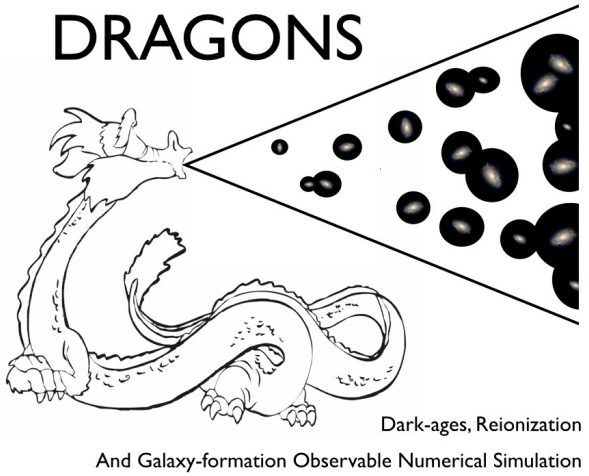
Cosmic Dawn at high-latitudes

JWST bright galaxies at z>12: a signature from Pop. III star formation?

with Prof. Stuart Wyithe, Dr. Yuxiang Qin and Dr. Balu Sreedhar

THE UNIVERSITY OF MELBOURNE

ASTRO 3D



Emanuele (Manu) Ventura – PhD – UniMelb

First stars… What?

Population III stars

- **Pristine chemical composition**

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Population III stars

- **Pristine chemical composition**

Little to no metals! → Below critical metallicity ($\mathbf{Z_{crit}}$)

First stars… What?

Population III stars

- **Pristine chemical composition**

Little to no metals! → $Z_{crit} = 10^{-4} Z_{sol}$

First stars... What?

Population III stars

- **Pristine chemical composition**

  → Metallicity $< Z_{crit}$ → Population III star

  → Metallicity $\geq Z_{crit}$ → Population II/I star

First stars… What?

Population III stars

- **Pristine chemical composition**
- **Often form in the first structures (aka minihalos)**

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  Large uncertainties on their **parameters**

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  Initial mass?

  How efficiently gas is converted into stars?

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How efficiently gas is converted into stars?

Simulations!!

First stars... What?

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Large uncertainties on their **parameters**

→ Generally more massive → Shorter lifetimes

→ Generally more massive → More supernovae and black holes

First stars… What?

Population III stars

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- **Never observed!**

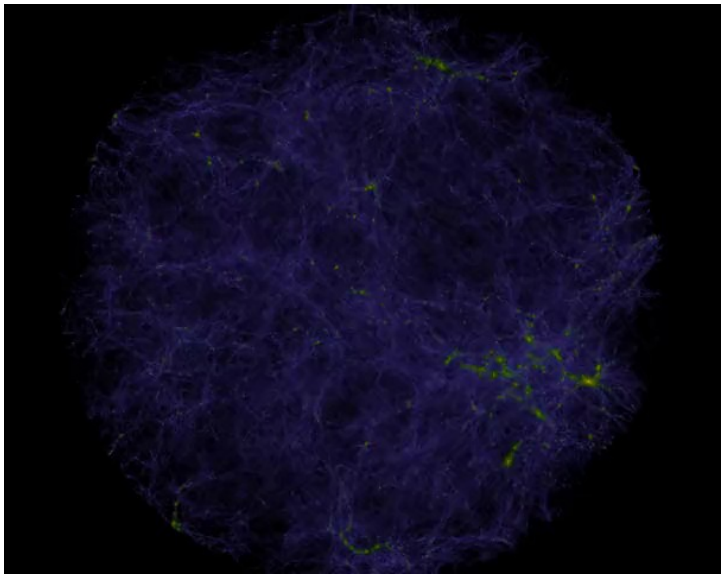
  └ Large uncertainties on their **parameters**

→ Generally more massive
  - Shorter lifetimes
  - More supernovae and black holes

→ Pristine gas is less efficient to form stars → star formation efficiency is lower

Meraxes

MERAXES: **a semi-analytical model of galaxy formation**



N-body simulation

Physics of galaxy formation

Meraxes

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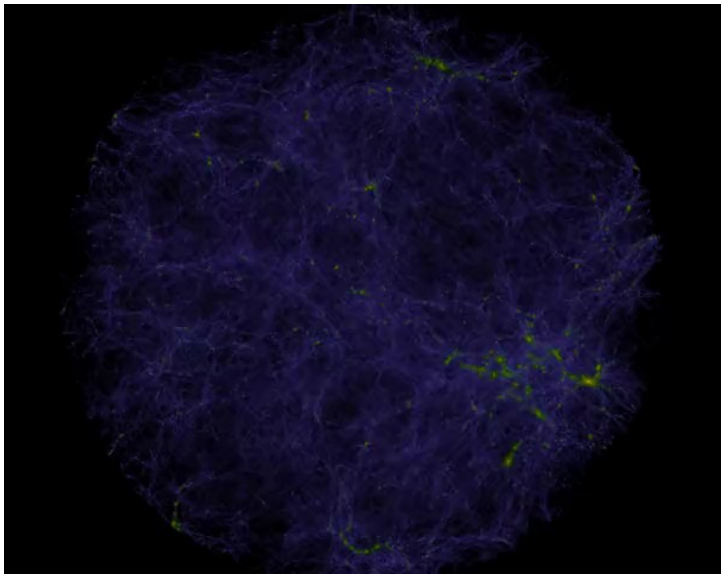

N-body simulation

- **Information on the spatial location of dark matter halos**

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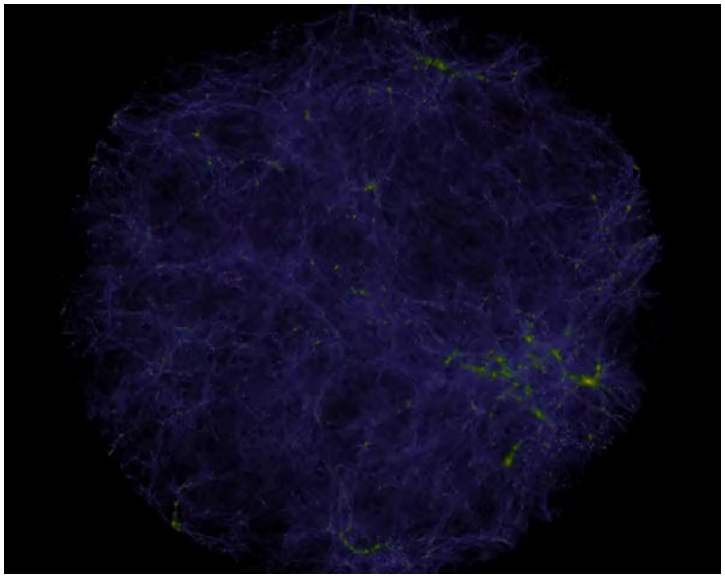

N-body simulation

- **Information on the spatial location of dark matter halos**
- **Can resolve all dark matter halos down to few 10^5 solar masses (we can resolve all minihalos!)**

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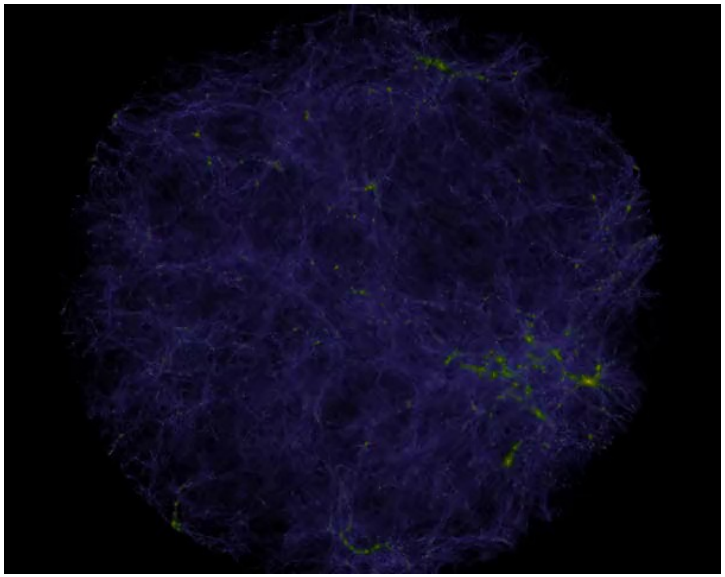

N-body simulation

- **Information on the spatial location of dark matter halos**
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- **10 cMpc/h on a side (quite small!)**

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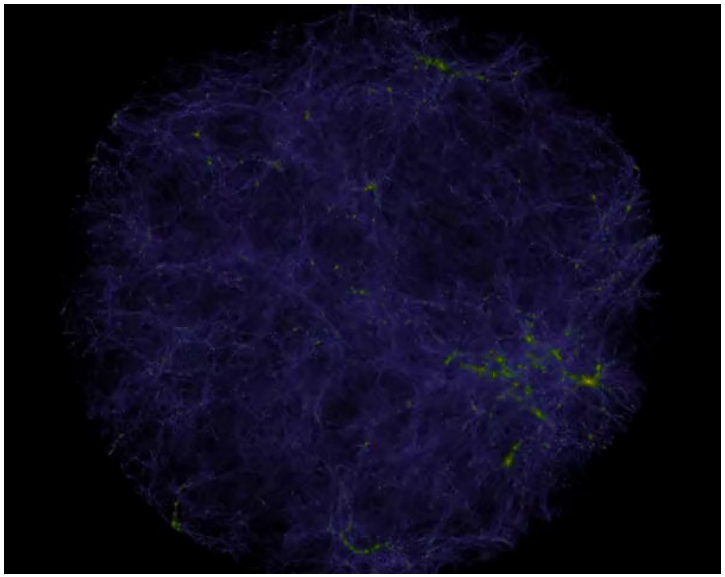

N-body simulation

- Information on the spatial location of dark matter halos
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- From z = 30 to z = 5.

Meraxes

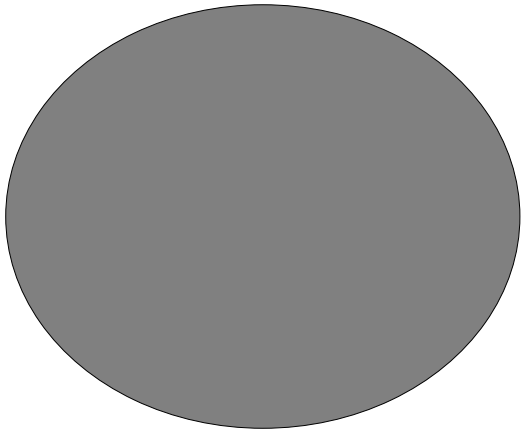
MERAXES: a semi-analytical model of galaxy formation

Physics of galaxy formation

Meraxes

MERAXES: a semi-analytical model of galaxy formation

Physics of galaxy formation:



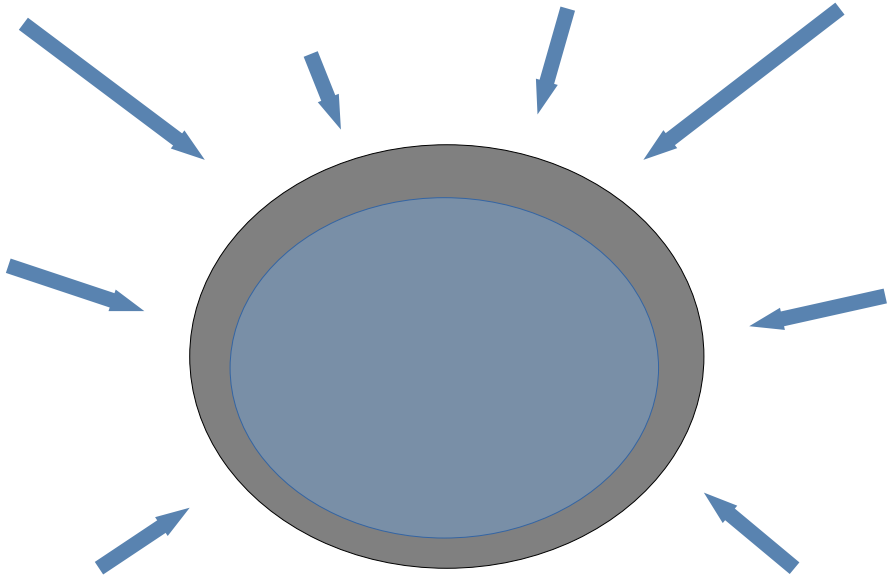
I am a dark matter halo!

Meraxes

MERAXES: a semi-analytical model of galaxy formation

Physics of galaxy formation:

1) Gas Infall



Meraxes

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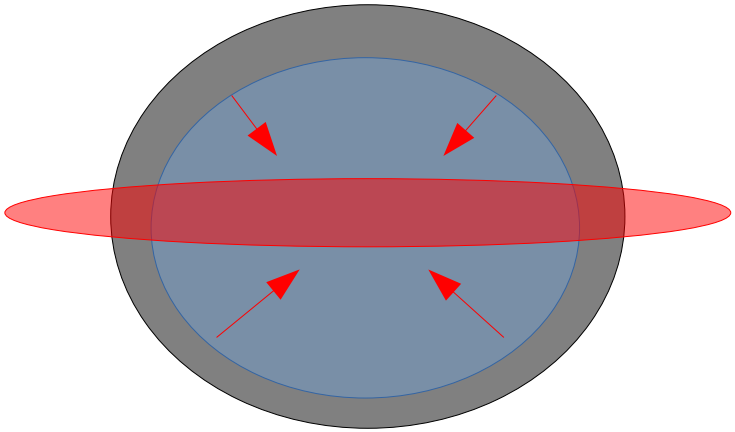
2) Gas Cooling (including H_2)



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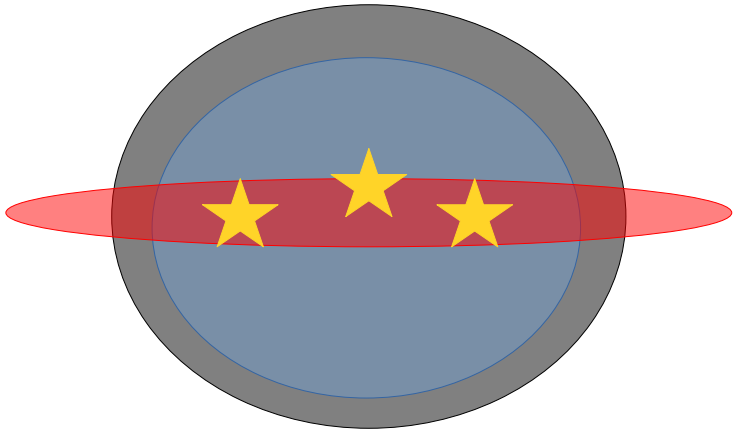

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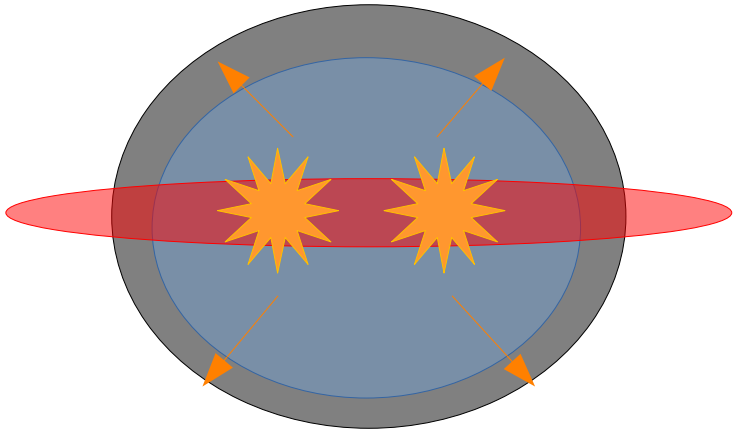

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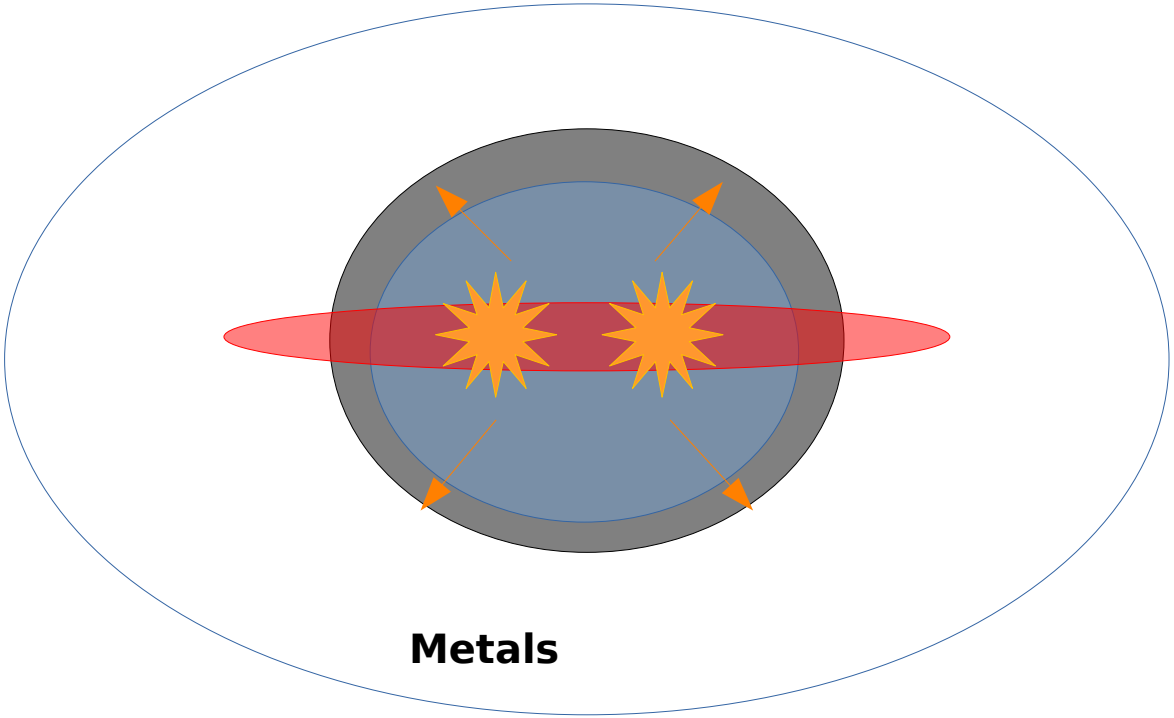

Meraxes

MERAXES: a semi-analytical model of galaxy formation *and reionization*

Physics of galaxy formation:

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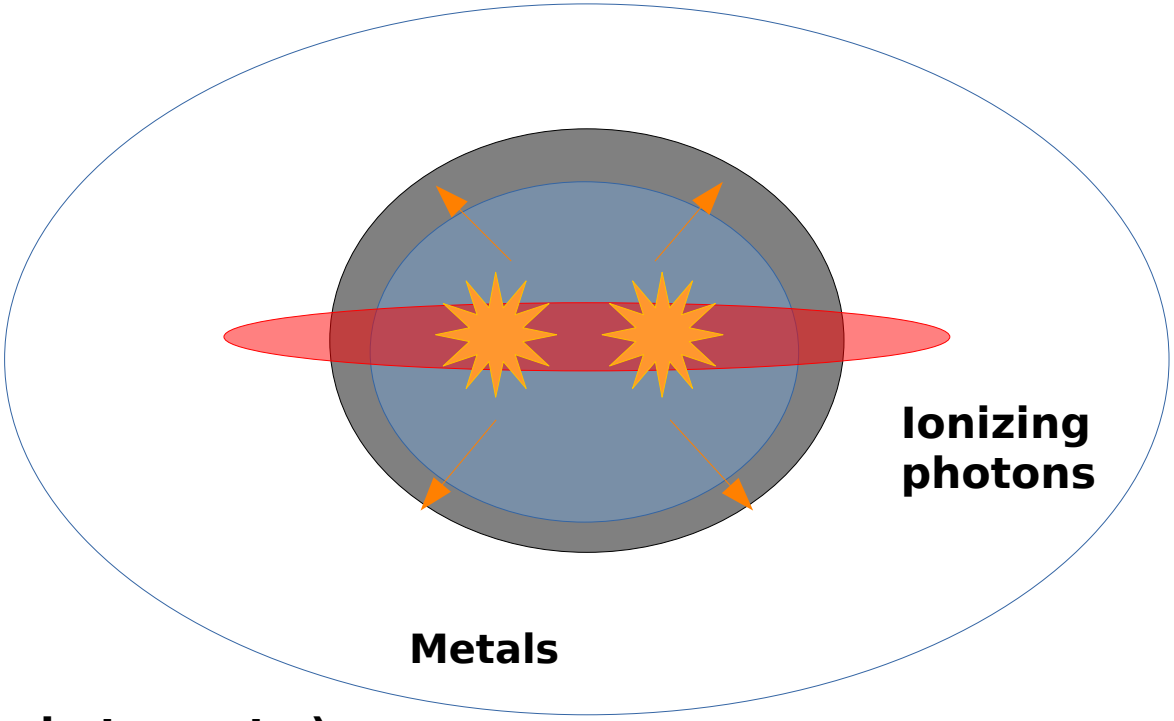
6) Compute reionization (ionizing photons etc.)



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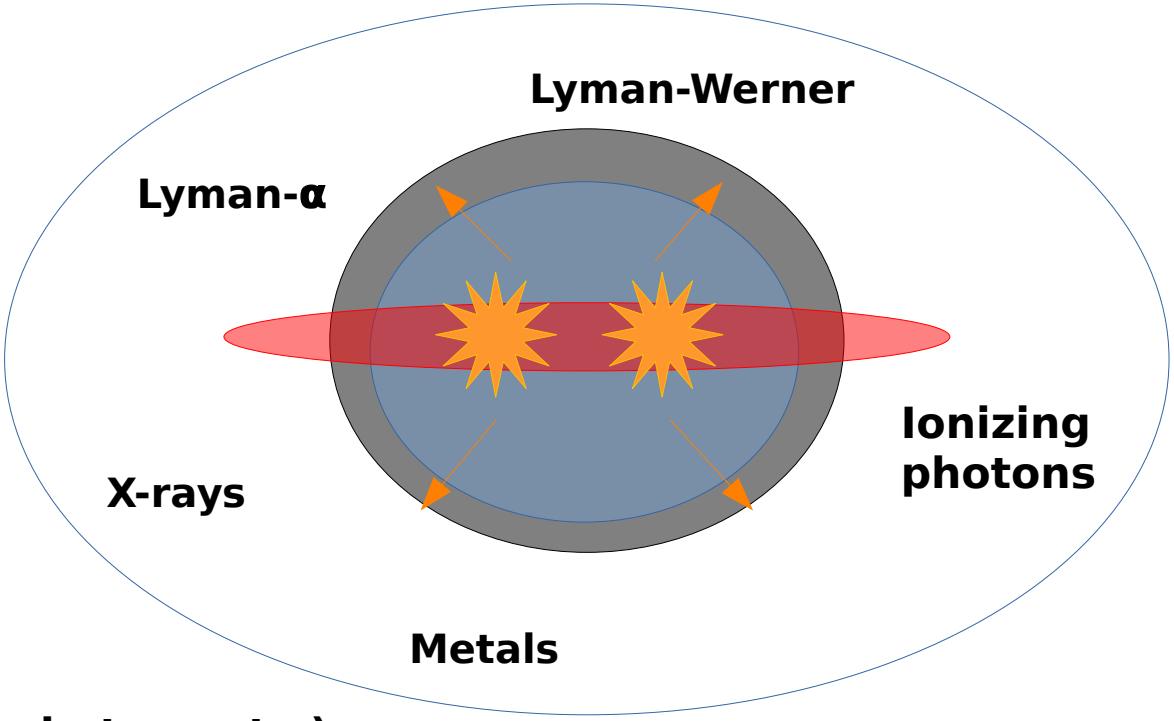


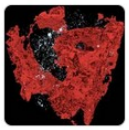
6) Compute reionization (ionizing photons etc.)

7) Compute radiative backgrounds

Meraxes

MERAXES: a semi-analytical model of galaxy formation *and reionization*

First public release!



Meraxes Devs

Developers of the Meraxes semi-analytic galaxy formation model

Follow

README.md

Welcome to meraxes-devs

The home of the Meraxes semi-analytic model and associated projects.

Meraxes

The Meraxes model itself.

Dragons

A Python package for reading and processing Meraxes output.

Sector

Construct spectral energy distributions (SEDs) from star formation and metallicity histories.
Used by Meraxes internally, but can also be used separately.

View as: Public

You are viewing the README and pinned repositories as a public user.

People

Top languages

C Python

https://github.com/meraxes-devs

Pop. III star formation in Meraxes

MERAXES: a semi-analytical model of galaxy formation *and reionization*

Physics of galaxy formation:

1) Gas Infall

2) Gas Cooling

3) Star Formation → Pop. III stars

Pop. III properties (IMF, SF efficiency...)

↓

Free parameters, we can change these each run!

Pop. III star formation in Meraxes

MERAXES: **a semi-an**
reionization

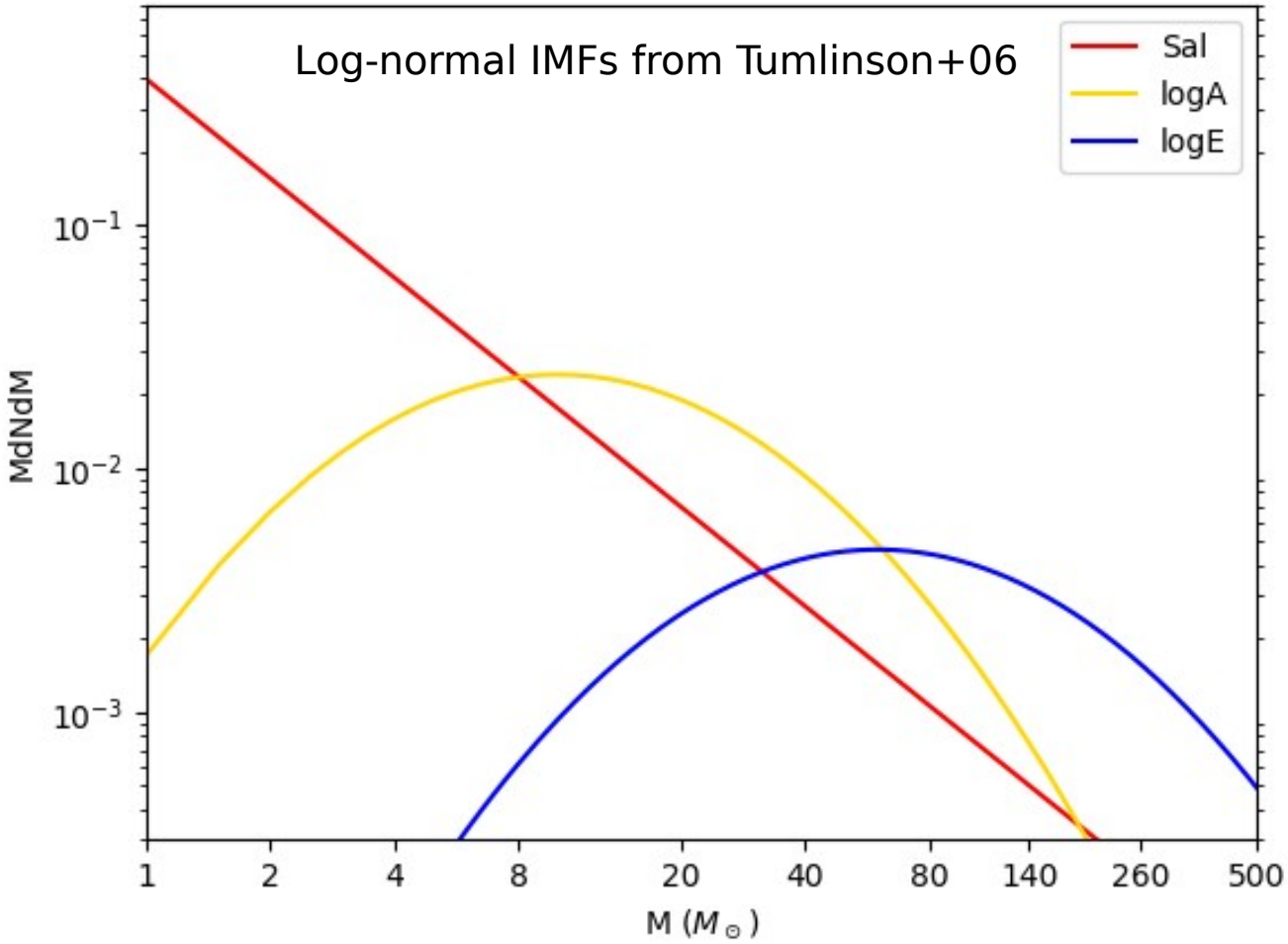
Physics of galaxy formation:

1) Gas Infall

2) Gas Cooling

3) Star Formation

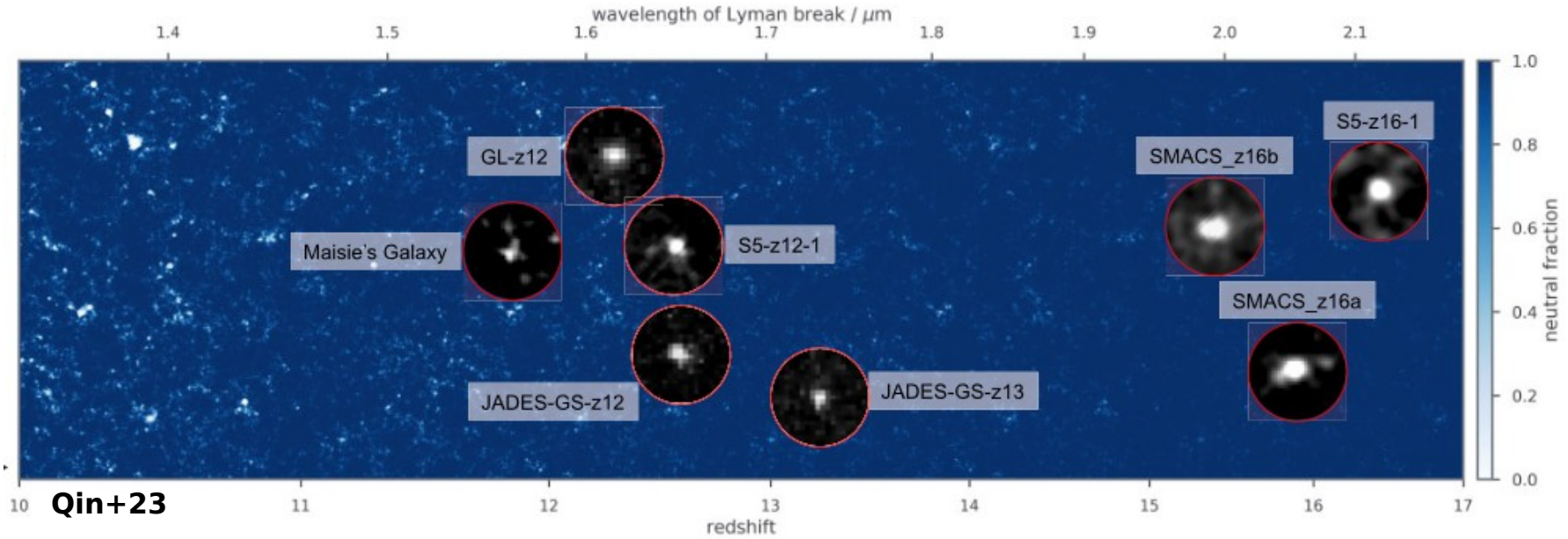
Pop. III IMF



Free parameter, we can change this each run!

Too many, too bright

Bright galaxies at z > 10



Qin+23

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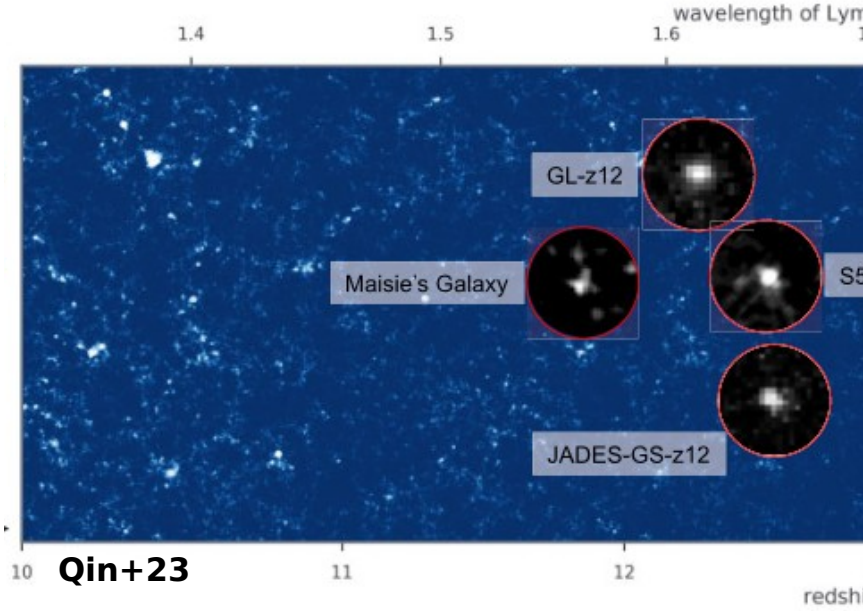

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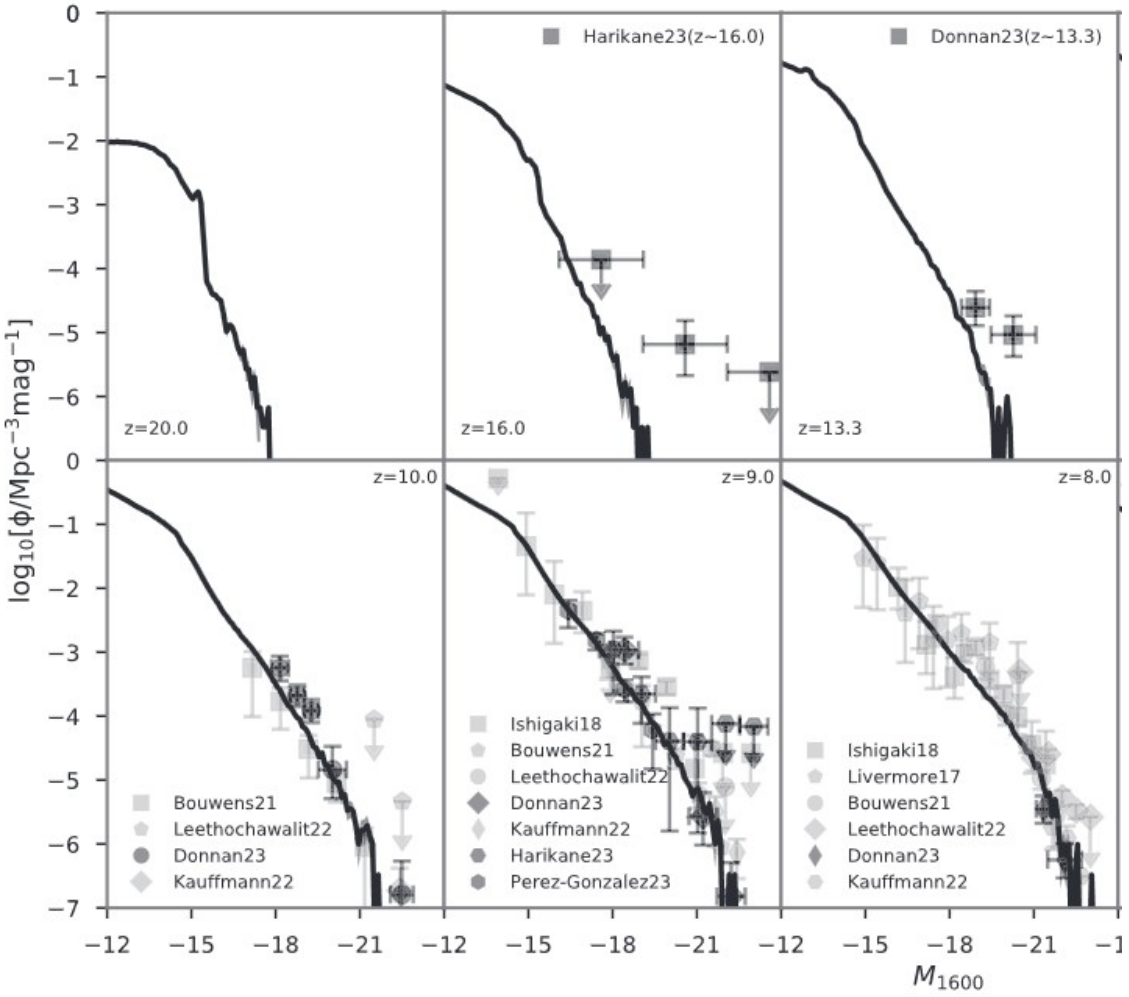

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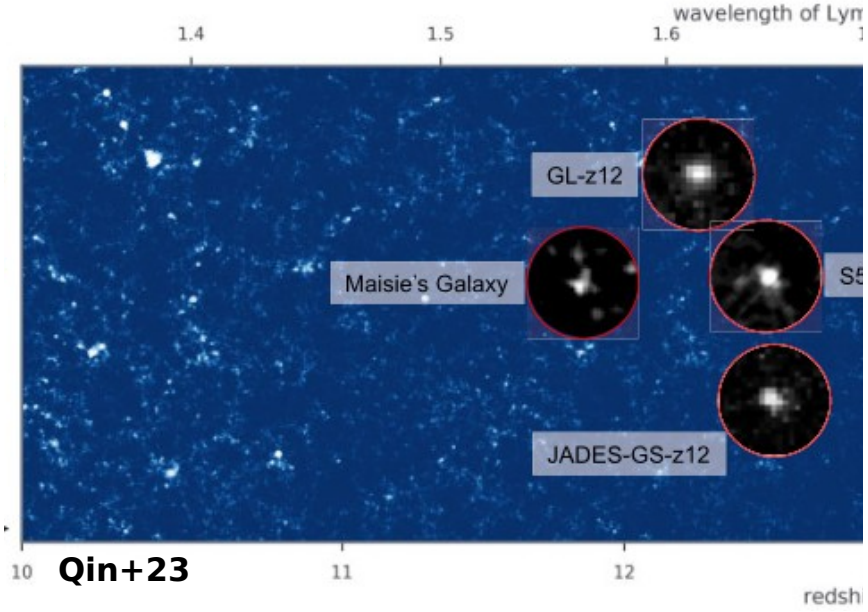

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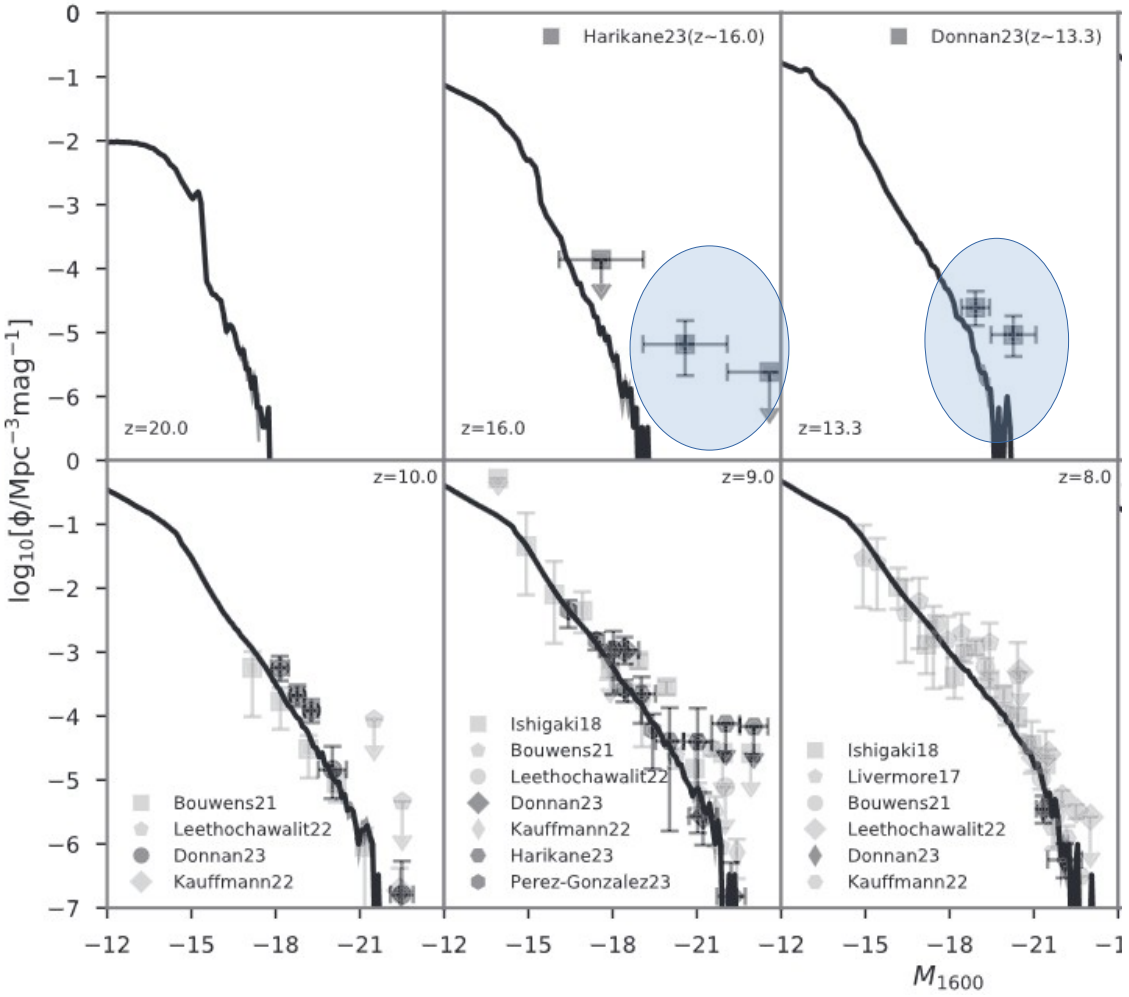
Excess of bright galaxies at z ≥ 12



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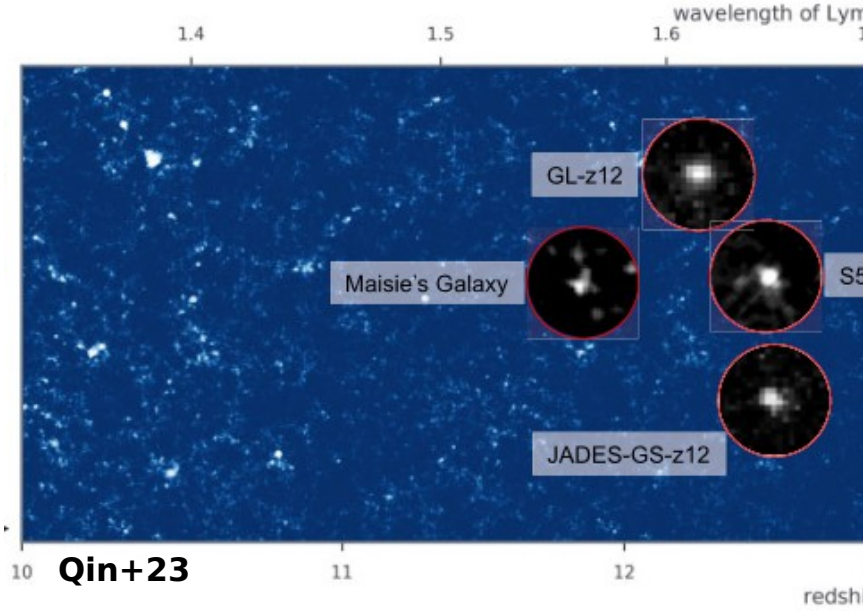

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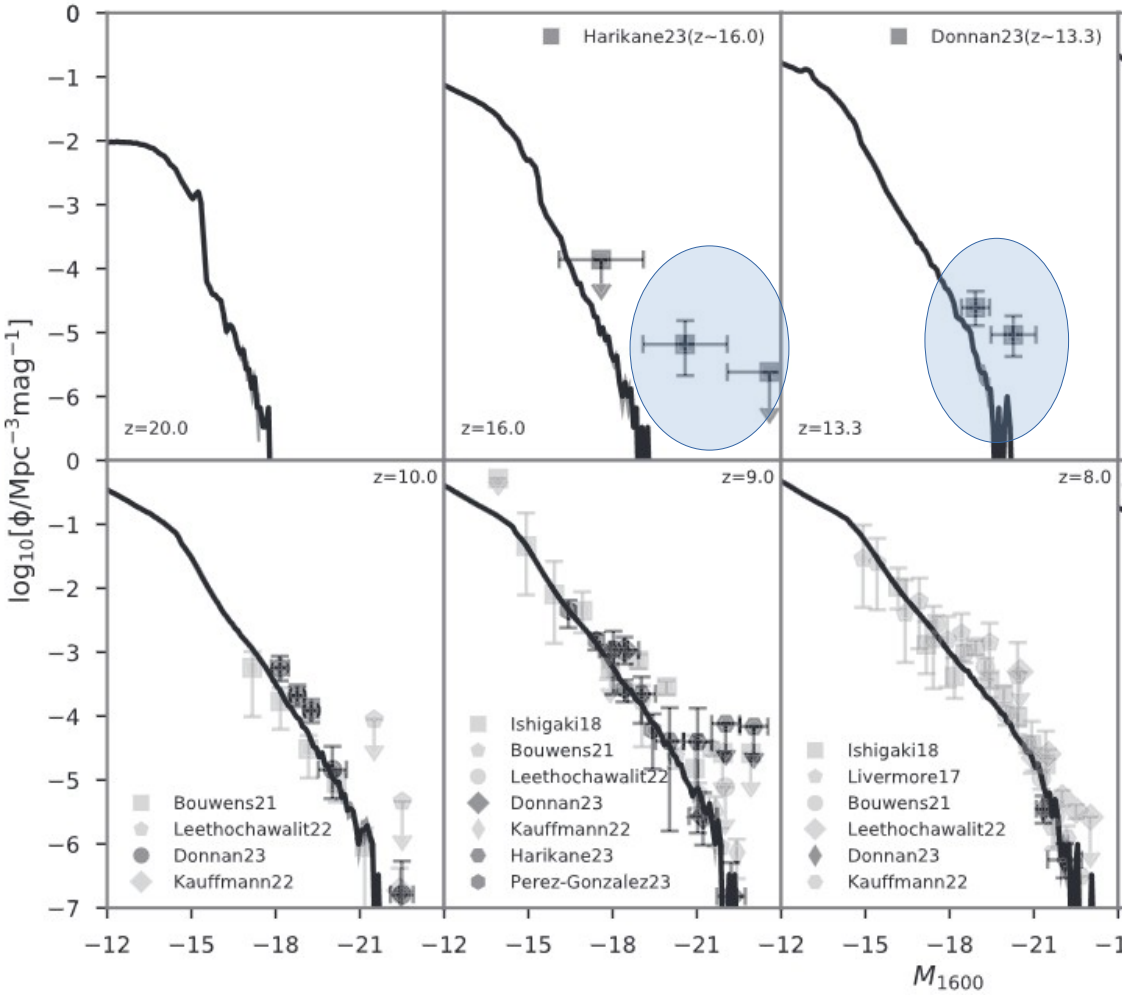
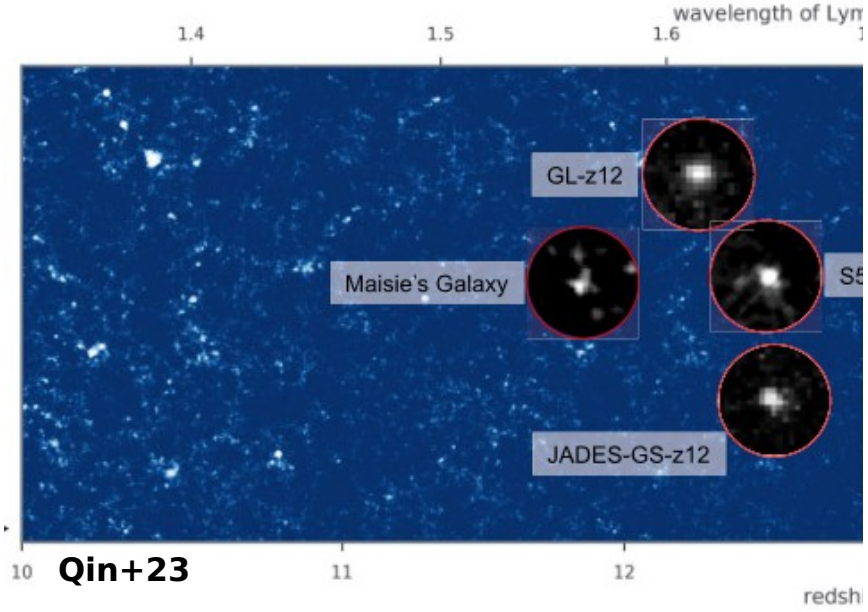


Excess of bright galaxies at z ≥ 12

- Increase SF efficiency

Too many, too bright

Bright galaxies at z > 10



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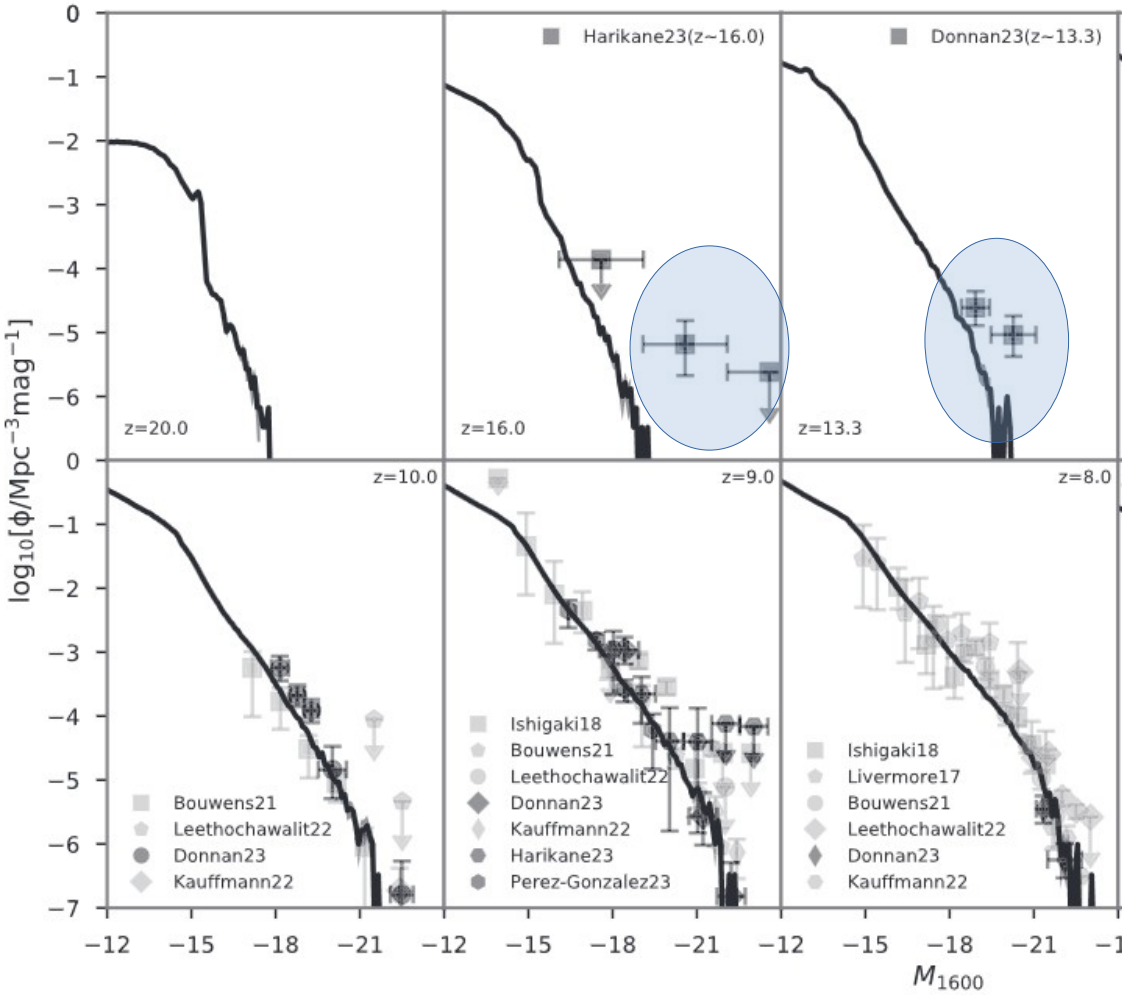

Excess of bright galaxies at z ≥ 12

- Increase SF efficiency
- Reduce feedback

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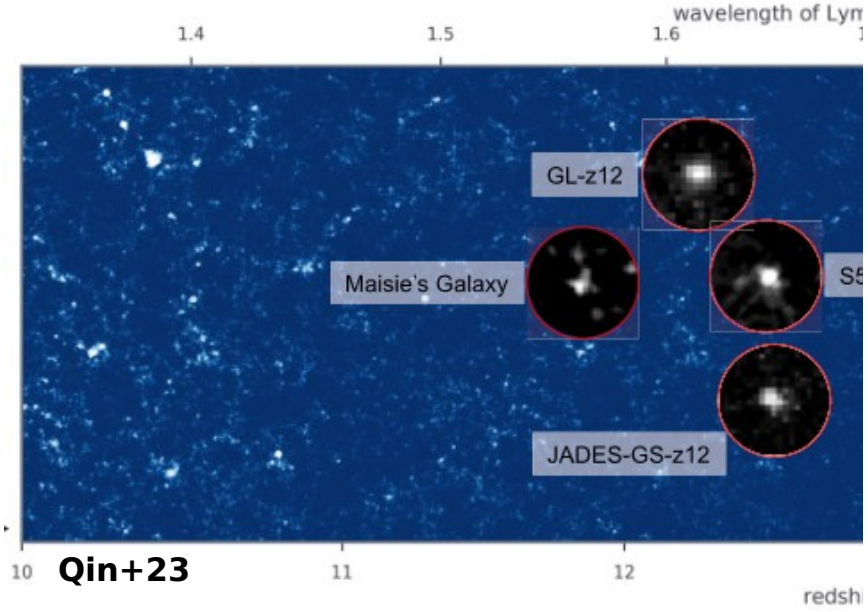
Bright galaxies at z > 10



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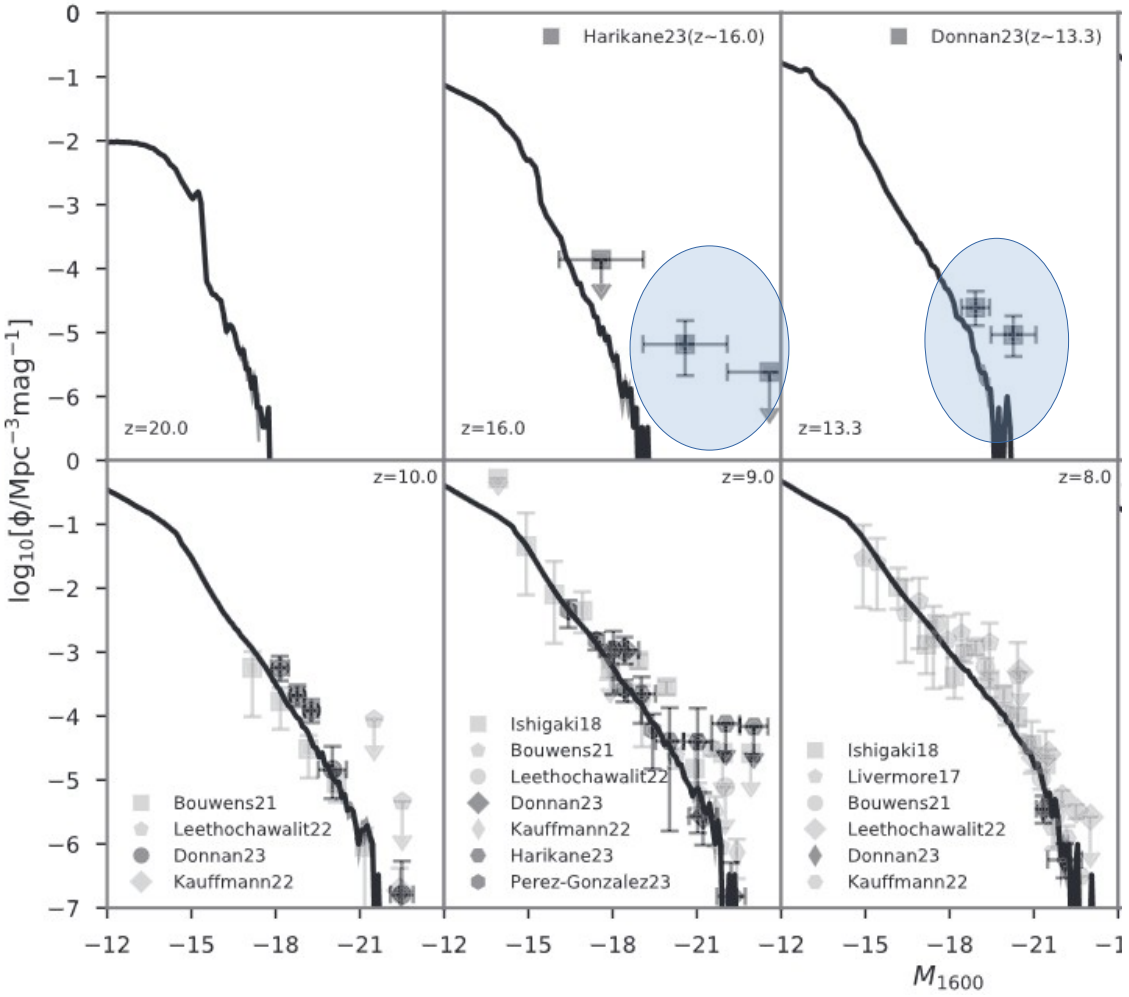

Excess of bright galaxies at z ≥ 12

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- Tension with ΛCDM model

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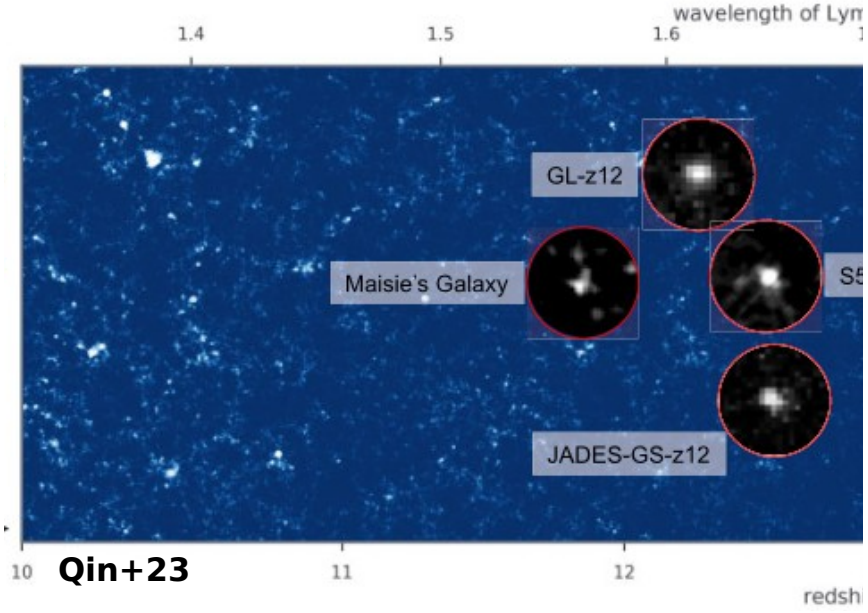

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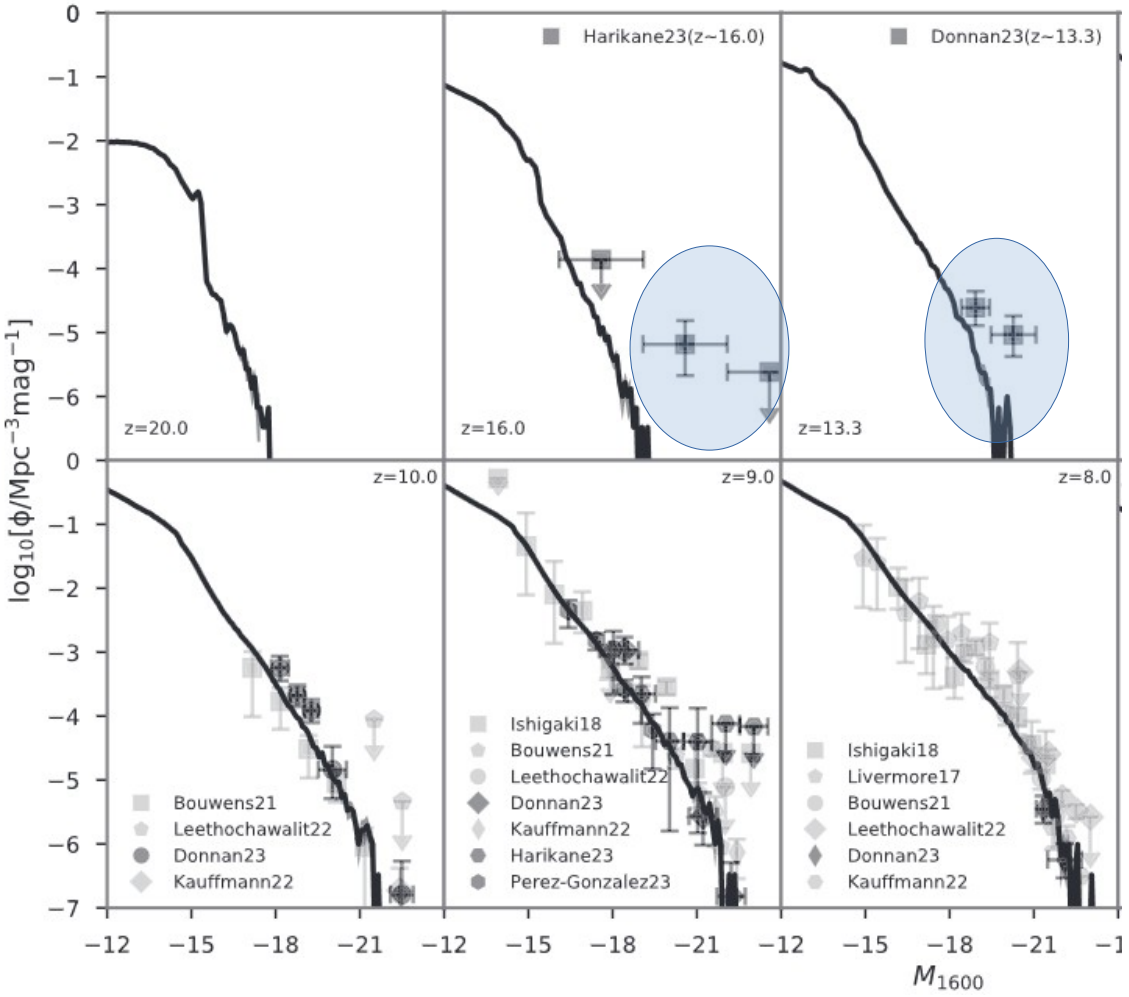

Excess of bright galaxies at z ≥ 12

- Increase SF efficiency
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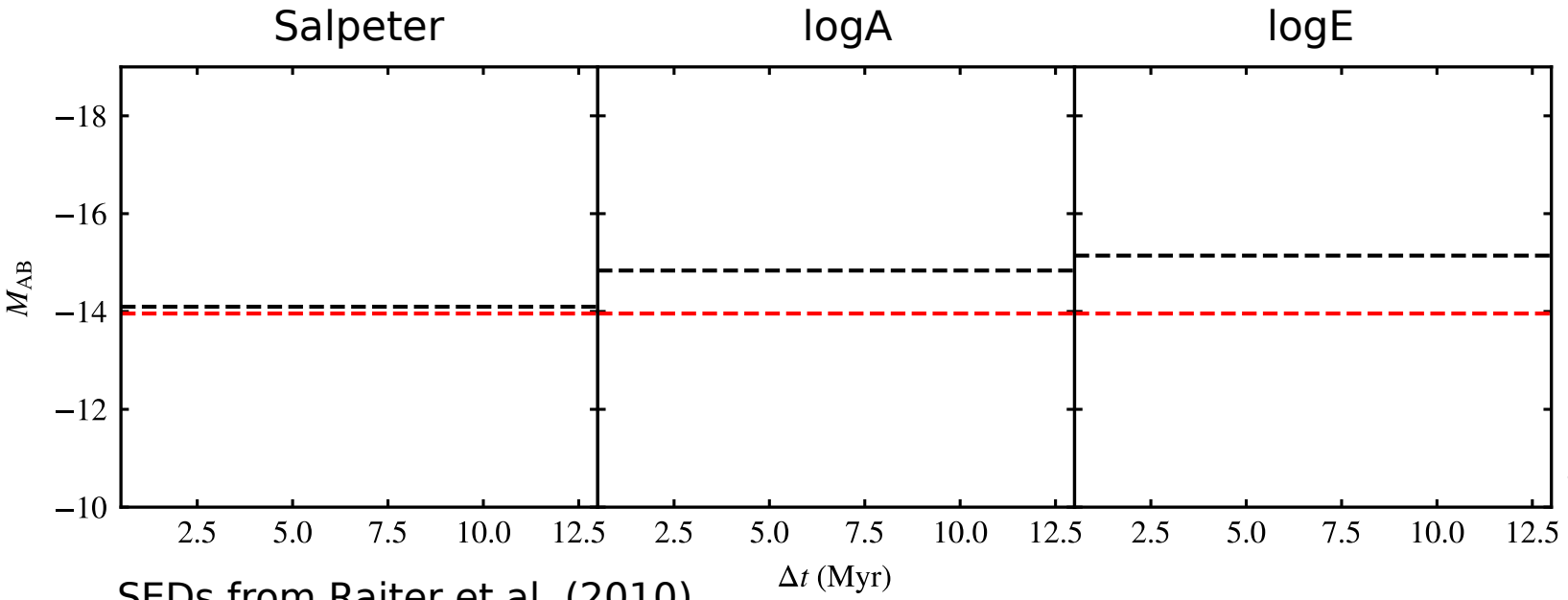
- **Pop. III galaxies**

Luminosity of a Pop. III galaxy



z = 8
10^5 M_{sun}

Pop. III galaxy

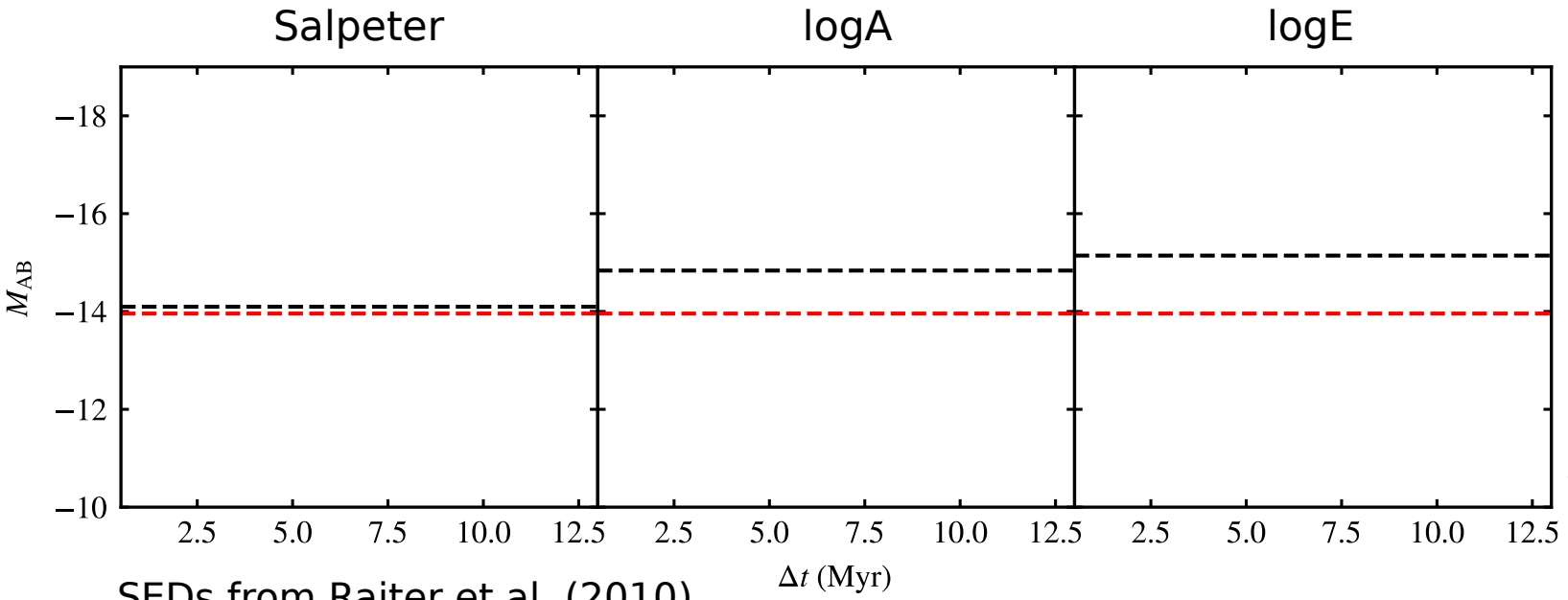
Pop. II galaxy

Ventura+24

SEDs from Raiter et al. (2010)

Assuming Pop. III stars form **continuously** throughout the snapshot:

Luminosity of a Pop. III galaxy



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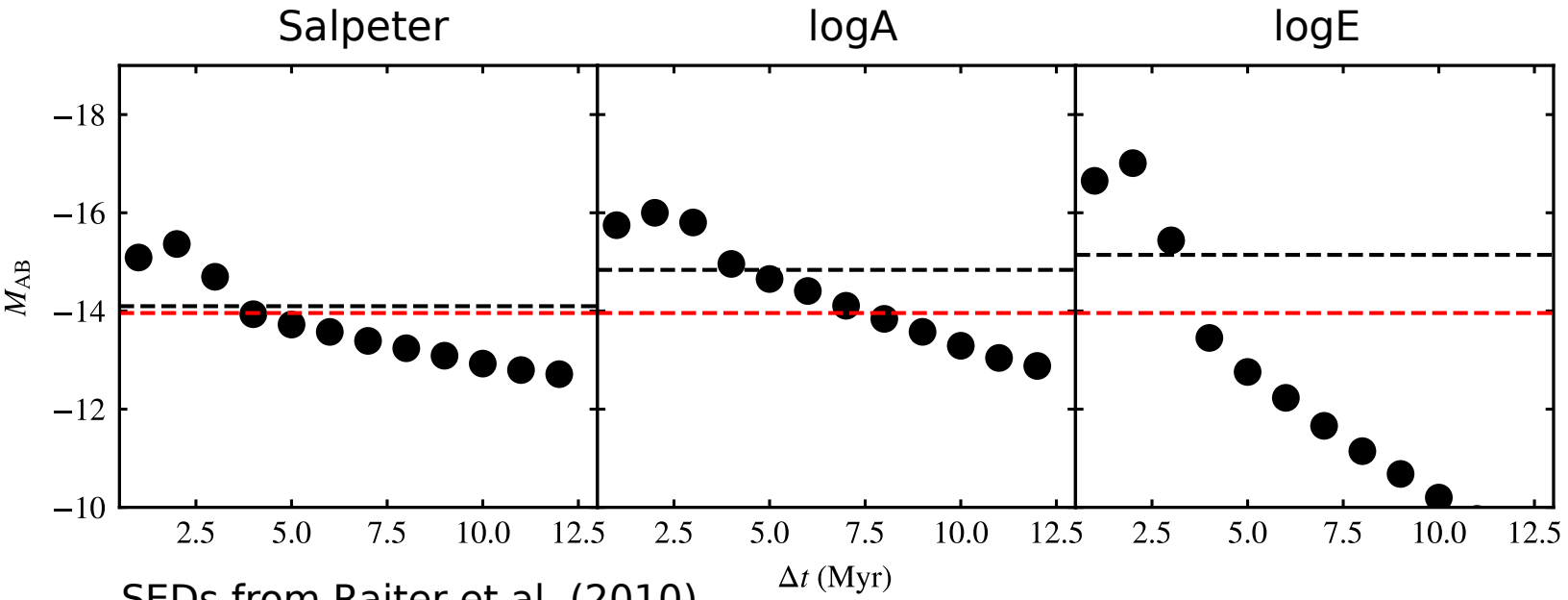
Luminosity of a Pop. III galaxy



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Pop. III galaxy

Pop. II galaxy

Ventura+24

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Assuming Pop. III stars form **continuously** throughout the snapshot:

- **Pop. III** galaxies can be **≥ 1 mag brighter** than **Pop. II** galaxies

Assuming Pop. III stars form **in a single burst** at the beginning of the snapshot:

- **Pop. III** galaxies can be **up to 3 mag brighter** than **Pop. II** galaxies

Let’s go back

JWST bright galaxies at z>12: can we explain these with Pop. III star formation?

Let’s go back

NO*

* Unless...

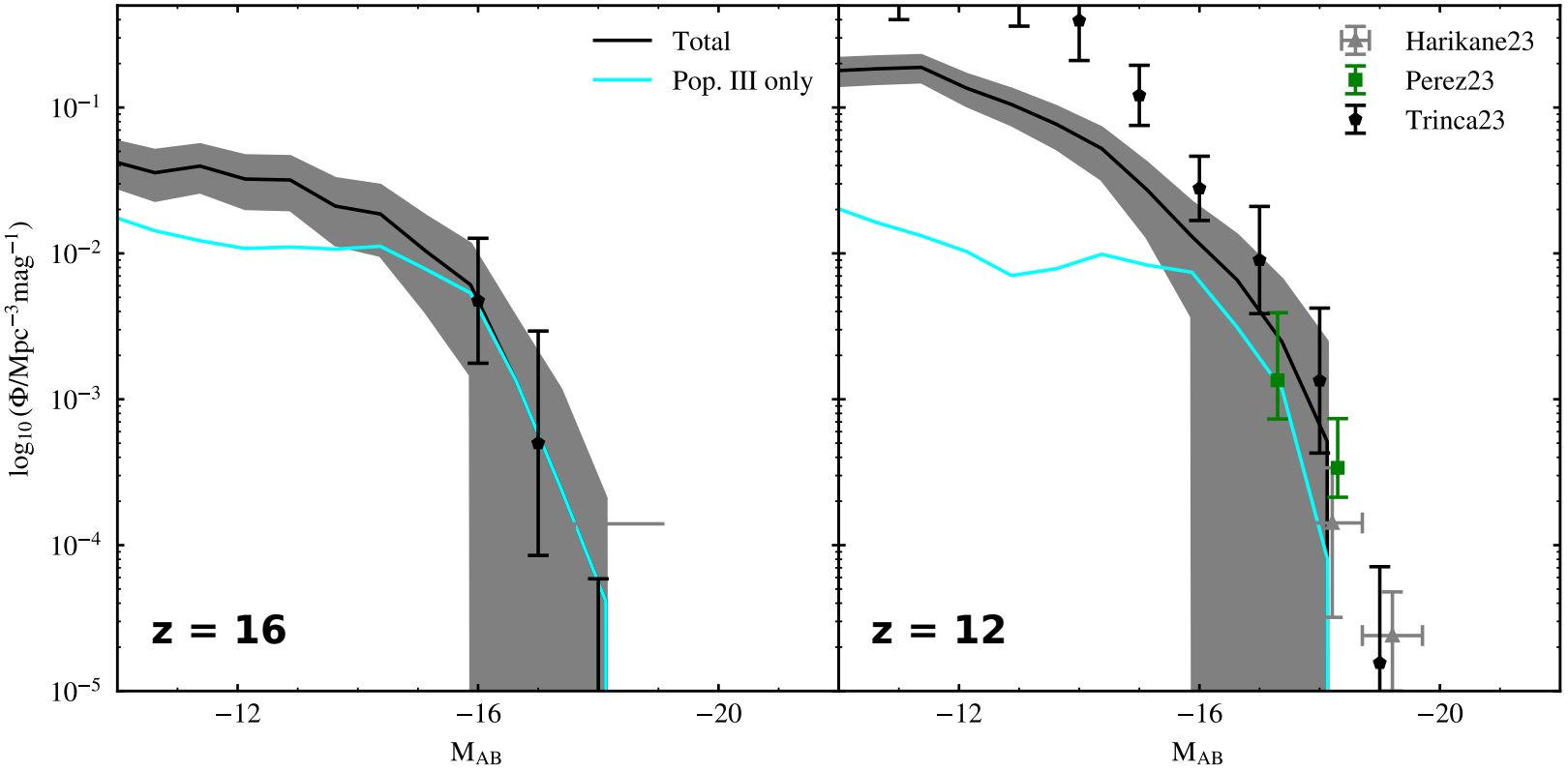
Impact on the UV luminosity function

logE IMF

Pop.III SF occurs in a single burst

Pop. III SF efficiency same as Pop. II

Impact on the UV luminosity function



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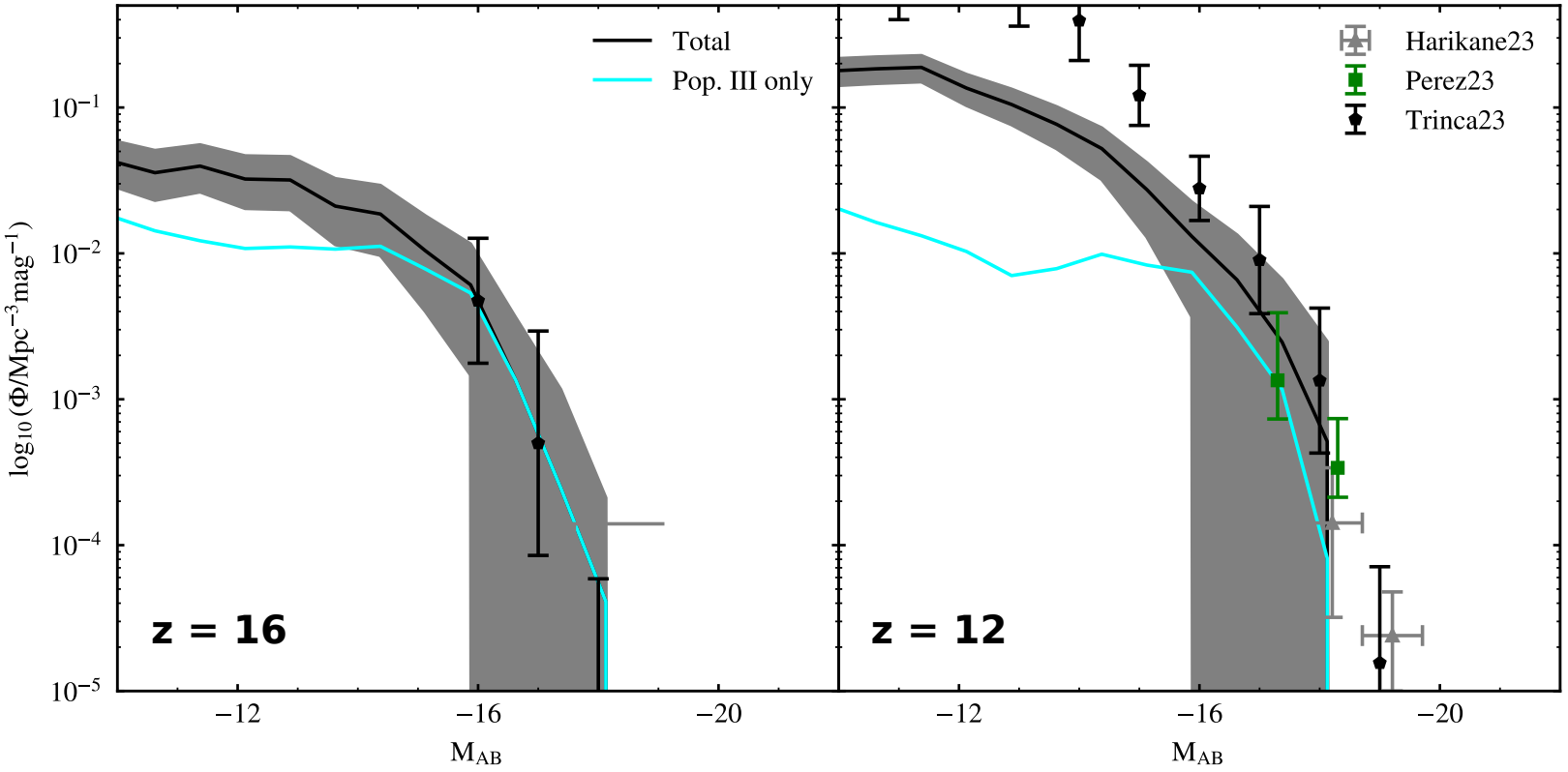
Impact on the UV luminosity function



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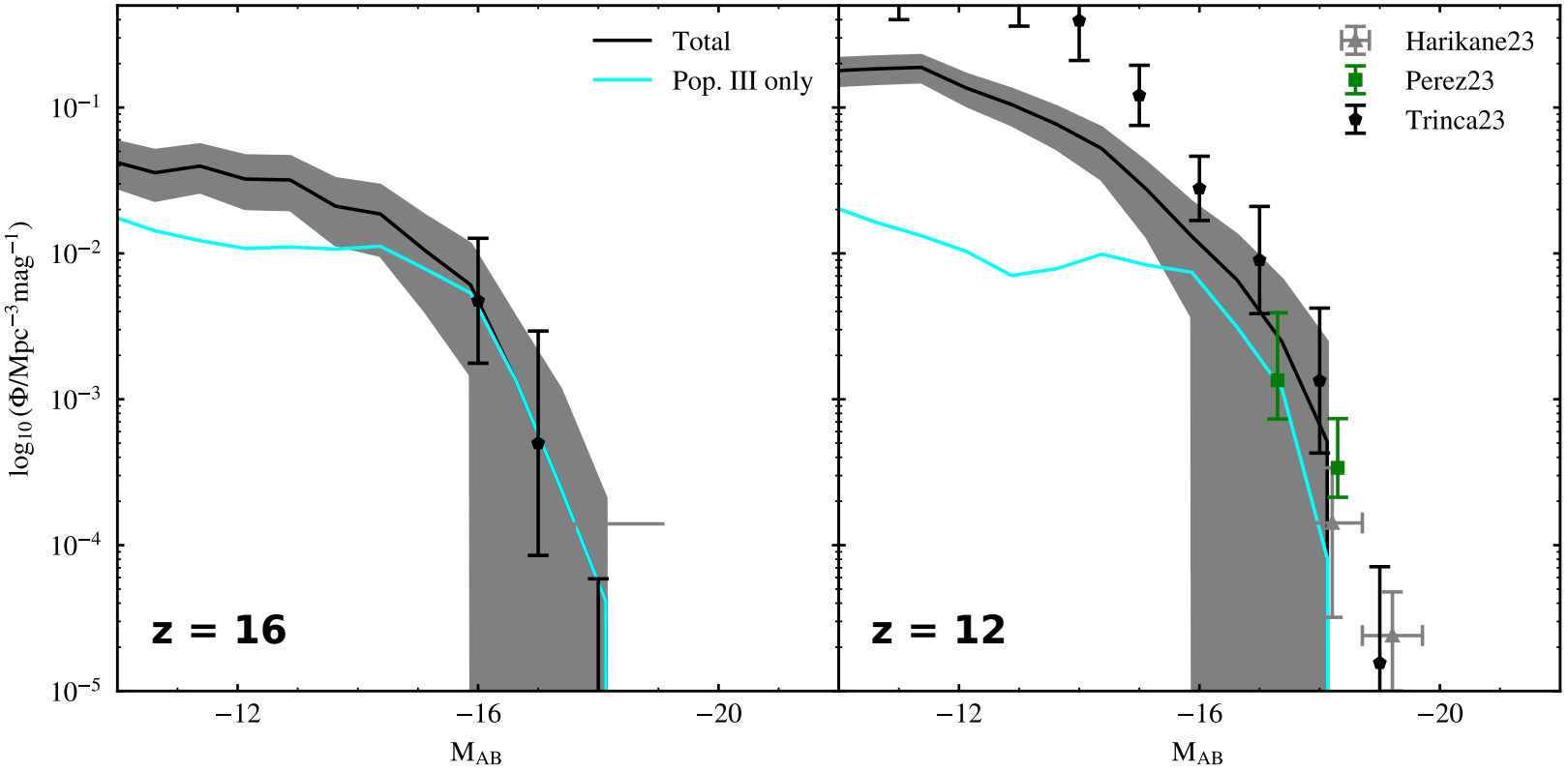
- At z = 16 the brightest galaxies are Pop. III galaxies.

Impact on the UV luminosity function



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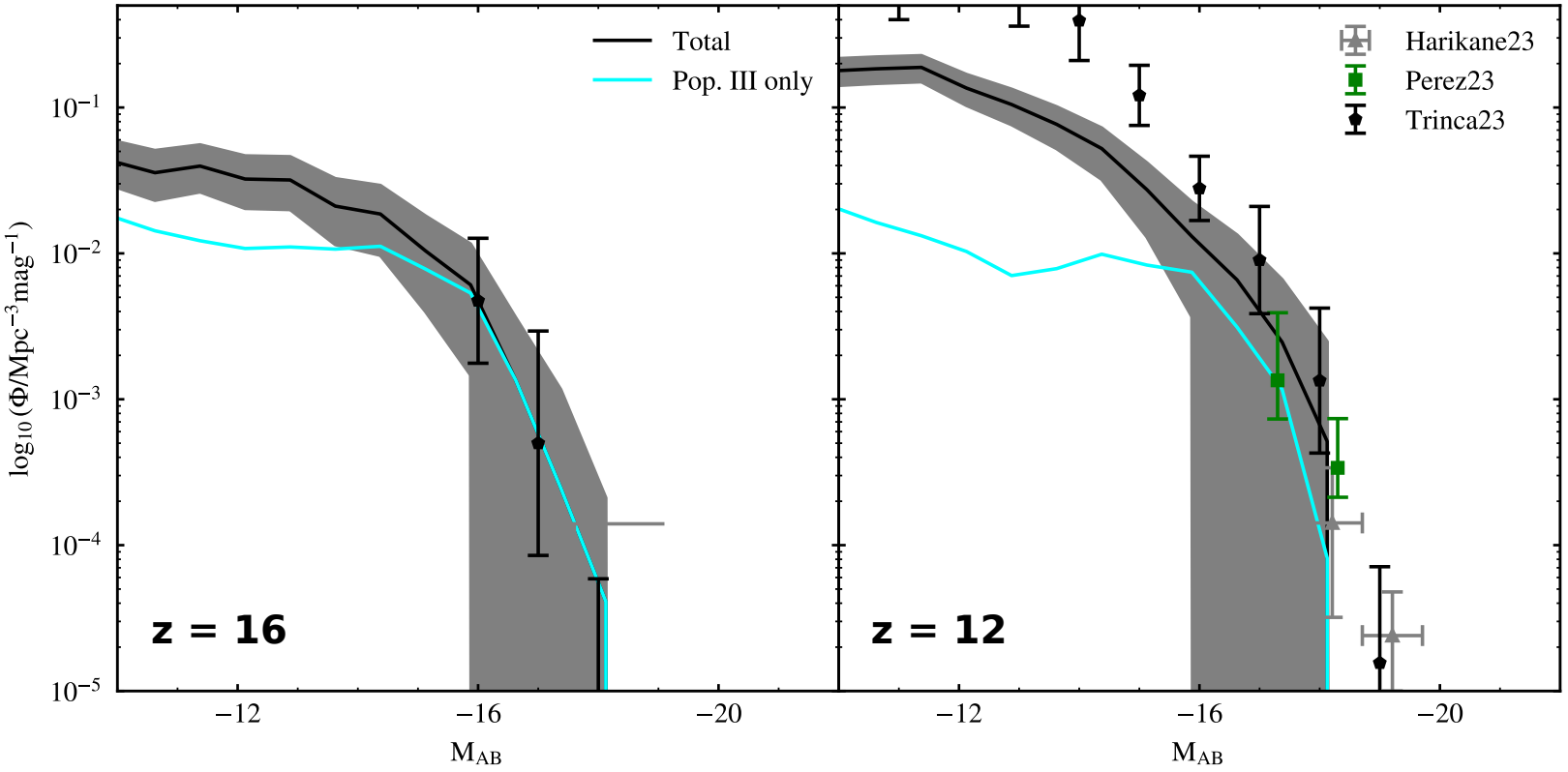
Impact on the UV luminosity function



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- Both models consistent with observations at z < 12

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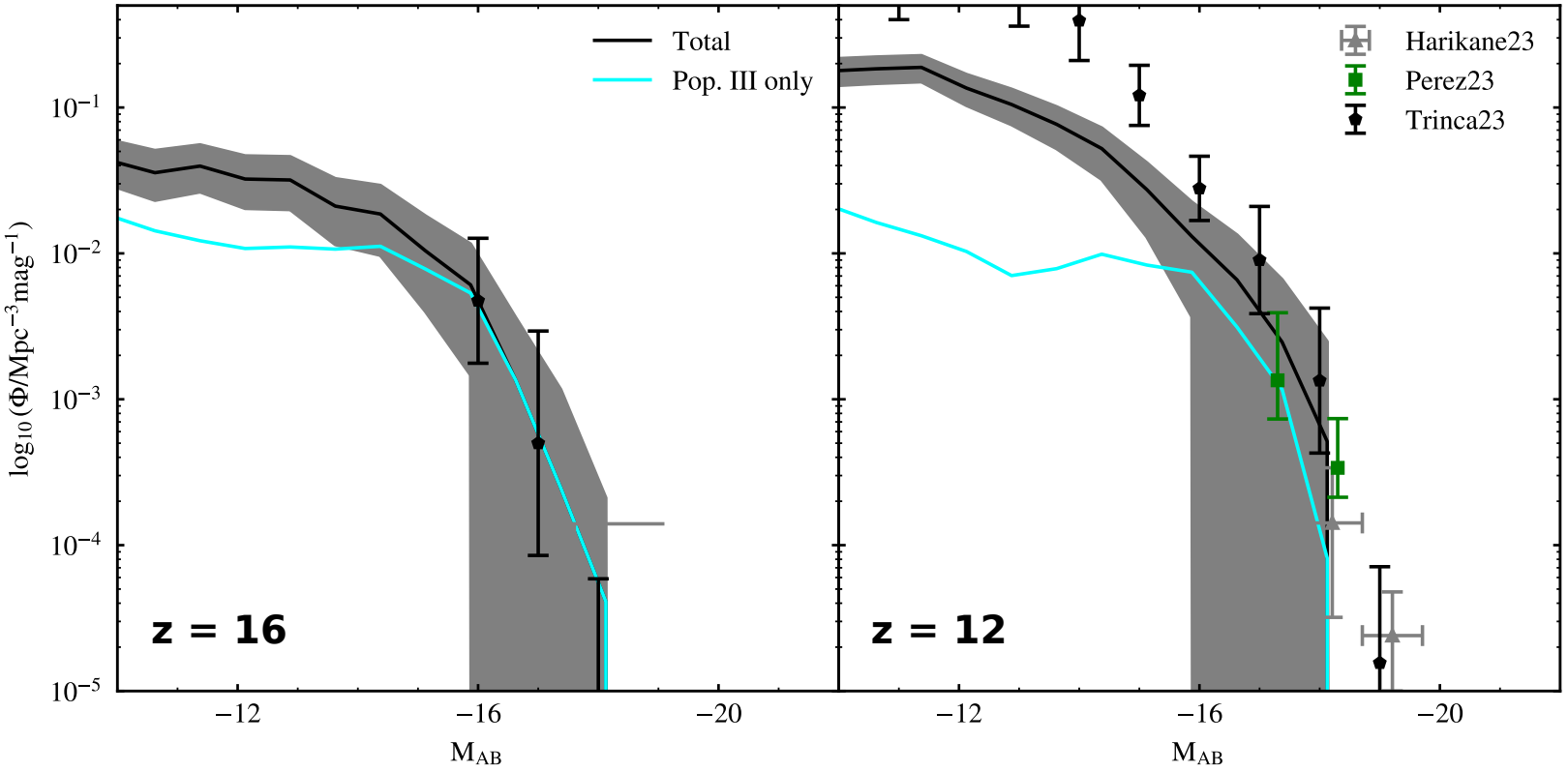

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- Need for a larger box!

Conclusions

We effectively implemented Population III star formation in MERAXES which is now publicly available:

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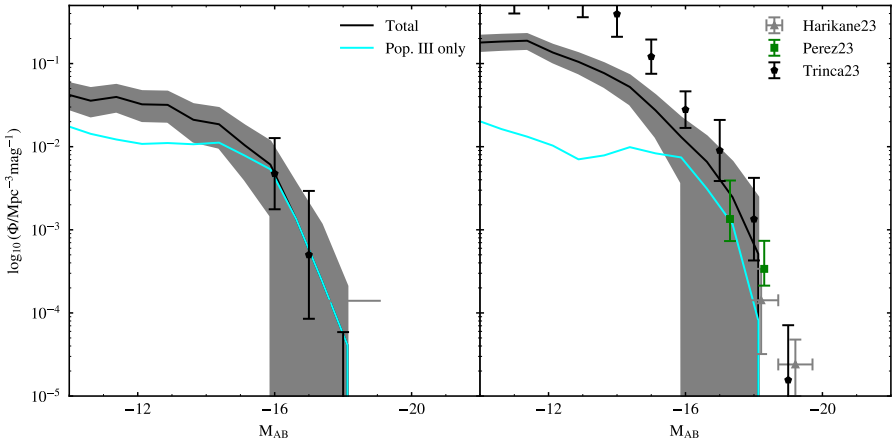
Pop. III galaxies with a top-heavy IMF, might explain the abundance of very bright galaxies at z > 12 without requiring extreme physics:



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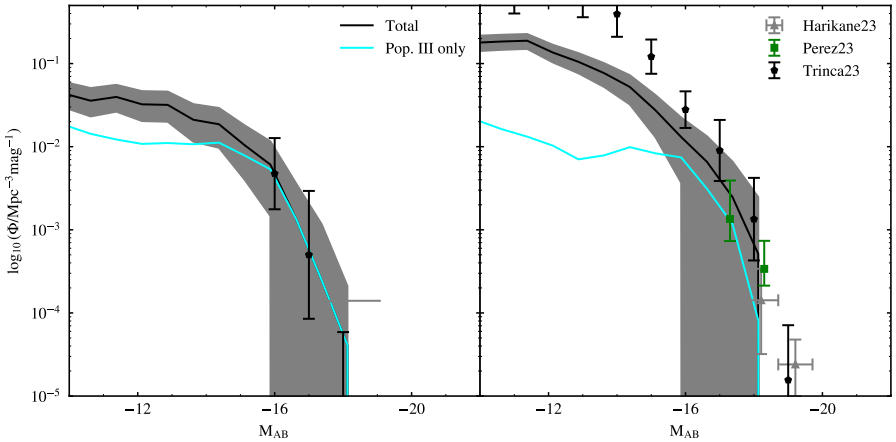

Need to extend for larger volumes!

Cosmic Dawn at High Latitudes

Thank you!

Here for a cool paper.

Check me out! I am a dragon!

THE UNIVERSITY OF MELBOURNE

ASTRO 3D