The impact of an evolving IMF on galaxy evolution and reionisation

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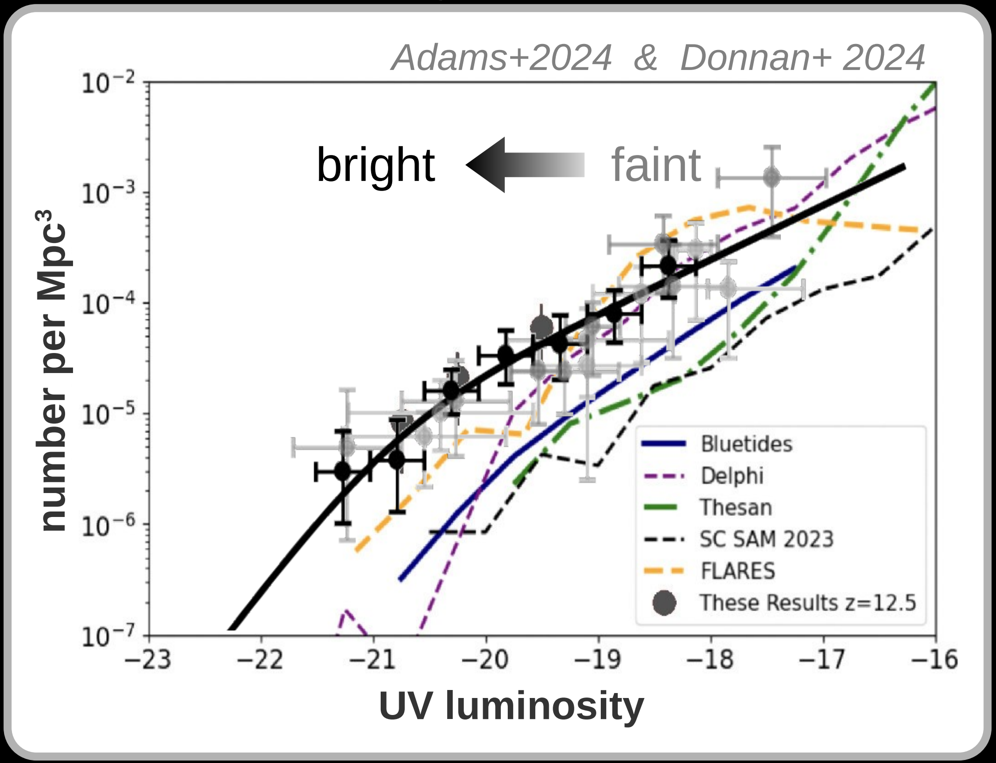
Why do we see a high abundance of bright galaxies at z>10?

UV luminosity function at z ~ 12.5

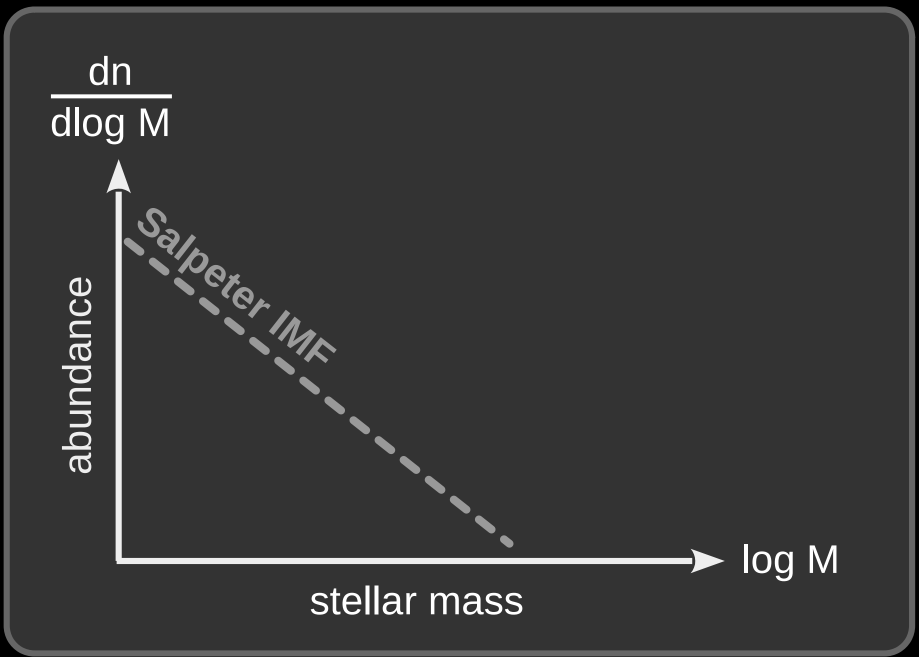


see also Harikane+ 2023, McLeod+ 2024, Robertson+ 2023, Perez-Gonzalez+ 2023, Donnan+ 2023 and many more...

Due to bursty star formation, radiative feedback pushing dust from star forming region, feedback-free starbursts, and/or top-heavier IMF?

see e.g. Dekel+ 2023, Ferrara+2023, Mason+2022, Trinca+2023

How could the IMF evolve?



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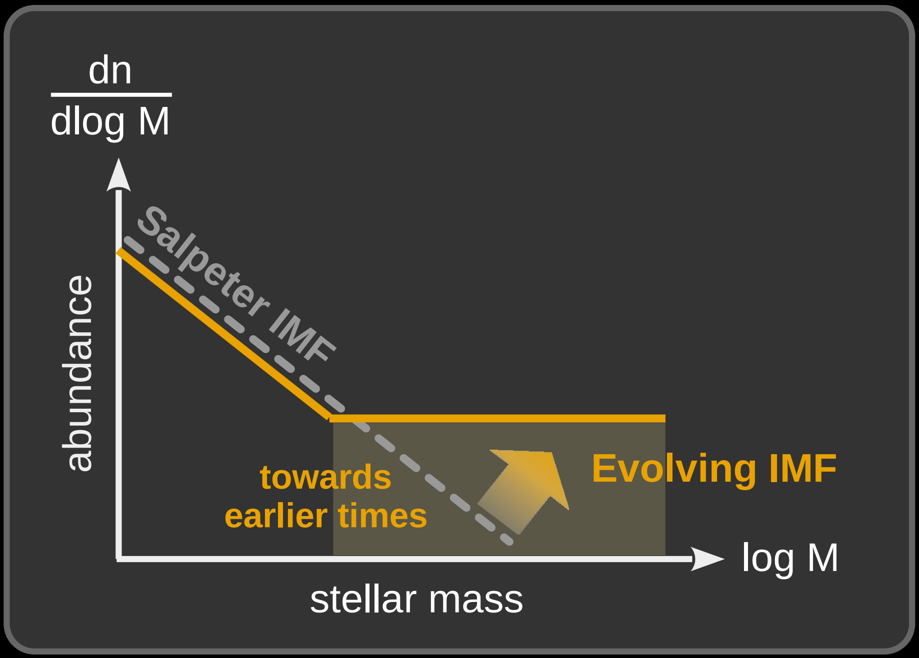

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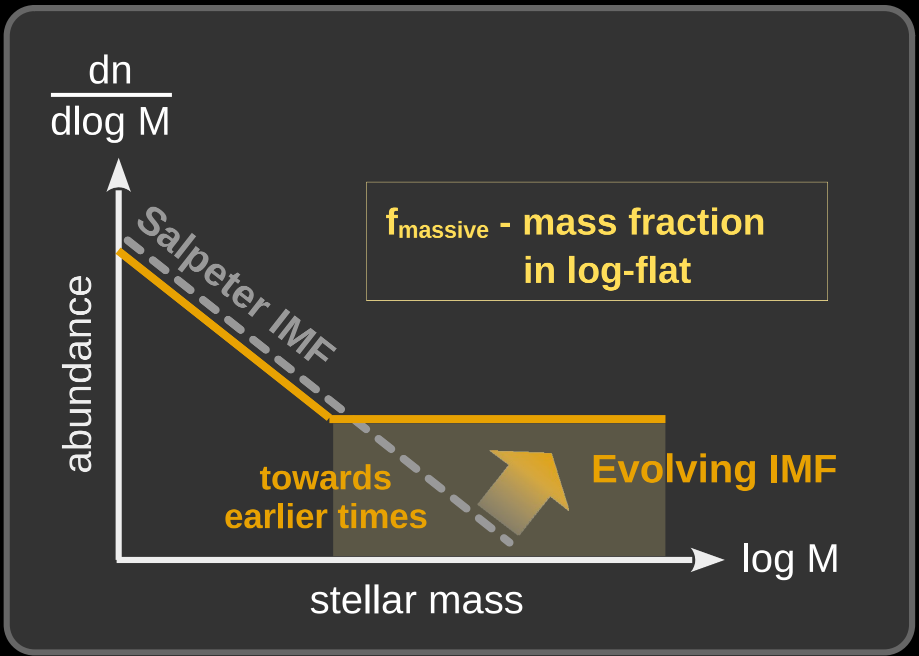

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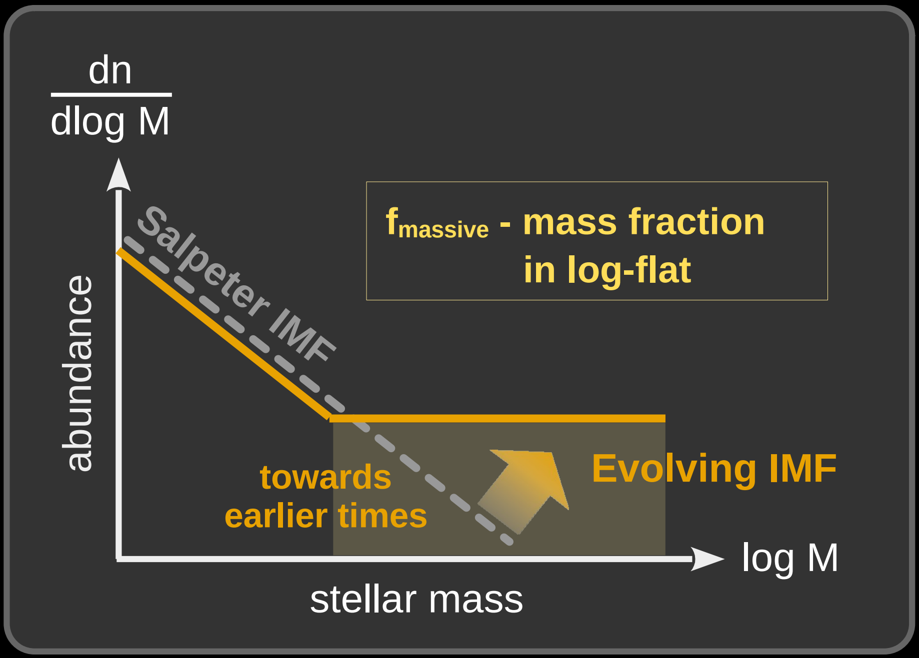

Scenario 1: *Cueto, Hutter + 2024*

Top-heavier IMF with higher gas temperature (lower metallicity, higher CMB temperature)

Simulations of star-forming clouds
Chon+ 2022

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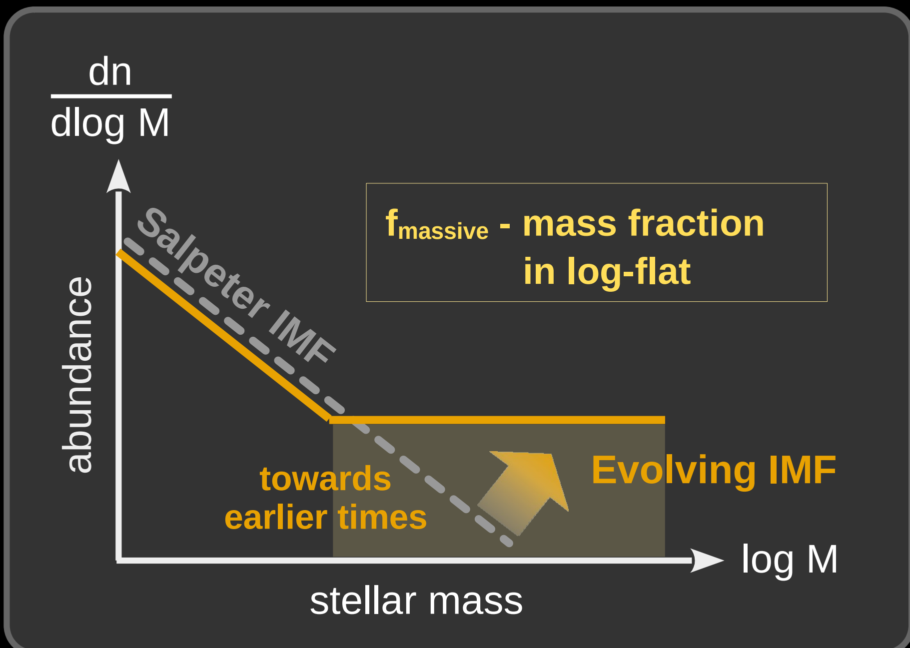

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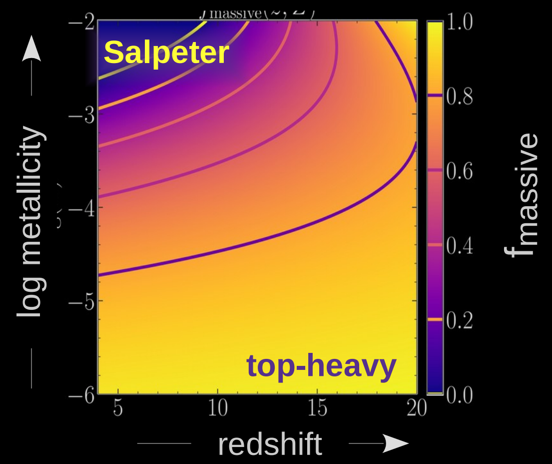

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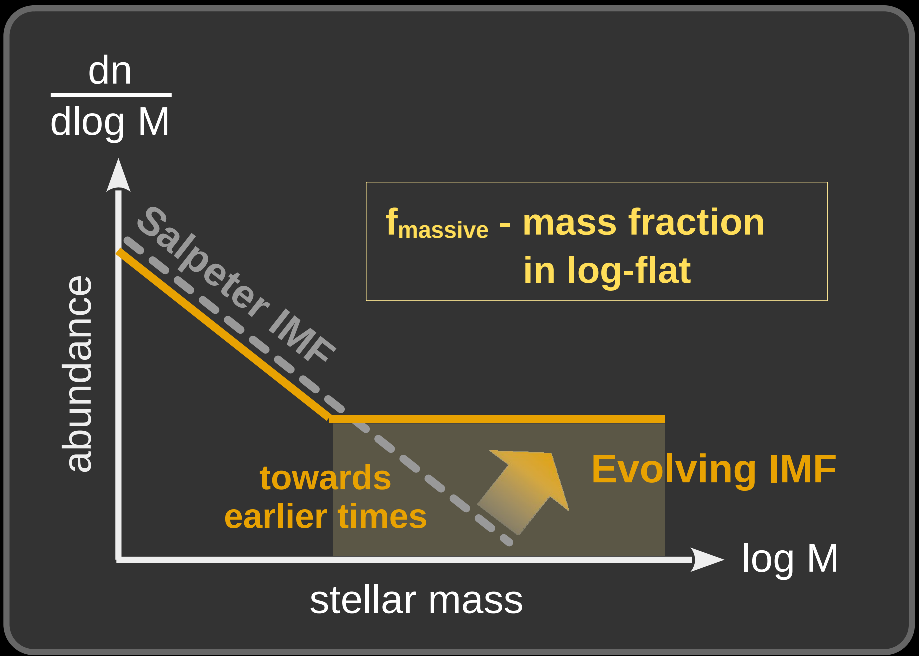

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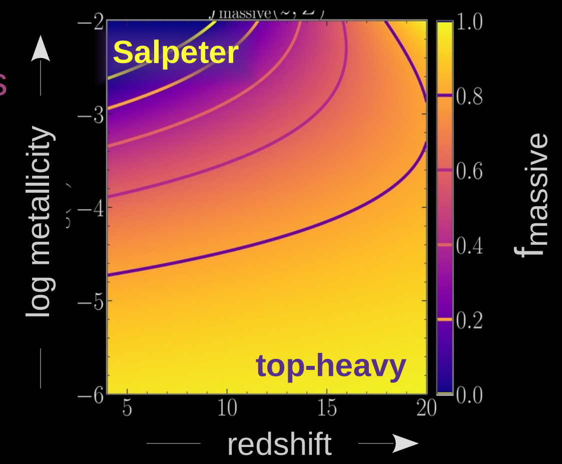


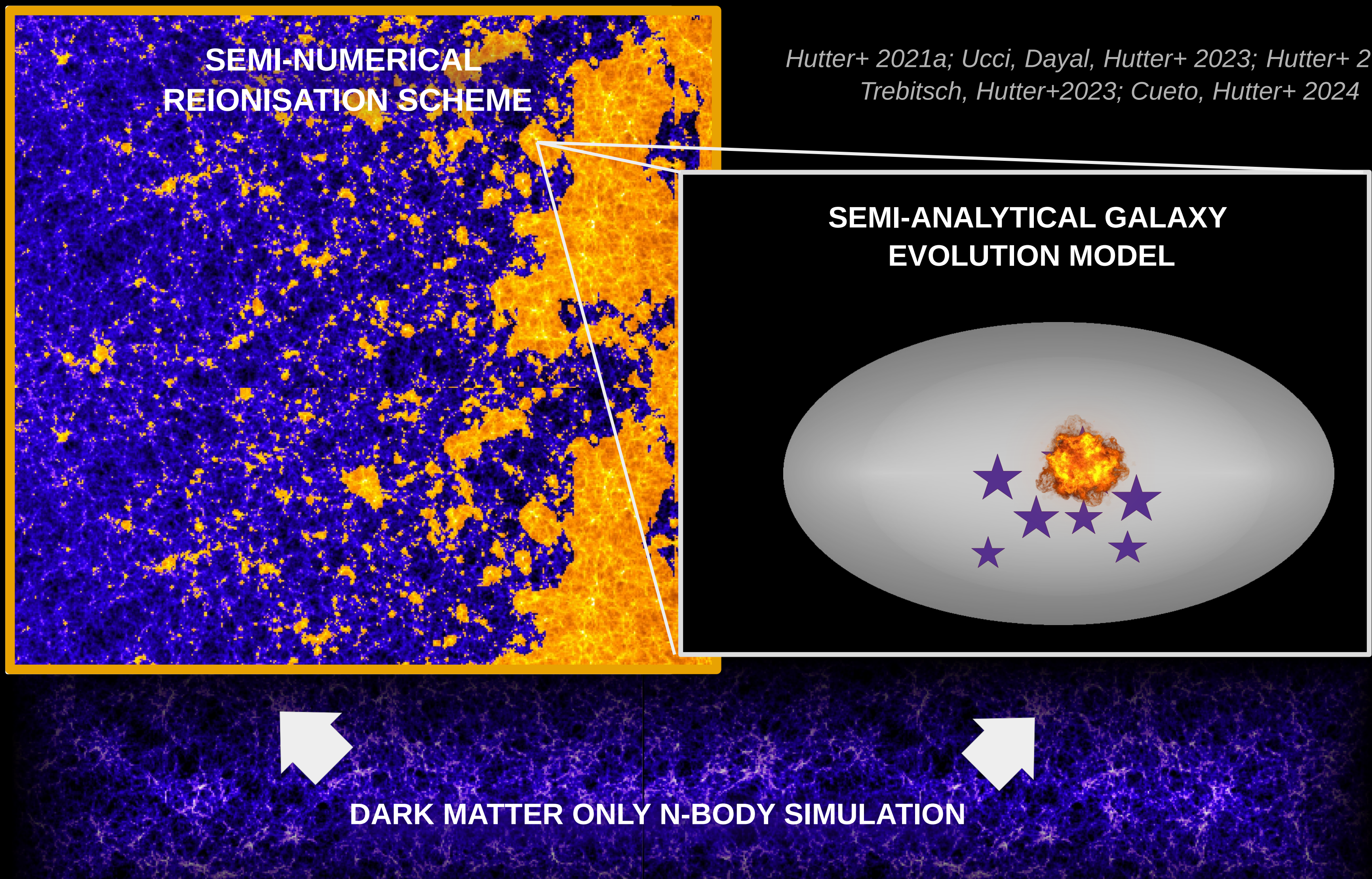
Scenario 2: *Hutter+ in prep.*

Top-heavier IMF with higher gas density (higher sSFR)

Local observations
Gunawardhana+ 2011, Zhang+ 2018

Astraeus – a fast framework for simulating the evolution of the first galaxies and the intergalactic medium

Hutter+ 2021a; Ucci, Dayal, Hutter+ 2023; Hutter+ 2023a; Trebitsch, Hutter+2023; Cueto, Hutter+ 2024



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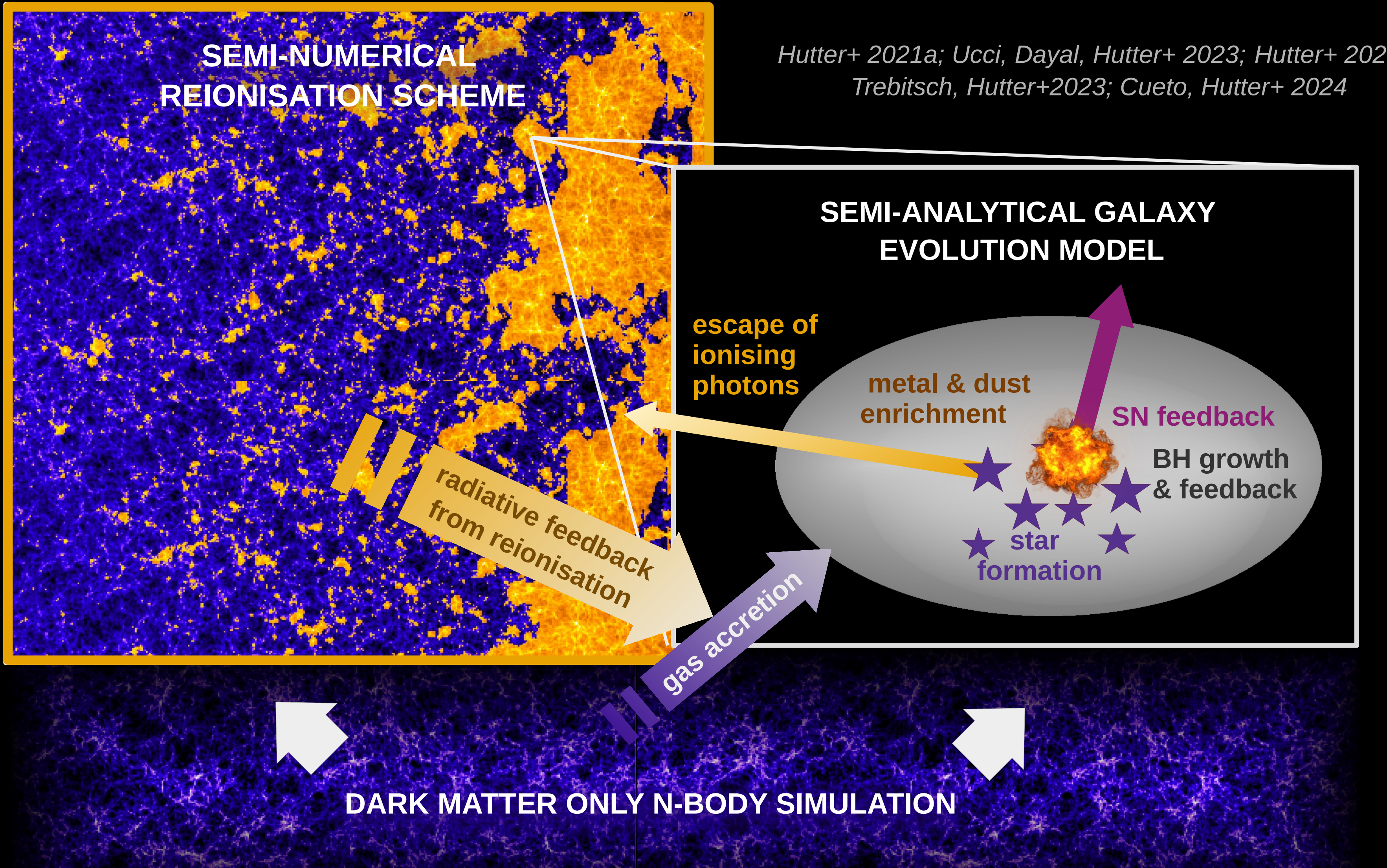

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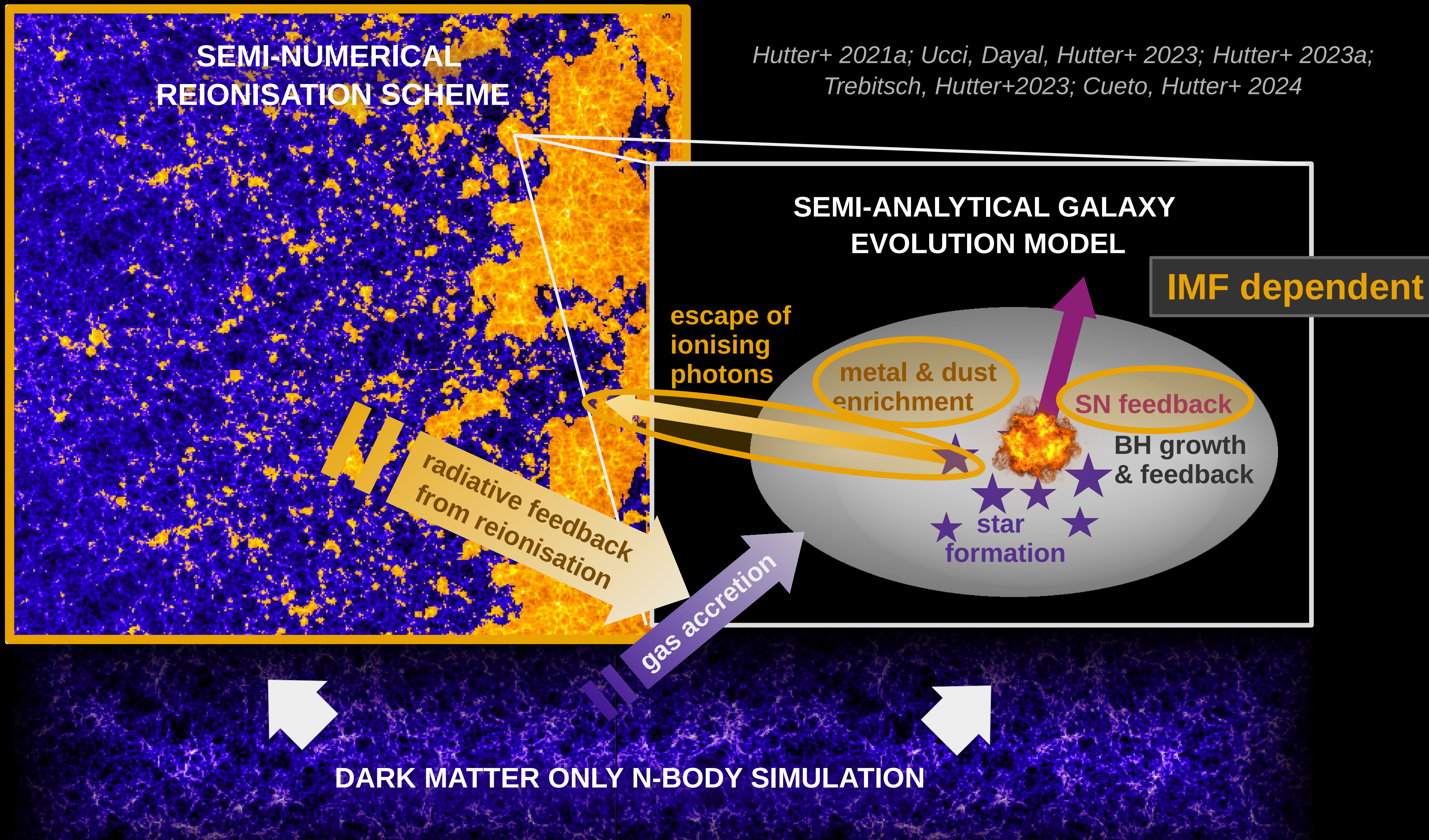
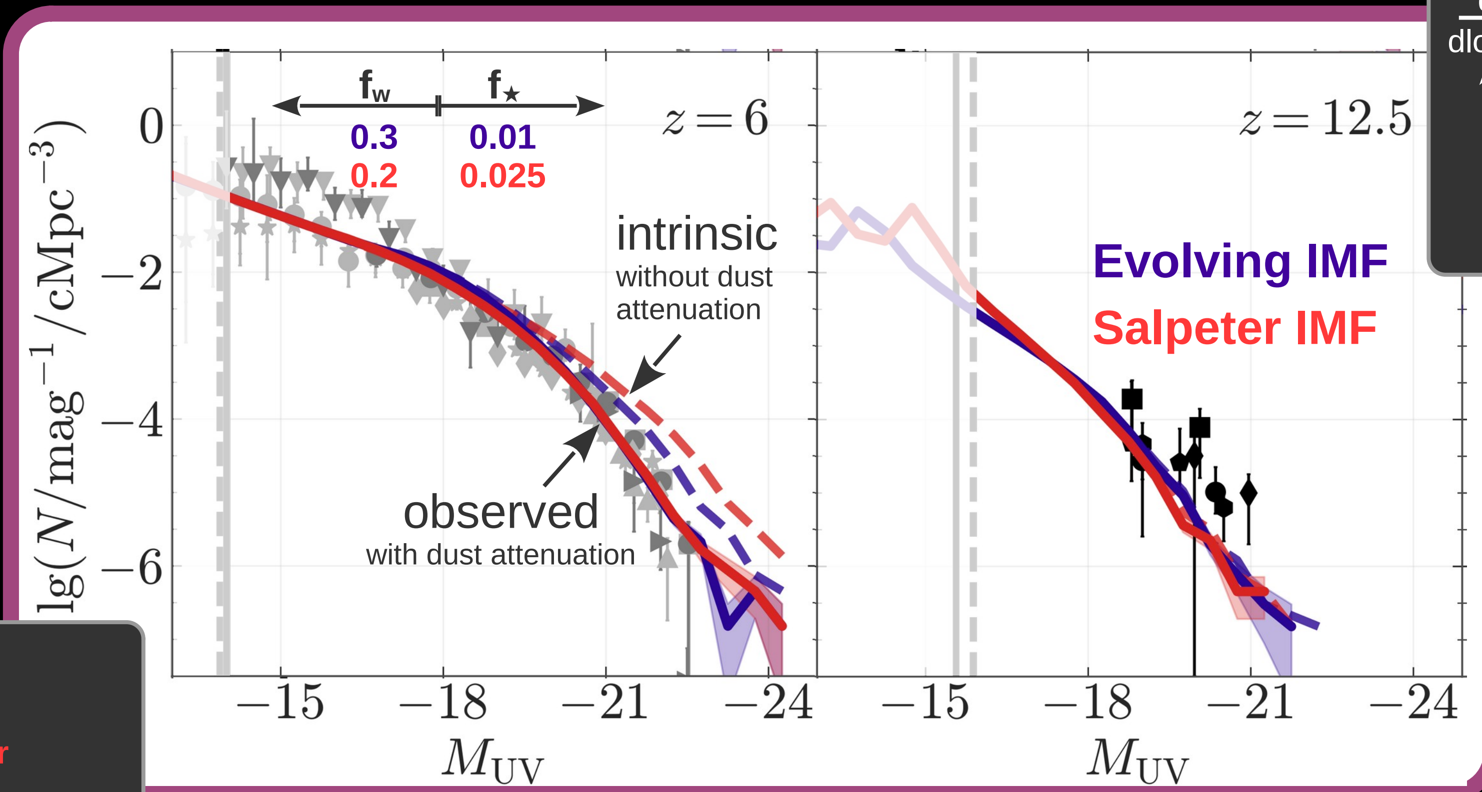
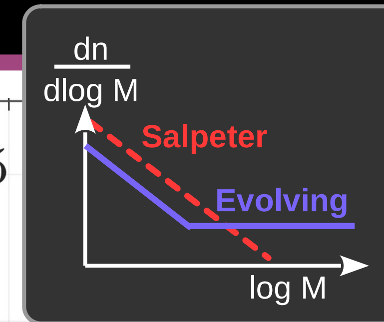


Scenario 1 - The evolution of the UV LFs at z=5-13 hardly changes for an evolving IMF!





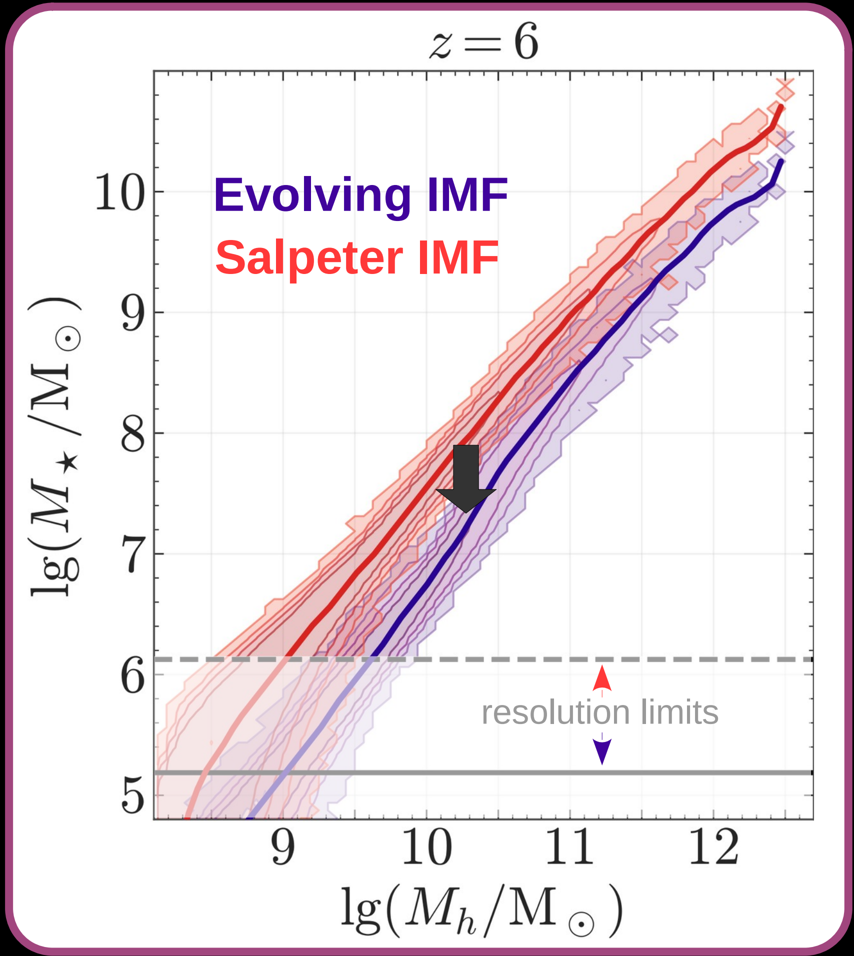
top-heavy

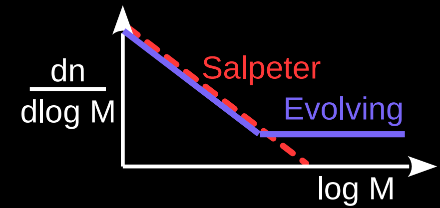
Salpeter like

The evolving IMF's lower mass-to-light ratio is compensated by a smaller star formation efficiency and stronger supernovae feedback.

Cueto, Hutter+ 2024

Scenario 1 - Evolving IMF: Lower star formation efficiency leads to stellar masses being ~0.5-1 dex lower in same z=6-12 halos

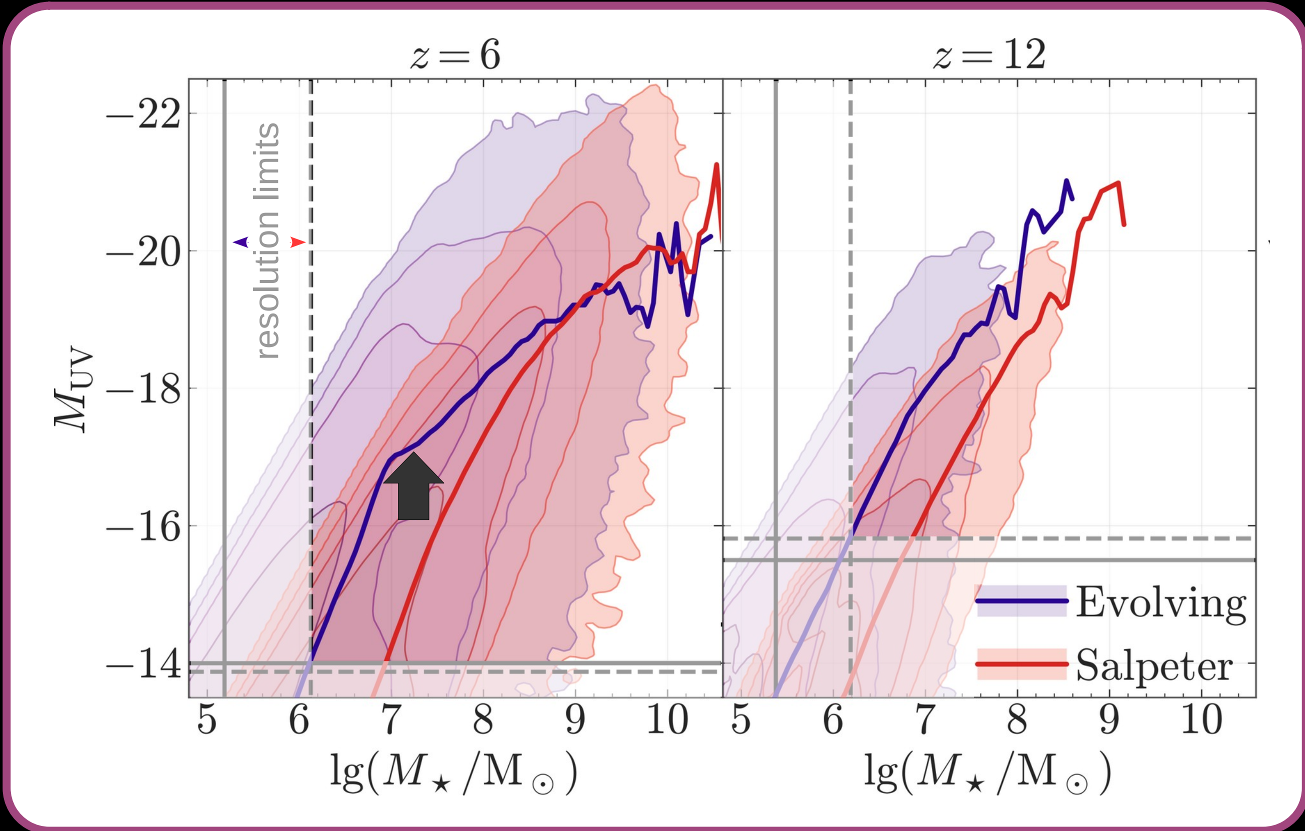


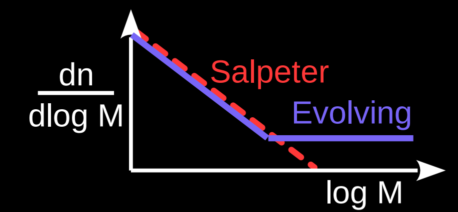


Main characteristics of the evolving IMF:

1. **slower build-up of stellar mass** due to lower star formation efficiency

Scenario 1 - Evolving IMF: Lower stellar mass-to-light ratio

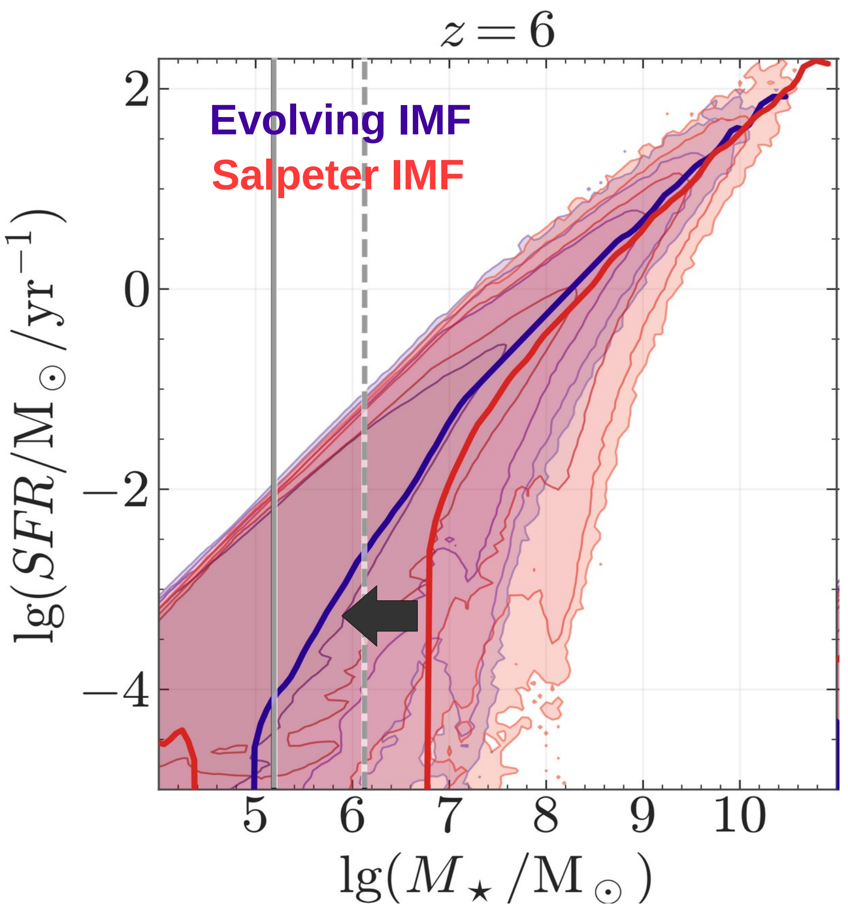


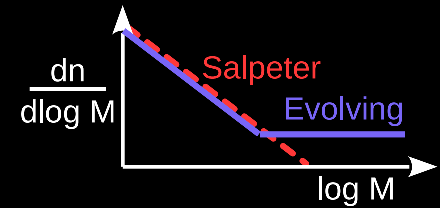


Main characteristics of the evolving IMF:

1. **slower build-up of stellar mass** due to lower star formation efficiency
2. **reduced mass-to-light ratio** due to a higher abundance of massive stars

Scenario 1 - Evolving IMF: star formation main sequence hardly changes

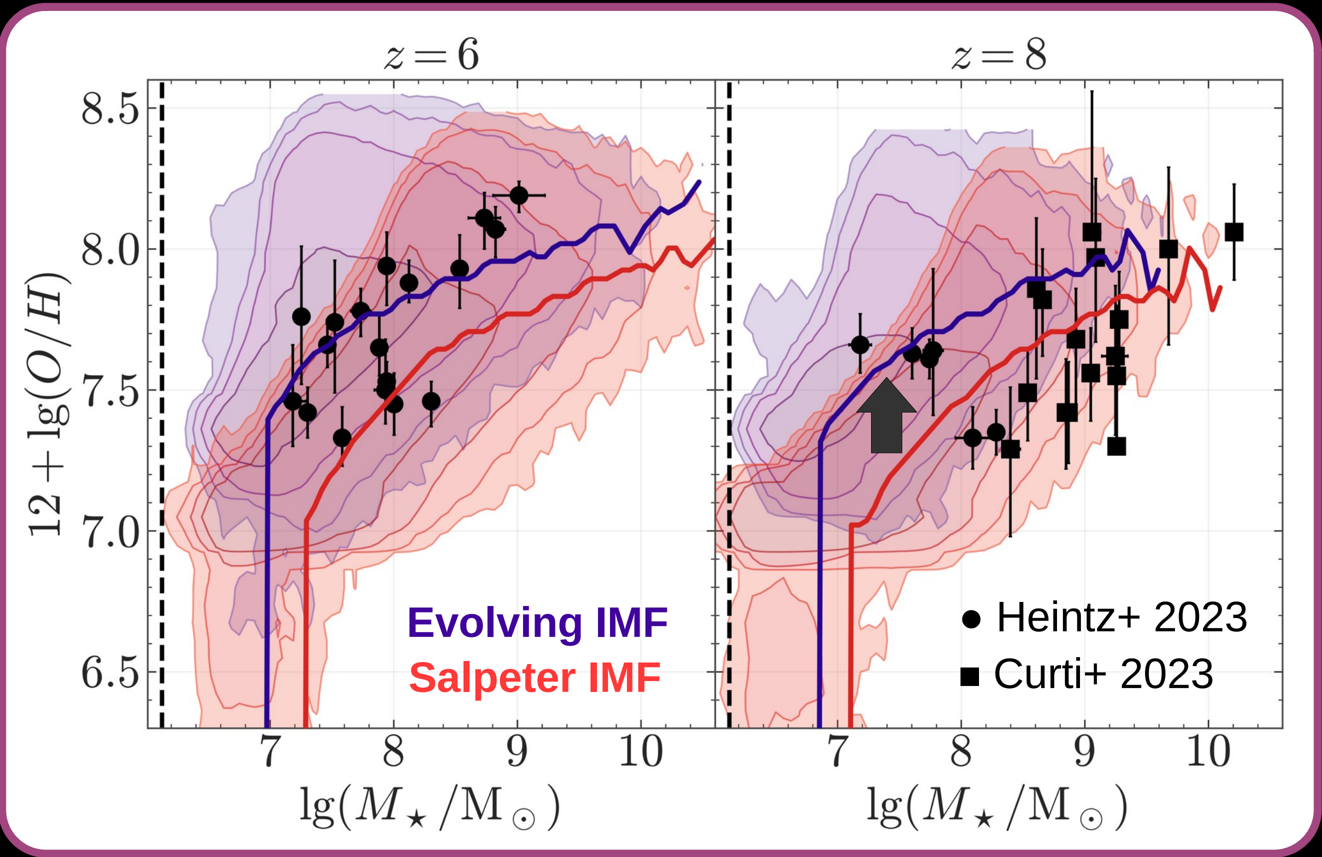




Characteristics of the evolving IMF:

1. **star formation main sequence unchanged** due to self-similar mass growth of halos
2. **higher SFR for low stellar mass galaxies** due to SN feedback being less delayed & located in more massive halos

Scenario 1 - Evolving IMF: mass – metallicity relation shifts to higher metallicities



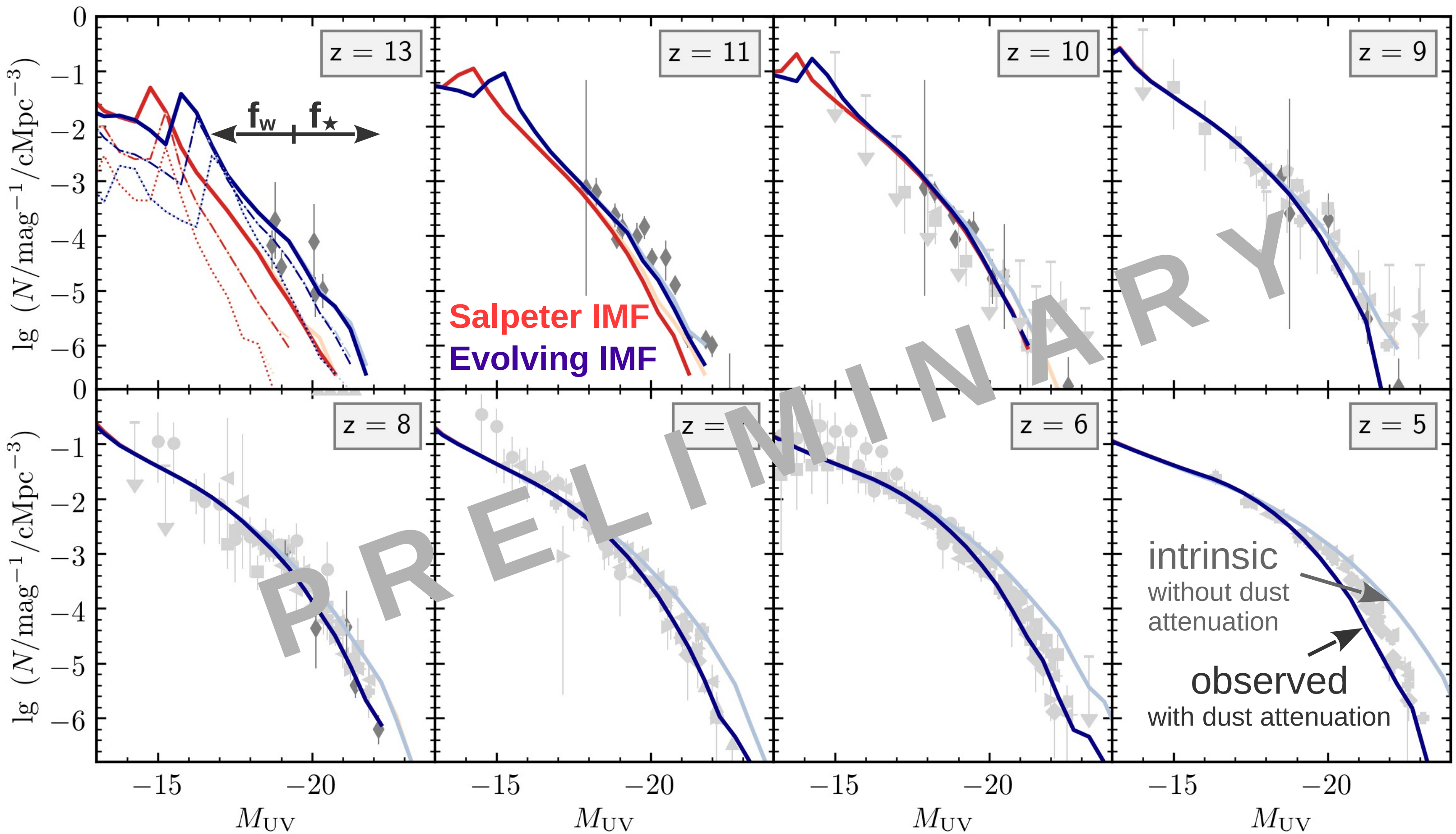
Characteristics of the evolving IMF:

1. **higher metallicities at same stellar masses** due to lower stellar-to-halo mass ratio & higher oxygen abundance

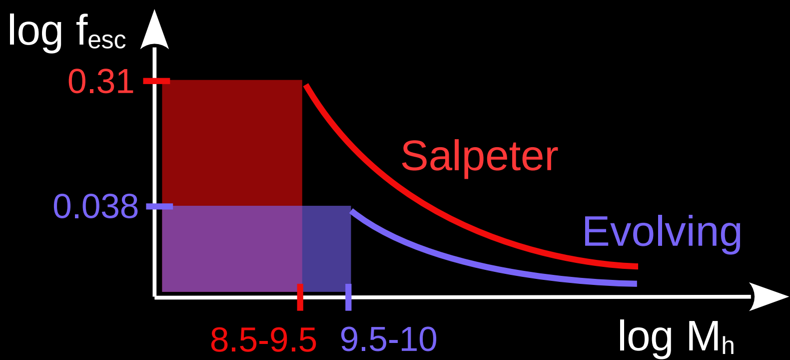
Note: metallicity-halo mass relation and metallicity-luminosity relation hardly change!

Scenario 2 – The evolution of the UV LFs at z=5-13 reproduces the observations for an evolving IMF!

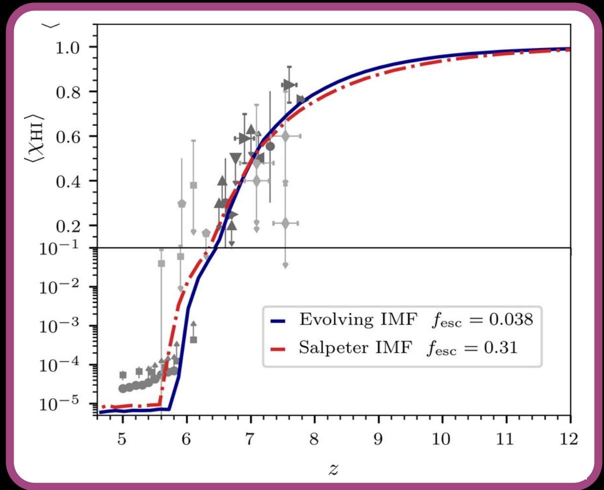
Galaxy model parameters (f_w, $f_\star$) remain unchanged!



Evolving IMFs: Impact on reionisation

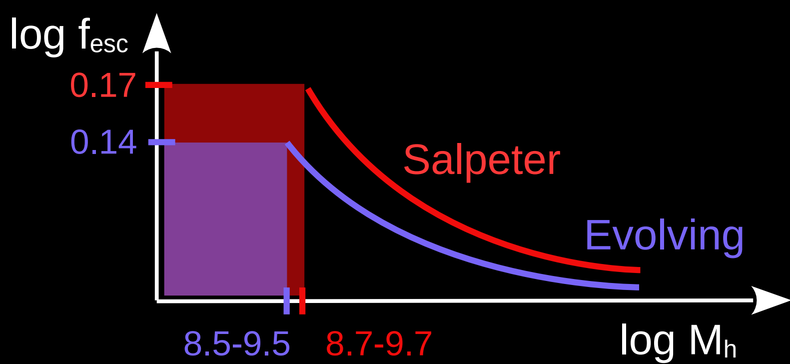


similar ionisation history



Scenario 1

Assume: f_{esc} scales with ejected gas fraction & adjust f_{esc} normalisation



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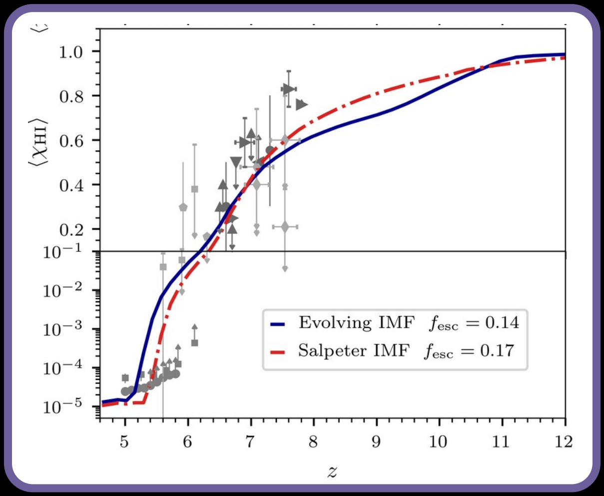
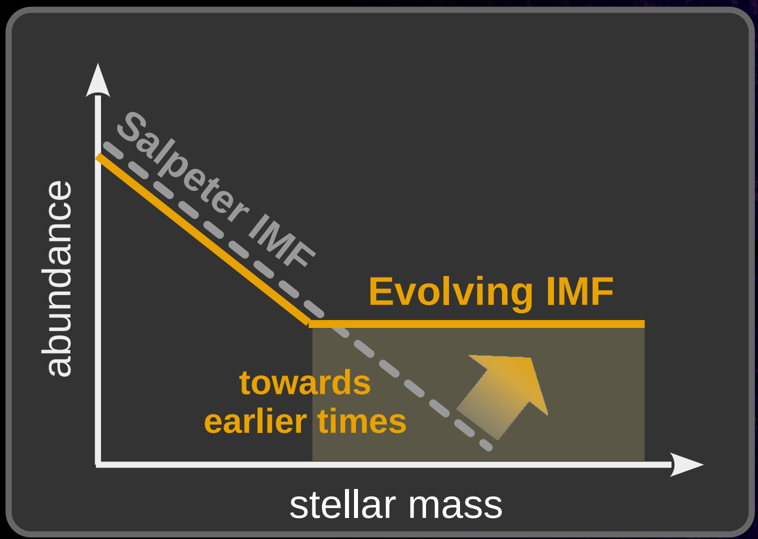


Scenario 2

Conclusions

Explain high abundance of bright z>10 sources with a top-heavy initial mass function?



Top-heavier IMF with higher gas temperature compared to constant Salpeter IMF

- Slower build-up of stellar mass due to stronger SN feedback
- Lower stellar mass-to-light ratio
- Stellar mass – metallicity relation shifted to higher metallicities
- Reionisation history and topology change only minorly.

arXiv: 2312.12109

Top-heavier IMF with higher gas density

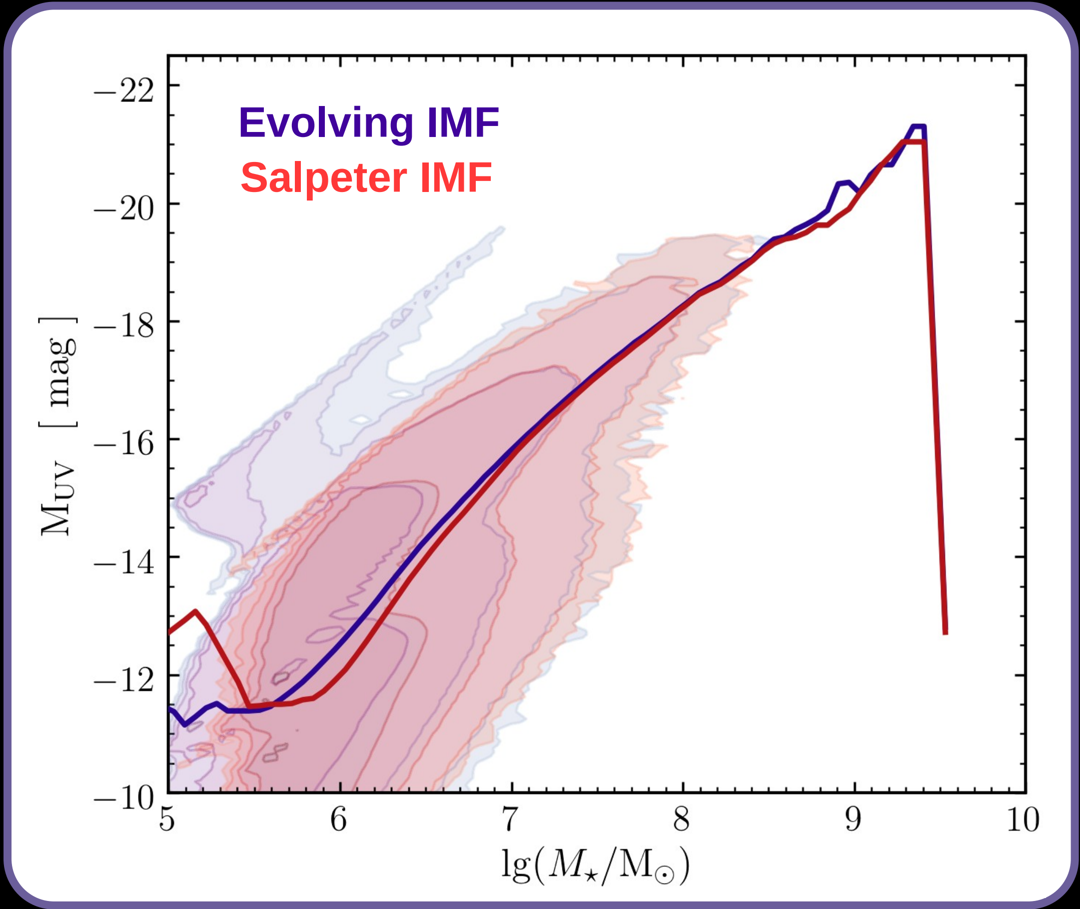
- Similar trends but far weaker and only at z>10
- **Fits UV LFs at z=5-13 !**

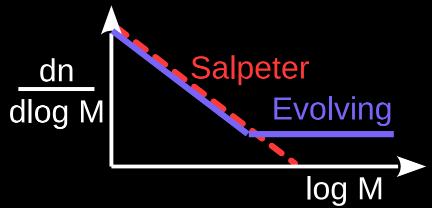
in prep.

ASTRAEUS:

- Publicly available at: *https://github.com/annehutter/astraeus*
- **Includes now different implementations of evolving IMFs!**

Scenario 2 - Evolving IMF: Lower stellar mass-to-light ratio

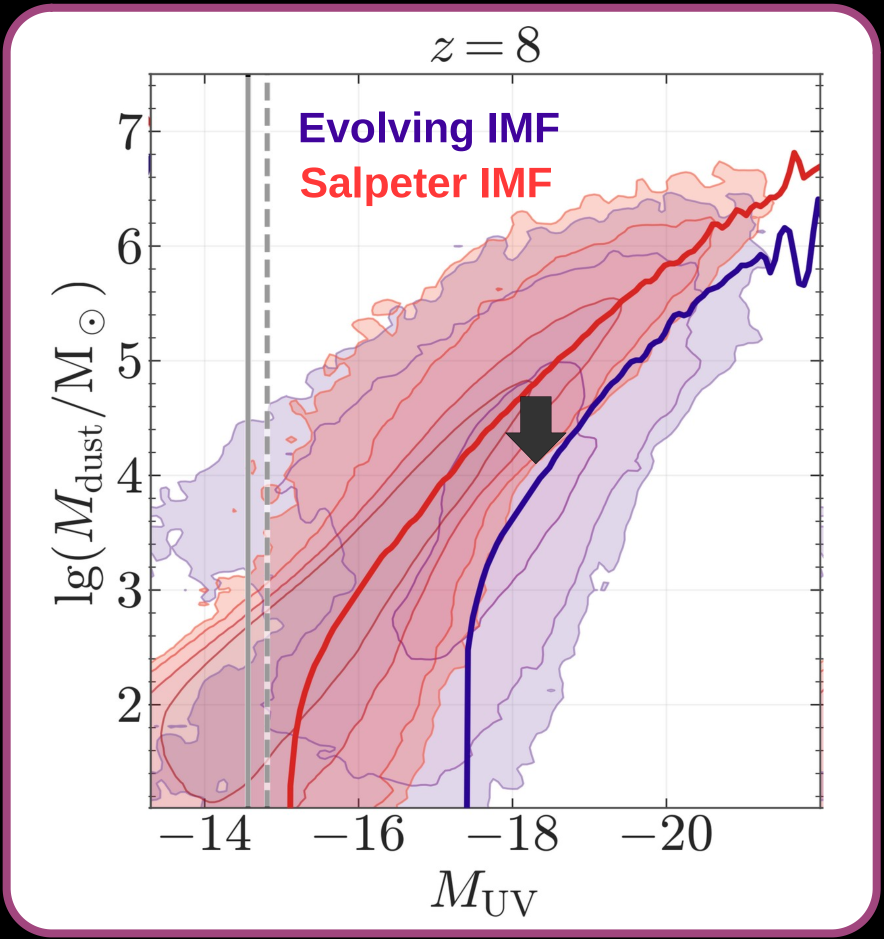


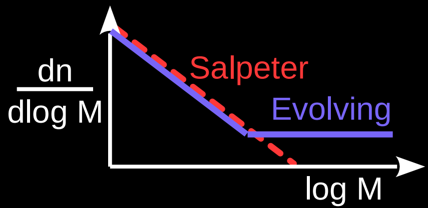


Main characteristics of the evolving IMF:

1. **reduced mass-to-light ratio** at z>10 due to a higher abundance of massive stars

Scenario 1 - Evolving IMF: dust mass – luminosity relation differs!



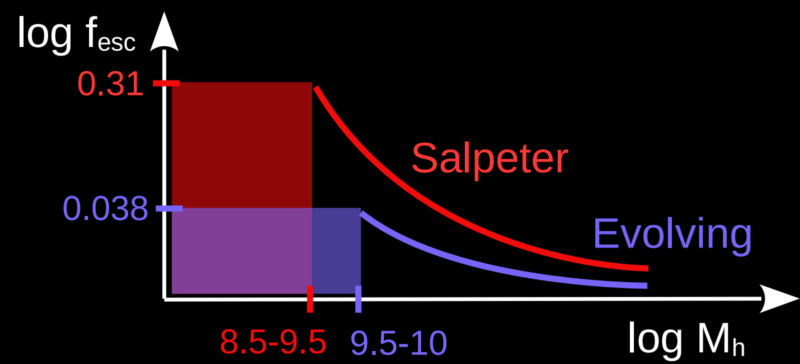


Characteristics of the evolving IMF:

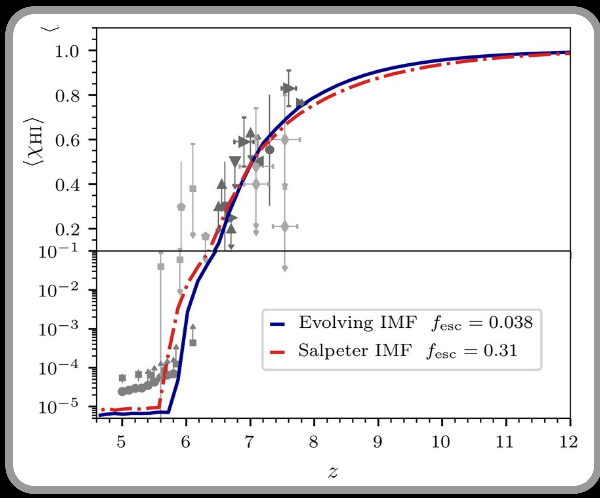
1. **Lower dust masses at same luminosity** due to lower stellar mass-to-light ratio and ~0.3dex lower dust-to-metal mass ratio
2. **Larger scatter in luminosity** due to SN feedback being less delayed & located in more massive halos

Scenario 1 - Evolving IMF: Only minor impact on reionisation topology

Assume: f_{esc} scales with ejected gas fraction

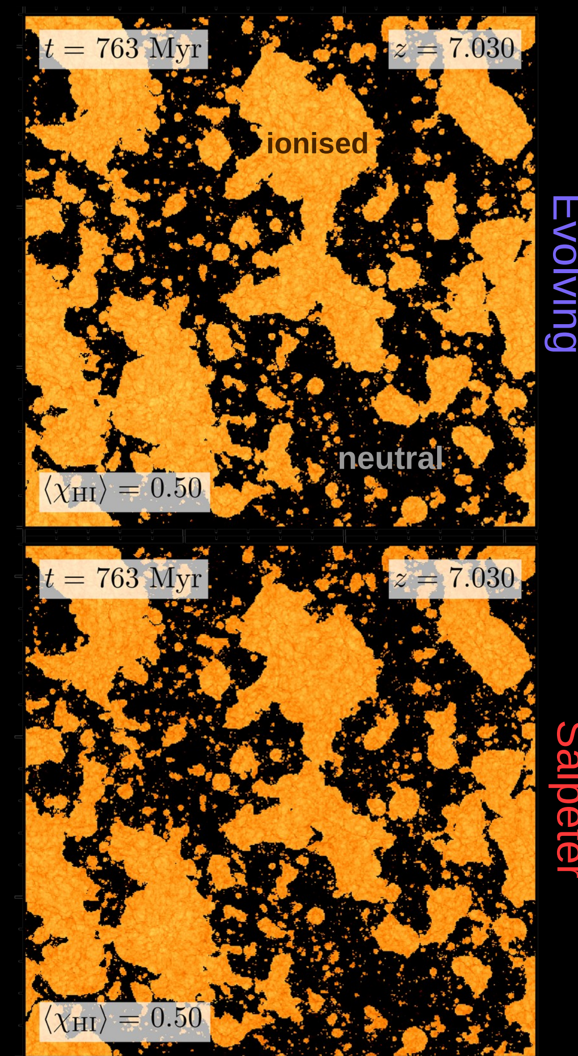


Adjust f_{esc} normalisation

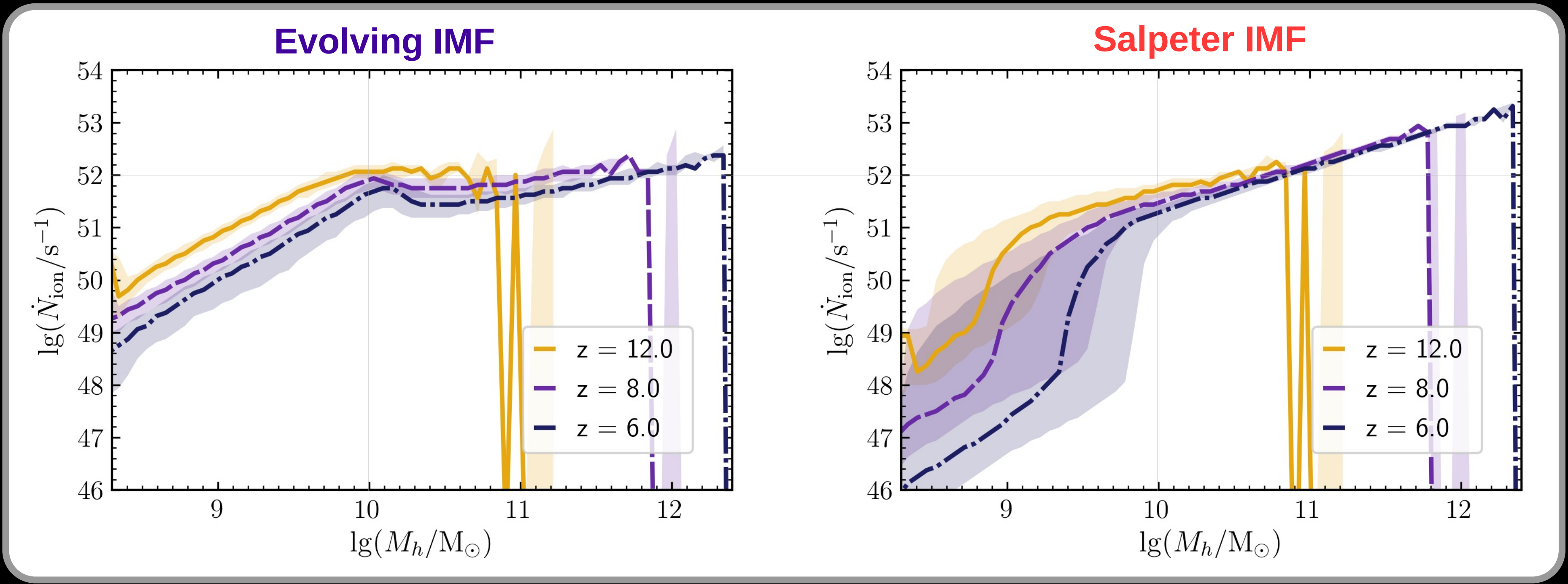


similar ionisation history

only minor changes to ionisation topology

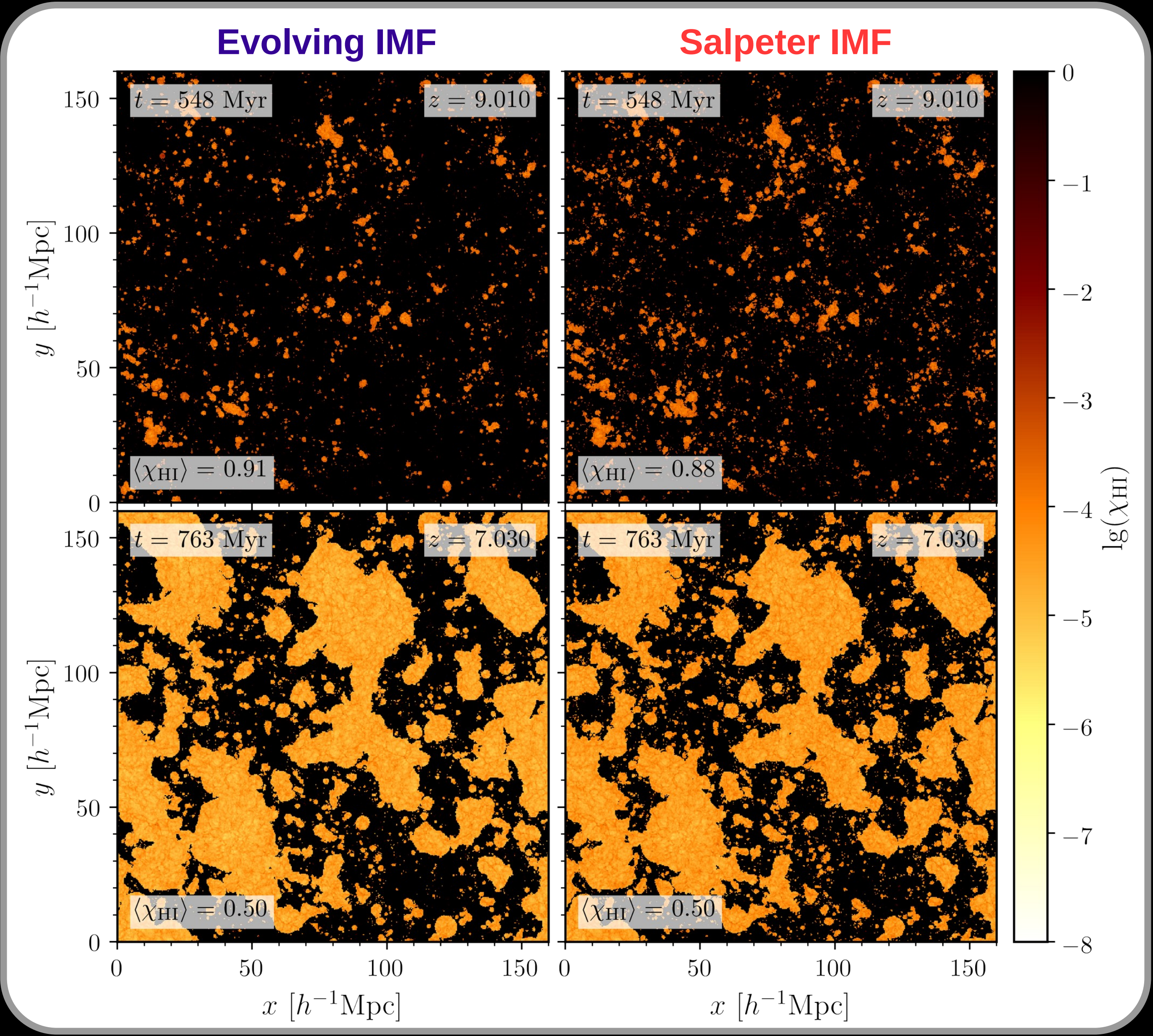


Scenario 1 - Evolving IMF: Ionising emissivity is stronger correlated to the underlying density distribution



Characteristics of the evolving IMF:

1. **Shallower N_{ion}-M_h relation** due to the IMF's metallicity dependence
2. **Higher Nion for medium galaxies**
3. **Higher Nion and less scatter for low mass galaxies** due to SN feedback being less delayed



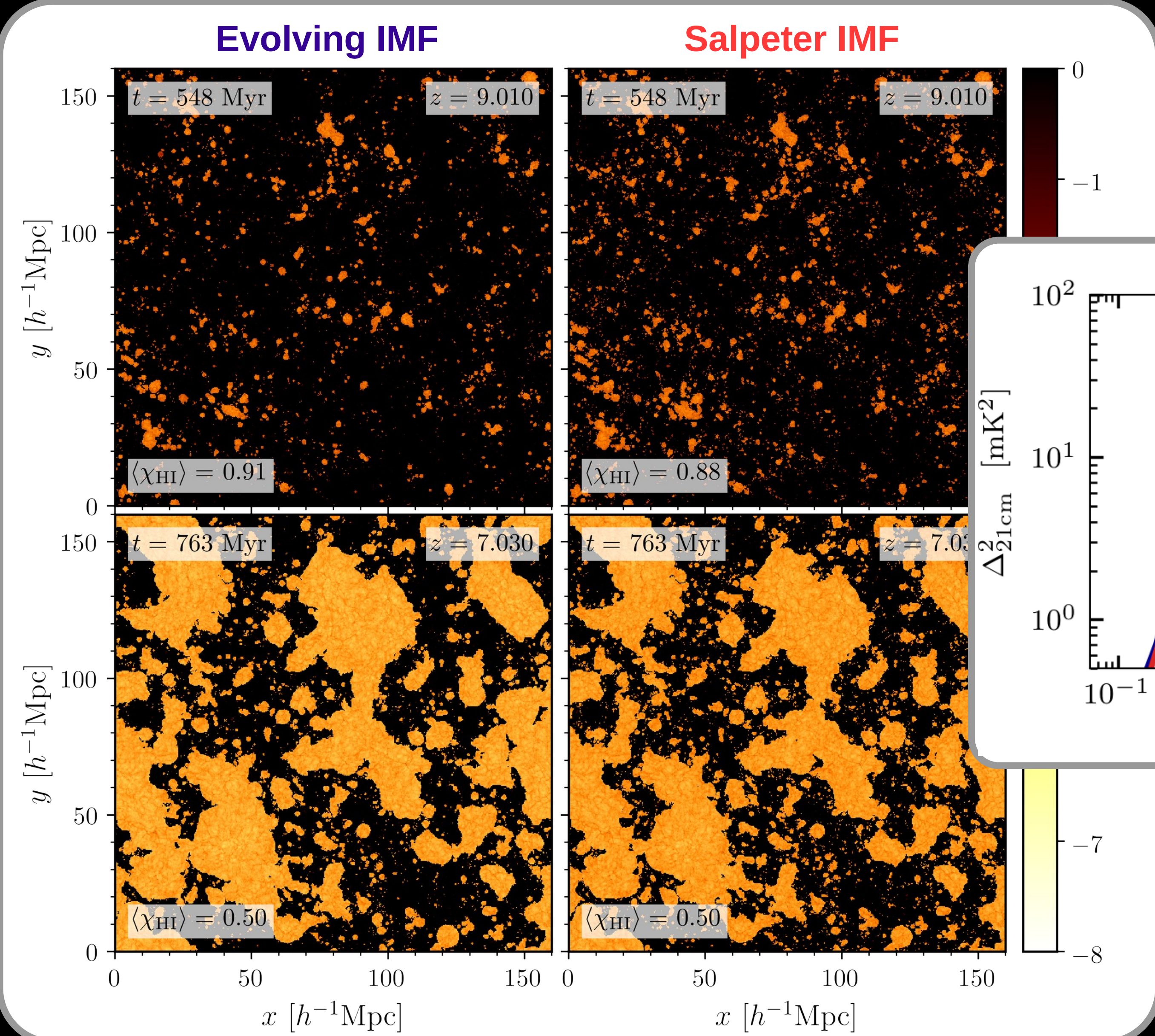
Scenario 1 -

Evolving IMF: Only minor changes to ionisation topology

larger medium-to-large ionised regions

&

less <1-2cMpc ionised regions



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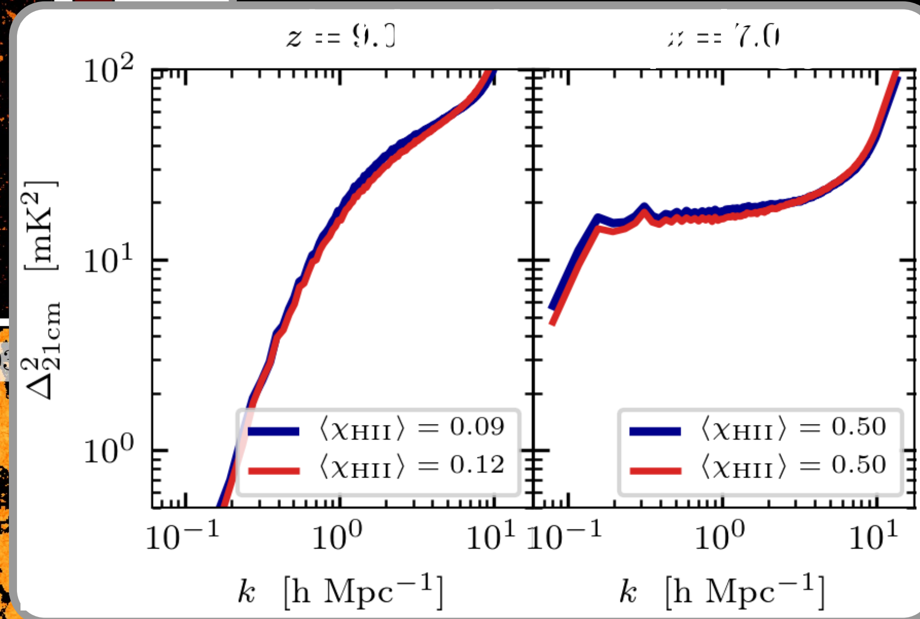

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