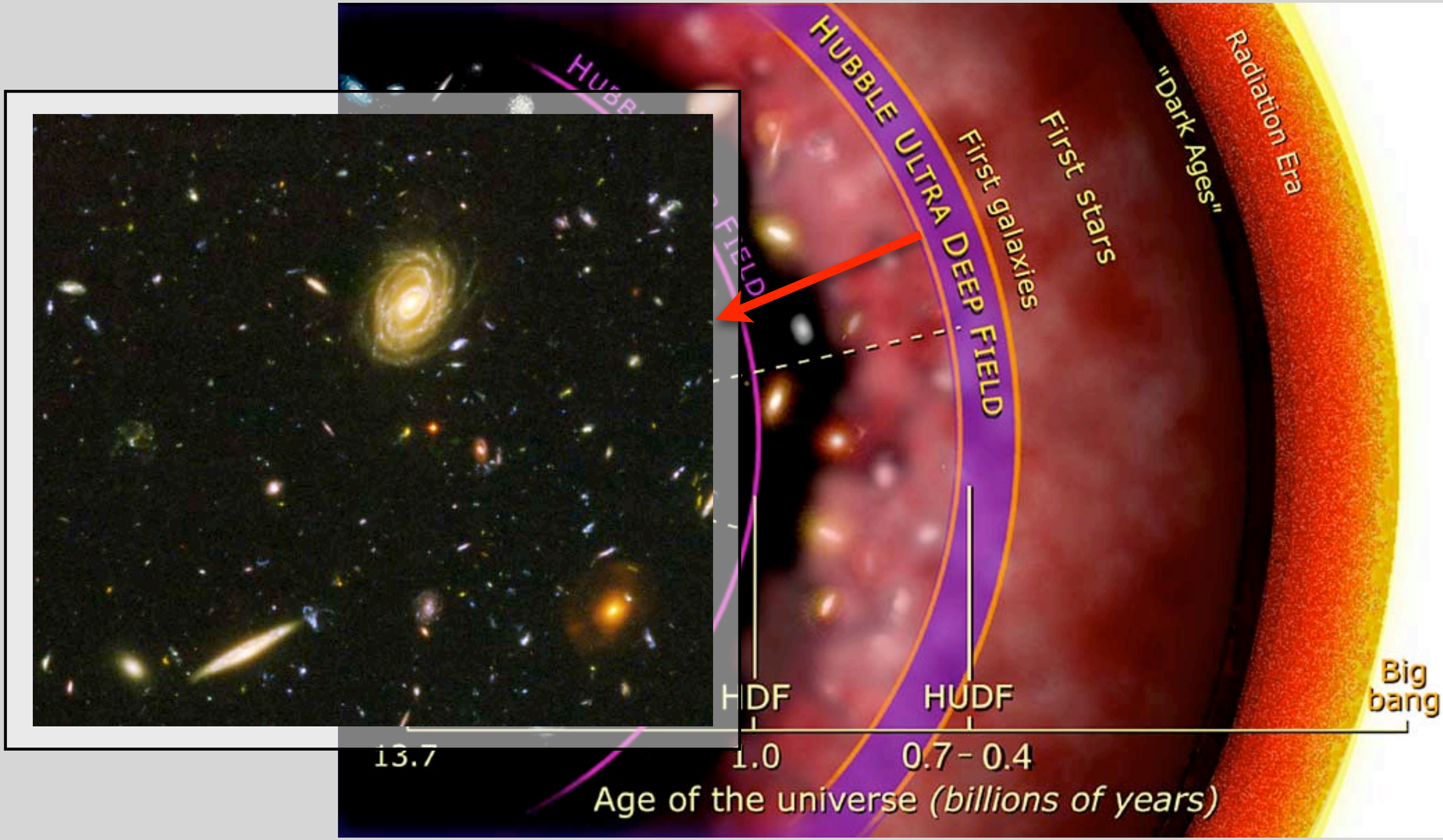

Cosmological Timeline

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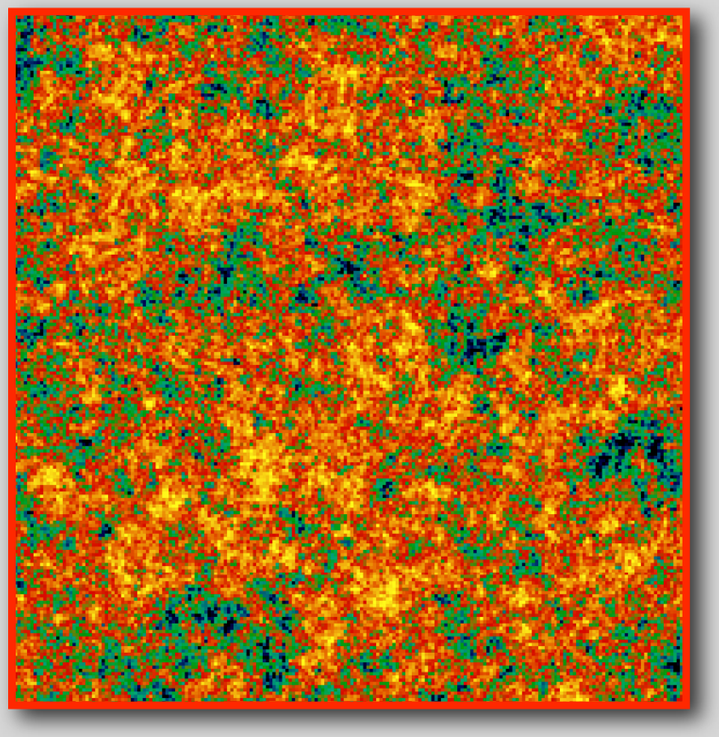
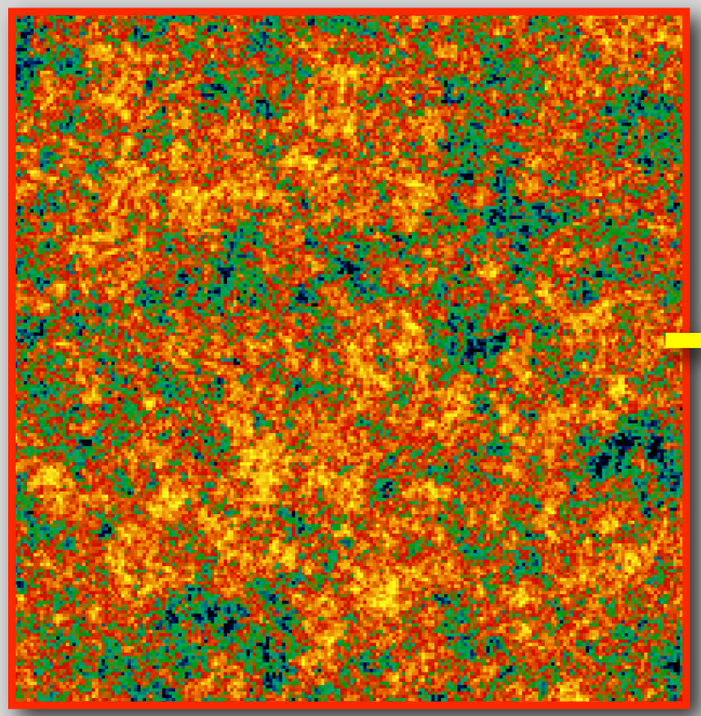
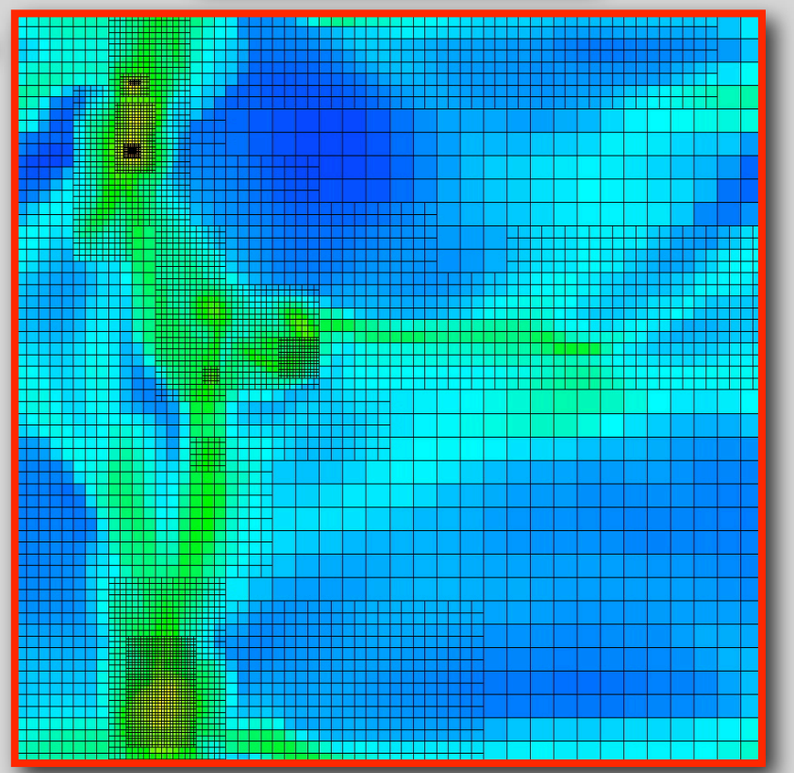
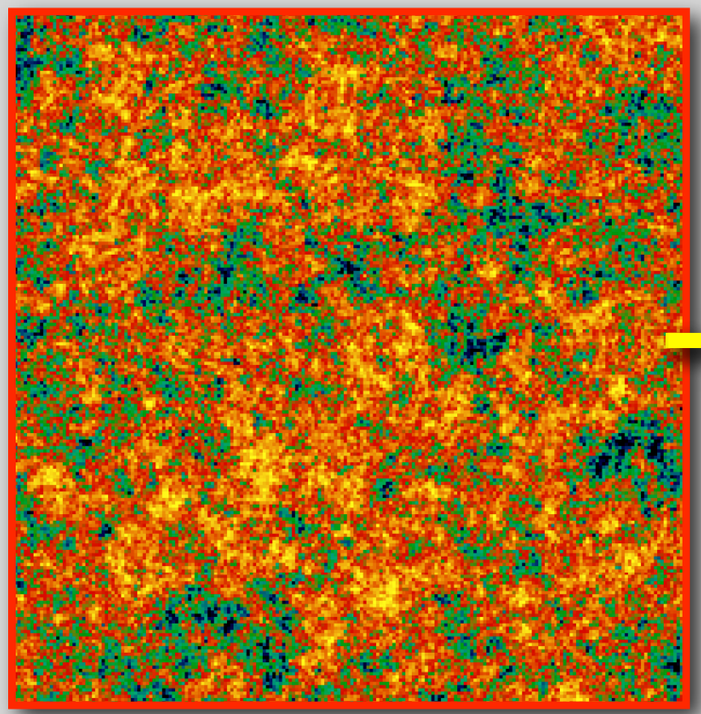


Computational approach to structure formation

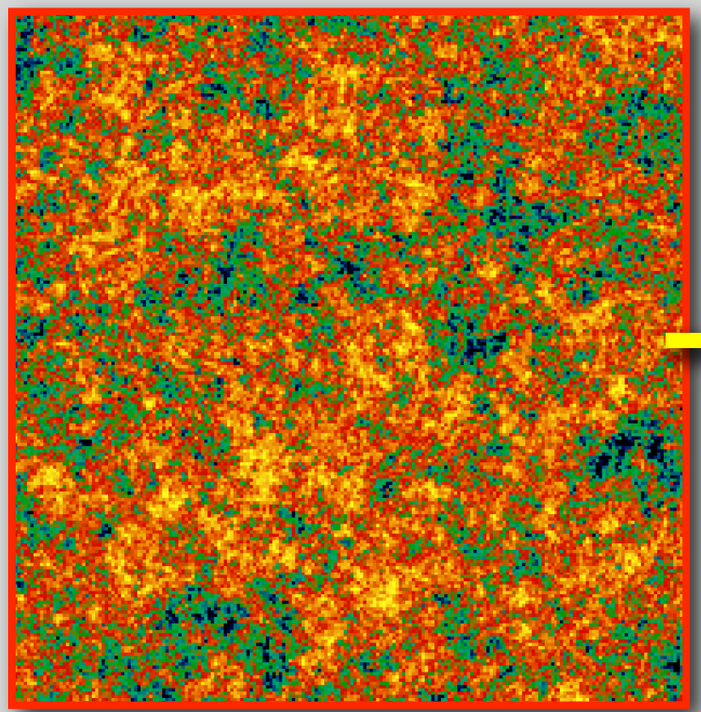




Computational approach to structure formation



Computational approach to structure formation



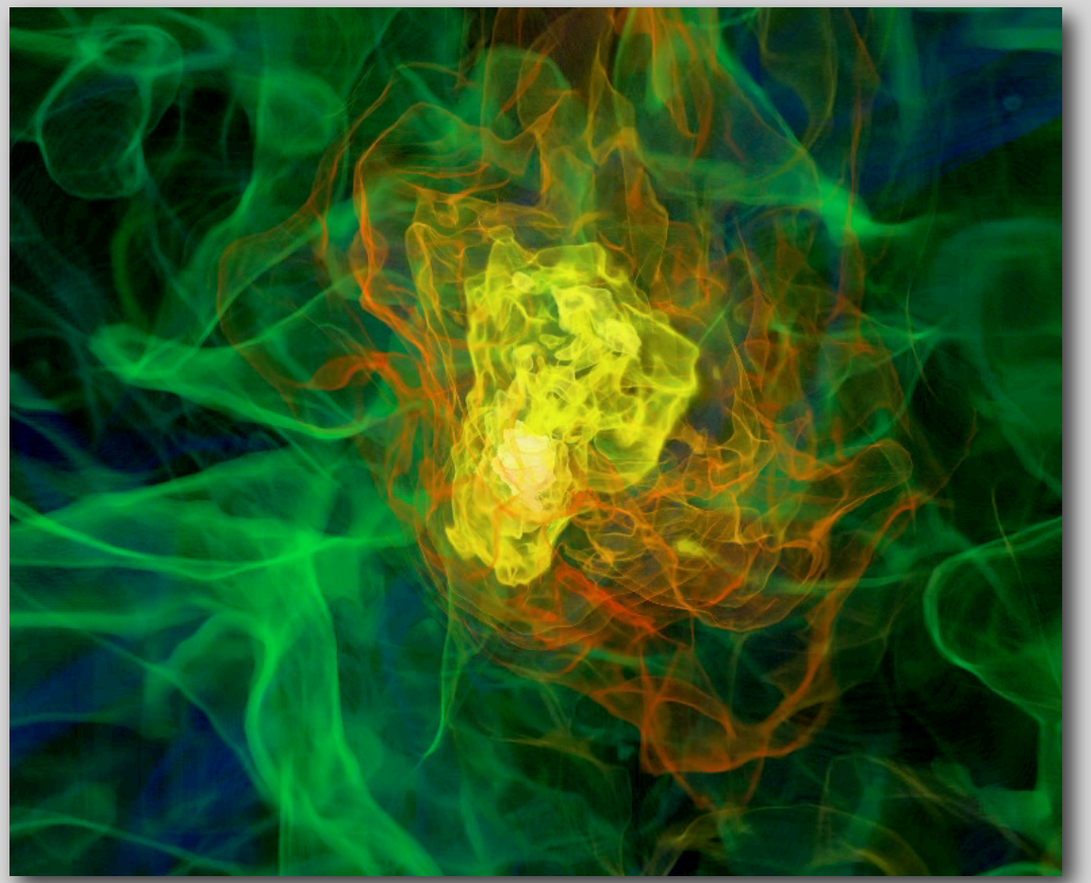
Gravity
Hydrodynamics
Gas Chemistry
Magnetic Fields
Star Formation
Radiative Transfer

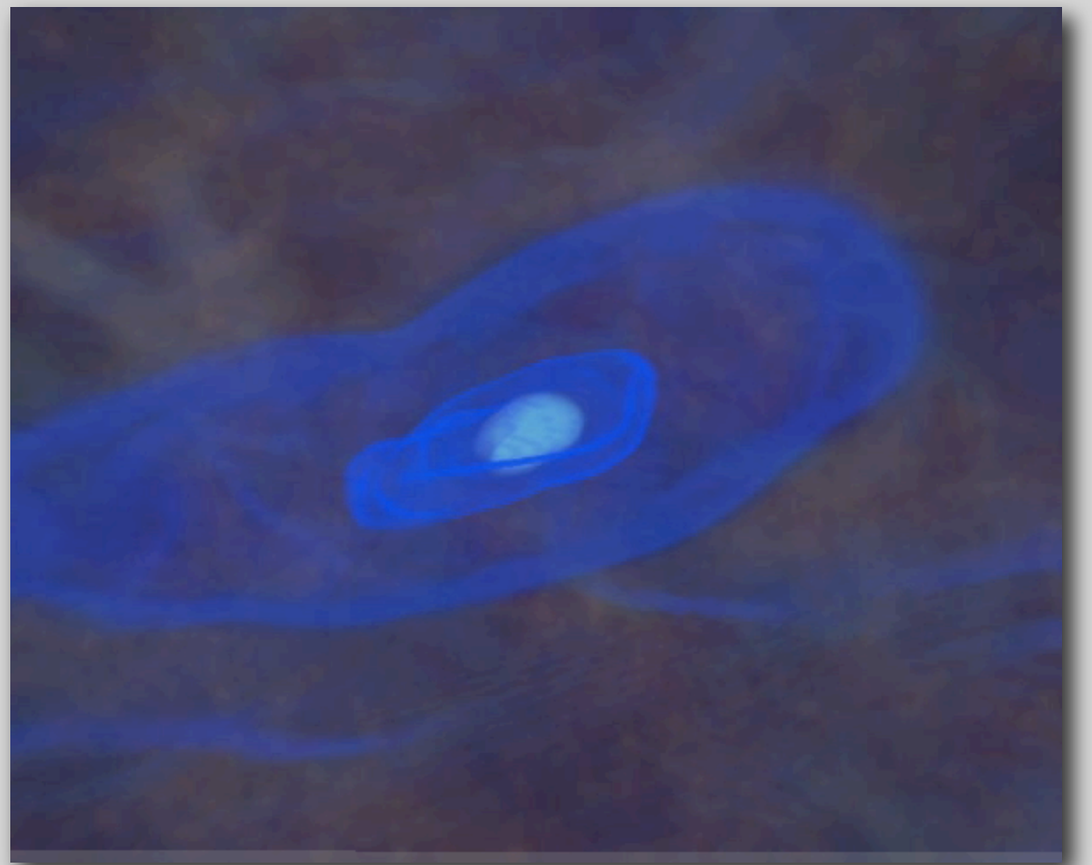
Adaptive Mesh
Refinement

Computational approach to structure formation

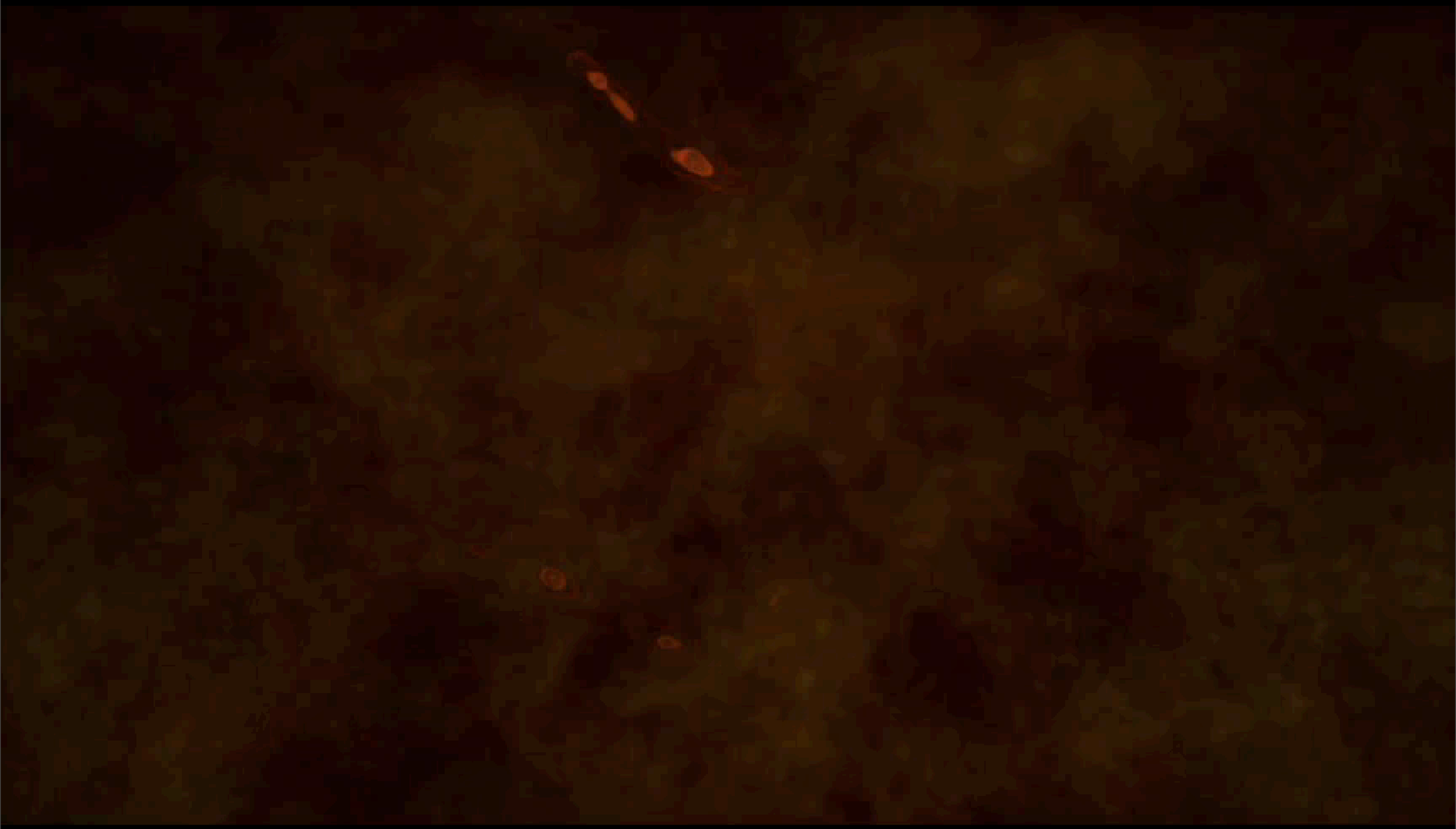
The First Stars

- Form between 50 Myr and 1 Gyr after the Big Bang
- Contained within dark matter haloes of ~10^6 solar masses
- No fragmentation, one per halo
- Very massive (~100 solar masses) and luminous (~10^6 solar luminosities)
- Metal-free
- Provide the first ionizing radiation and heavy elements to the universe





Abel, Bryan, Norman (2002), Abel, Wise, & Bryan (2007), Turk & Abel (2007), Wise & Abel (2007)



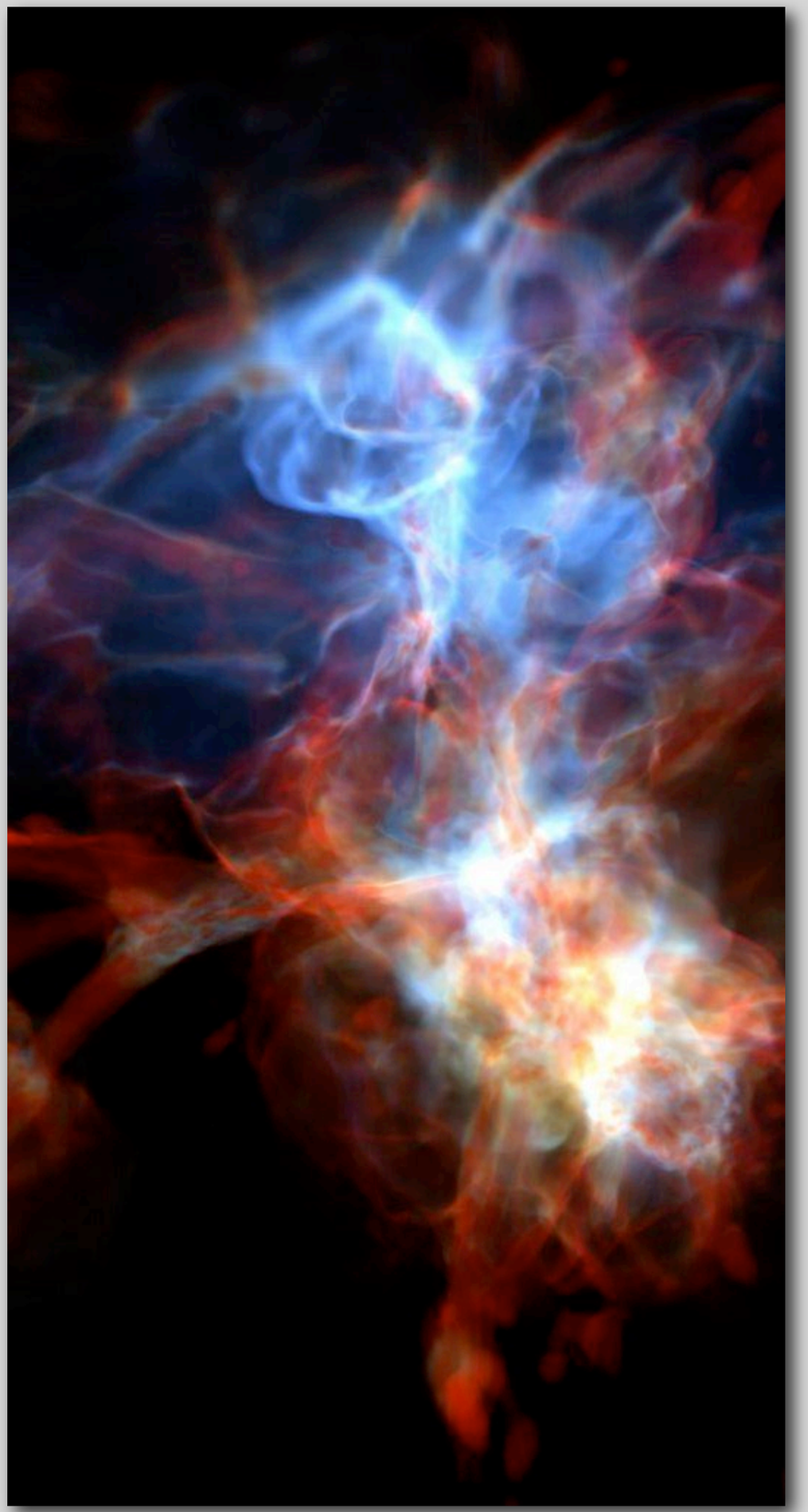
Abel, Bryan, & Norman (2002)
Viz: Kähler, Patterson, Levy, Cox, Abel
“The Unfolding Universe” Discovery Channel

Photorealistic volume rendering of a primordial stellar lifetime and SN
Colors correspond to the gas' blackbody spectrum
Hardware accelerated rendering at 10 fps

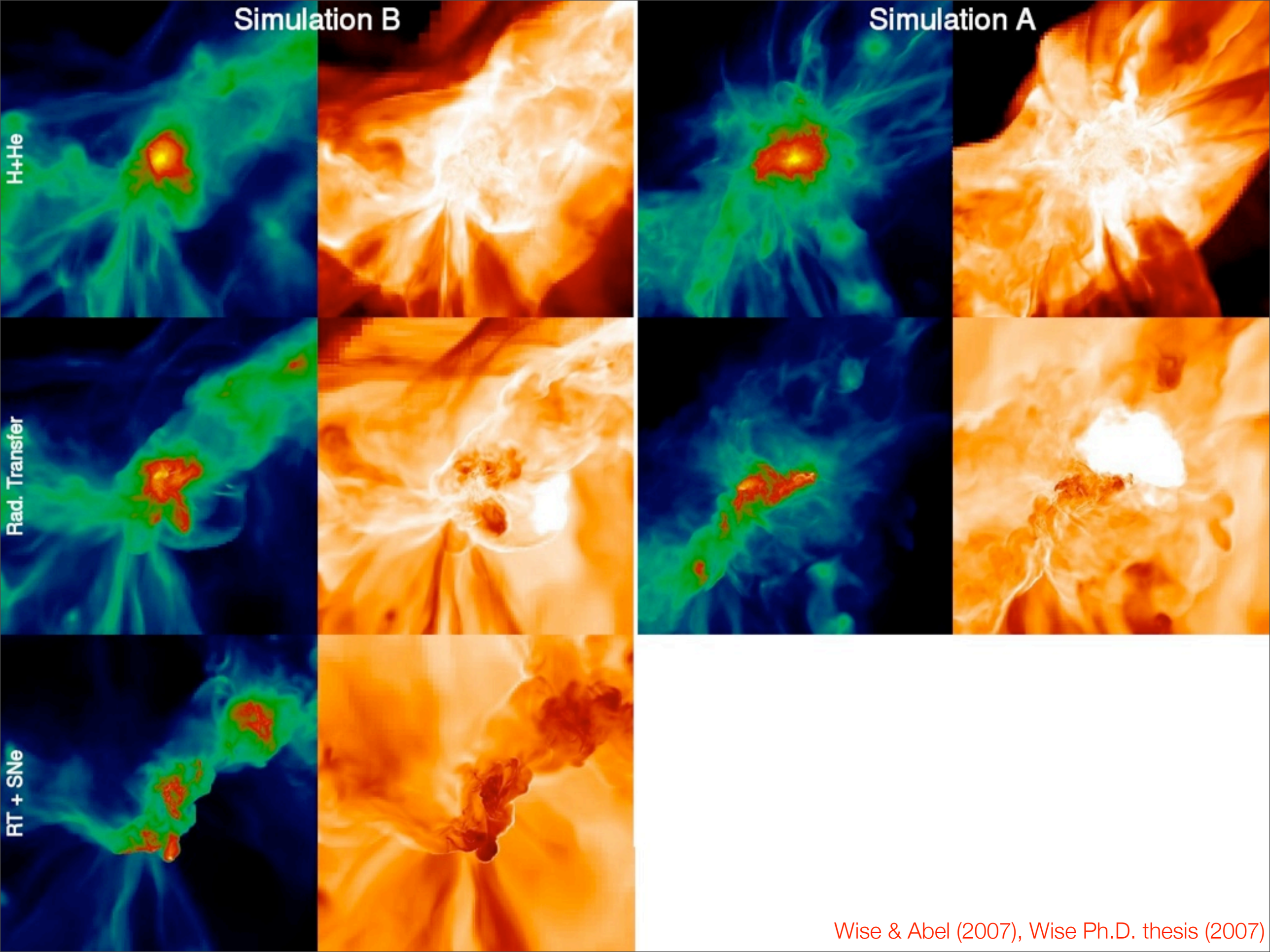
Abel, Wise, & Bryan (2007). Viz: Kähler, Wise, Abel

The First Galaxies

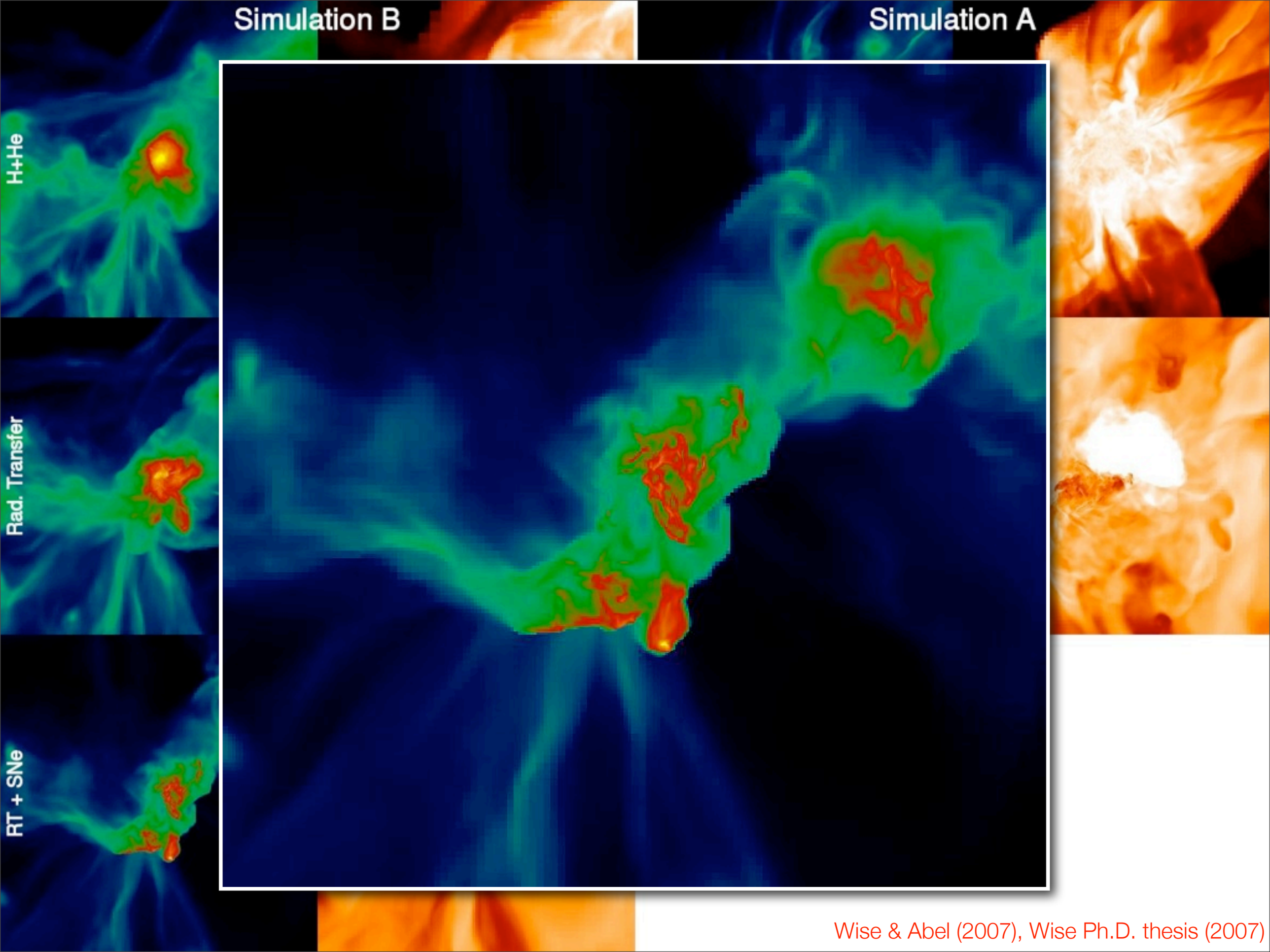
- Radiative feedback from the first stars have a dramatic effect on the formation of early galaxies.
- Decreases their baryon fractions by ~50%
- Increases their angular momentum up to 10 times.
- Enriches the galactic gas to 10^{-3} of solar metallicity.
- Creates a multi-phase interstellar medium similar to Galactic environments.



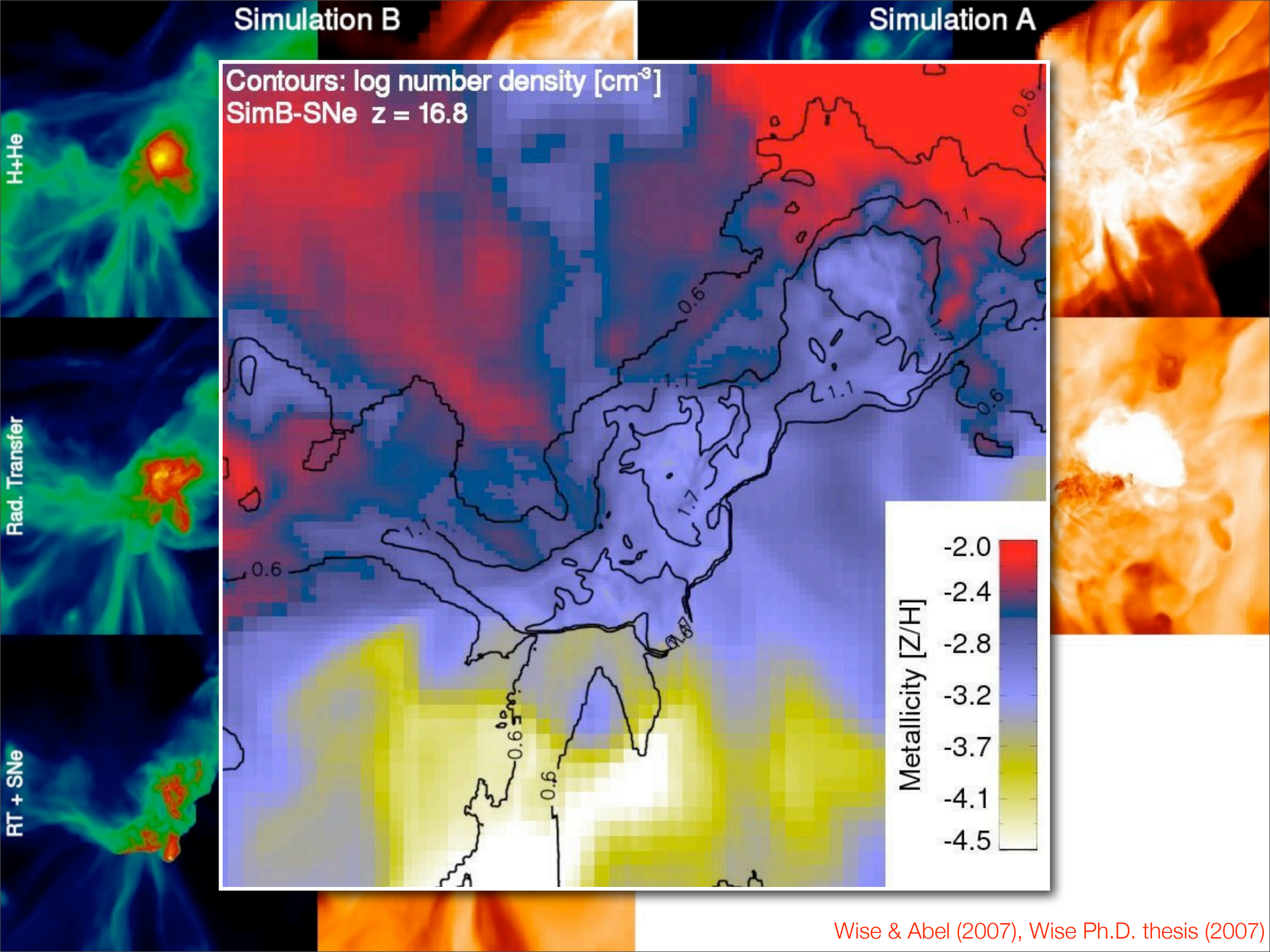
Wise & Abel (2007), Wise Ph.D. thesis (2007)



Wise & Abel (2007), Wise Ph.D. thesis (2007)



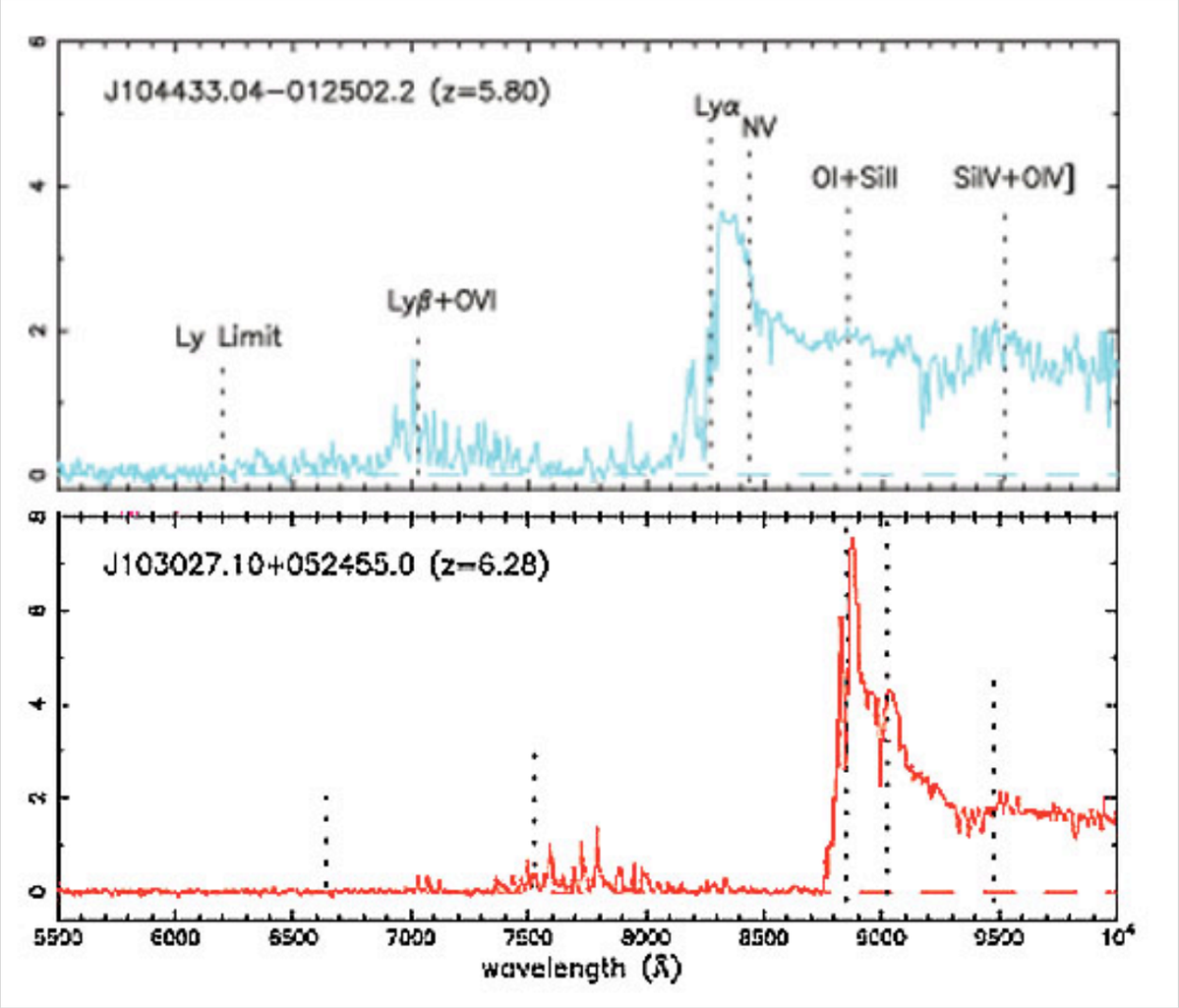
Wise & Abel (2007), Wise Ph.D. thesis (2007)



Wise & Abel (2007), Wise Ph.D. thesis (2007)

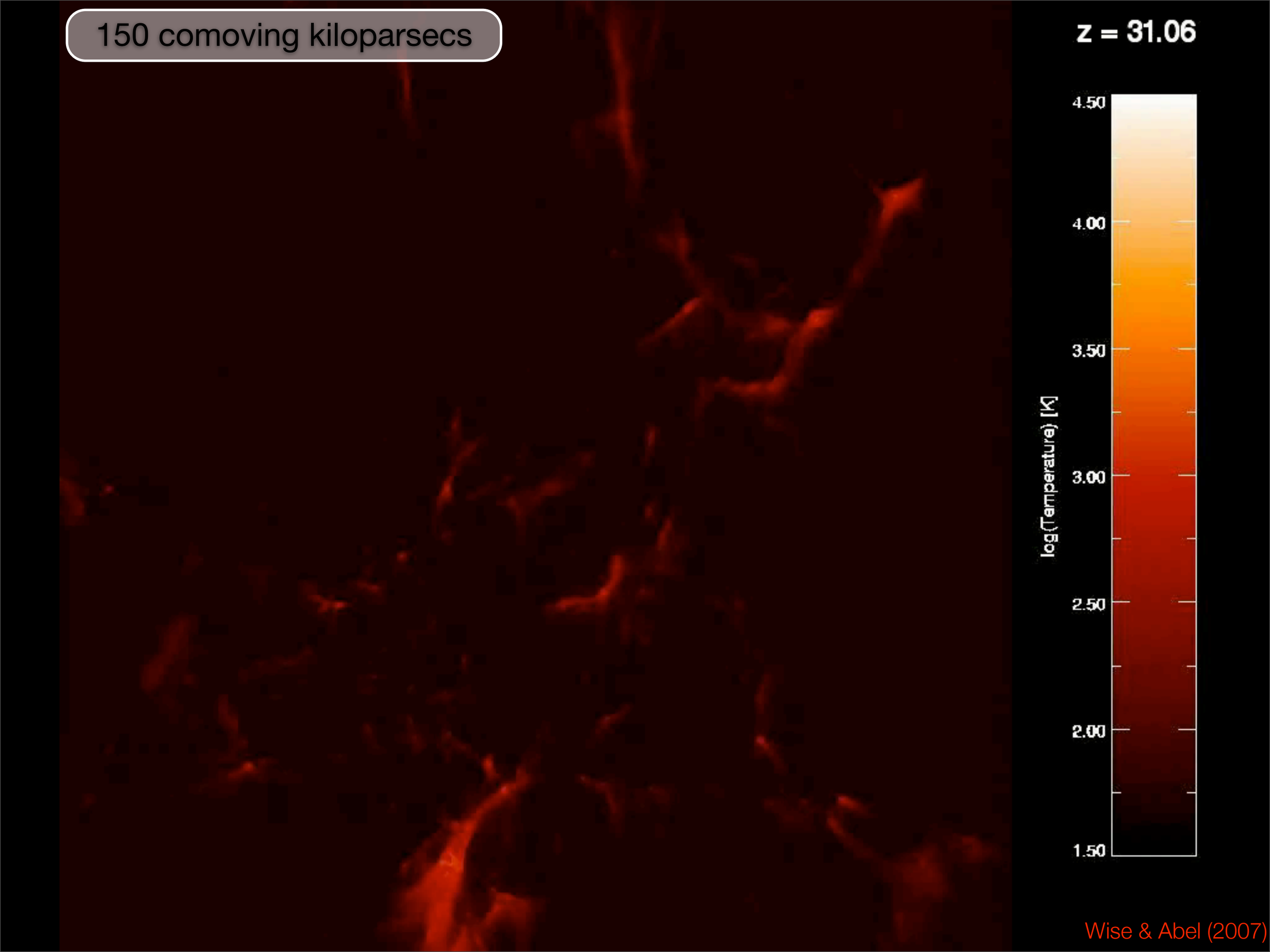
Reionization

- Spectra of high-redshift quasars reveal that cosmological reionization is ending at z ~ 6.
- The first stars begin reionization to a filling fraction of ~20%
- However, galaxies in dark matter halos with masses >10^8 solar masses are mainly responsible for completing reionization.
- Quasar spectra also show that the surrounding environment was pre-ionized by the host and nearby galaxies before the quasar became active.



Credit: SDSS

Alvarez & Abel (2007), Wise & Abel (2005, 2007), Wise Ph.D. thesis (2007)



Wise & Abel (2007)

Alvarez (2007)
Viz: Kähler, Alvarez, Wise, Abel

Summary

- Numerical simulations are beneficial in both
  1. Discovering new physical scenarios of cosmological structures
  2. Interpreting observations and the underlying physics of astrophysical objects
- The first stars are very massive (~100 solar masses) and luminous and form in isolation in their halo dark matter halos.
- Radiation from such stars play a key role in shaping the characteristics of early galaxies.
- Cosmological simulations of reionization show the evolution and morphology of the ionized regions.
- *Other topics:* Magnetic field generation from the first stars and supernovae; Cosmic strings; Galaxy clustering and occupation fractions; Supermassive black hole formation and evolution