Institute for Astronomy

The First Billion Years Simulations

The First Billion Years Simulation (FiBY)

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with

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The FiBY Project

Reduce 'the mass gap' by following the formation of galaxies from primordial star formation in min-haloes to massive haloes during the first billion years of the Universe

- GADGET-2 version used for the OWLS project (Schaye et al. 2010): SF; metal enrichment; metal line cooling from 11 elements; BH growth and feedback
- Thermal SN feedback (Dalla Vecchia & Schaye)
- Added molecular networks and cooling
- Added POPIII formation, evolution, and yields; seed BHs
- Added dust from PISN, AGB & SNII; thermal sputtering
- Inclusion of Lyman-Werner background (11.3 - 13.6 eV)
- Self-shielding against radiation
- Coupled to radiative transfer scheme SIMPLEX in post-processing

$$V = (8\mathrm{Mpc})^3$$
$$N = 2 \times 1368^3$$
$$m_{gas} = 890 M_{\odot} h^{-1}$$
$$m_{DM} = 4375 M_{\odot} h^{-1}$$

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FiBY Simulation Suite

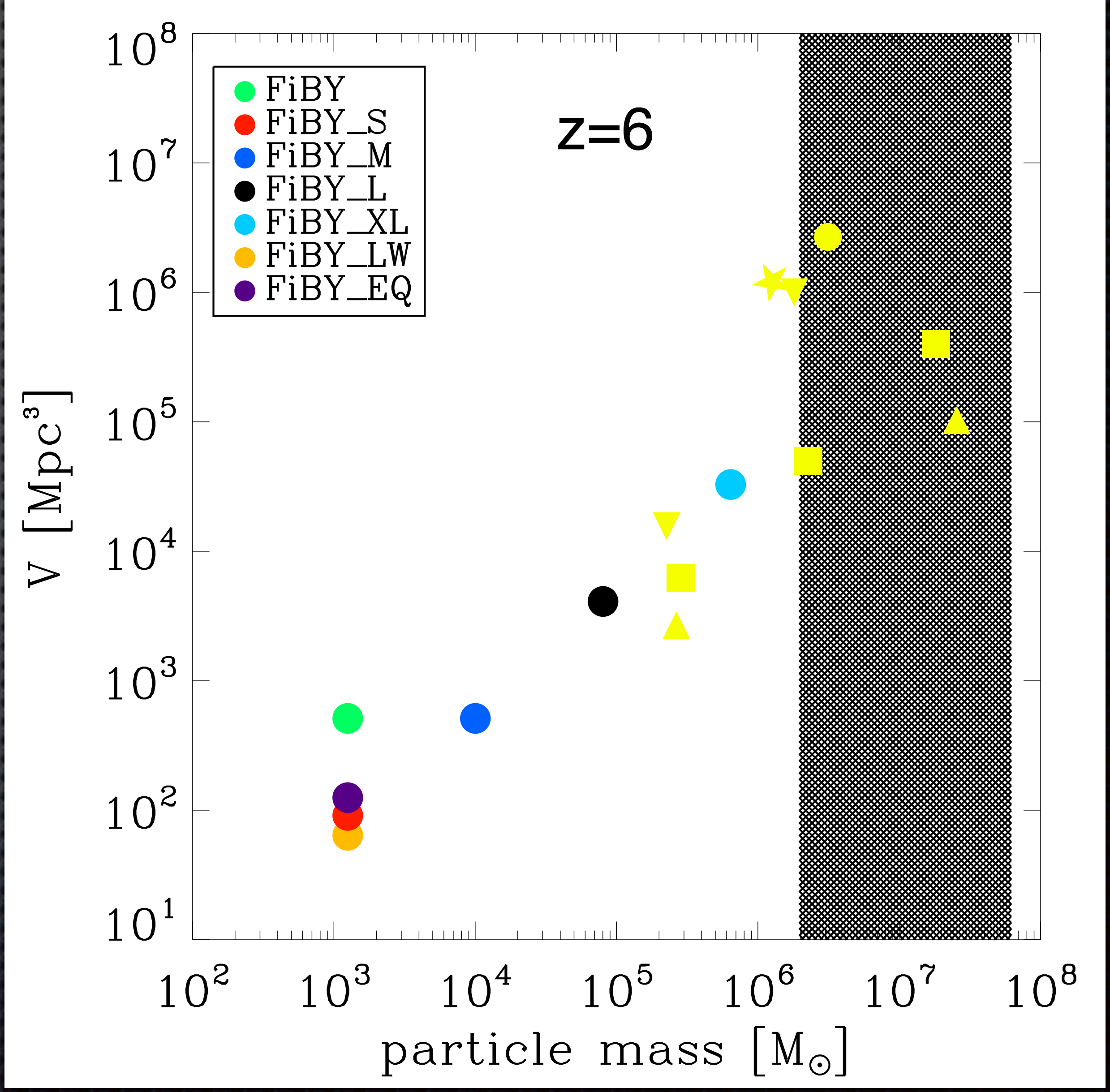
Run	L[Mpc/h]	M_{SPH} [$M_\odot/h$]	M_{DM} [$M_\odot/h$]	N_{SPH}	N_{DM}	ϵ [pc]	n_{SF} [cm^{-3}]	z_f	colour
FiBY	5.68	890	4372	1368^3	1368^3	234	10	8.6	green
FiBY_S	2.84	890	4372	684^3	684^3	234	10	6	red
FiBY_M	5.68	7120	3.5×10^4	684^3	684^3	453	10	6	dark blue
FiBY_L	11.36	56960	2.8×10^5	684^3	684^3	935	10	4	black
FiBY_XL	22.72	455680	2.24×10^6	684^3	684^3	1870	10	4	light blue
FiBY_LW	2.84	890	4375	684^3	684^3	234	10	6	yellow
FiBY_EQ	2.84	890	890	684^3	1121^3	143	10	6	purple
FiBY_DMO	2.84	–	4375	–	684^3	234	–	6	–

- Resolve the Jeans mass at the onset of molecular hydrogen cooling.

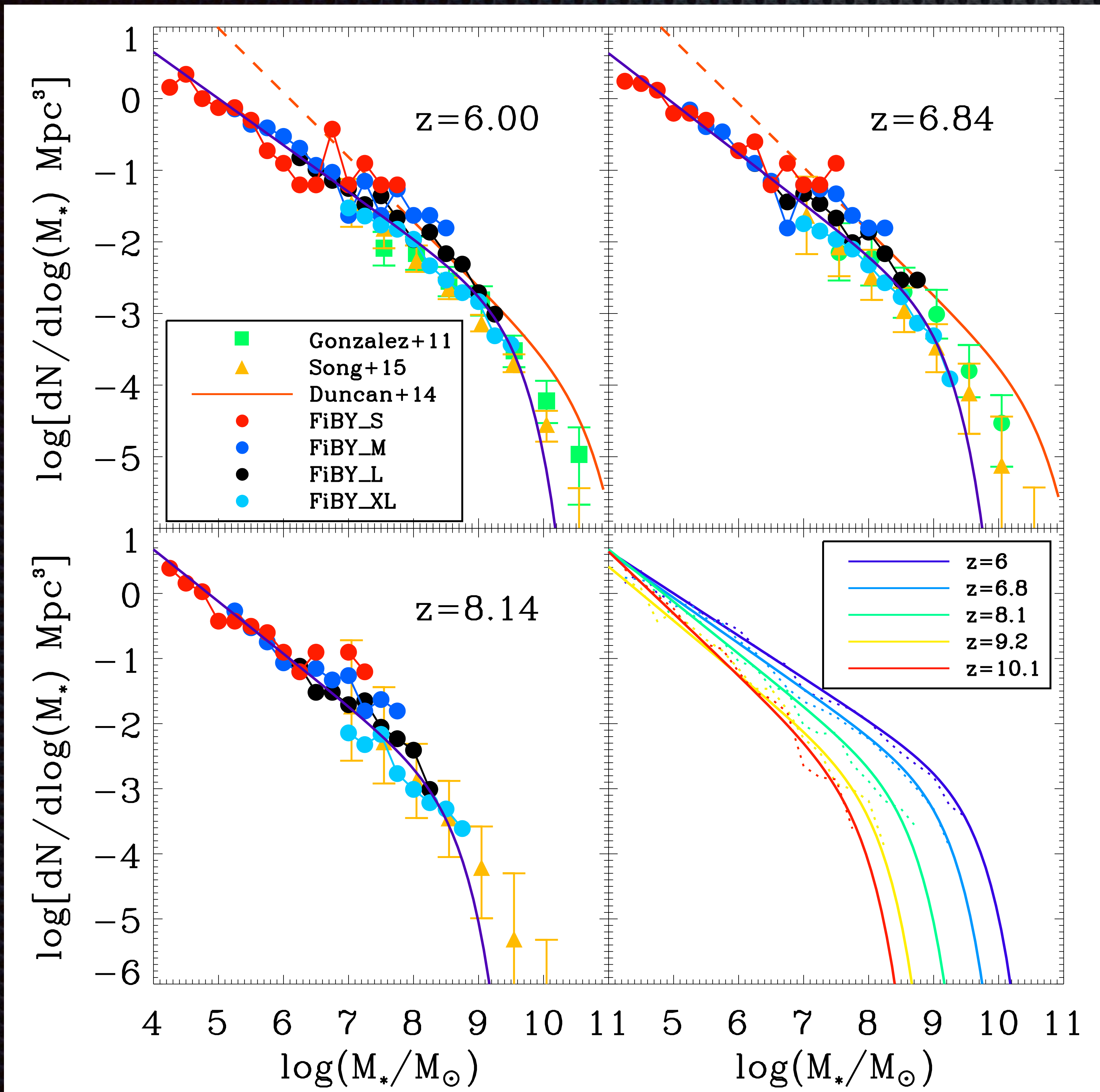
  At ~1/ccm, H_2 formation kicks in via:

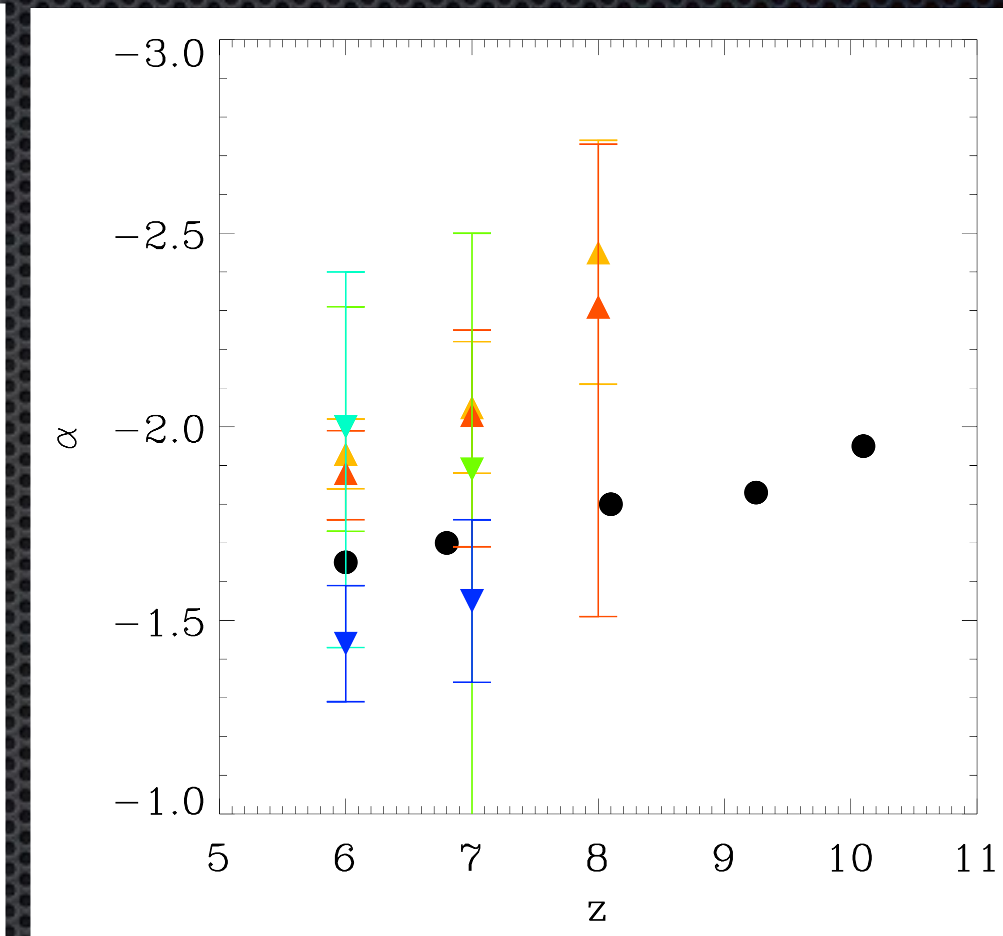
$$H^- + H \rightarrow H_2^- \rightarrow H_2 + e^-$$

- Dynamical range in mass, volume and resolution covered is complementary to existing simulations at z=6



Stellar Mass function





Khochfar+16, in prep

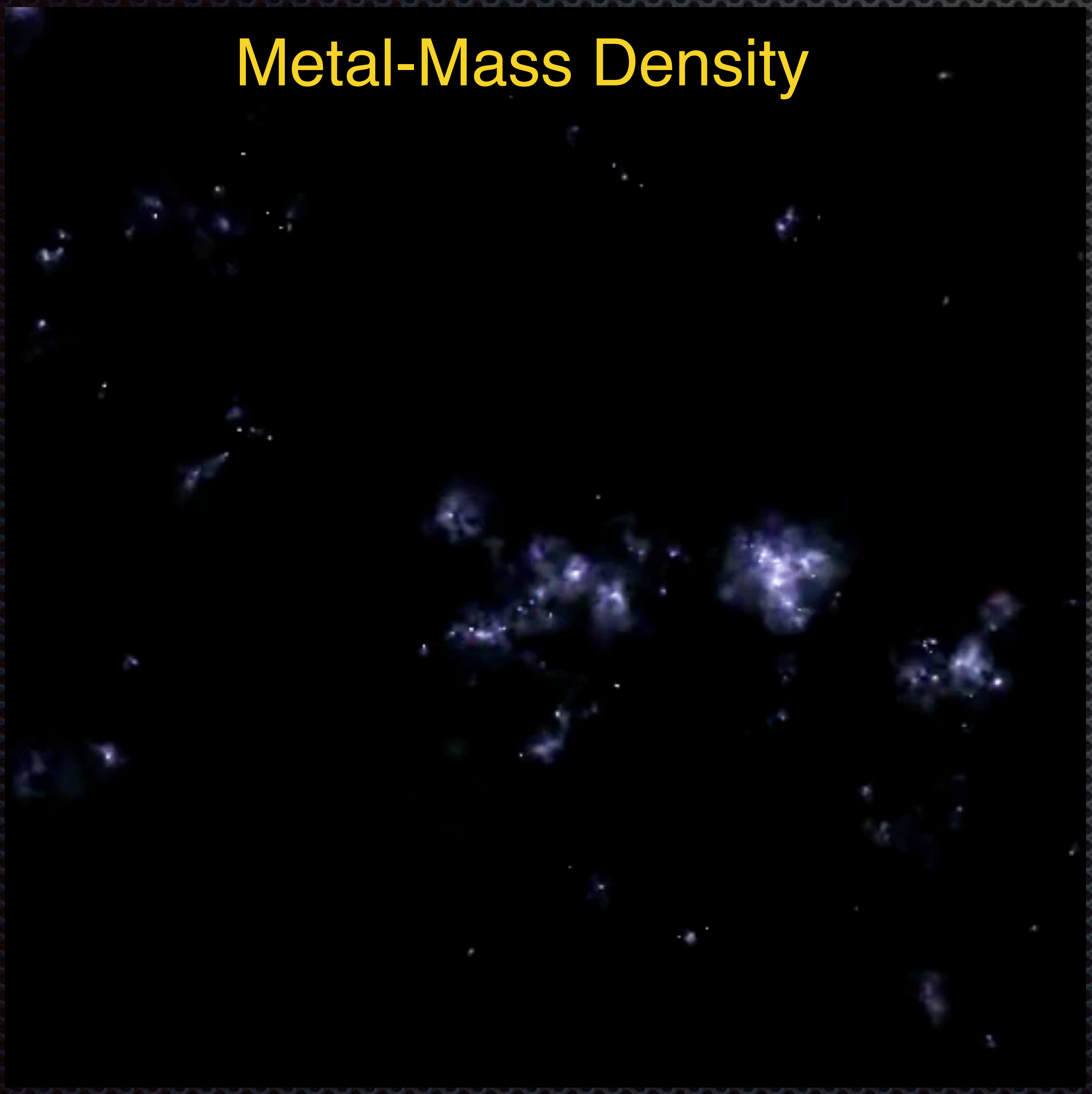
- Predicted low-mass-slope is lower than the one extrapolated from observations.
- Limited observed dynamical range of masses biases towards steeper slopes.
- Slope gets steeper at high z

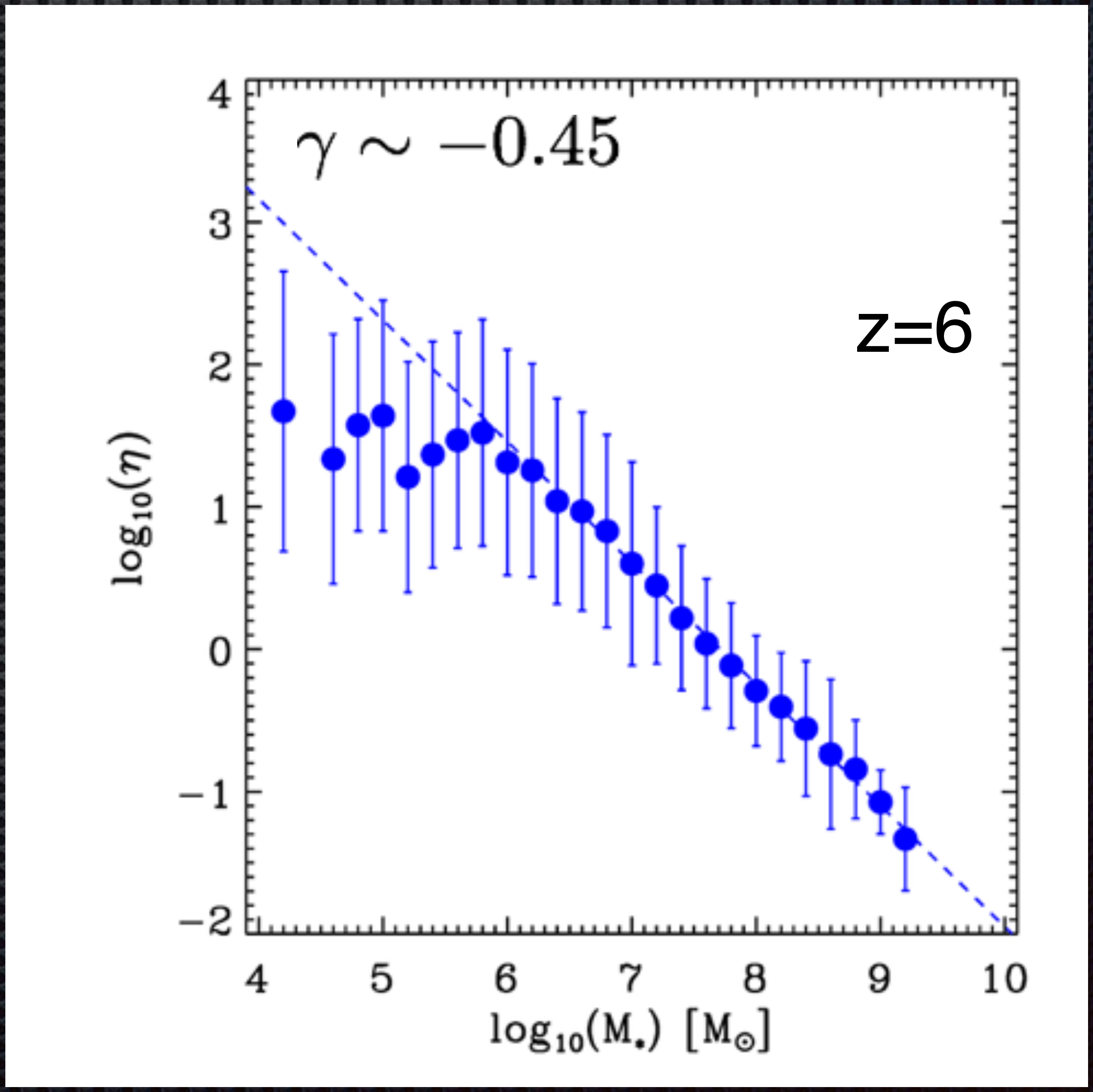
SN Feedback

Mass loading:

$$\dot{M}_* \propto M_*^{0.9} \rightarrow M_*^{0.9}(1+\eta) \propto M_{DM}^{1.15}$$

$$\eta = \frac{\dot{M}_{outflow}}{SFR}$$





Movie: C. Dalla Vecchia

Dalla Vecchia & Khochfar 2016, in prep

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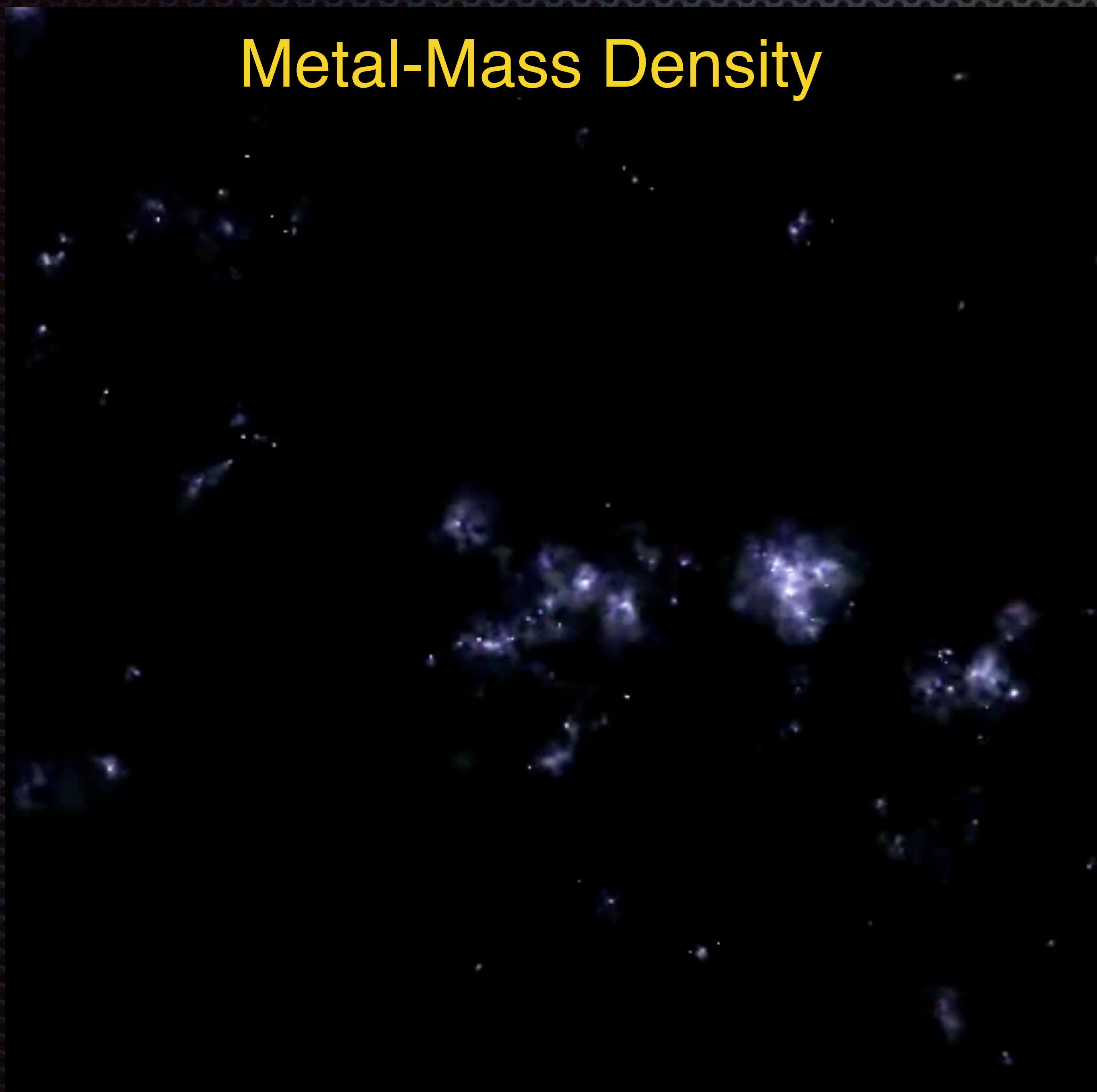

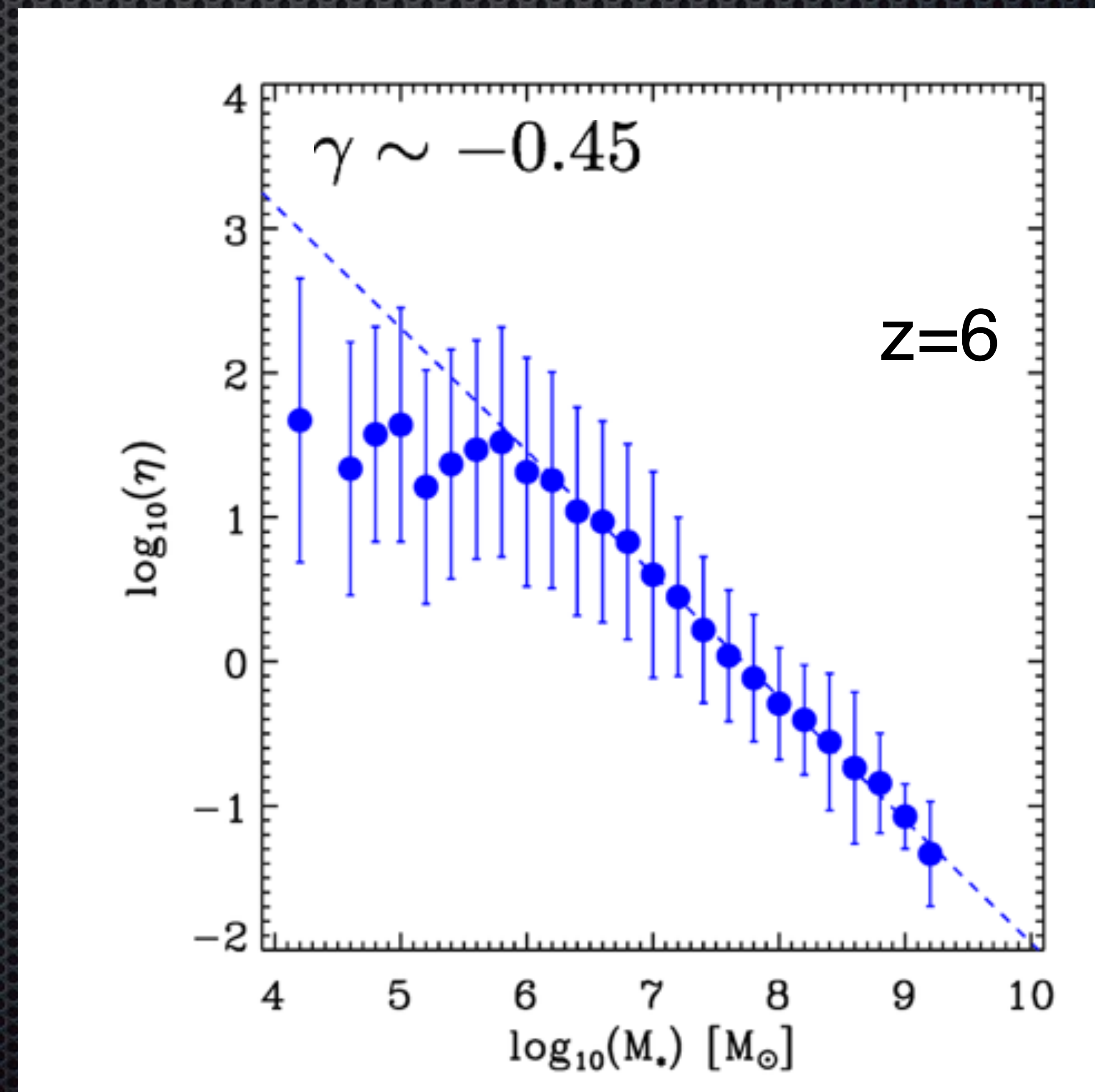

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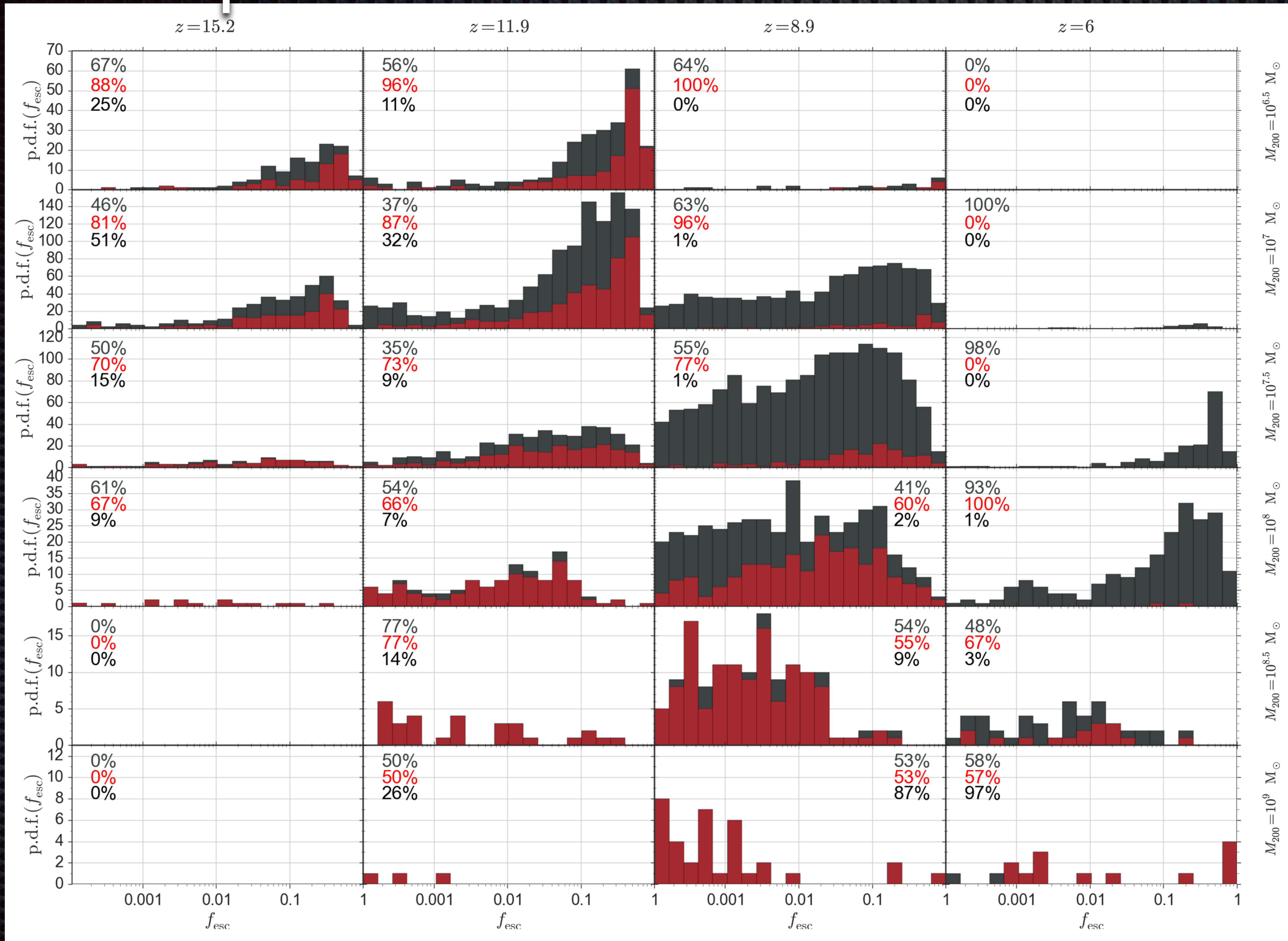
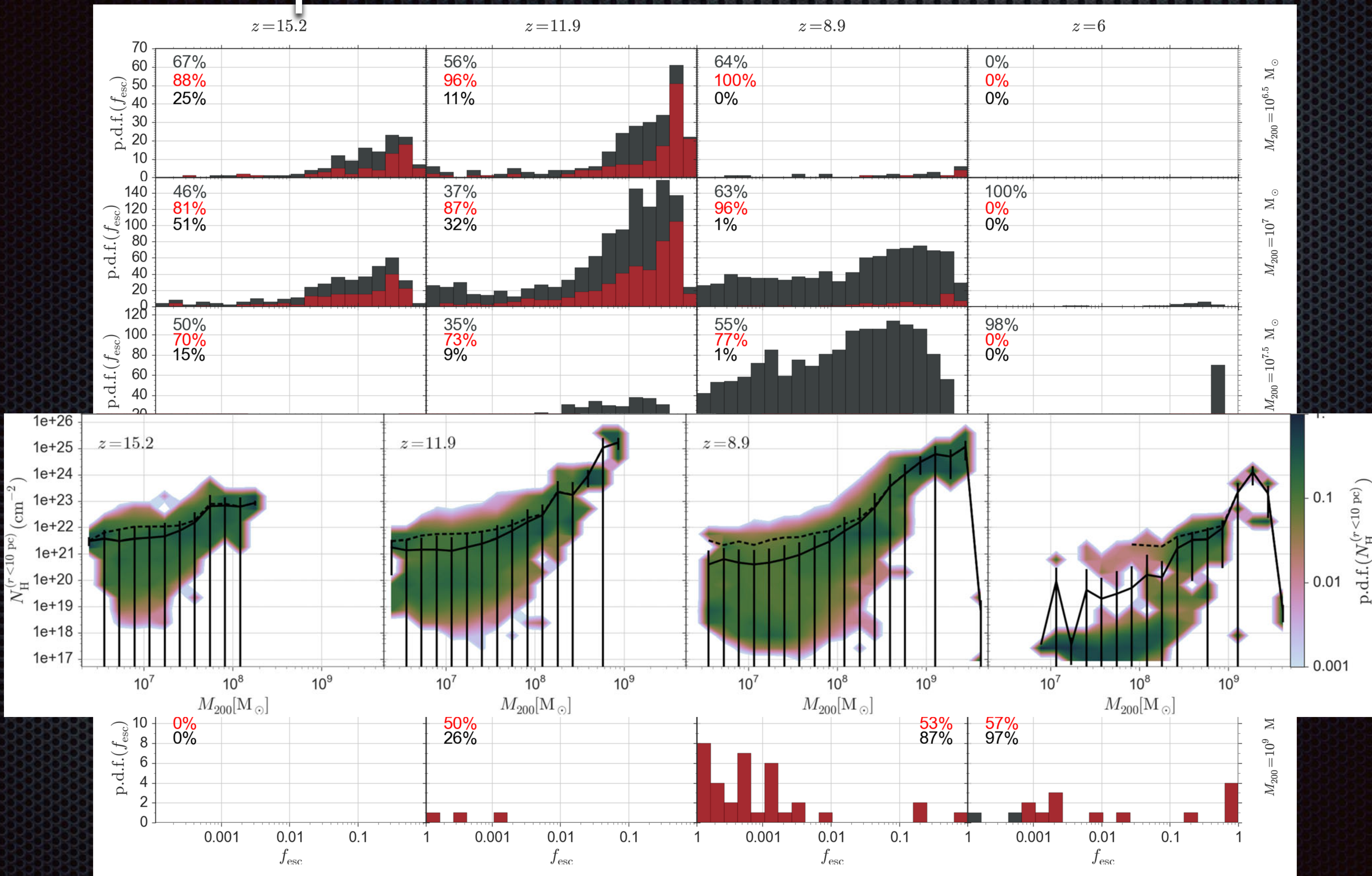
Escape Fractions



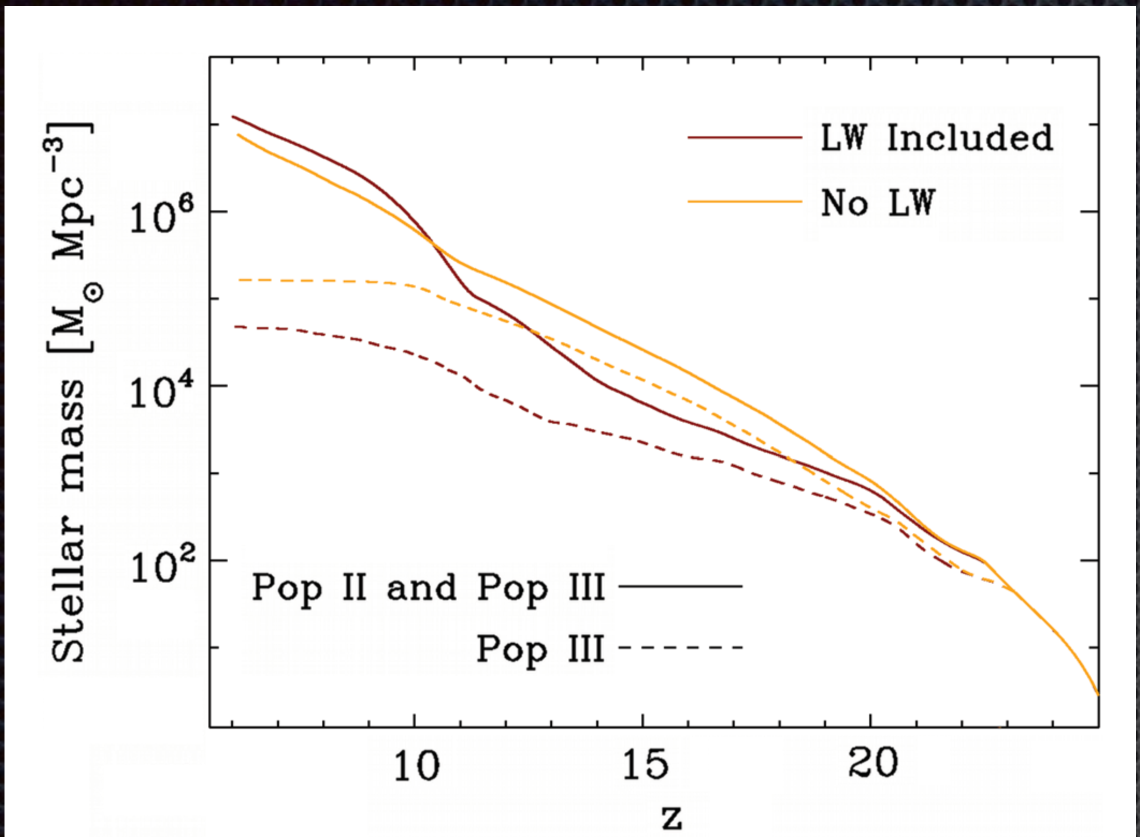
Paardekooper, SK et al. 2015

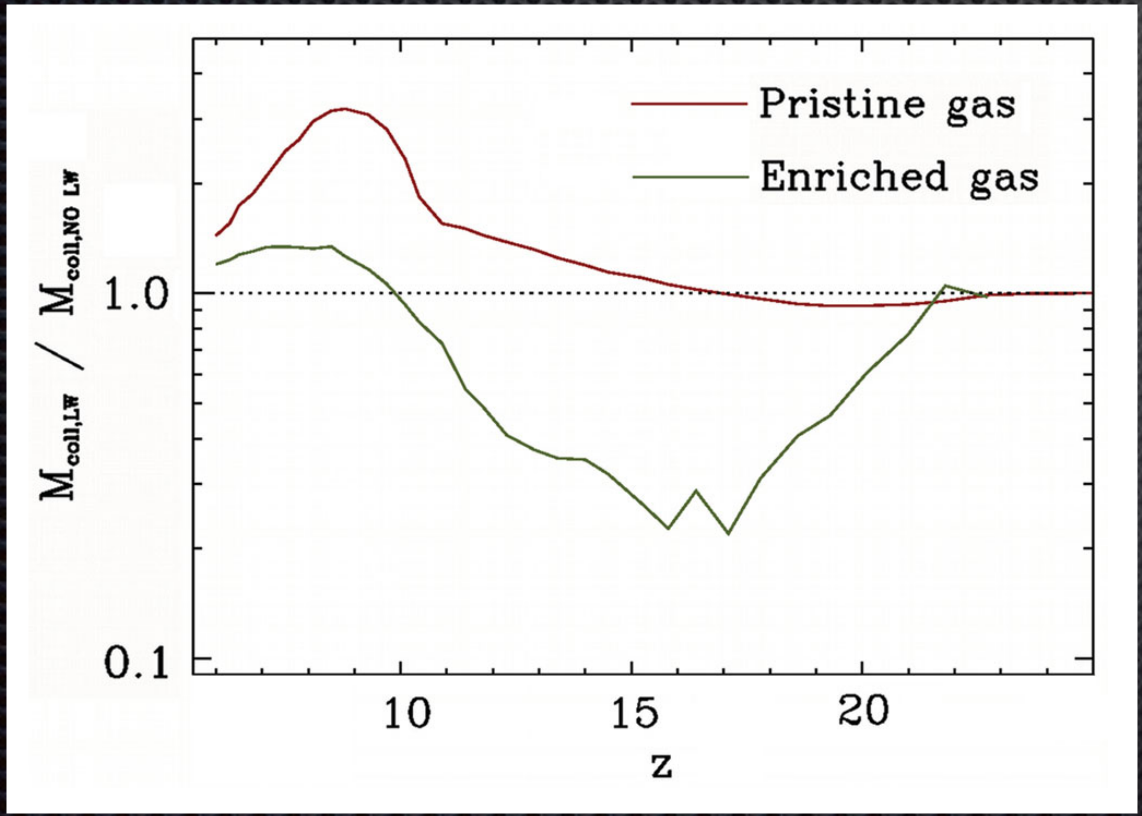
Escape Fractions

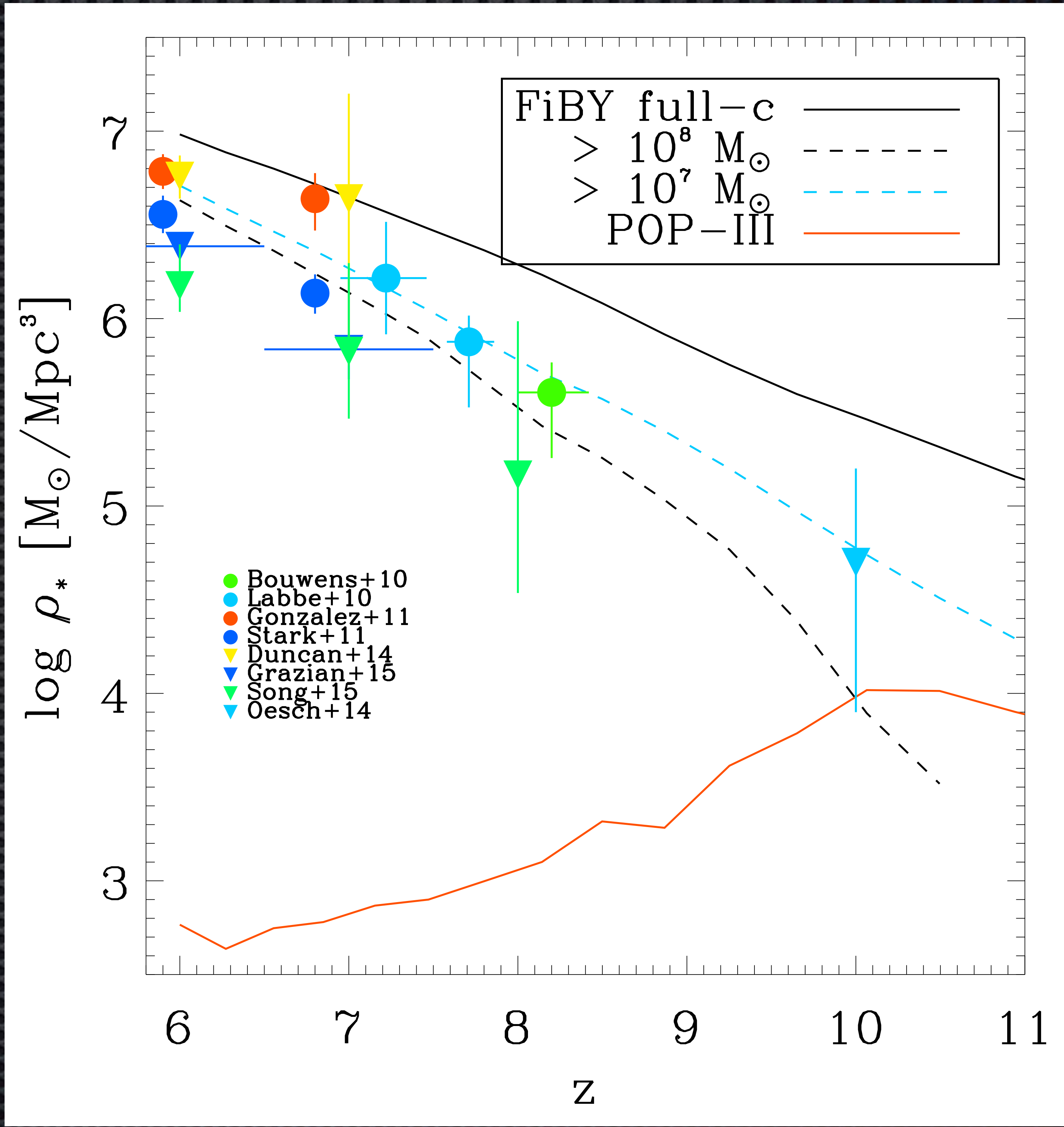


Paardekooper, SK et al. 2015

Role of POP-III Stars



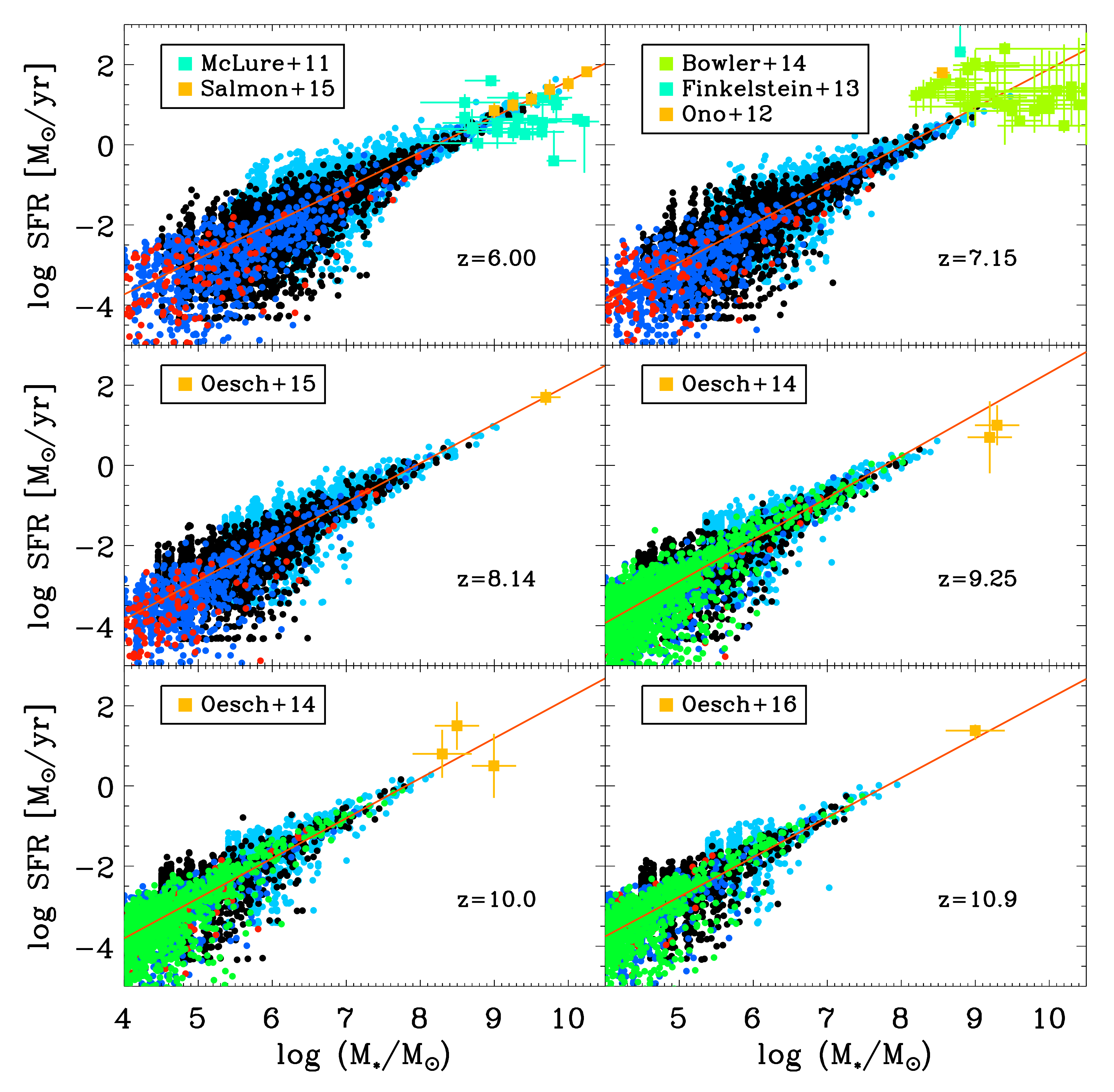




Khochfar+16, in prep

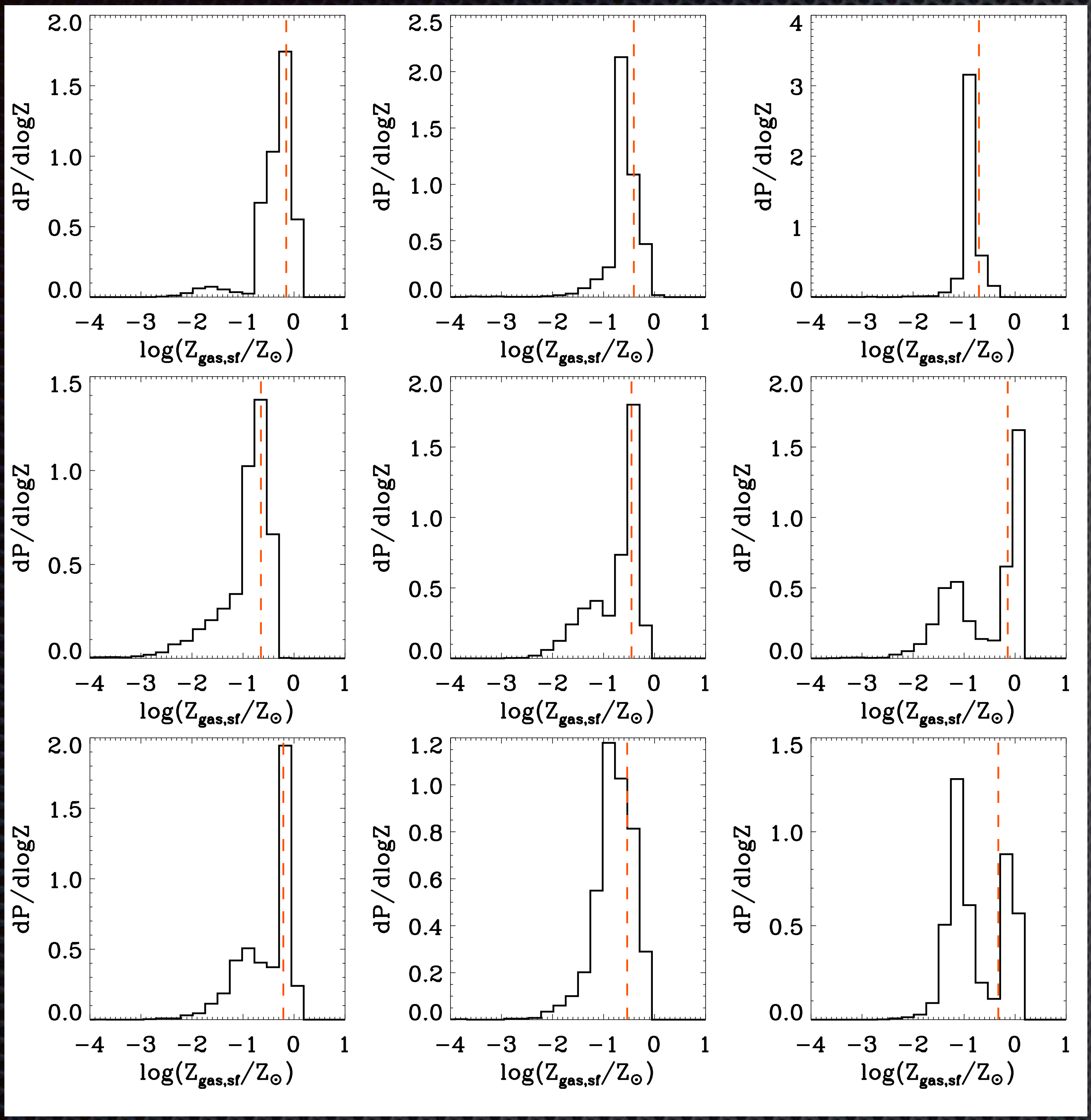
Johnson, Dalla Vecchia & SK 2013

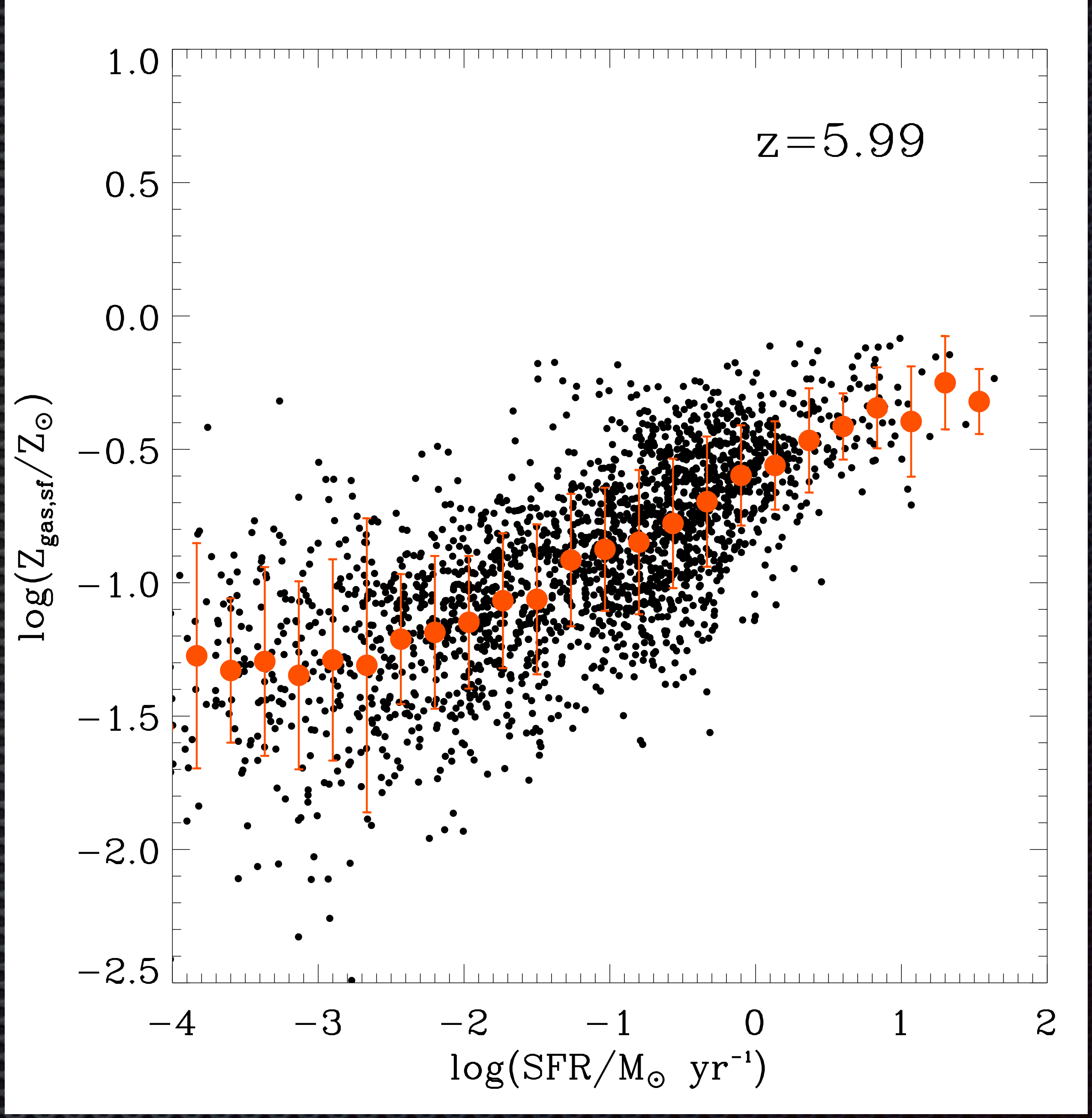
SFR Main Sequence



Khochfar+16, in prep.

SFR-Metallicity





Summary

- Supernovae feedback regulates the low-mass slope of the GSMF, through two modes: 1. directly regulating SF in the lowest mass galaxies; 2. reducing the baryon fraction accreting onto more massive haloes
- Low mass slopes are > -2 at $z > 10$
- Escape fractions decline towards massive galaxies, and low mass galaxies drive re-ionization the Universe
- The metallicity of the ISM for SFRs ~ 10 solar masses/yr is on average 0.5 solar but shows a large scatter
- Cold accretion flows are enriched in the ISM before getting converted into stars