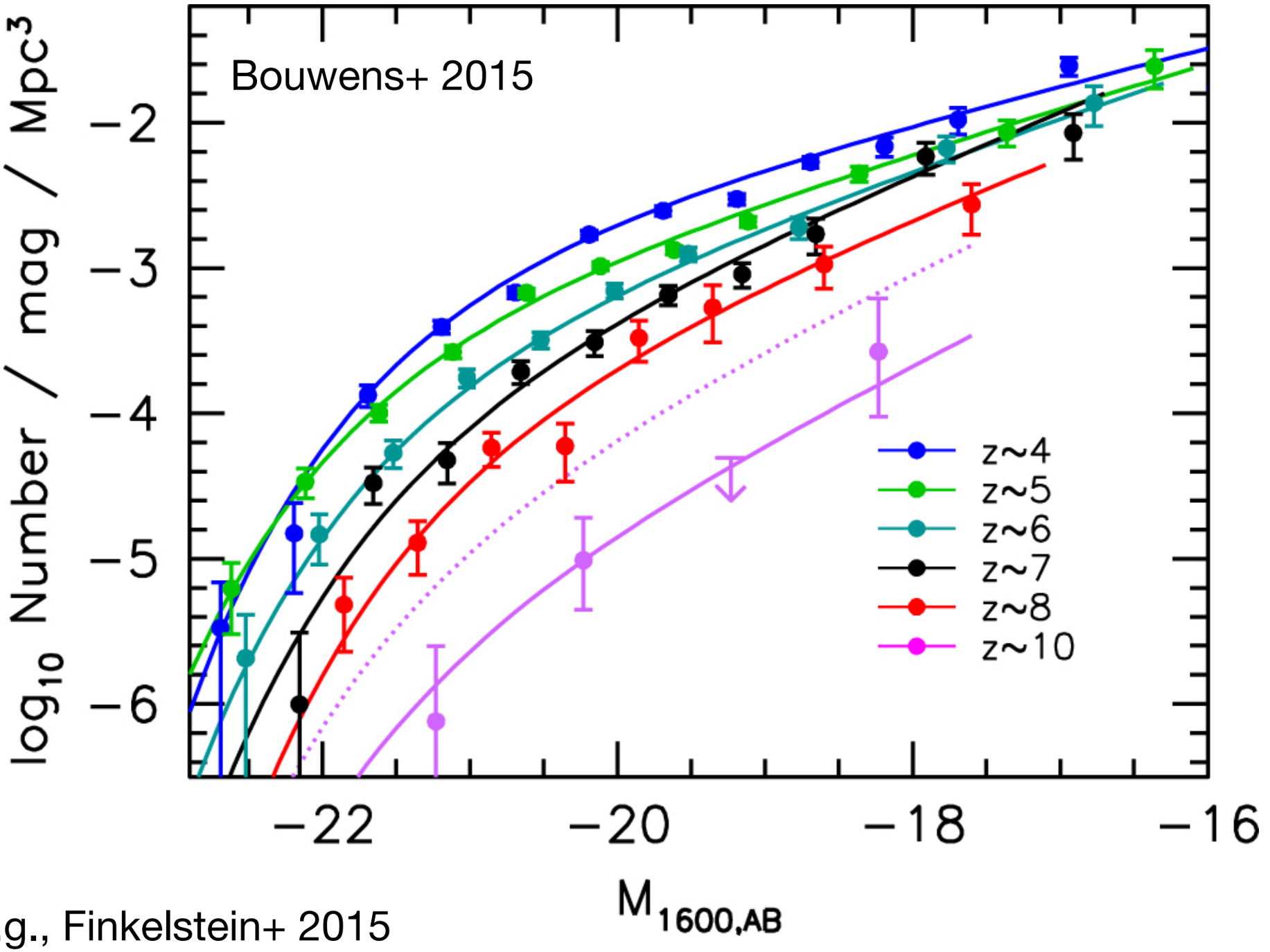
The Global 21-cm Signal in the Context of High-z Galaxy Surveys

Jordan Mirocha (McGill)

Outline

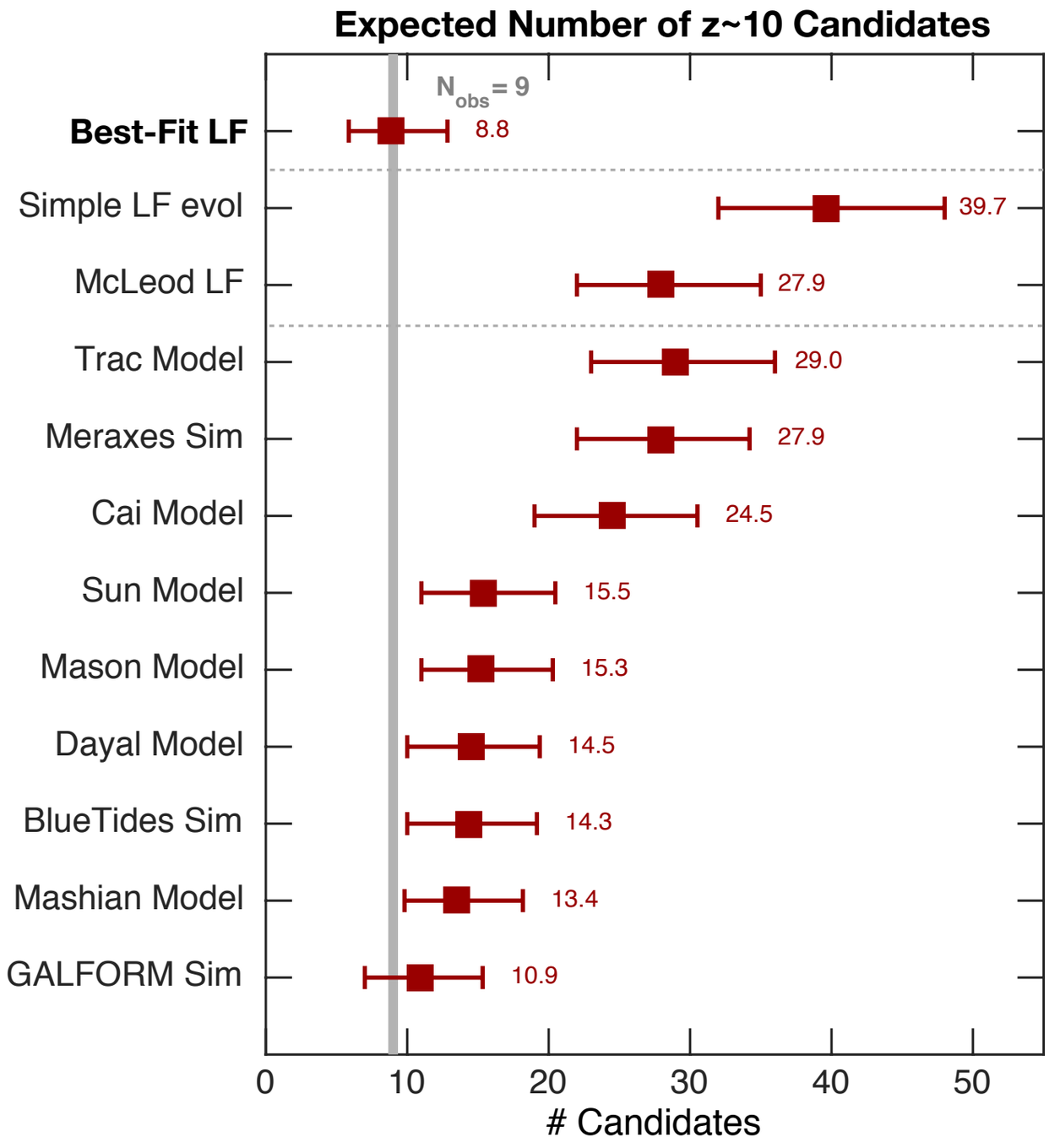
- Current status of high-z galaxy surveys
- Translating survey results into 21-cm predictions
- Joint inference — what do we learn from both?

Current Status: UDF



See also, e.g., Finkelstein+ 2015

Rapid decline in z~8-10 SFRD?

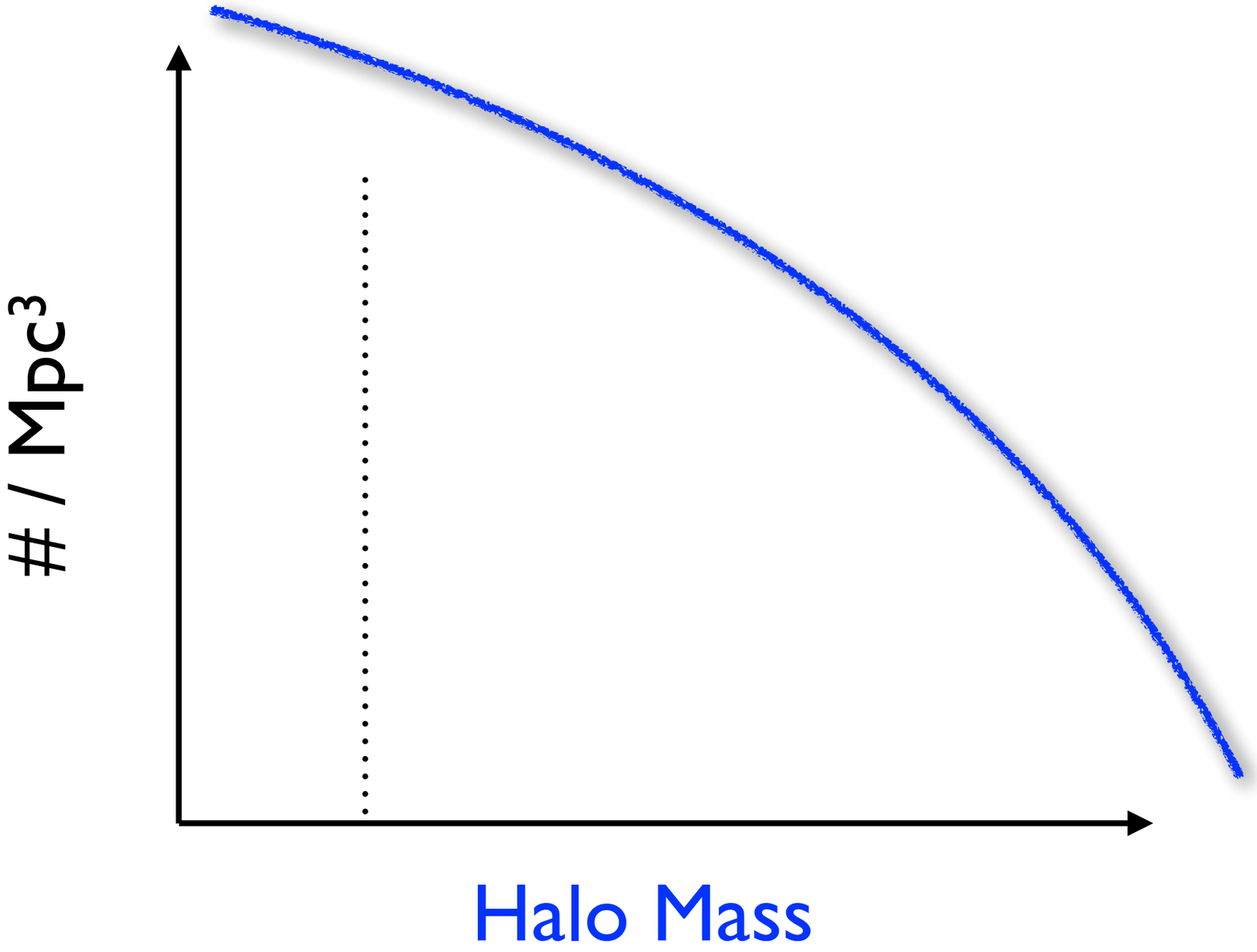


empirical extrapolation

semi-empirical, semi-analytic, and fully-numerical models

Oesch+ 2018

UVLF v. HMF



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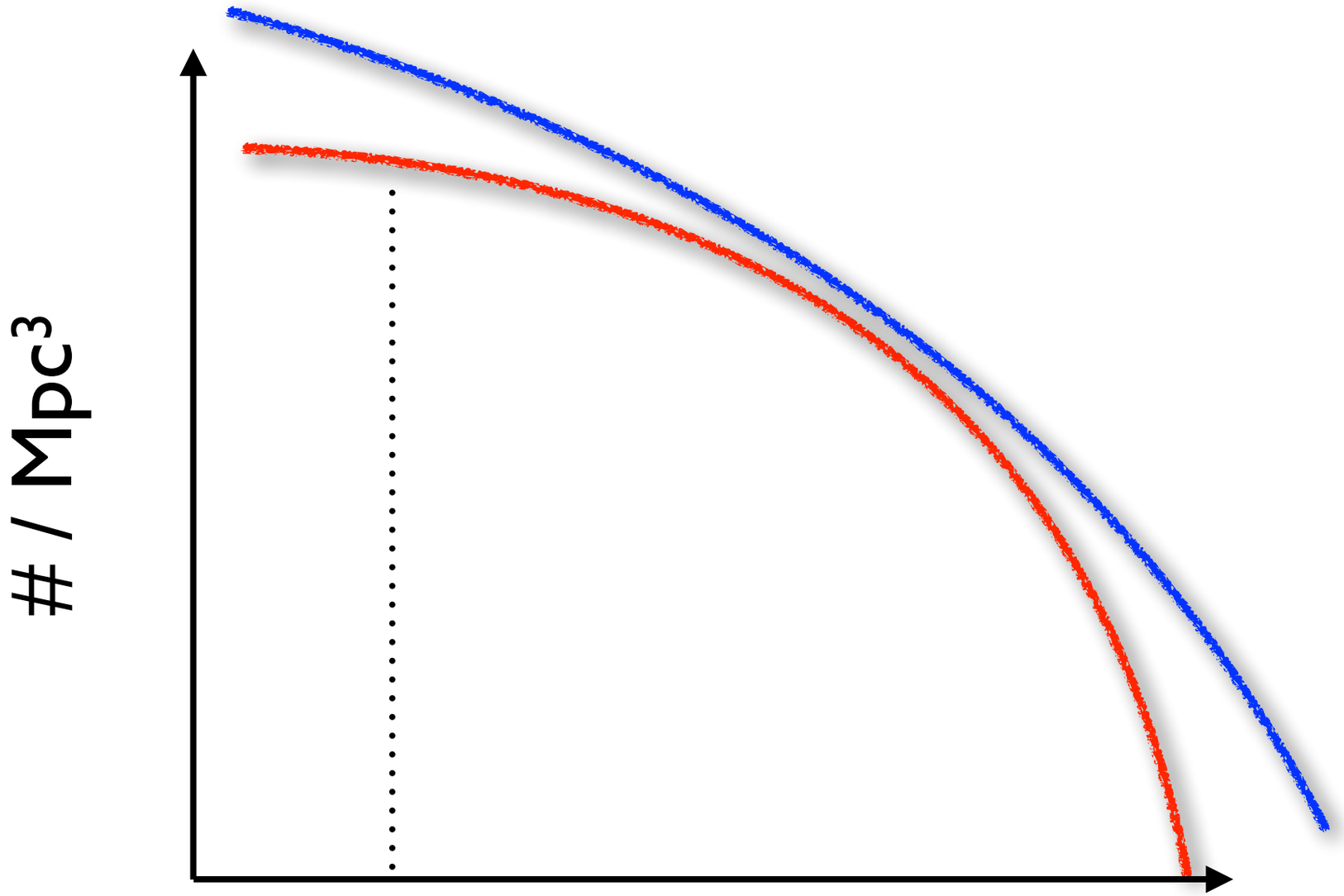
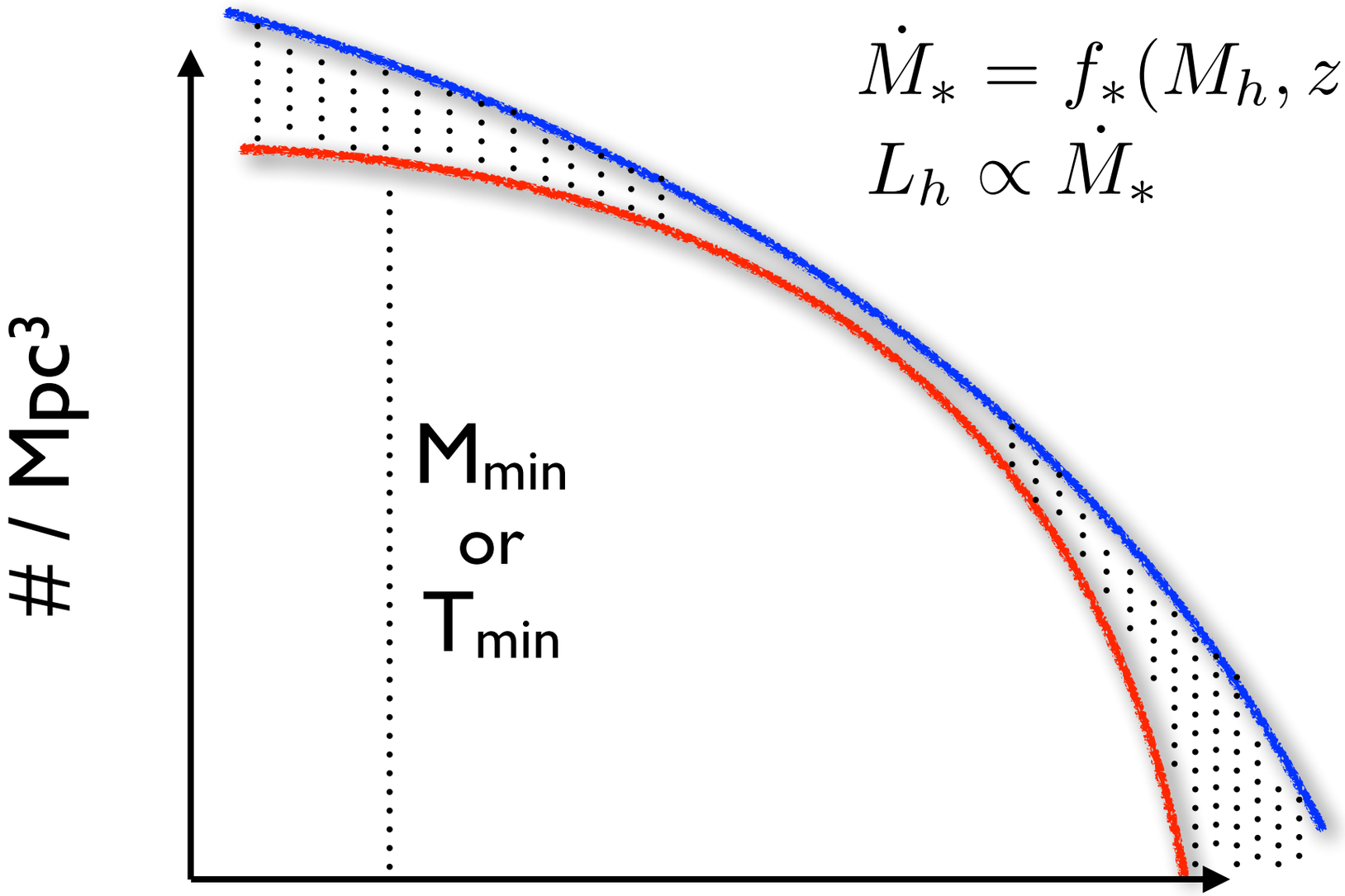
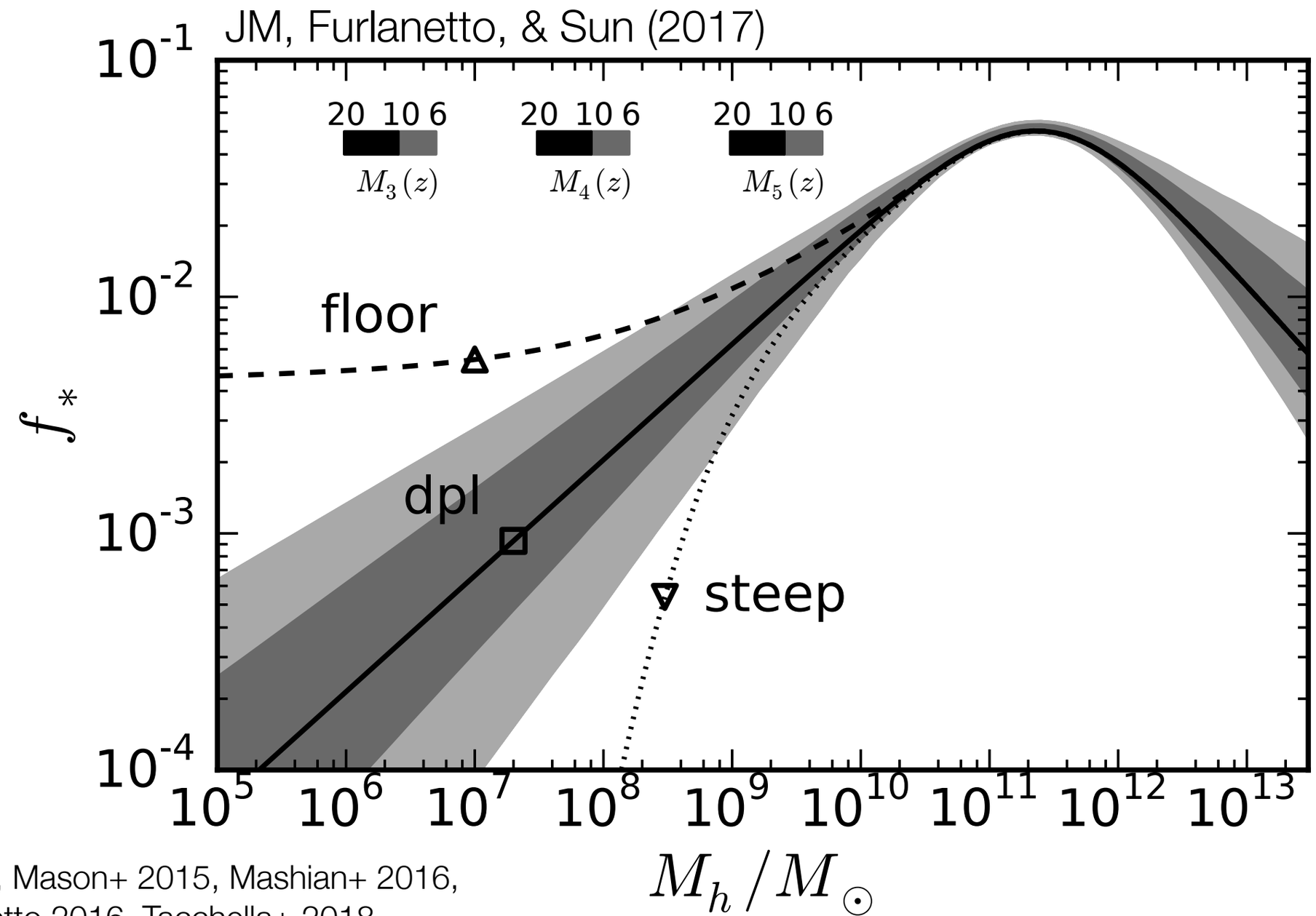


UVLF v. HMF

$$\dot{M}_* = f_*(M_h, z)\dot{M}_h(M_h, z)$$
$$L_h \propto \dot{M}_*$$

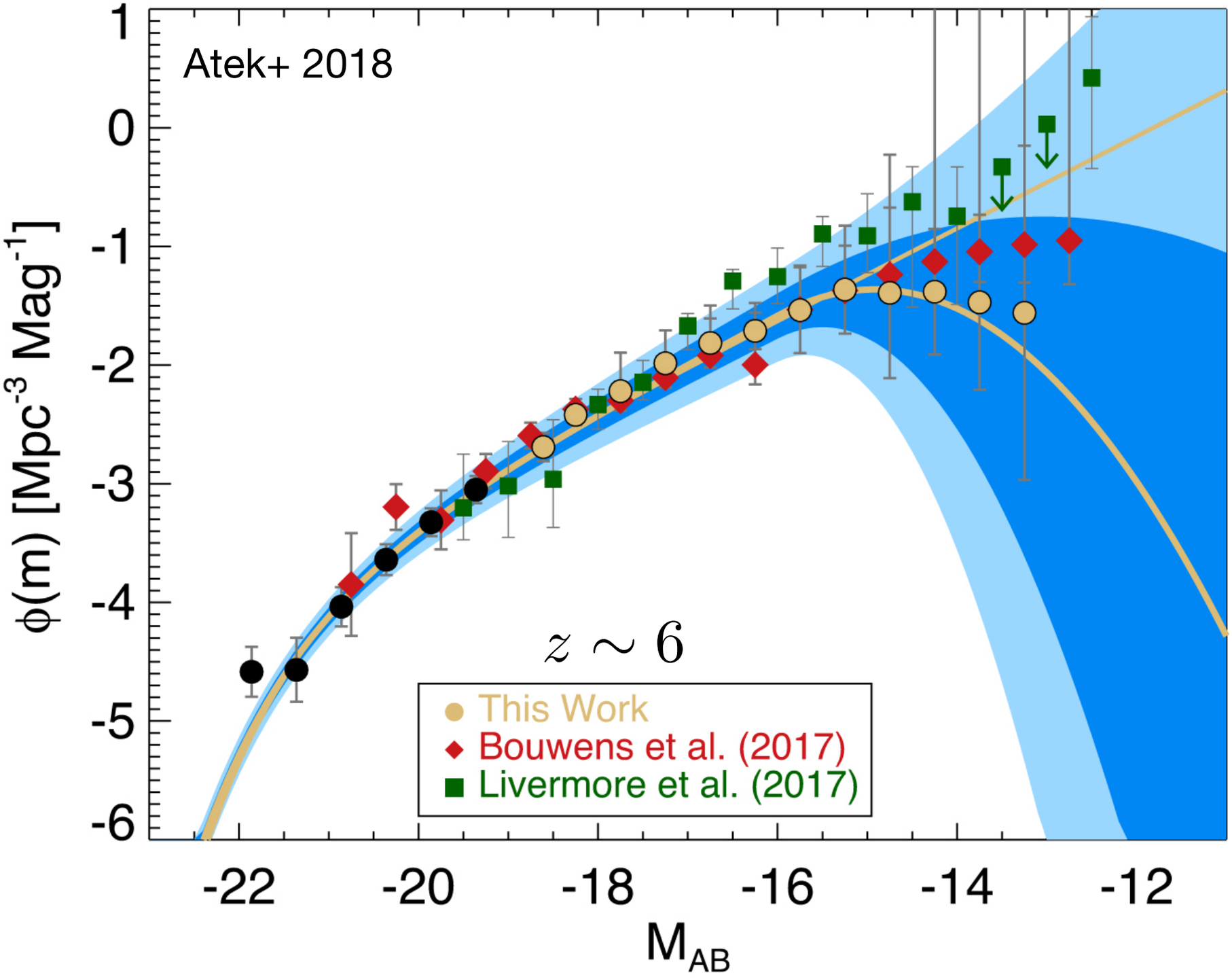


Semi-Empirical Models



see also, e.g., Mason+ 2015, Mashian+ 2016, Sun & Furlanetto 2016, Tacchella+ 2018, Behroozi+ 2019

Turn-over in UVLF?



What does this mean for the global 21-cm signal?

Disclaimer

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- In what follows I take a “semi-empirical” approach:
  - Assume normal stellar populations.
  - Fit models to current z>6 observations.
  - Extrapolate down to the atomic threshold.

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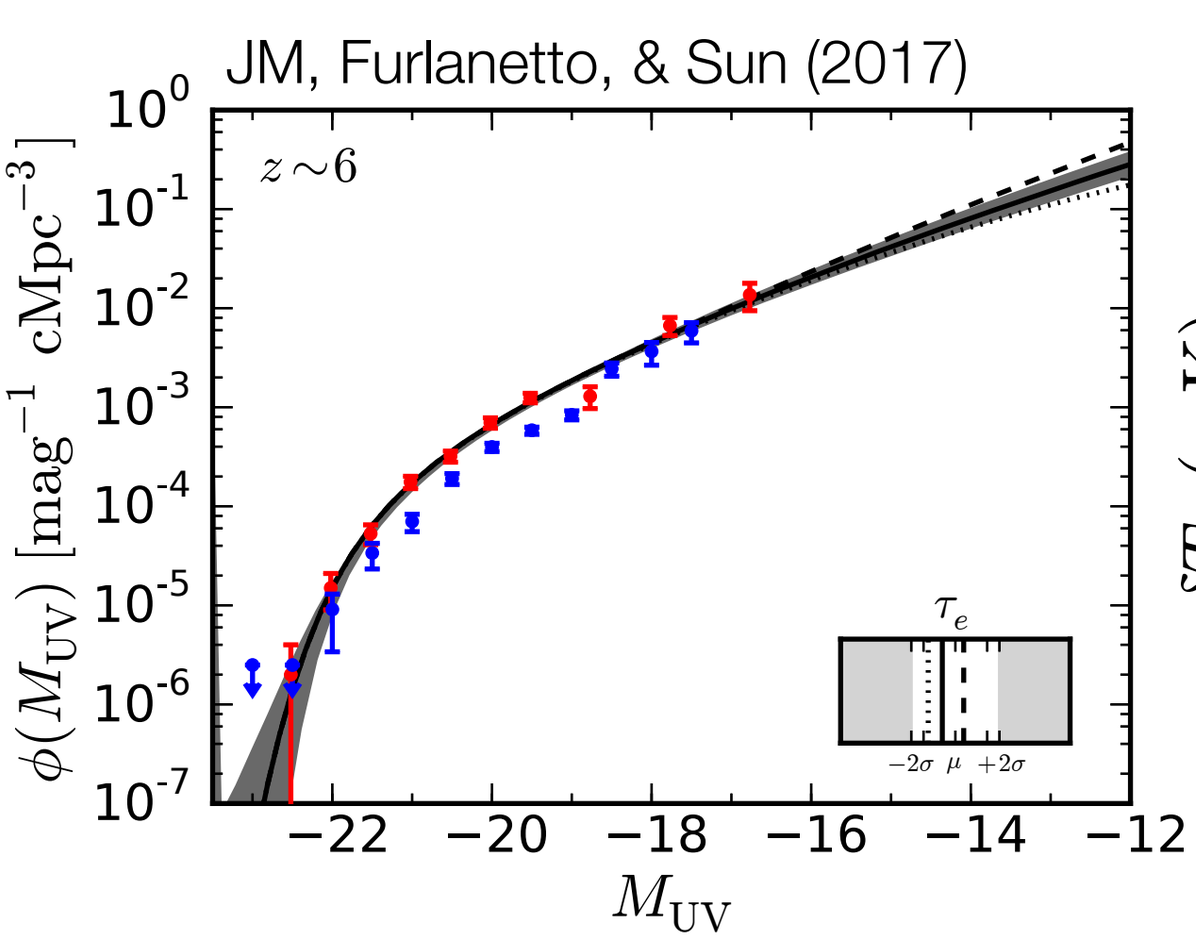
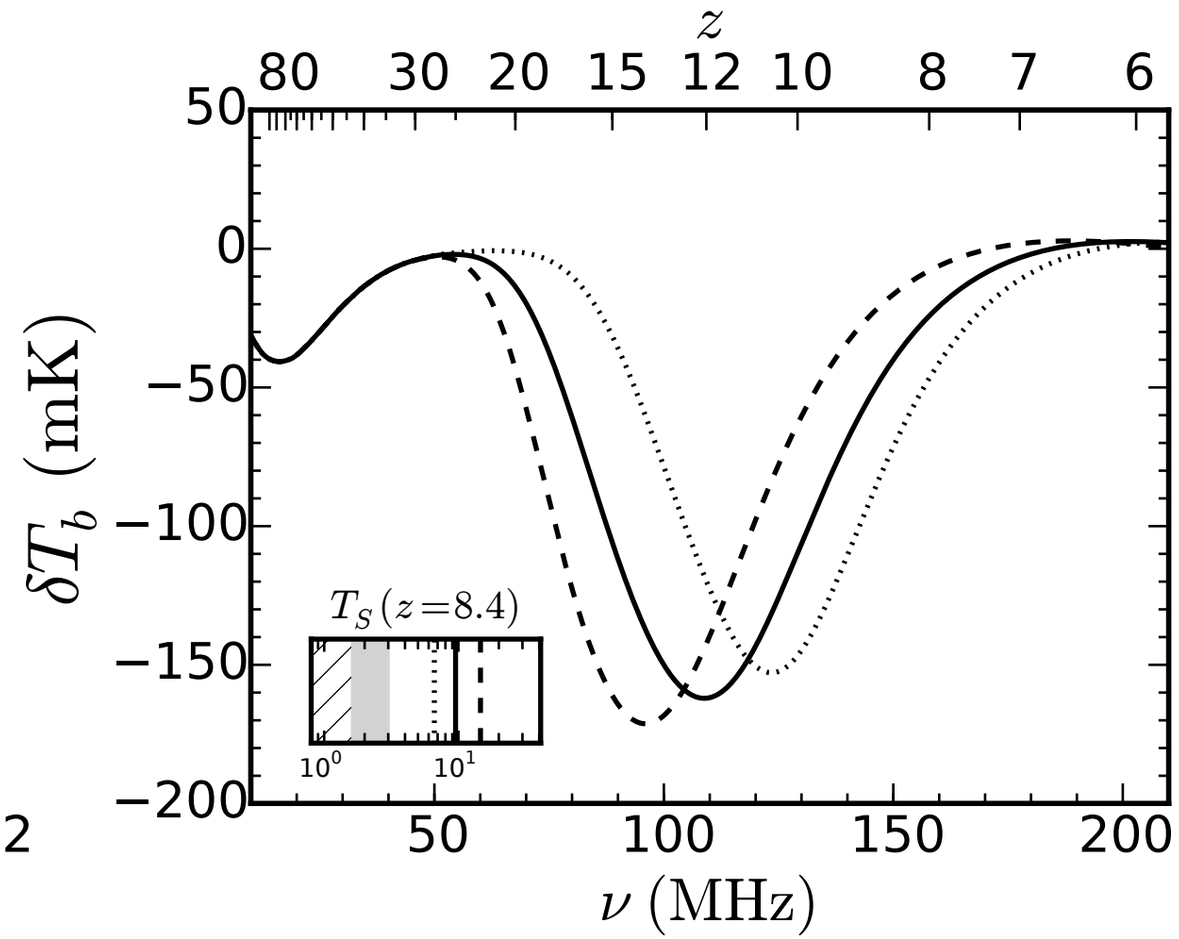
- In what follows I take a “semi-empirical” approach:
  - Assume normal stellar populations.
  - Fit models to current z>6 observations.
  - Extrapolate down to the atomic threshold.
- This approach is intensionally conservative!
  - Key point: ruling out such models provides evidence of “new” source populations, star formation physics, and/or stellar properties.
  - “We will all be very sad if these predictions turn out to be true.”

    - Steve Furlanetto

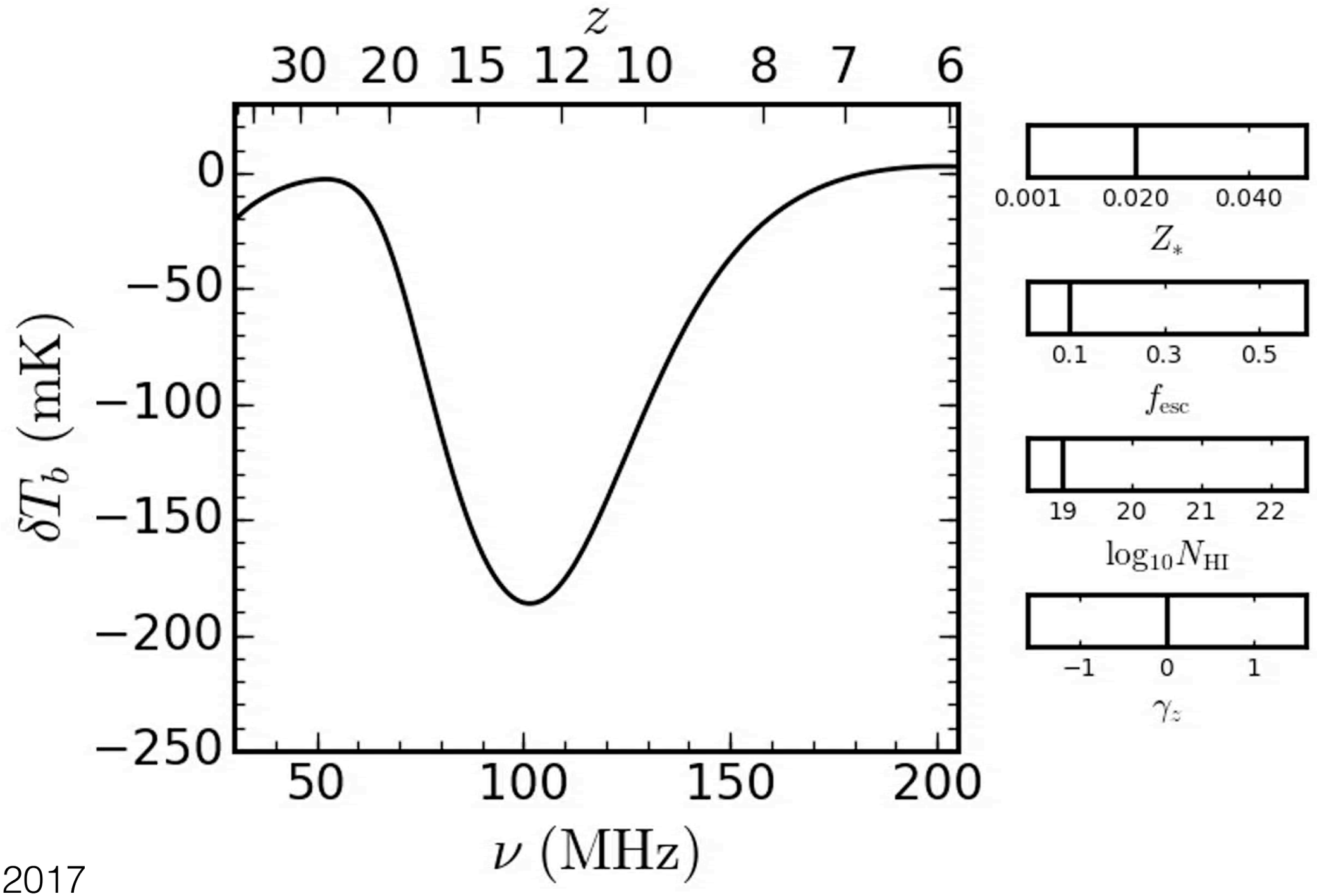
UVLF-Calibrated Predictions





- Calibrate to Bouwens+ 2015 UVLFs, use BPASS v1 SPS models, Mineo+ 2012 L_X-SFR.
- N_{ion}, N_{lw}, f_X replaced by stellar metallicity, SFE anchored to UVLF measurements.
- f_{esc}, T_{min} are only remaining parameters that are entirely free.

More rigid than past models



JM+ 2017

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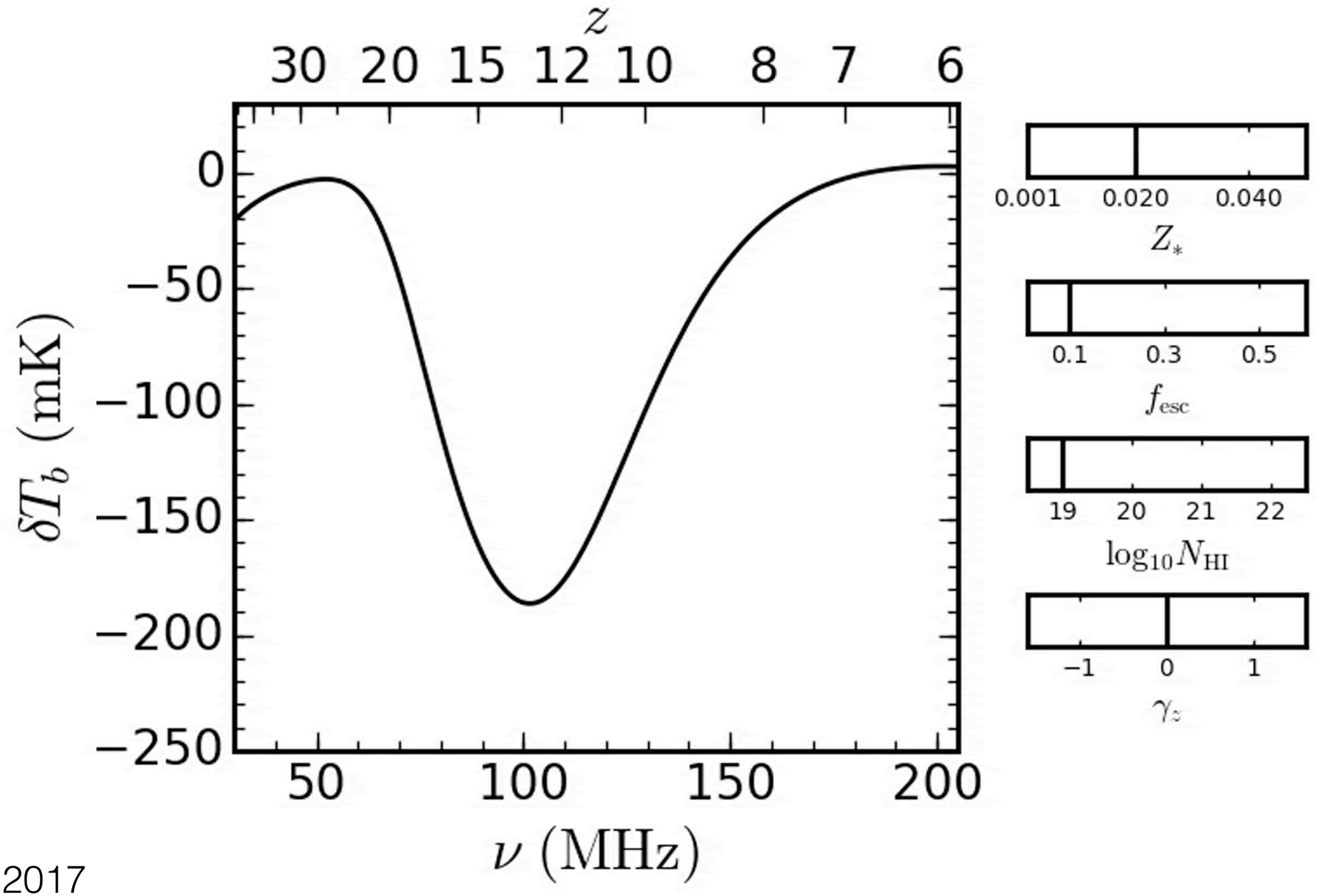

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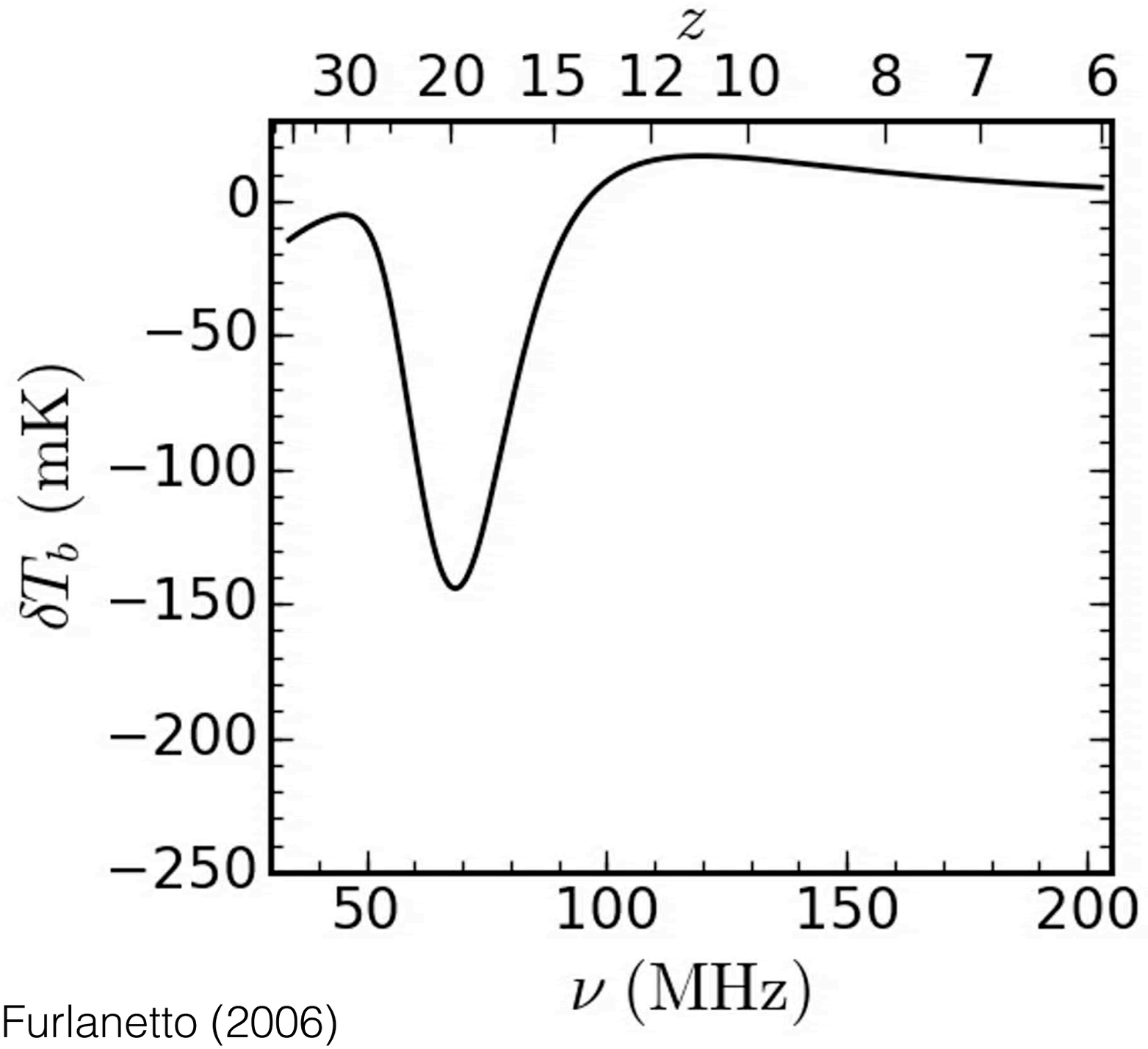
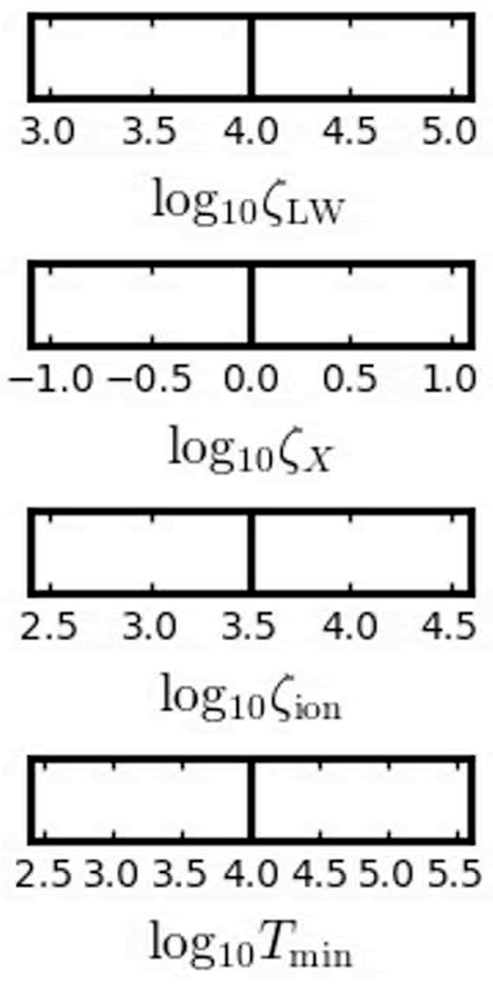


$$\mathrm{SFRD} \propto f_* \frac{df_{\mathrm{coll}}}{dt}$$



$$\zeta_i = f_* N_i f_{\mathrm{esc},i}$$

e.g., Furlanetto (2006)

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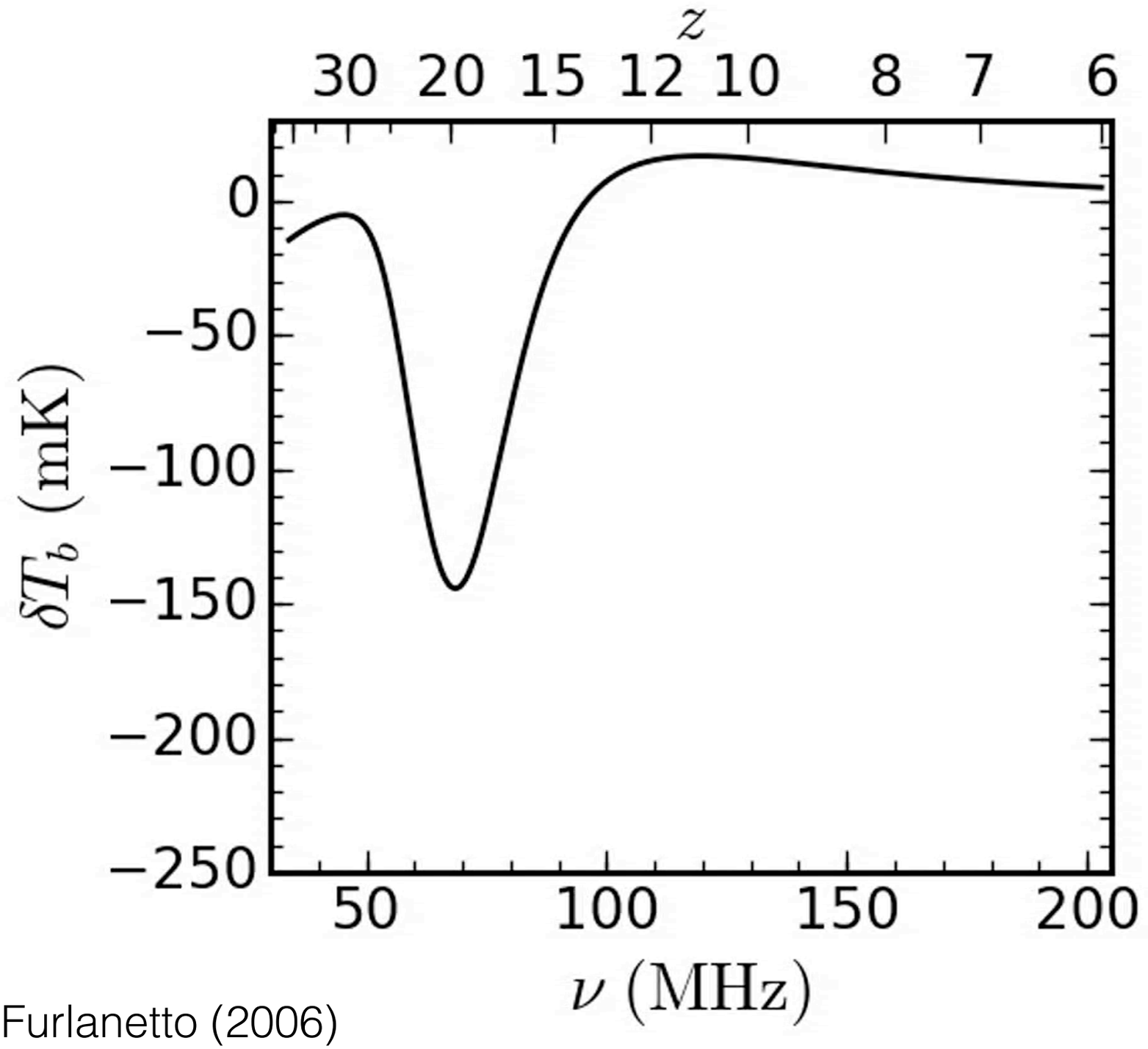

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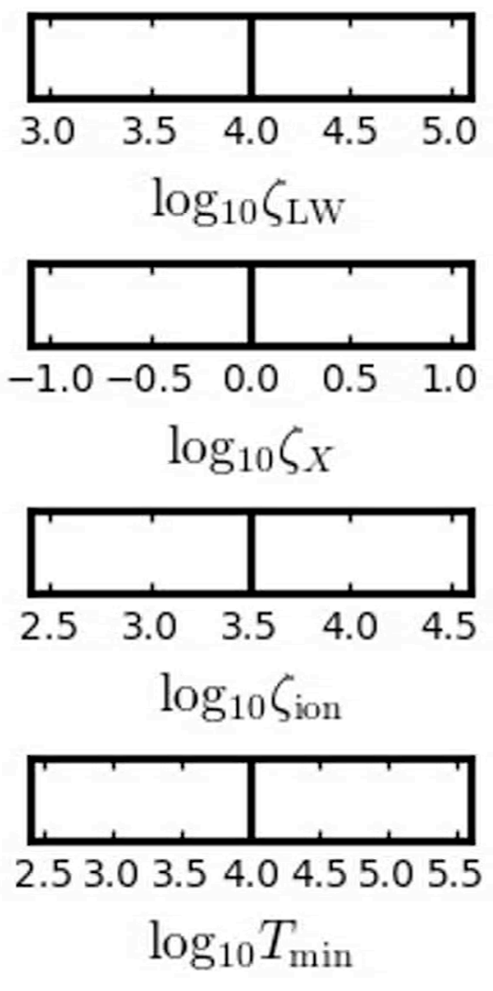

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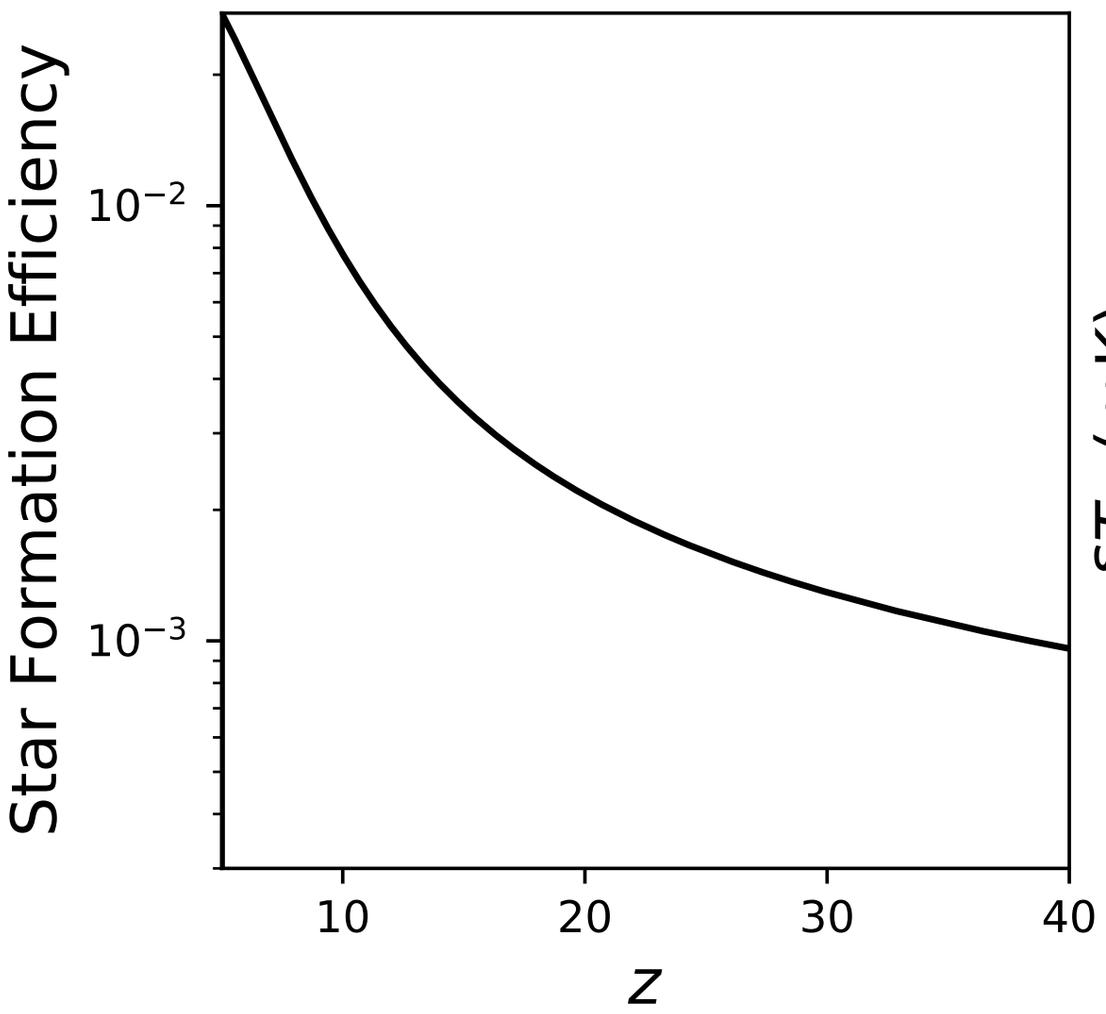
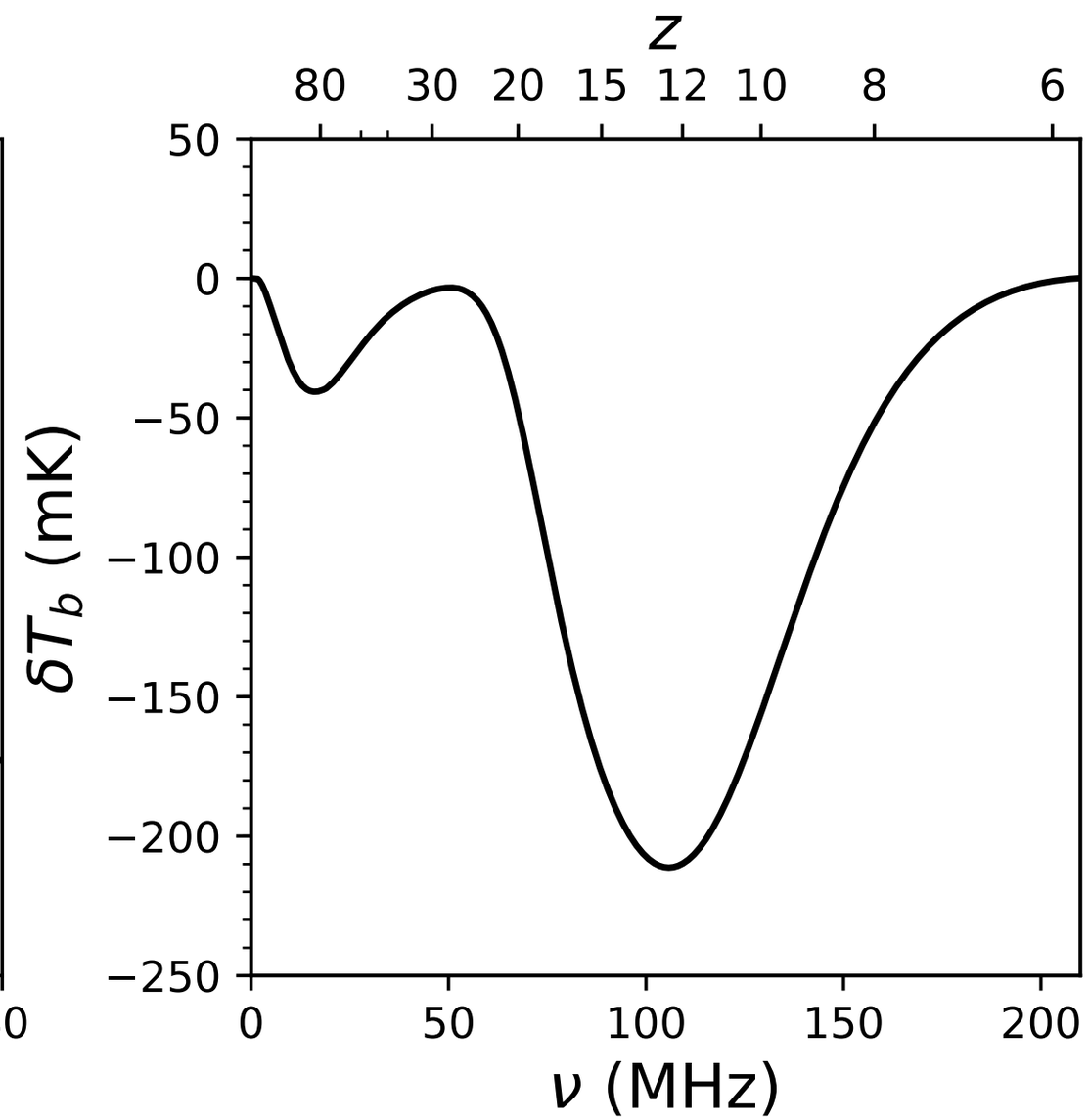
Translation: effective SFE evolves

$$\dot{\rho}_* = f_{*,\mathrm{eff}} f_b \dot{f}_{\mathrm{coll}}$$





Mass-dependent SFE results in time-dependent *effective* SFE, i.e., one averaged over the entire galaxy population.

Translation: effective SFE evolves

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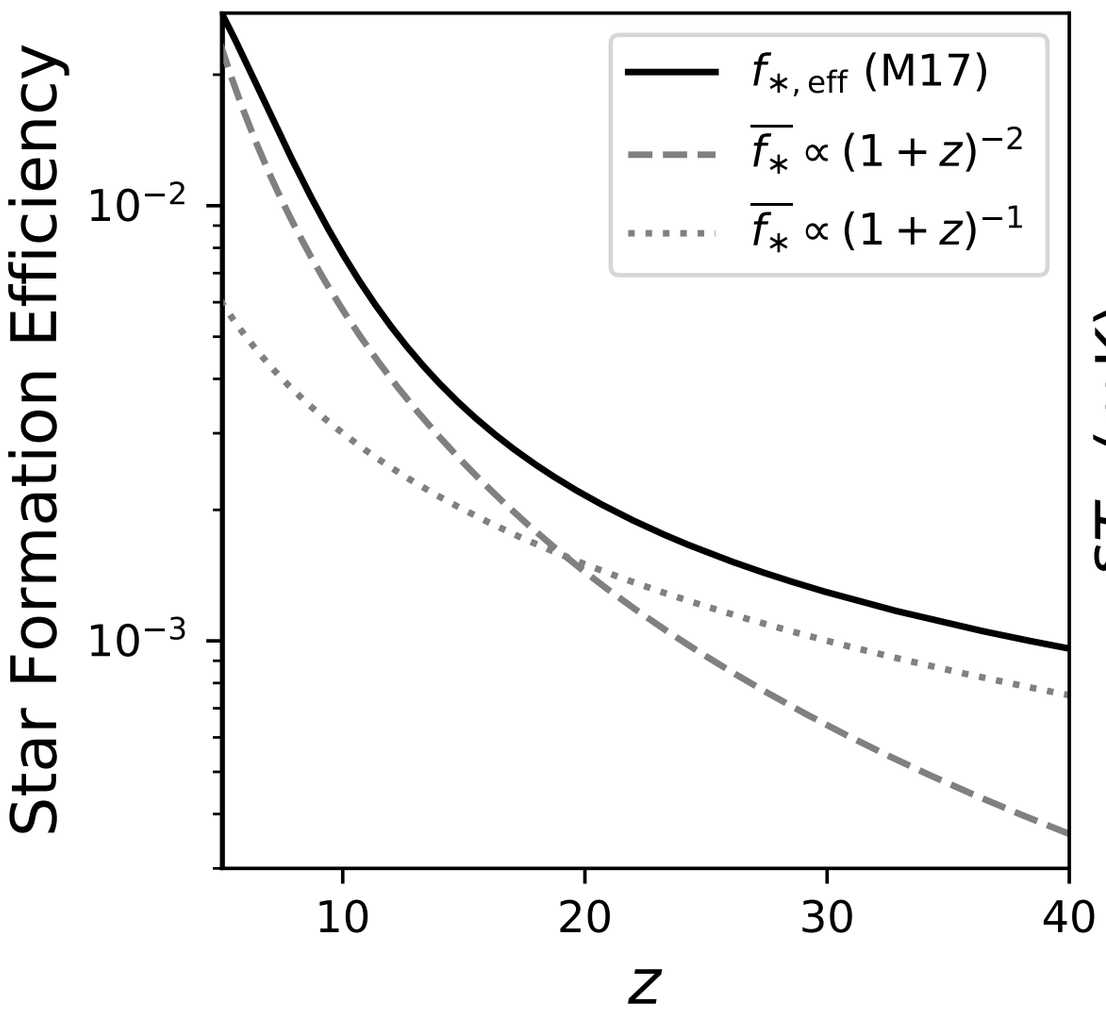

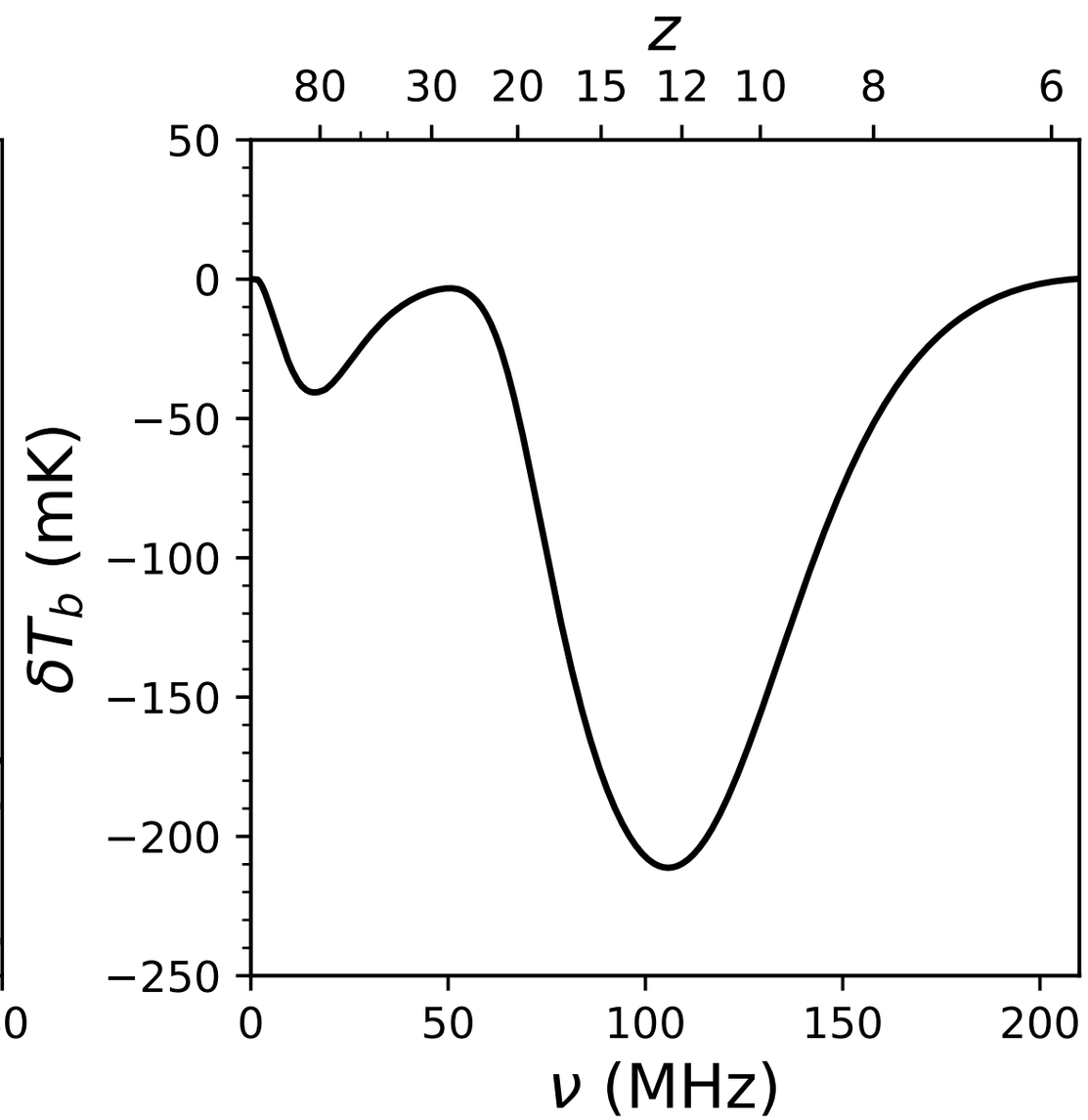

This effective SFE is smaller than you might have expected, and its evolution is non-trivial.

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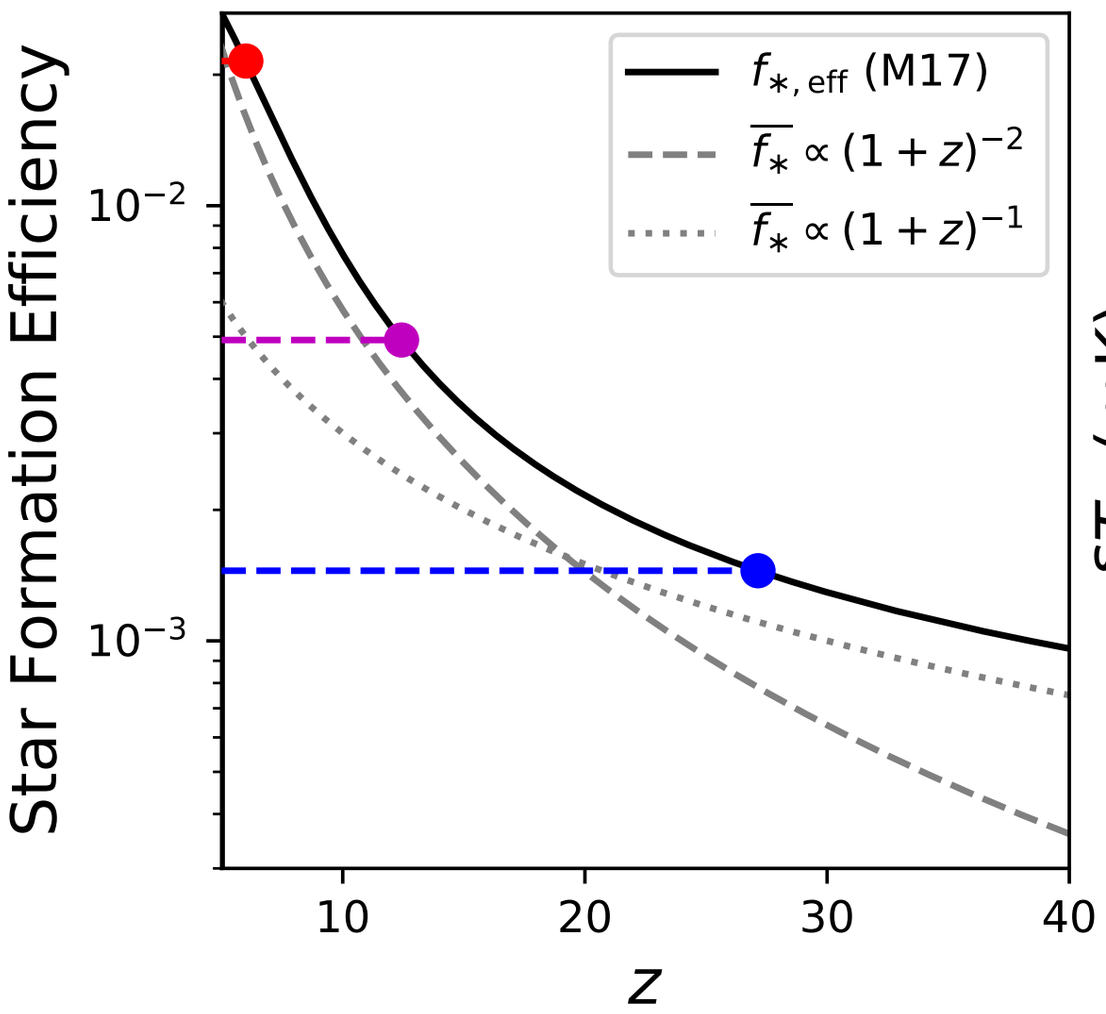
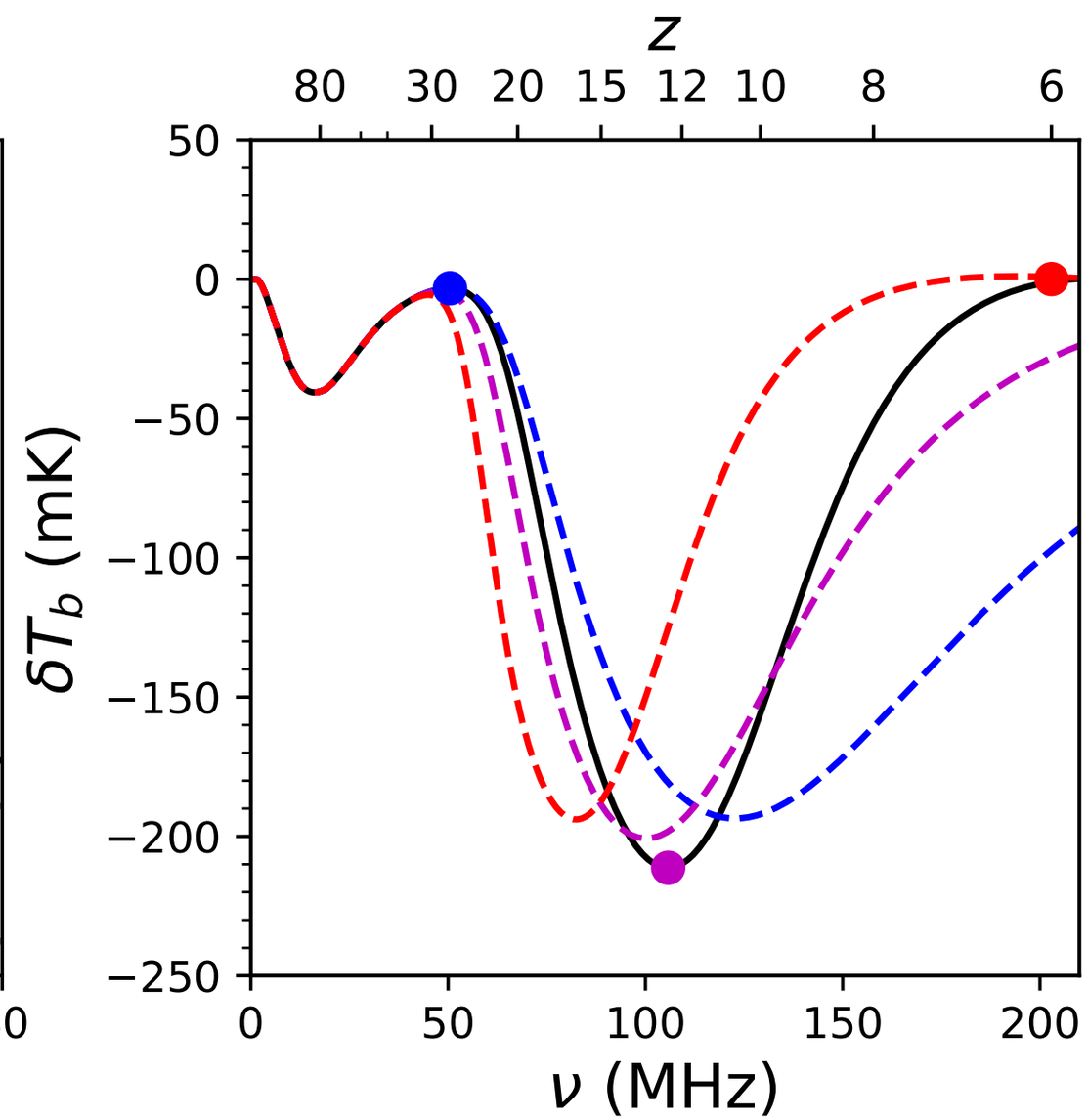
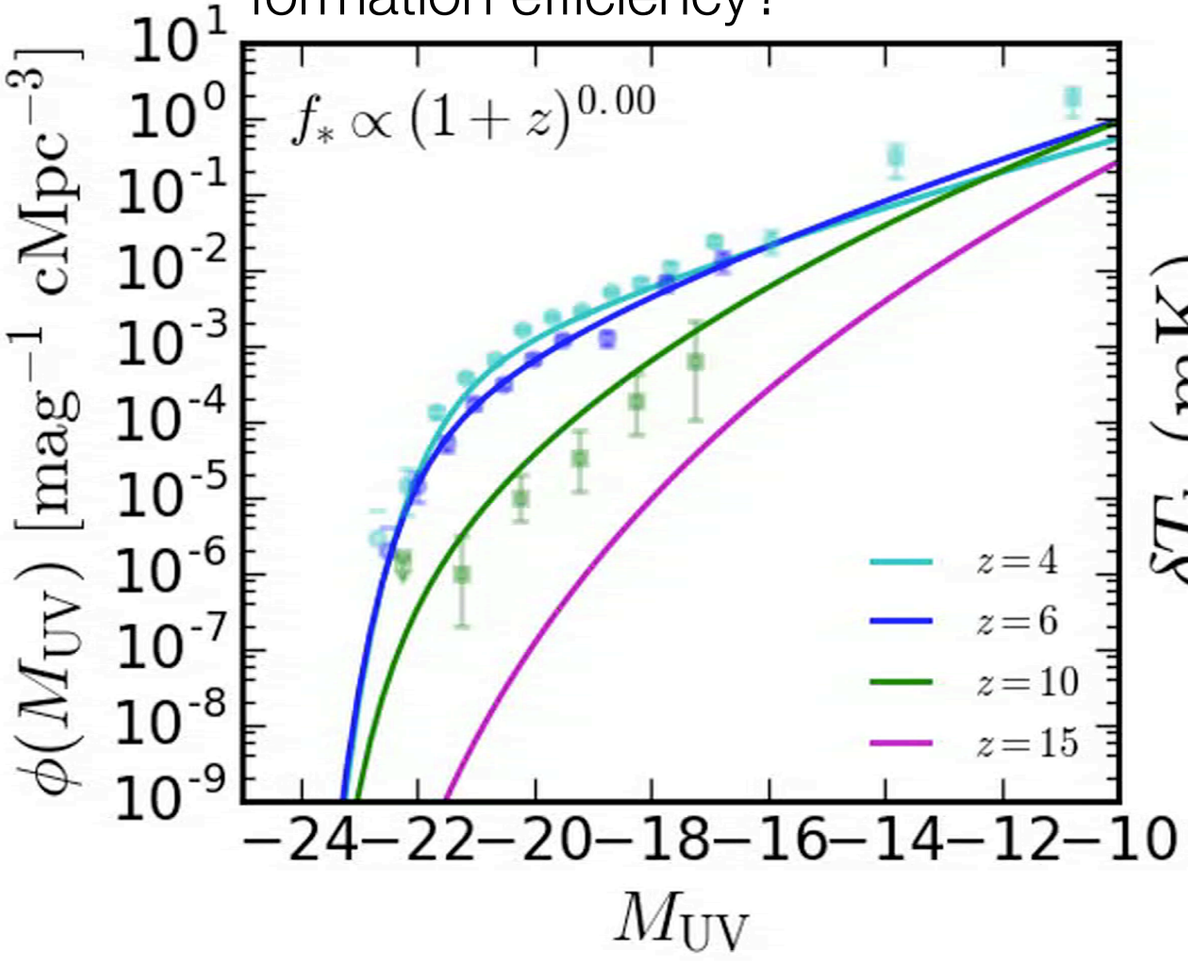


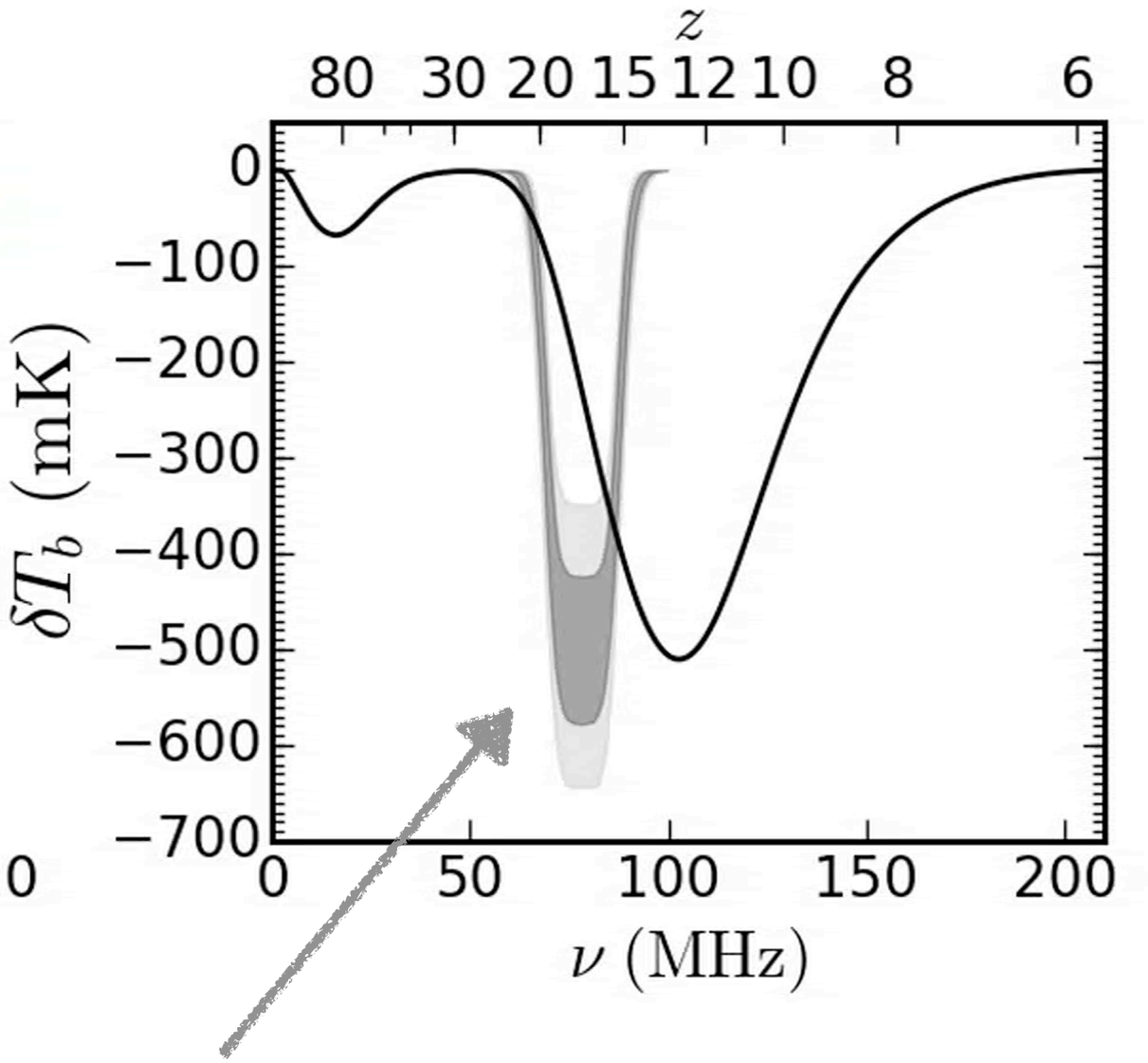


Models tuned to SFE in narrow redshift interval are qualitatively OK (magenta above), but signal shapes are different.

Getting to 78 MHz

Redshift evolution in star formation efficiency?





JM & Furlanetto (2019)

EDGES signal (Bowman+ 2018)

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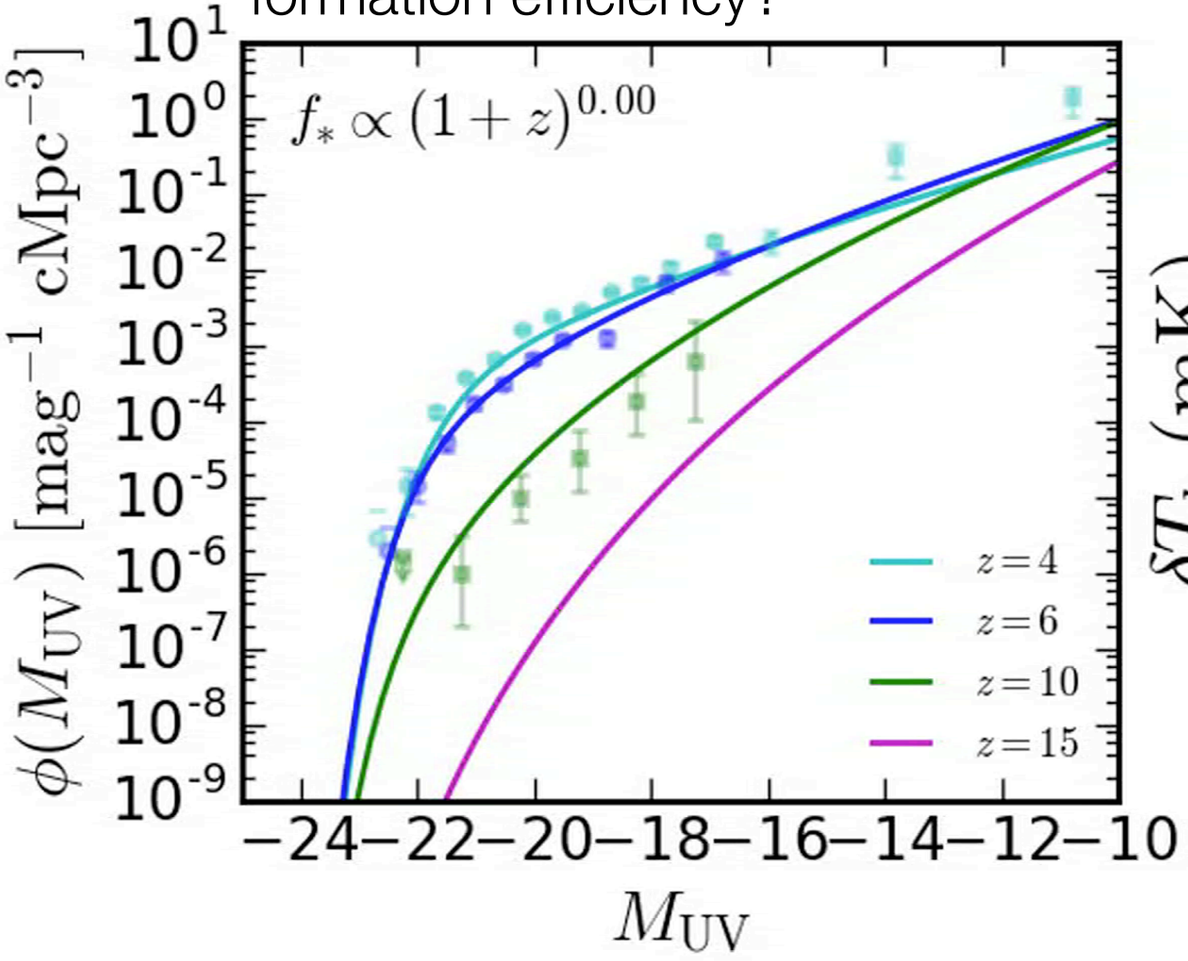

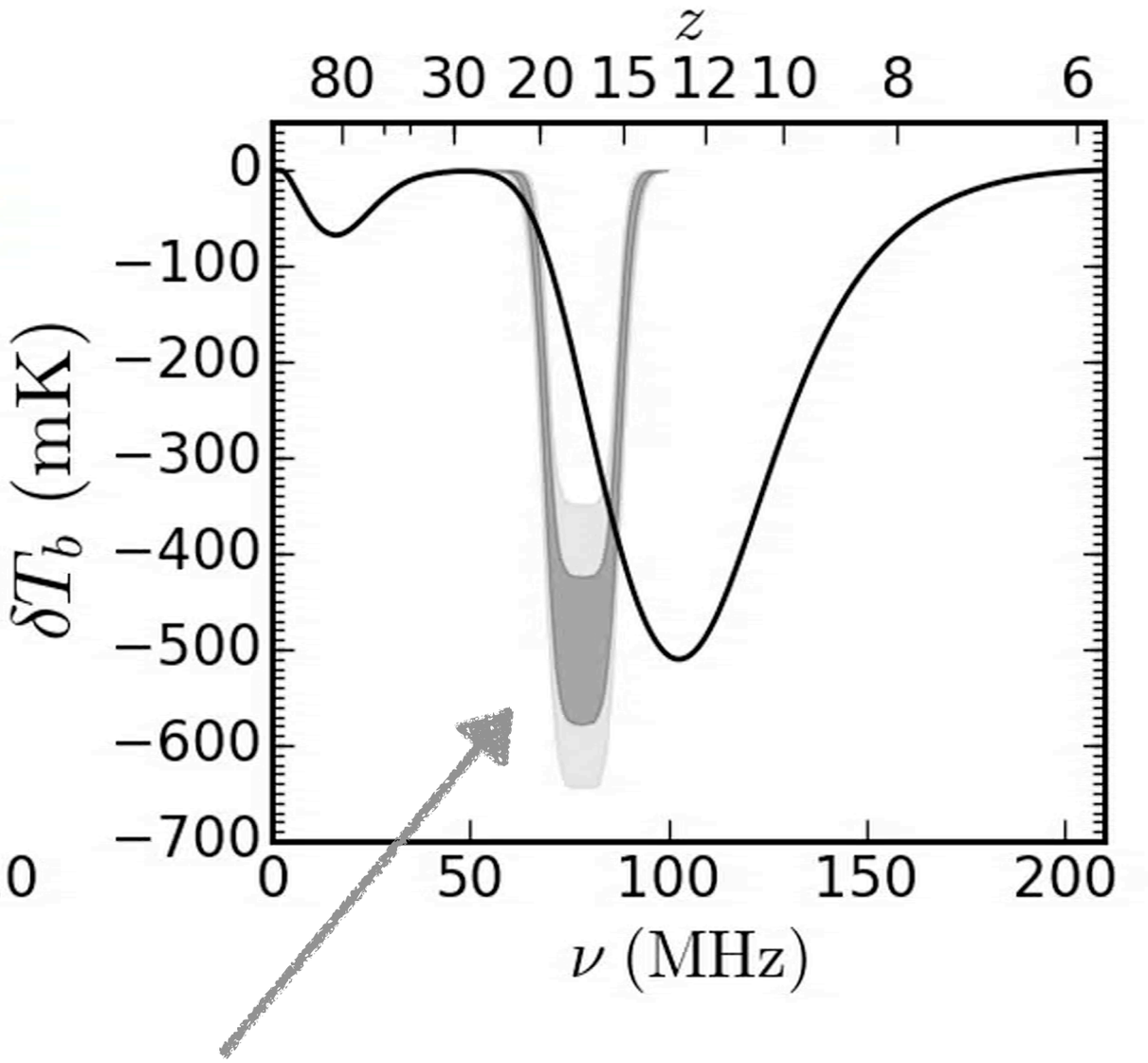

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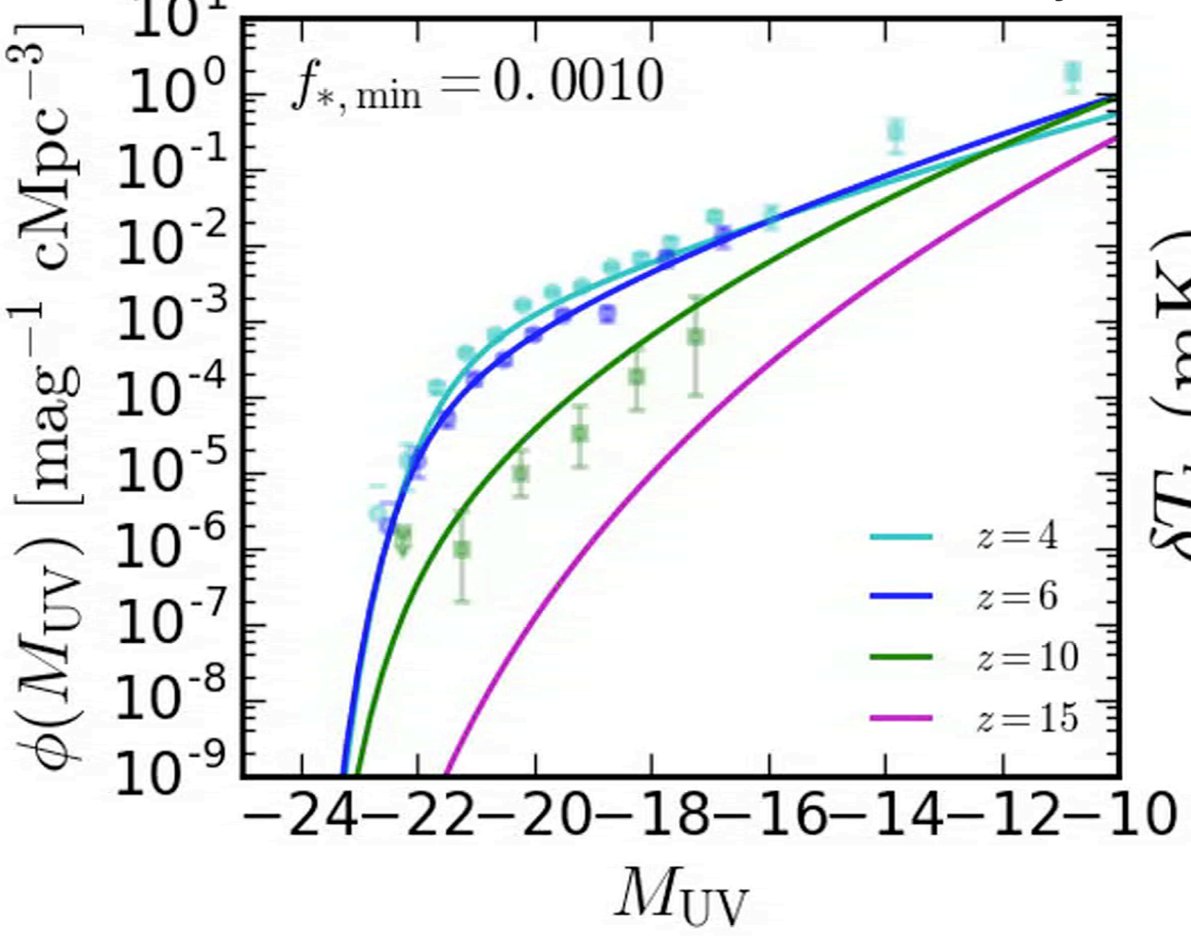

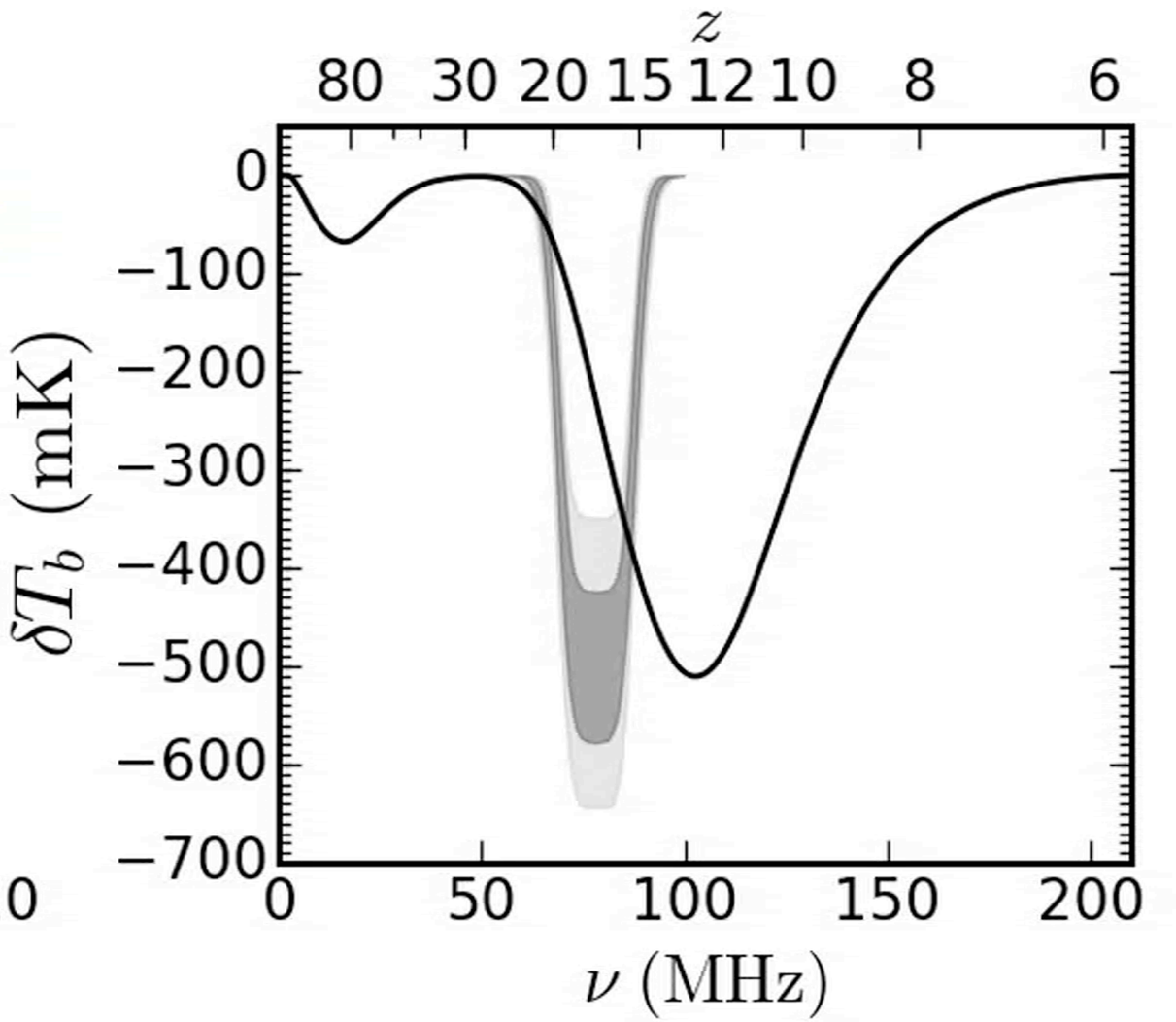

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Still problems with shape!

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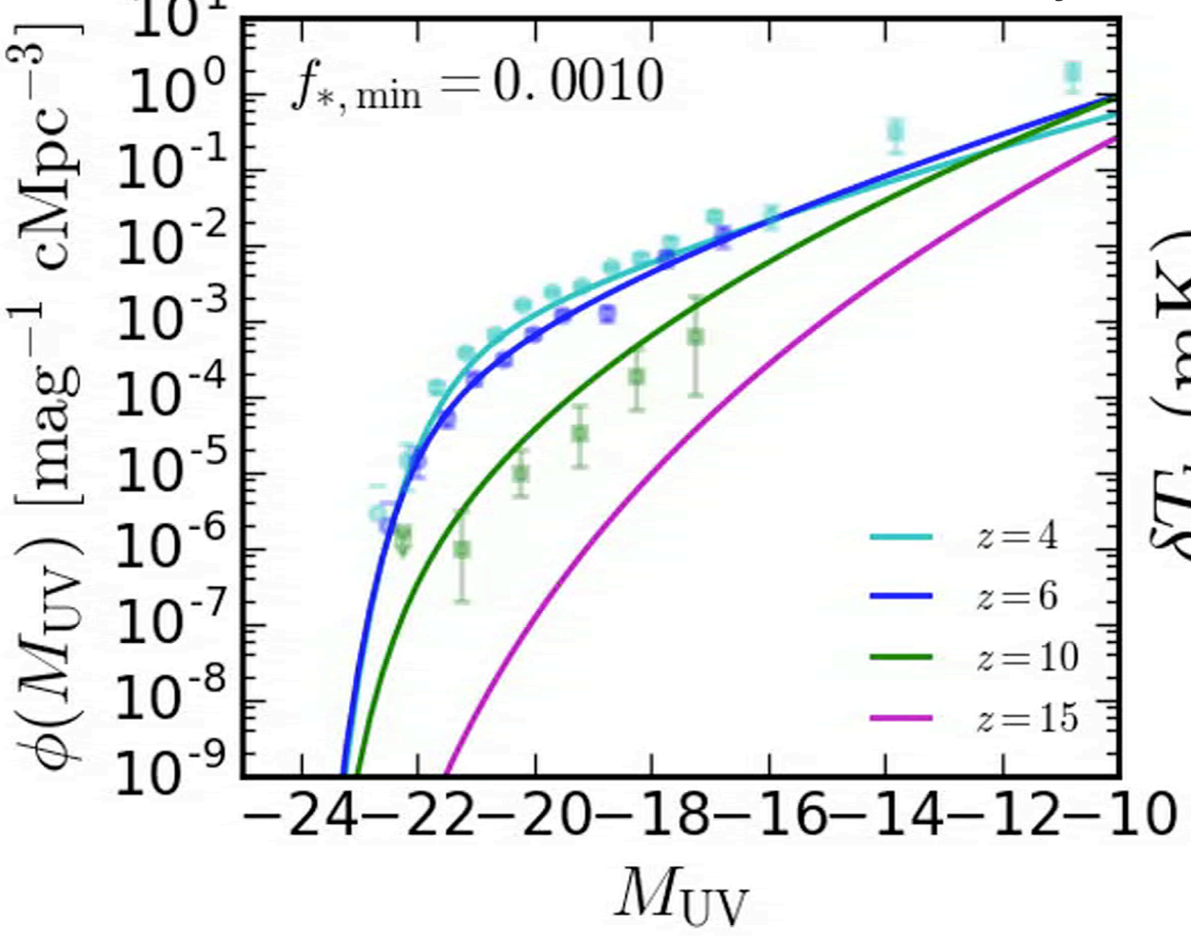

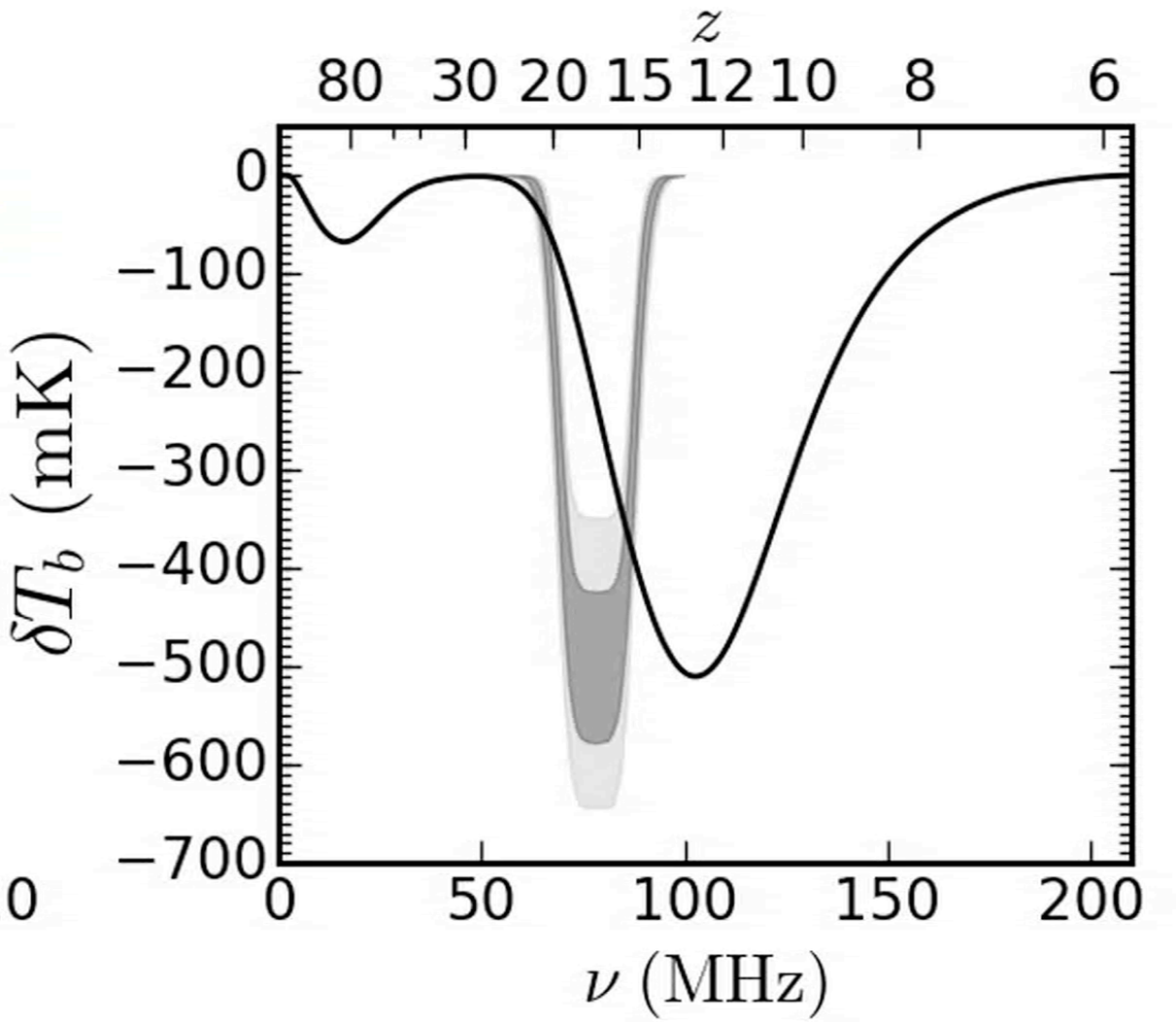

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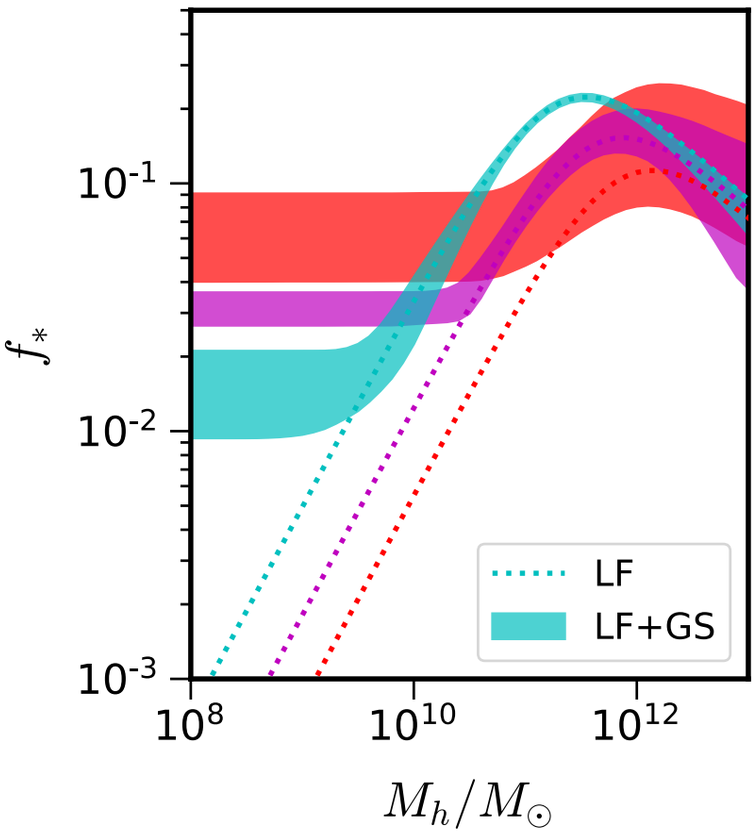
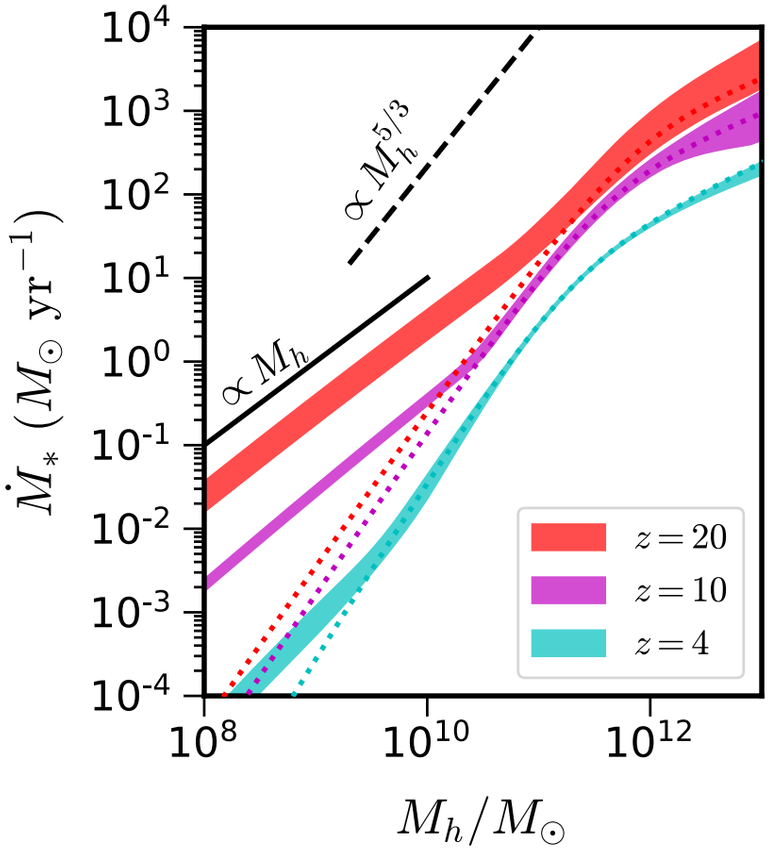
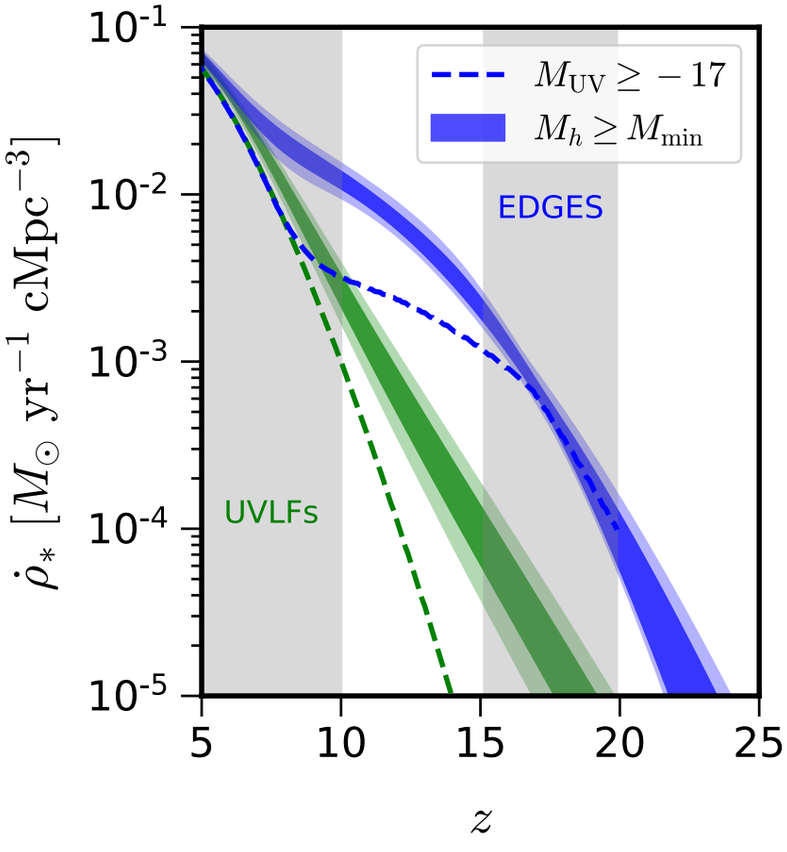
Engineering a Solution

Q. What must SFE be to fit EDGES signal?







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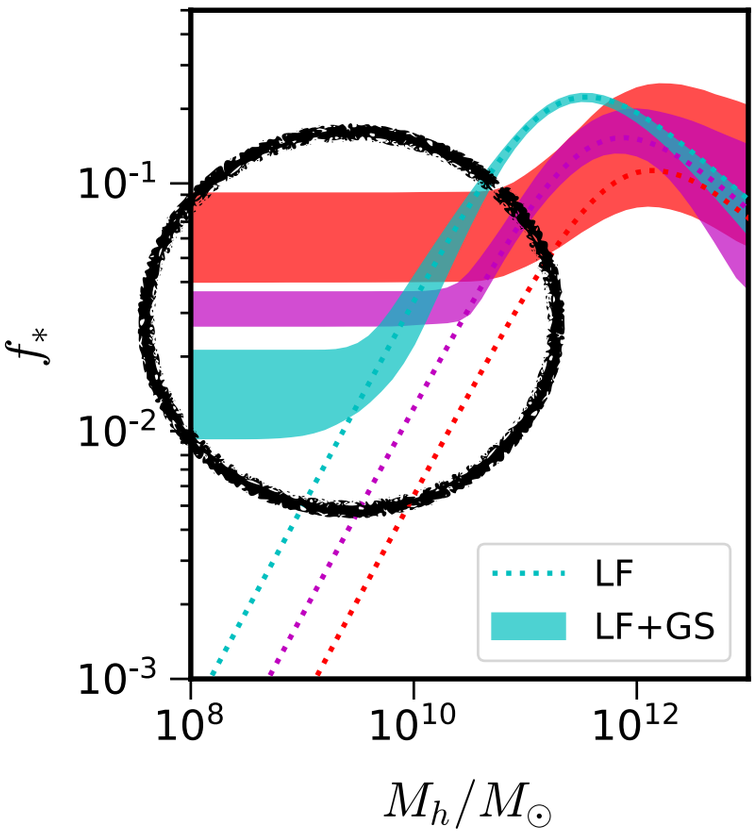
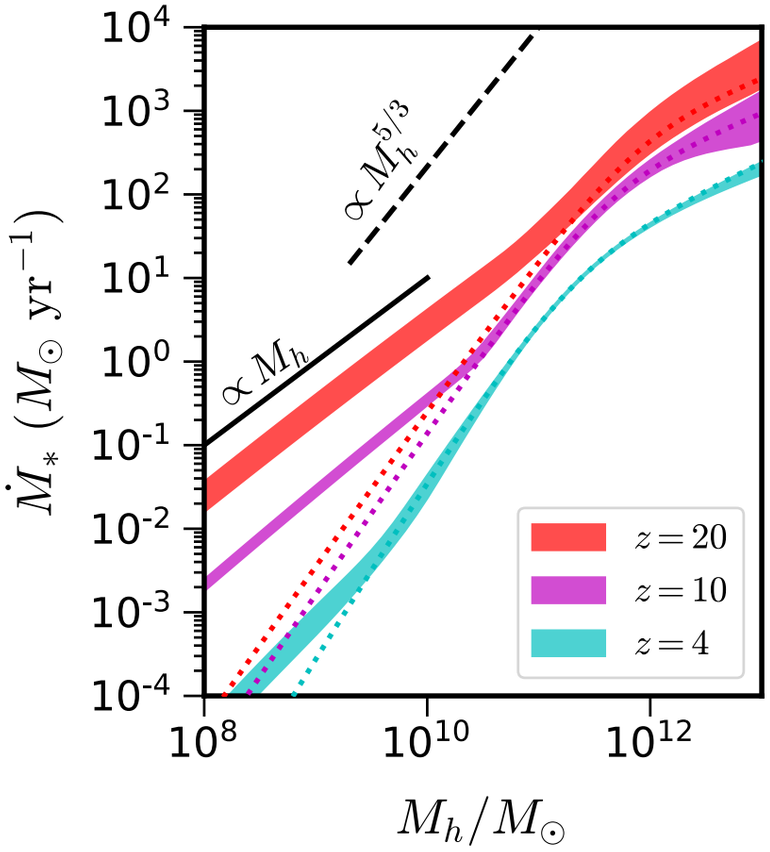
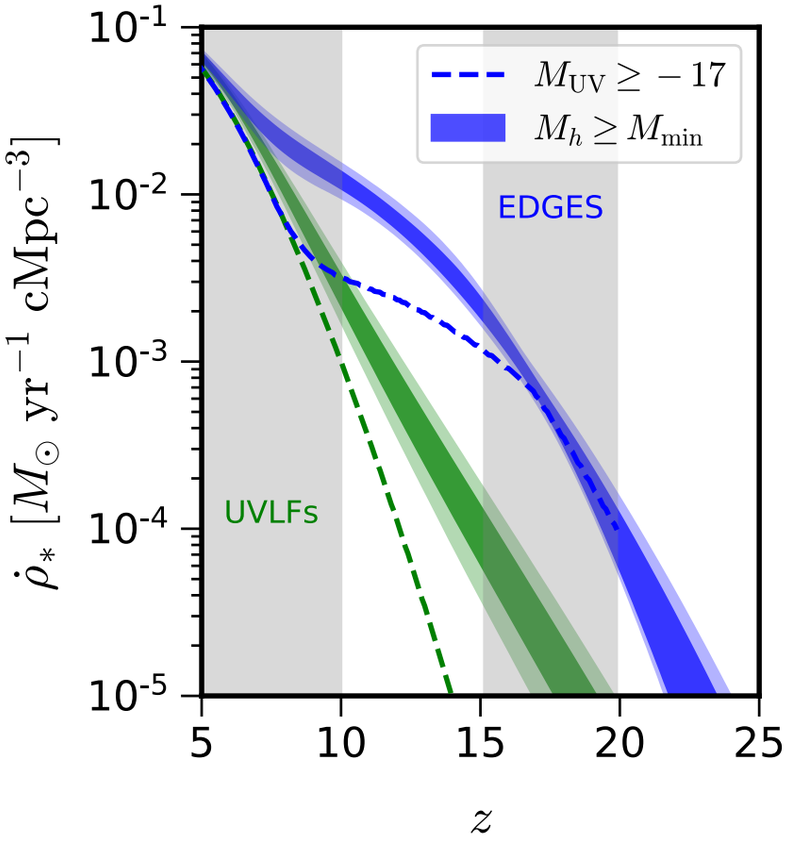




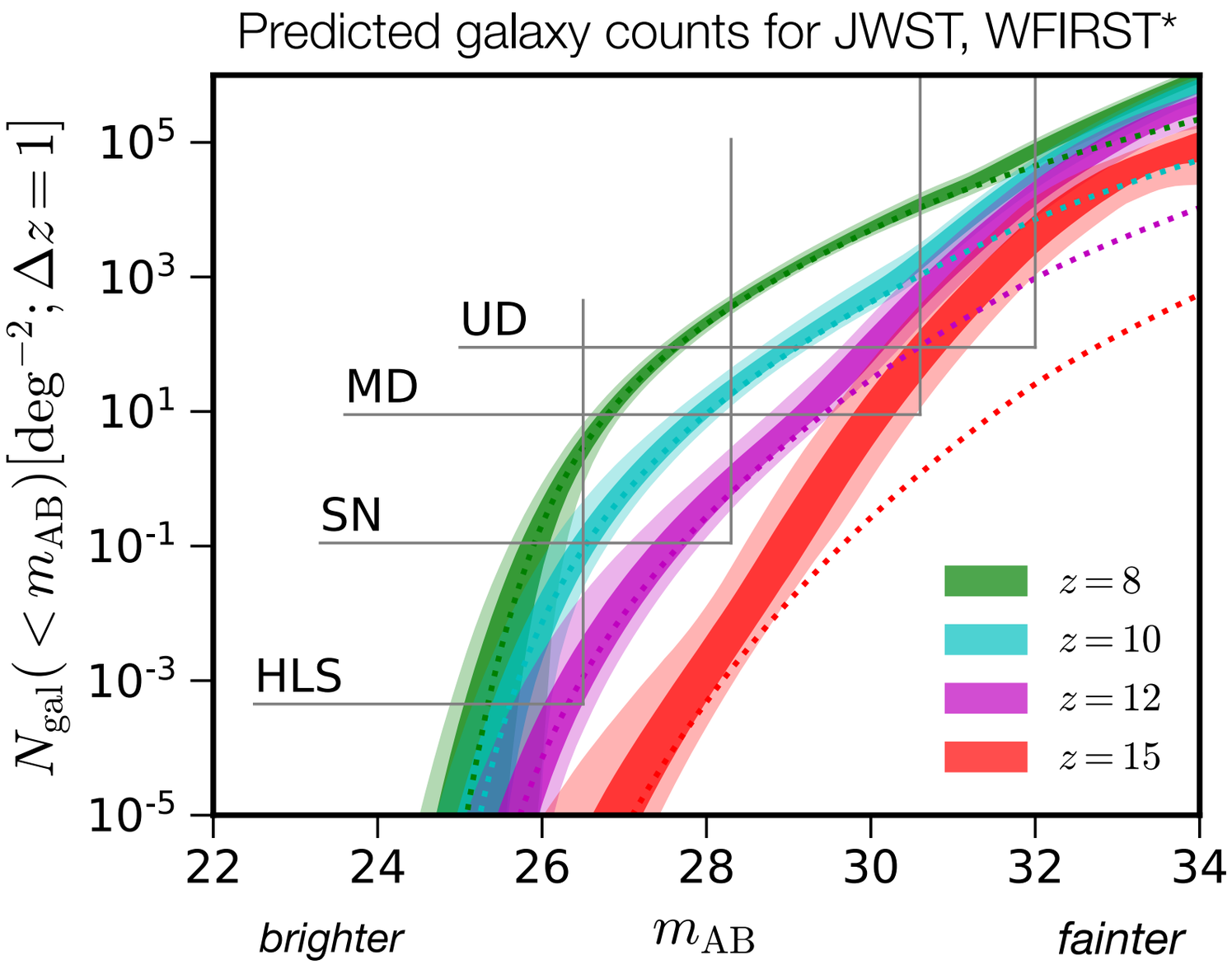


***Flattened SFE not necessarily expected but need not persist to late times.**

JM & Furlanetto (2019)

Why appeal to SFE evolution?

This model is readily testable with a JWST UDF.



JM & Furlanetto (2019)

*survey strategies from Mason et al. (2015)

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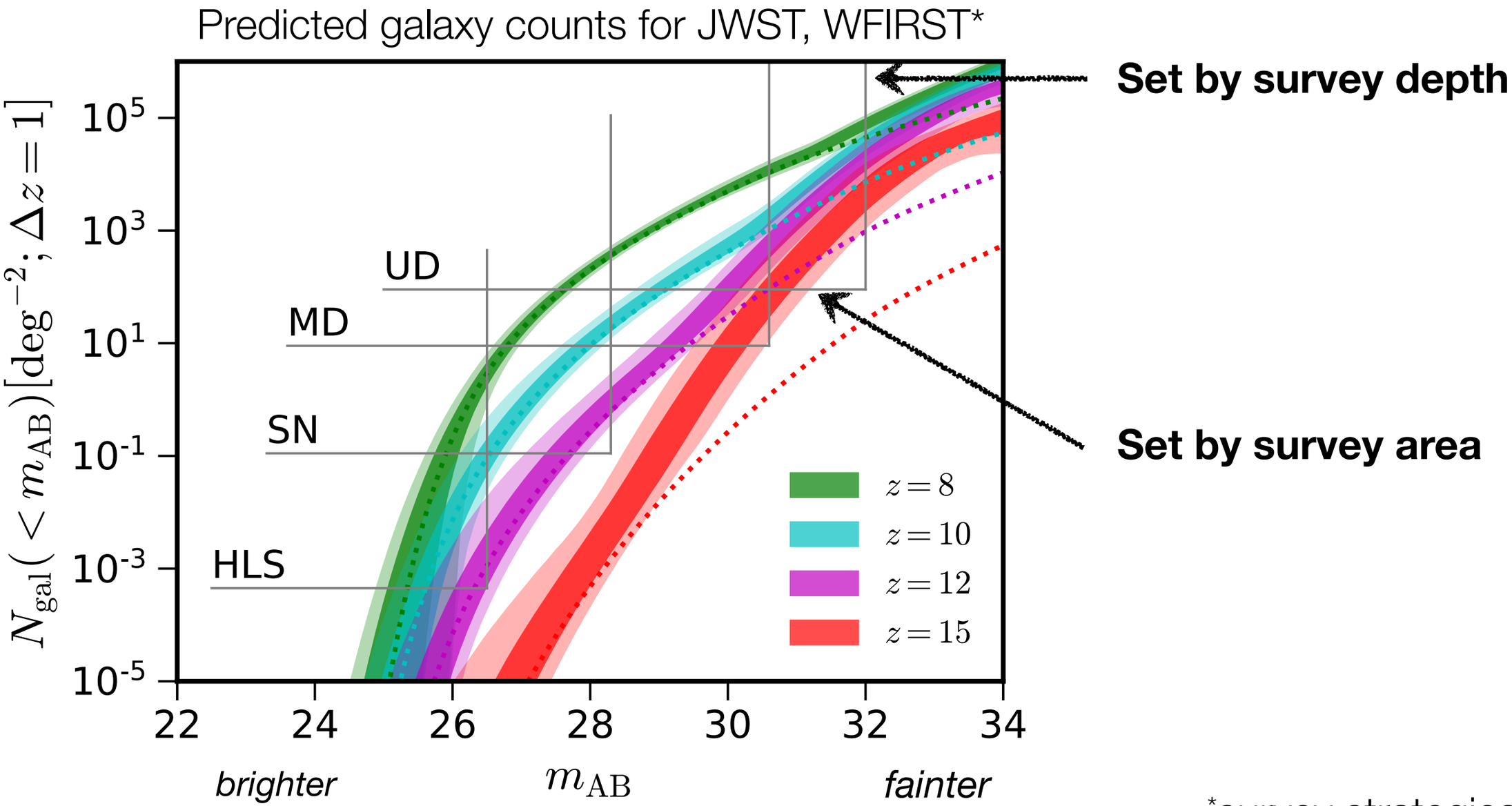

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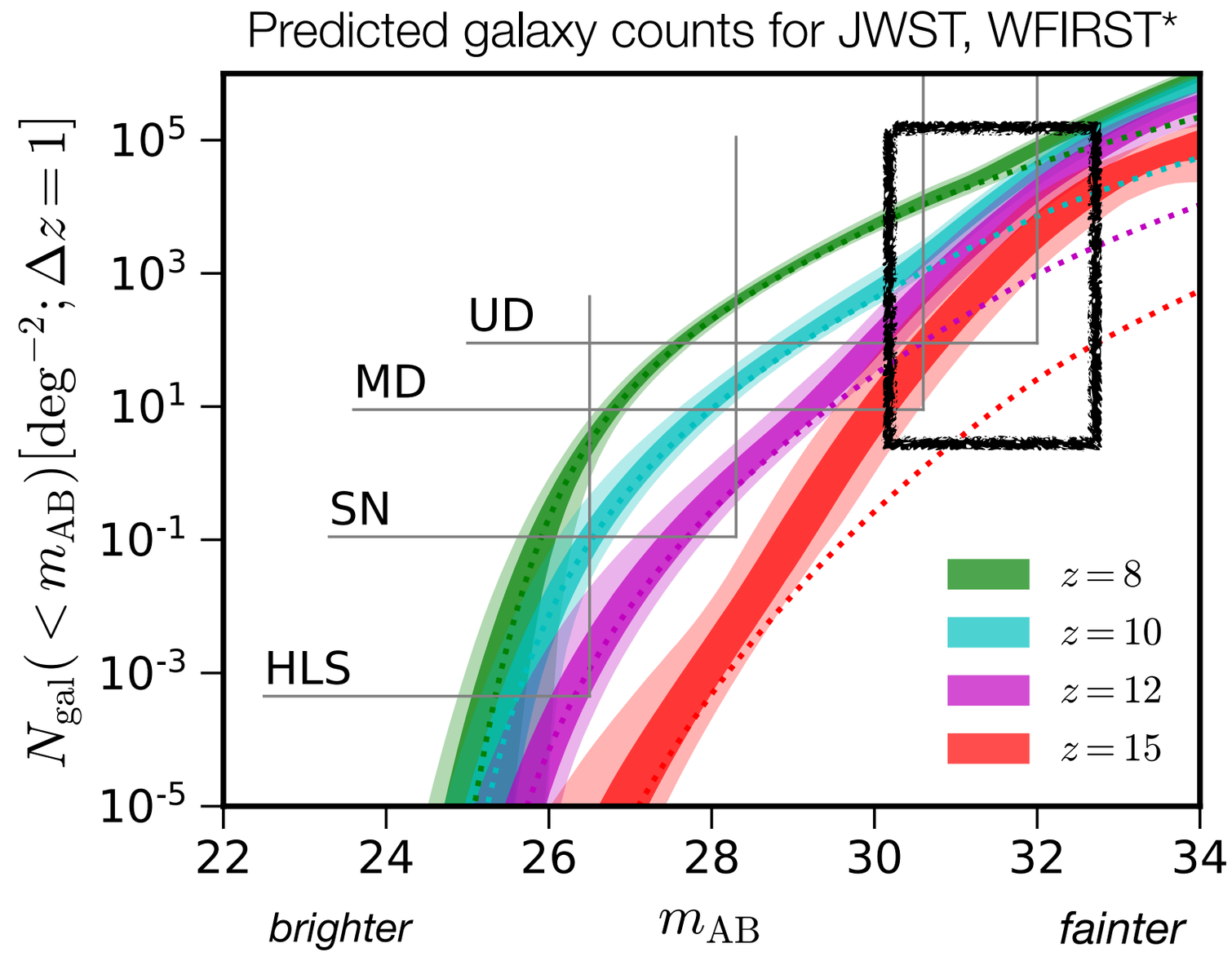


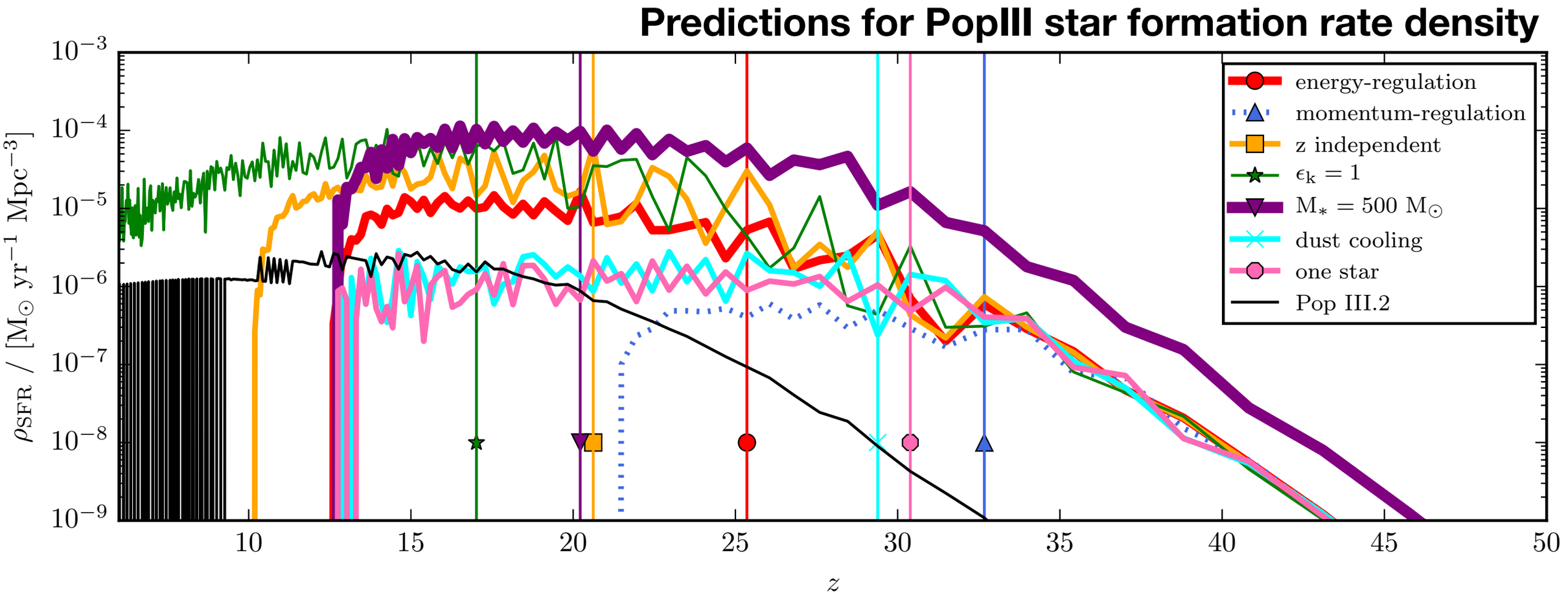
JM & Furlanetto (2019)

If a JWST UDF sees anything at z~12-15, maybe this isn't crazy.

If a JWST UDF sees *nothing* at z~12-15, we may need PopIII.

*survey strategies from Mason et al. (2015)

PopIII Possibilities



Mebane, JM, & Furlanetto (2018)

Mebane, JM, & Furlanetto, in prep. (re: EDGES)

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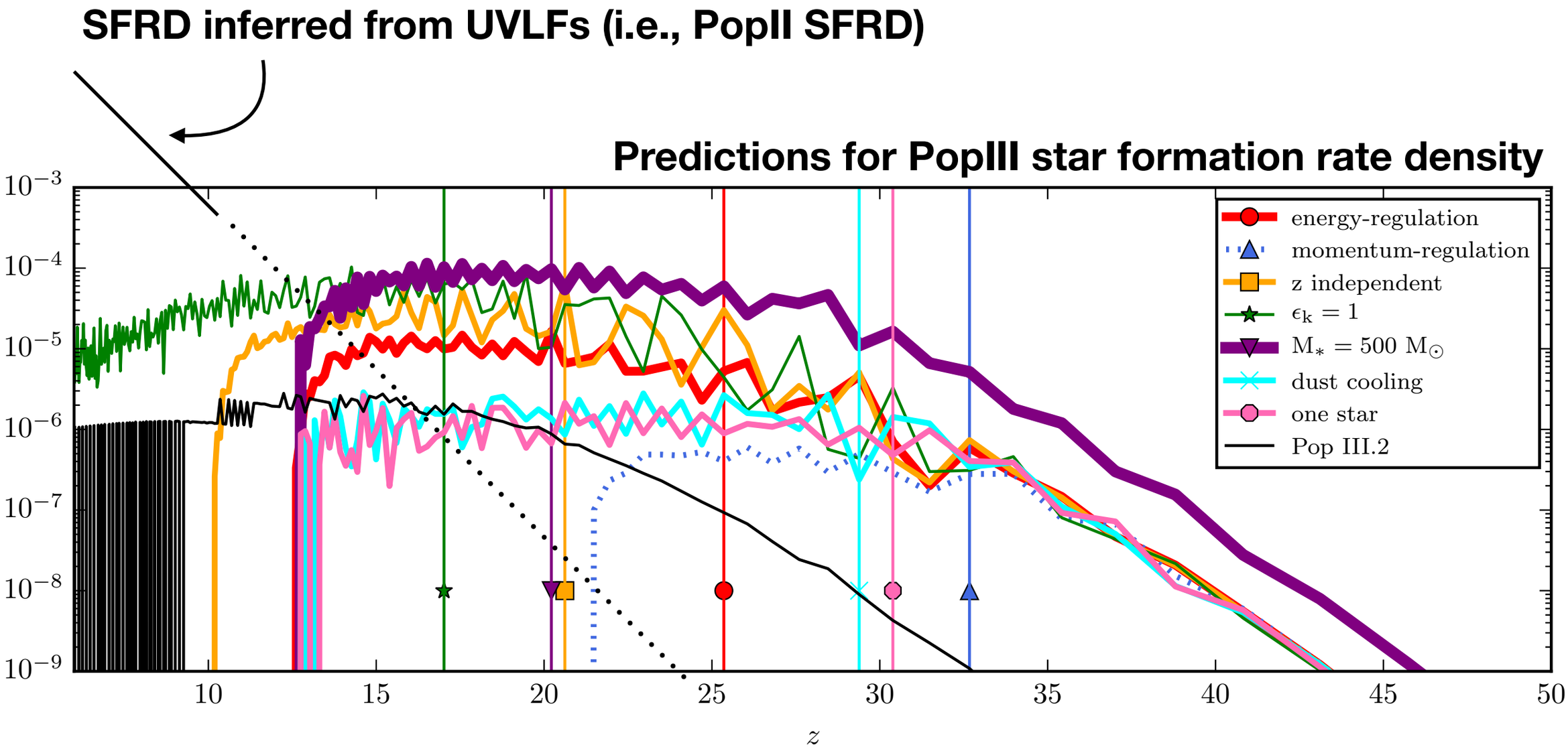

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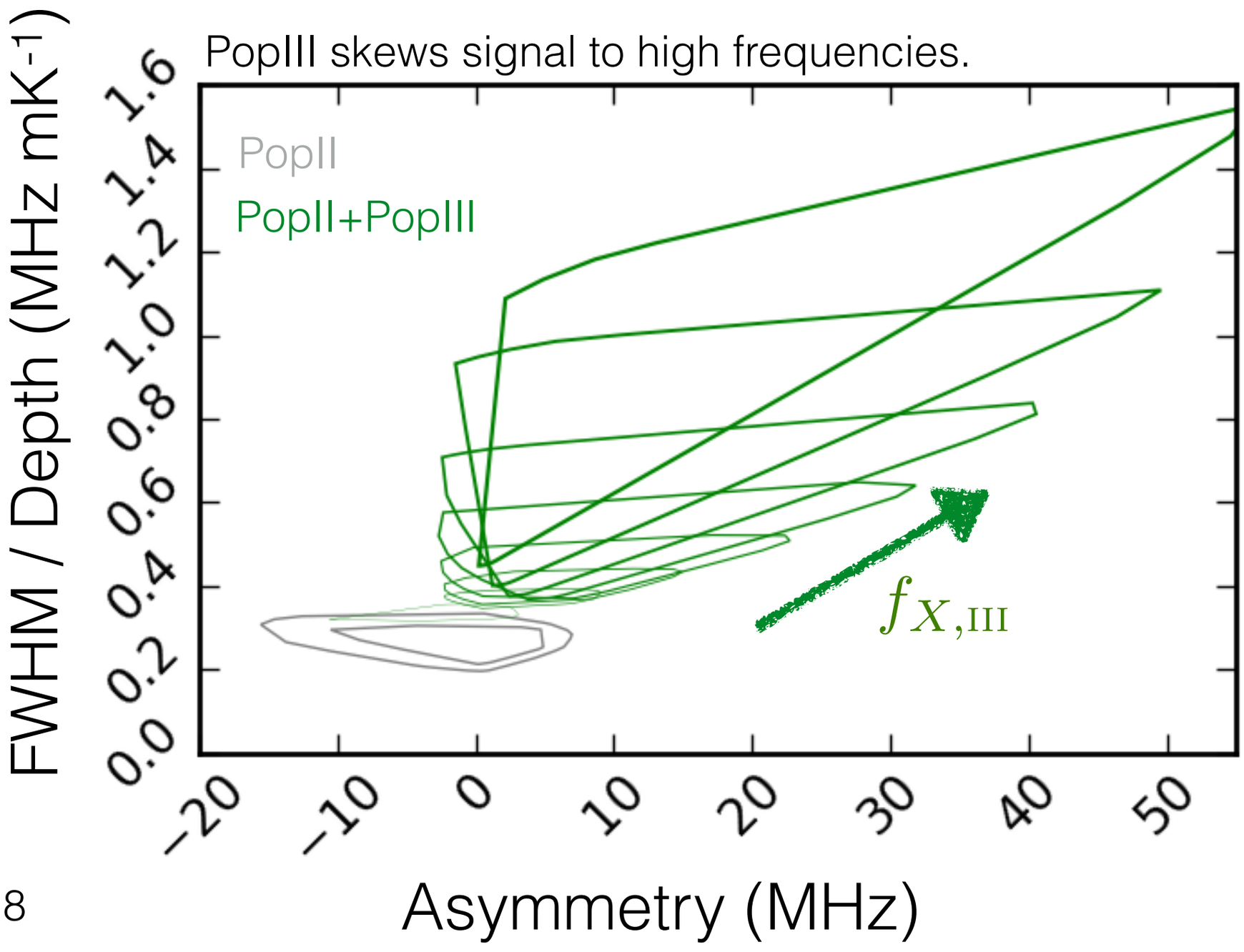
PopII vs. PopIII



JM+ 2018

Advertisement

```
import ares

pars = ares.util.ParameterBundle('mirocha2017:base')

sim = ares.simulations.Global21cm(**pars)
sim.run()

ax, zax = sim.GlobalSignature()
```

https://bitbucket.org/mirochaj/ares

Questions?