



Pablo Picasso — The Blue Room (1901)



Infrared Study Reveals Hidden Man in Picasso Painting (~2014)



Precision Tests of CO and [CII] Power Spectra Models against Simulated Intensity Maps

Farnik Nikakhtar (UPenn)

In collaboration with: Azadeh Moradinezhad (Geneva), Karto Keating (Harvard), Emanuele Castorina (Milan)

arXiv: 2111.03717

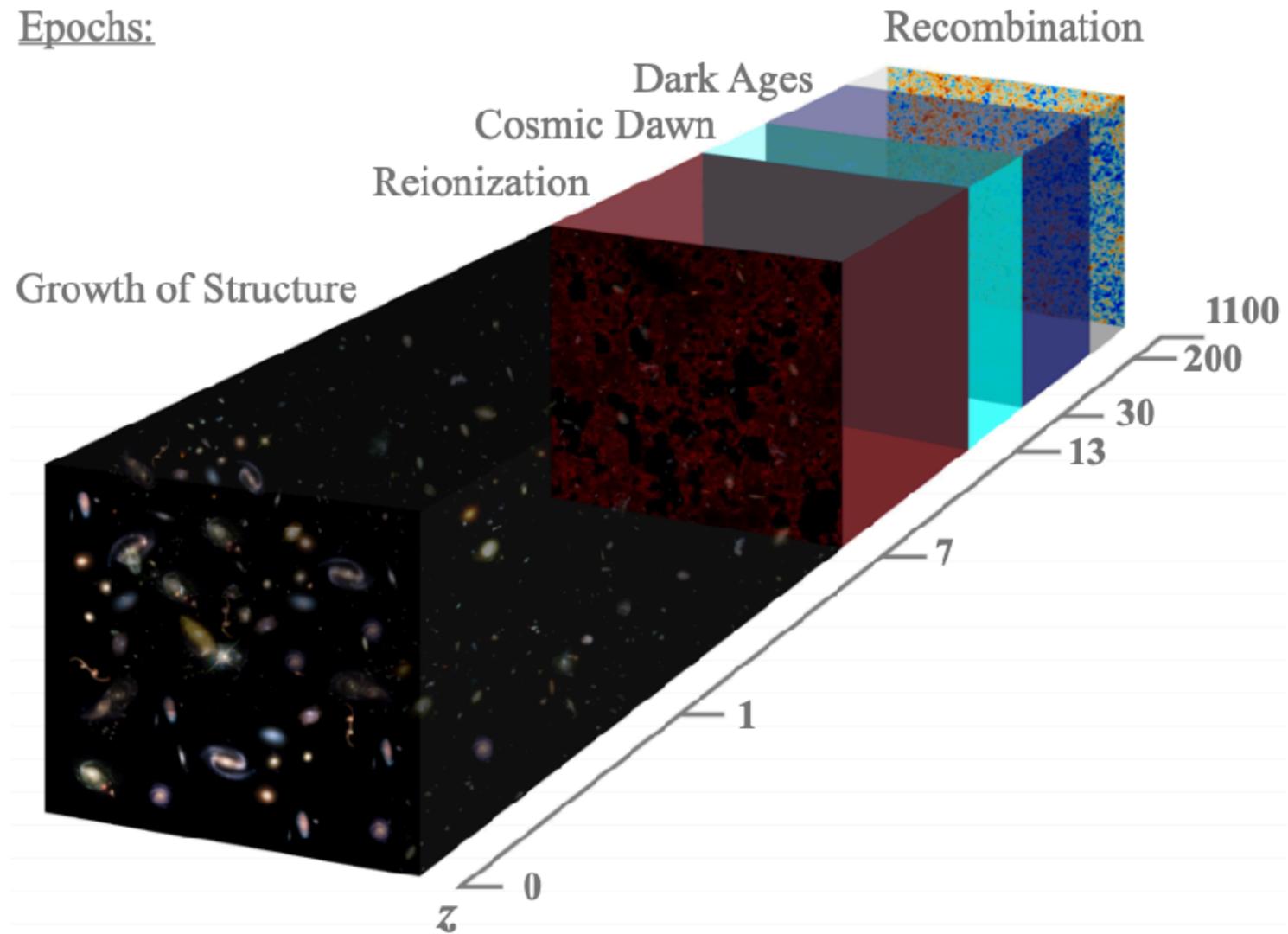
BCCP Cosmology Seminar, November 2021

Outline

- Line Intensity Mapping
- Theoretical Modeling
- Comparison with Simulations
- Summary & Conclusion

Line Intensity Mapping

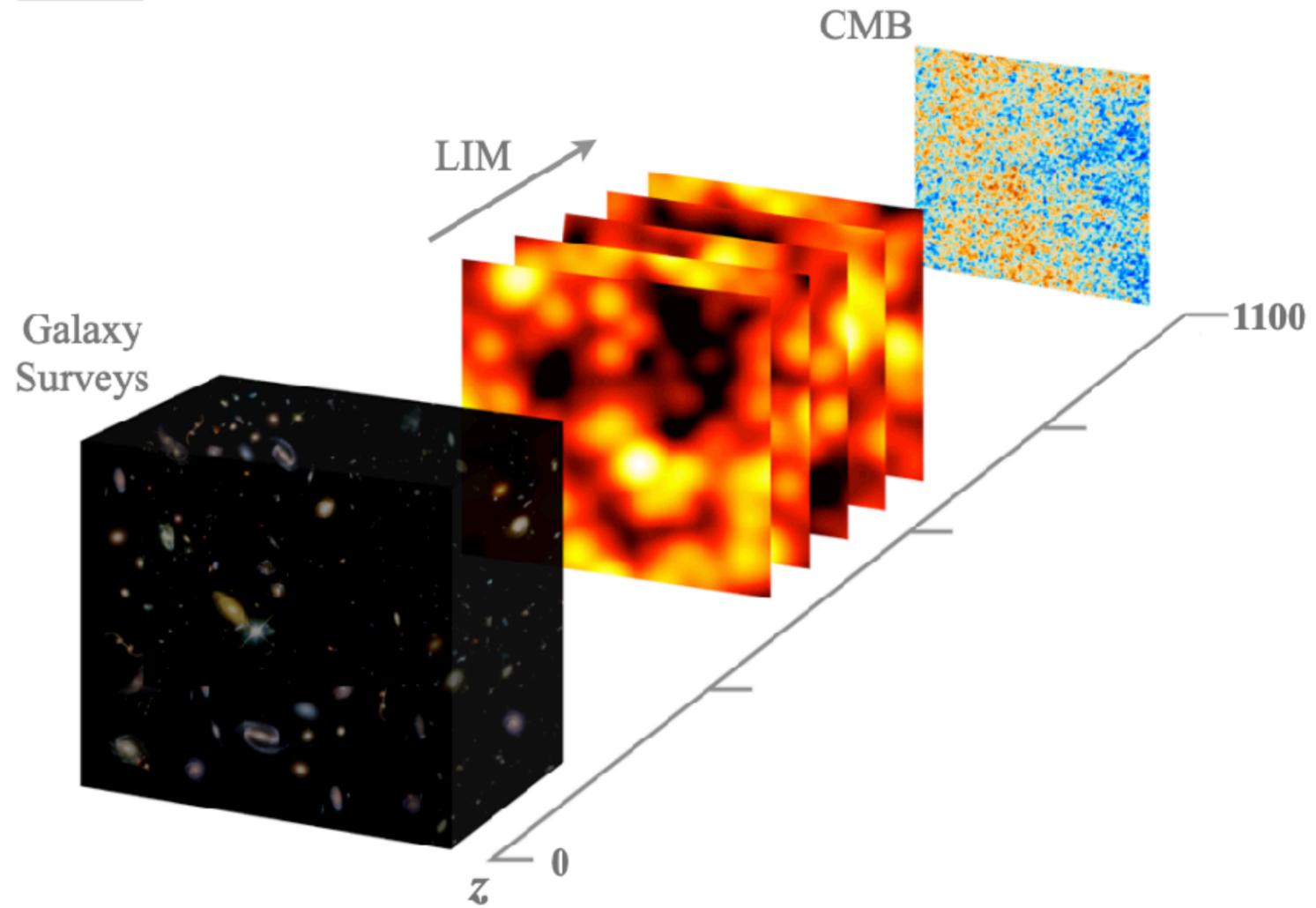
High Redshifts & Ultra Large-Scales



Line Intensity Mapping

High Redshifts & Ultra Large-Scales

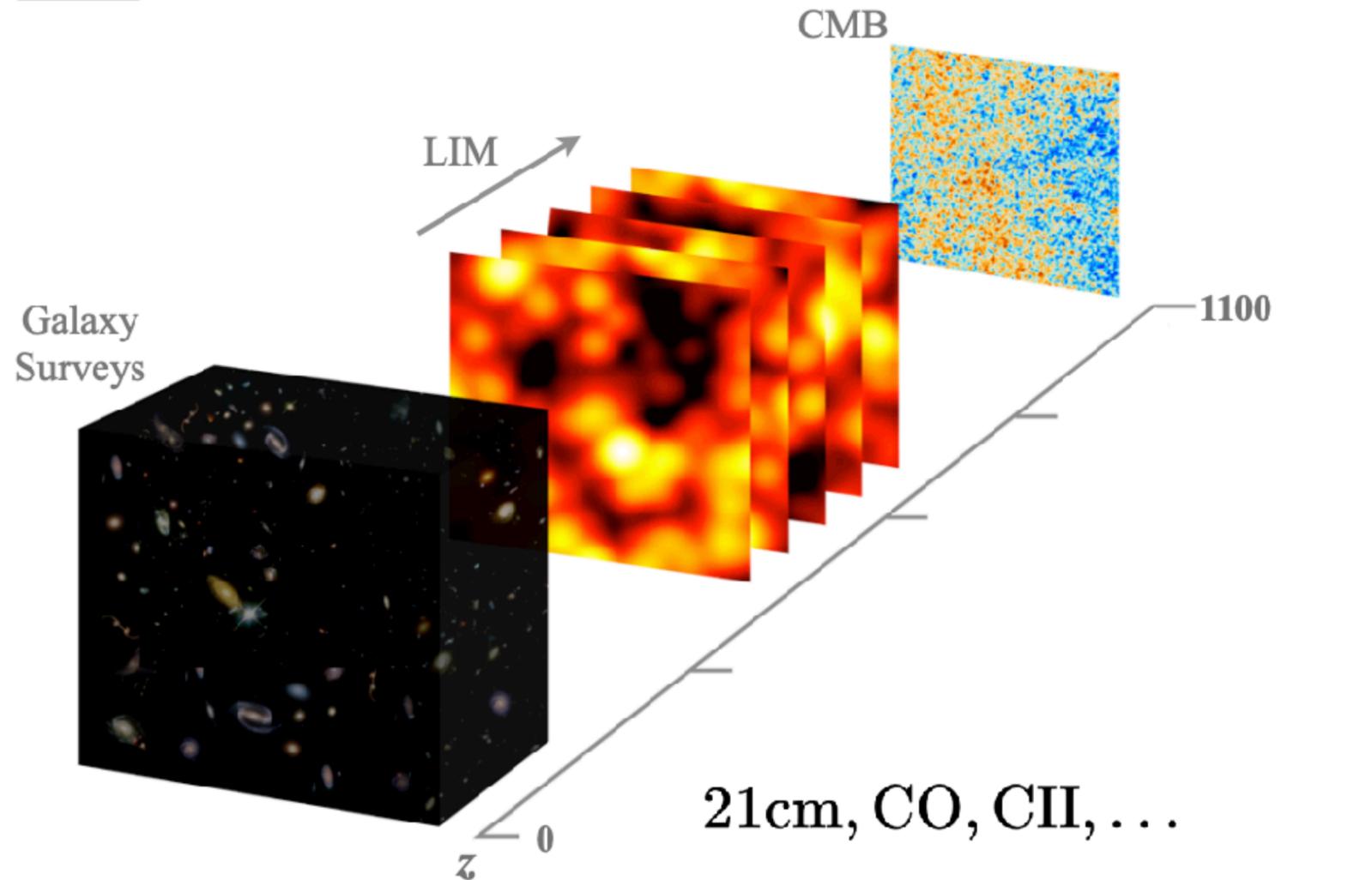
Probes:



Line Intensity Mapping

High Redshifts & Ultra Large-Scales

Probes:



Kovetz et al. 2019

$$\bar{\nu}_{\text{CO}} \simeq 115\text{GHz} \quad \text{CO}(J \rightarrow J - 1)$$

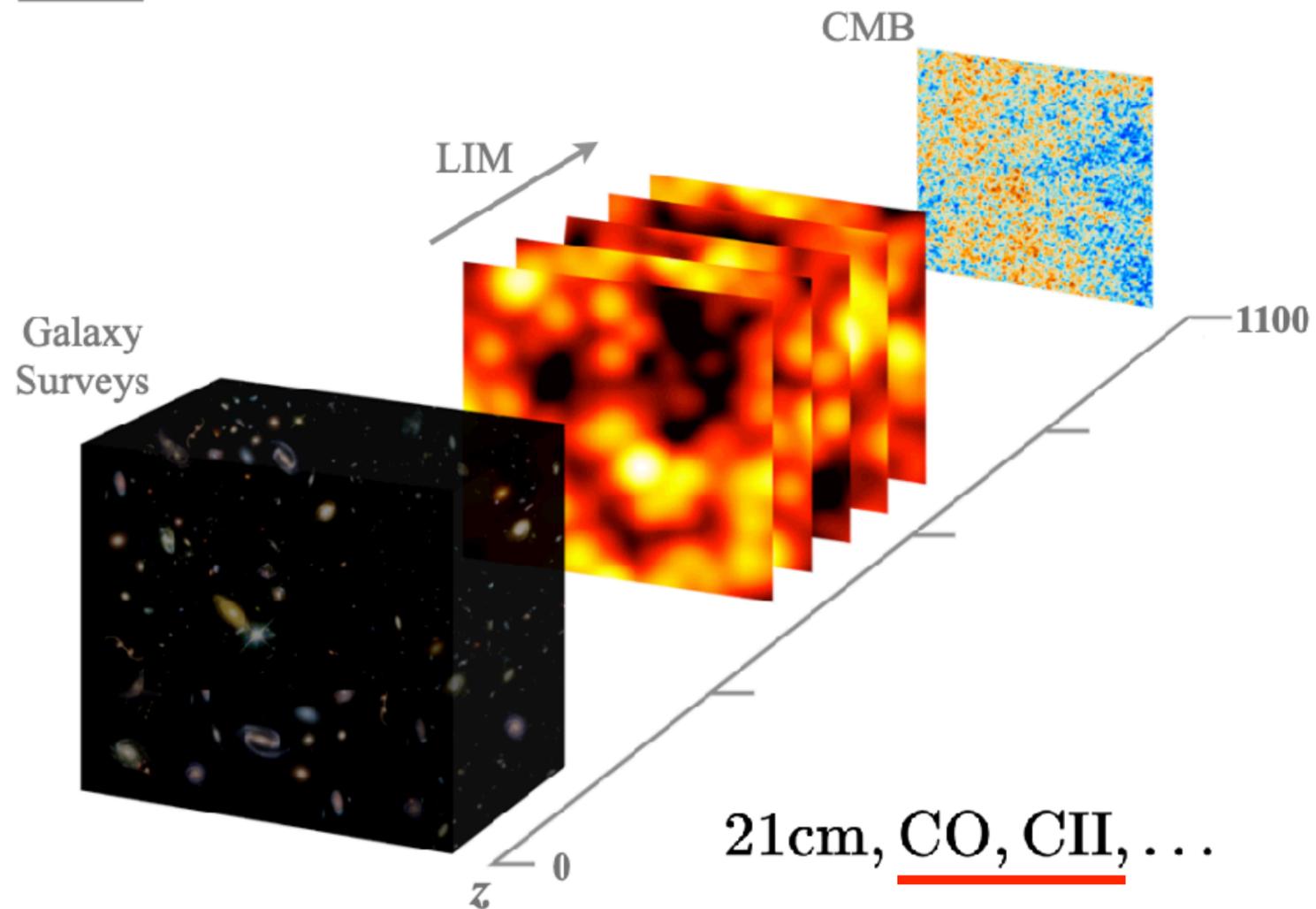
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$$\bar{\nu}_{21\text{cm}} \simeq 1420\text{MHz}$$

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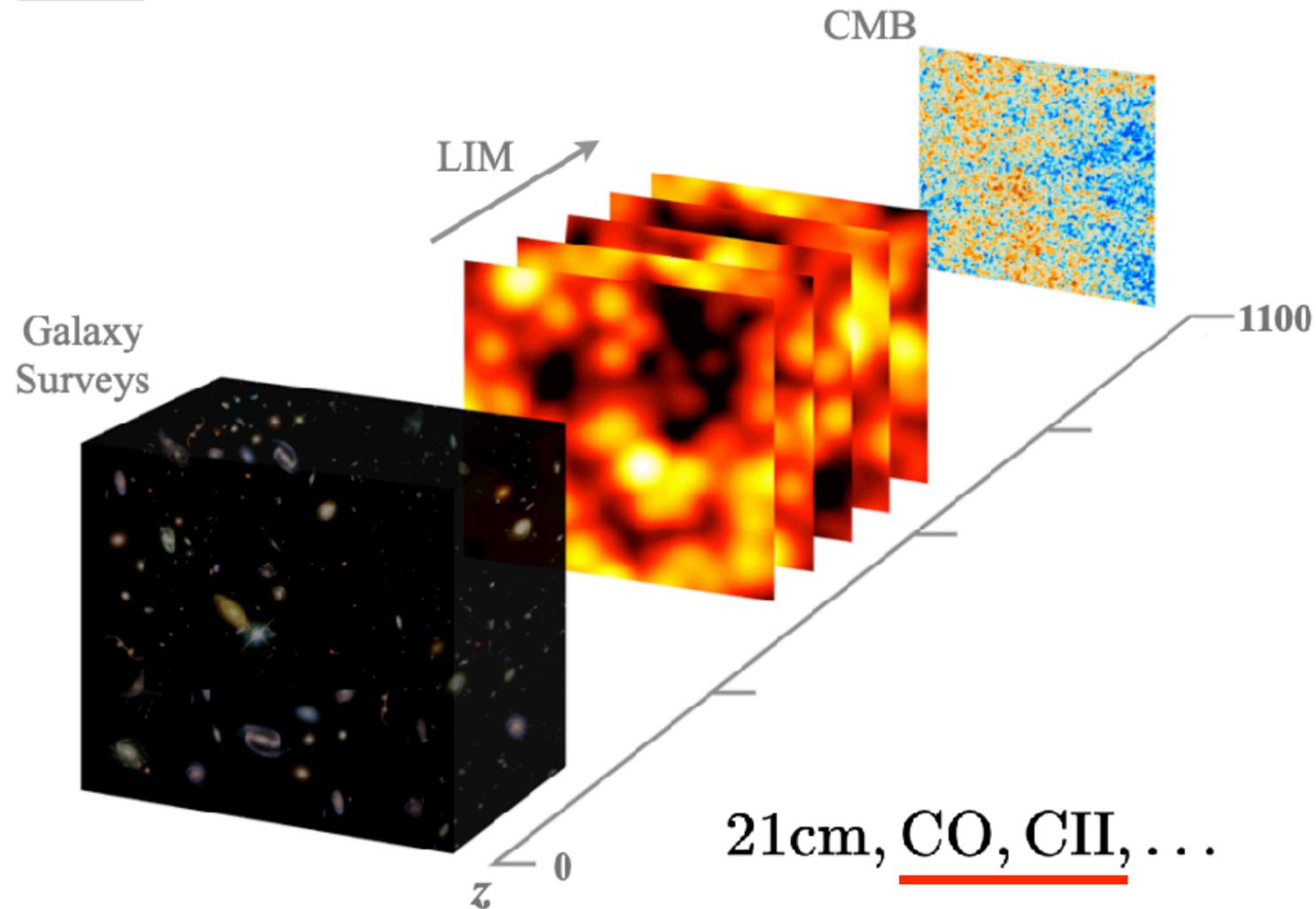
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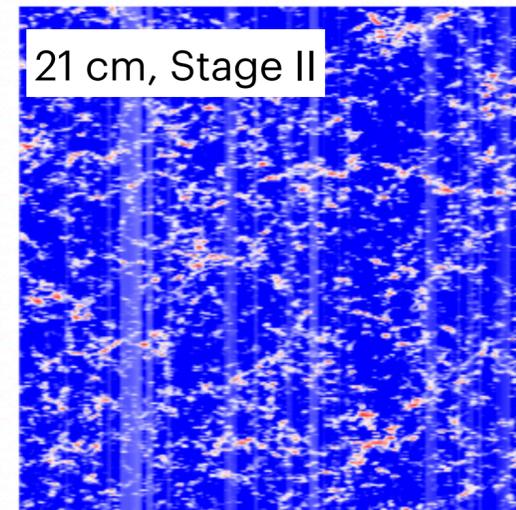
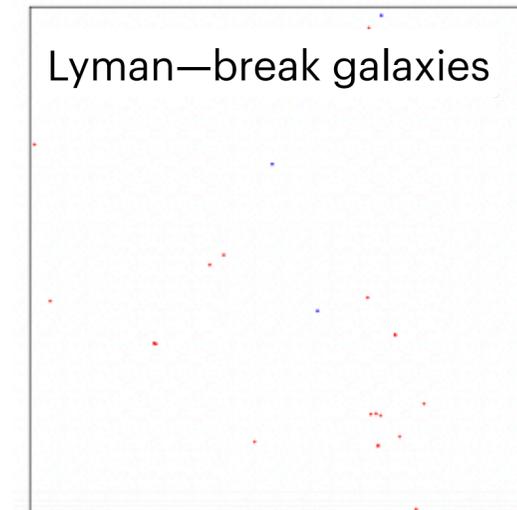
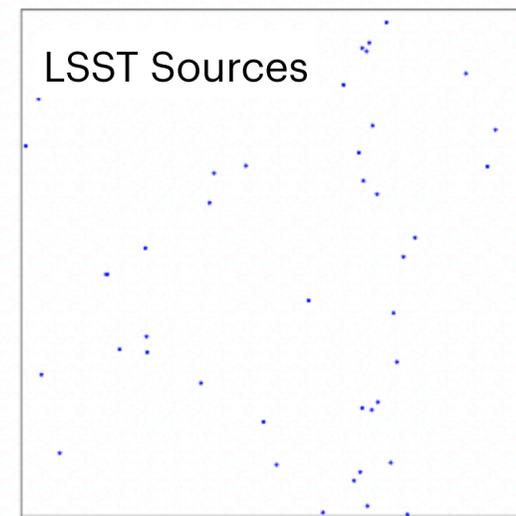
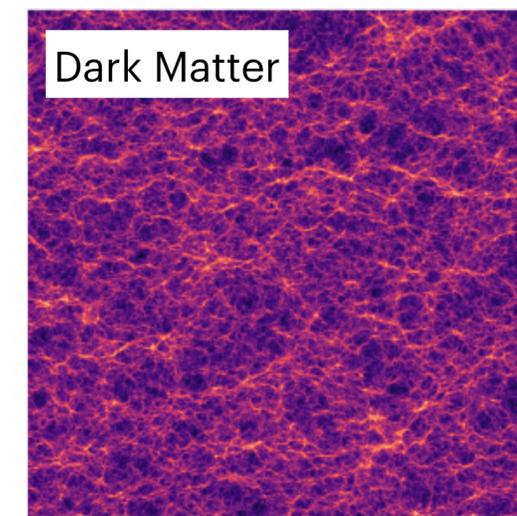
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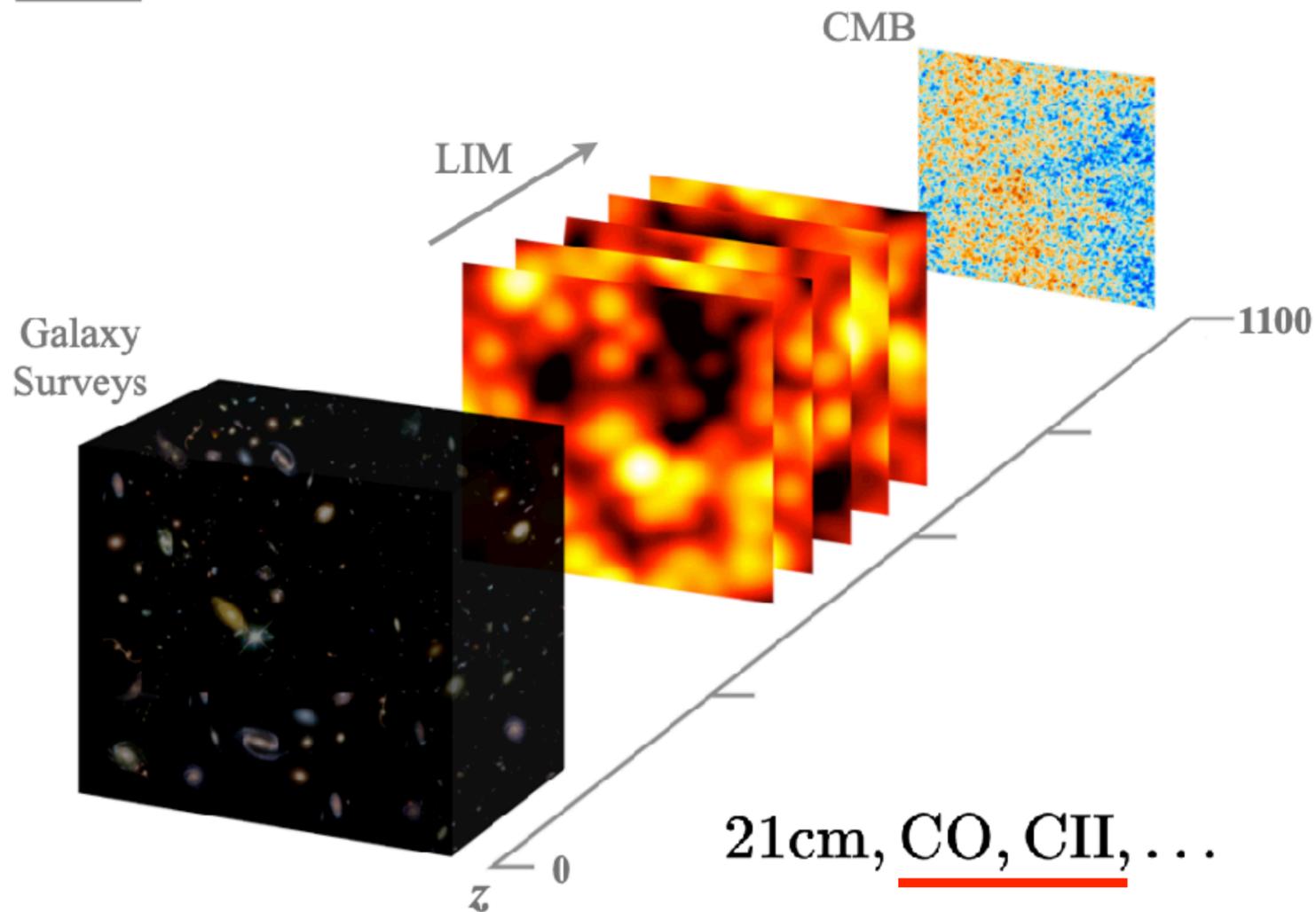
$z = 5$



Line Intensity Mapping

High Redshifts & Ultra Large-Scales

Probes:



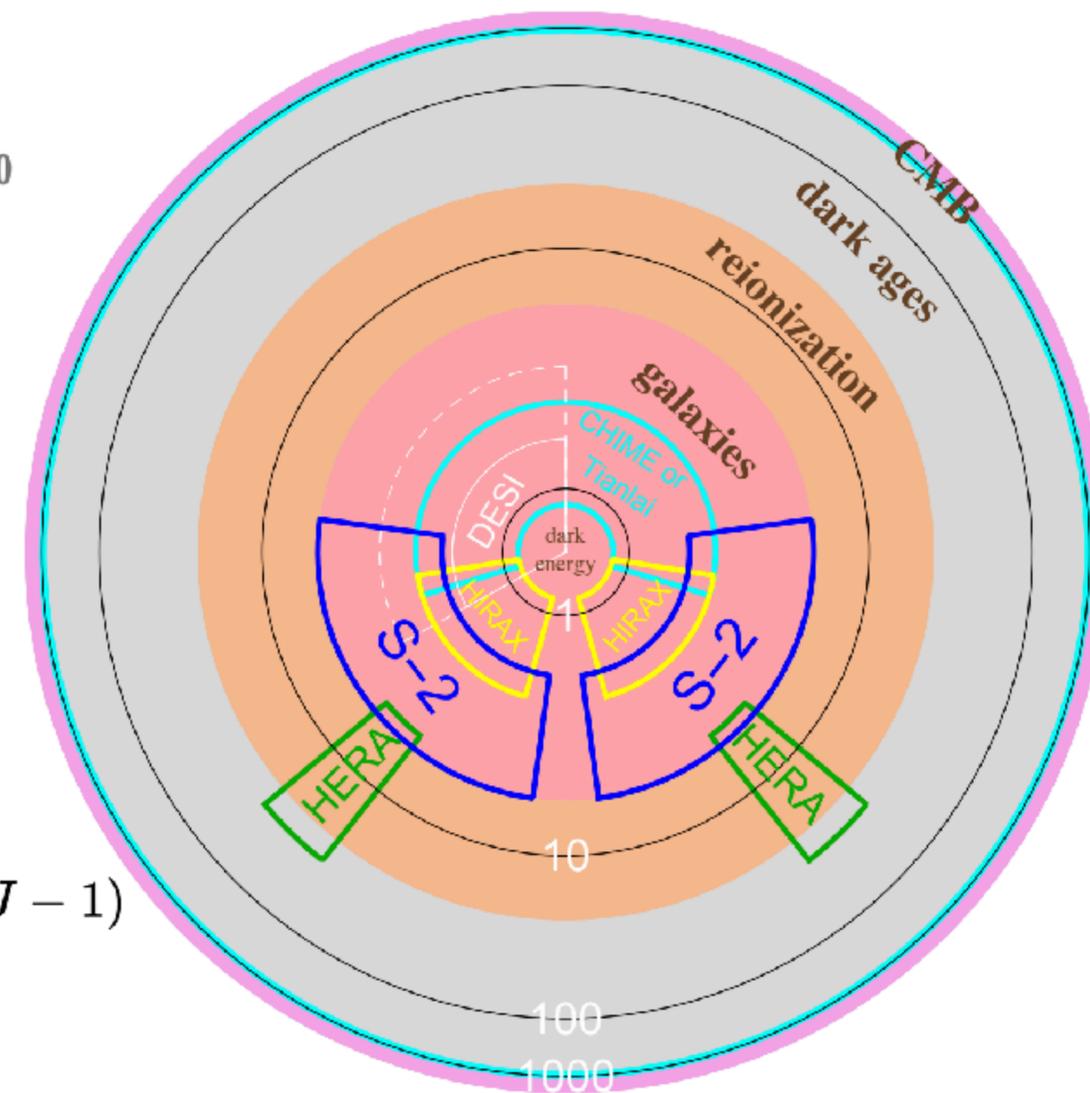
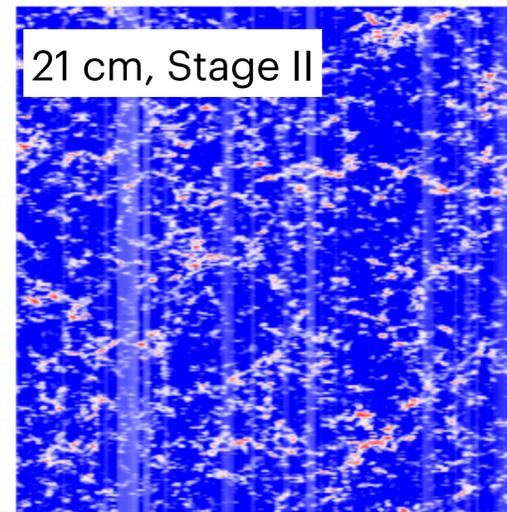
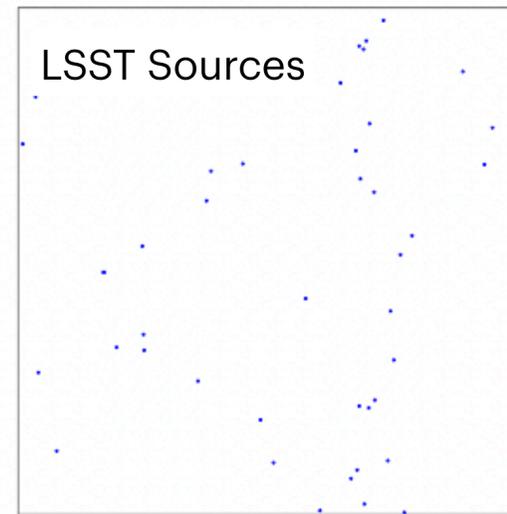
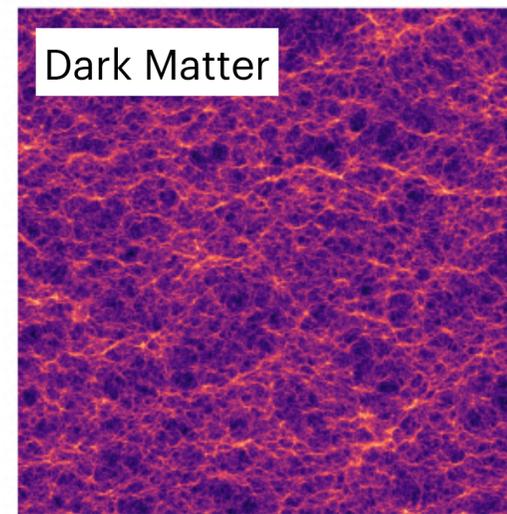
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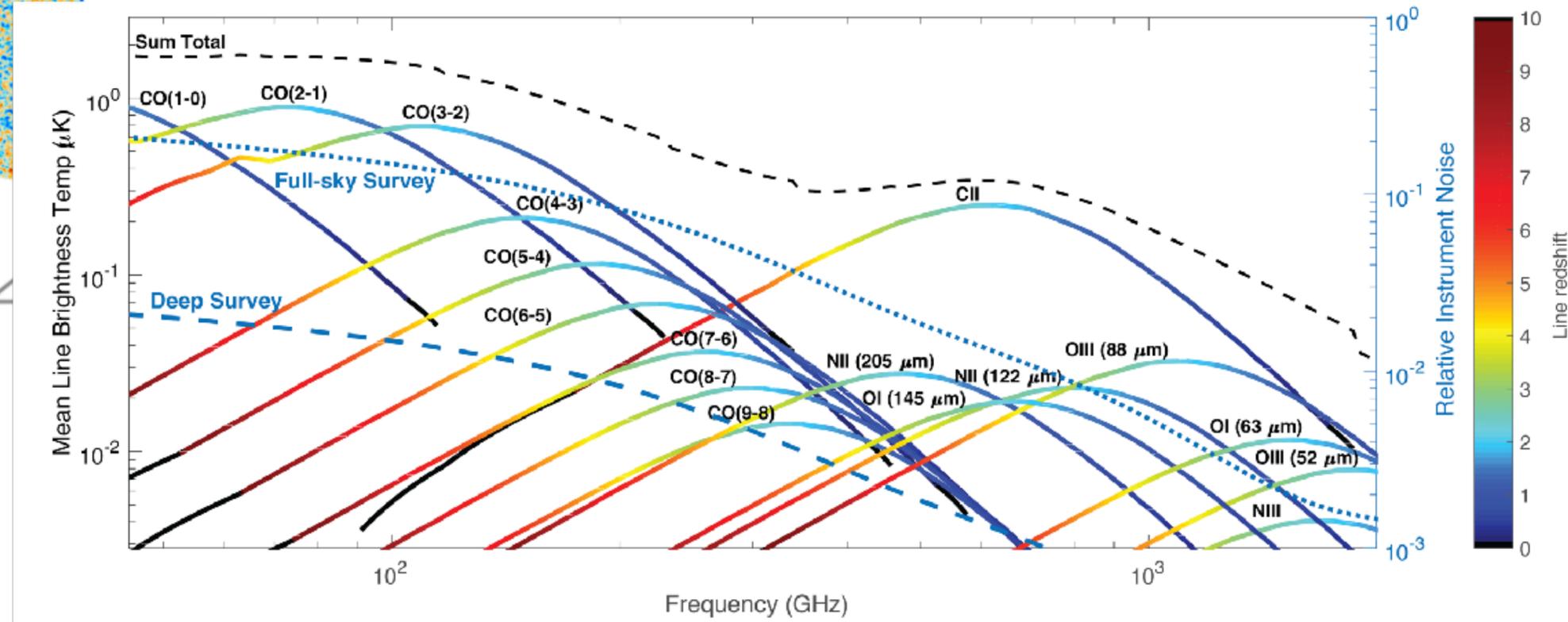
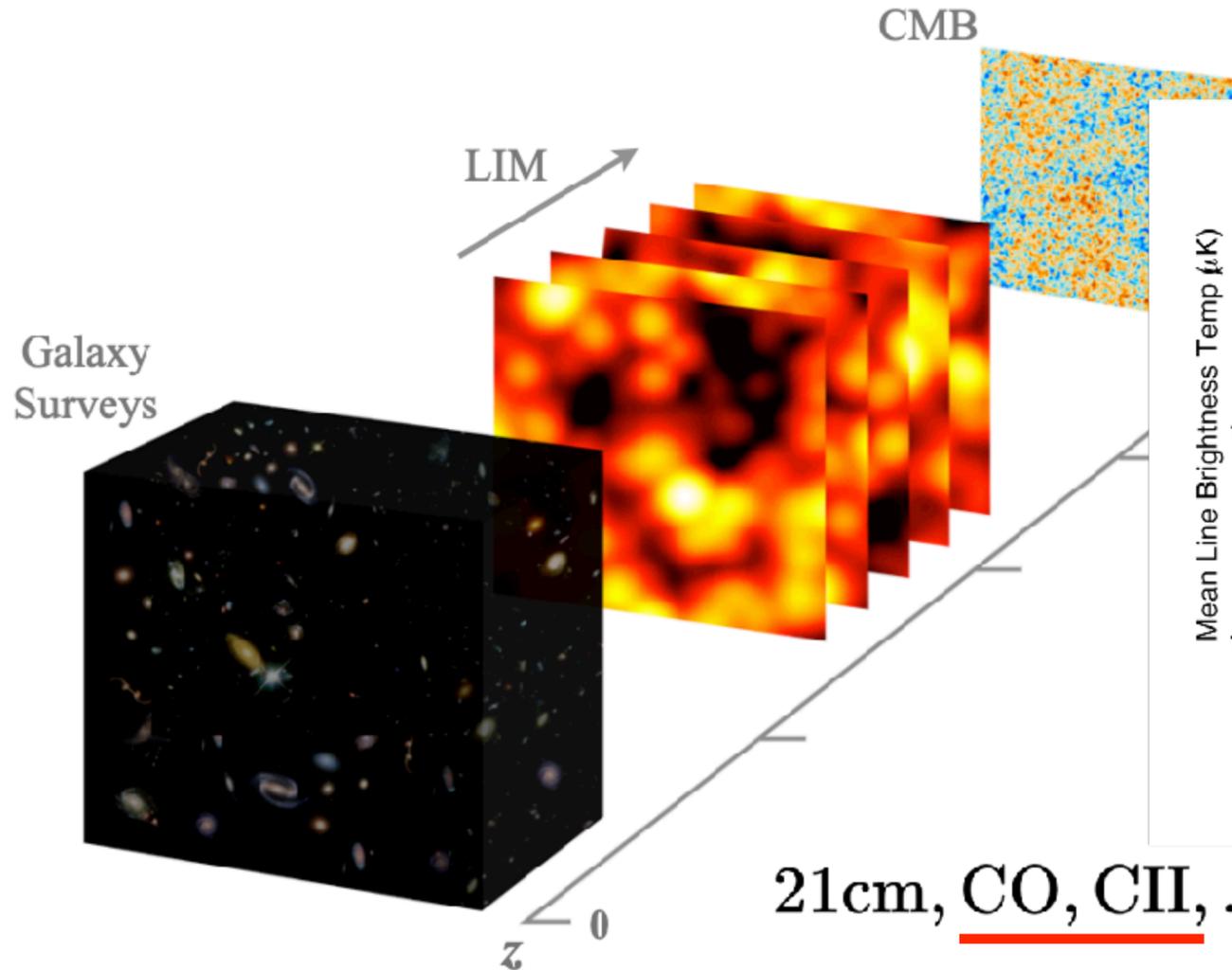
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Line Intensity Mapping

High Redshifts & Ultra Large-Scales

Probes:



21cm, CO, CII, ...

ESA Voyage-2050 White Paper; Silva et al. 2019

Kovetz et al. 2019

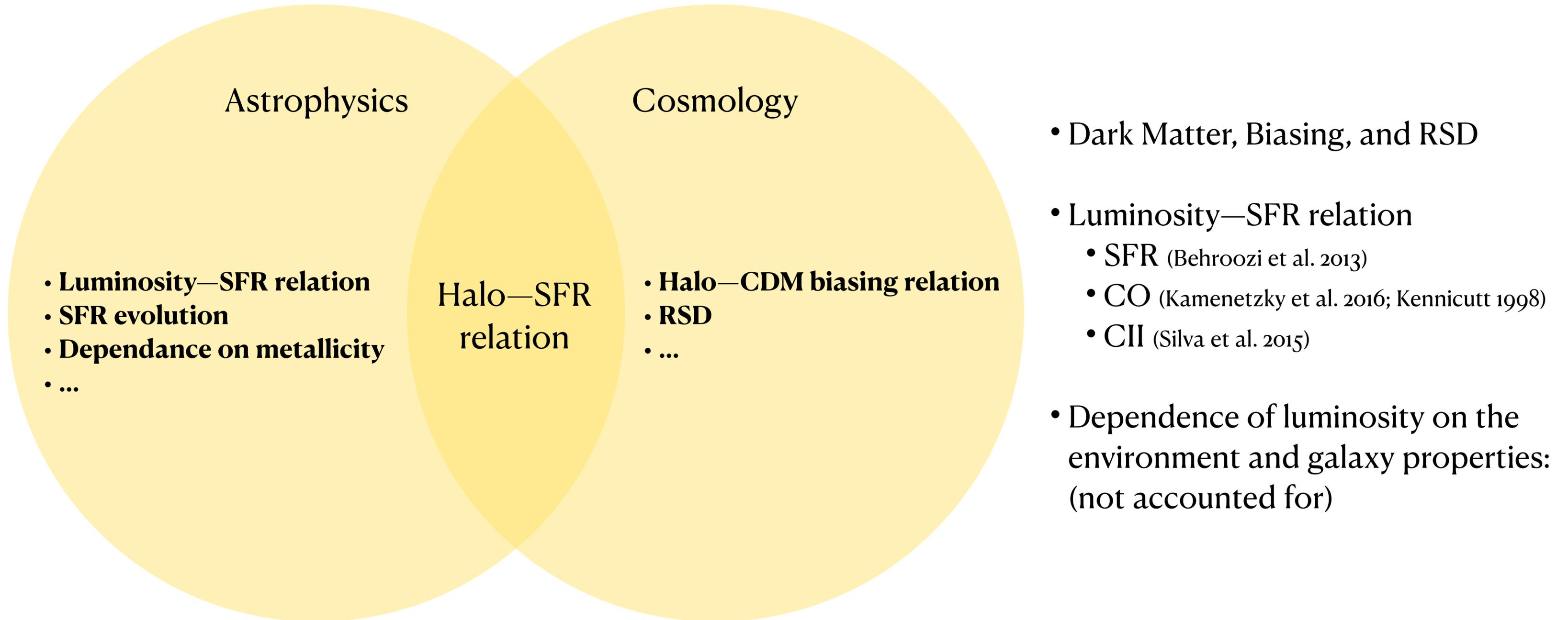
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Theoretical Modeling

Nonlinear Matter and Biasing in Real-Space



Halo Model of Line Power Spectrum

- Observed Power Spectrum

$$P_{\text{line}}^{\text{tot}}(k, z) = P_{\text{clust}}(k, z) + P_{\text{shot}}(k, z) + P_N(k, z)$$

$$P_{\text{line}}^{\text{tot}}(k, z) = \left[P_{\text{line}}^{1h}(k, z) - \lim_{k \rightarrow 0} P_{\text{line}}^{1h}(k, z) \right] + P_{\text{line}}^{2h}(k, z) + P_{\epsilon\epsilon}^{\text{line}}(k, z) + P_N(k, z)$$

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Effective Field Theory of LSS + Halo Model

Eulerian renormalized biased expansion

$$\begin{aligned}\delta_h^G(\mathbf{x}) = & b_1 \delta(\mathbf{x}) + b_{\nabla^2 \delta} \nabla^2 \delta(\mathbf{x}) + \frac{b_2}{2} \delta^2(\mathbf{x}) + b_{\mathcal{G}_2} \mathcal{G}_2(\mathbf{x}) \\ & + \frac{b_3}{6} \delta^3(\mathbf{x}) + b_{\mathcal{G}_3} \mathcal{G}_3(\mathbf{x}) + b_{(\mathcal{G}_2 \delta)} \mathcal{G}_2(\mathbf{x}) \delta(\mathbf{x}) + b_{\Gamma_3} \Gamma_3(\mathbf{x})\end{aligned}$$

(Desjacques, Jeong, Schmidt 2016) Large-Scale Galaxy Bias review

- **EFT counter-term: Impact of small-scale stress-tensor on large-scale fluctuations** (e.g. Carrasco et al. 2012)
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Stochasticity Beyond the Poisson Limit

- Deviations from Poisson shot-noise due to halo exclusion and nonlinear clustering

Hamaus et al (2011), Baldauf et al (2013), Guinzburg et al (2017)

$$\epsilon_{\text{line}}(k, z) = \delta_{\text{line}}(k, z) - \bar{T}_{\text{line}}(z)b_{\text{line}}(z)\delta(k, z)$$

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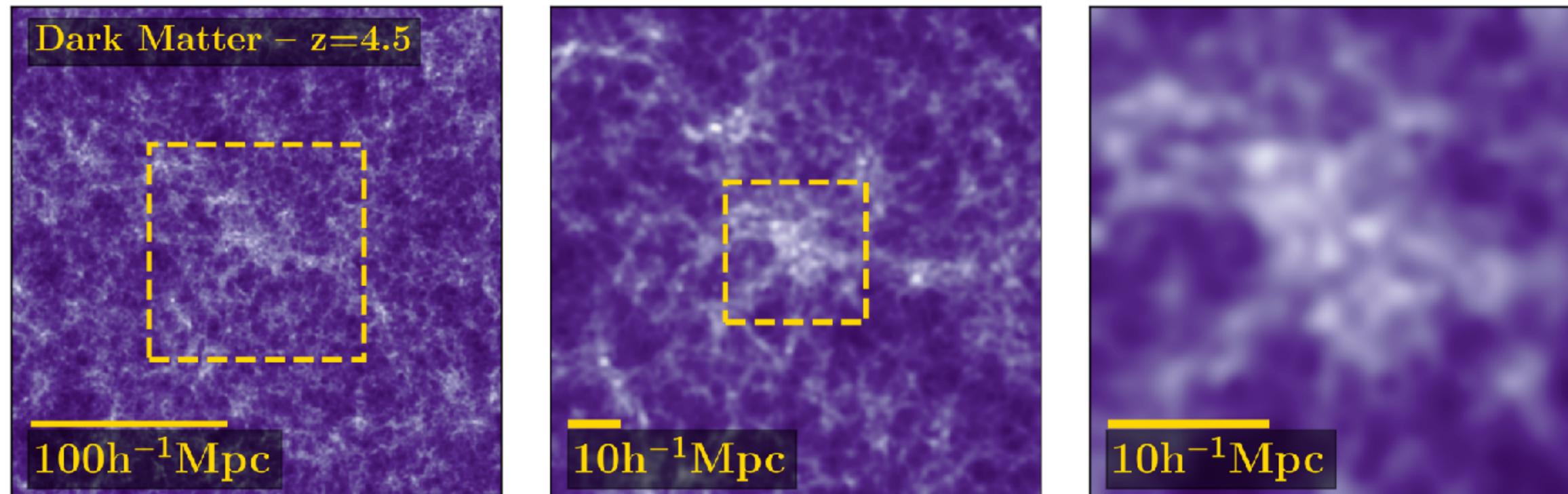
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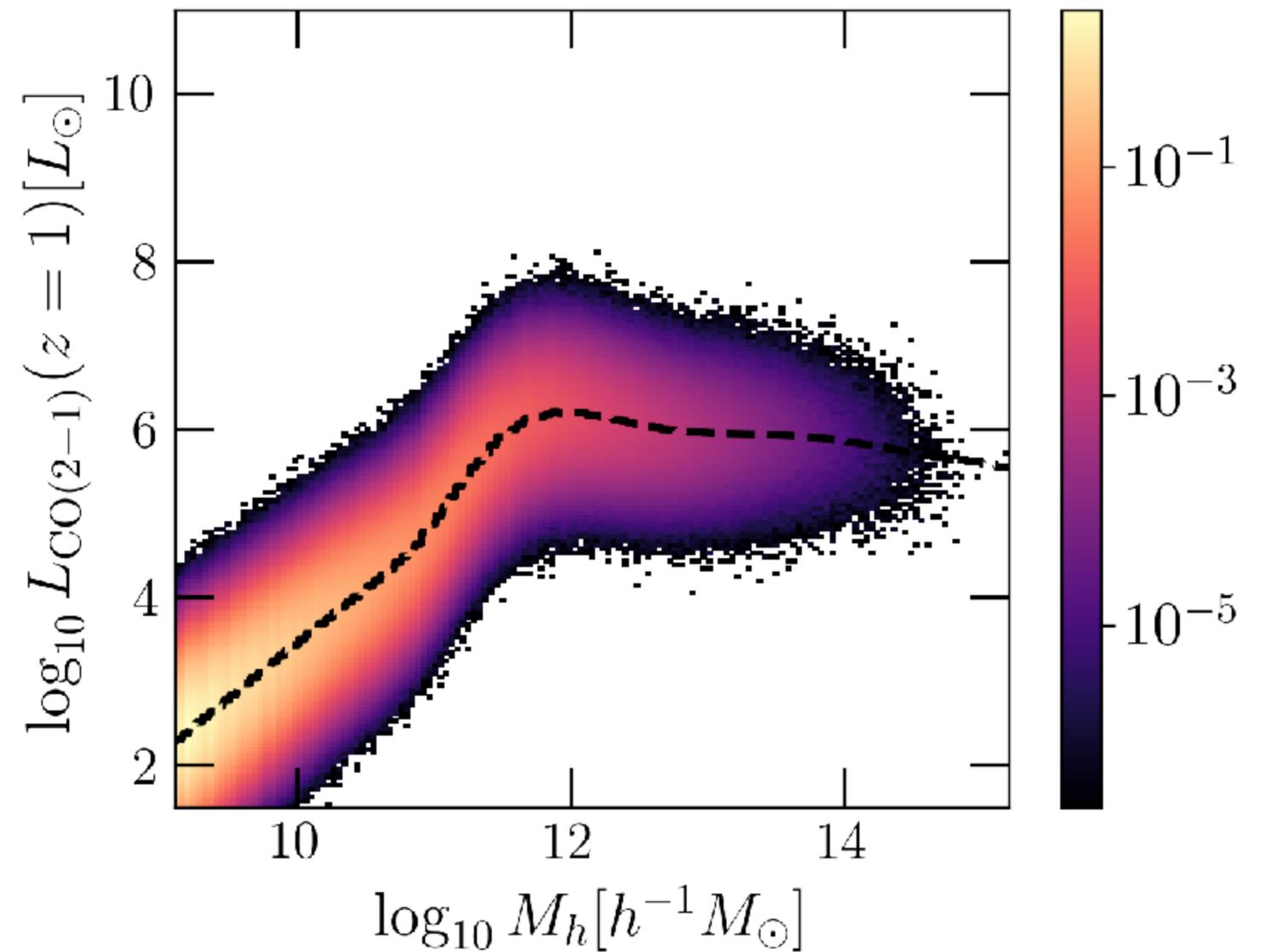
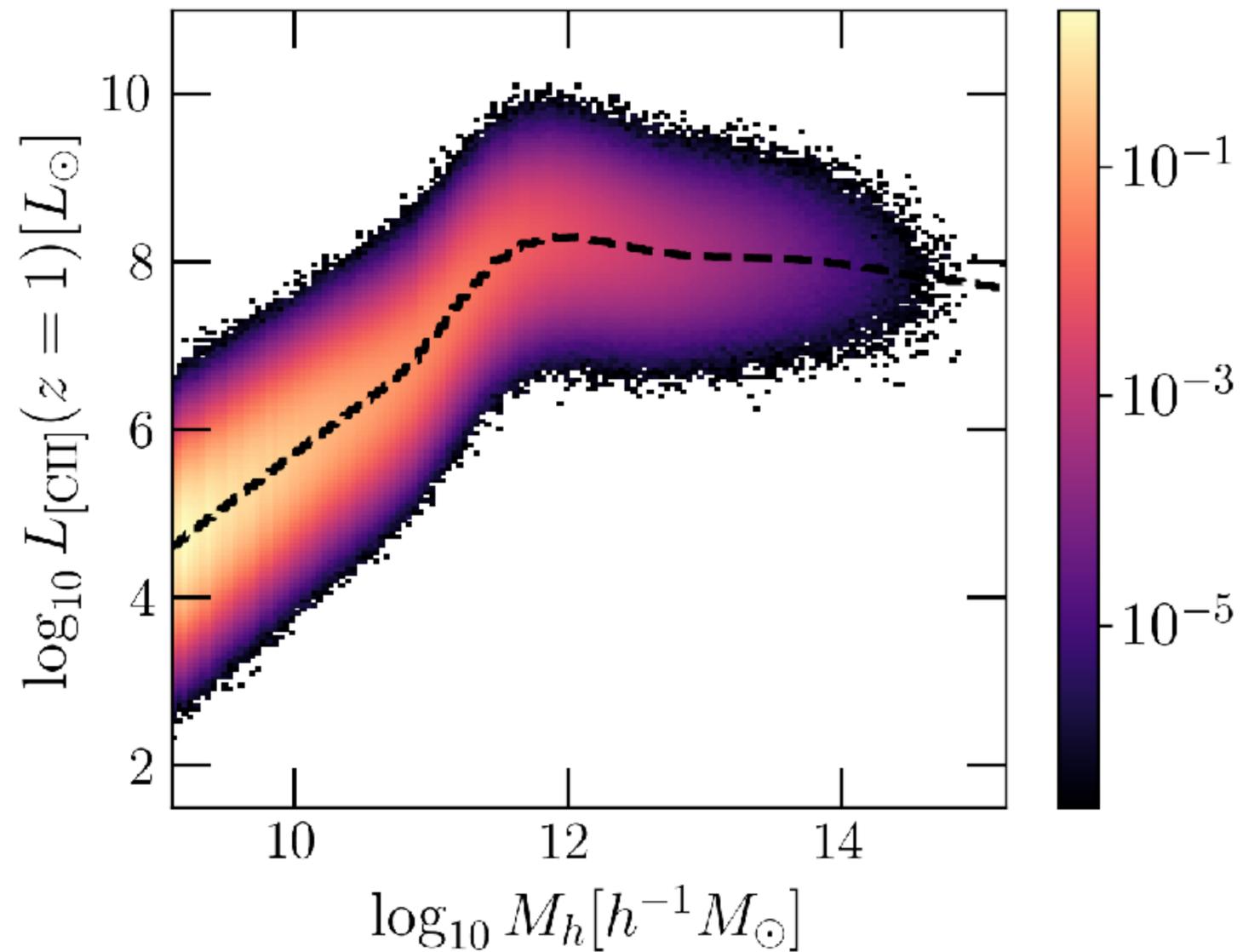
Simulation Specifications

- FastPM halo catalog from Hidden Valley simulation suites (Modi et al. 2019)
- 10240^3 particles in a box of side 1 Gpc/h
- Snapshots in redshifts [0.5 – 6]
- Mass resolution: $M_{\min} = 8.57 \times 10^7 h^{-1} M_{\odot}$

CO/CII galaxies are painted according to models of line luminosity



Mithra* Line Intensity Mapping Simulations

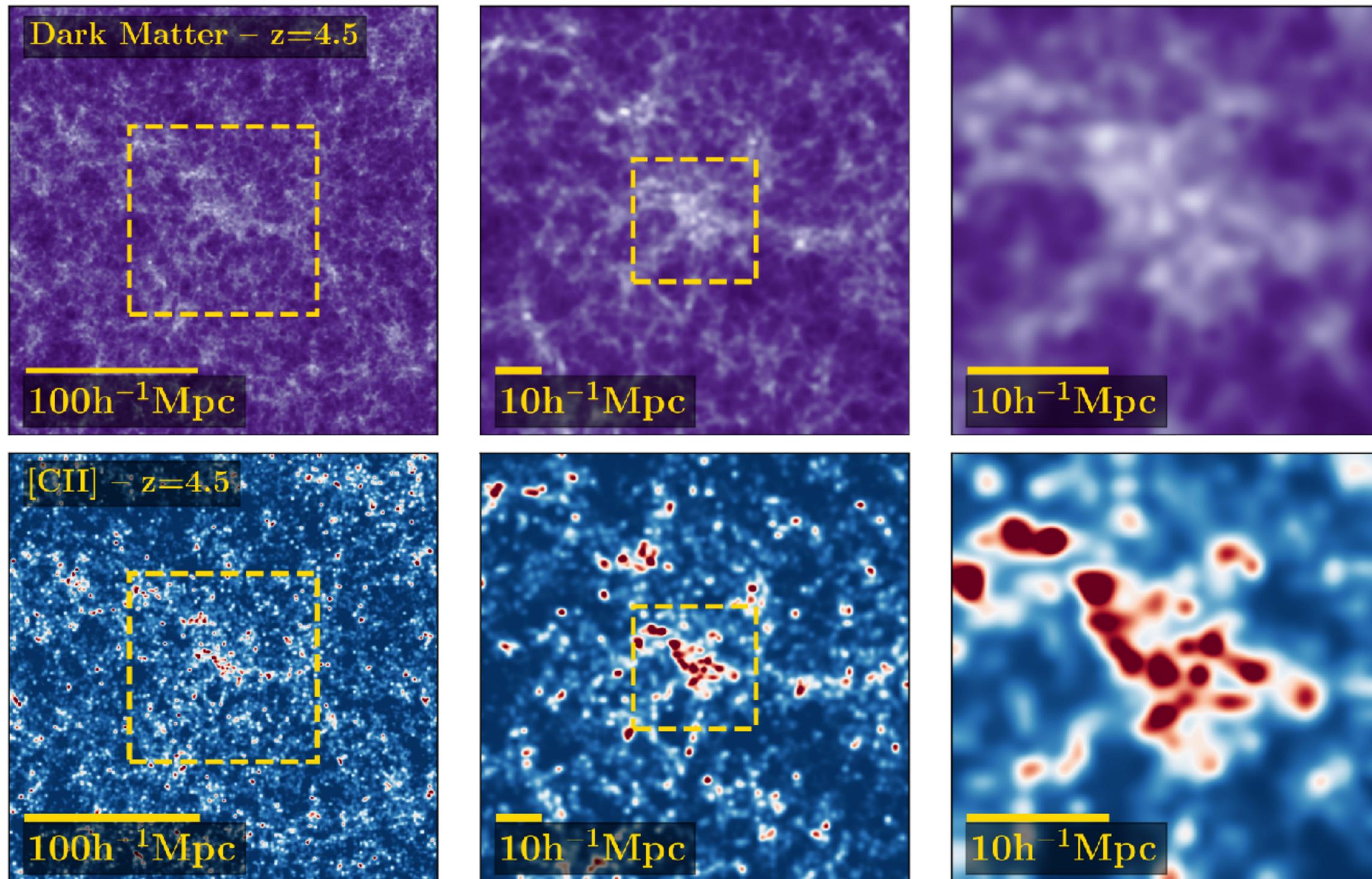


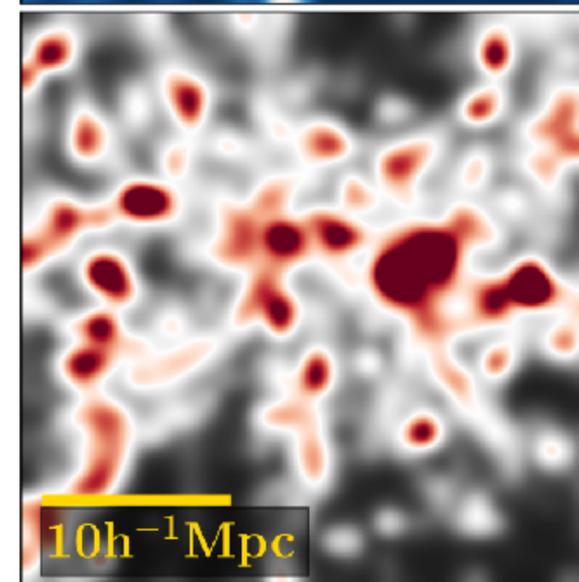
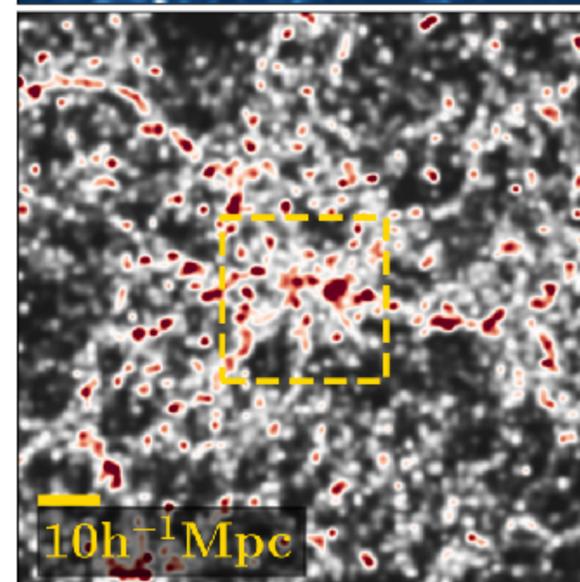
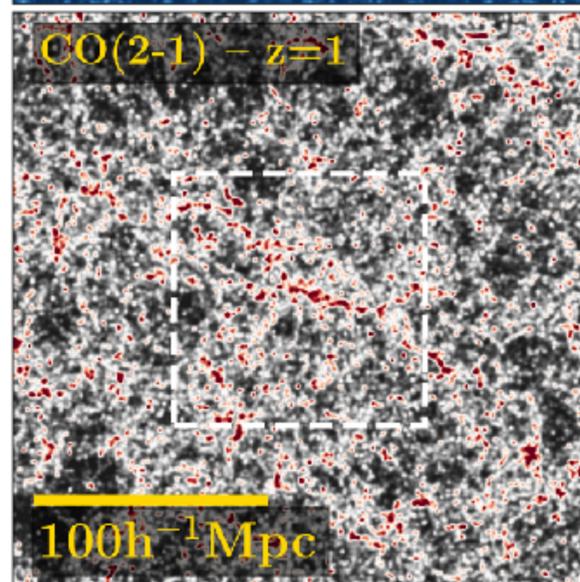
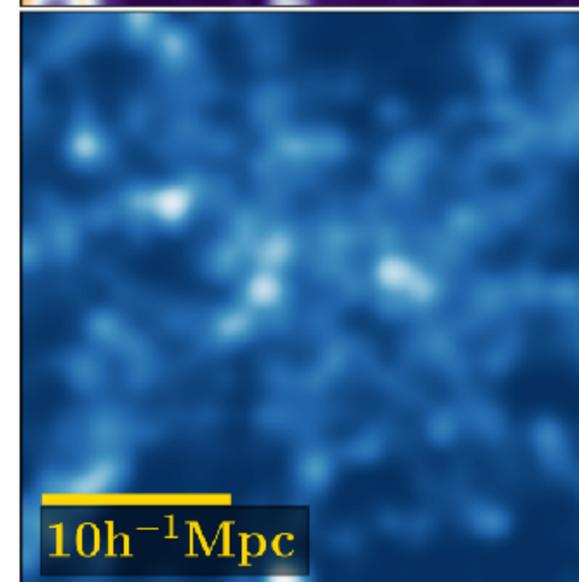
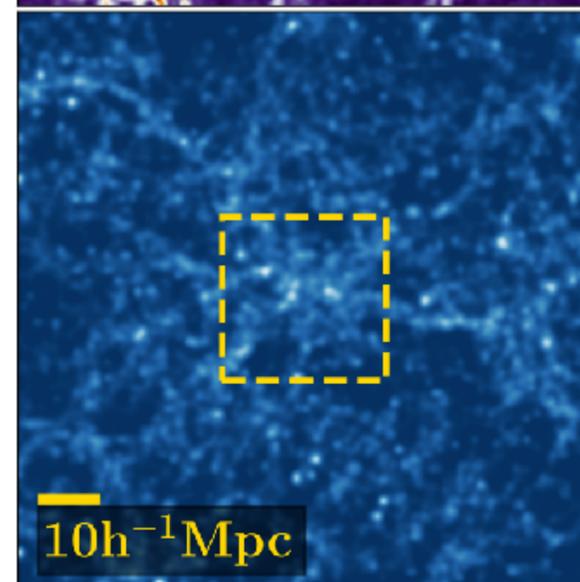
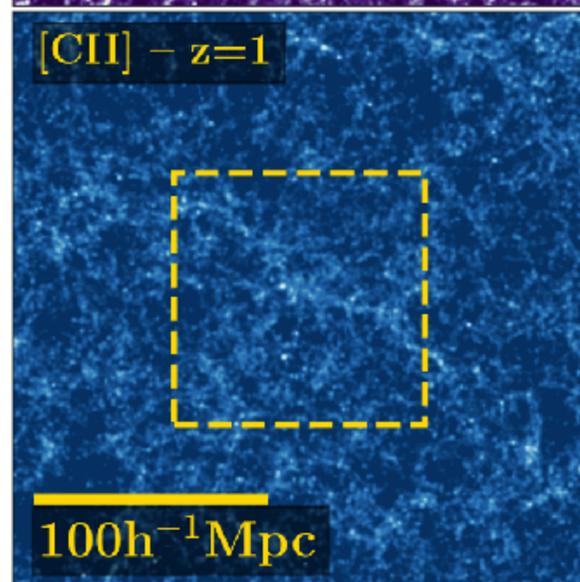
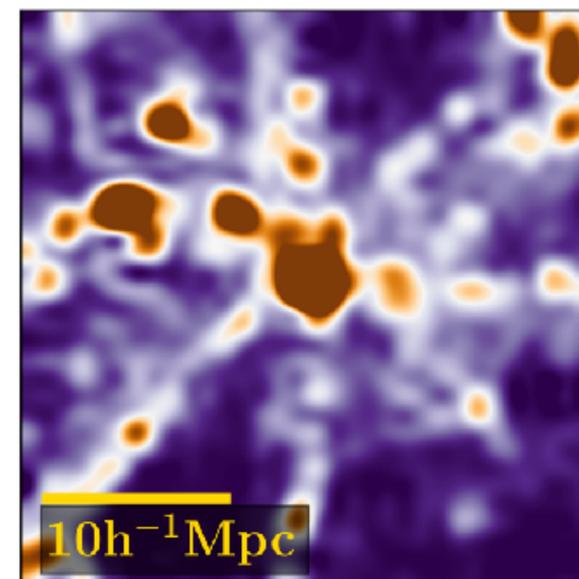
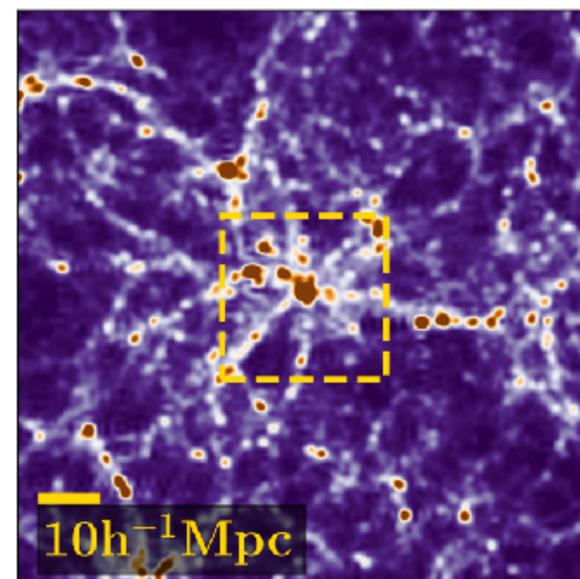
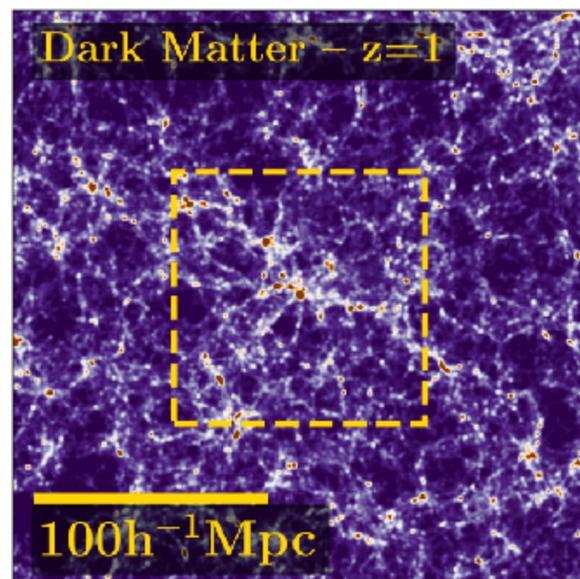
Moradinezhad, **Nikakhtar**, Keating, Castorina (arXiv: 2111.03717)

- CO (Kamenetzky et al. 2016; Kennicutt 1998)
- CII (Silva et al. 2015)

* Mithra, also spelled Mithras, or Mitra, in ancient Persian mythology is the god of light.

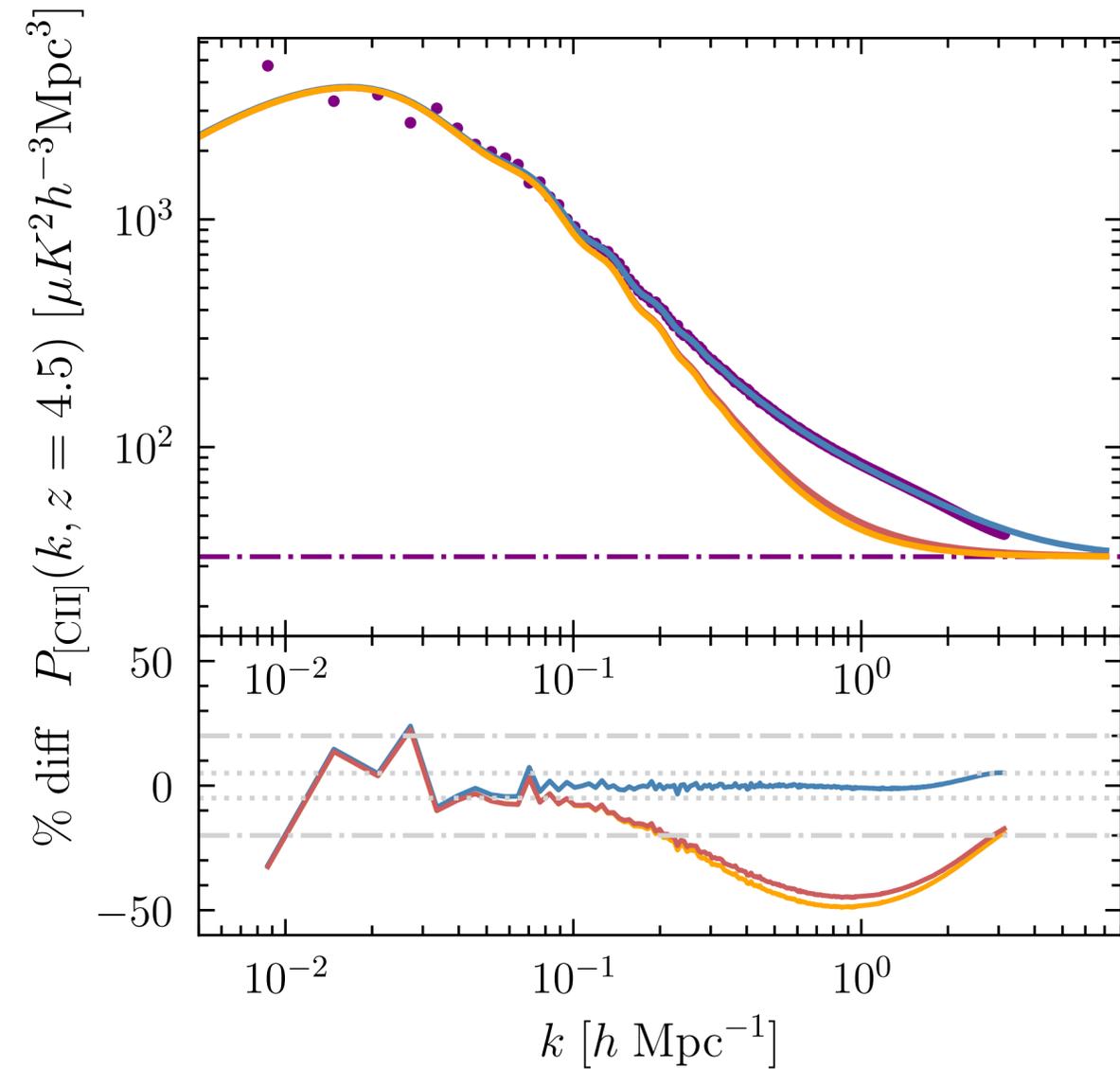
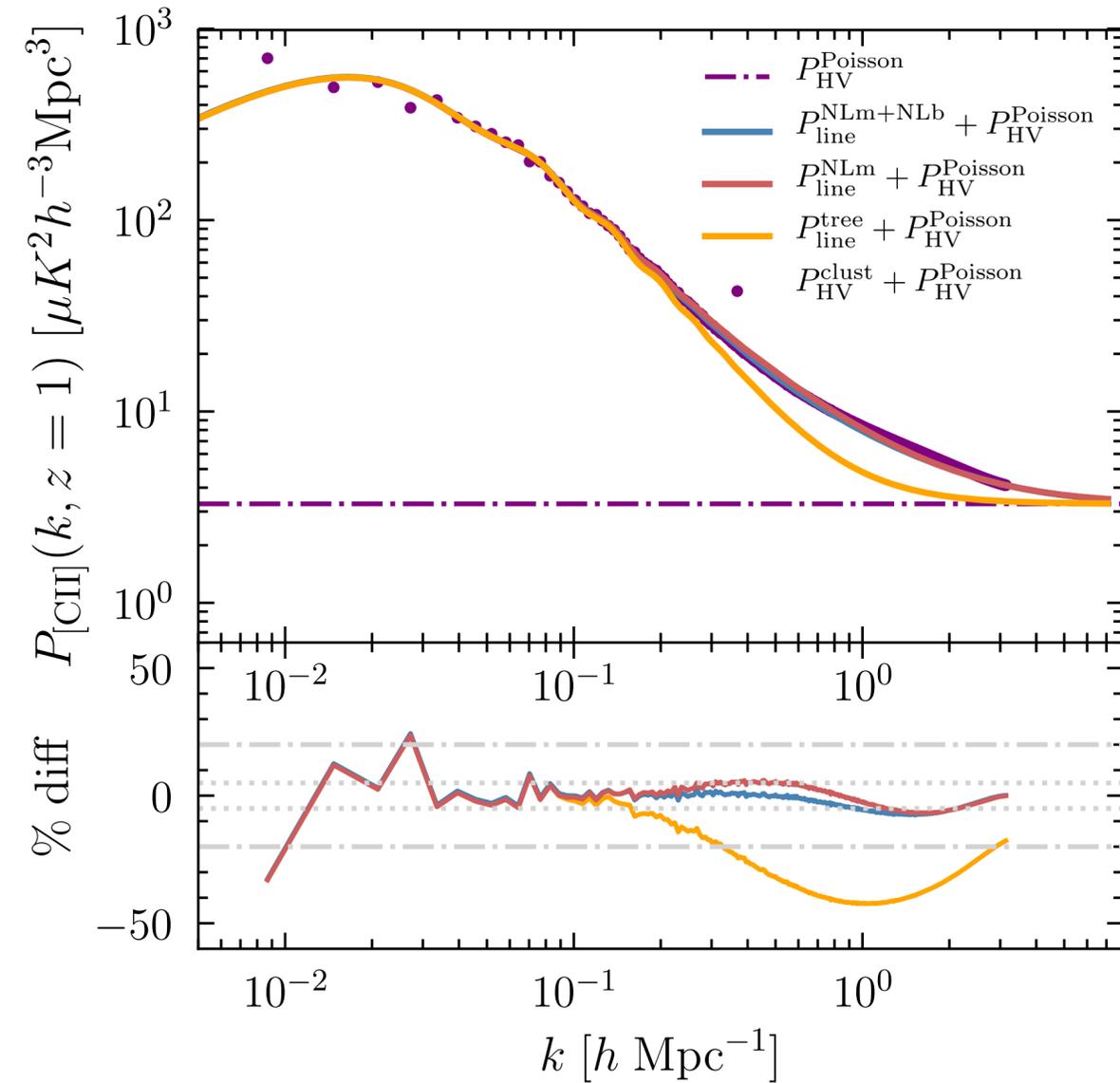
Mithra Line Intensity Mapping Simulations





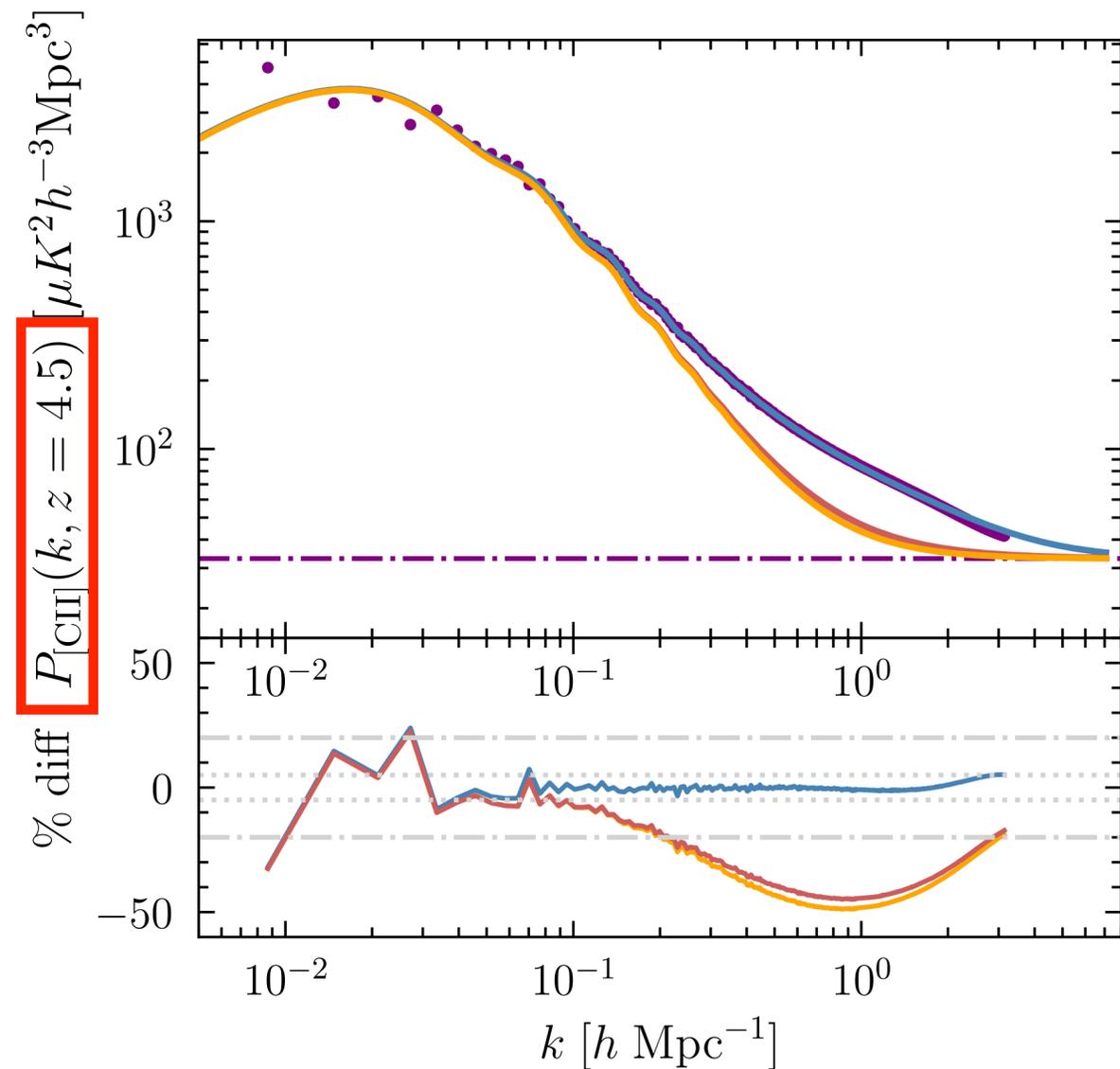
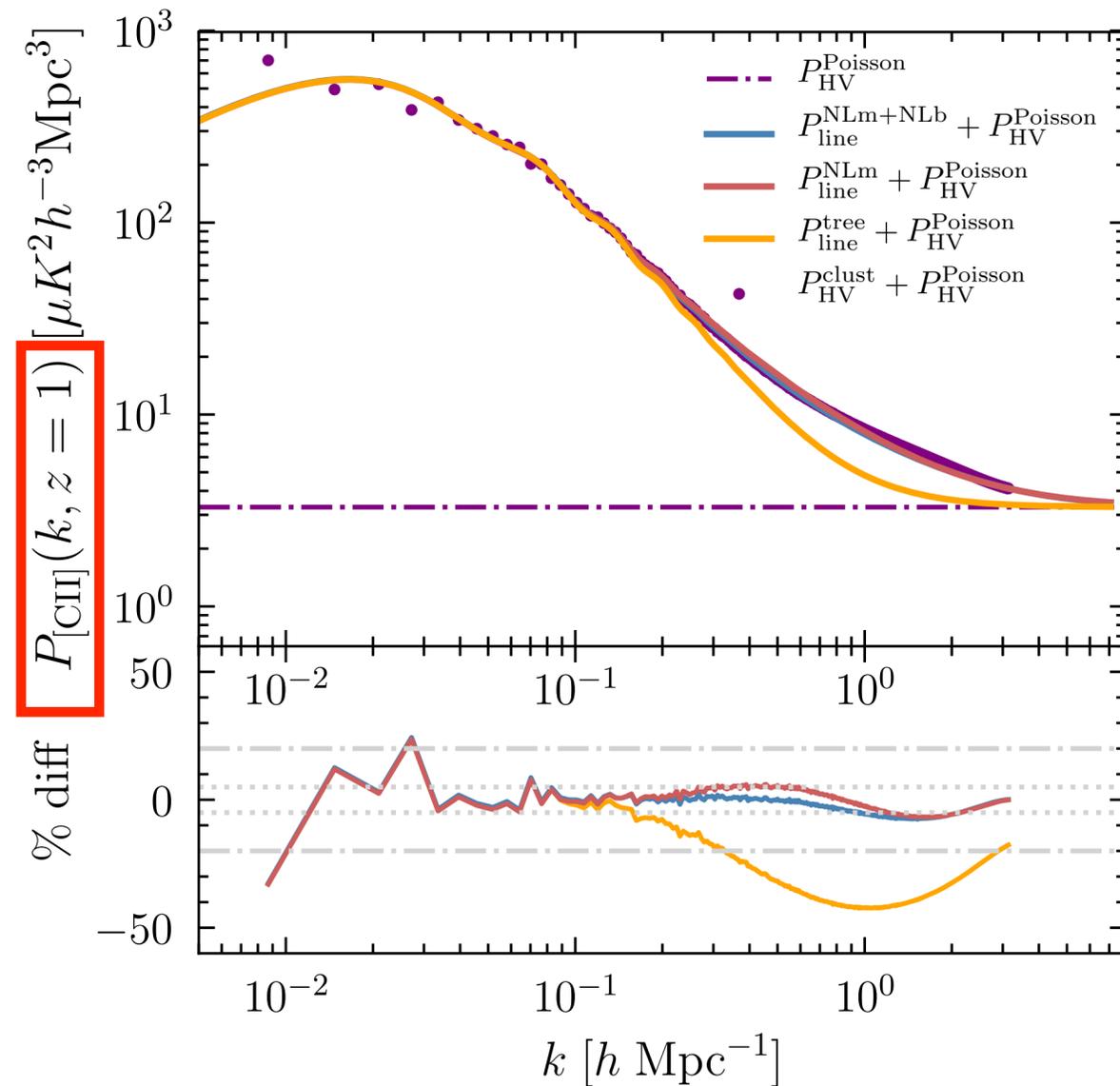
Line Power Spectrum

- Model fits the data by better than 5% (fitting a single parameter)
- Non-linear biasing is crucial (in particular at high redshift)

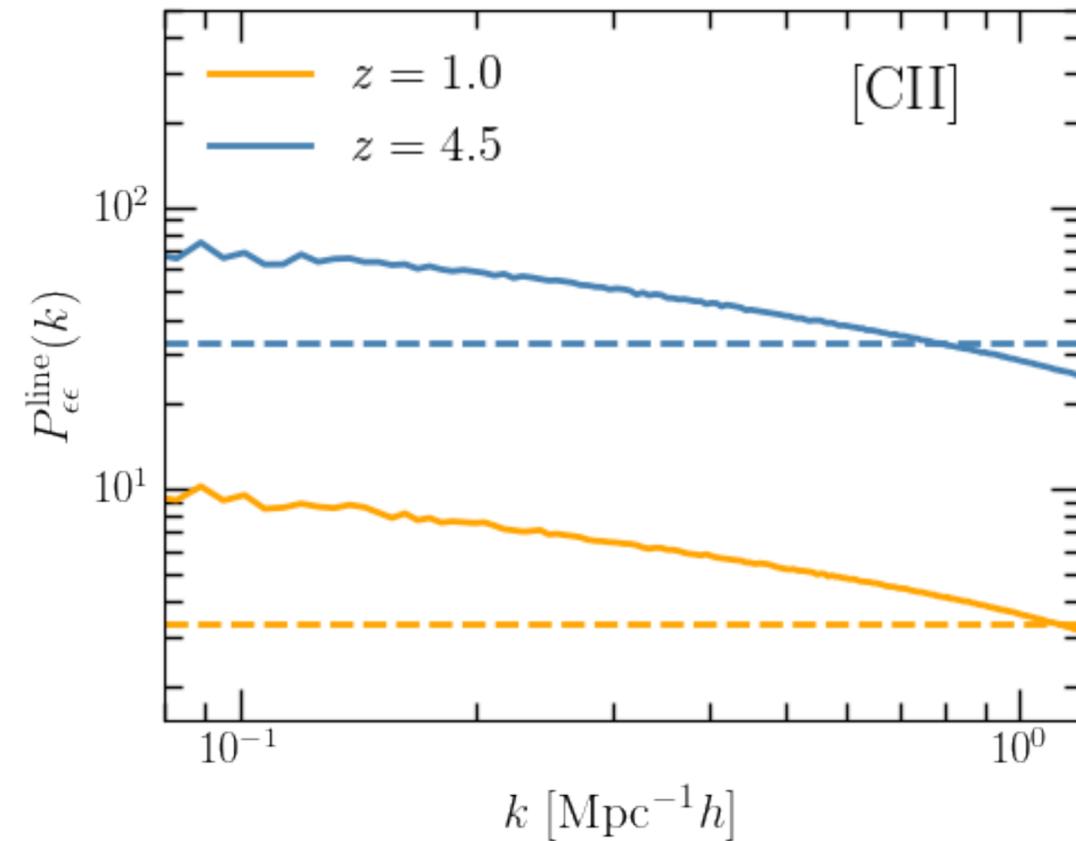
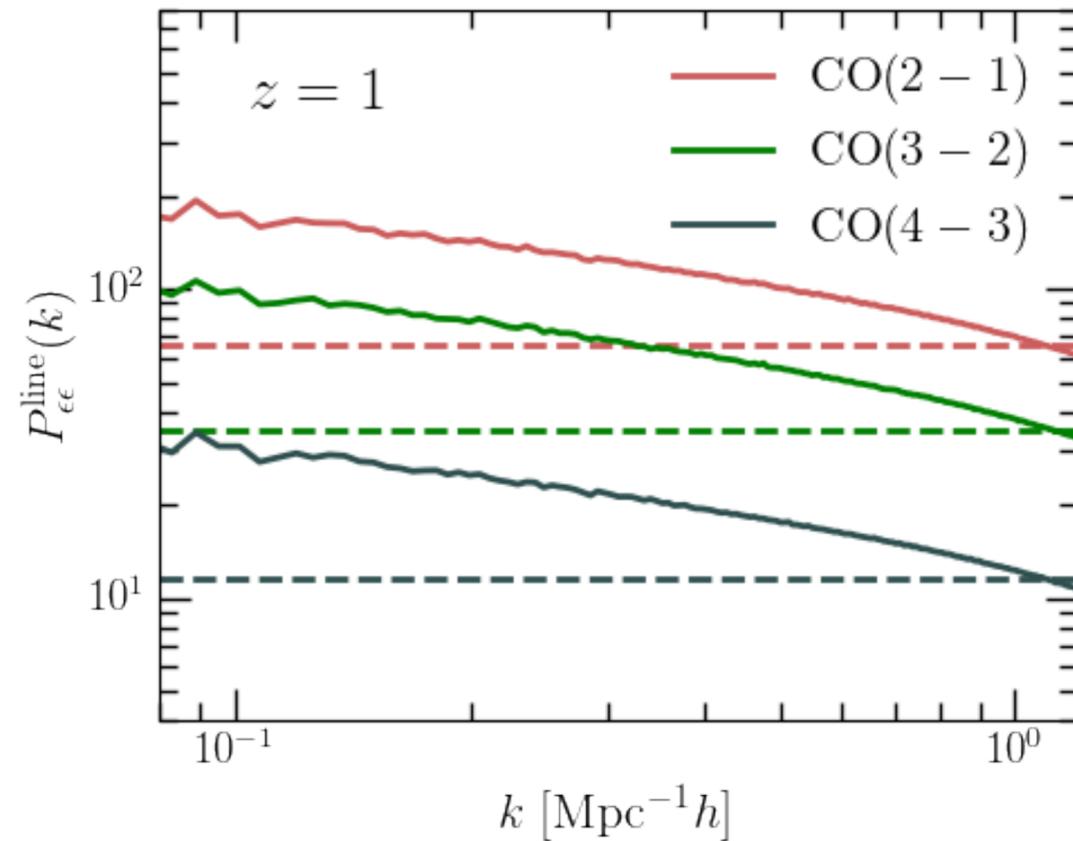


Line Power Spectrum

- Model fits the data by better than 5% (fitting a single parameter)
- Non-linear biasing is crucial (in particular at high redshift)



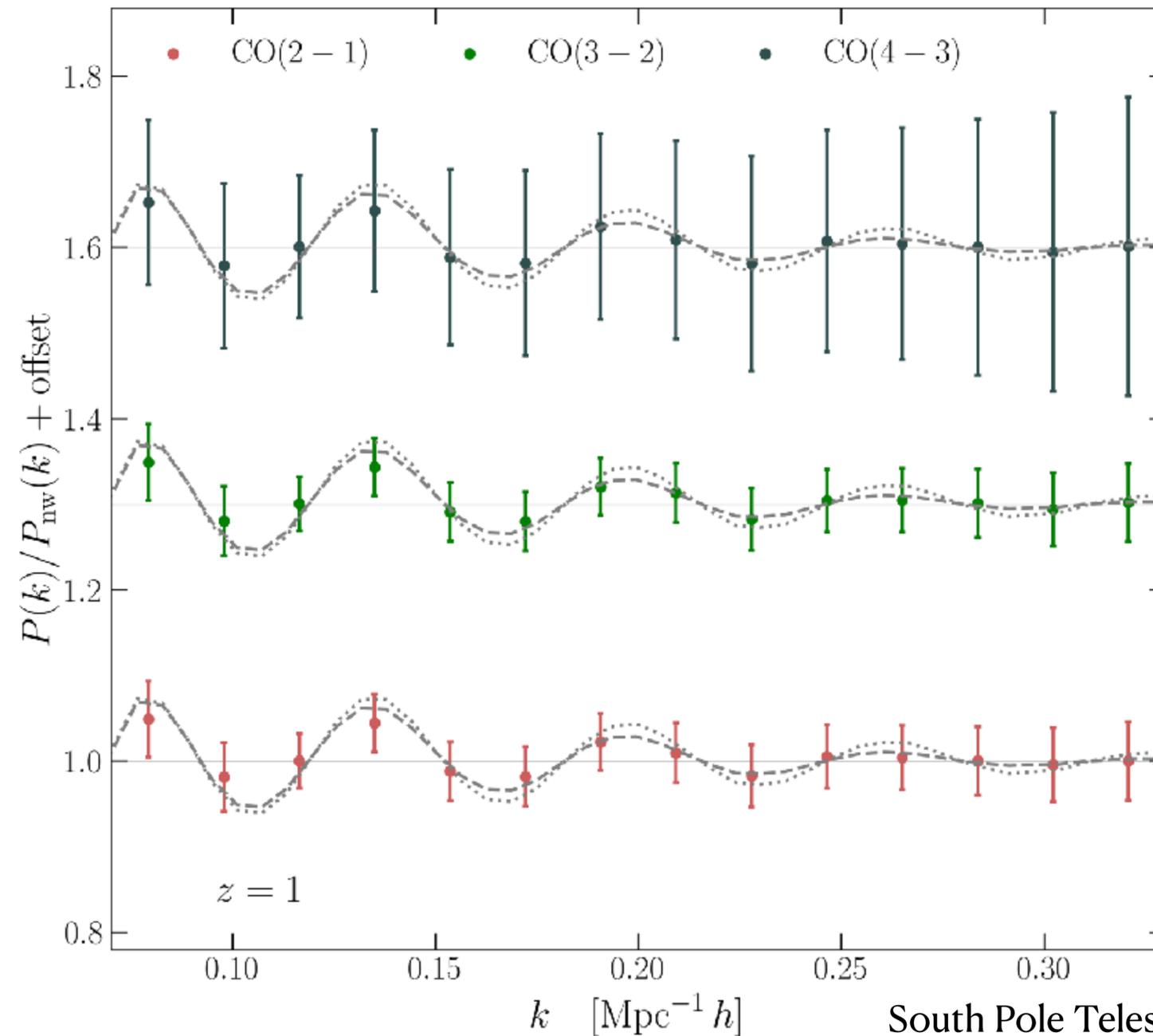
Stochasticity Beyond the Poisson Limit



Super-Poissonian

BAO Signature

- Non-linear damping of oscillations
- Detection possibility?

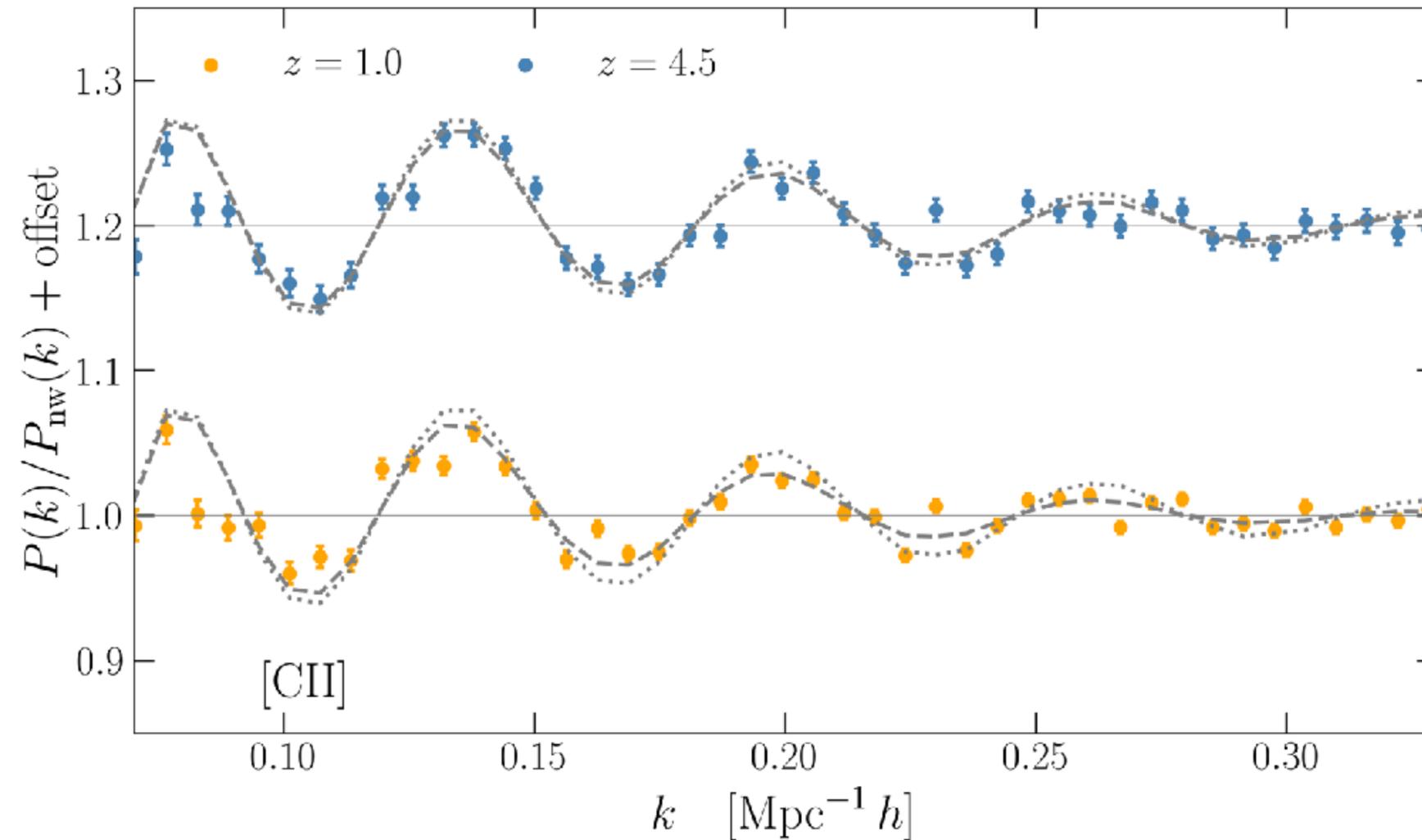


SPT-SLIM

South Pole Telescope—Summertime Line Intensity Mapper

BAO Signature

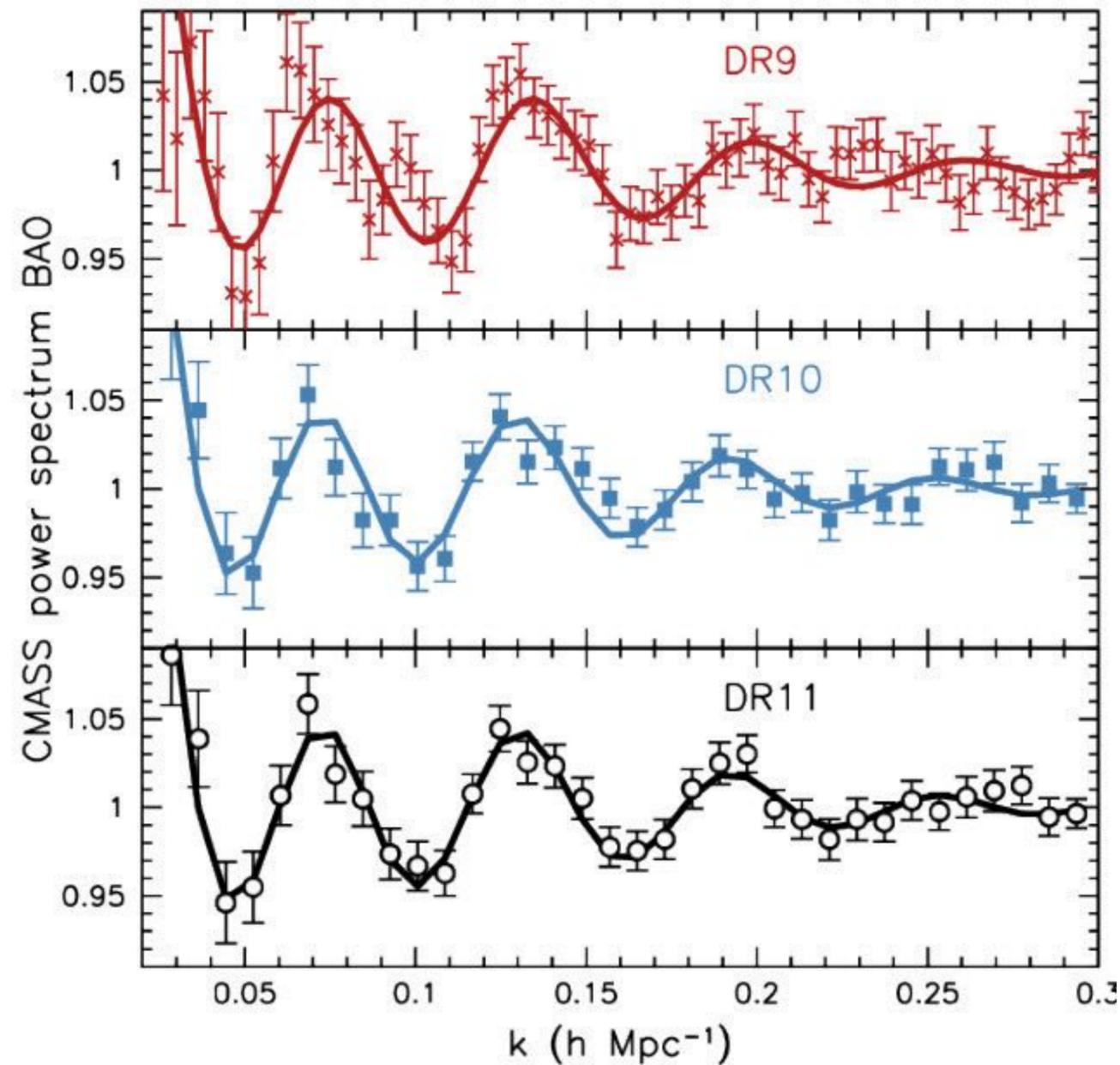
- Non-linear damping of oscillations
- Detection possibility?



ESA Voyage-2050 White Paper; Silva et al. 2019; Delabrouille et al. 2019

BAO Signature

- Non-linear damping of oscillations
- Detection possibility?



Summary

- Cosmological simulations of CO and [CII] intensity fluctuations
- Model fits the data by better than 5%
- Non-linear biasing is crucial
- Non-linear damping of oscillations

Thank you!

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