SISSA


UNIVERSITÉ DE GENÈVE

EUCAPT ANNUAL SYMPOSIUM
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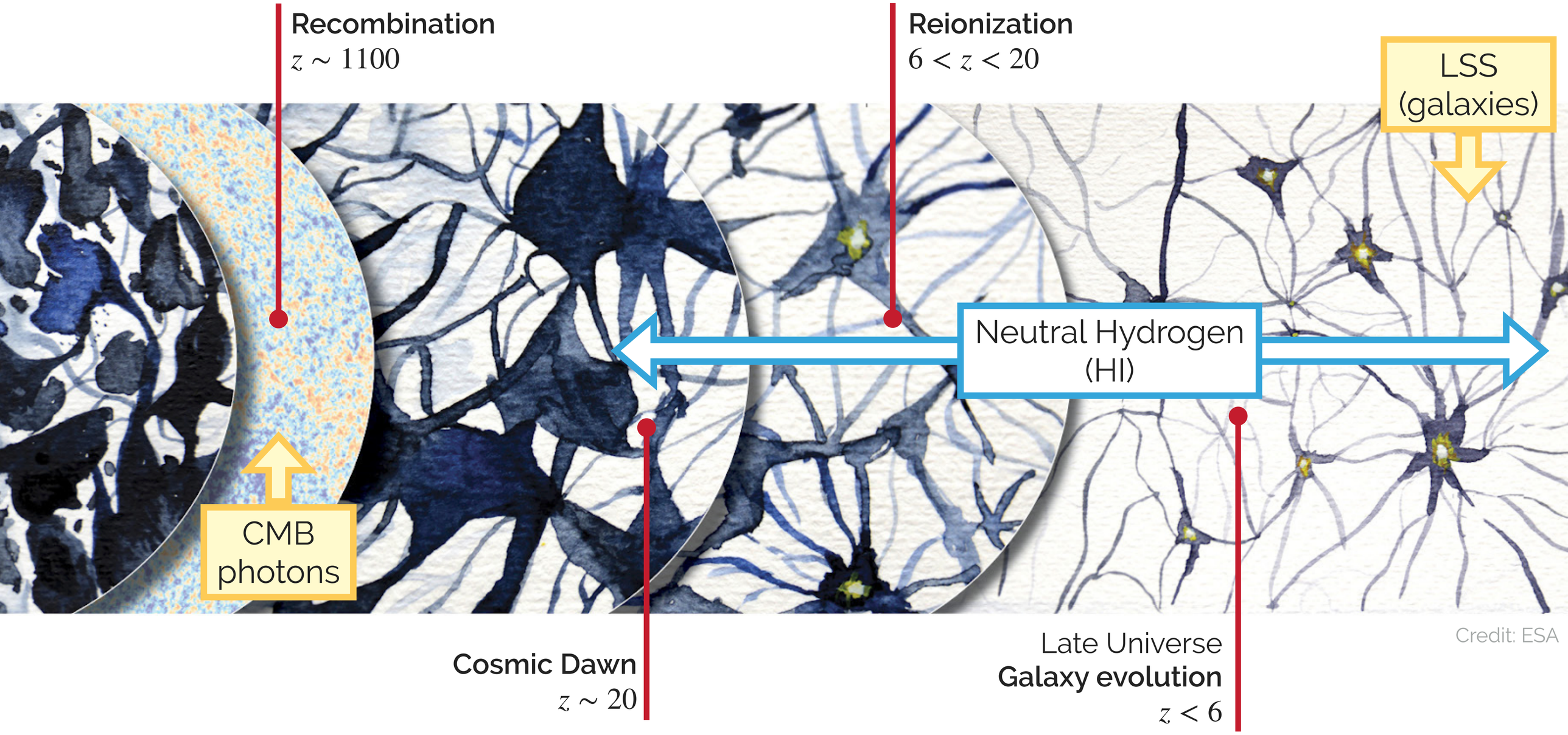
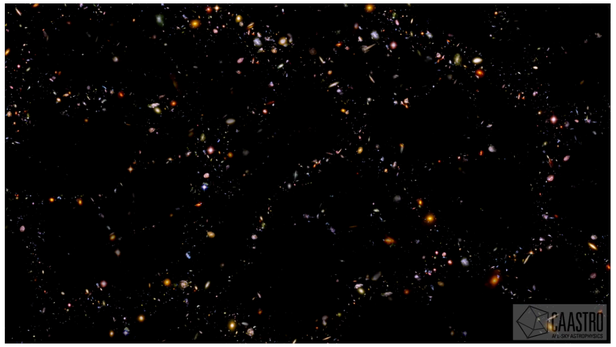
Probing the ΛCDM Universe with 21cm Intensity Mapping Surveys

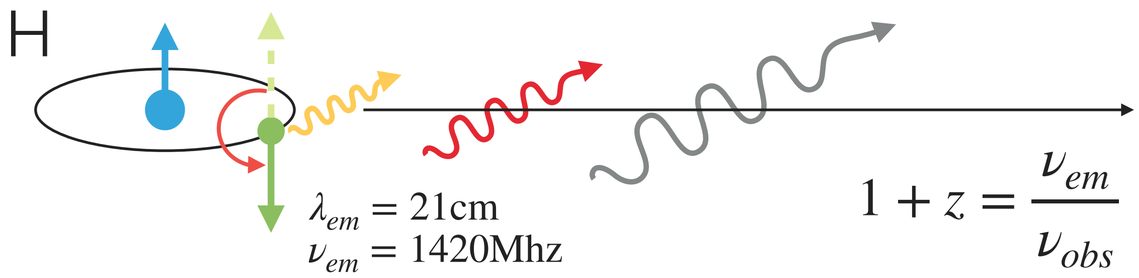
Hydrogen Through Cosmic Time

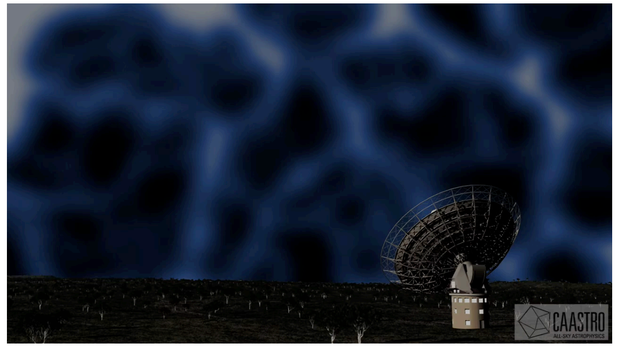


Credit: ESA

21cm Intensity Mapping





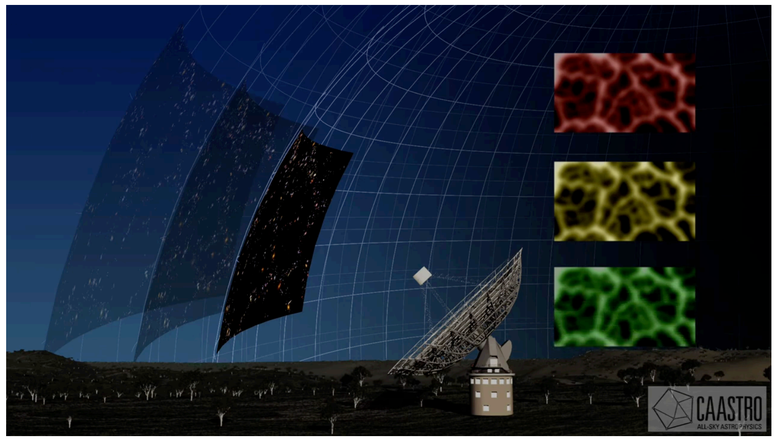


Total intensity of the 21cm emission line in a **large pixel** (low spatial resolution)

↓

Integrated emission from multiple galaxies

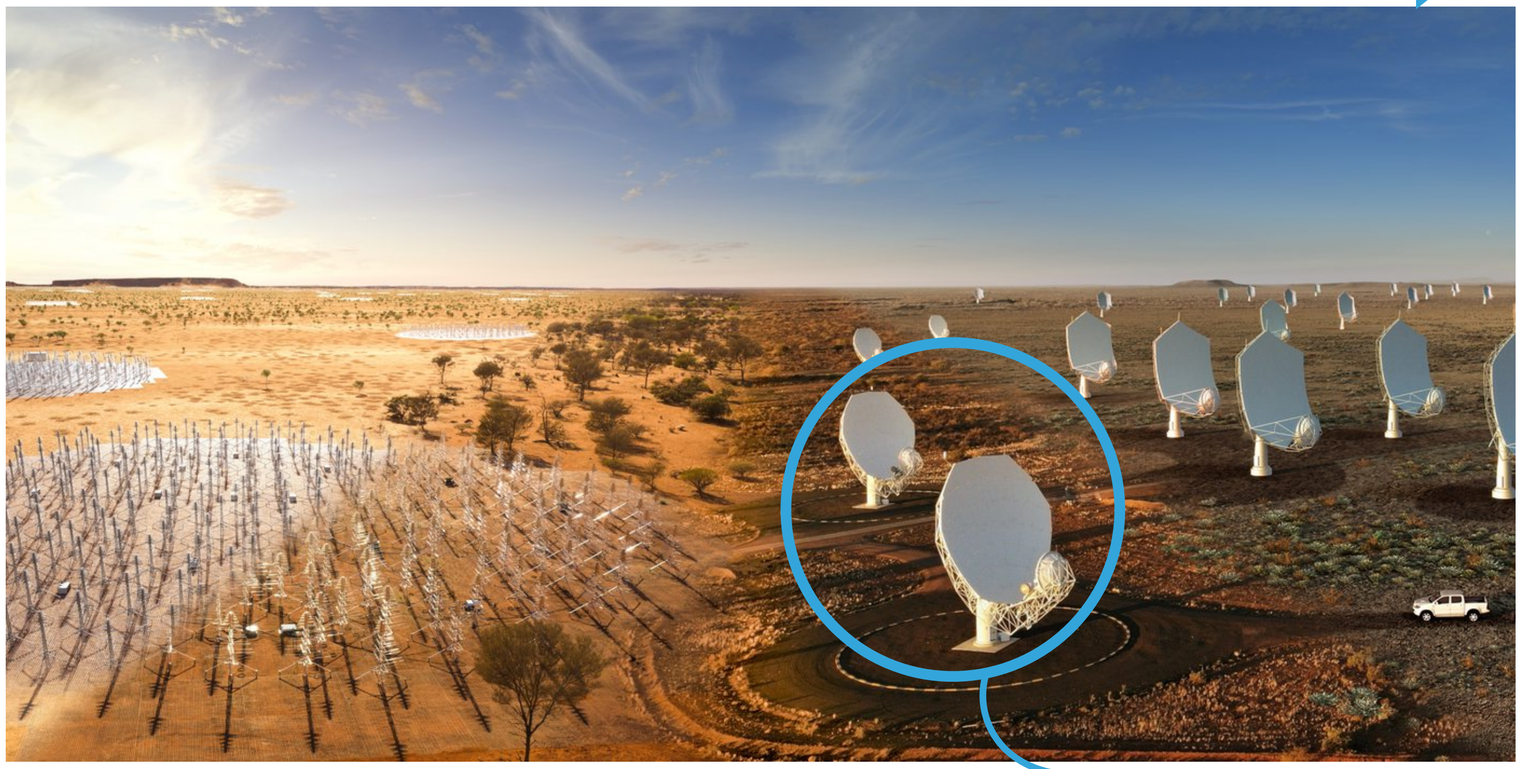
High spectral resolution → **Tomographic** nature



SKA Observatory (SKAO)

Cosmic Dawn, Reionization → post-Reionization Universe

SKA-LOW
50 MHz - 350 MHz
$30 > z > 3$



Credit: skatelescope.org

SKA-MID
350 MHz - 13.5 GHz
$3 > z > 0$

MeerKAT
(SKA pathfinder)
$1.5 > z > 0$

→ Radio frequencies

→ Covers all the relevant frequencies with unprecedented sensitivity

Forecasted 21cm Observations

Credit: skatelescope.org

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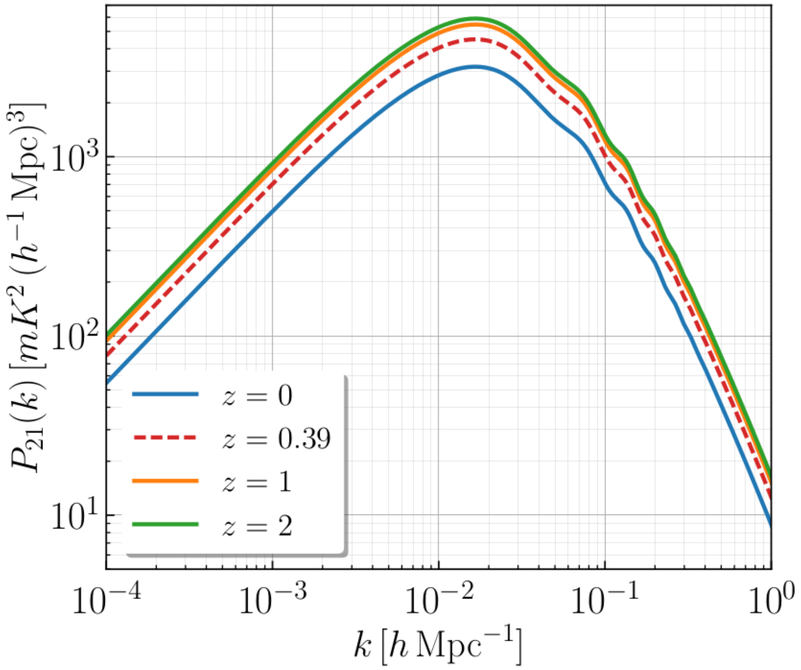
Berti et al. (2022)



We model it as[1]

$$P_{21}(z,k,\mu) = \bar{T}_{\mathrm{b}}^2(z)\ \left[b_{\mathrm{HI}}(z) + f(z)\,\mu^2\right]^2 P_{\mathrm{m}}(z,k)$$

where

- $\bar{T}_{\mathrm{b}}^2(z)$ is the mean brightness temperature
- $b_{\mathrm{HI}}(z)$ is the HI bias
- $f(z)$ is the growth rate
- $\mu = \hat{k} \cdot \hat{z}$
- $P_{\mathrm{m}}(z,k)$ is the matter power spectrum

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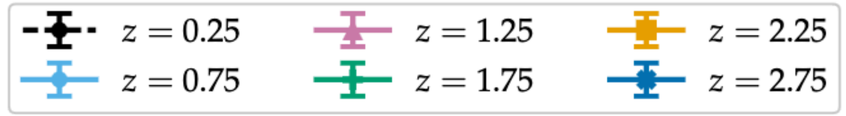
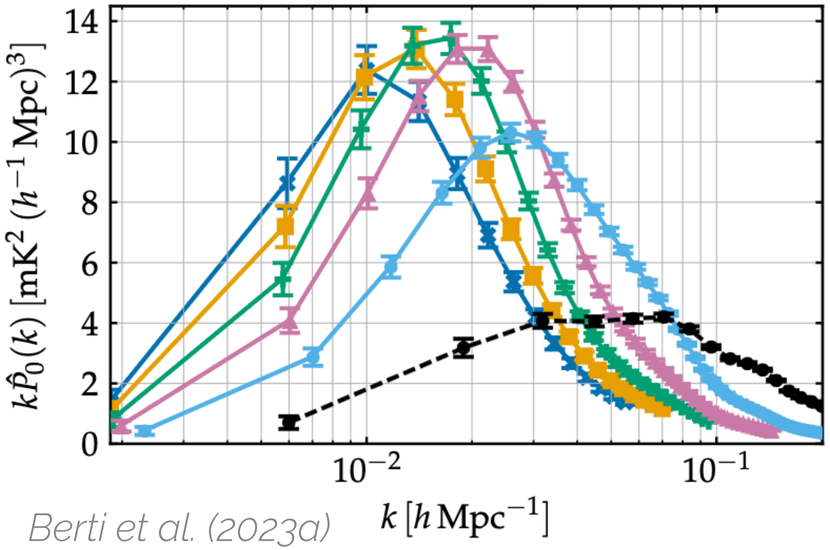
$$P_\ell(z,k) = \frac{(2\ell+1)}{2}\,\bar{T}_{\rm b}^2(z)\,P_{\rm m}(z,k)\int_{-1}^{1} {\rm d}\mu\,\mathscr{L}_\ell(\mu)\,\left[b_{\rm HI}(z)+f(z)\,\mu^2\right]^2$$

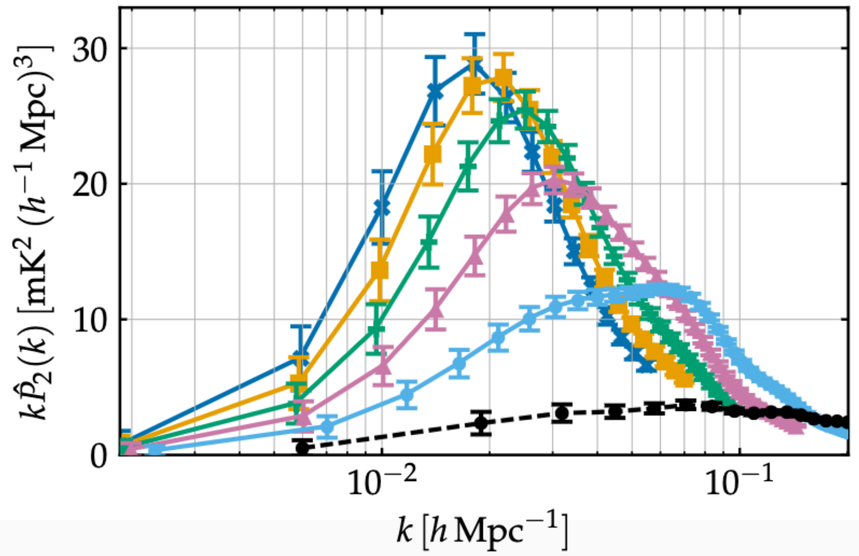
$$P_{21}(z,k,\mu) = \bar{T}_{\rm b}^2(z)\,\left[b_{\rm HI}(z)+f(z)\,\mu^2\right]^2 P_{\rm m}(z,k)$$

SKAO
Power spectrum monopole and quadrupole
Six bins in $z = 0 - 3$





Berti et al. (2023a)



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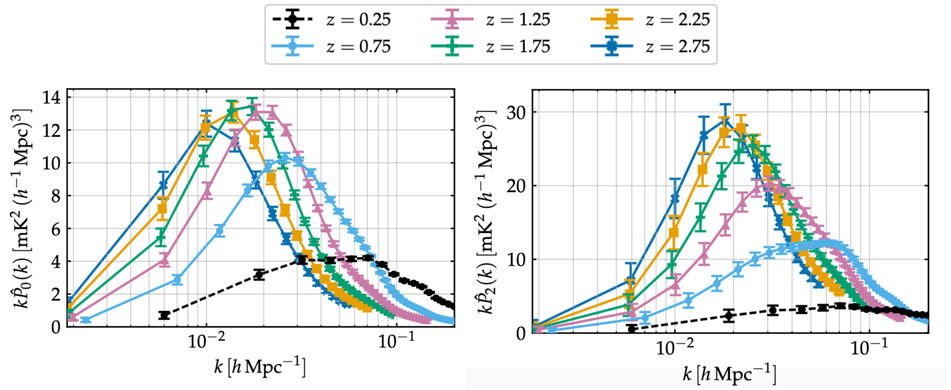


Monopole

Quadrupole

Analysis

MCMC analysis on the full set of cosmological parameters, from 21cm observables alone and combined with CMB → Likelihood code integrated with CosmoMC

Testing

ΛCDM

$\Omega_c h^2$ $\Omega_b h^2$
τ θ_s A_s
n_s

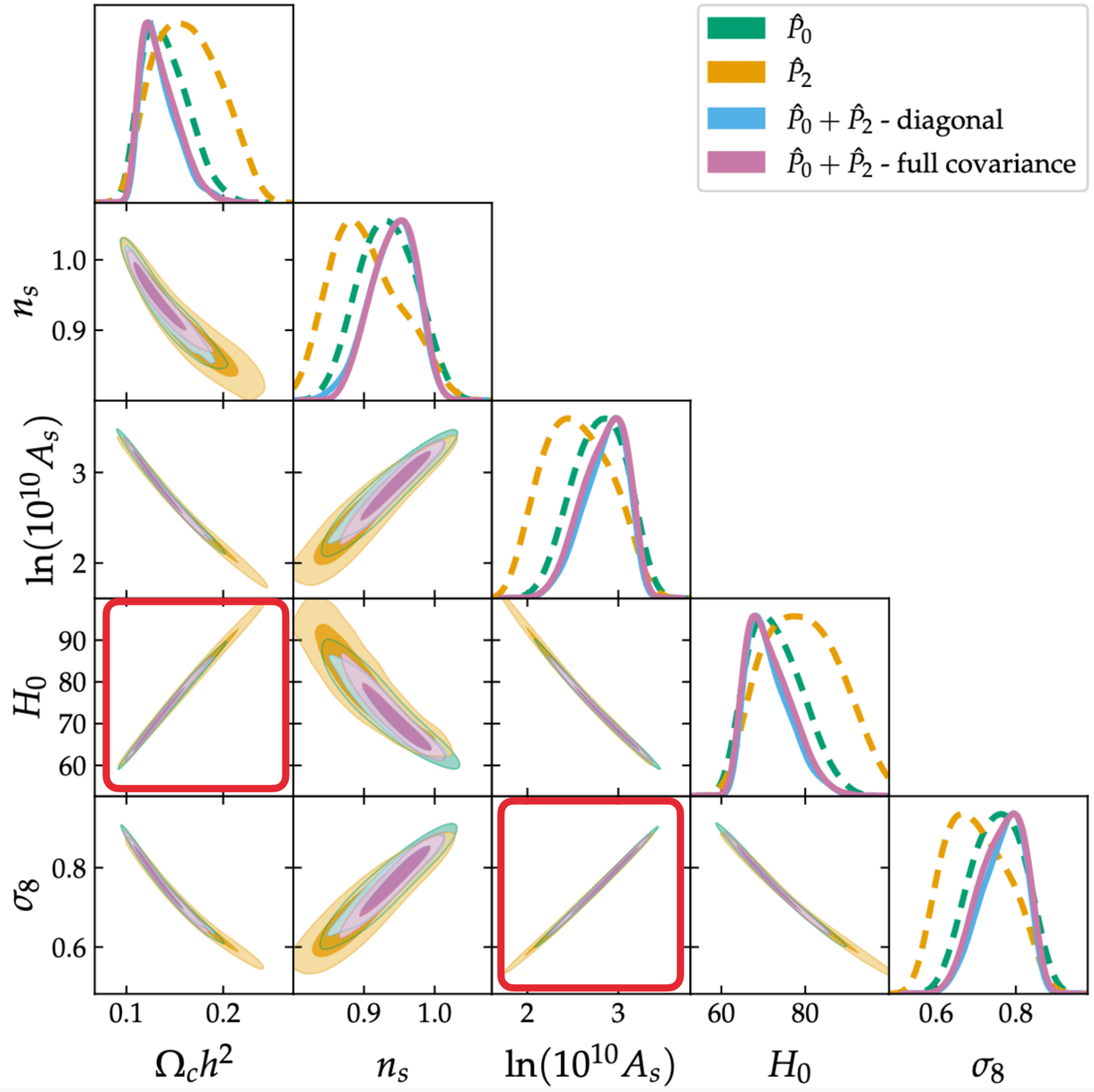
EFT of Dark Energy

$\Omega_0^{\rm EFT}$

Neutrino cosmologies

Σm_ν

Constraints From the 21cm Signal



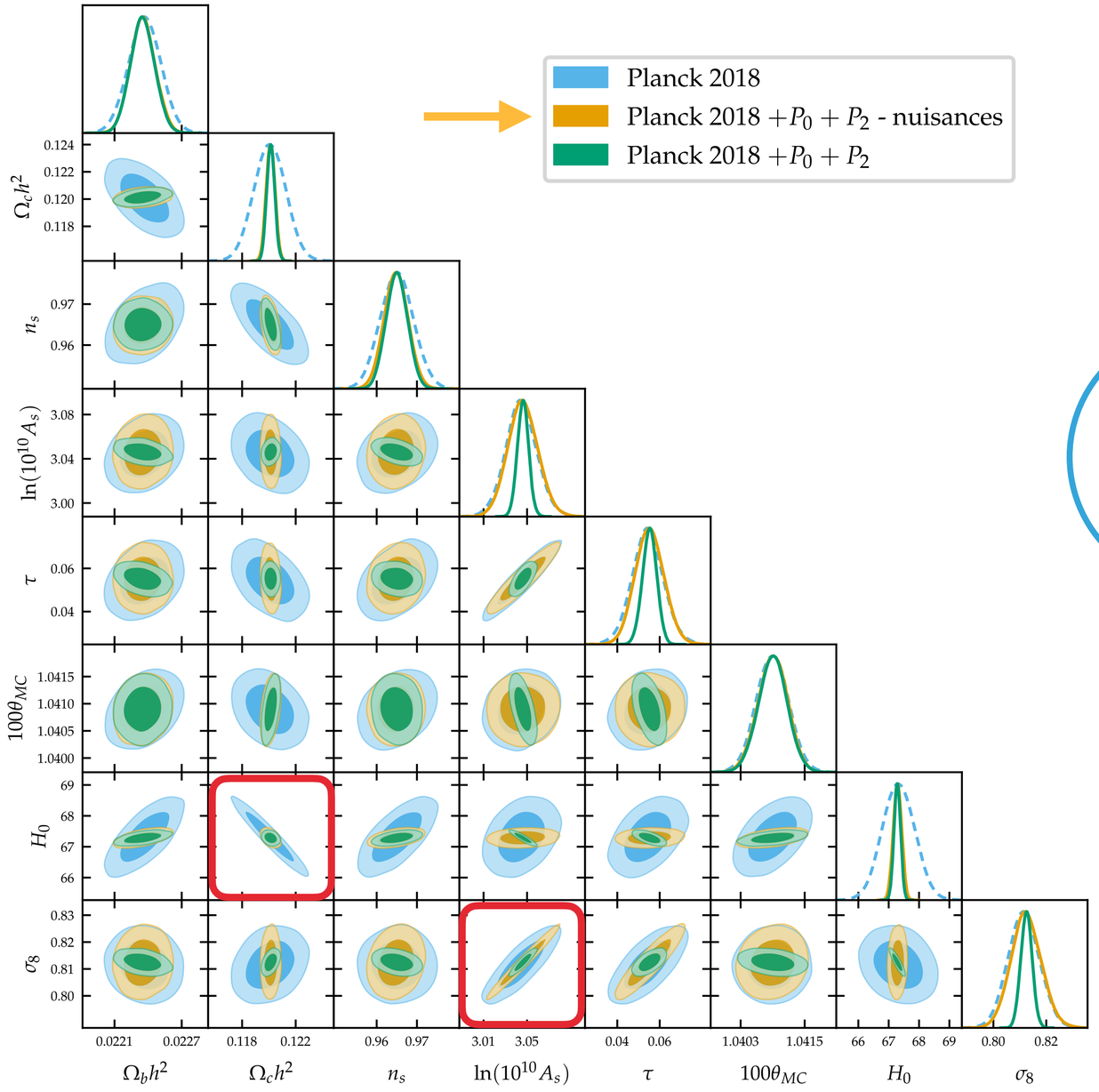
Berti et al. (2023a)

Analysis set up

- Full MCMC analysis
- Implement a new likelihood code integrated with CosmoMC
- Varying the full set of cosmological parameters $\{\Omega_b h^2, \Omega_c h^2, \tau, \theta_{\rm MC}, A_s, n_s\}$
- Test the constraining power of the 21cm signal alone and combined with CMB

- Multiples' mock data set - 6 bins
- 21cm alone has a good constraining power on the cosmological parameters
- Marked correlations ($\Omega_c h^2 - H_0$ and $\sigma_8 - A_s$)

Constraints in Combination With CMB



Berti et al. (2023a)

Planck TT, TE, EE + lowE + lensing

Parameter	Planck 2018	$+P_0 + P_2$
$\Omega_b h^2$	0.64%	0.49%
$\Omega_c h^2$	0.99%	0.25%
n_s	0.42%	0.27%
$\ln(10^{10} A_s)$	0.46%	0.17%
τ	13.44%	6.09%
$100\theta_{MC}$	0.03%	0.03%
H_0	0.79%	0.16%
σ_8	0.73%	0.26%

- Constraints are significantly improved with respect to Planck alone
- Removed degeneracies
- We loose constraining power when introducing astrophysical nuisances

Conclusions

1. The results we found are in agreement with similar works in the literature and confirm the key role of present and future late-time 21cm intensity mapping observations.
2. Combining 21cm power spectrum measurements to CMB observations leads to a substantial improvement of the constraints on $\Omega_c h^2$ and H_0.
3. 21cm intensity mapping measurements provide a new interesting cosmological probe, that carries rich information complementary to other high-precision cosmological observations.

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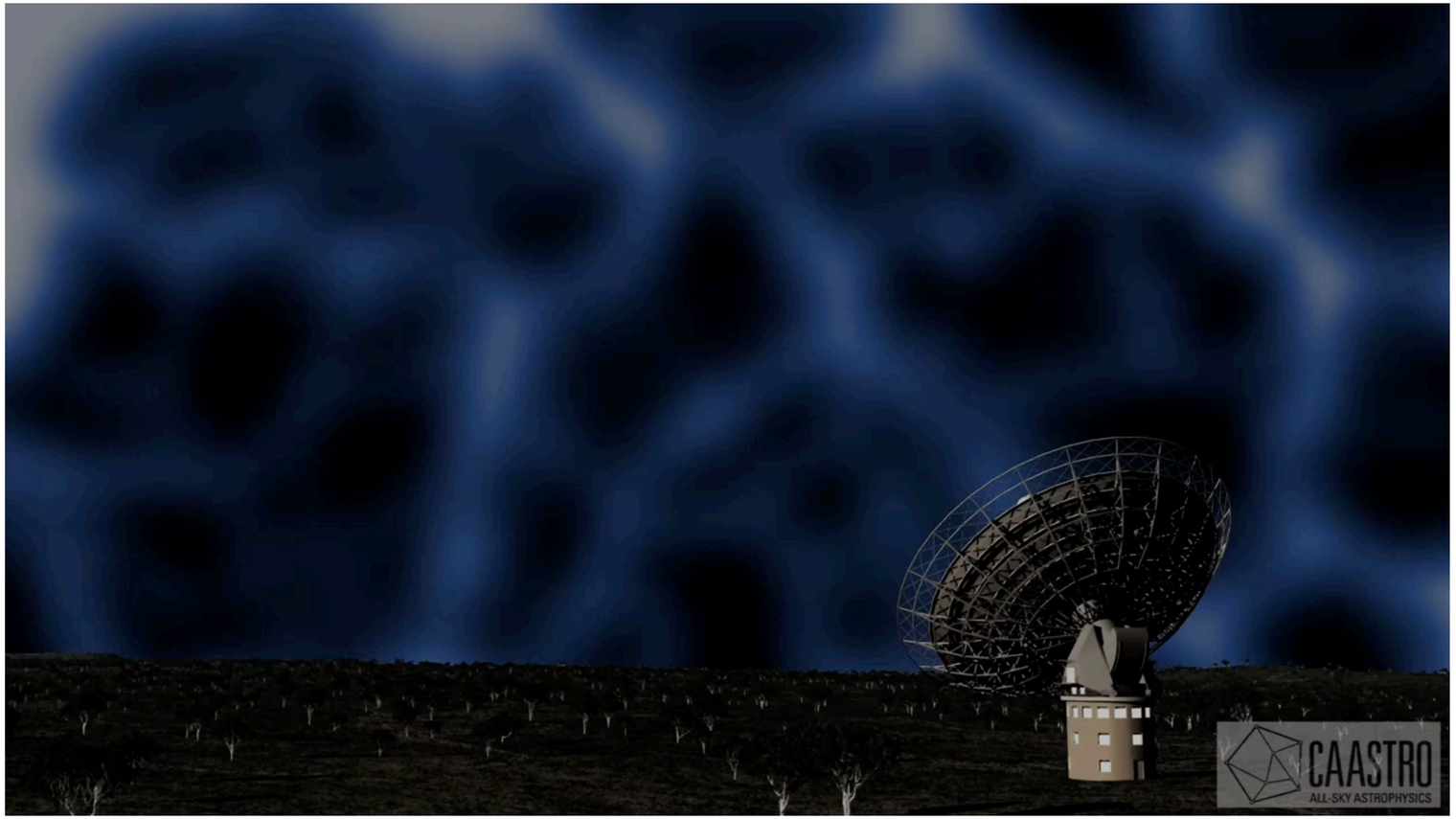

M. Berti, M. Spinelli, B. S. Haridasu, M. Viel, A. Silvestri, JCAP 01.01 (2022), ArXiv:**2109.03256**.

M. Berti, M. Spinelli, M. Viel, Mon. Not. Roy. Astron. Soc. 521.3 (2023), ArXiv:**2209.07595**.

M. Berti, M. Spinelli, and M.Viel, Mon. Not. Roy. Astron. Soc. 529.4 (2024), ArXiv:**2309.00710**.

Thank you!