



# LINE INTENSITY MAPPING QUEST TO SOLVE THE JWST “PUZZLE”

Sarah Libanore

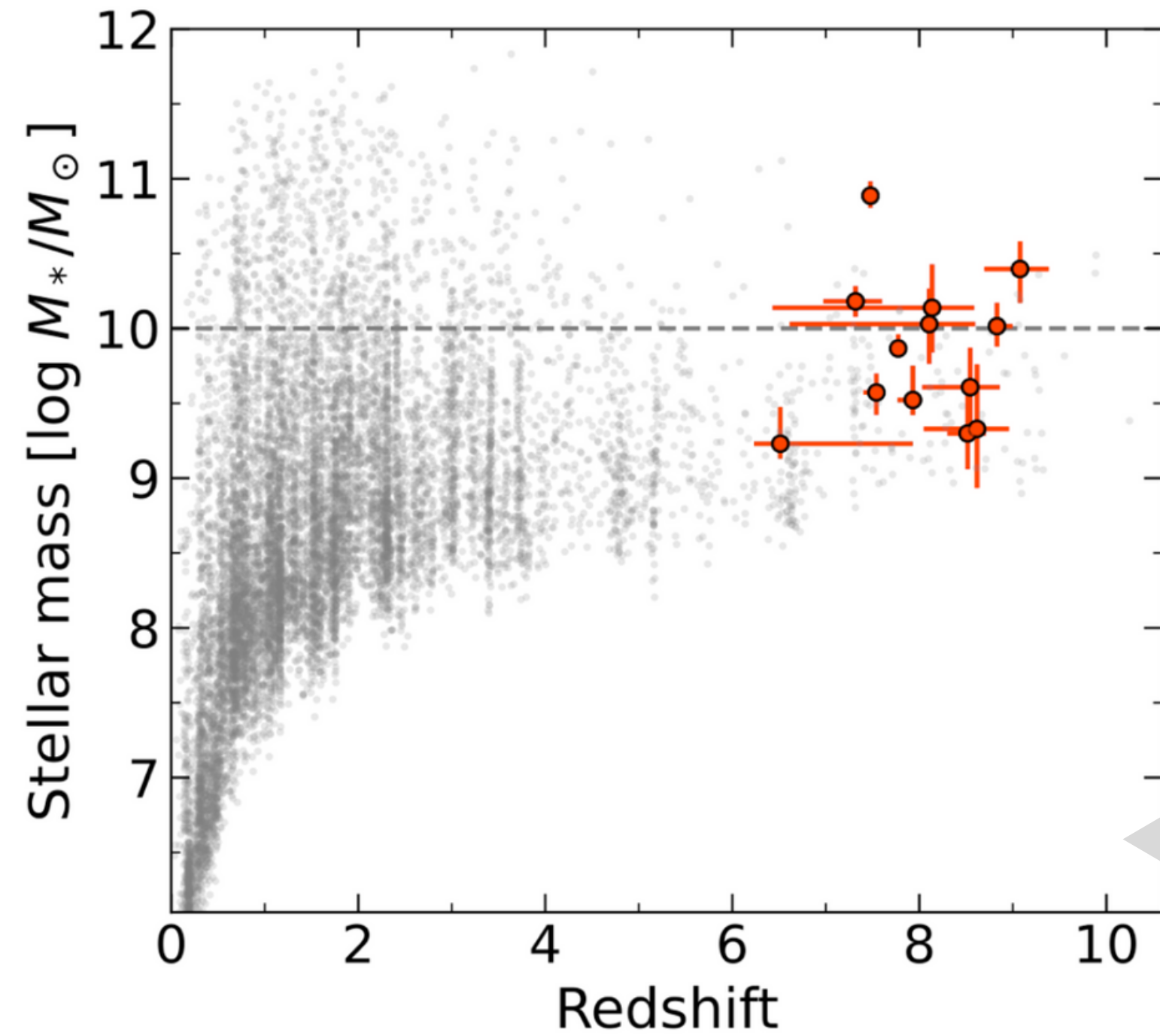
Cosmology in the Alps | March 18, 2024  
Les Diableretes (Switzerland)  
SKAO International Scholarship

Ben Gurion University of the Negev  
Azrieli International Postdoctoral Fellow

# INTRODUCTION: THE “PUZZLE”

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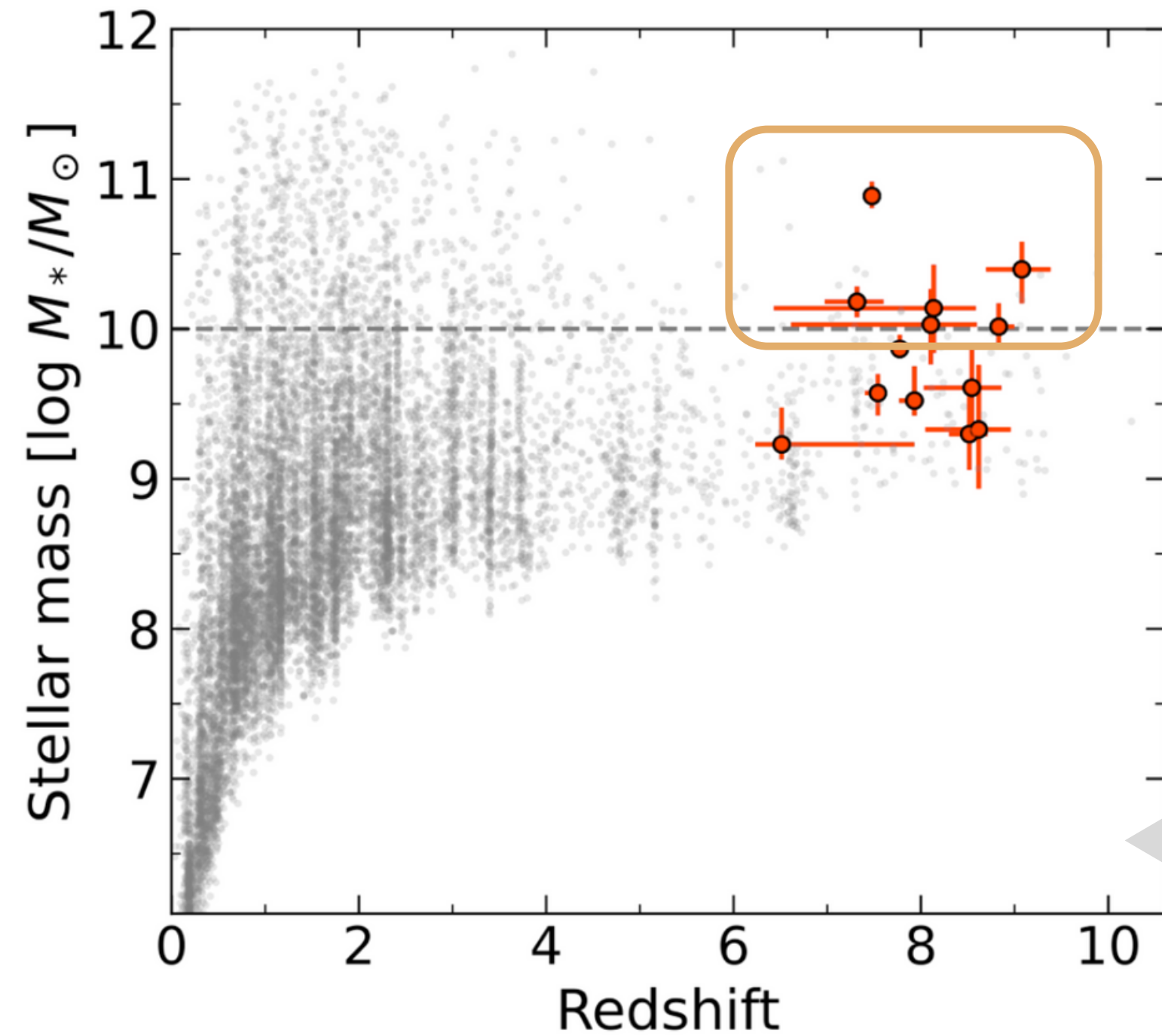
## JWST Observations



Labbé et al. (2023)  
Nature, 616, 7956

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## JWST Observations



Larger number density  
than expected  
from theoretical models

Labbé et al. (2023)  
Nature, 616, 7956



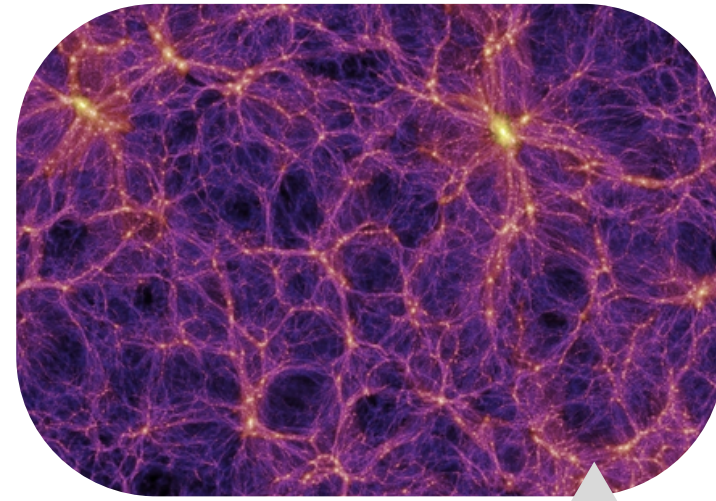
**INTRODUCTION:  
THE “PUZZLE”**

**A QUICK “RECIPE”**

# INTRODUCTION: THE “PUZZLE”

## A QUICK “RECIPE”

$$P_m(k, z)$$

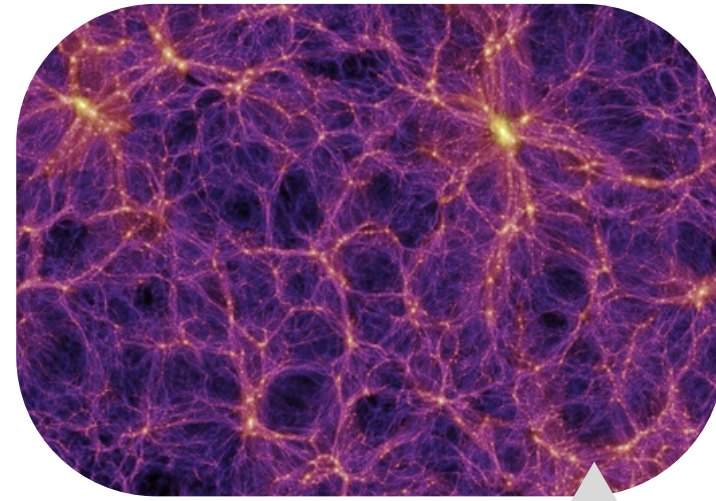


Millennium simulation ©

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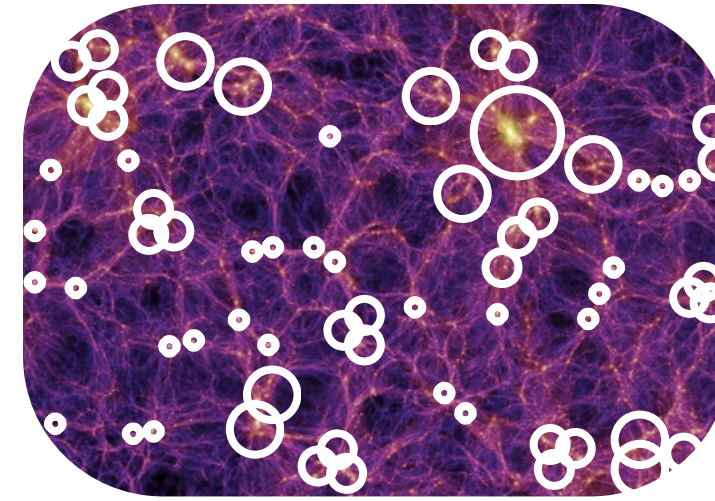
## A QUICK “RECIPE”

$$P_m(k, z)$$



Millennium simulation ©

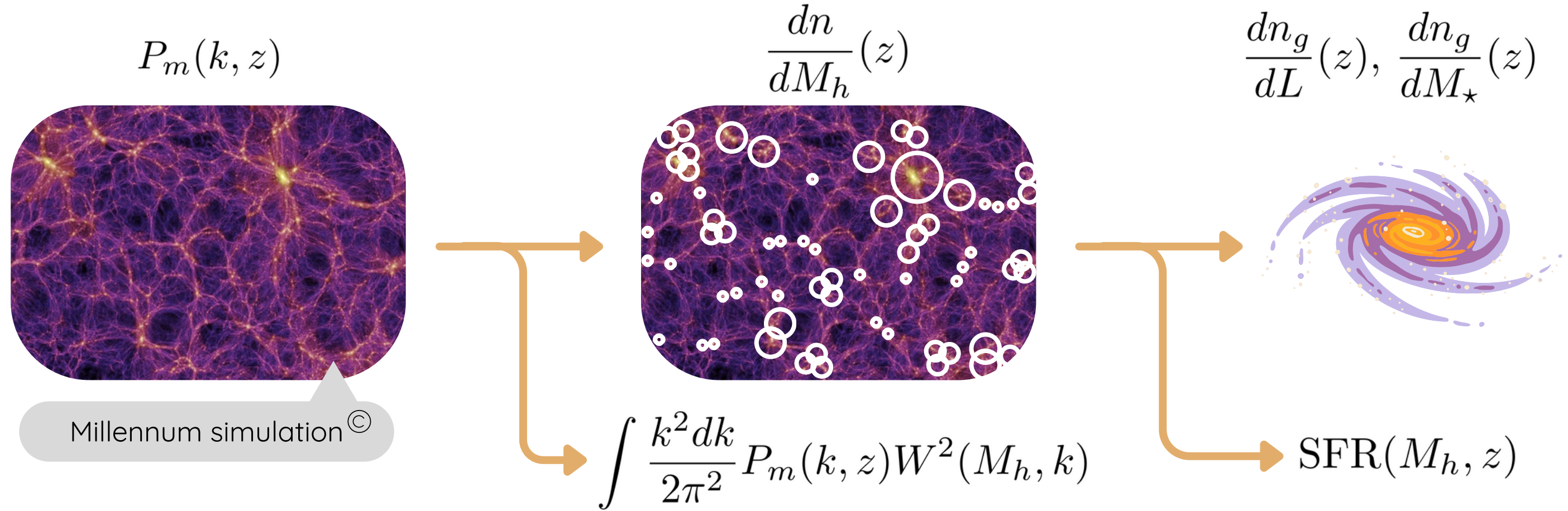
$$\frac{dn}{dM_h}(z)$$



$$\int \frac{k^2 dk}{2\pi^2} P_m(k, z) W^2(M_h, k)$$

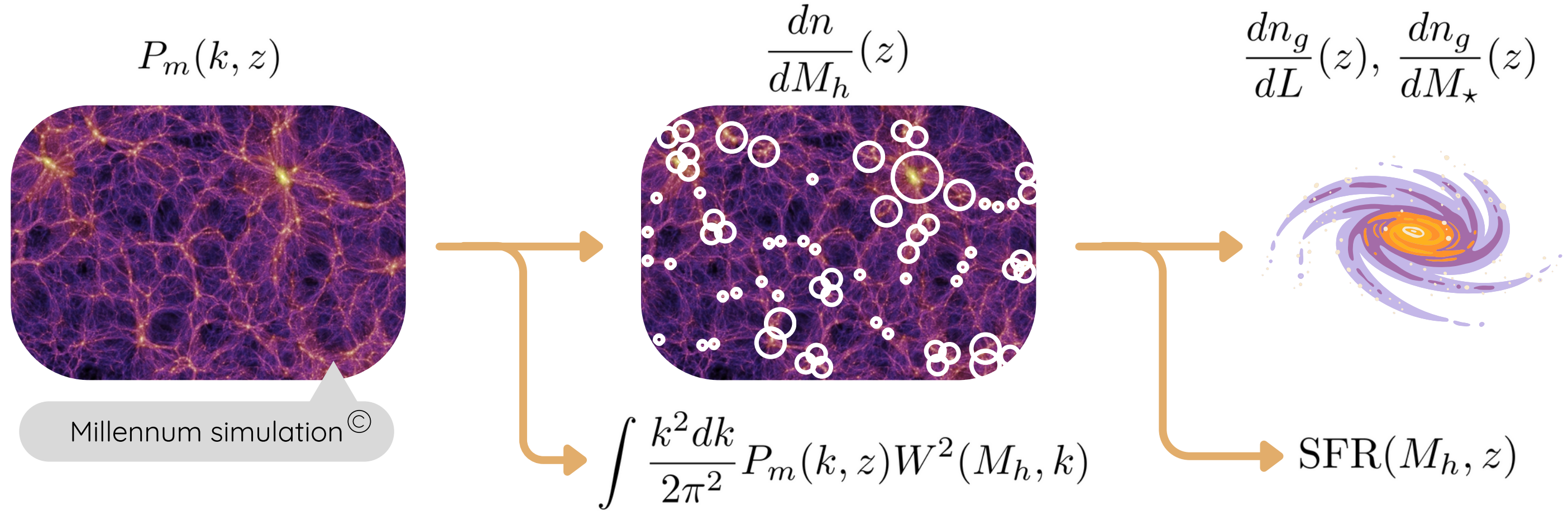
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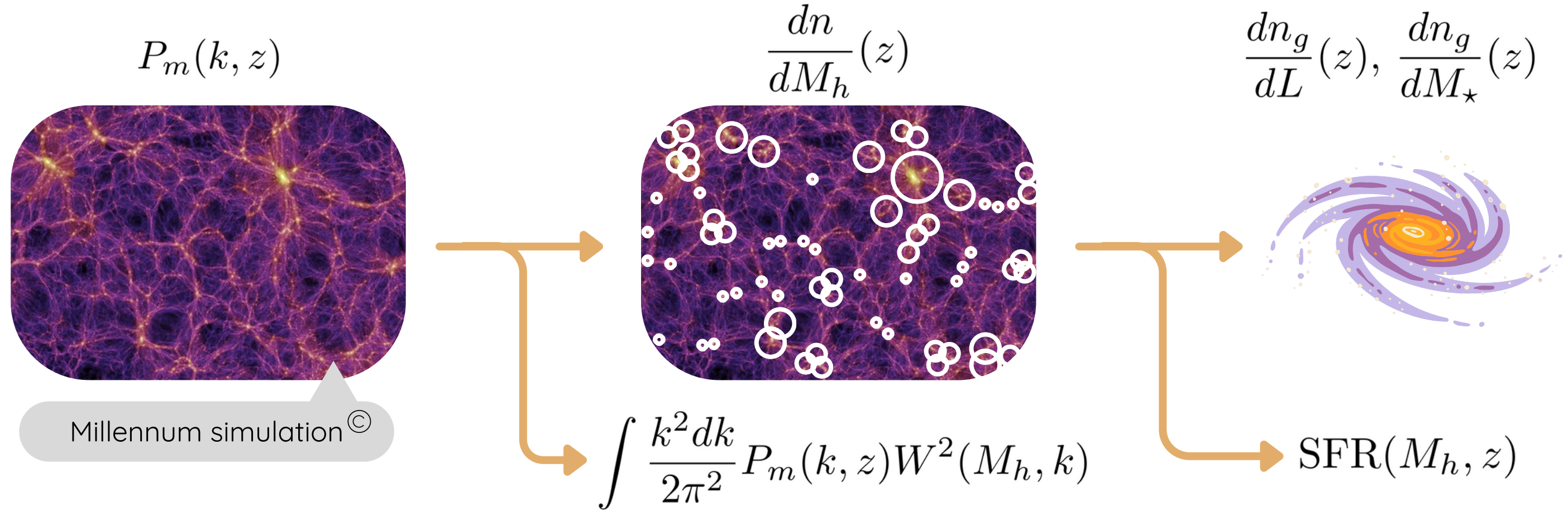


Unexpected result in JWST data ?



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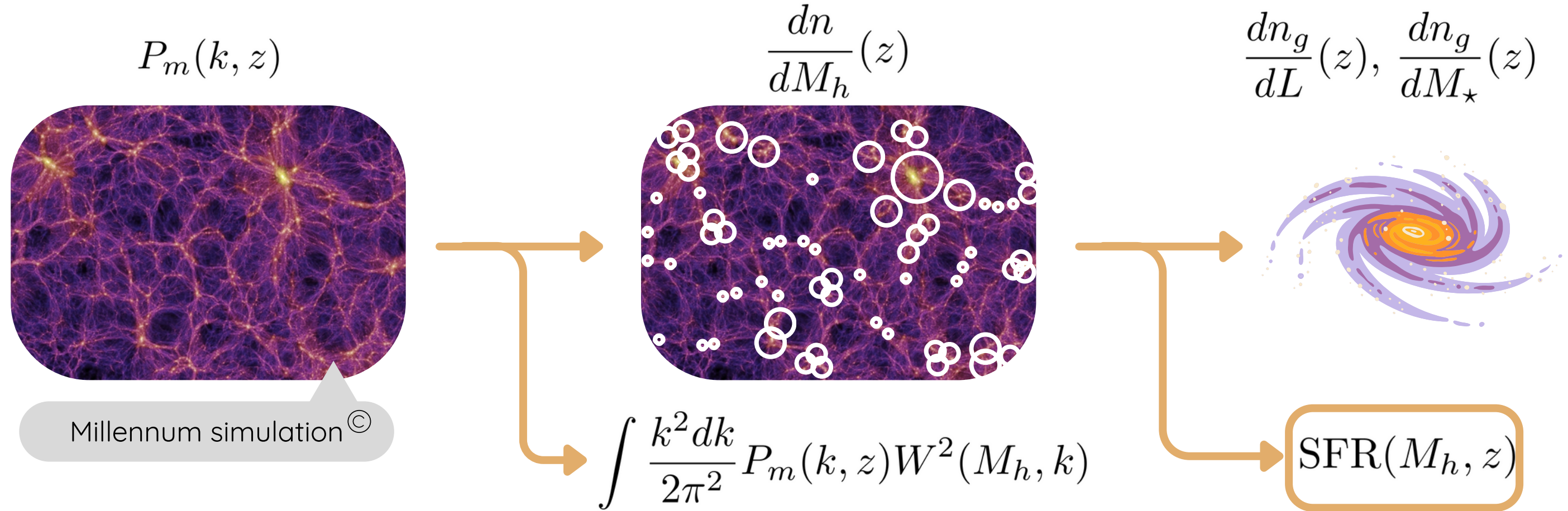


Unexpected result in JWST data ?

Necessity for a different model ?

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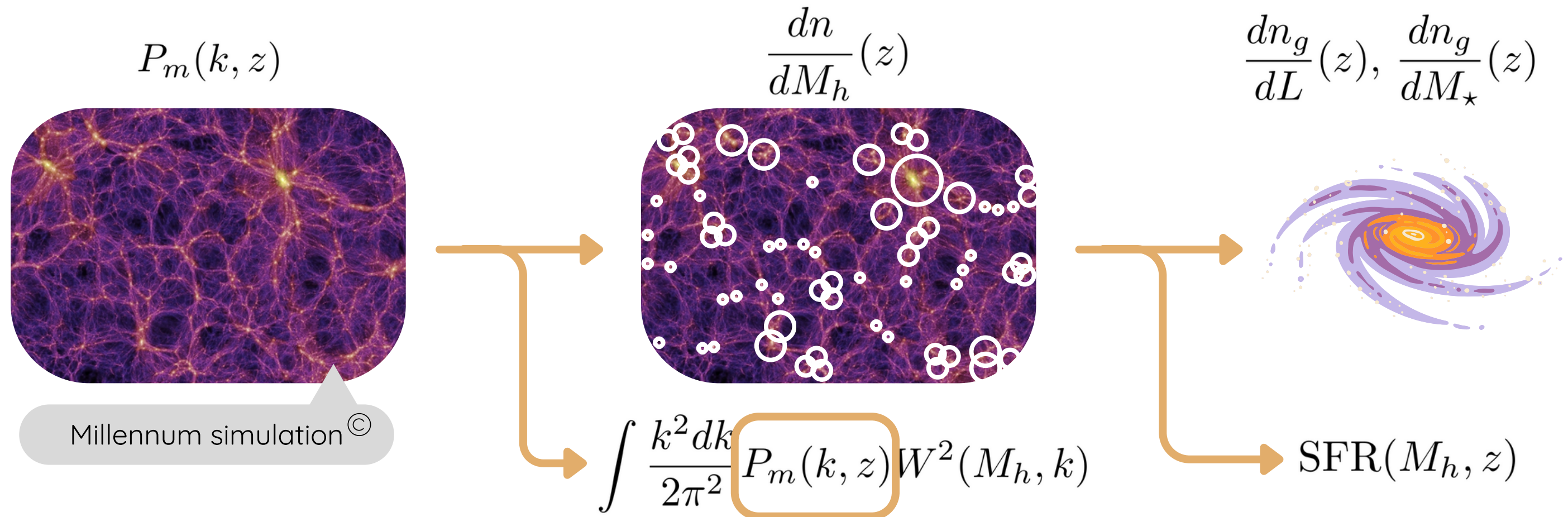
Unexpected result in JWST data ?

Necessity for a different model ?

Astrophysics ?

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Unexpected result in JWST data ?

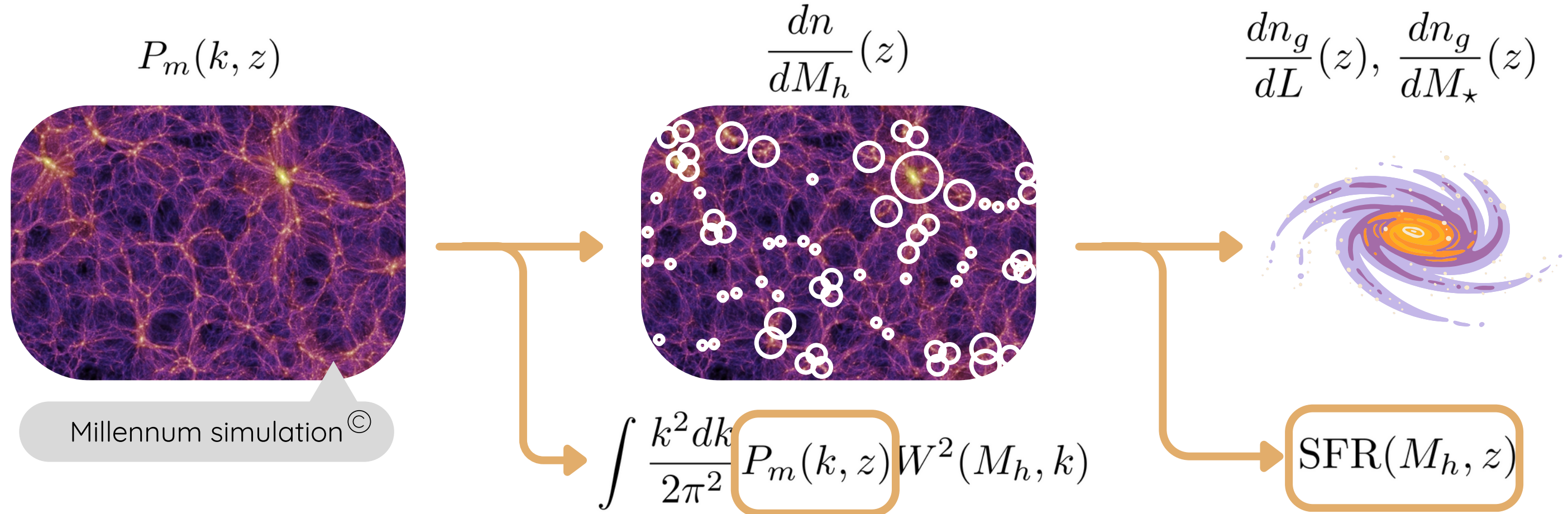
Necessity for a different model ?

Cosmology ?



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Unexpected result in JWST data ?

Necessity for a different model ?

Astrophysics or Cosmology ?

🔍 LOOK FOR ANOTHER TRACER ✕

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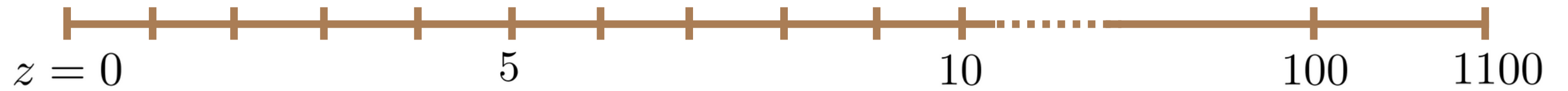
**LINE INTENSITY  
MAPPING**



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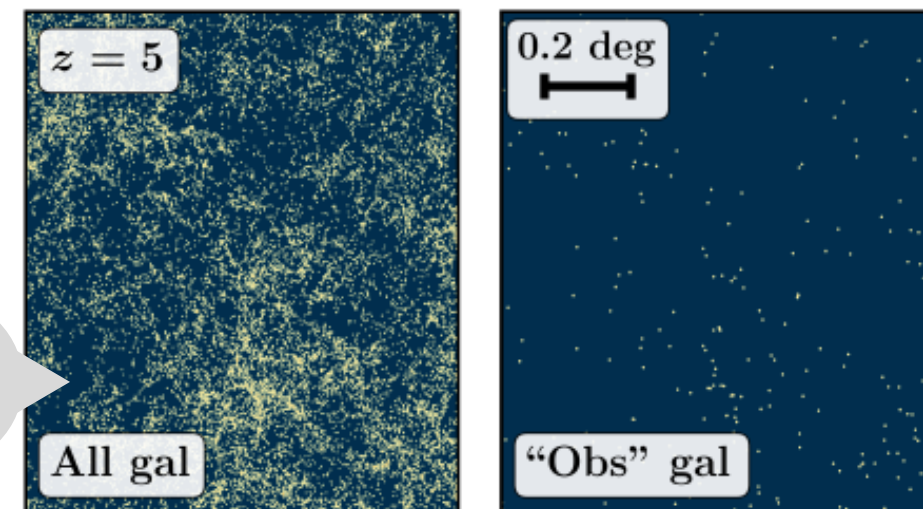
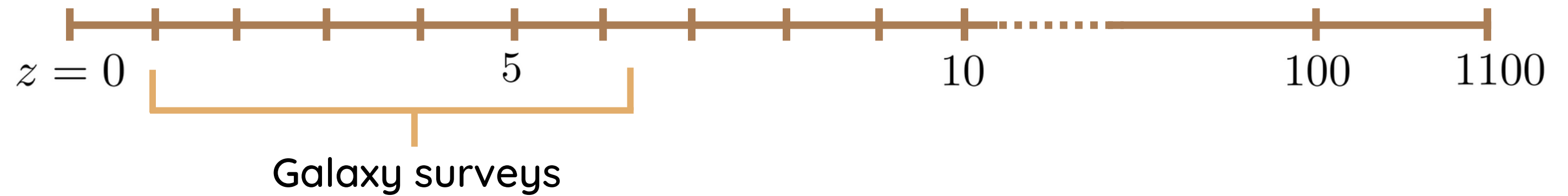
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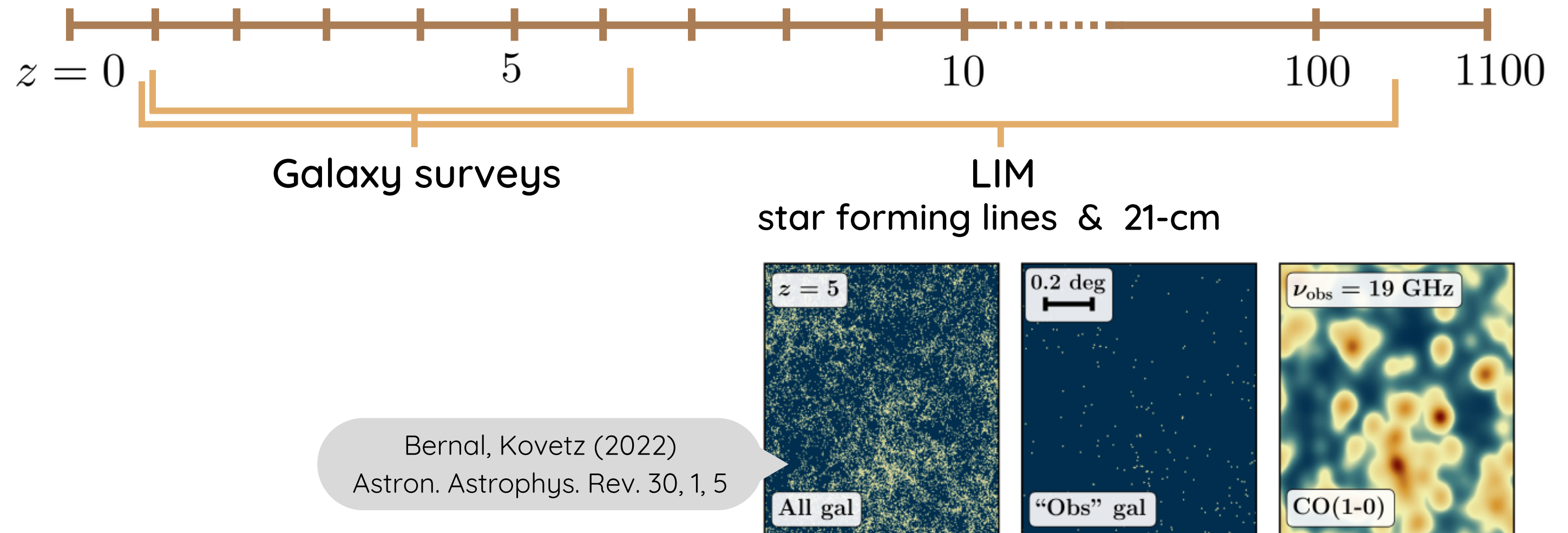


Bernal, Kovetz (2022)  
Astron. Astrophys. Rev. 30, 1, 5

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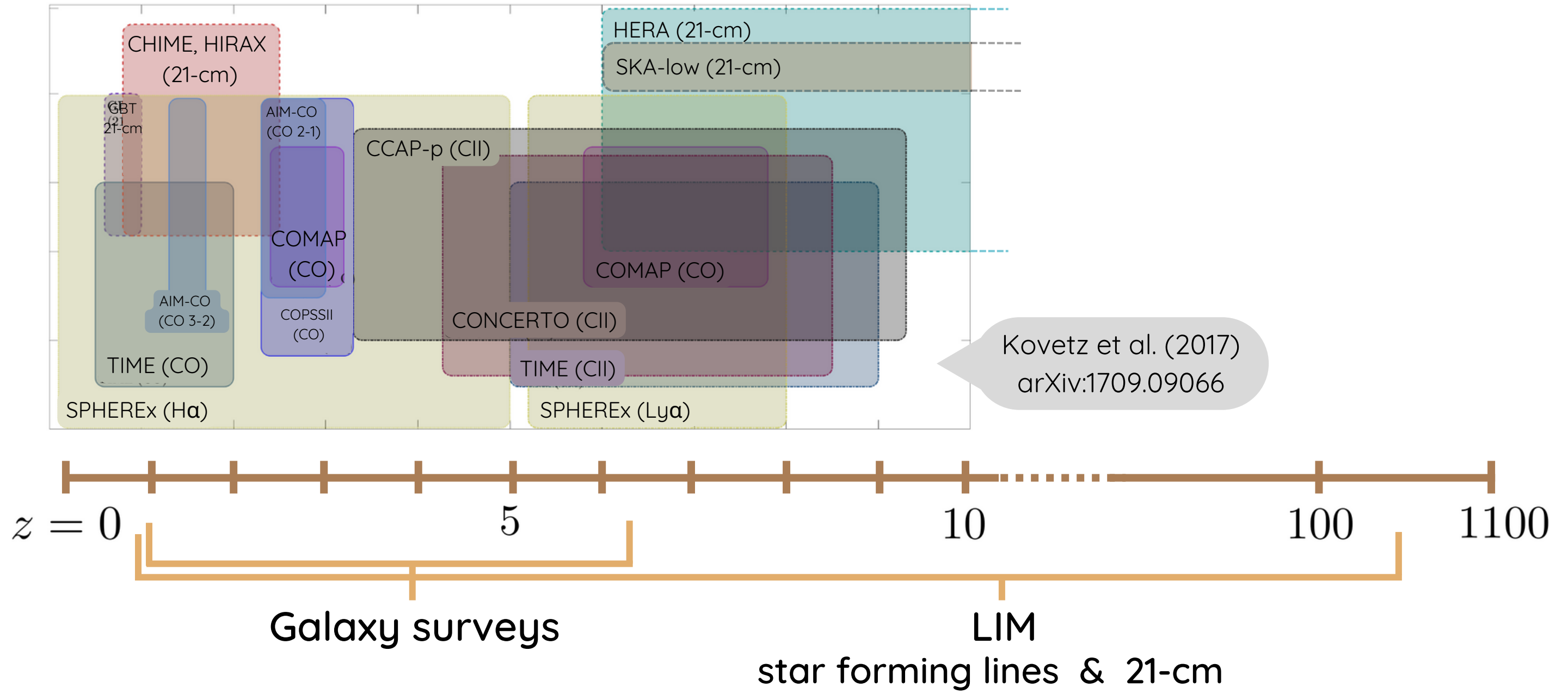
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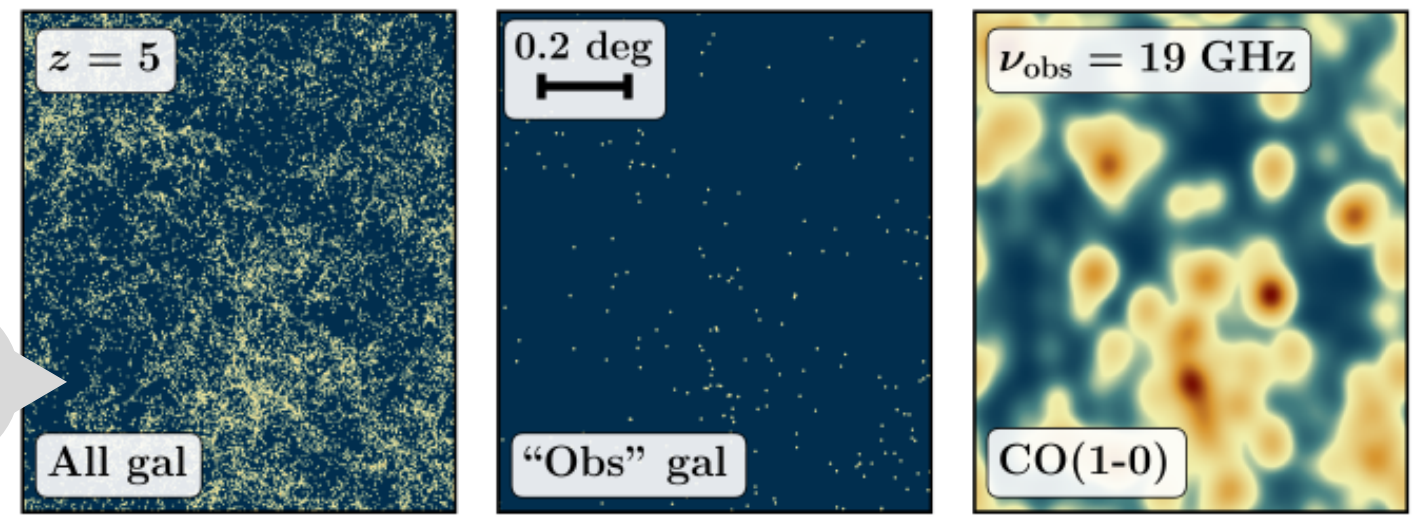
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Kovetz et al. (2017)  
arXiv:1709.09066

Bernal, Kovetz (2022)  
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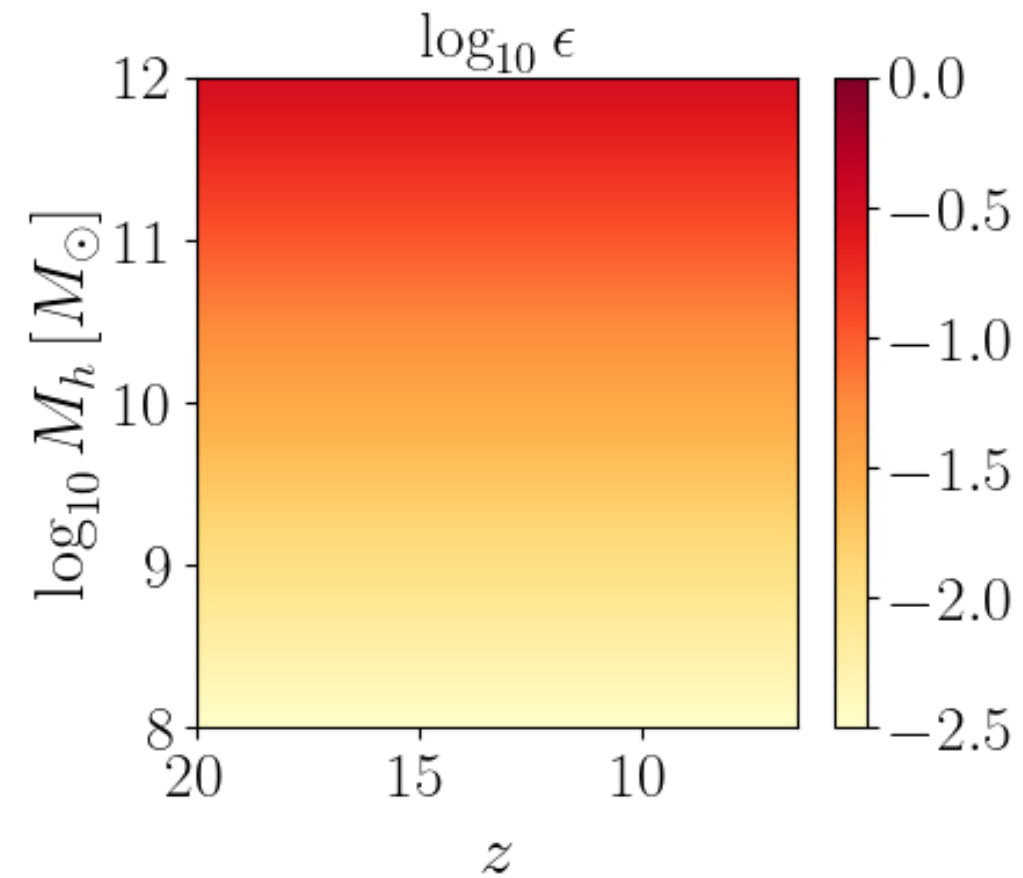
## A QUICK “RECIPE”

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## ASTROPHYSICS

Star Formation Efficiency...

$$\epsilon(M_h) \propto f_* M_h^{\alpha_*}$$



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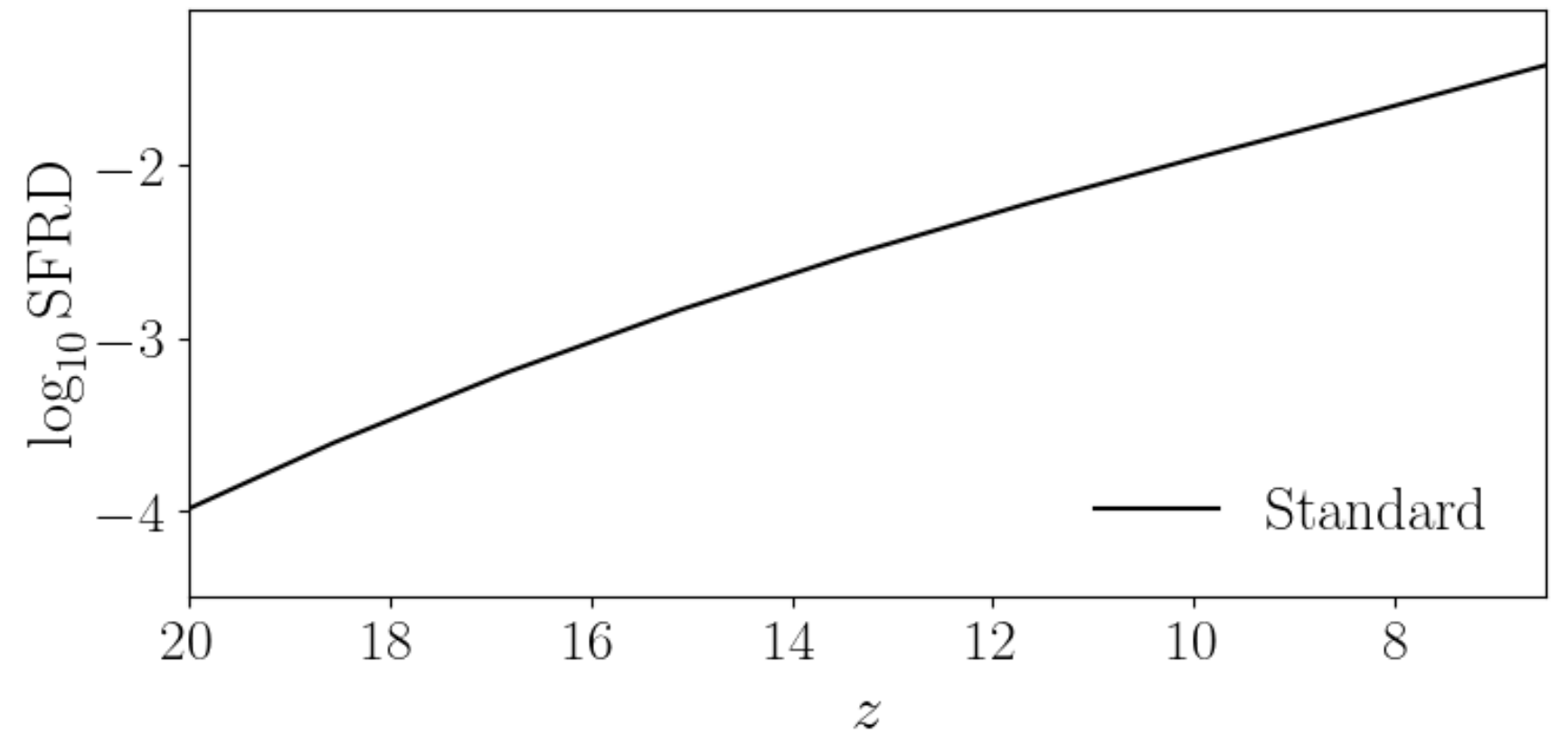
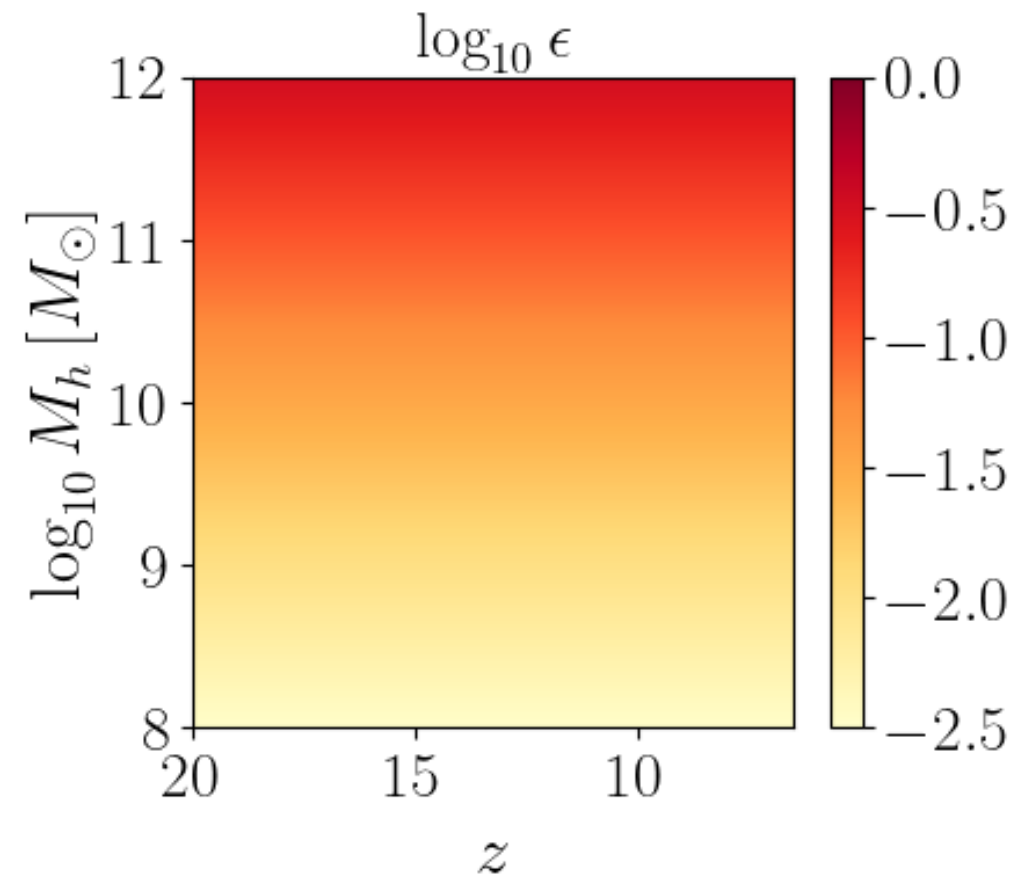
# A QUICK “RECIPE”

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Star Formation Efficiency...

$$\epsilon(M_h) \propto f_* M_h^{\alpha_*} \longrightarrow \text{SFR}(M_h, z) \longrightarrow \text{SFRD}(z) \propto \int dM_h \frac{dn}{dM_h} \text{SFR}(M_h, z)$$



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# FEEDBACK FREE STARBURSTS



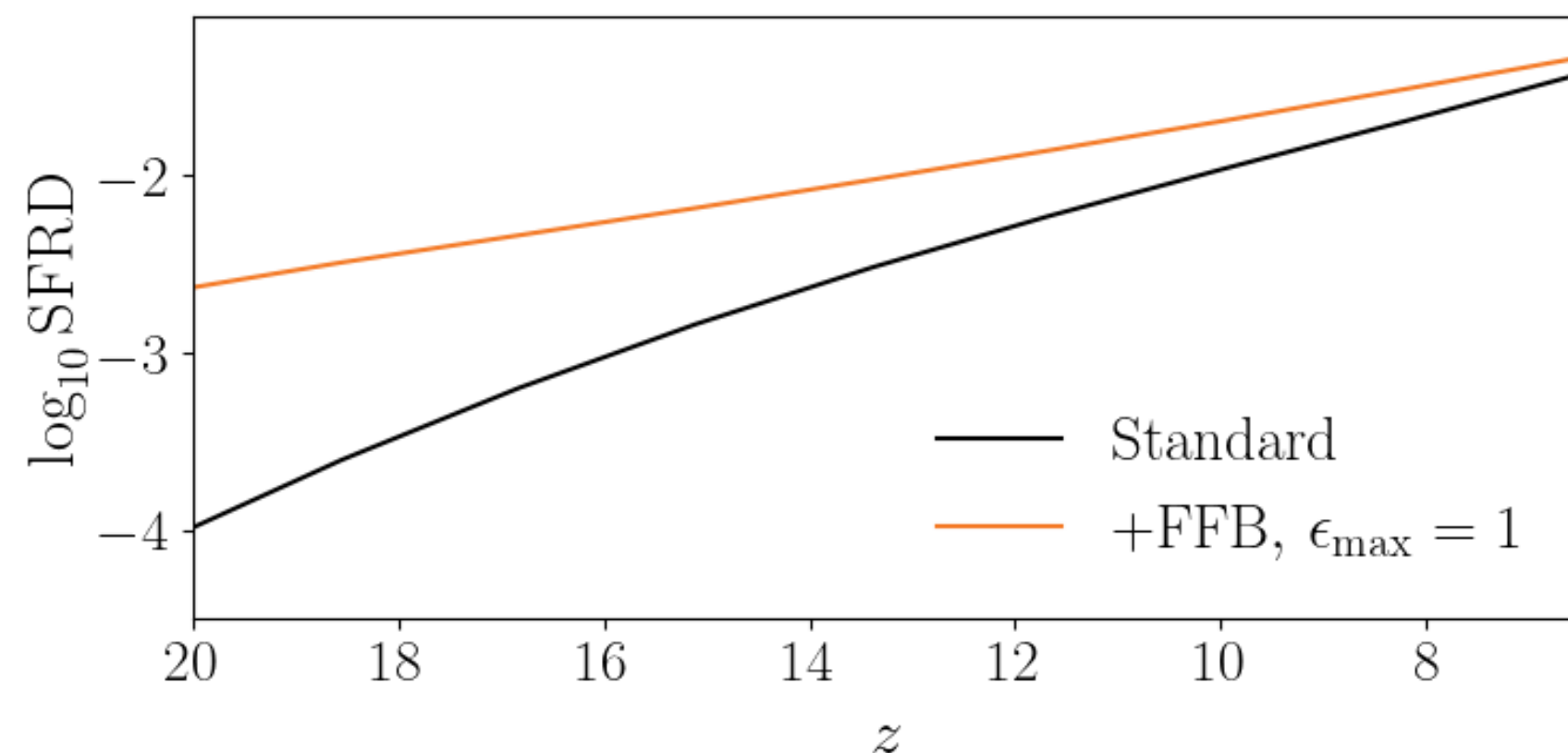
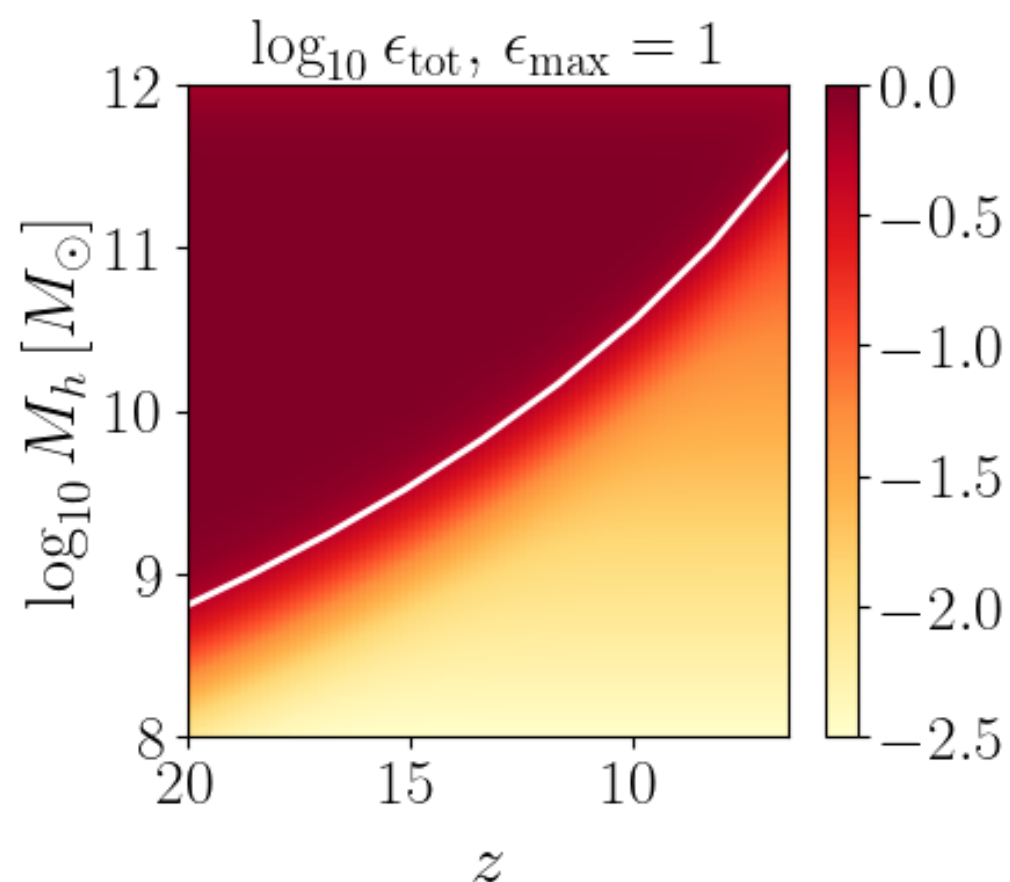
## CANDIDATE SOLUTION FOR THE JWST “PUZZLE”

Dekel et al. (2023)  
arXiv:2303.04827  
Libanore et al. (2023)  
arXiv:2310.03021

Star Formation Efficiency...

...Boosted in halos above mass threshold

$$\epsilon(z, M_h) \propto f_* (1 - f_{\text{FFB}}) M_h^{\alpha_*} + f_{\text{FFB}} \epsilon_{\text{max}}$$



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**SIGNATURES ON 21-CM**



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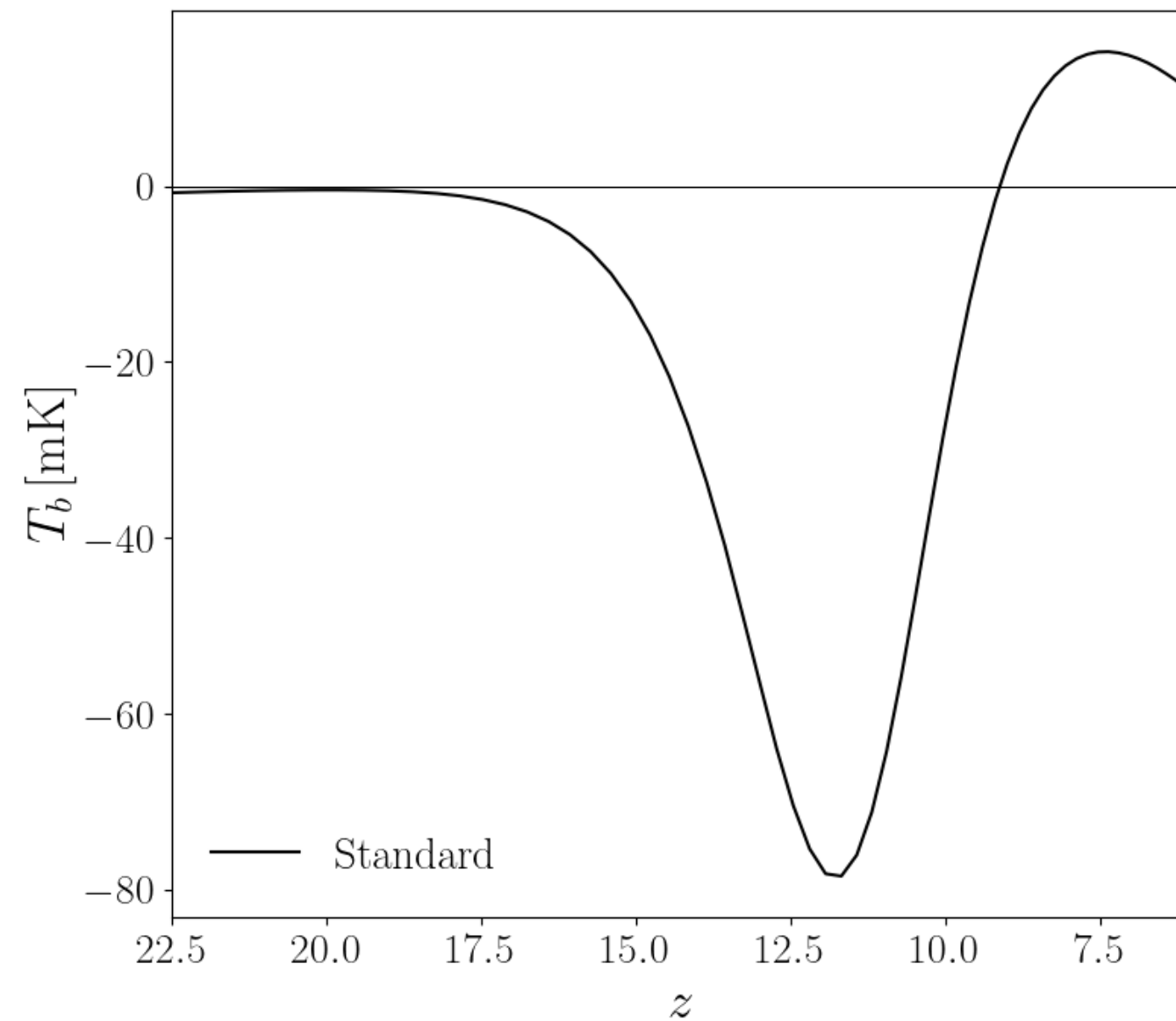
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21-cm Global Signal





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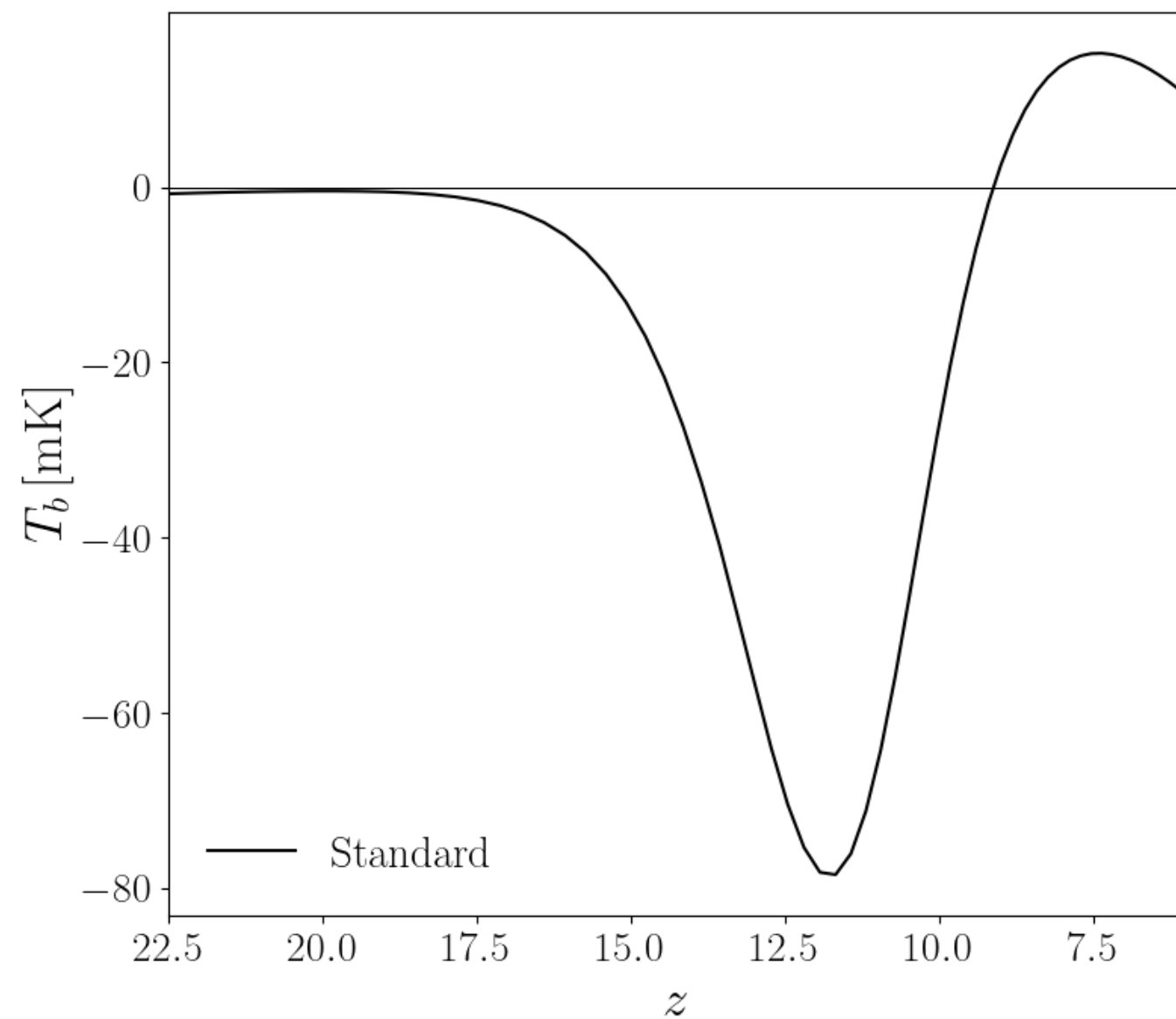
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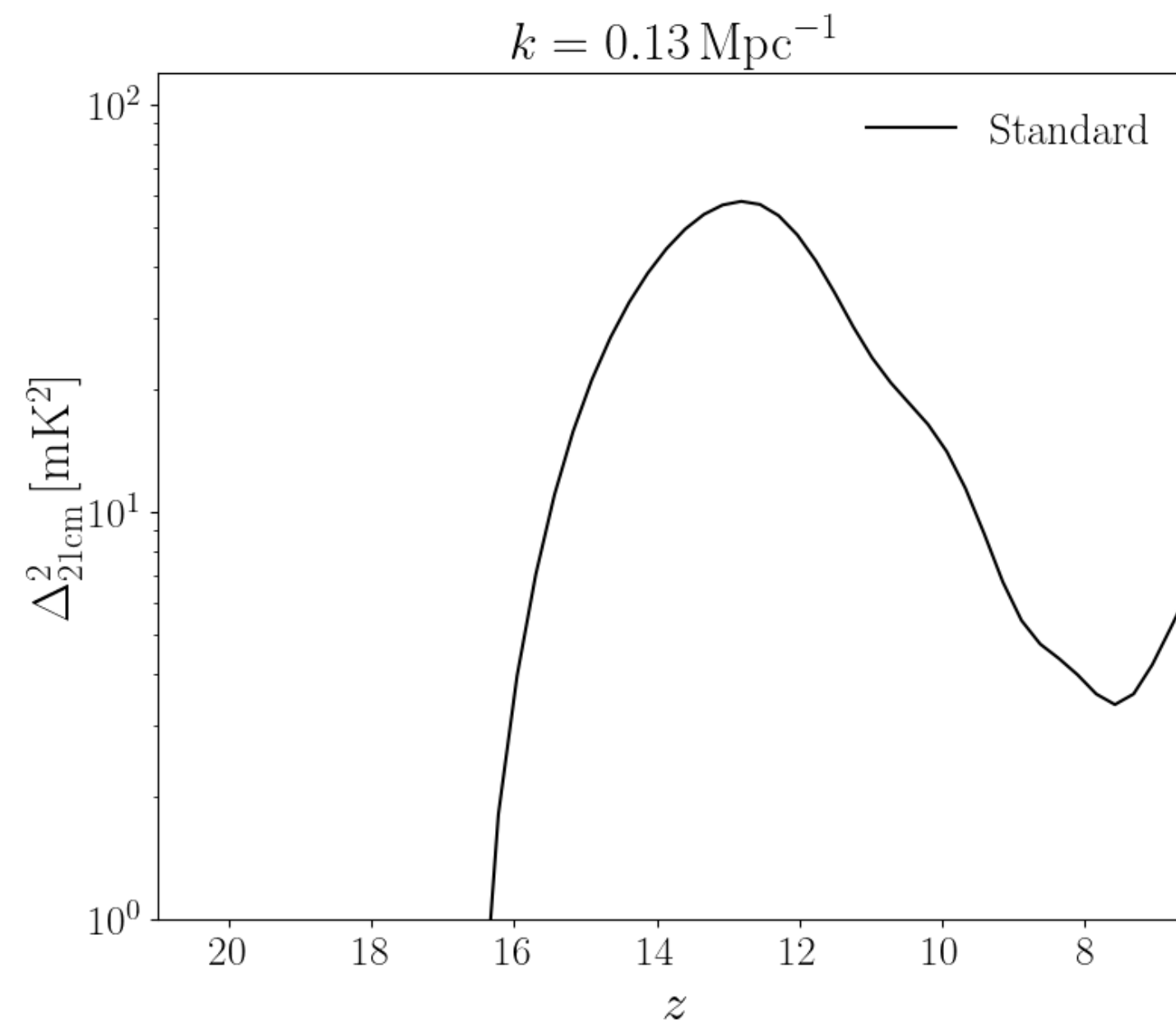
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### 21-cm Global Signal



### 21-cm Power Spectrum



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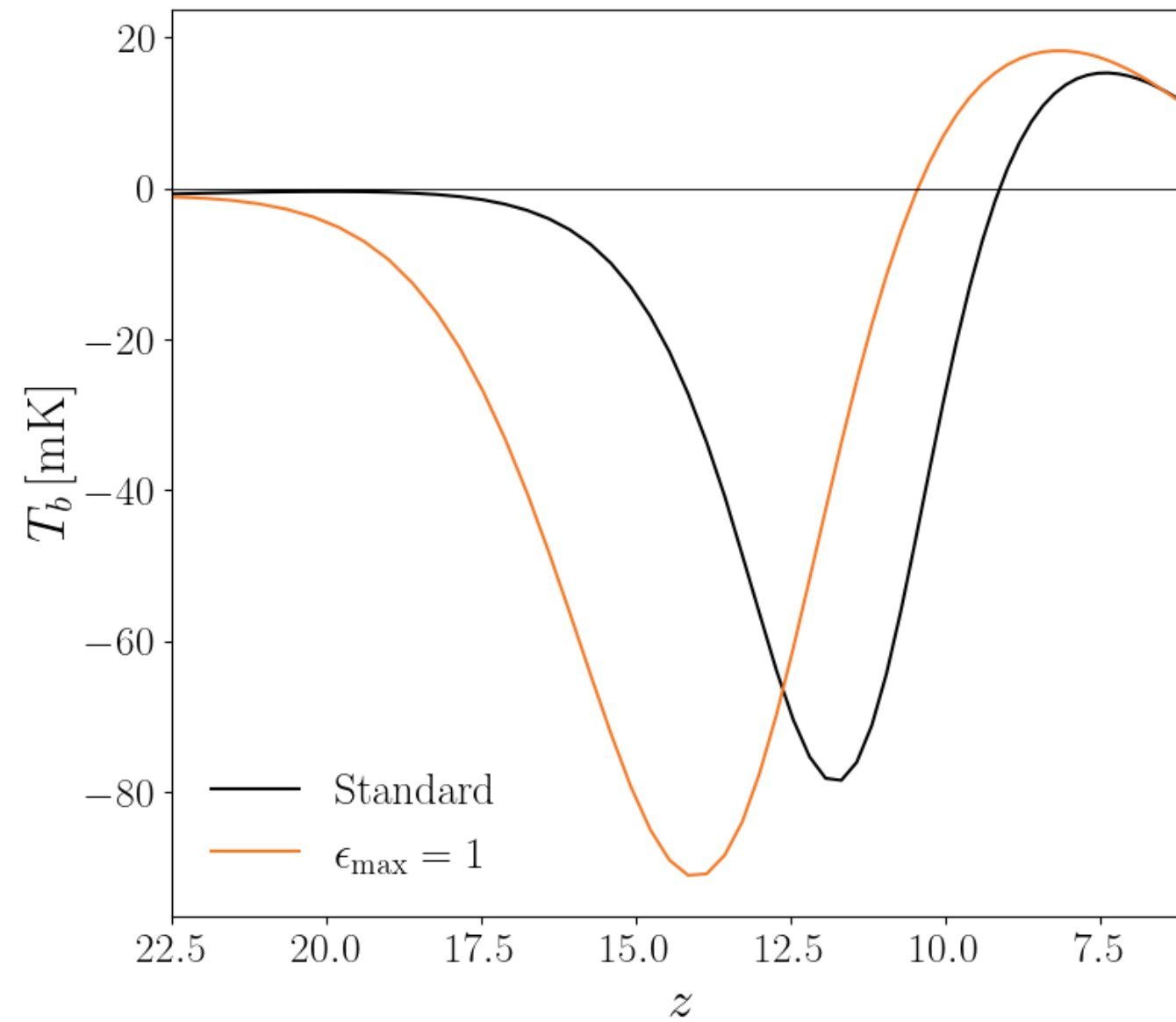
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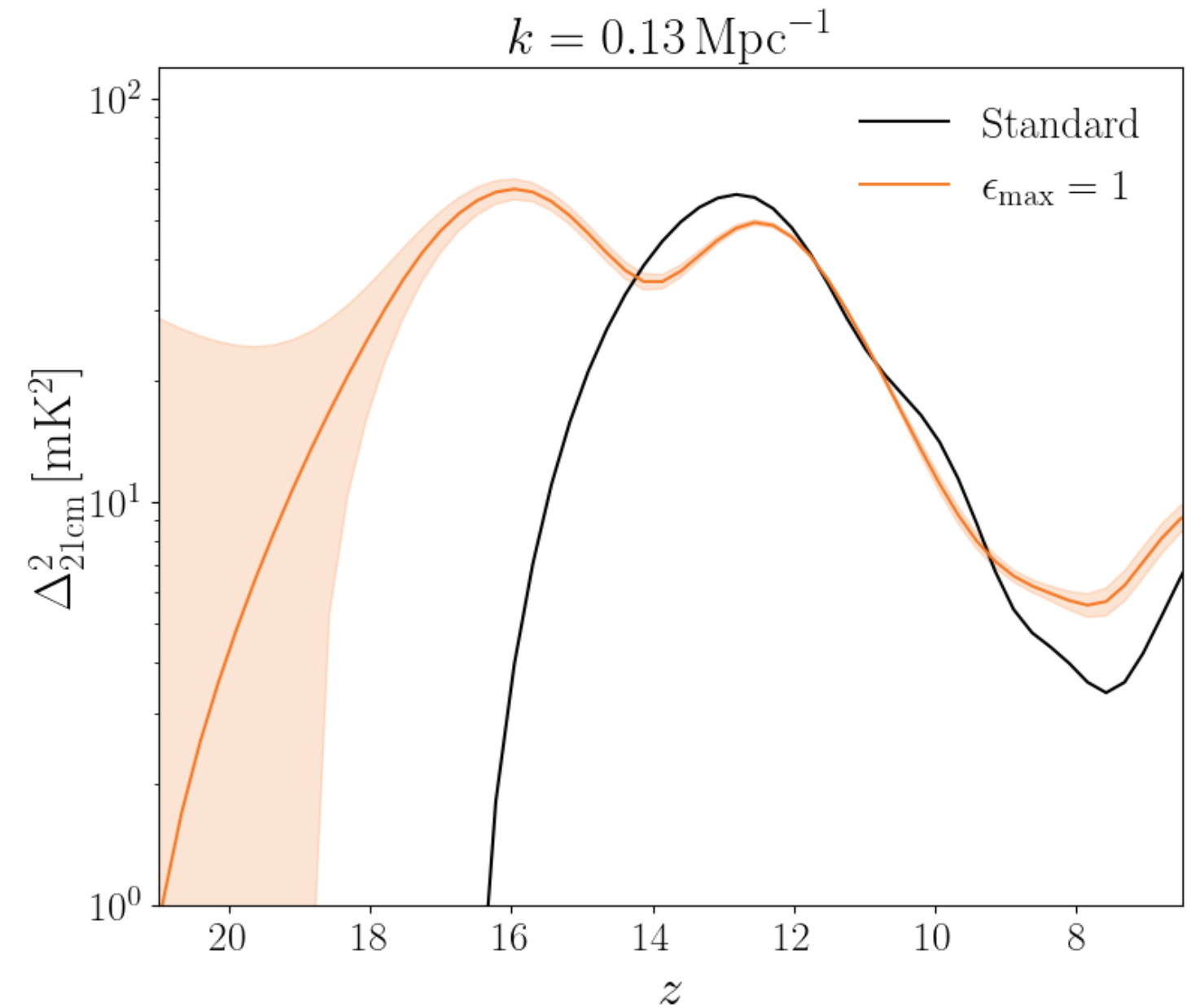
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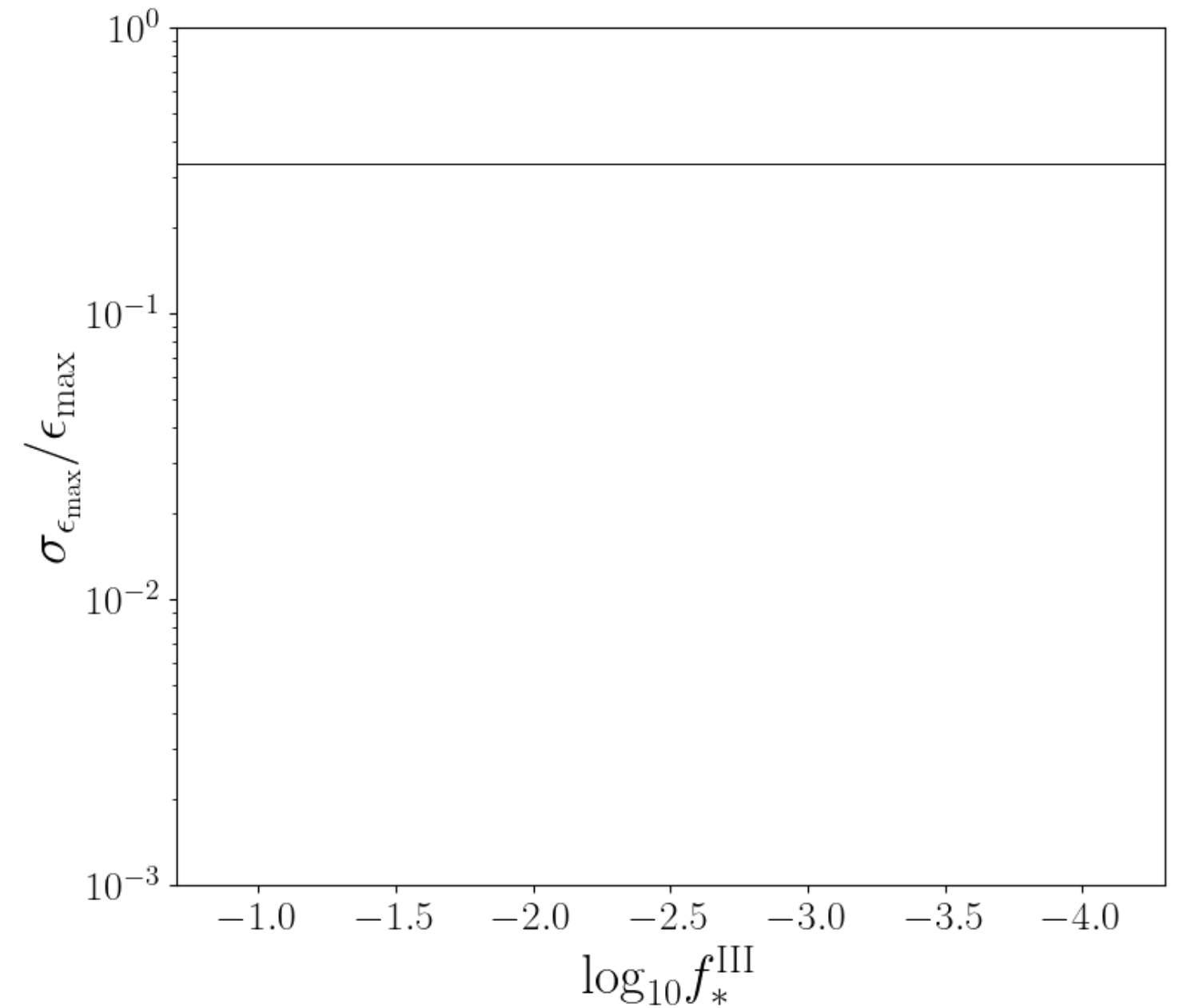
## FEEDBACK FREE STARBURSTS



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Detectability of FFB signatures  
with Full-HERA



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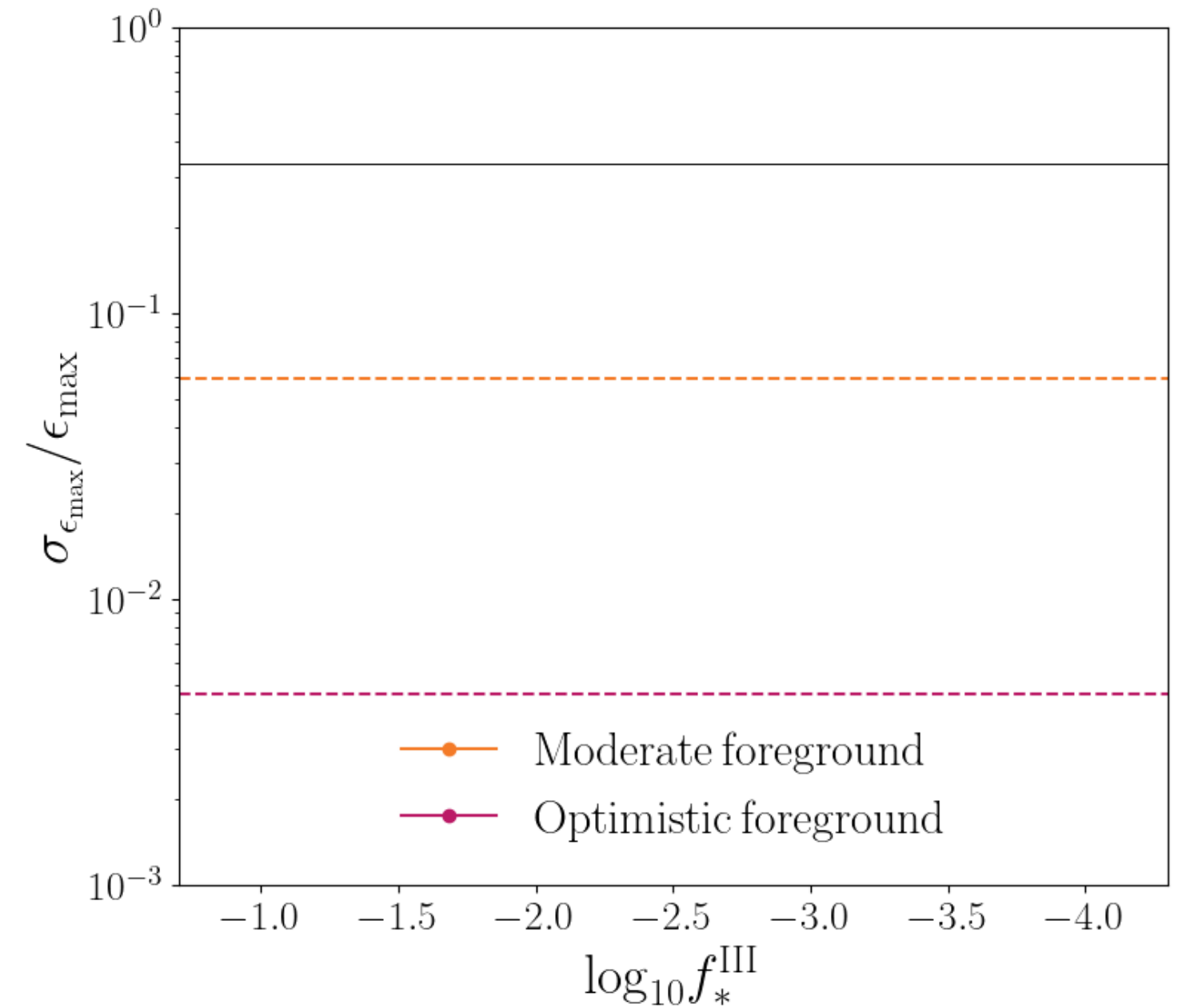
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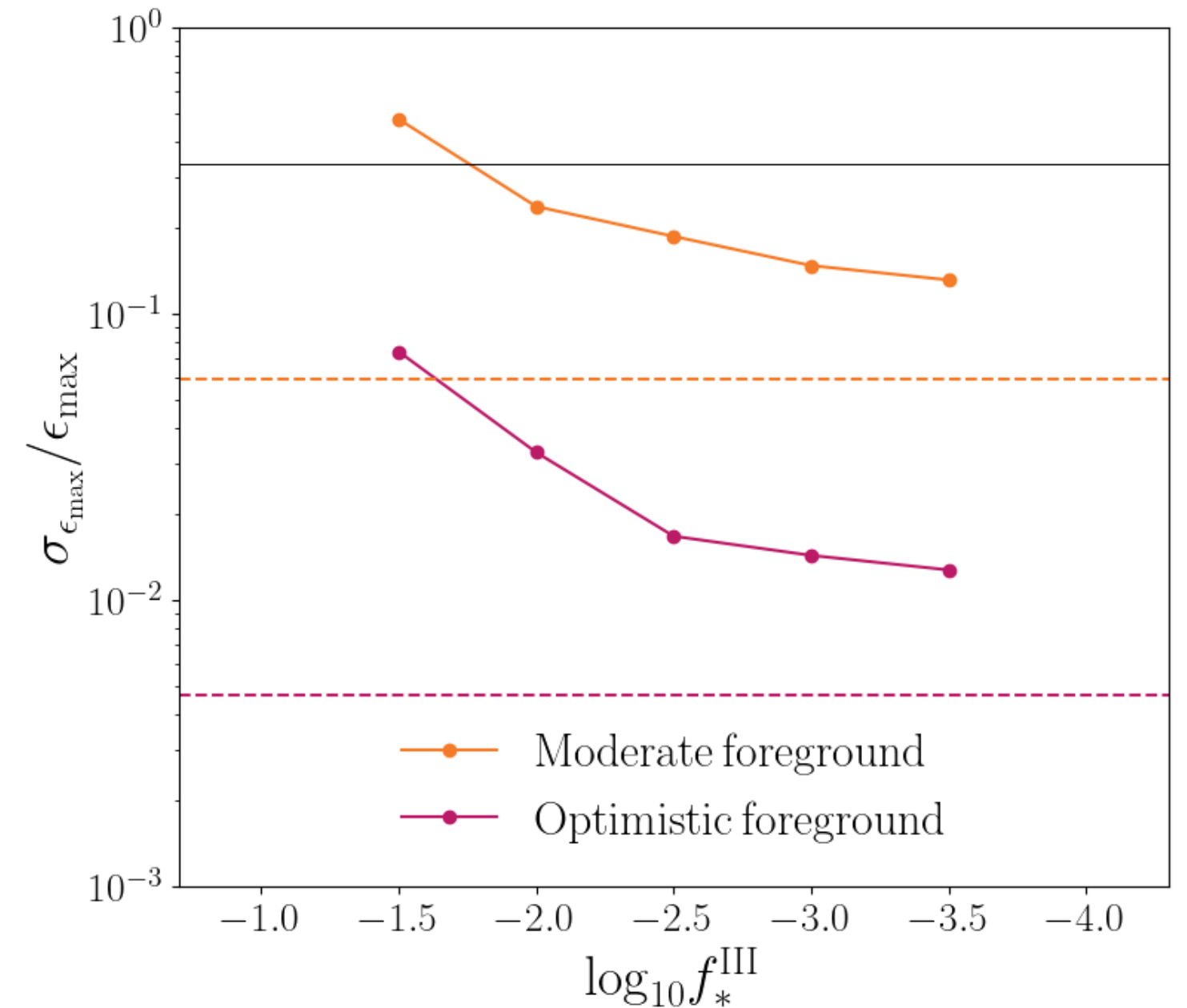


CANDIDATE SOLUTION FOR THE JWST “PUZZLE”

Dekel et al. (2023)  
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Detectability of FFB signatures  
with Full-HERA

Reduced in case of  
efficient pop III star formation



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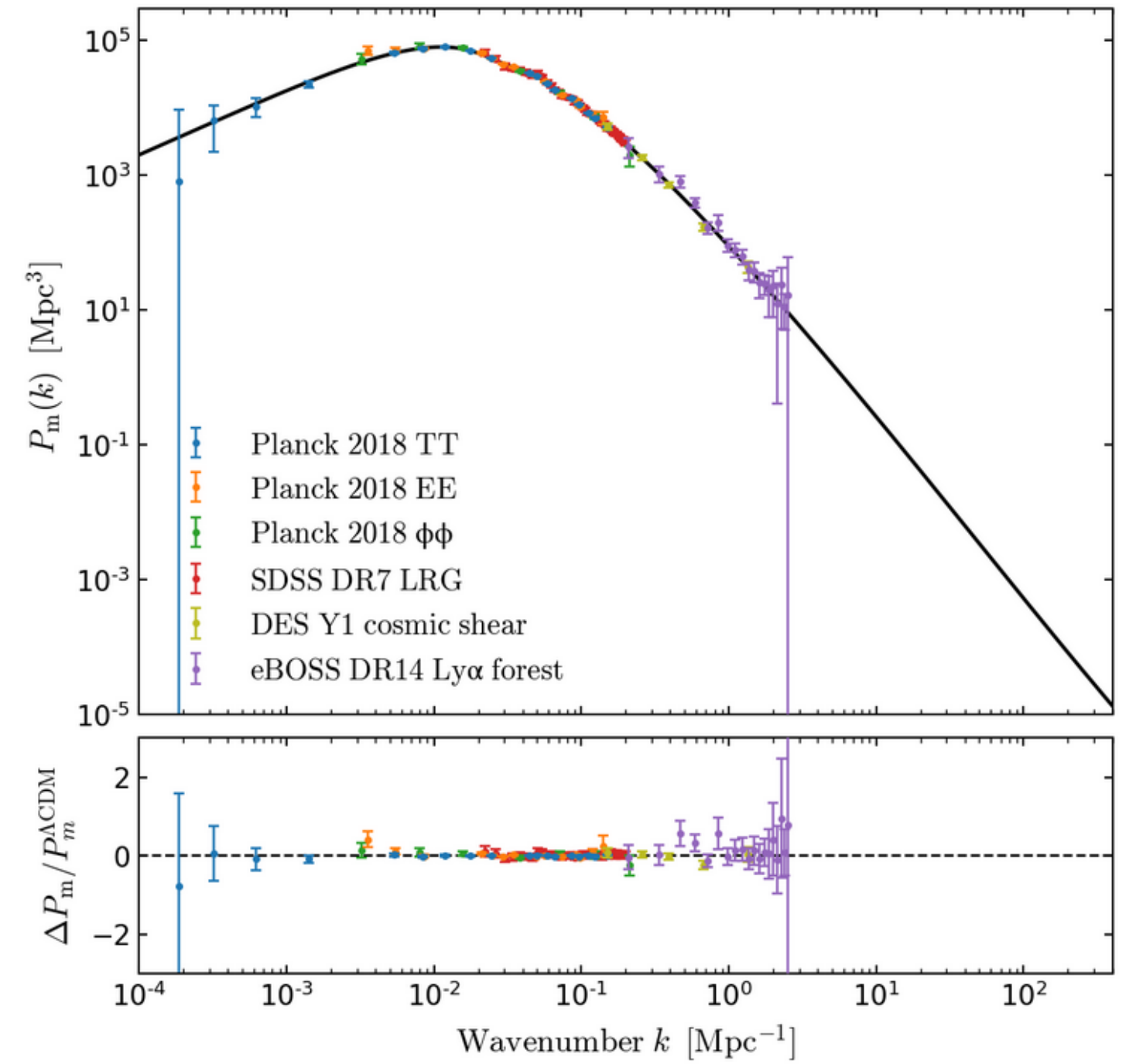
# LINE INTENSITY MAPPING

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$$P_m(k, z)$$



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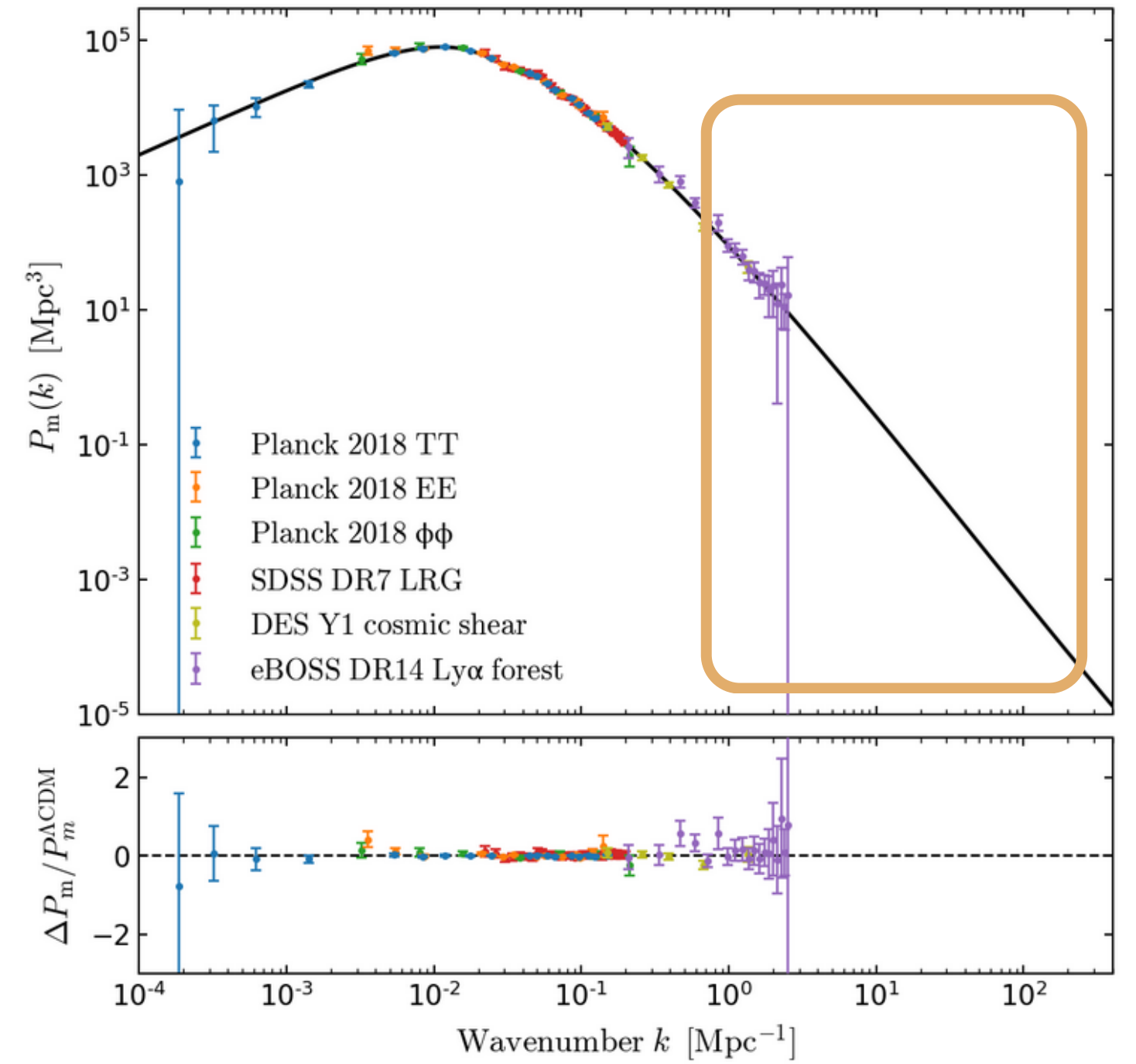
## ASTROPHYSICS

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## COSMOLOGY

$$P_m(k, z)$$

Small scale regime  
unconstrained



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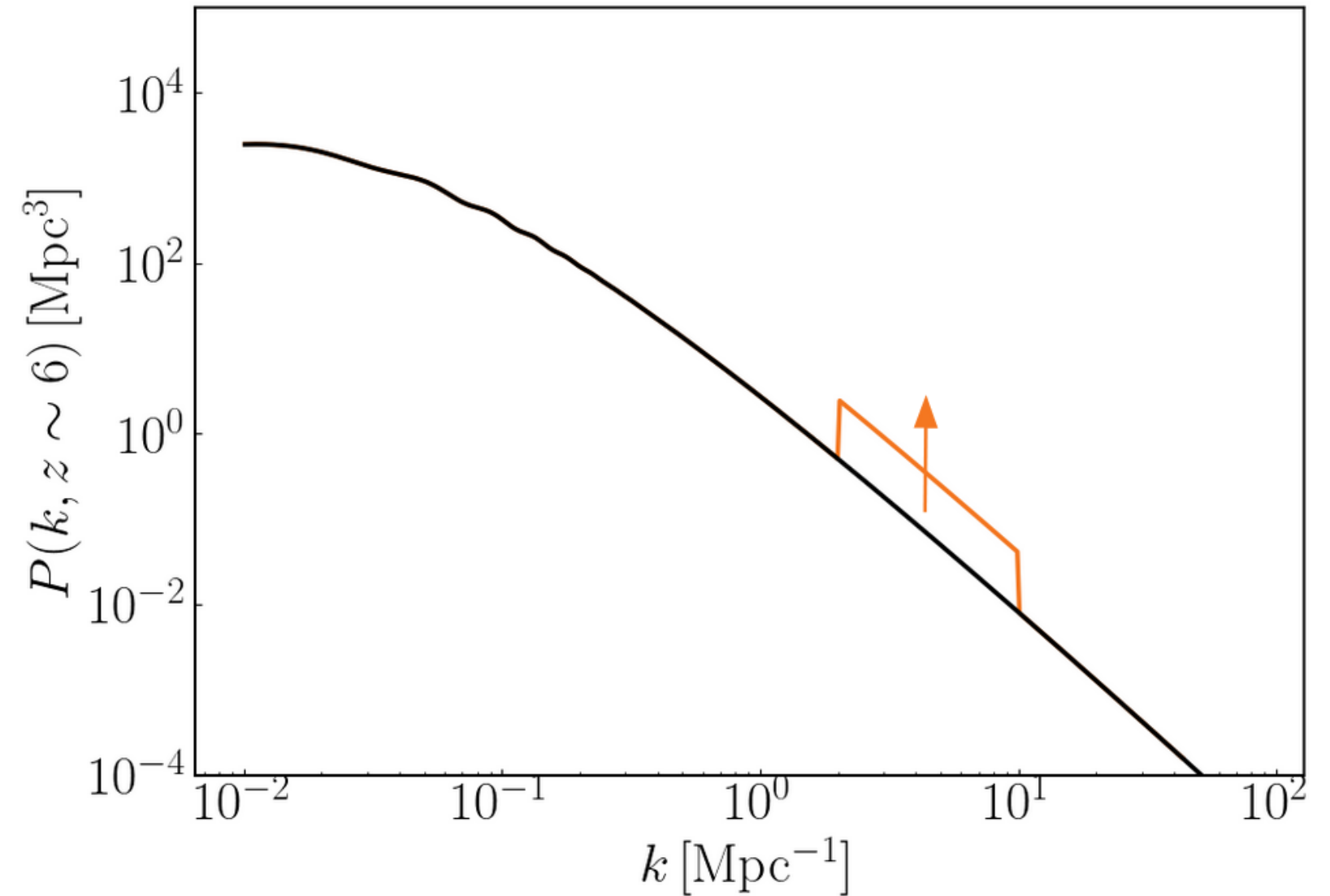
## DEVIATIONS FROM LCDM



**CANDIDATE SOLUTION FOR THE JWST “PUZZLE”**

Sabti et al. (2022)  
Astrophys. J. Lett. 928, 2  
Libanore et al. (2022)  
Phys. Rev. D 106, 12

$$P_m(k, z)$$



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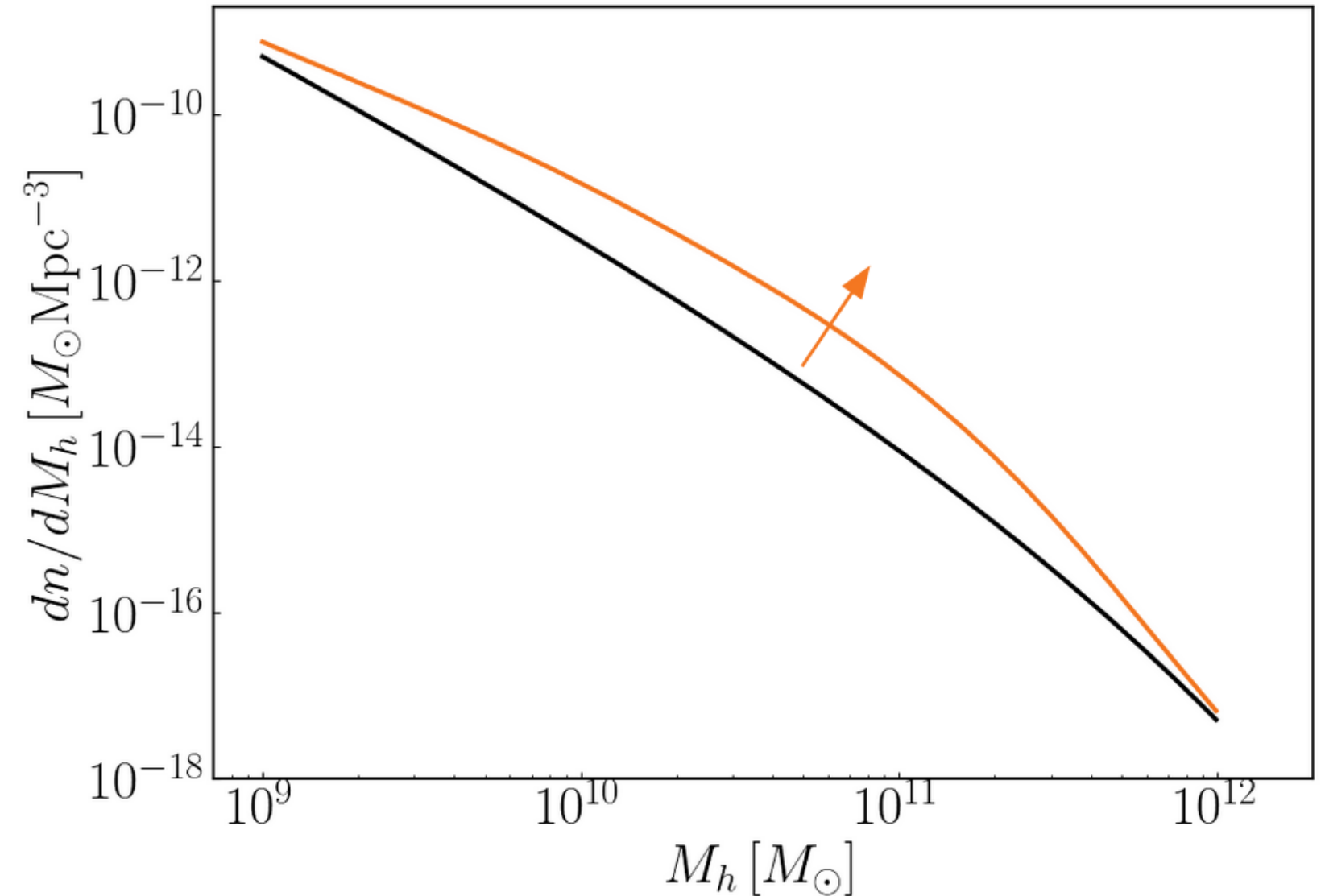


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Libanore et al. (2022)  
Phys. Rev. D 106, 12

$$P_m(k, z) \rightarrow dn/dM_h$$

Boost  
intermediate - small halos



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## DEVIATIONS FROM LCDM



**CANDIDATE SOLUTION FOR THE JWST “PUZZLE”**

$$P_m(k, z) \longrightarrow dn/dM_h \longrightarrow \text{SFR}(M_h, z)$$

Enhanced number  
of small and faint galaxies

Sabti et al. (2022)  
Astrophys. J. Lett. 928, 2  
Libanore et al. (2022)  
Phys. Rev. D 106, 12



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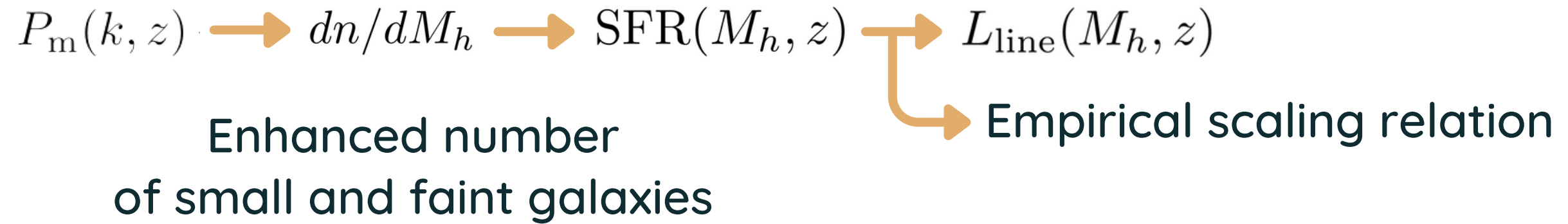
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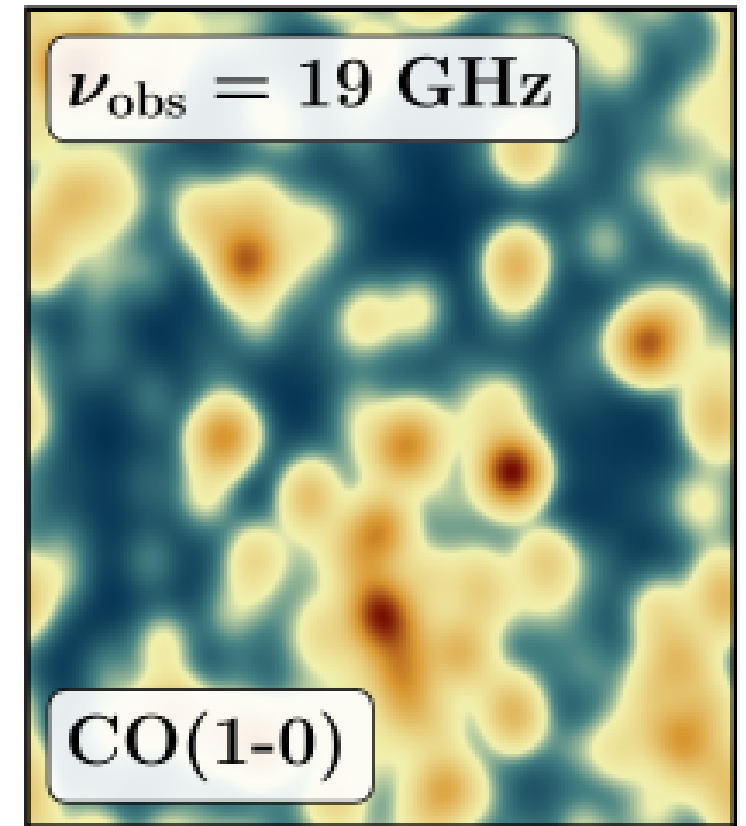
**DEVIATIONS FROM LCDM**

**CANDIDATE SOLUTION FOR THE JWST “PUZZLE”**

Libanore et al. (2022)  
Phys. Rev. D 106, 12, 123512



Detection from star forming lines



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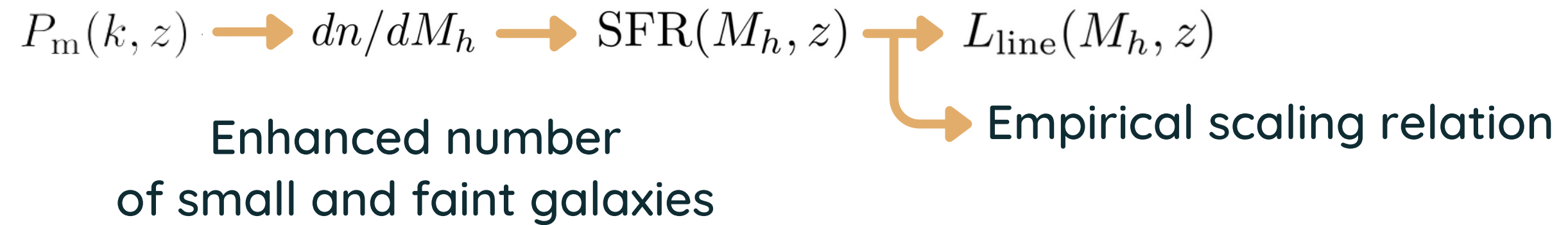


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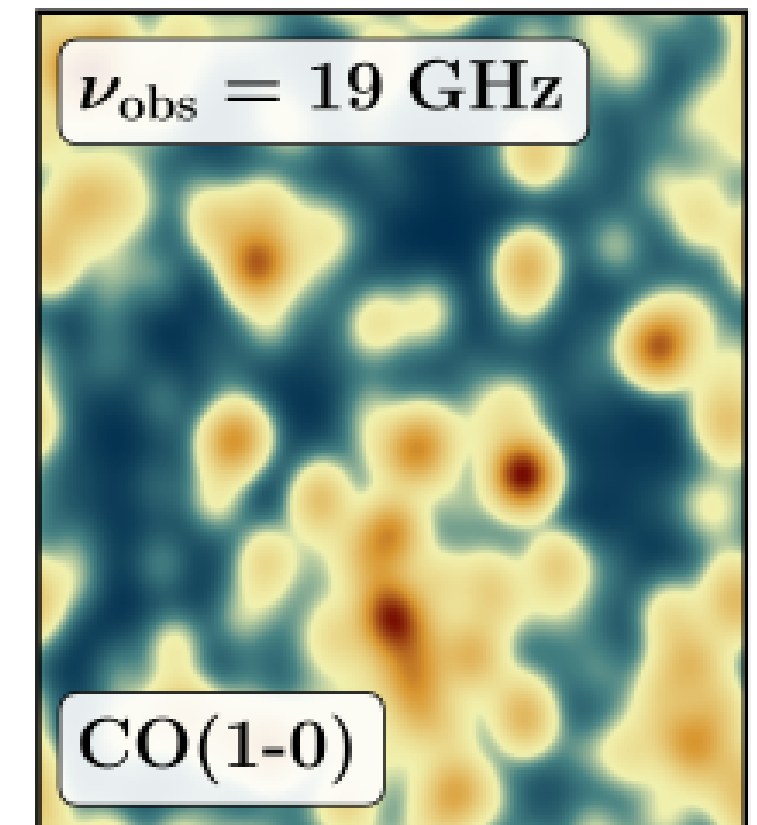
## CANDIDATE SOLUTION FOR THE JWST “PUZZLE”

Libanore et al. (2022)  
Phys. Rev. D 106, 12, 123512



Detection from star forming lines

Summary statistics of  
intensity fluctuations in the map



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**VOXEL INTENSITY  
DISTRIBUTION**



**DEVIATIONS FROM LCDM**



**CANDIDATE SOLUTION FOR THE JWST “PUZZLE”**

Breysse et al. (2017)  
MNRAS 467, 3

Libanore et al. (2022)  
Phys. Rev. D 106, 12

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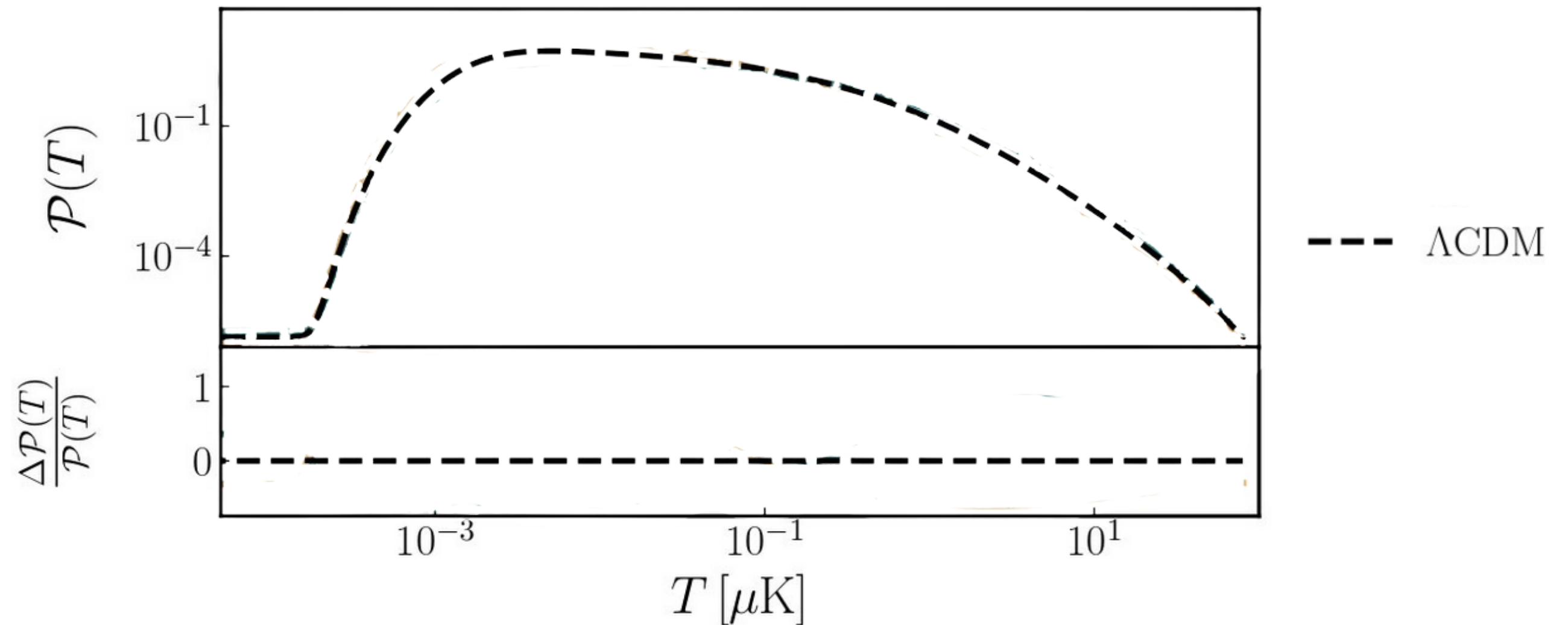
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Histogram of the intensity within voxels



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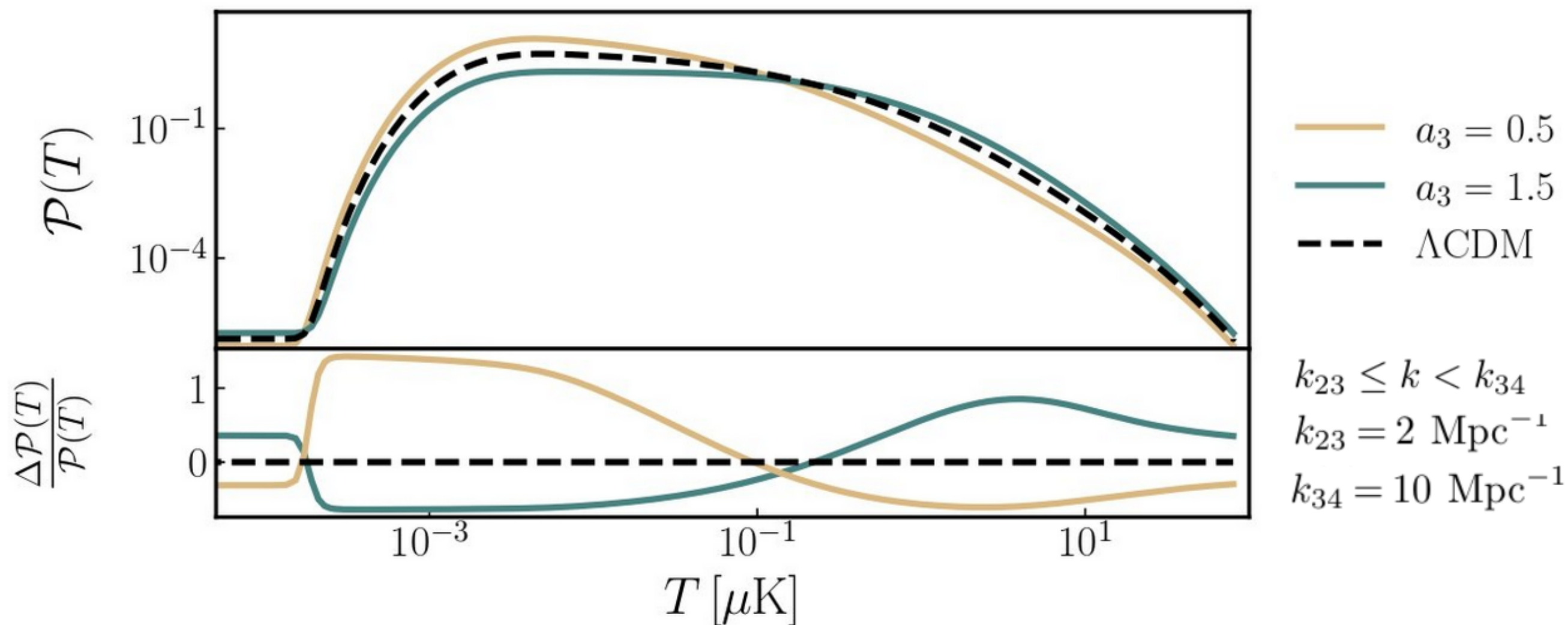
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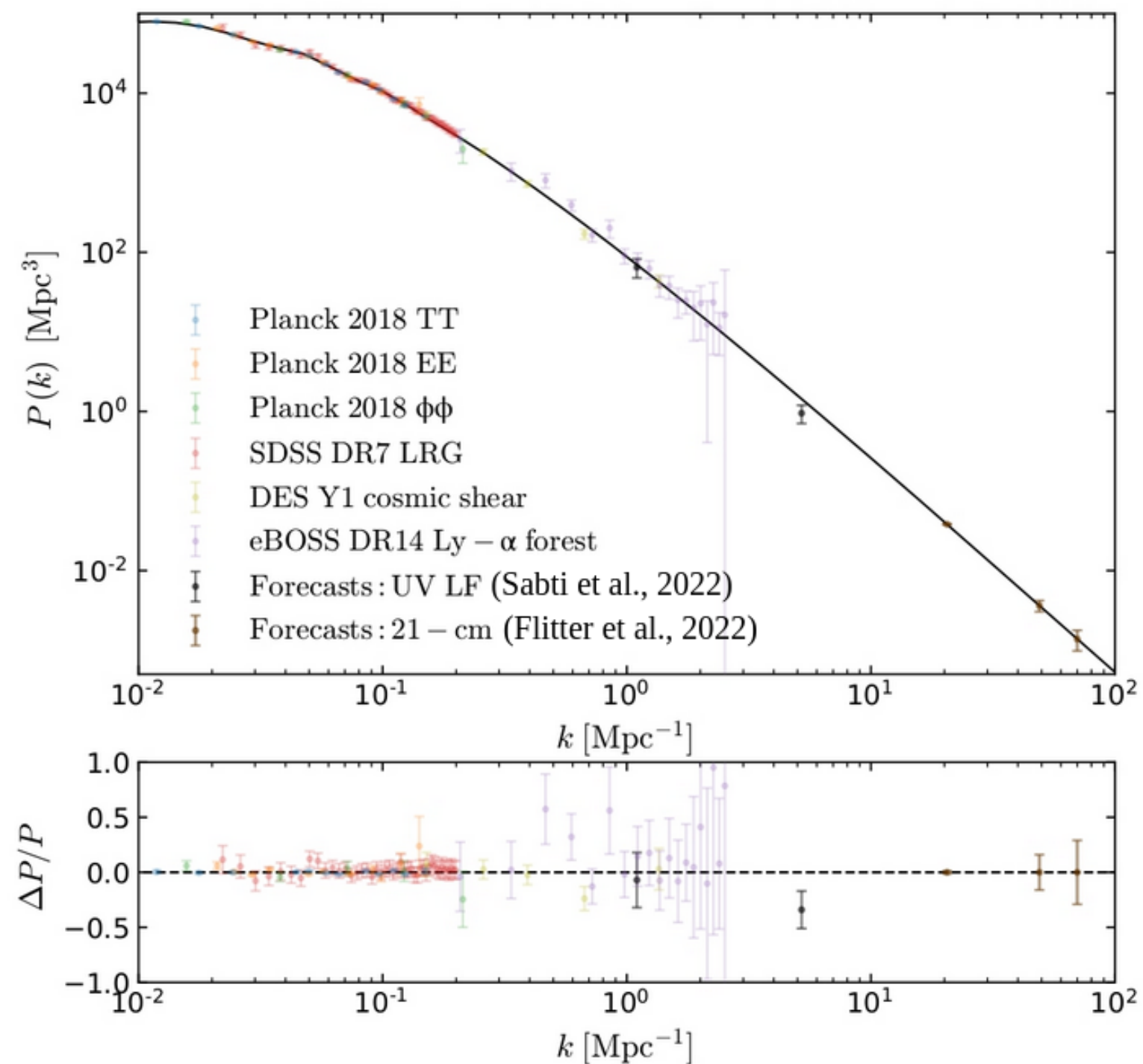
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Libanore et al. (2022)  
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Detectability of  
small scale variations  
in the matter power spectrum  
with COMAP-EoR and Stage 3





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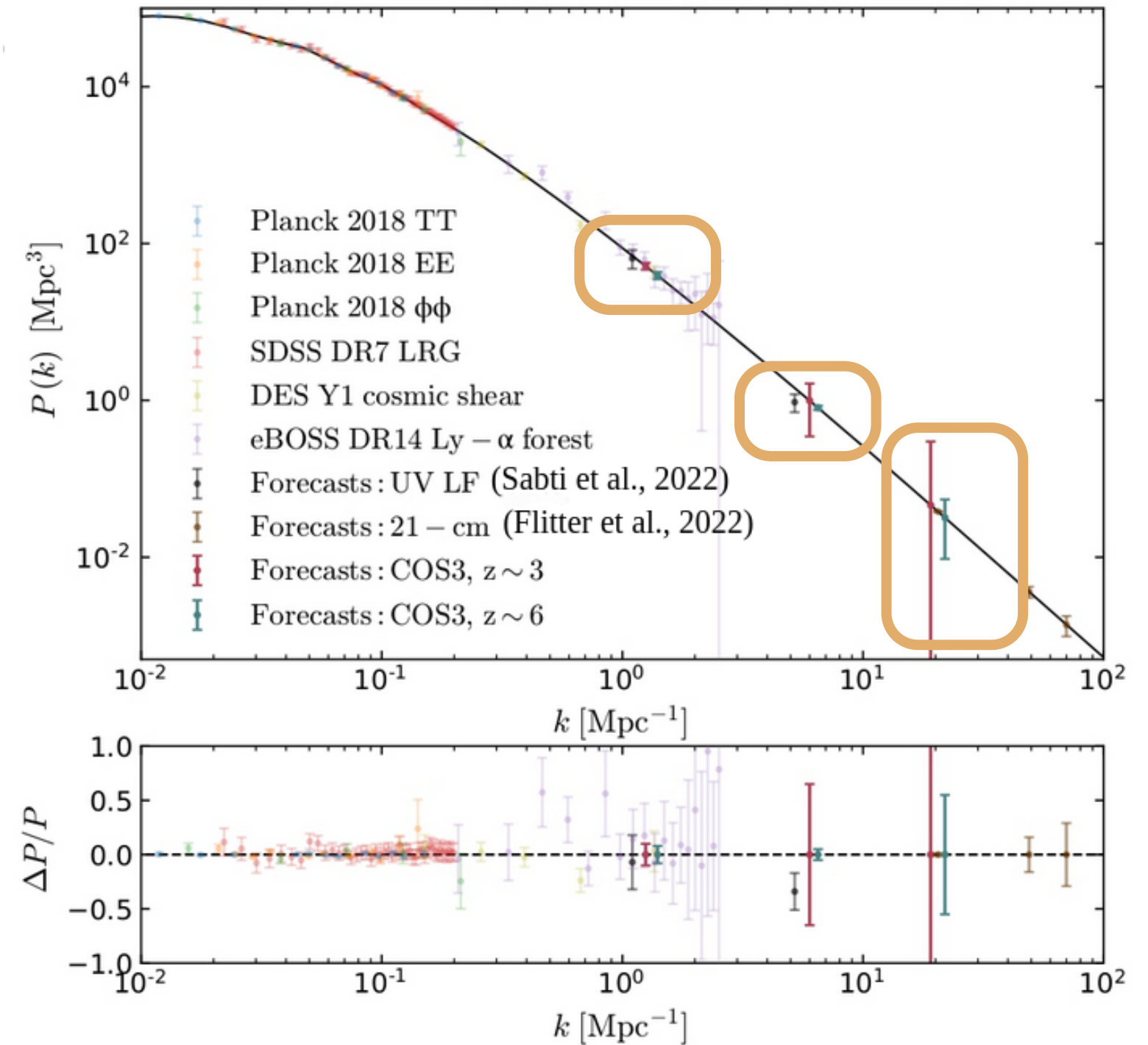
**VOXEL INTENSITY  
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**JWST PUZZLING  
OBSERVATIONS**

**Problems in our astrophysical or cosmological models?**

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**LIM IS A  
COMPLEMENTARY  
TRACER**

Different lines can be used to access physics  
from the high redshift and the small scales

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CASE STUDY #1:  
SFR TEST  
WITH 21-CM

Test the Feedback Free Starburst model  
with 21-cm power spectrum of Full-HERA



## INTRODUCTION: THE “PUZZLE”

## A QUICK “RECIPE”

## LINE INTENSITY MAPPING

## ASTROPHYSICS

## SIGNATURES ON 21-CM

## COSMOLOGY

## VOXEL INTENSITY DISTRIBUTION

## TAKE HOME MESSAGES

JWST PUZZLING  
OBSERVATIONS

Problems in our astrophysical or cosmological models?

LIM IS A  
COMPLEMENTARY  
TRACER

Different lines can be used to access physics  
from the high redshift and the small scales

CASE STUDY #1:  
SFR TEST  
WITH 21-CM

Test the Feedback Free Starburst model  
with 21-cm power spectrum of Full-HERA


CASE STUDY #2:  
COSMOLOGY TEST  
WITH VID

Test the matter power spectrum on small scales  
with VID of COMAP-EoR and Stage 3 surveys



# CHECK OUT OUR WORK!



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🔍 LIBANORE, FLITTER, KOVETZ, LI, DEKEL (2023)  
[arXiv:2310.03021]

🔍 LIBANORE, UNAL, SARKAR, KOVETZ (2022)  
PRD 106, 12, 123512 [arXiv:2208.01658]

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