Formation of the first low-mass stars from cosmological initial conditions

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Modern Star Formation

- Molecular clouds with supersonic turbulence
  - SF dominated by shock compression → Jeans unstable
- Fragmentation governed by:
  - Turbulence, rotational, magnetic field support
  - Complex rel. between heating and cooling
- Star Formation peaks at ~ 0.1 – 0.5 Msun

Early Star Formation is Different

Pop III stars:

- Formed from pristine (Z ~ 0) gas
- H_2 Cooling essential (and inefficient)
- CMB temperature sets cooling floor

Typical star more massive (maybe ~ 100Msun)

Produced the first metals that affect future SF

How did Pop III → Pop I

Dust and metals change the game completely

Not clear which is dominant effect....

Possible observables:

1) Nature of reionization
2) Still alive today in metal poor regions
3) Observed directly at high z with JWST

Simulating the first metal stars

Perform a cut-out simulation of previous work

- Cosmological simulation
- Large (million solar mass halo)
- Initially pristine, populated with metals
- Evolved to “star” formation
- Resolution limited

Want to resolve fragmentation at all scales

All of the fancy physics

FLASH – grid based, AMR hydro code

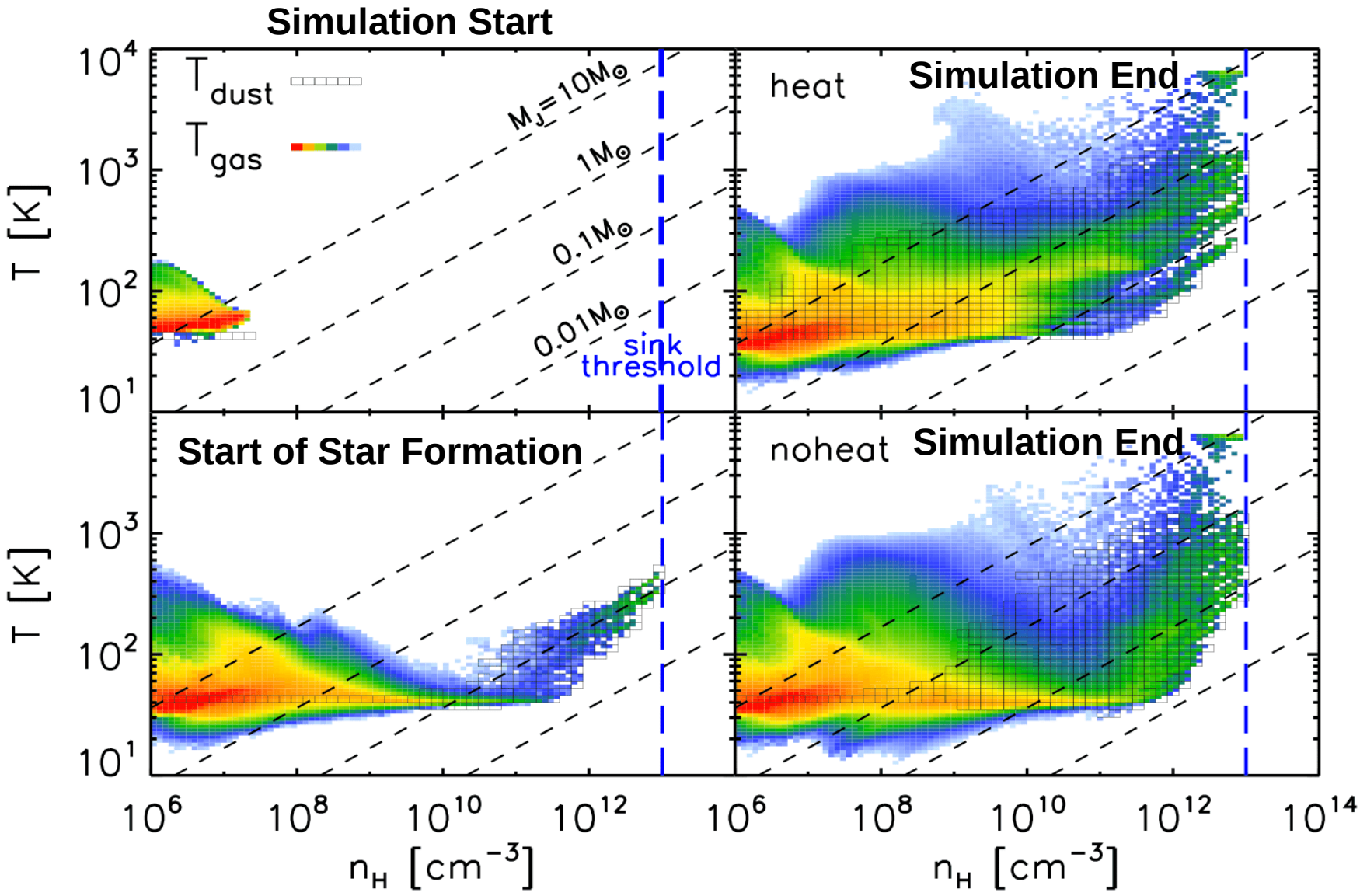
High resolution ($n \sim 10^{7} - 10^{13}\ cm^{-3}$)

Sink particle formation for stars

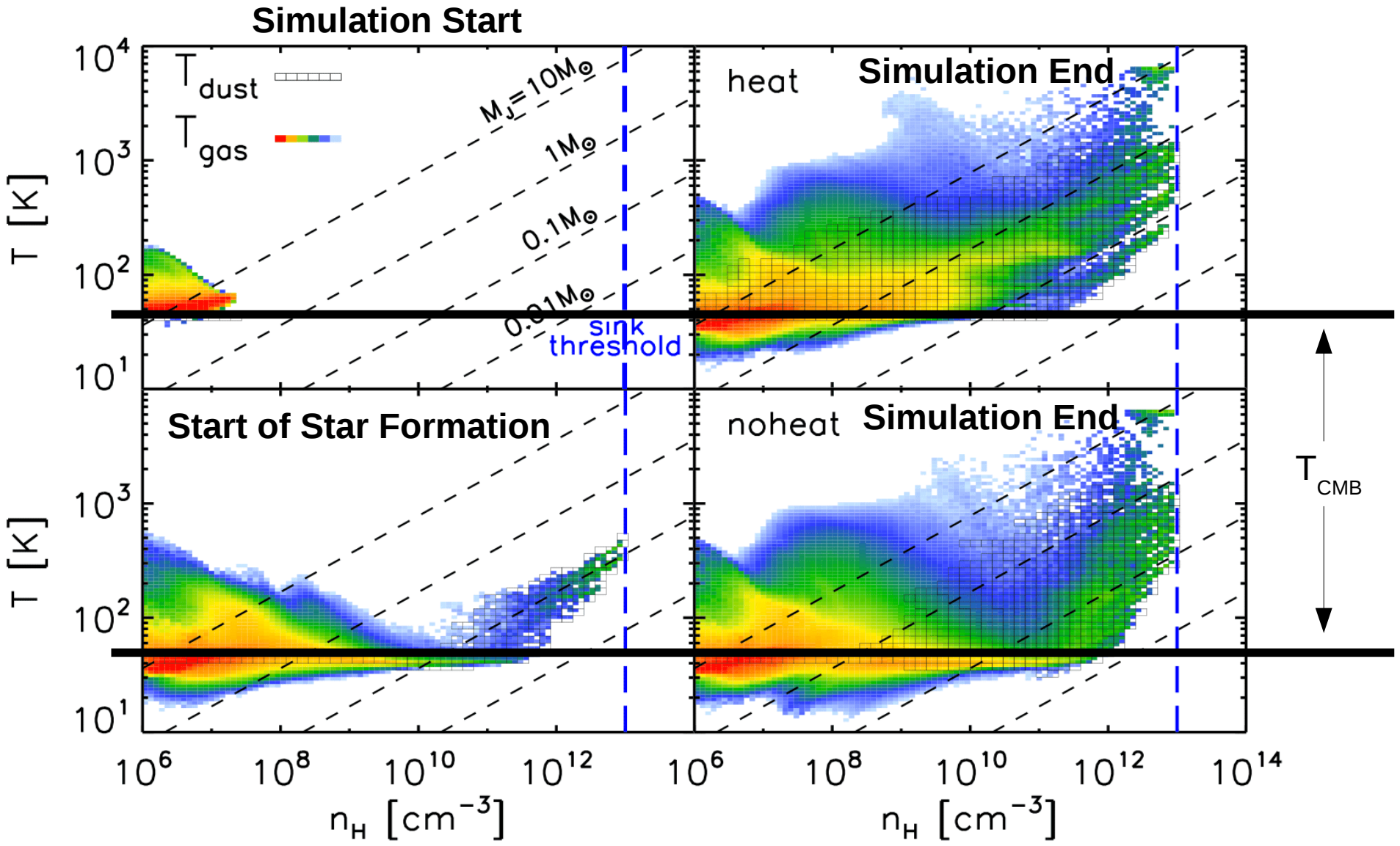
Include:

- Non-eq primordial chemical network (12 species)
- Populate metal chemistry (C,C+, Si, Si+, O,O+)
- Coupling between dust and gas (cooling and heating)

Gas and Dust Phases



Gas and Dust Phases



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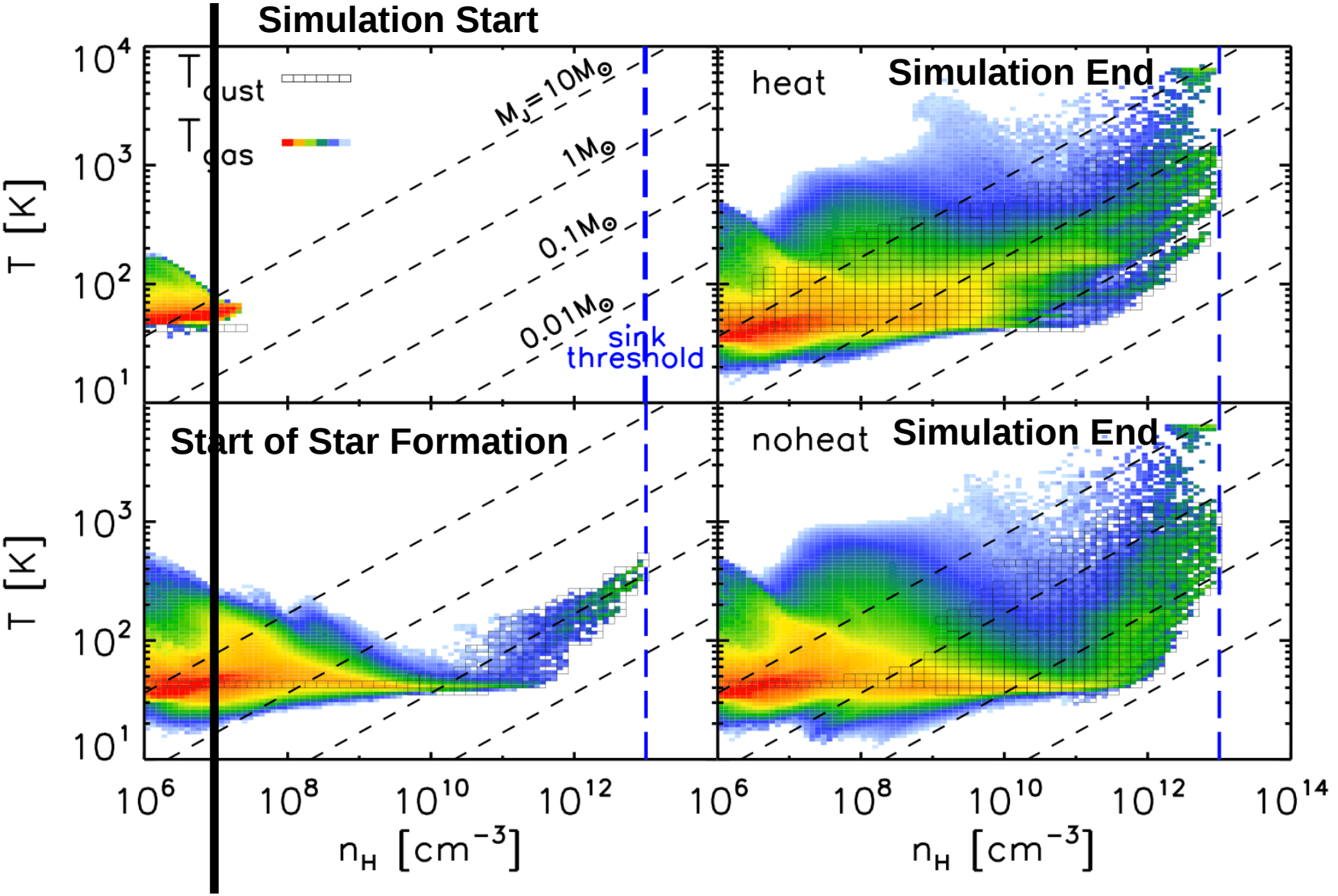
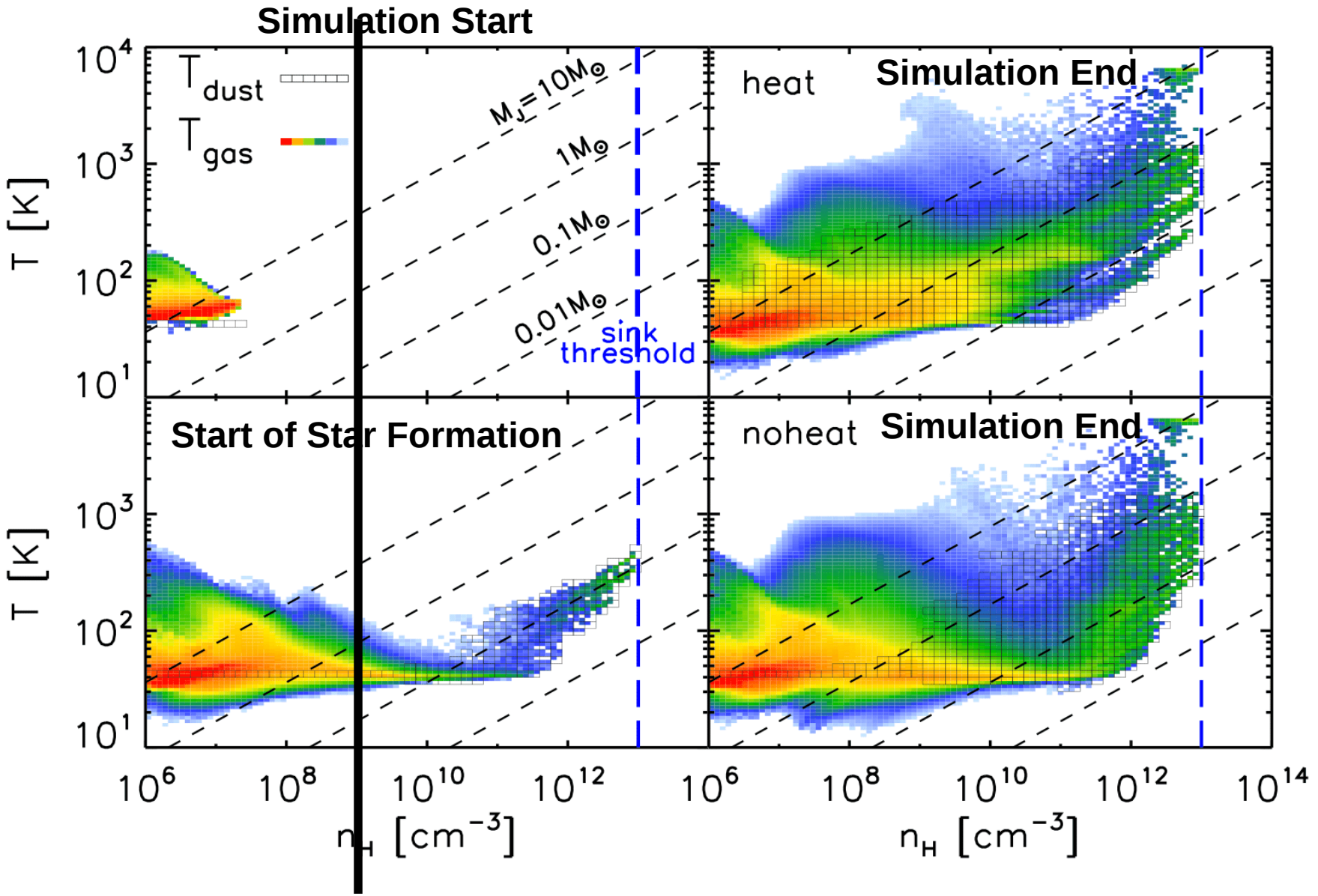


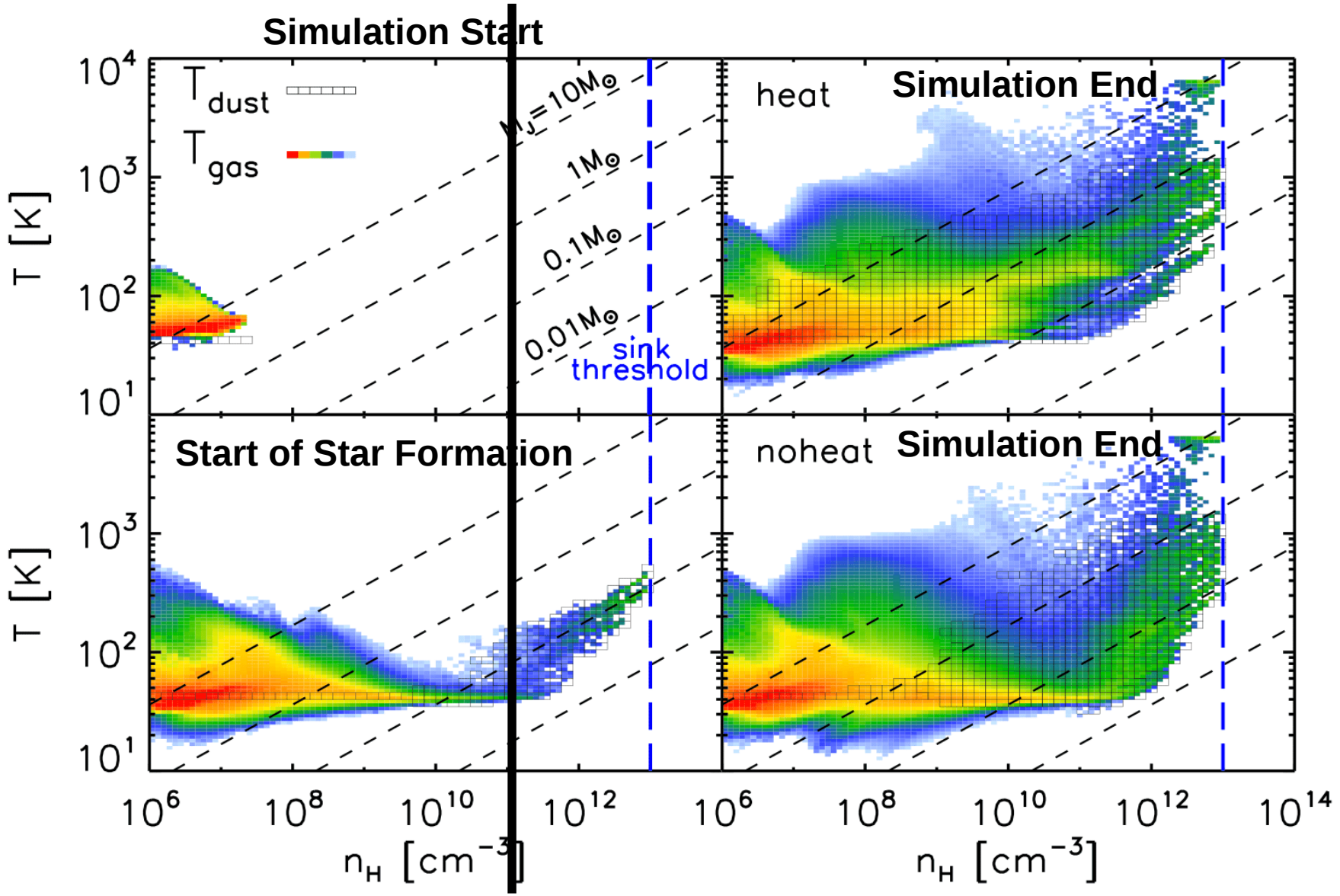
Optically thick to line cooling

Gas and Dust Phases



Coupling between dust and gas causes cooling

Gas and Dust Phases



Adiabatic Evolution of Gas

Filamentary Star Formation

Sink particle formation in filament

- Supersonic, colliding flow of gas

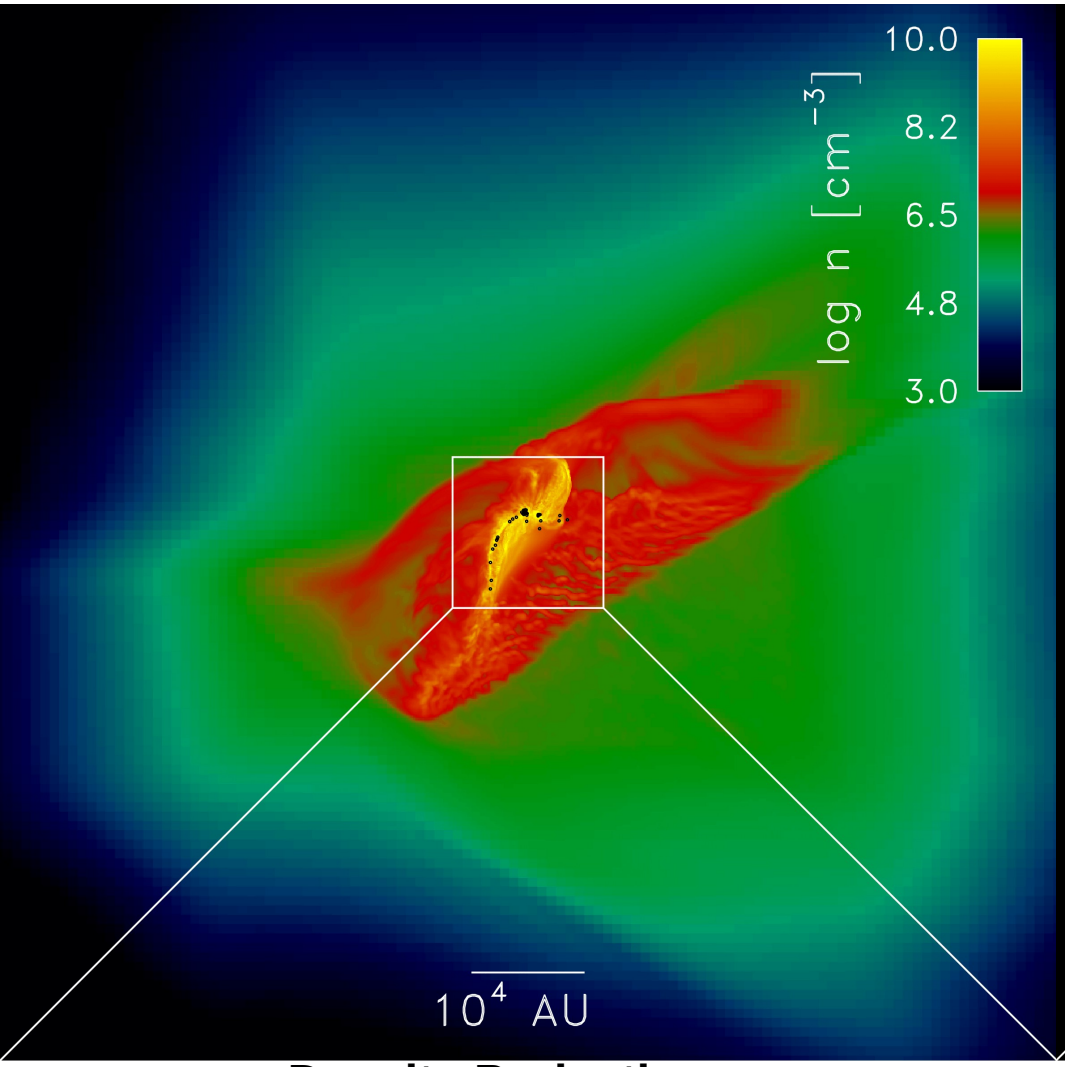
Filament fragmentation

Discy structures → Sites of SF

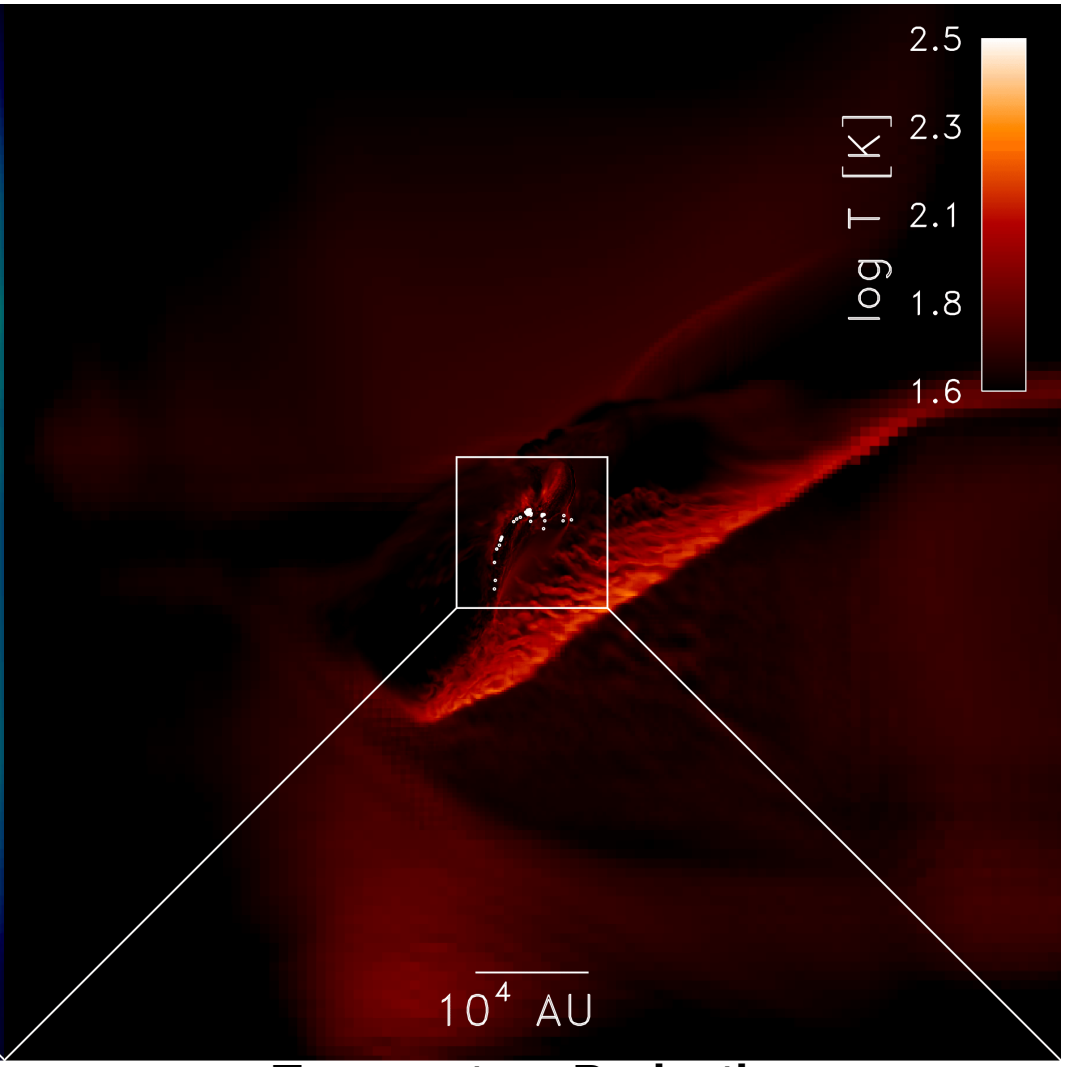
With / without dust heating:

- 37 vs 46 sink particles
- 15 vs 16 total solar masses

Collapse and Star Formation



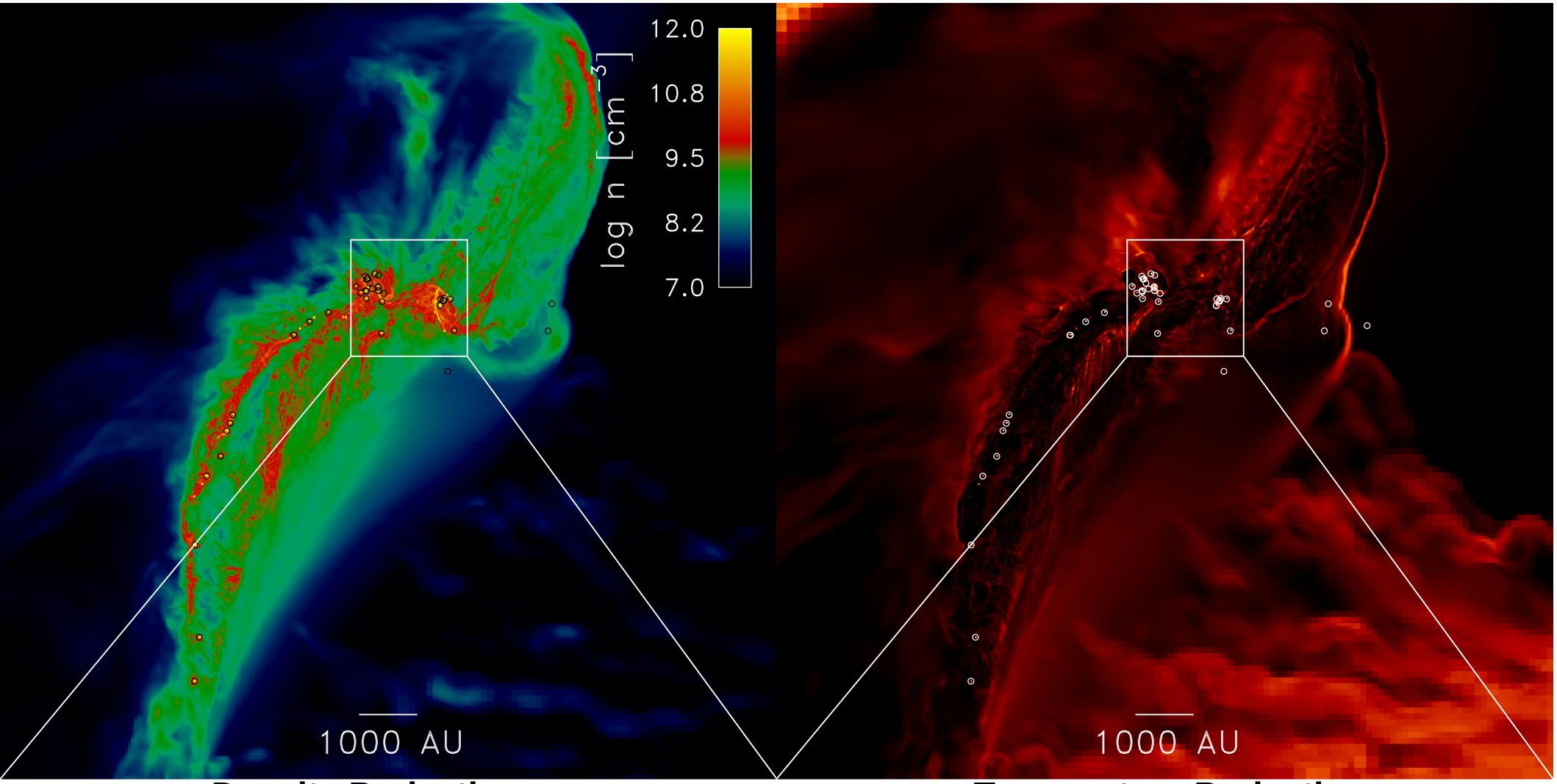
Density Projection



Temperature Projection

Forming in Filamentary Flows

Zooming in on the SF filament

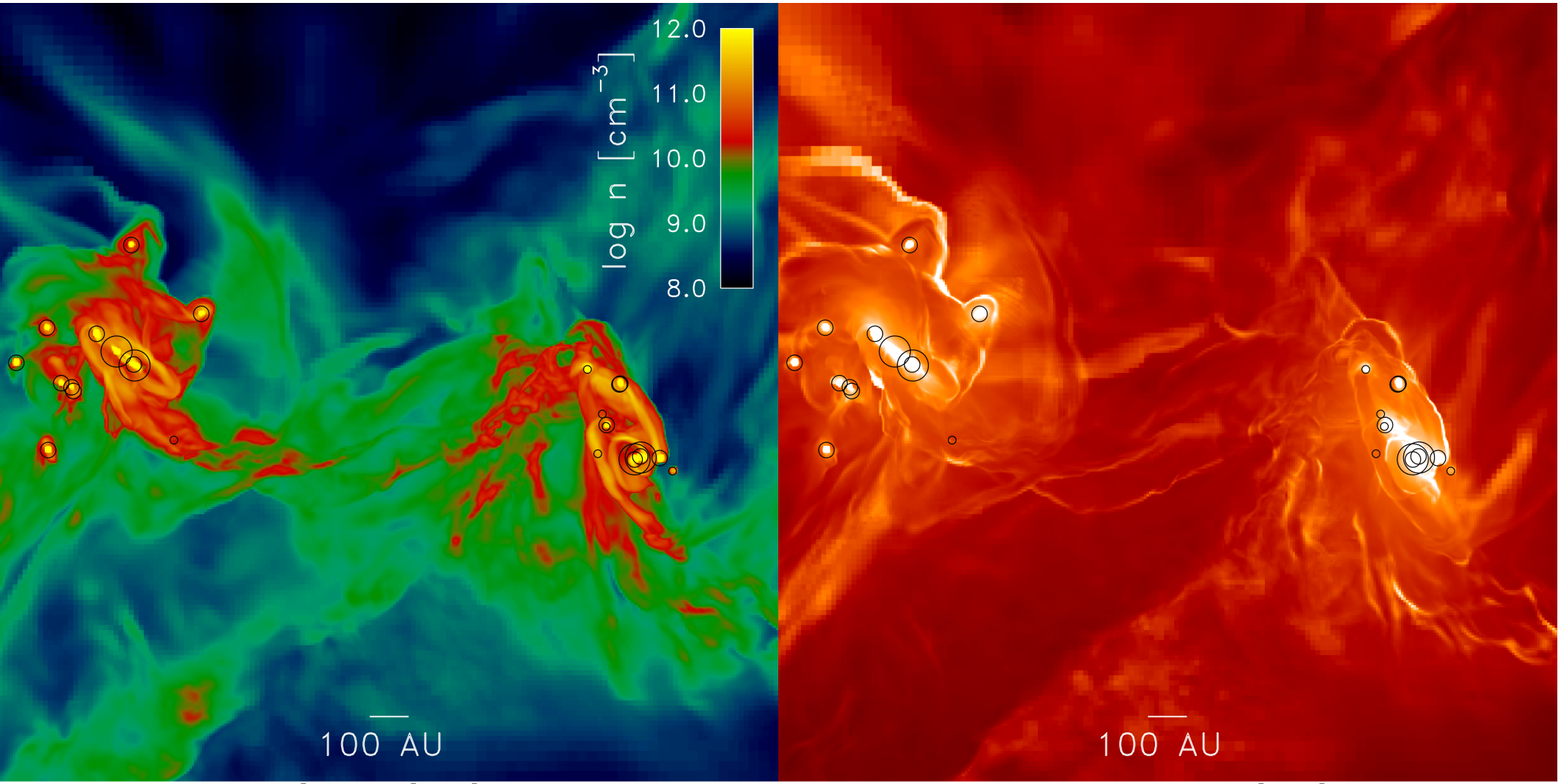


Density Projection

Temperature Projection

Formation in Discy Flows

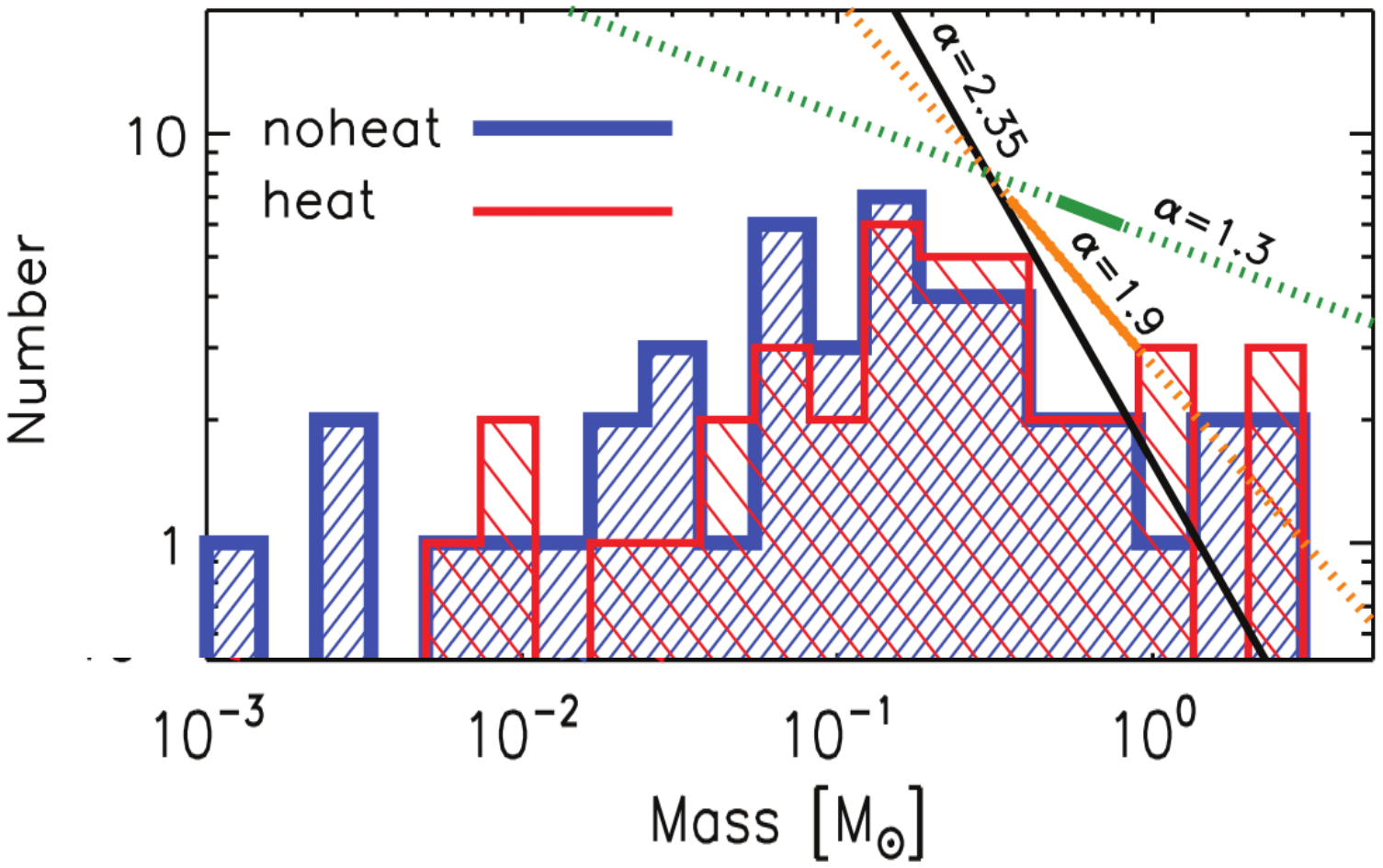
Star forming discs at the core of the flow



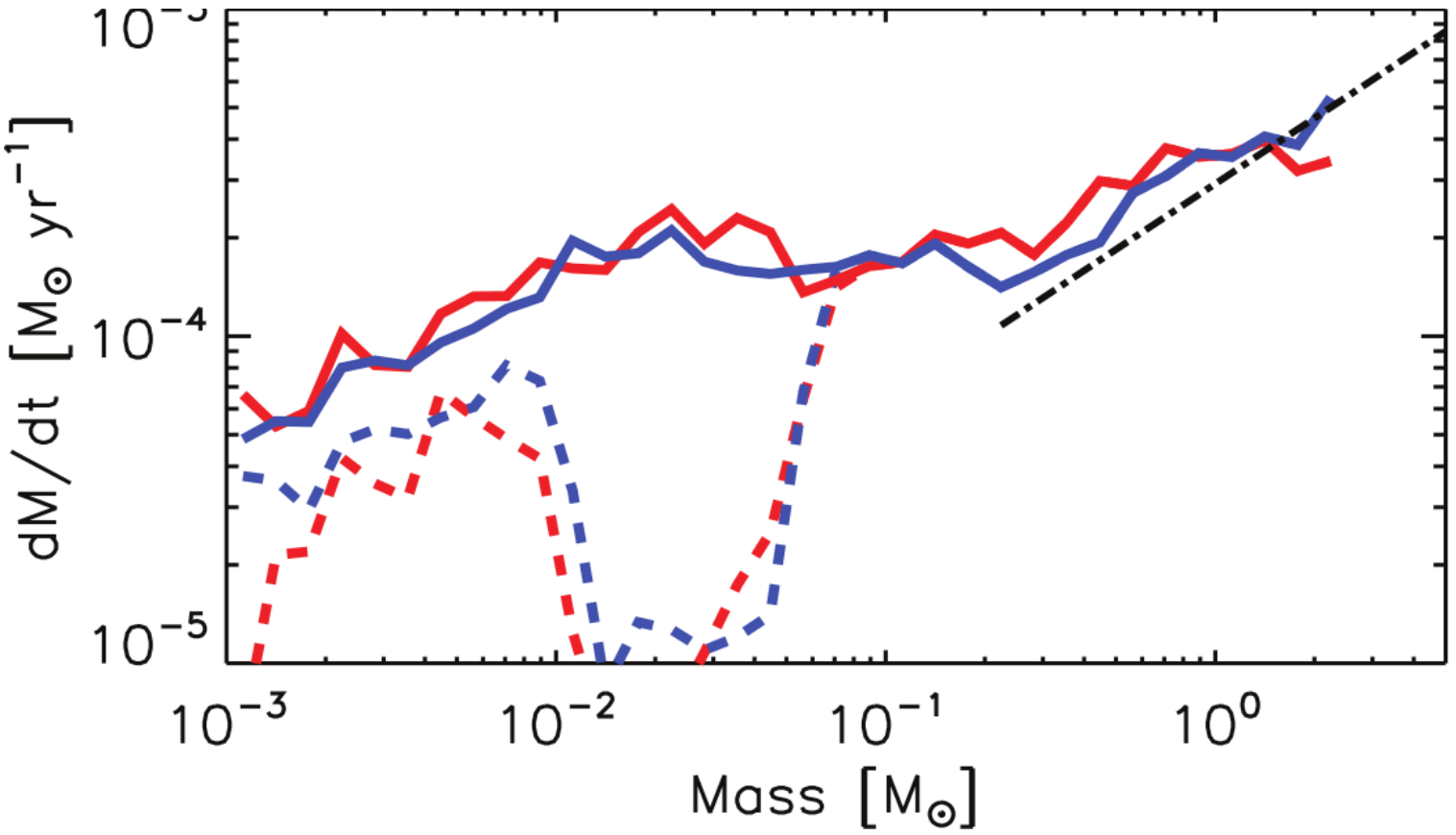
Density Projection

Temperature Projection

Sink Mass Function



Sink Accretion over Time



Summary

Explored to high resolution the first stages of star formation of the first metal stars

Sink IMF is tentatively consistent with UDF galaxies

Dust heating affects low mass fragmentation

What to do from here....

Characterization of role of turbulence

Inclusion of magnetic field support (MHD)

More realistic metal population model (explore inhomogeneities)

With much more computing power...

- Higher resolution to resolve ALL fragmentation
- Run simulation much longer
  - Requires larger box (boundary conditions problems)
  - higher resolution
  - Would need to worry about SF feedback
- Currently unfeasible:
  - Full box simulation down to current res, not cut out