HERA Phase I Limits on the Cosmic 21-cm Signal:

Constraints on Astrophysics and Cosmology During the Epoch of Reionization

(2108.07282)

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- neutral hydrogen fraction
- 21-cm signal and its power spectra
- X-ray luminosity
- IGM temperature during the EoR

Reionization and 21cm

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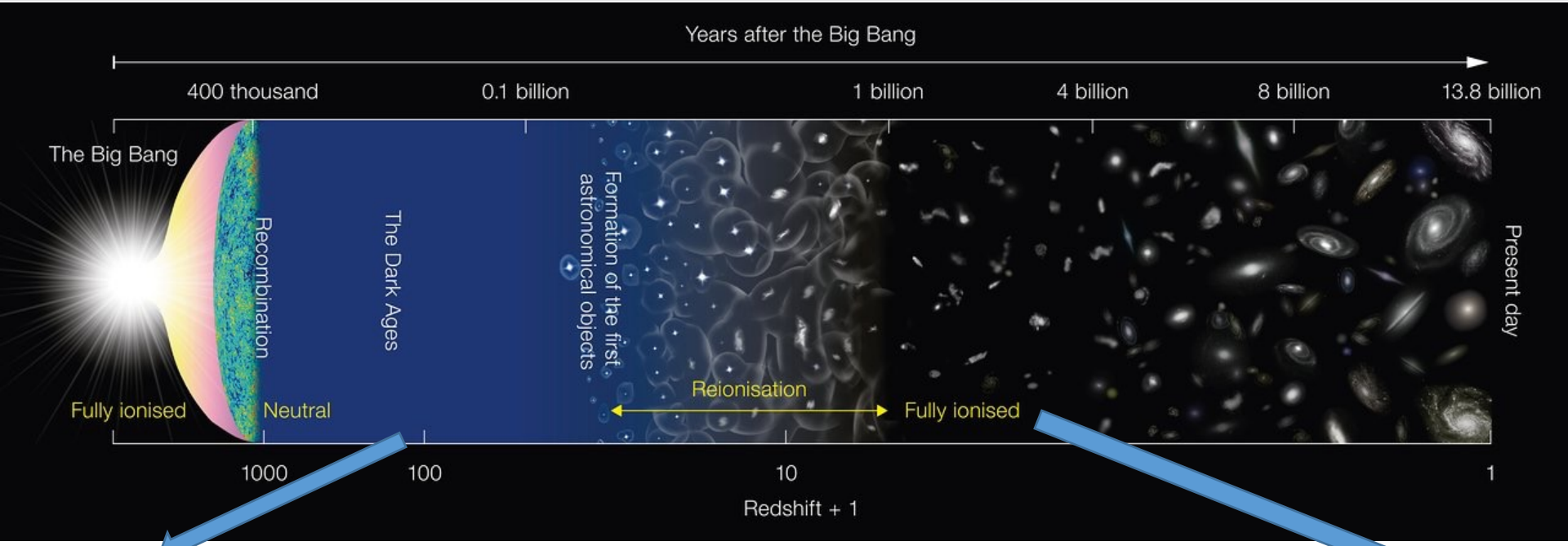

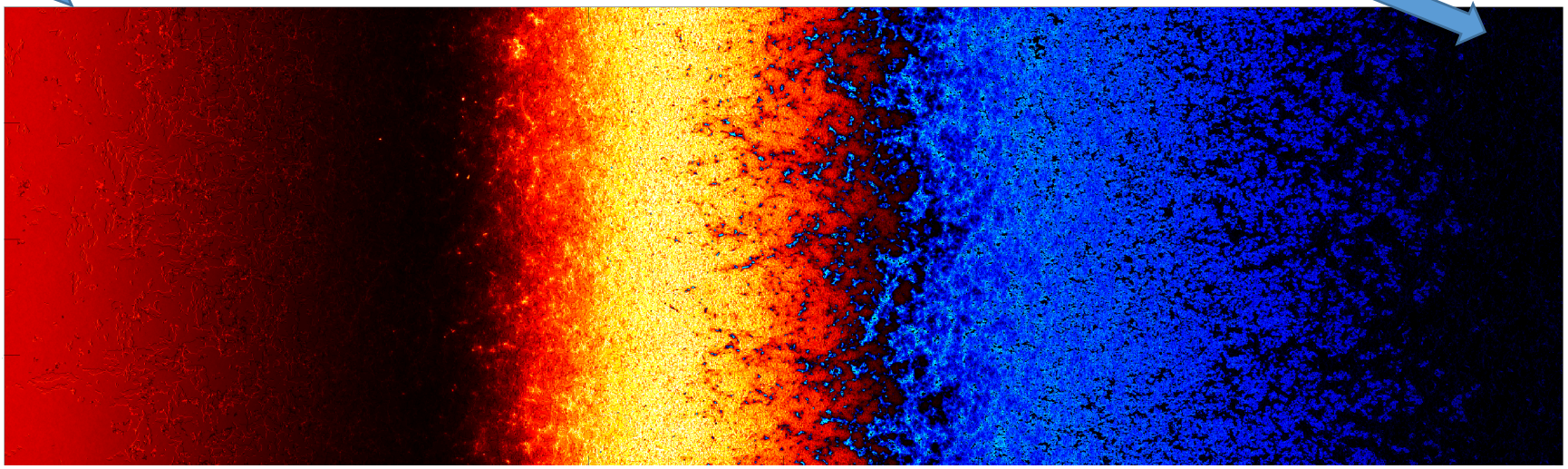

Reionization and 21cm

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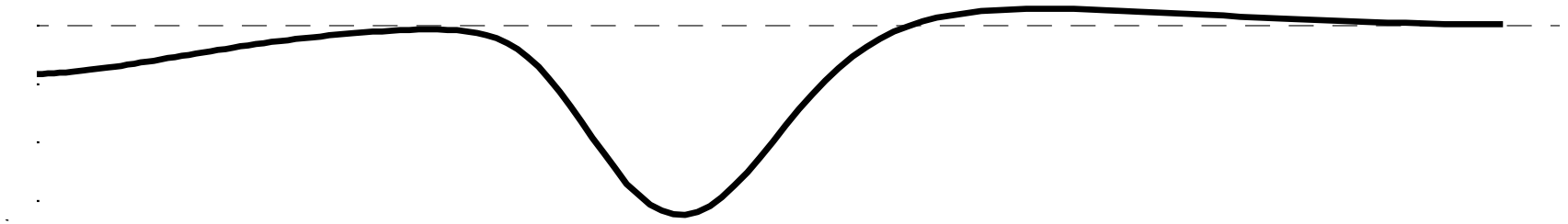
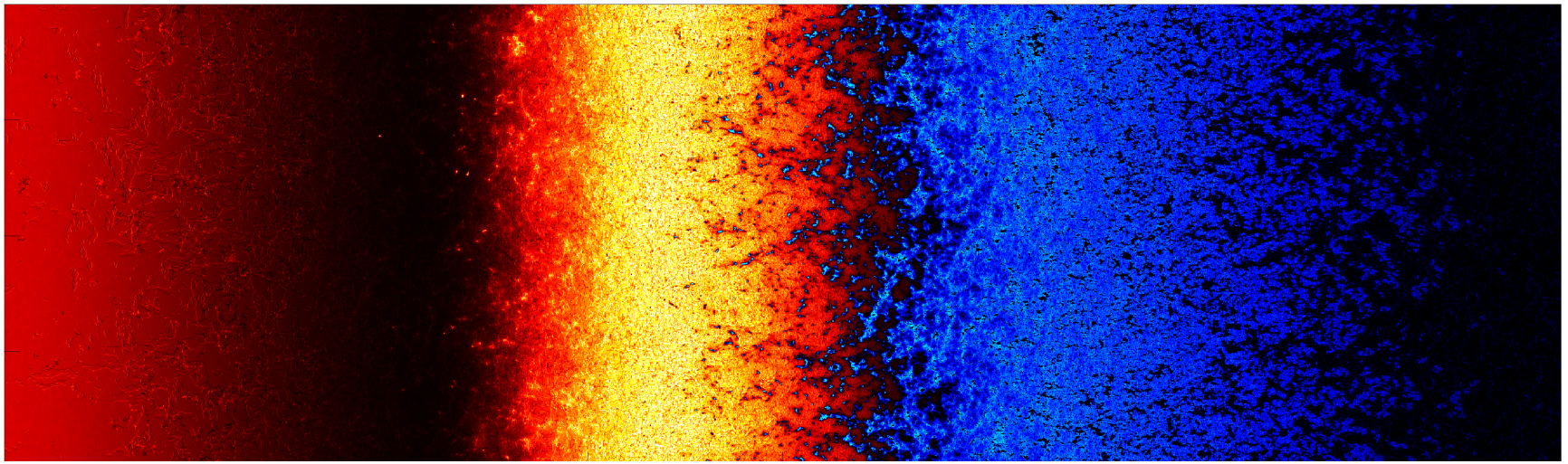
$$\delta T_{\rm b}(\nu) = \left(T_{\rm s} - T_{\rm CMB}\right)\frac{1-e^{-\tau_{\nu_0}}}{1+z} \approx 21{\rm mK}\frac{1+\delta}{1+H^{-1}\frac{{\rm d}v}{{\rm d}r}}\, x_{\rm HI}\left(1-\frac{{\rm T_{CMB}}}{T_{\rm s}}\right)\sqrt{\frac{1+z}{10}\frac{0.15}{\Omega_{\rm m}h^2}\frac{\Omega_{\rm b}h^2}{0.023}}$$

21cm measures HI emission

21cm is physics rich, involving cosmology and galaxy properties including UV ionizing and X-ray heating





The Hydrogen Epoch of Reionization Array

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HERA is now under construction in the Karoo Desert of South Africa (DeBoer et al. 2017).

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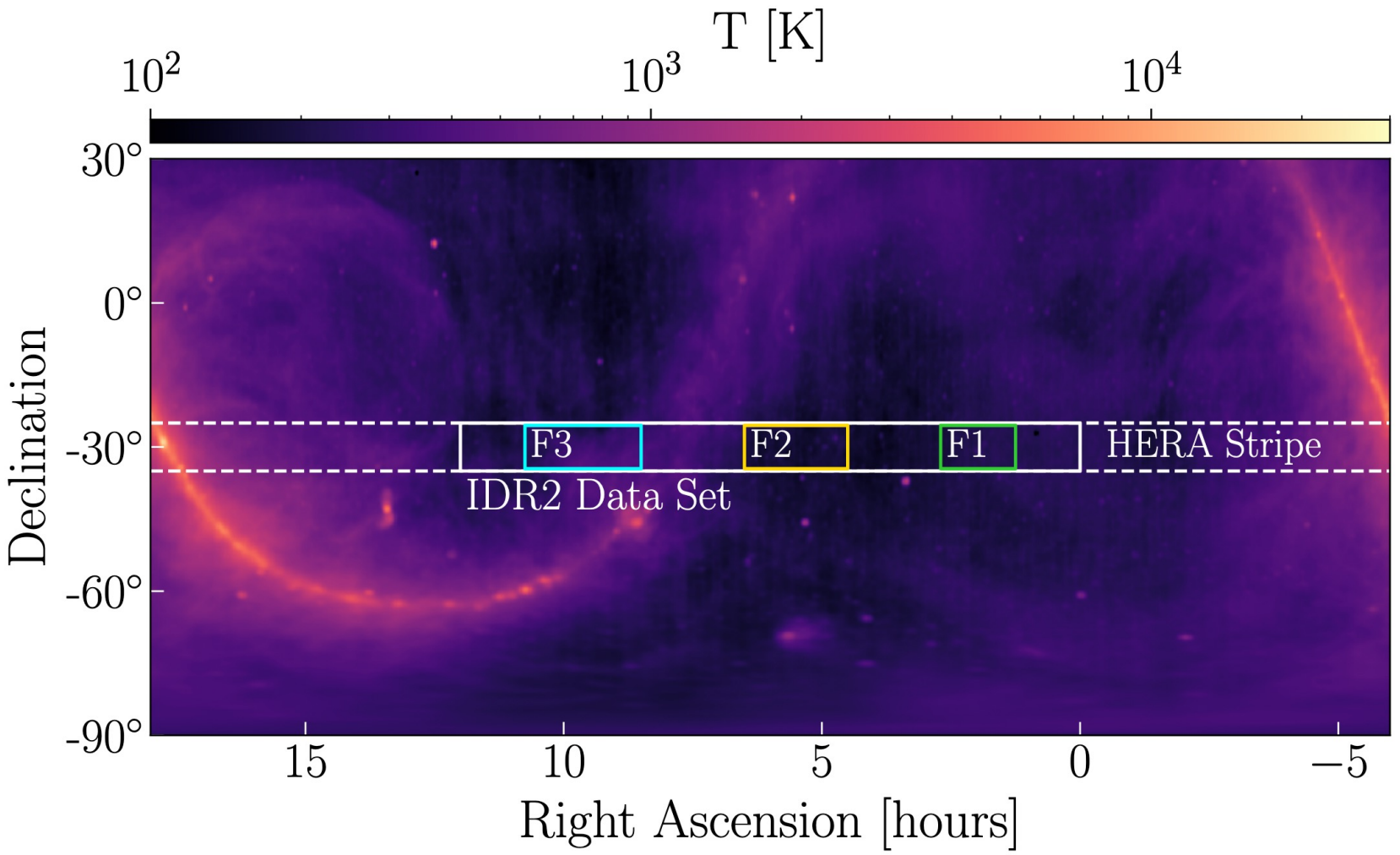
An initial observing campaign in 2017-18, with just 39/~350 antennas (2108.02263).



The Hydrogen Epoch of Reionization Array

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HERA is now under construction in the Karoo Desert of South Africa (DeBoer et al. 2017).
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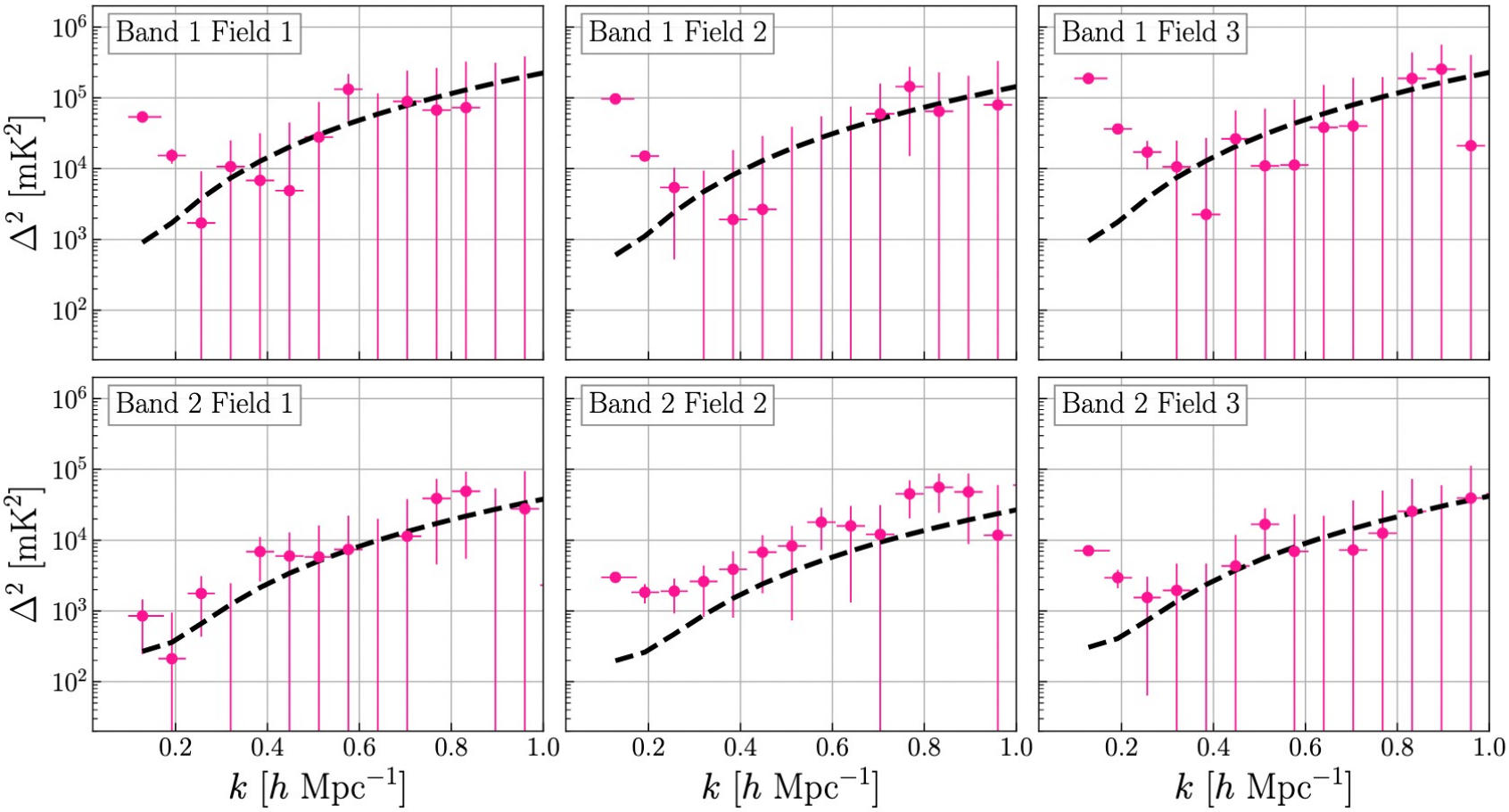
Upper limits obtained from 3 fields (Field 1 is the best) over two bands (z=10.4 and 7.9).



21cmFAST

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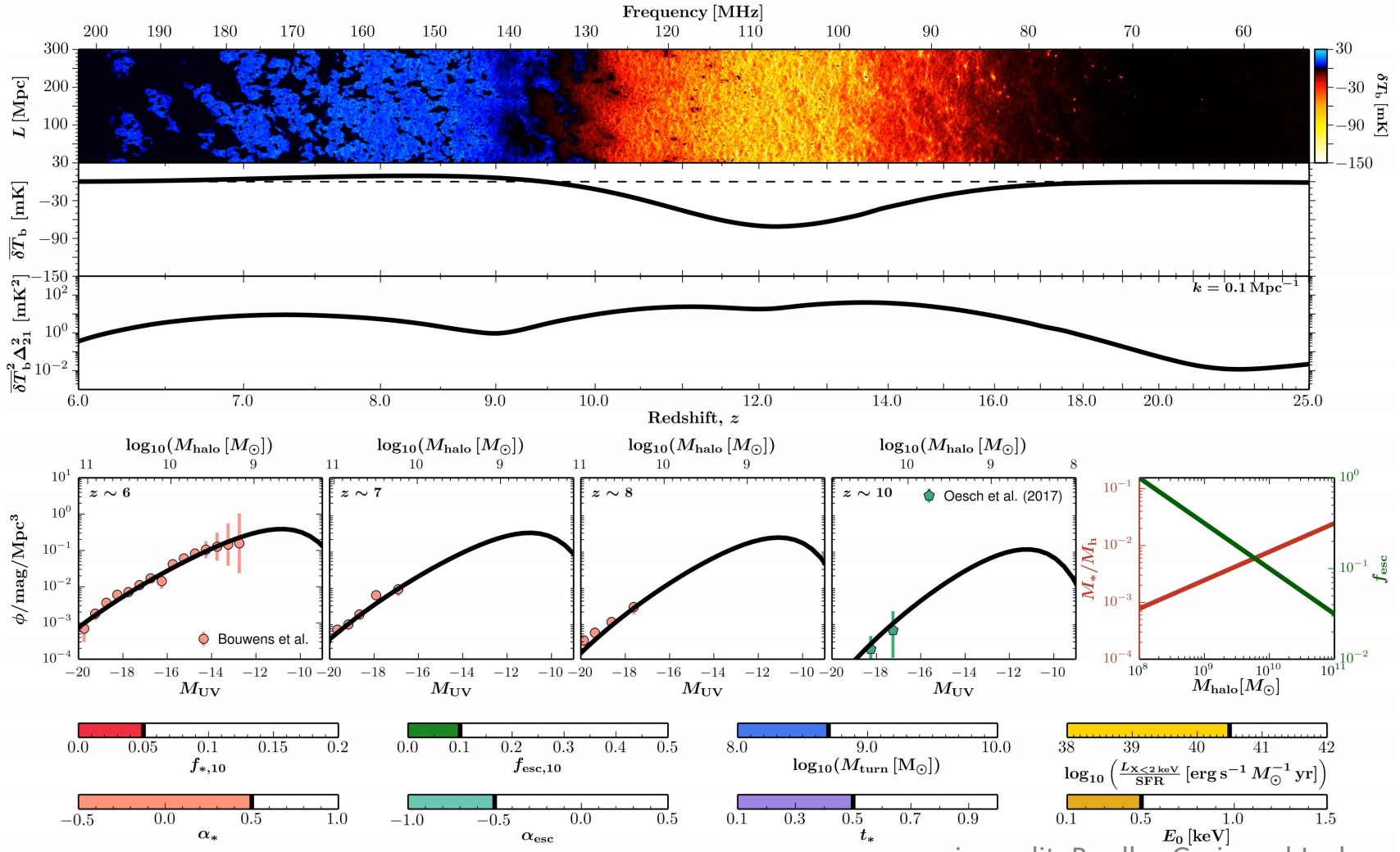
For each inference, we ran 500,000 simulations like this, varying 9 free parameters representing galaxy UV ionizing and X-ray heating properties.



movie credit: Bradley Greig and Jaehong Park

21CMMC

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Bayes' rule
Posterior = Prior x Likelihood

Inferencing steps:

Choose a point in high dimensional parameter space

↓

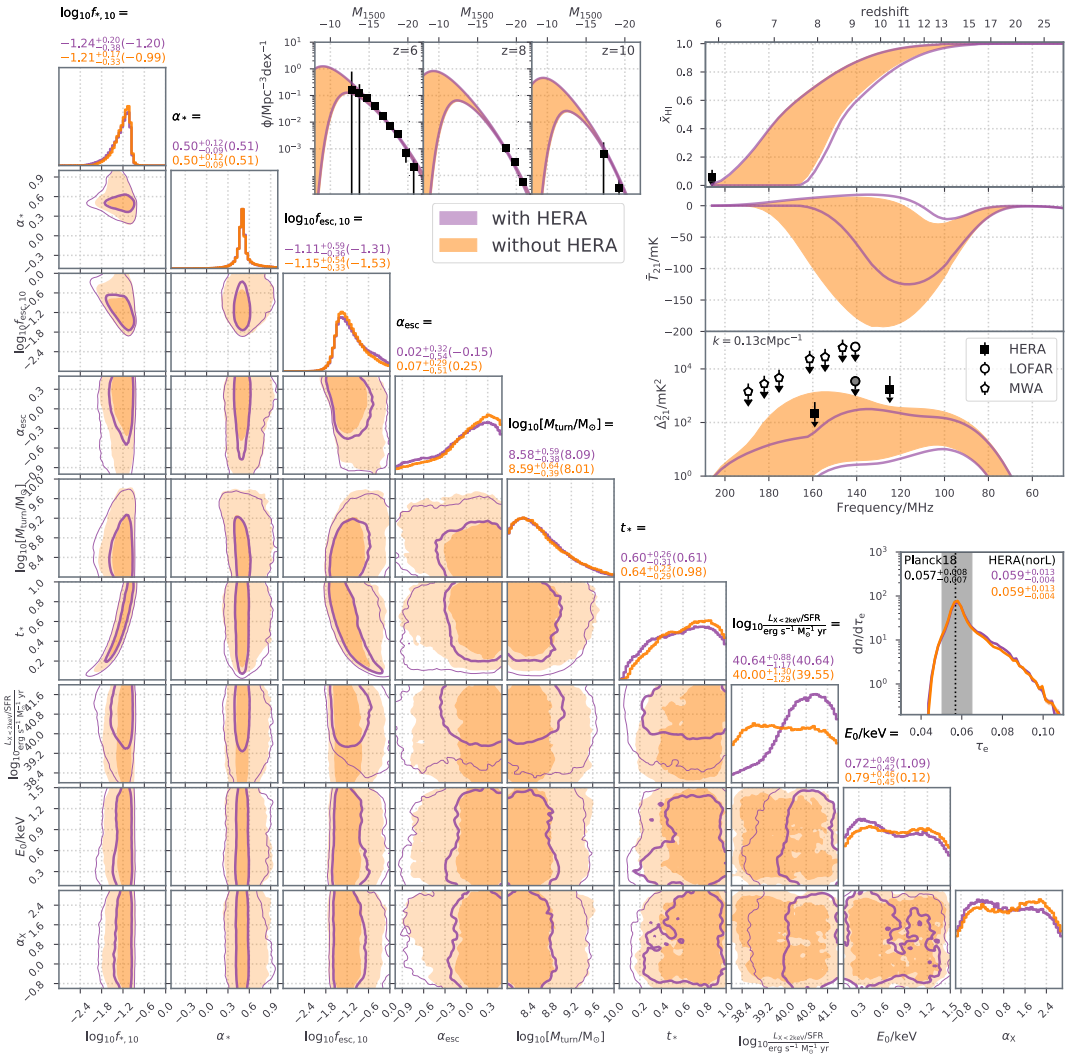
Forward model observables

↓

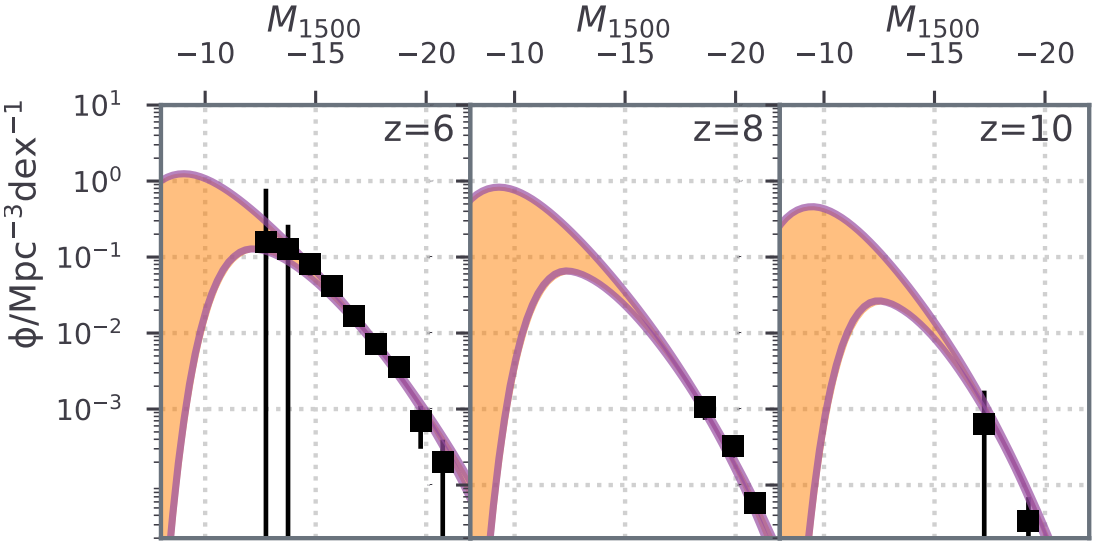
Compare the prediction against real observation (i.e. evaluate a likelihood probability)

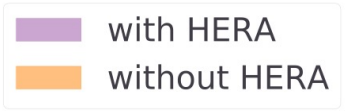
↓

Accept/reject the point



Results – LF, CMB, xH





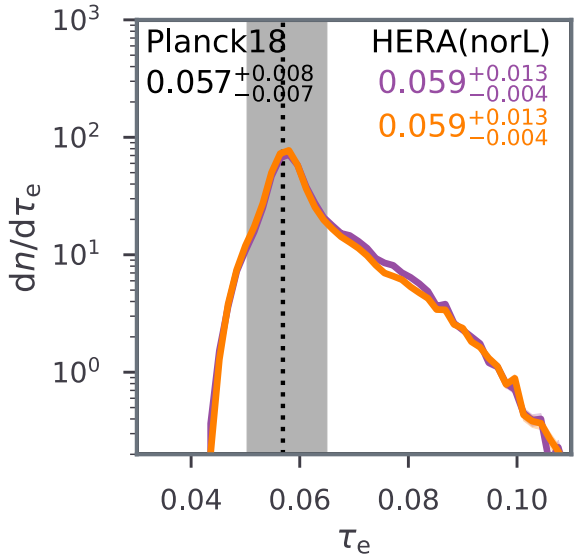
Observational constraints include:

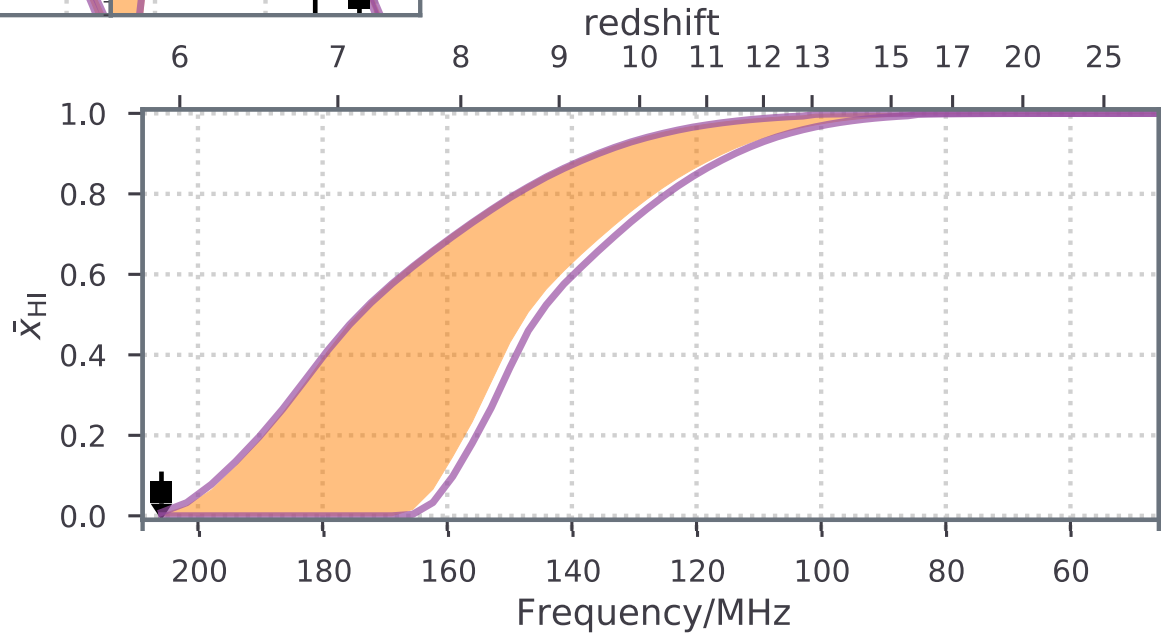
High-z UV LF (Bouwens+15,16; Oesch+17)

CMB tau_e (Planck+18; Qin+20)

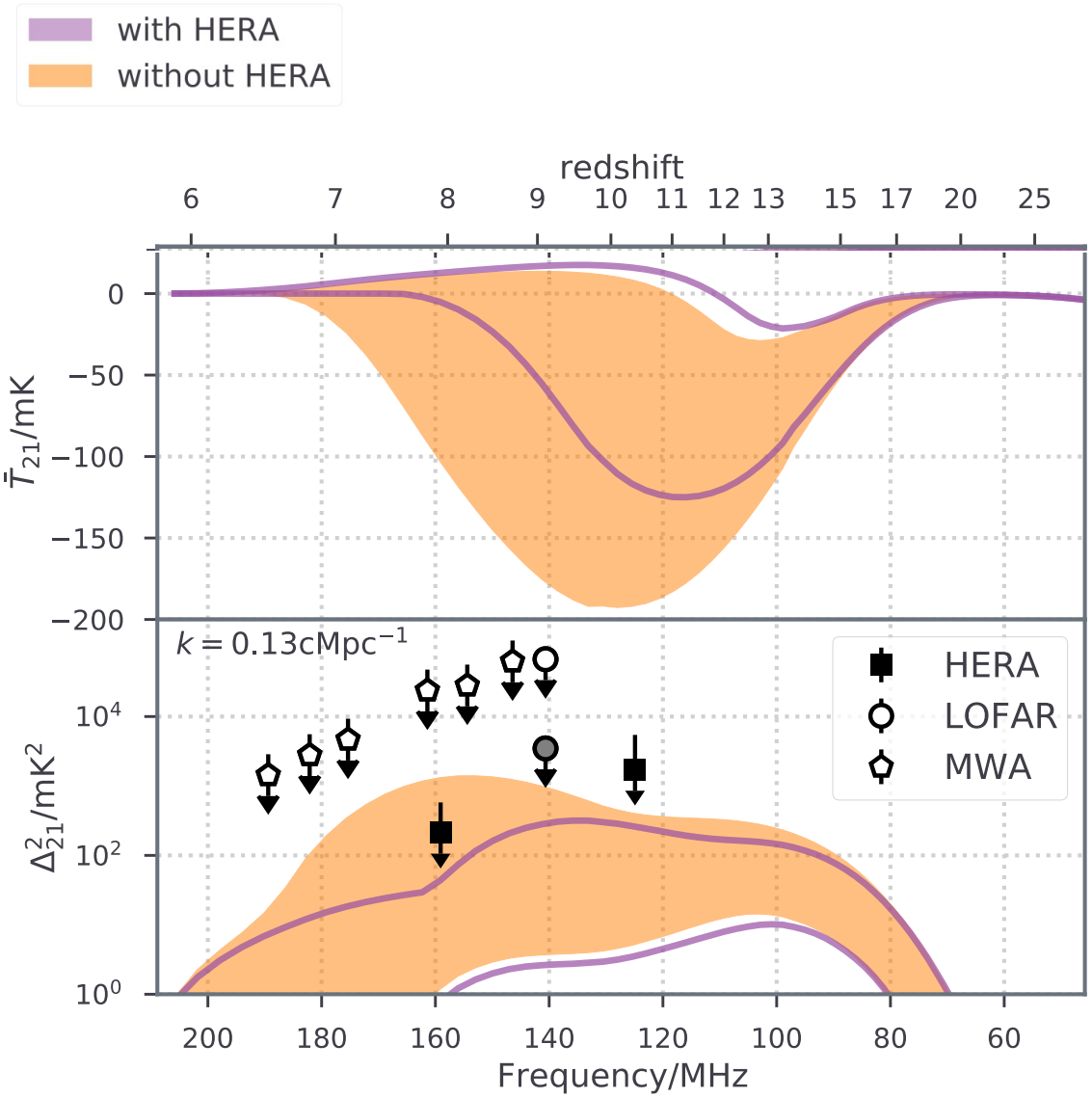
Quasar spectra xH(z=6) (McGreer+15)

With or without HERA, the posterior looks very similar





Results – 21cm signal and power spectra

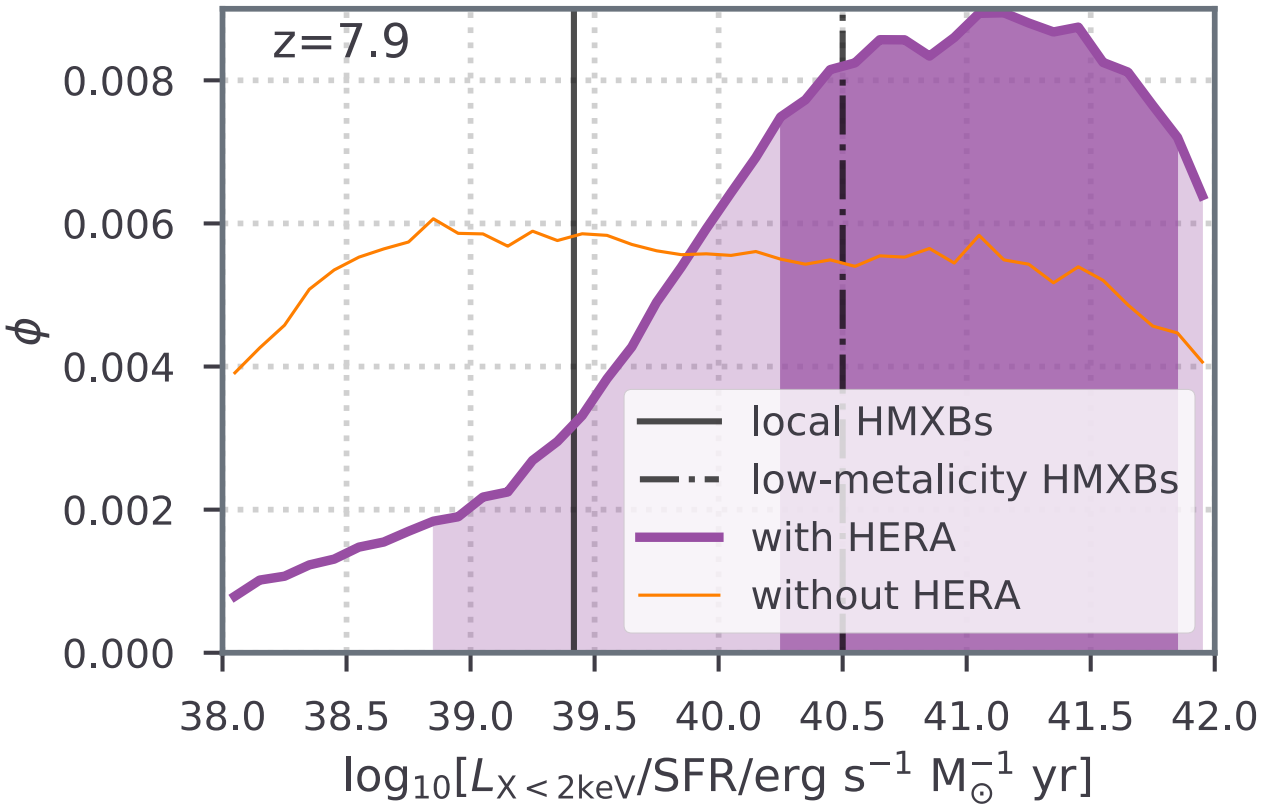


HERA does help rule out a few models with excessive power (due to weak heating) at z=7.9

HERA has the lowest (i.e. best) upper limits so far compared to LOFAR (Mertens+20; Greig+20) and MWA (Trott+20; Greig+21)

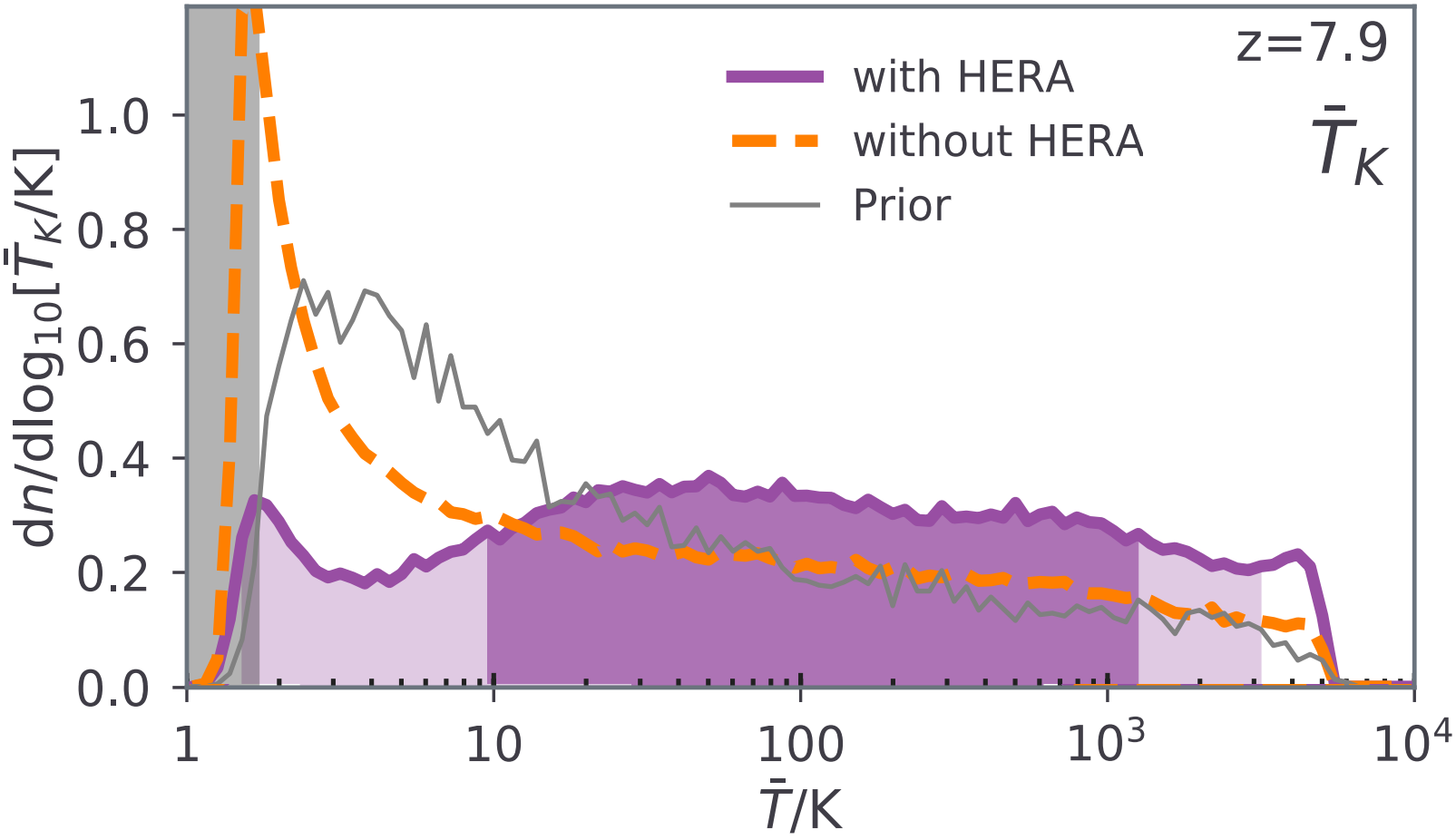
:

Results – X-ray luminosity



HERA is the first observation to constrain the X-ray luminosities of Cosmic Dawn galaxies (e.g., Fragos+13), disfavoring the values seen in local, metal- enriched galaxies (e.g., Mineo+12) at > 1σ.

Results – IGM temperature



HERA limits indicate that the neutral IGM must have been heated to 8.9-1300K (68% C.L.) at z=7.9 (adiabatic cooling limit = 1.7K)

Conclusion

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21cm measures HI emission. It is physics rich, involving cosmology and galaxy properties including UV ionizing and X-ray heating

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Yet, it holds the lowest (i.e., best) upper limits so far compared to LOFAR (Mertens+20; Greig+20) and MWA (Trott+20; Greig+21)

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Thanks!

More results in 2108.07282 (e.g., inverse likelihood, density-driven bias model; phenomenological models; dark-matter interpretation; extra radio background)

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