

# Fundamental Physics with the SKA

*- efforts in Switzerland -*

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**Scientific collaborator and PI, SNSF Ambizione Grant  
Université de Genève**

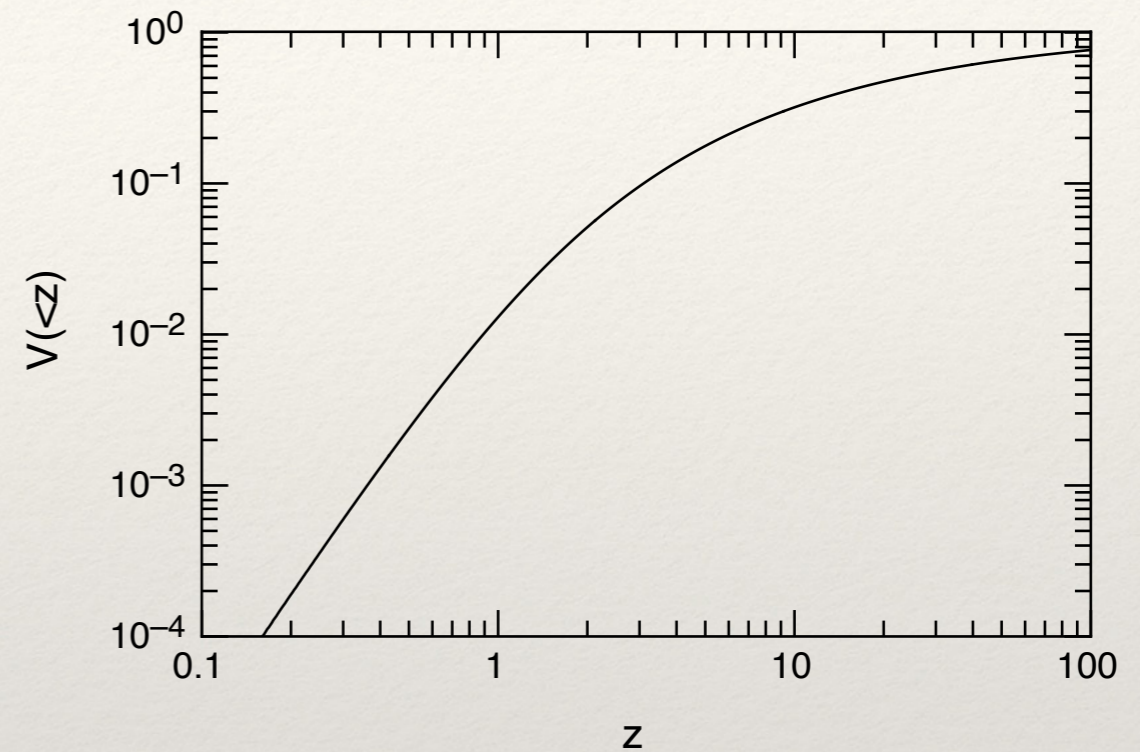
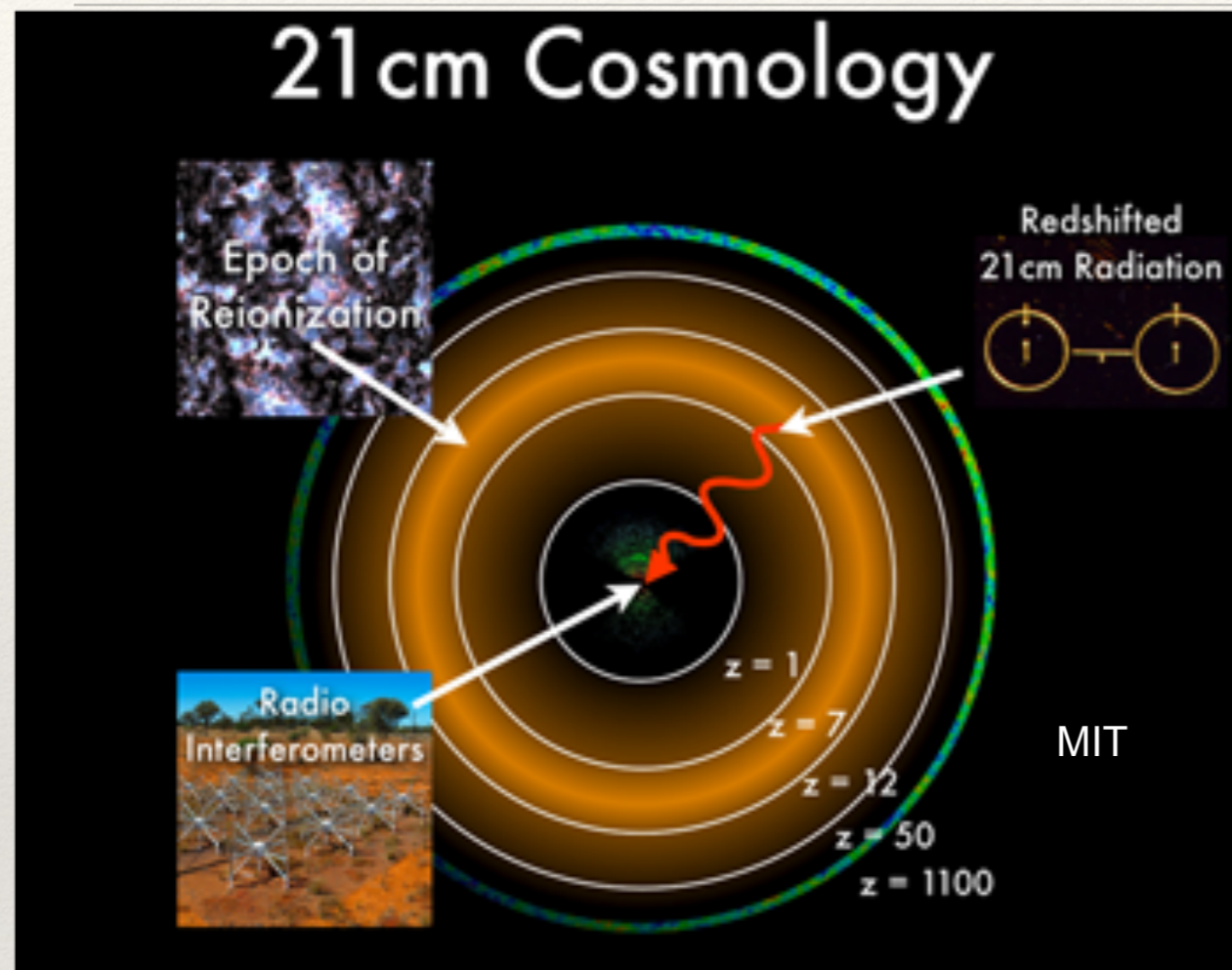


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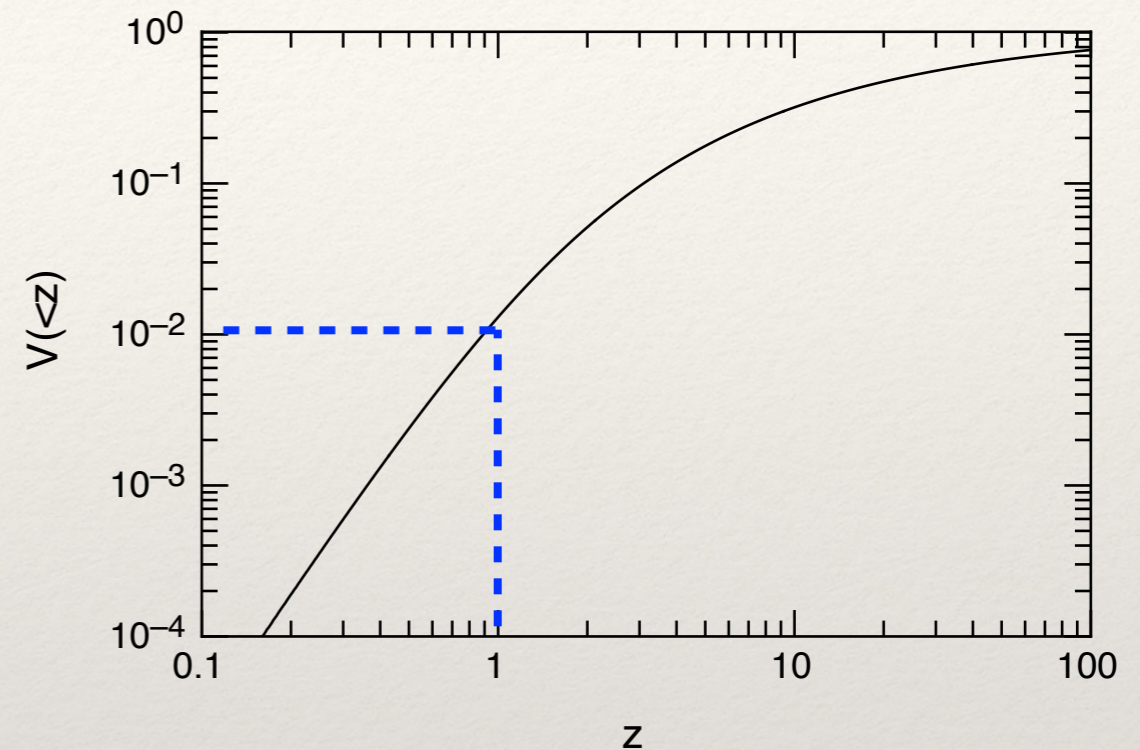
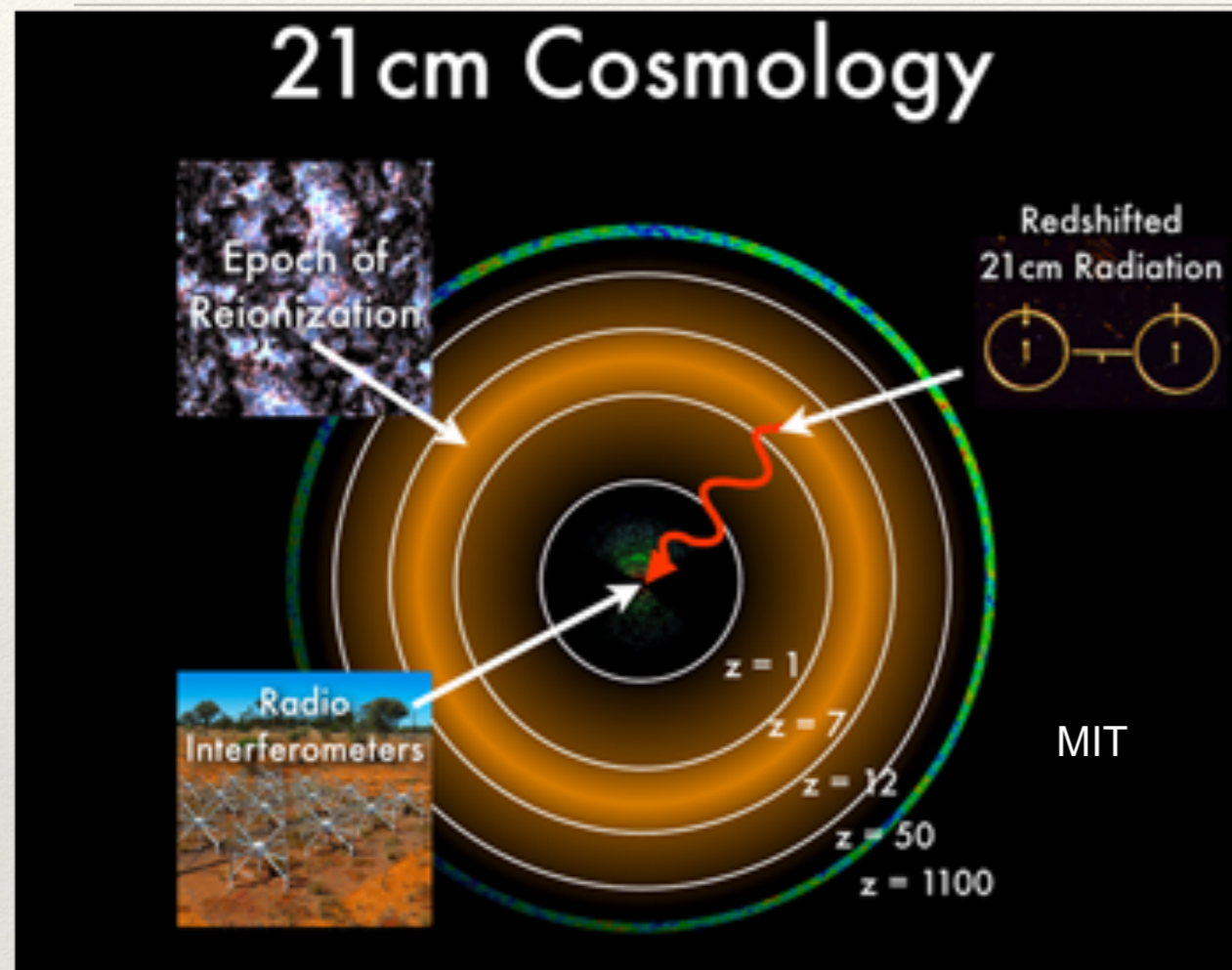
# The SKA will survey a huge volume in baryons ...



[Loeb & Wyithe (2008)]

Several thousand more modes, much smaller scales than galaxy surveys/CMB

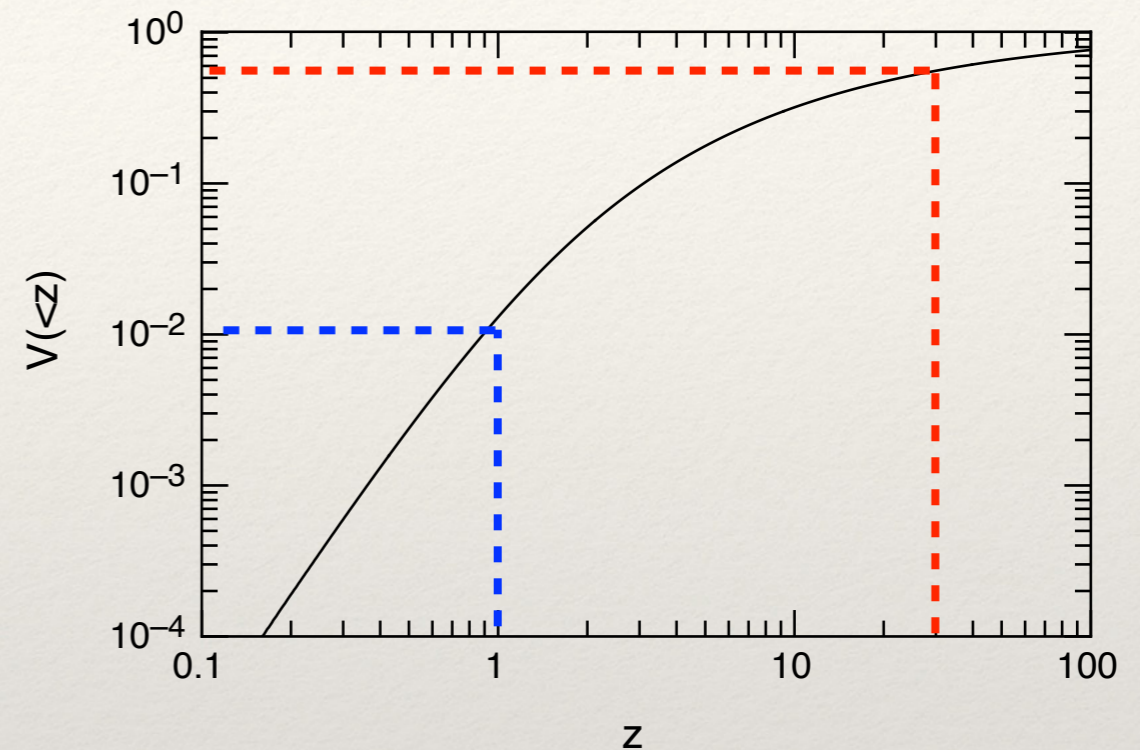
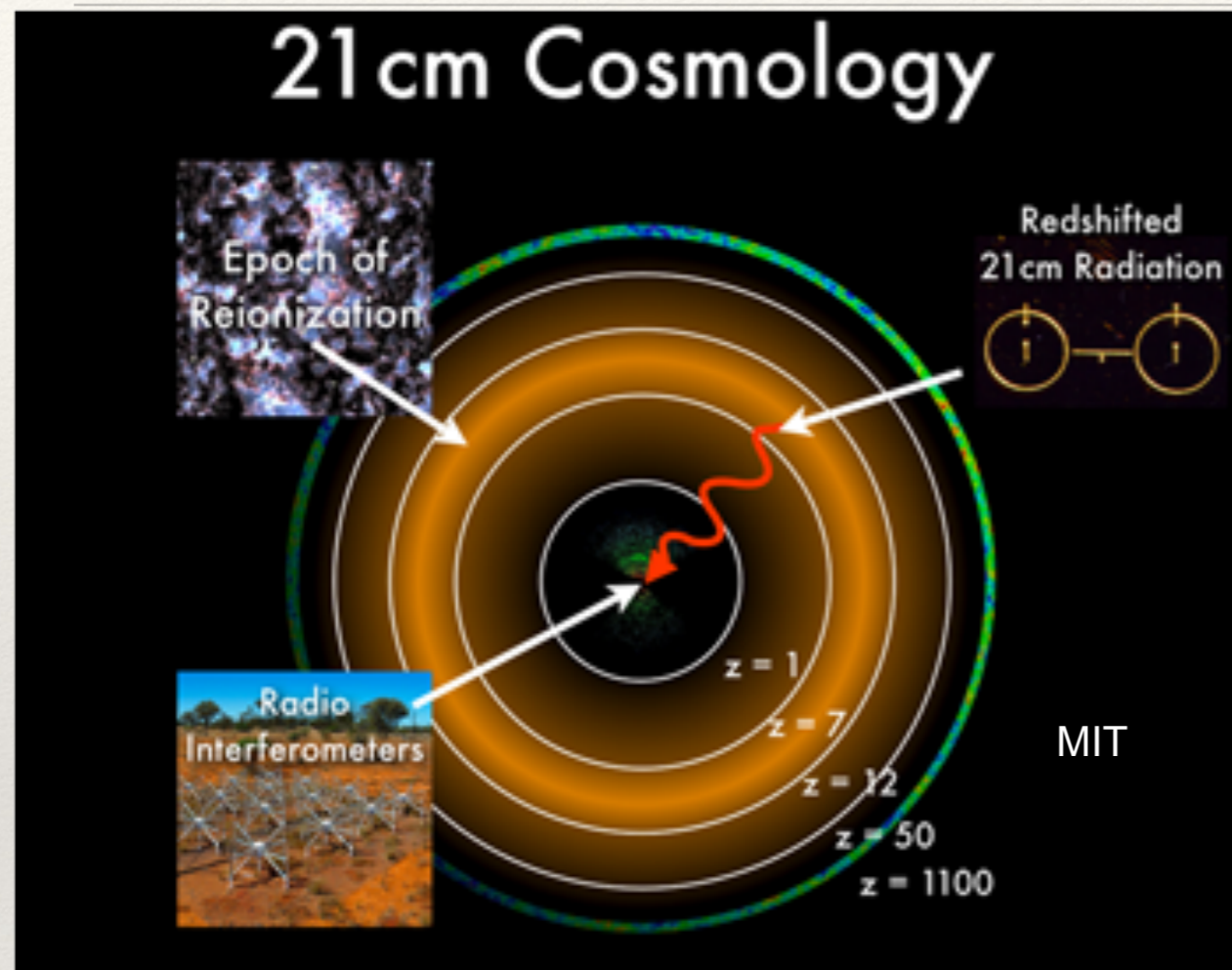
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$$N_{21\text{cm}} \sim 8 \times 10^{11} \left( \frac{k_{\text{max}}}{3 \text{ Mpc}^{-1}} \right)^3 \left( \frac{\Delta v}{v} \right) \left( \frac{1+z}{100} \right)^{-1/2}$$

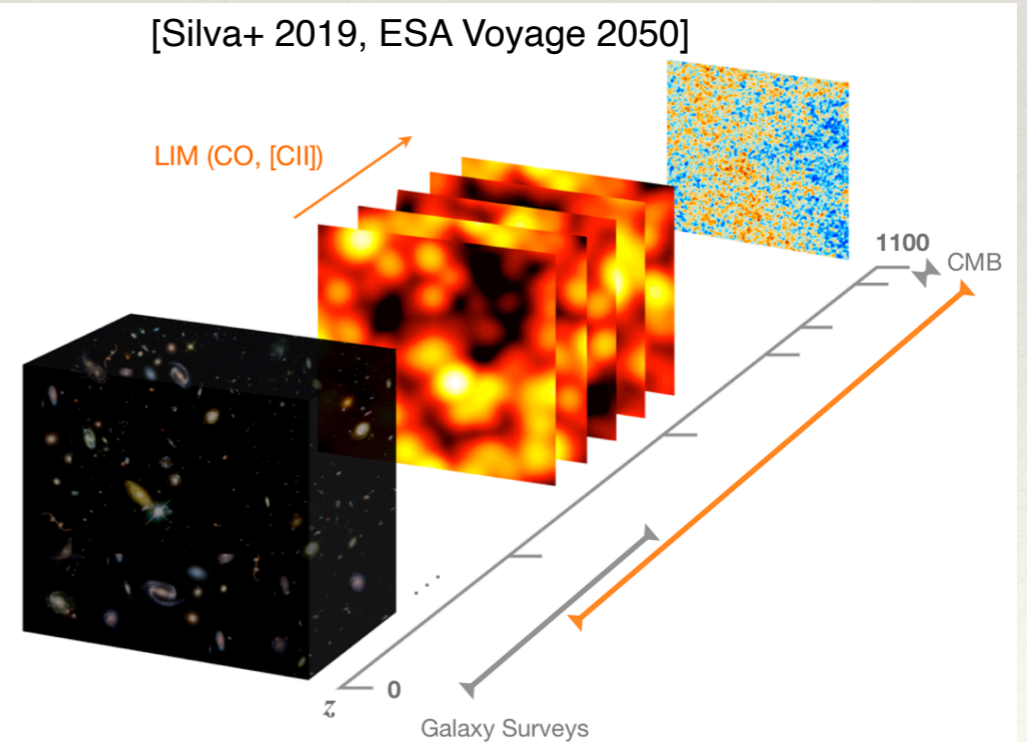
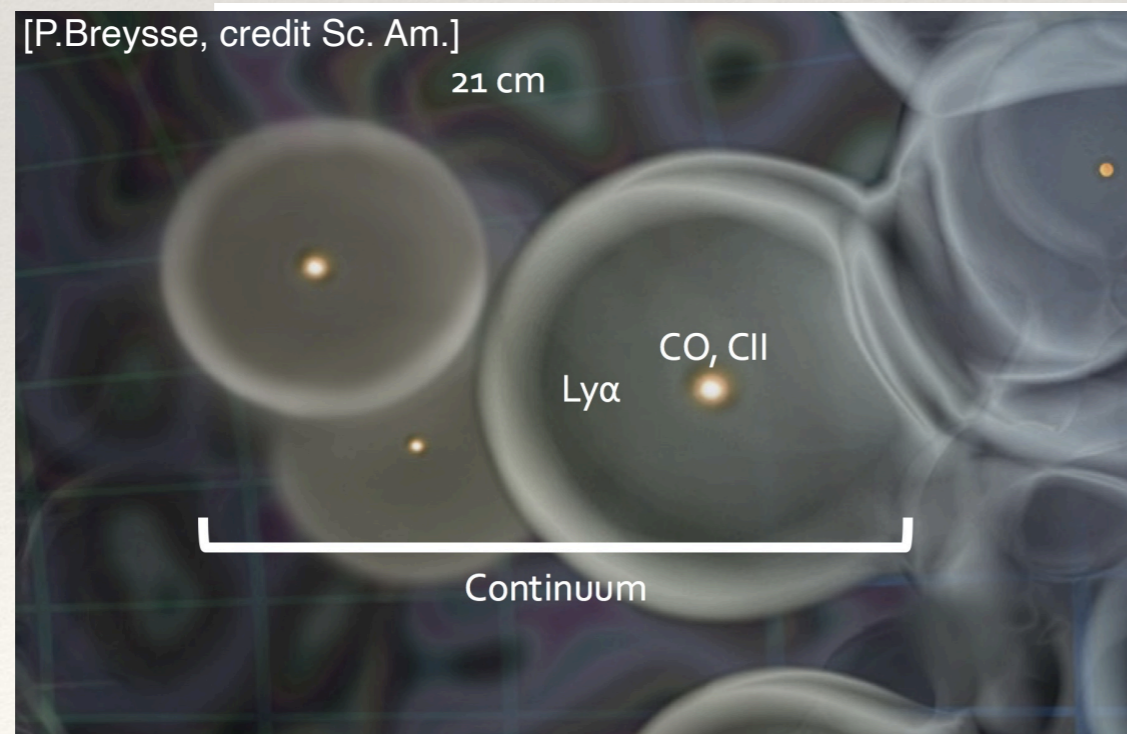
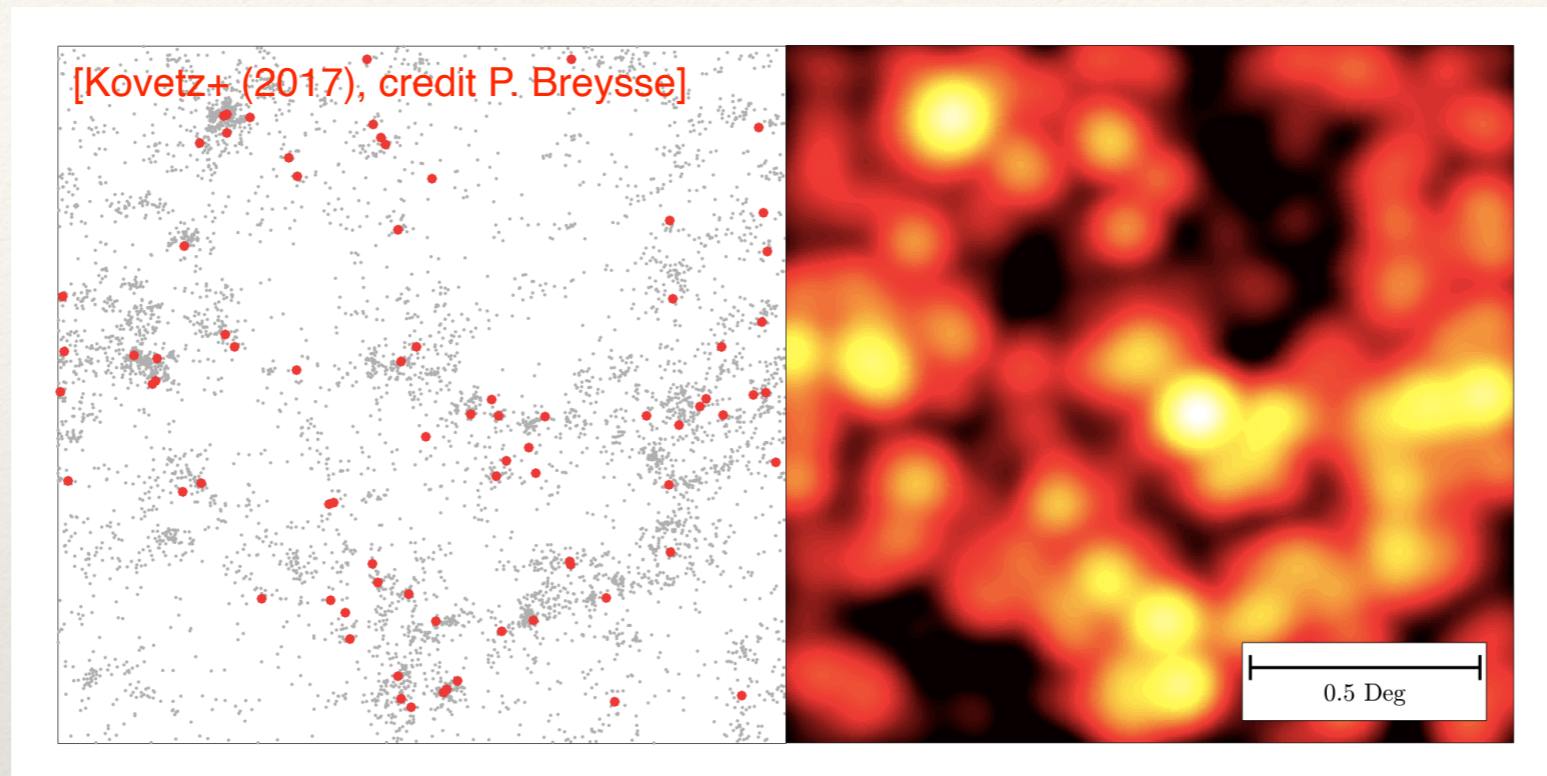
$$\text{Dark Ages : } k_{\text{max}} \sim 1000 \text{ Mpc}^{-1}$$

$$N_{\text{CMB}} \sim 10^7$$

[Furlanetto (2019)]

# Intensity mapping (IM)

[Early studies: Hogan and Rees 1979, Sunyaev and Zeldovich 1972,1974, Bebington 1986]



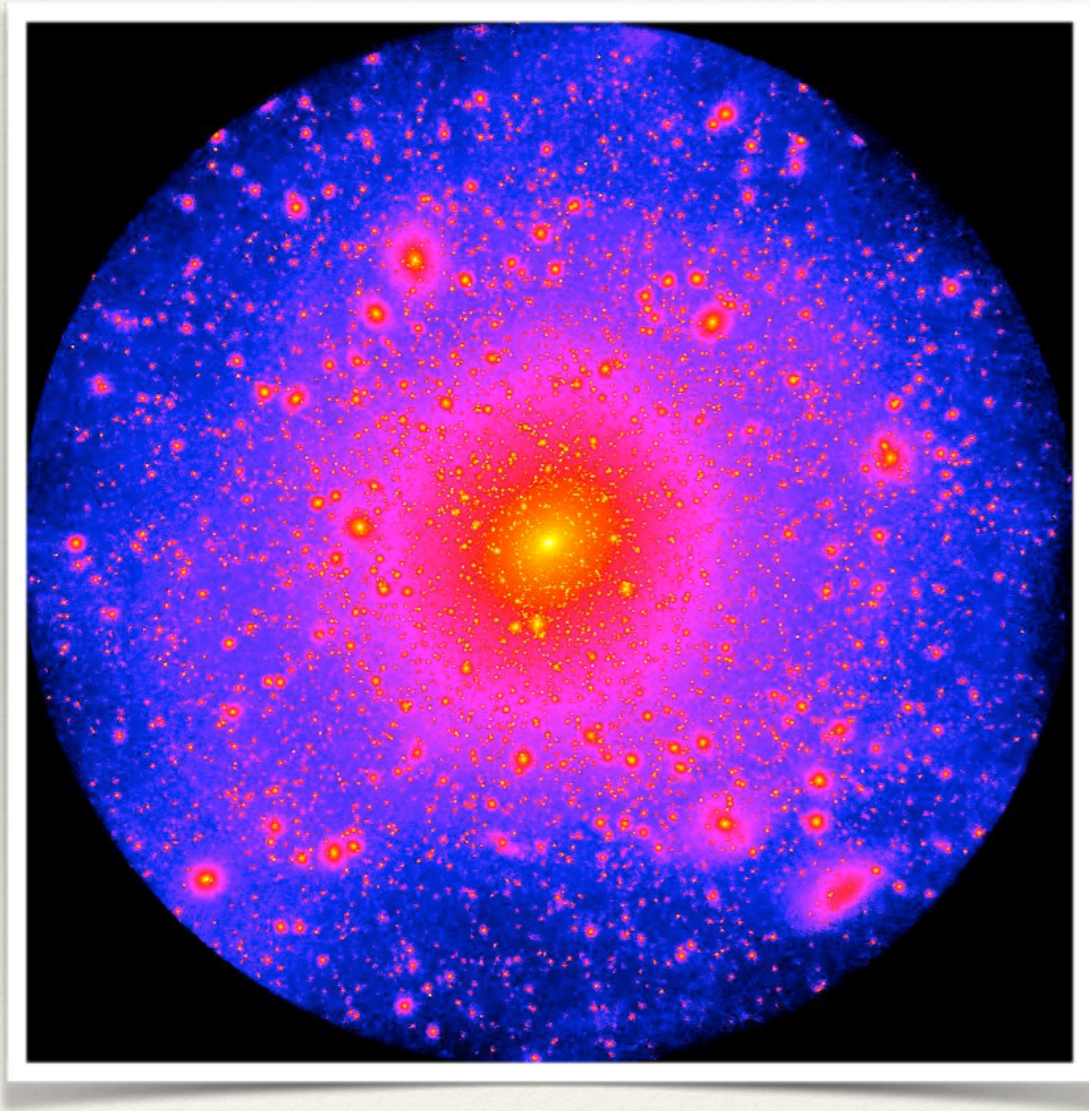
# A halo model for cosmological neutral hydrogen

[HP+ (MNRAS, 2016, 2017a, 2017b)]

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Going from ...

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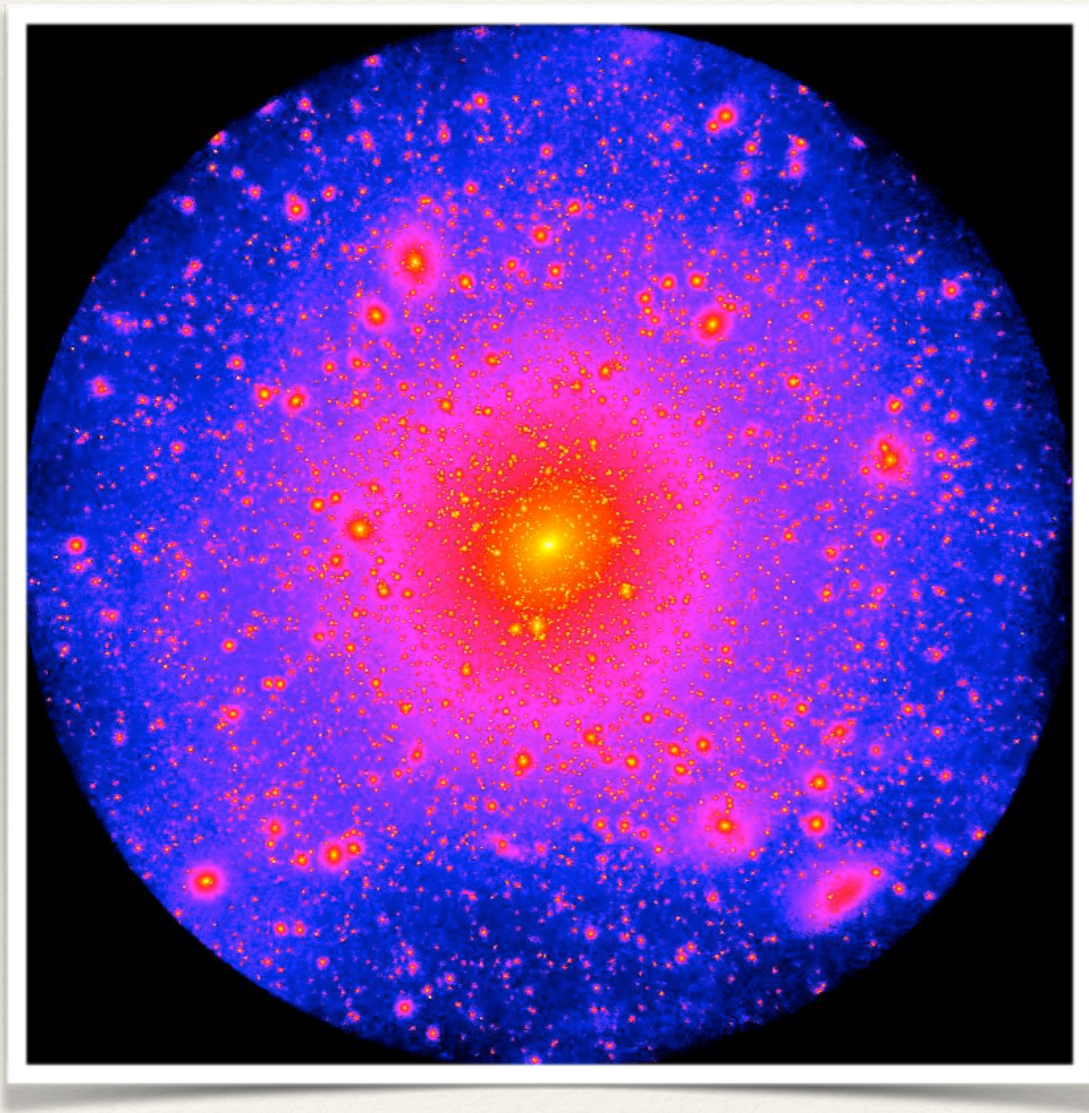
(UW / HPCC)

[e.g. Cooray & Sheth (2002)]

# A halo model for cosmological neutral hydrogen

Going from ...

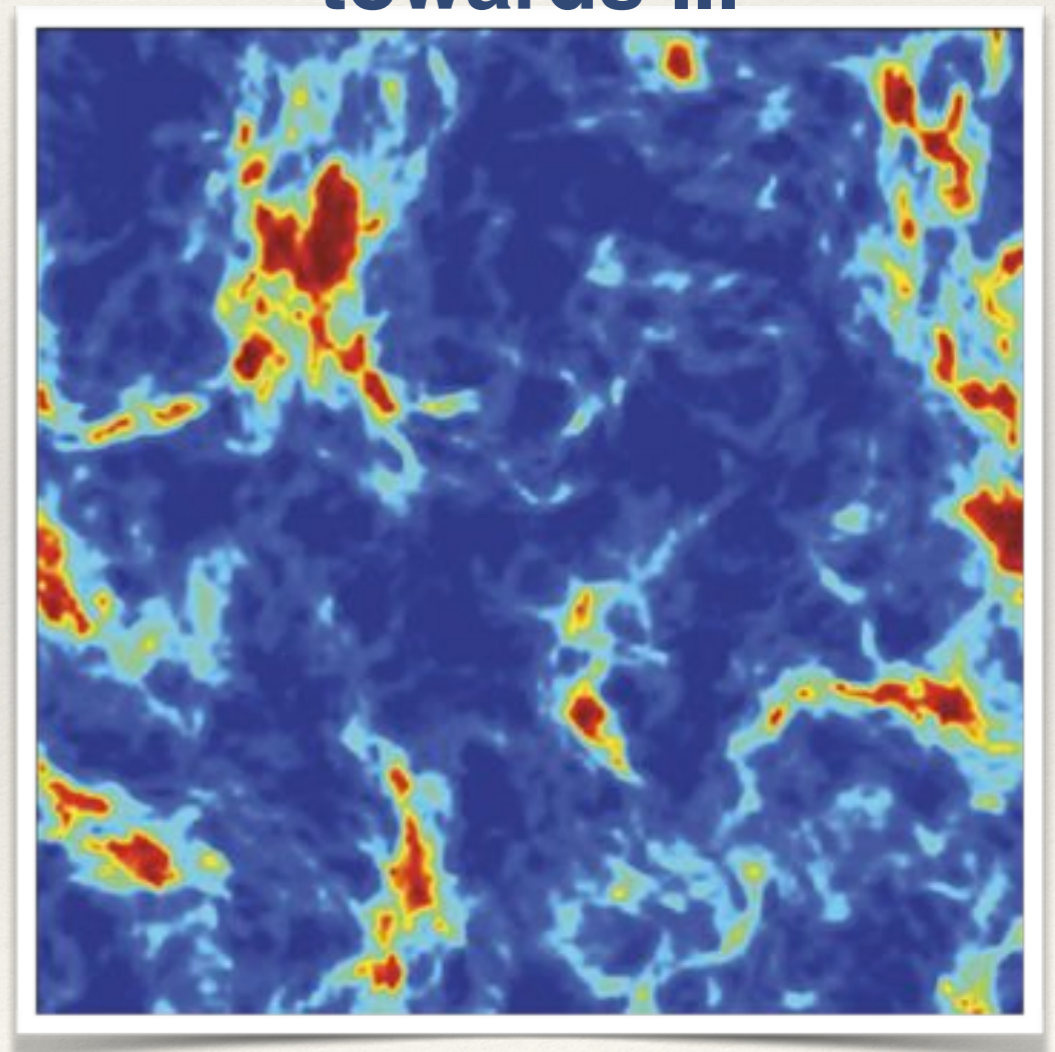
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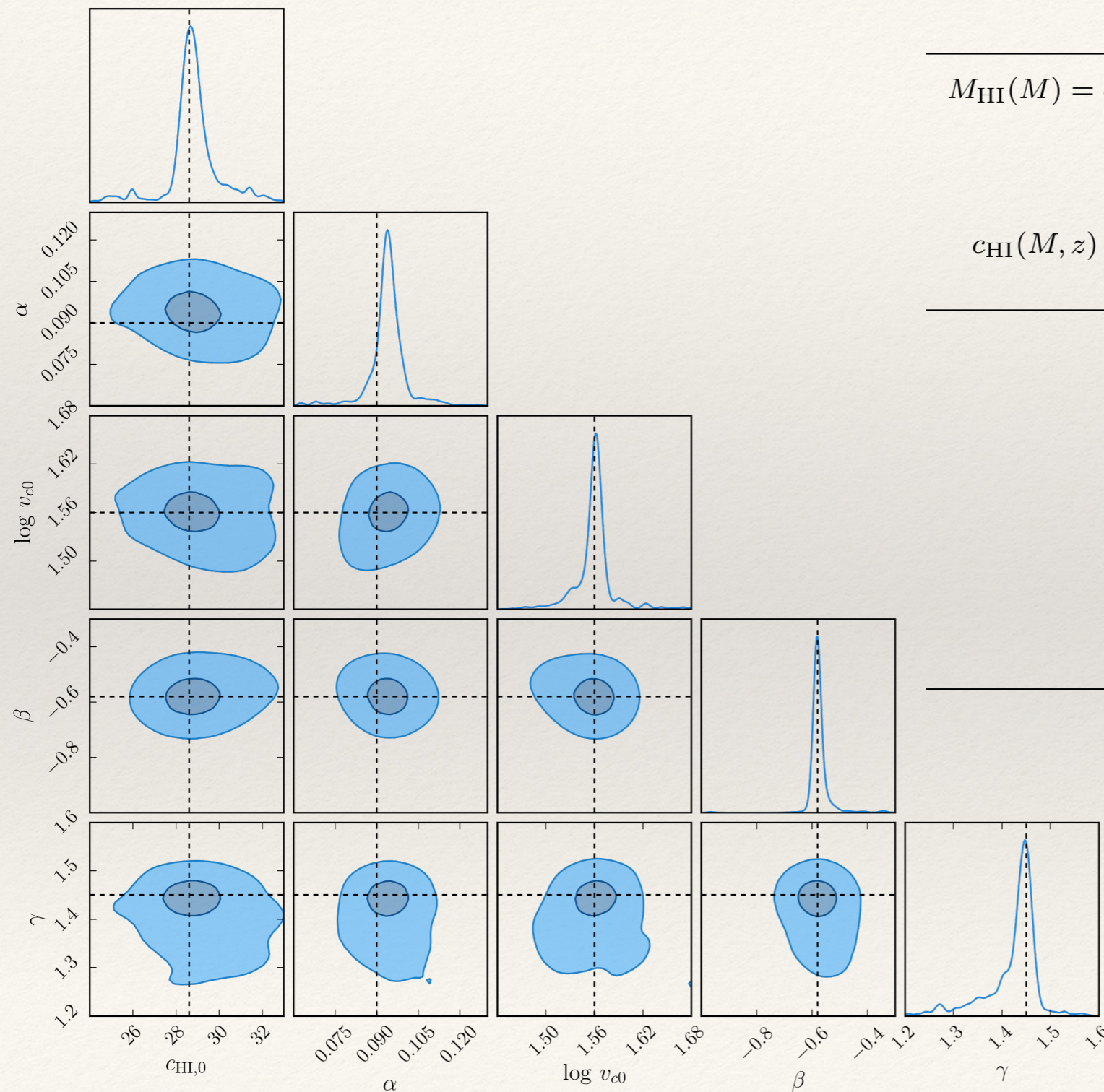
towards ...



[Fialkov+ (2013)]

# Constraints

[HP+, MNRAS (2017), HP & Kulkarni (2017)]



$$M_{\text{HI}}(M) = \alpha f_{H,c} M (M/10^{11} h^{-1} M_{\odot})^{\beta} \exp \left[ - (v_{c0}/v_c(M))^3 \right]$$

$$\rho_{\text{HI}}(r) = \rho_0 \exp(-r/r_s);$$

$$c_{\text{HI}}(M, z) \equiv R_v/r_s = c_{\text{HI},0} (M/10^{11} M_{\odot})^{-0.109} 4/(1+z)^{\gamma}$$

$$c_{\text{HI},0} = 28.65 \pm 1.76$$

$$\alpha = 0.09 \pm 0.01$$

$$\log v_{c,0} = 1.56 \pm 0.04$$

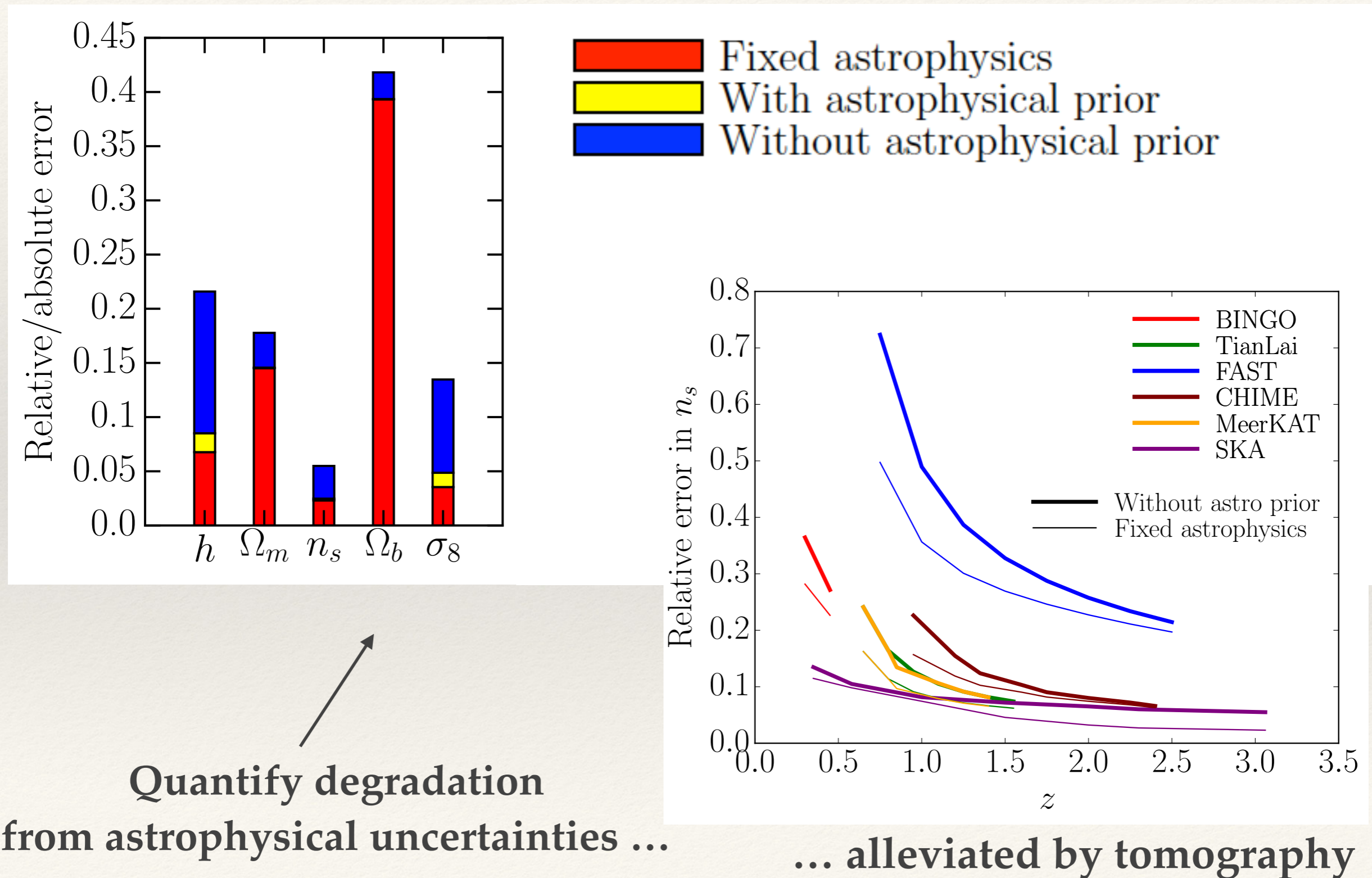
$$\beta = -0.58 \pm 0.06$$

$$\gamma = 1.45 \pm 0.04$$

**CONSTRAINTS FROM  
CURRENT HI GALAXY,  
DLA, IM DATA**

# Cosmological constraints: *precision*

[HP+ (MNRAS, 2019), arXiv:1804.10627]

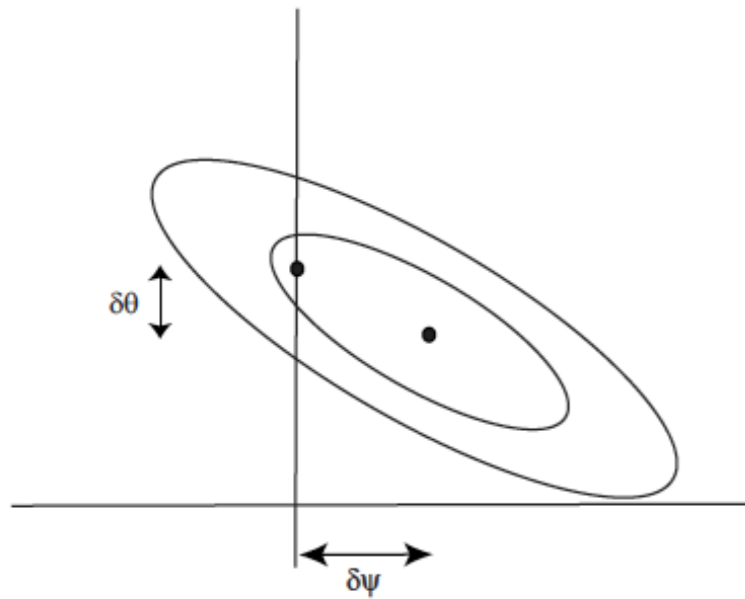


Quantify degradation  
from astrophysical uncertainties ...

# Cosmological constraints: *accuracy*

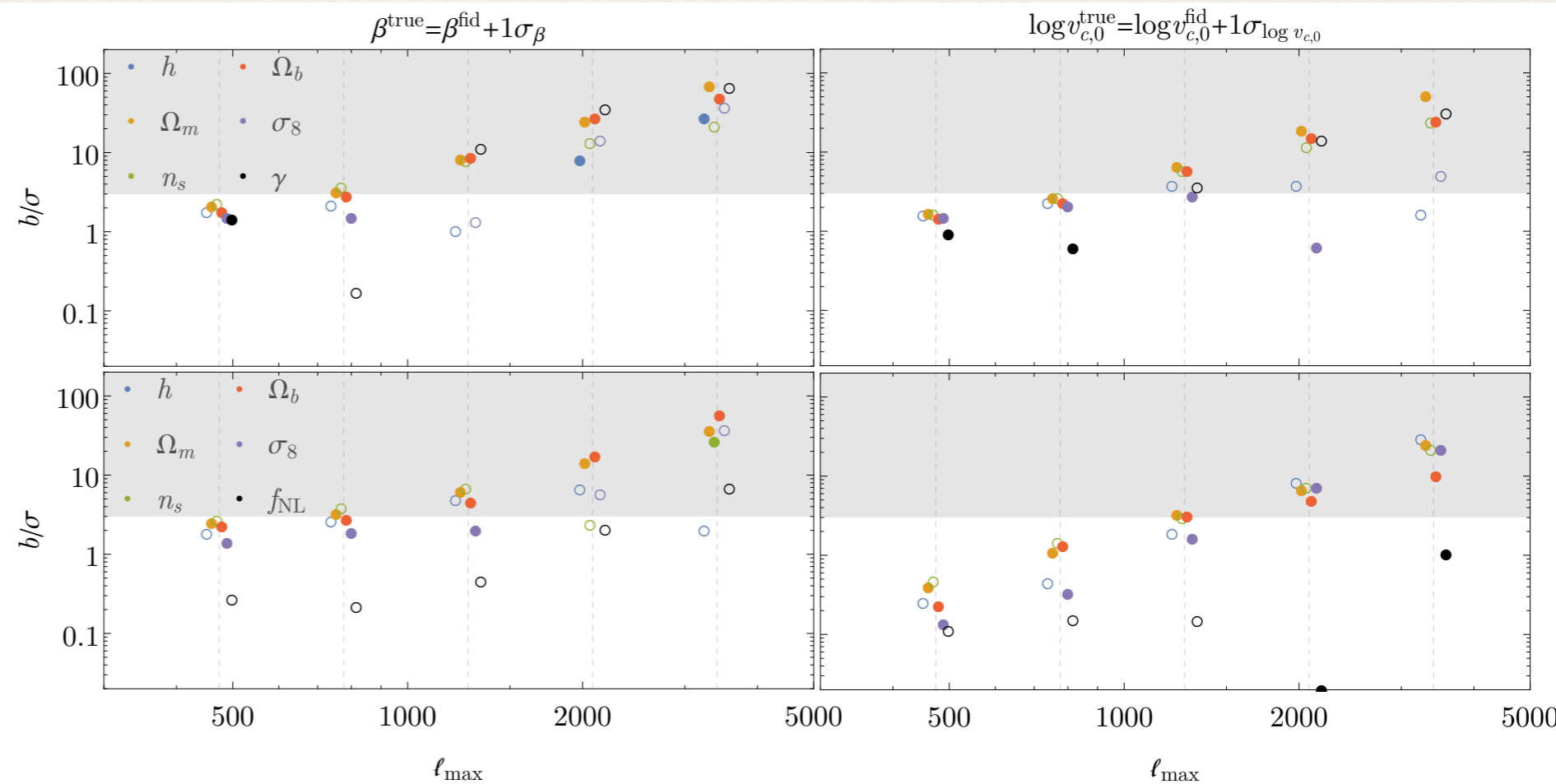
[Camera+, MNRAS (2011,2014)]

Nested, simpler model, *relative bias*



Parameter shift

[Heavens+ (2007)]



[Stefano Camera & HP,  
MNRAS (2020), arXiv:1910.11104]

# Is it $\Lambda$ CDM or ...

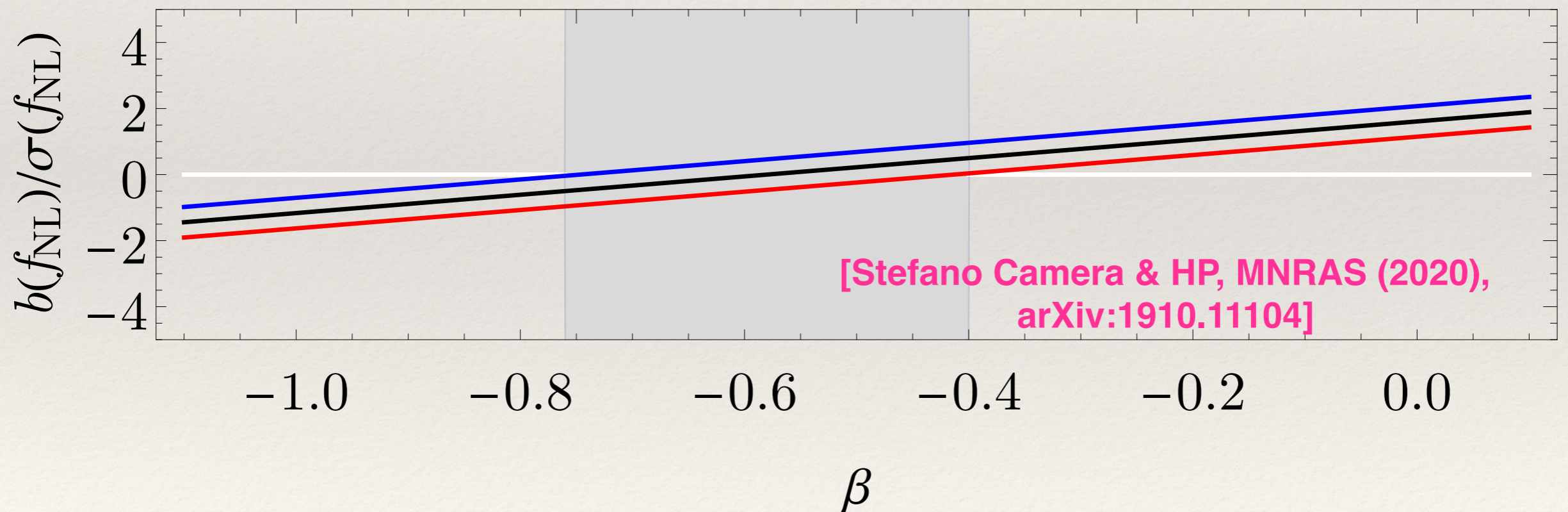
[Planck 2013]

$$f_{\text{NL}} = 0.8 \pm 5$$

[Dalal (2008), Verde & Matarese (2011)]

$$\Delta b_{\text{h}}(M, z, k) \propto [b_{\text{h}}(M, z) - 1] f_{\text{NL}}$$

[U Michigan]



[Stefano Camera & HP, MNRAS (2020),  
arXiv:1910.11104]

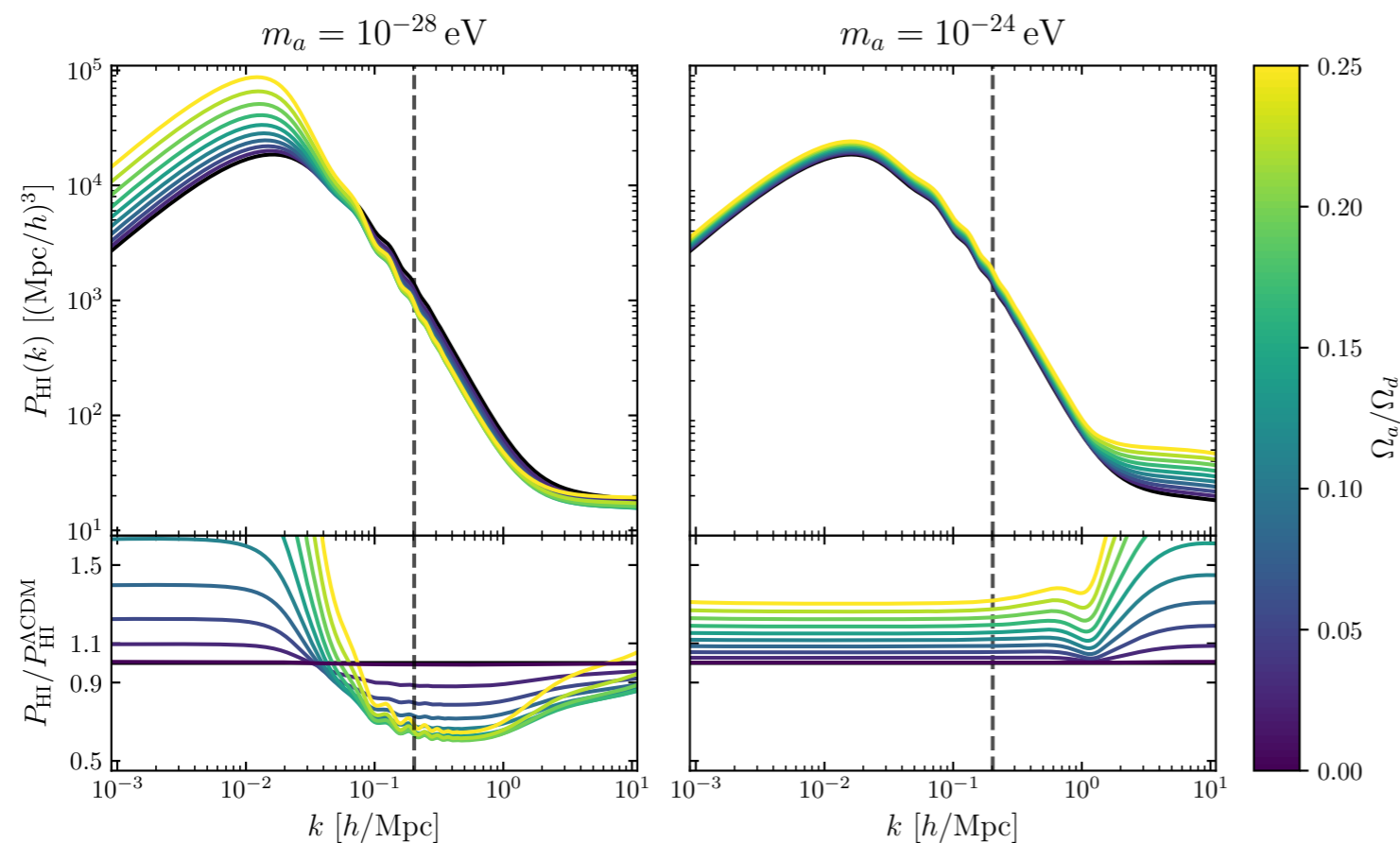
**Primordial non-Gaussianity is negligibly affected** by astrophysical  
uncertainties in HI IM surveys

# Nature of dark matter and gravity

Axion mass  $< 10^{-22}$  eV  
constrained  
at few percent level  
from SKAI-MID

Testing General Relativity with 21 cm intensity mapping

Alex Hall,<sup>1,\*</sup> Camille Bonvin,<sup>1,2</sup> and Anthony Challinor<sup>1,2</sup>



Parameter modification  
of  $f(R)$  gravity

$$B_0 < 7 \times 10^{-5}$$

[Bauer, ... HP, ... MNRAS (2021), arXiv:2003.09655]

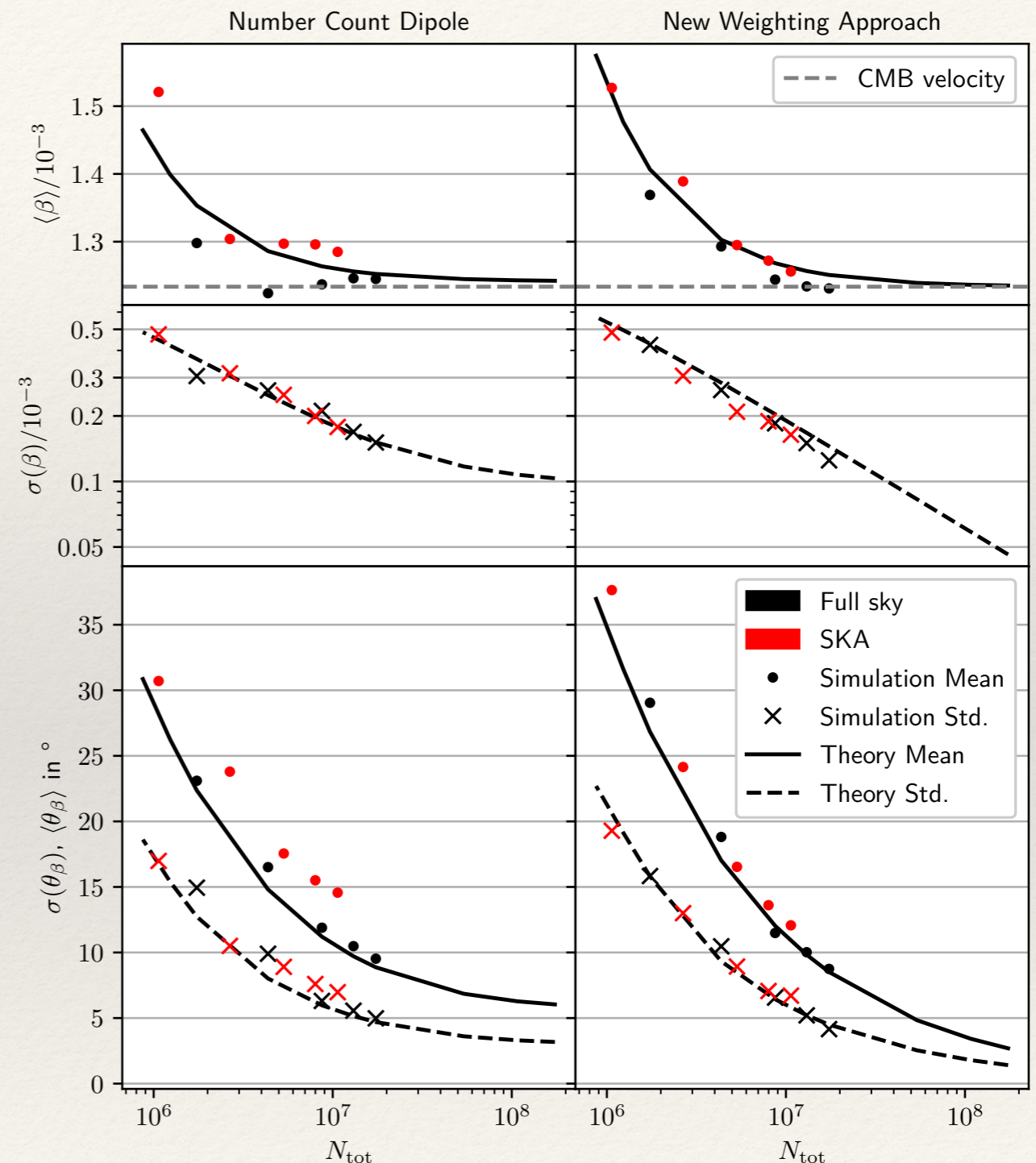
# Testing the cosmological principle

Measuring our velocity  
and the intrinsic dipole  
independently

$$\sigma_{\beta}/\beta \sim 4.5\%$$

$$\langle \theta_{\beta} \rangle \sim 3.9^{\circ}$$

[Nadolny, Durrer, Kunz, HP, submitted,  
arXiv:2106.05284]



# Fundamental physics from the Cosmic Dawn ...

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ULB-TH/20-03

## Variations in fundamental constants at the cosmic dawn

Laura Lopez-Honorez,<sup>1,\*</sup> Olga Mena,<sup>2,†</sup> Sergio Palomares-Ruiz,<sup>2,‡</sup>  
Pablo Villanueva-Domingo,<sup>2,§</sup> and Samuel J. Witte<sup>2,¶</sup>

## Gravitational wave backgrounds from coalescing black hole binaries at cosmic dawn: an upper bound

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**and several more ...**

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[arXiv.org](https://arxiv.org/abs/1810.02680) > [astro-ph](#) > [arXiv:1810.02680](#)

Astrophysics > Cosmology and Nongalactic Astrophysics

**Fundamental Physics with the Square Kilometer Array**

**Review article, Weltman+ (2020), PASA, chapter  
on *Cosmic Dawn and Reionization* [chapter leads: HP, Jonathan Pritchard]**

***To summarize ...***



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Thank you!