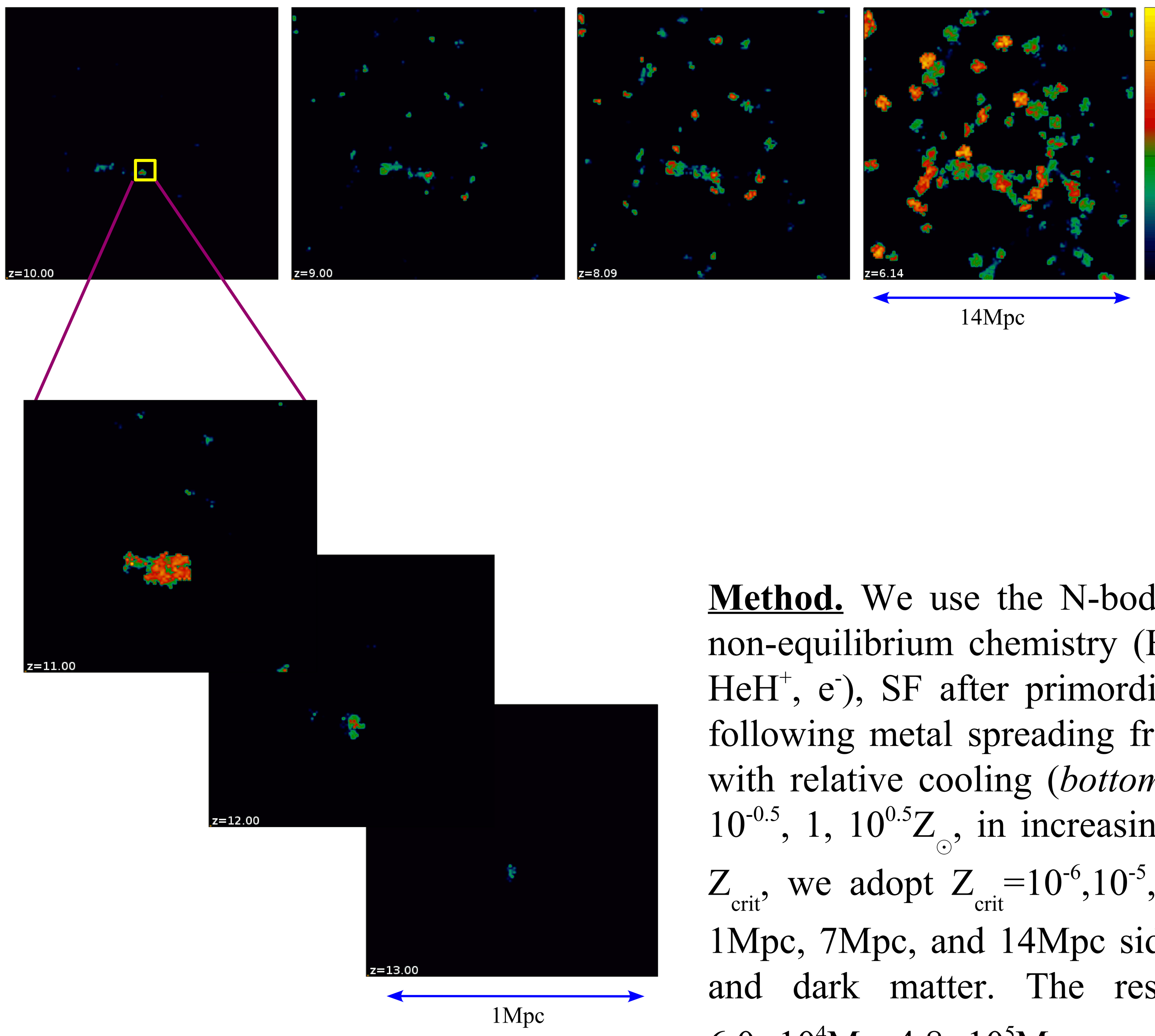
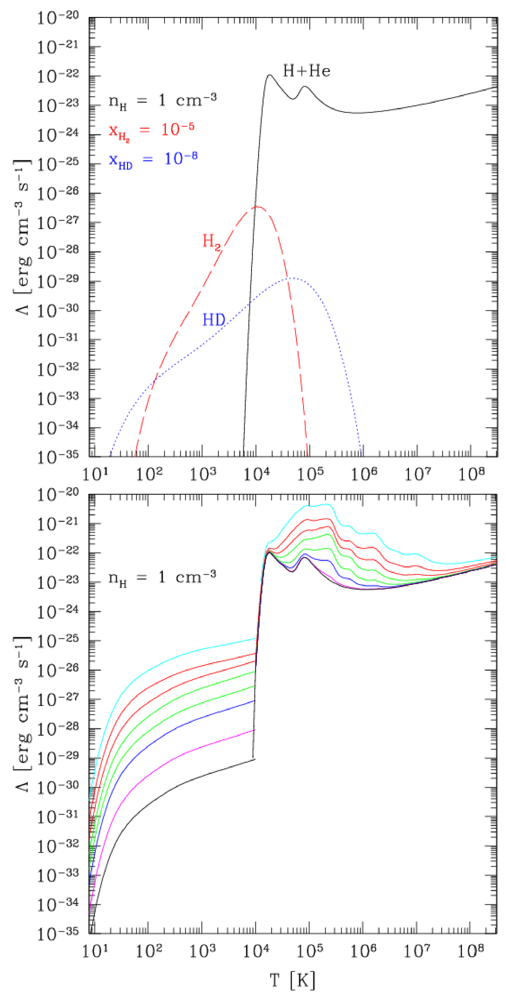
The transition from population III to population II-I

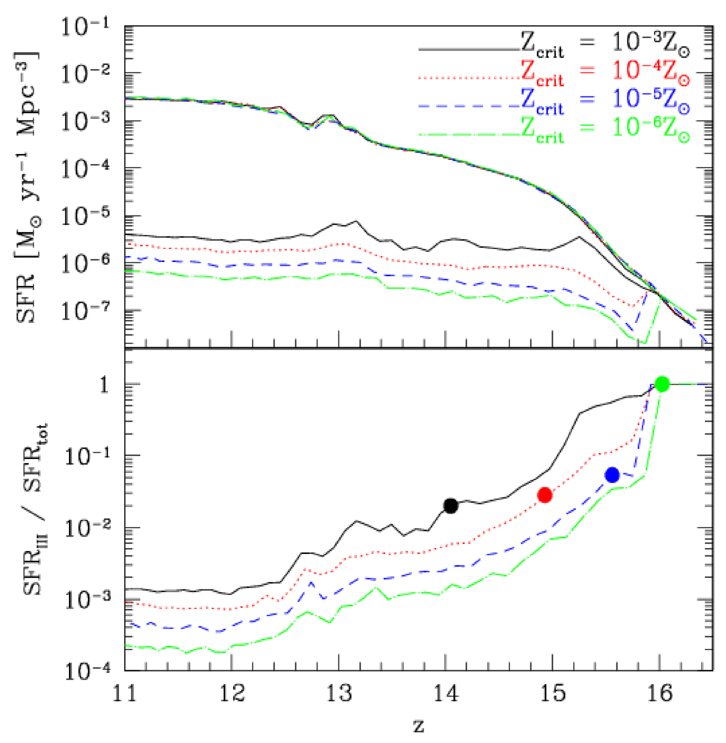
MAX PLANCK SOCIETY



Introduction. The first generation of structures is thought to be characterized by very massive stars, formed out from a pristine medium and described by a top-heavy IMF (population III, hereafter popIII). The successive stars are instead born in a medium pre-enriched of metals by the former generations. When the metallicity (Z) of the environment gets higher than a certain critical value, Z_{crit}, gas cooling is more efficient and the formed stars are smaller and distributed according to a Salpeter IMF, like the ones commonly observed today (population II-I, hereafter popII-I).
In order to address this *transition*, we perform numerical studies (in the frame of the "standard" ΛCDM cosmological model) of the early gas molecular cooling, the onset of primordial, metal-free, cosmic star formation (SF), and the subsequent metal spreading from stellar evolution.

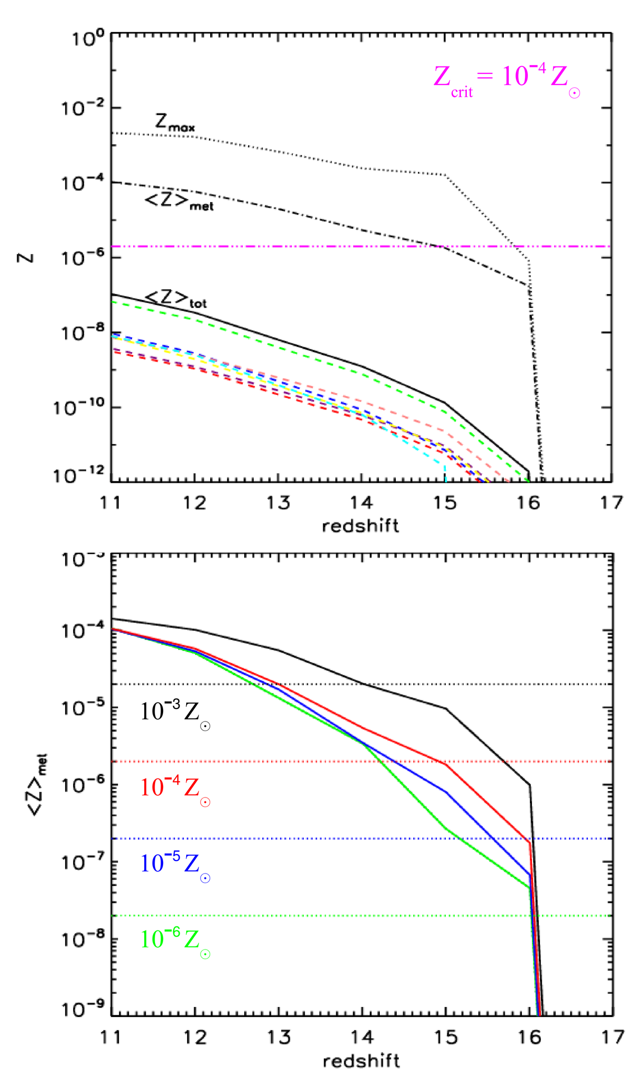
Method. We use the N-body/SPH code Gadget and implement molecular, non-equilibrium chemistry (H, H^+, H^-, He, He^+, He^{++}, H2, $H2^+$, D, D^+, HD, HeH^+, e^-), SF after primordial run-away cooling (see *top-right panel*), and following metal spreading from stellar evolution (C, O, Mg, S, Si, Fe, etc.) with relative cooling (*bottom-right panel*, for Z $=10^{-4}$, 10^{-3}, 10^{-2}, $10^{-1.5}$, 10^{-1}, $10^{-0.5}$, 1, $10^{0.5}Z_{\odot}$, in increasing order). Because of the many uncertainties on Z_{crit}, we adopt $Z_{crit}=10^{-6},10^{-5},10^{-4},10^{-3}Z_{\odot}$. The simulations are performed for 1Mpc, 7Mpc, and 14Mpc side boxes, sampled with $2\cdot 320^3$ particles for gas and dark matter. The resulting SPH mass resolution is $1.6\cdot 10^2 M_{\odot}$, $6.0\cdot 10^4 M_{\odot}$, $4.8\cdot 10^5 M_{\odot}$, respectively.
On the *left panels*, as an example, we show metallicity maps of metal enrichment at high redshift (z). We refer to $Z_{crit}=10^{-4}Z_{\odot}$.





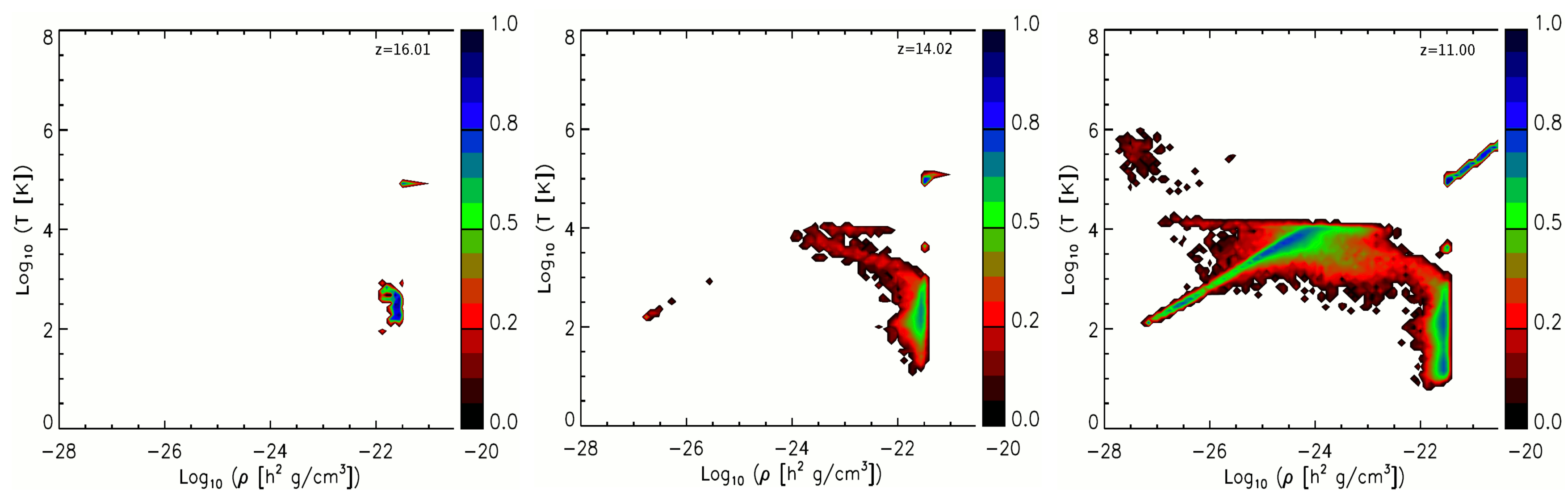
SFR for different Z_{crit}.

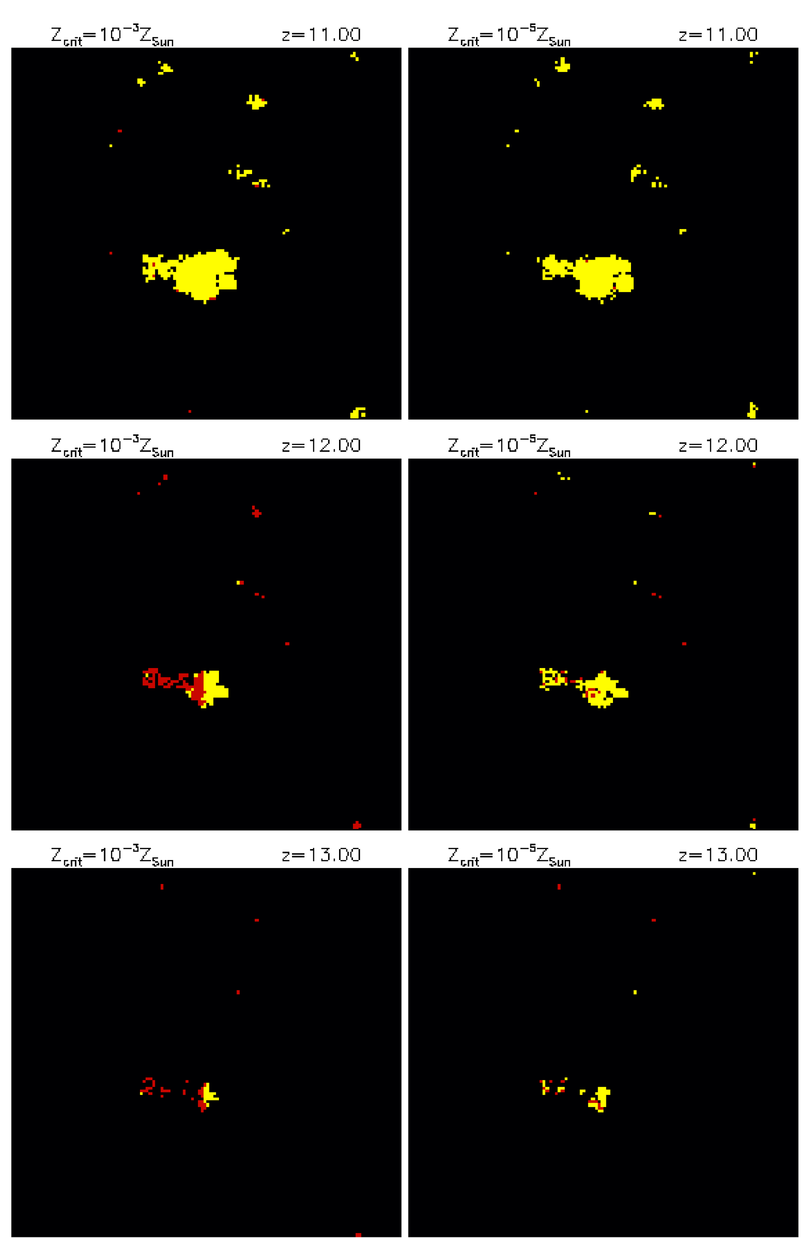
Star formation rates (SFR) for the 1Mpc simulations, corresponding to the four values adopted for Z_{crit}.
Top panel. Total SFRs are the upper lines; popIII SFRs are the lower lines.
Bottom panel. Corresponding popIII average contributions. Dots refer to the redshift when the average enrichment reaches Z_{crit}.



Metal pollution for different Z_{crit}.

Average enrichment for the $1Mpc^3$ boxes.
Top panel. Metallicity evolution for $Z_{crit}=10^{-4}Z_{\odot}$. Dotted line: maximum metallicity; dot-dashed line: average pollution; solid line: average metallicity in the whole box; dashed lines: individual metal contributions - C (blue), O (green), Mg (red), S (purple), Si (pink), Fe (yellow), and other metals (cyan).
Bottom panel. Average pollution (solid lines) for different Z_{crit} (horyzontal, dotted lines, as indicated by the labels).





Mixing primordial and enriched gas.

Upper panels. Phase diagram evolution with the corresponding probability distribution (see color scale), for the box of $1Mpc^3$, and $Z_{crit}=10^{-4}Z_{\odot}$. Metal enriched SPH particles have been chosen: after the onset of SF, as time passes, many metals are ejected, by wind feedback, from the dense, cold regions into the peripheral areas.
Left panels. Because of gas mixing, and the strong PISN metal yields, popIII sites (red in the maps) are found only in rare, isolated regions, or on the border of SF regions. This behaviour is quite independent from the Z_{crit} and the box size.

Conclusions. We have studied the popIII/popII-I *transition* via numerical simulations including non-equilibrium chemistry and metal pollution from stellar evolution. We found that, because of the high PISN yields and metal spreading, it happens in a short lapse of time and, independently from Z_{crit}, the dominant SF regime is soon the popII-I one.

References:
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