Boosting the Lyman-alpha line from stochastic IMF sampling

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In collaboration with Lluis Mas-Ribas (Oslo) and Mark Dijkstra (San Francisco)

Bariloche, 2017

Effects of star-formation stochasticity on the Lyα and Lyman continuum emission from dwarf galaxies during reionization

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1206.0726

BOOSTING LYα AND He II λ1640 LINE FLUXES FROM POPULATION III GALAXIES: STOCHASTIC IMF SAMPLING AND DEPARTURES FROM CASE-B

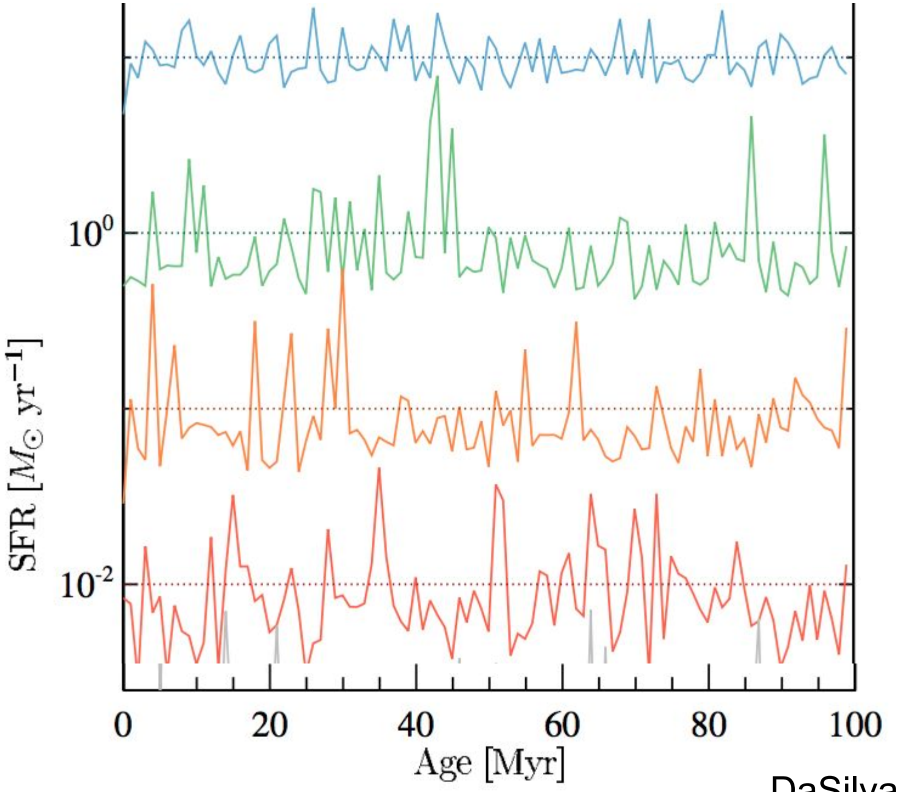
Lluís Mas-Ribas[1], Mark Dijkstra[1], and Jaime E. Forero-Romero[2]

1609.02150

Stochasticity arises from incomplete IMF sampling at low SFR

$$\xi(m)\,dm = m^{-\alpha}\,dm$$

Stochasticity shows up at low star formation rates



DaSilva, Fumagalli, Krumholz (2012)

A simple computational setup to follow the Lya EW

$$\mathrm{EW} \equiv \frac{L_{\mathrm{Ly}\alpha}}{L_{\lambda,\mathrm{UV}}} = \frac{\lambda_{\mathrm{UV}}}{\nu_{\mathrm{UV}}} \frac{L_{\mathrm{Ly}\alpha}}{L_{\nu,\mathrm{UV}}}$$

Salpeter IMF in the mass range 0.08-120 Msol + Constant SFR + All stars are formed in clusters + CMF with slope of 2.

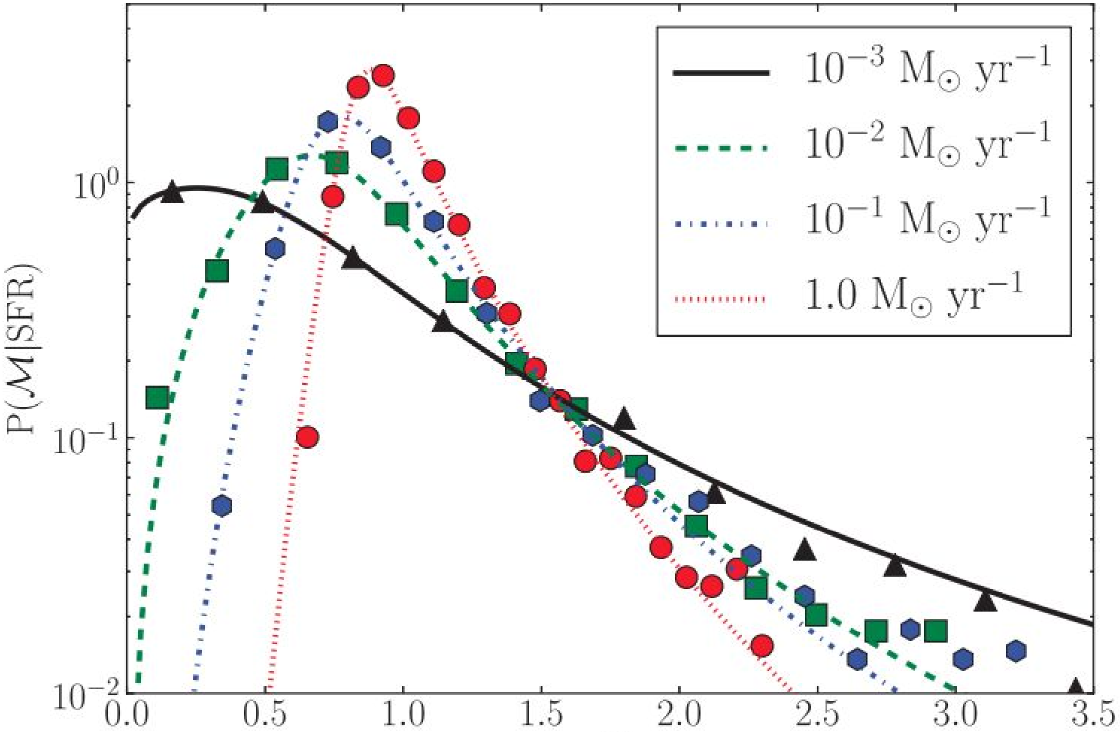
JEFR&Dijkstra (2012)

A simple scalar to quantify deviations in Lya EW

$$\mathcal{M} \equiv \frac{\mathrm{EW}}{\mathrm{EW}_0}$$

JEFR&Dijkstra (2012)

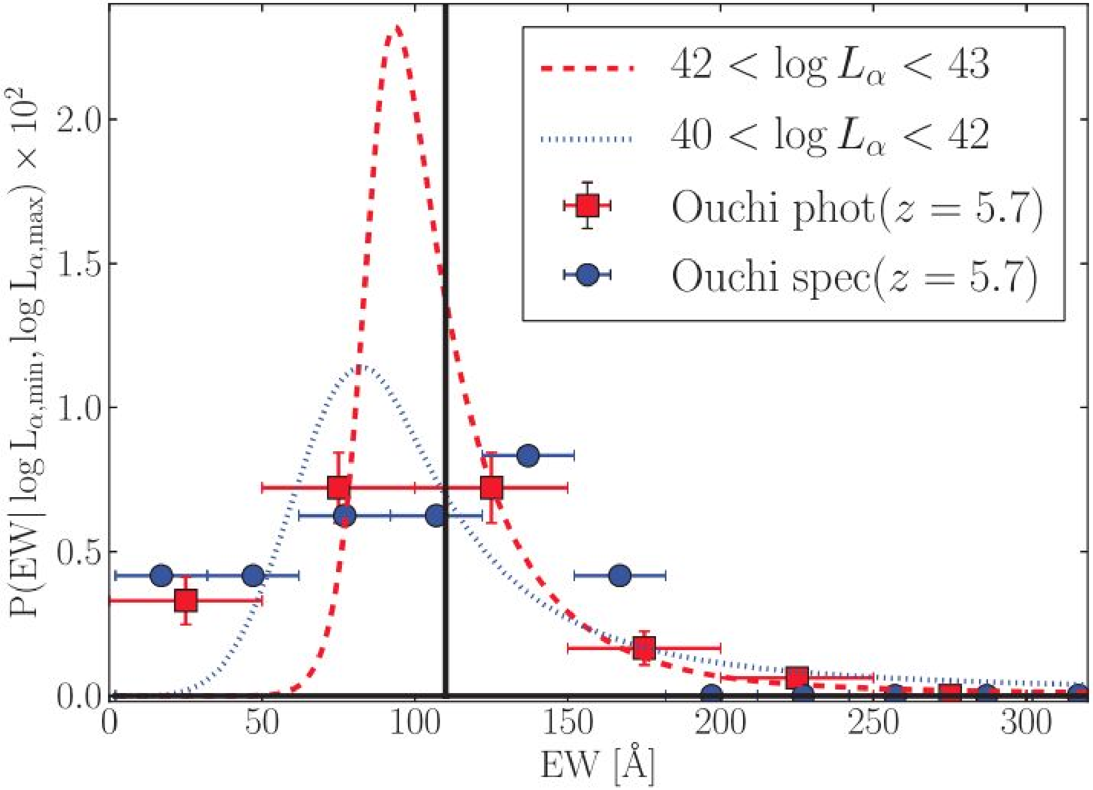
Stochasticity clearly impacts the Lya EW



$$\mathcal{M} \equiv \frac{\mathrm{EW}}{\mathrm{EW}_0}$$

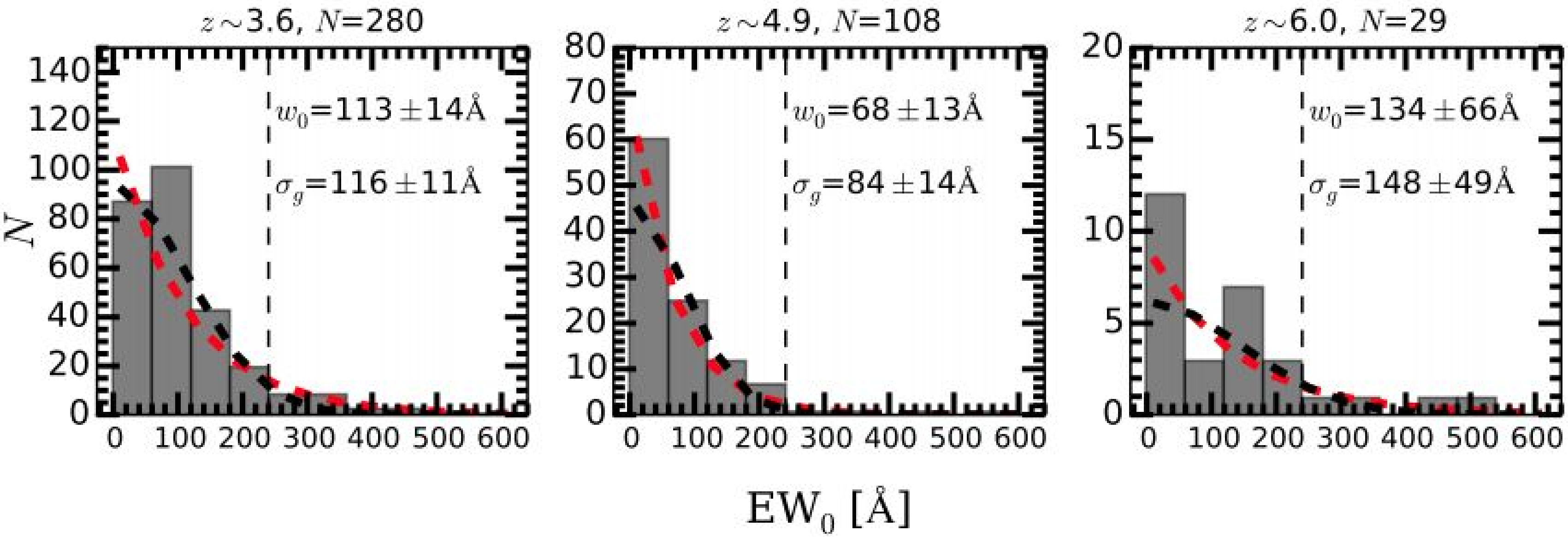
JEFR&Dijkstra (2012)

Stochasticity contributes to obs. EW Lya distributions



JEFR&Dijkstra (2012)

Stochasticity contributes to obs. EW Lya distributions



Hashimoto+2017

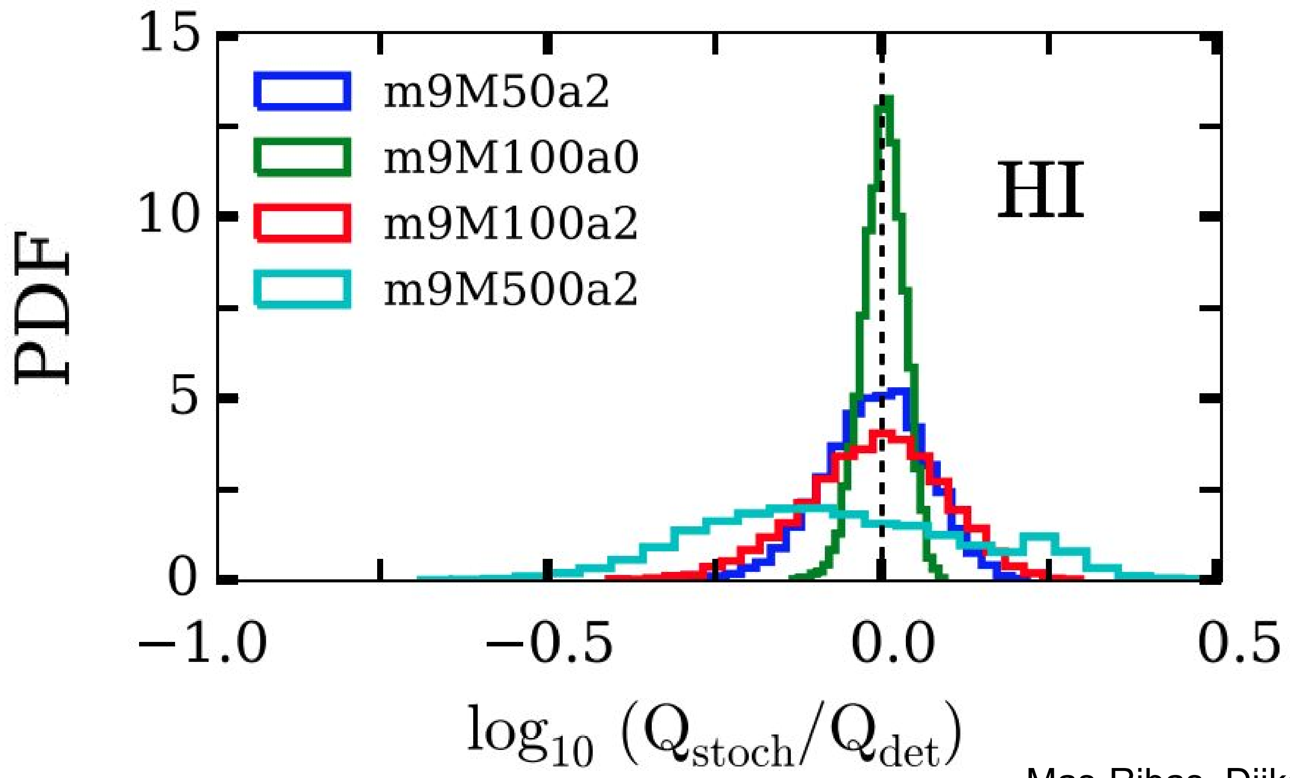
A simple computational setup to follow the Lya line in Pop III galaxies

Model	M_{min} [a]	M_{max} [a]	α
m9M50a0	9	50	0
m9M50a2	9	50	2.35
m9M100a0	9	100	0
m9M100a2	9	100	2.35
m9M500a0	9	500	0
m9M500a2	9	500	2.35
m50M1000a0	50	1000	0
m50M1000a2	50	1000	2.35

Different IMF + Pop III stellar tracks + Constant SFR + All stars are formed unclustered.

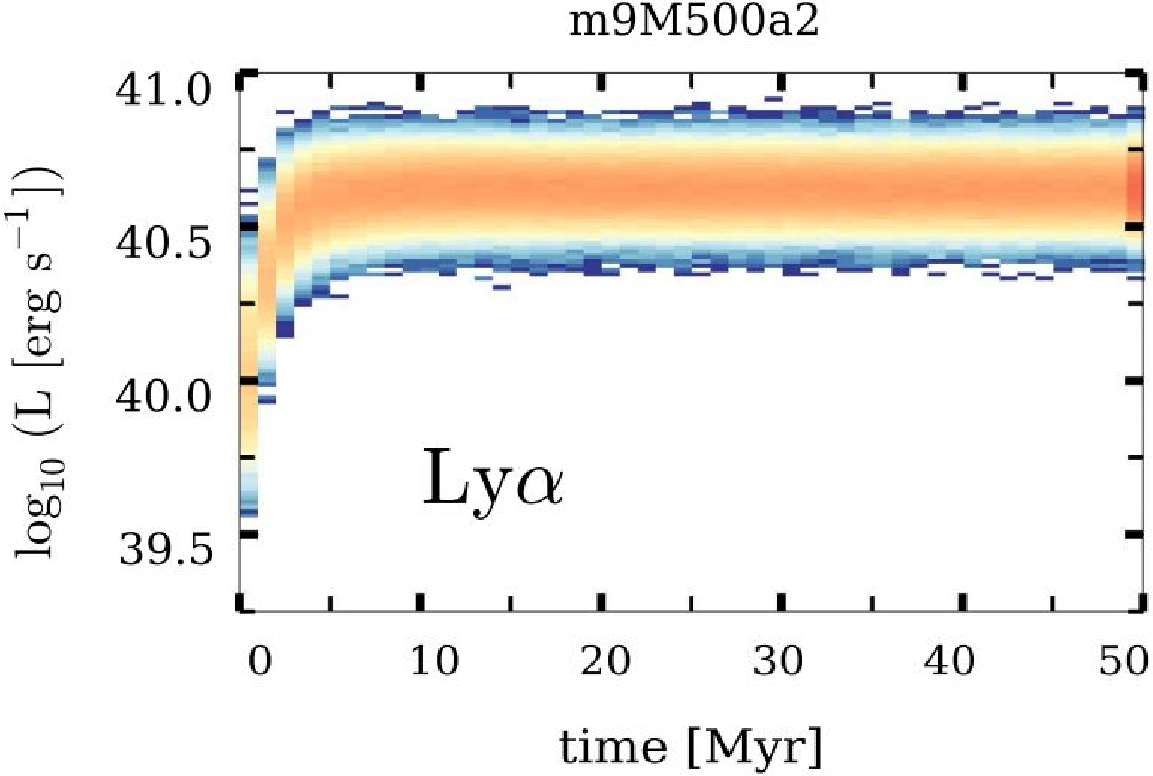
Mas-Ribas, Dijkstra, JEFR (2016)

5x HI ionizing rate fluctuations for some IMF choices



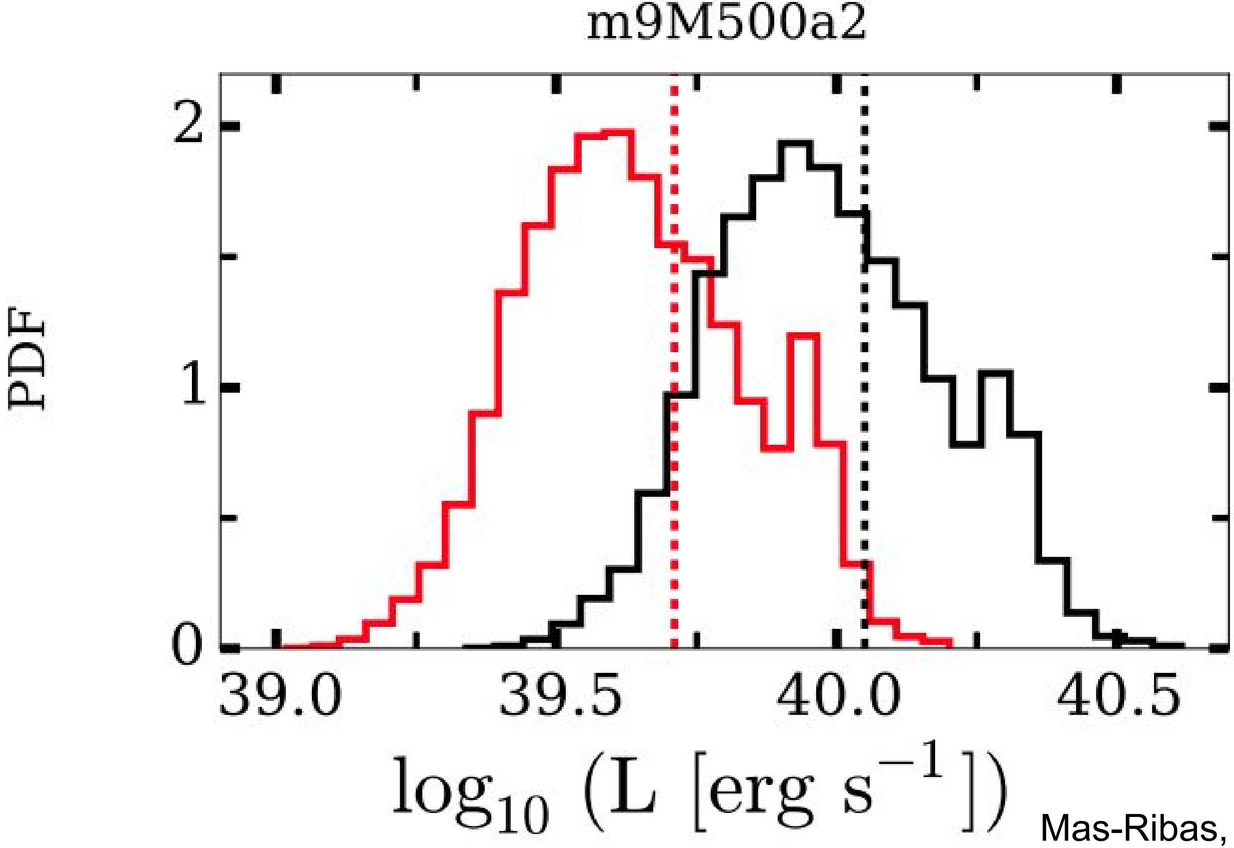
Mas-Ribas, Dijkstra, JEFR (2016)

Stochastic IMF sampling boosts pop III Lya



Mas-Ribas, Dijkstra, JEFR (2016)

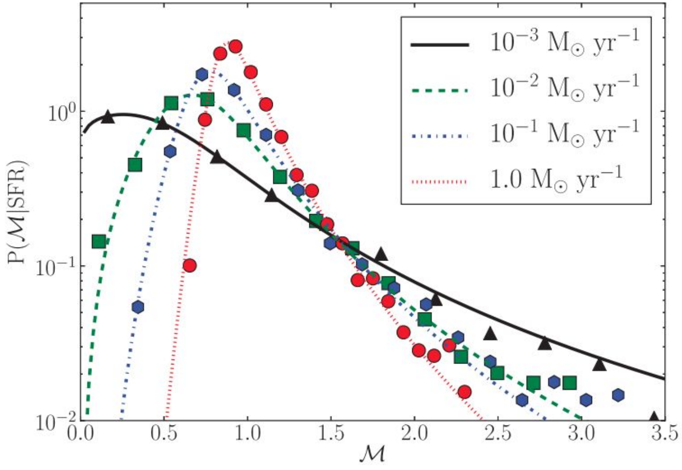
Stochastic IMF sampling boosts pop III Lya



Mas-Ribas, Dijkstra, JEFR (2016)

Summary

- Stochasticity from IMF sampling is a thing.
- Stochasticity kicks-in at 0.1 Msun/yr and gets stronger with decreasing SFR.
- Stochasticity easily gives you factors of 2 to 3 above/below the expected deterministic value for Lya line intensity and equivalent width.



IMF Stochasticity has three minimal ingredients

Probability

$$\xi(m)\,dm = m^{-\alpha}\,dm$$

Truncation mass

$$M \sim 3 \times 10^{3} \left(\frac{m}{100\,M_{\odot}} \right)^{1.35}$$

Minimal time-scale

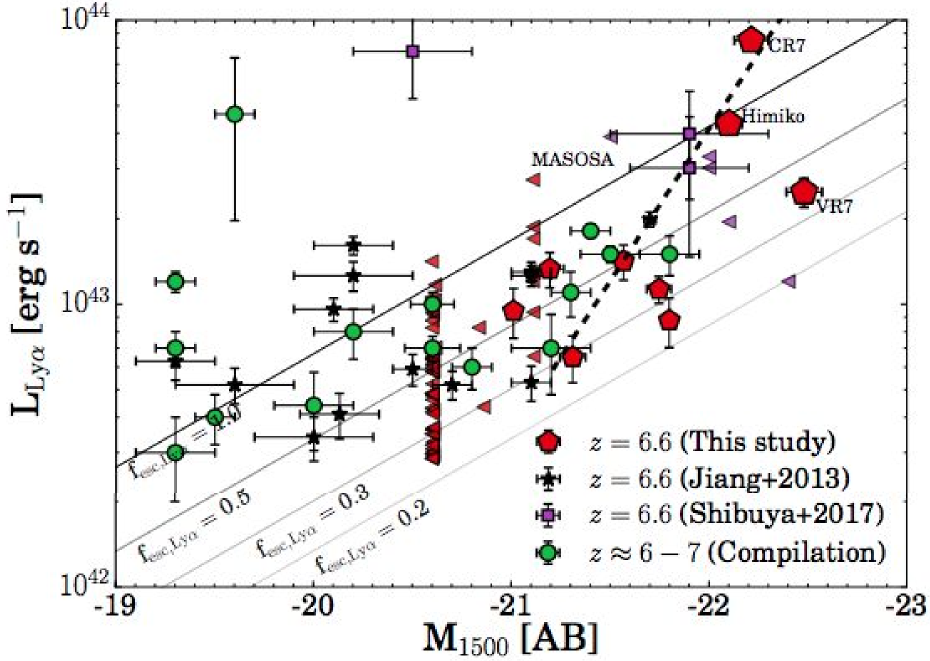
$$dt = \frac{M_{\mathrm{trunc}}}{\mathrm{SFR}} \ll 10^{6}\ \mathrm{yr}$$

Stochasticity impacts escape fraction estimates

$$f_{\mathrm{esc,rel}} = \frac{(f_{\mathrm{LyC}}/f_{1500})_{\mathrm{obs}}}{(f_{\mathrm{LyC}}/f_{1500})_{\mathrm{stel}}} \exp\left(\tau_{\mathrm{IGM}}\right)$$

JEFR&Dijkstra (2012)

High (>1) Lya escape fractions might be stochasticity



Matthee+2017