

Wenzer Qin

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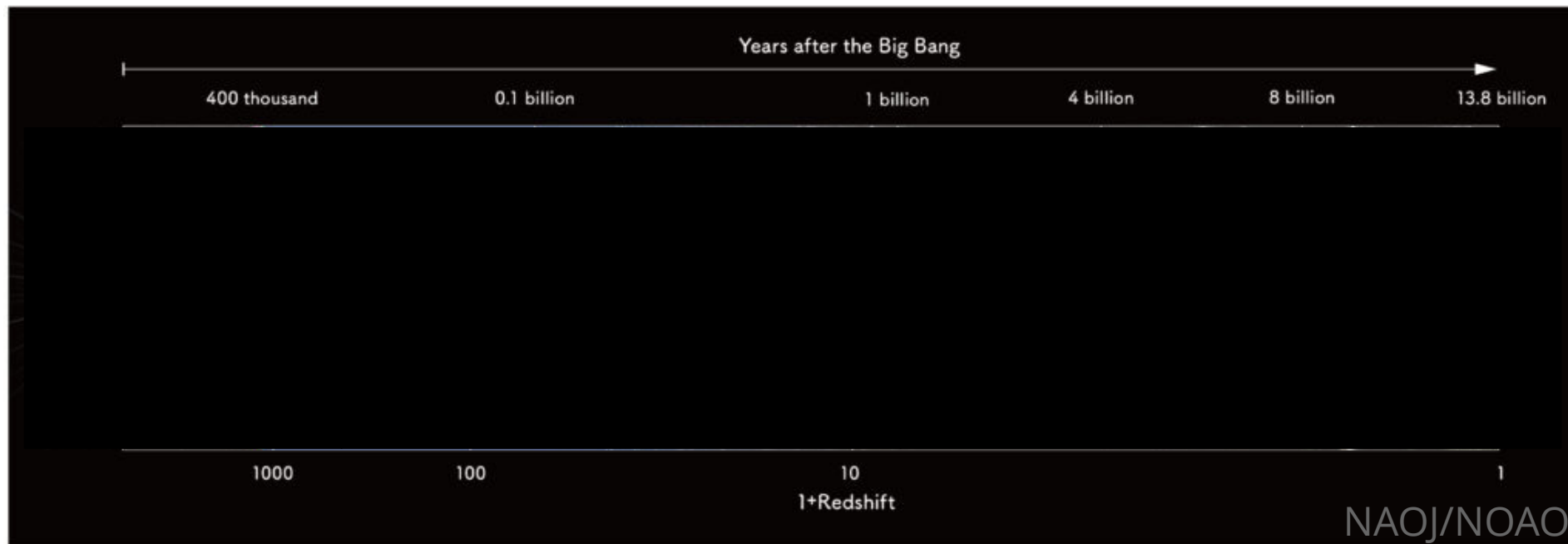
EXTENDING the EFFECTIVE FIELD THEORY of 21CM RADIATION

based on 2205.06270

*Pheno
MAY 9TH , 2023*

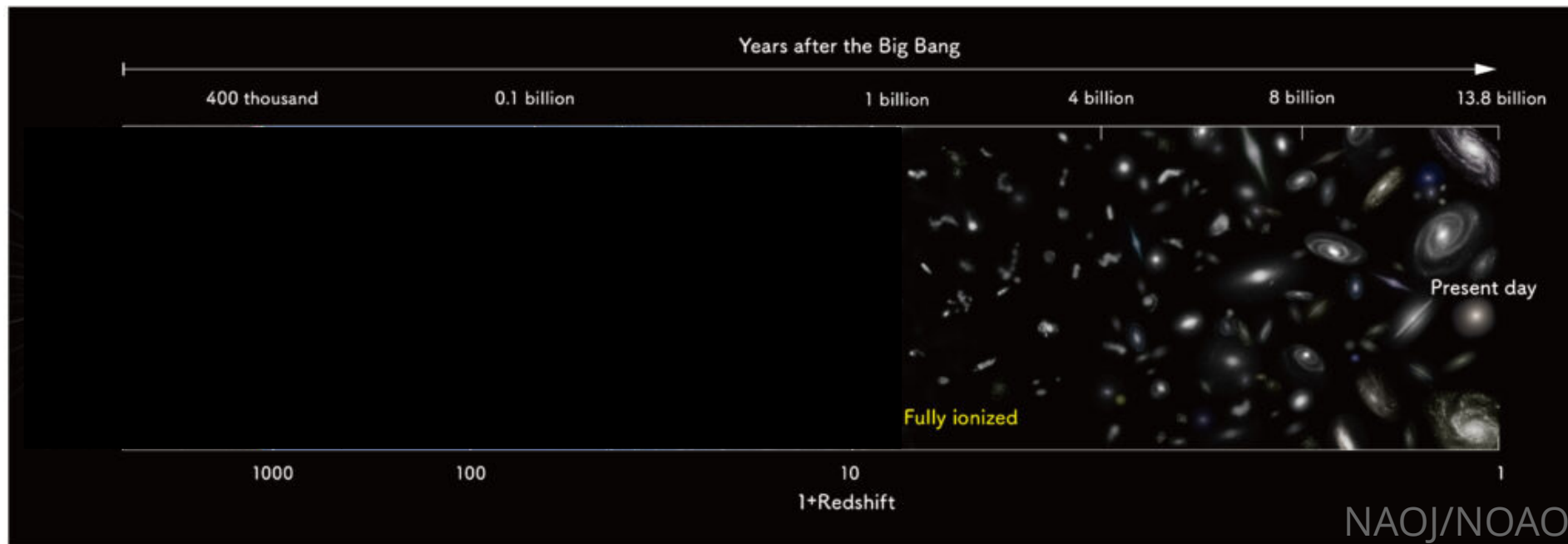
WHAT IS 21CM COSMOLOGY?

- What redshifts have we directly measured?



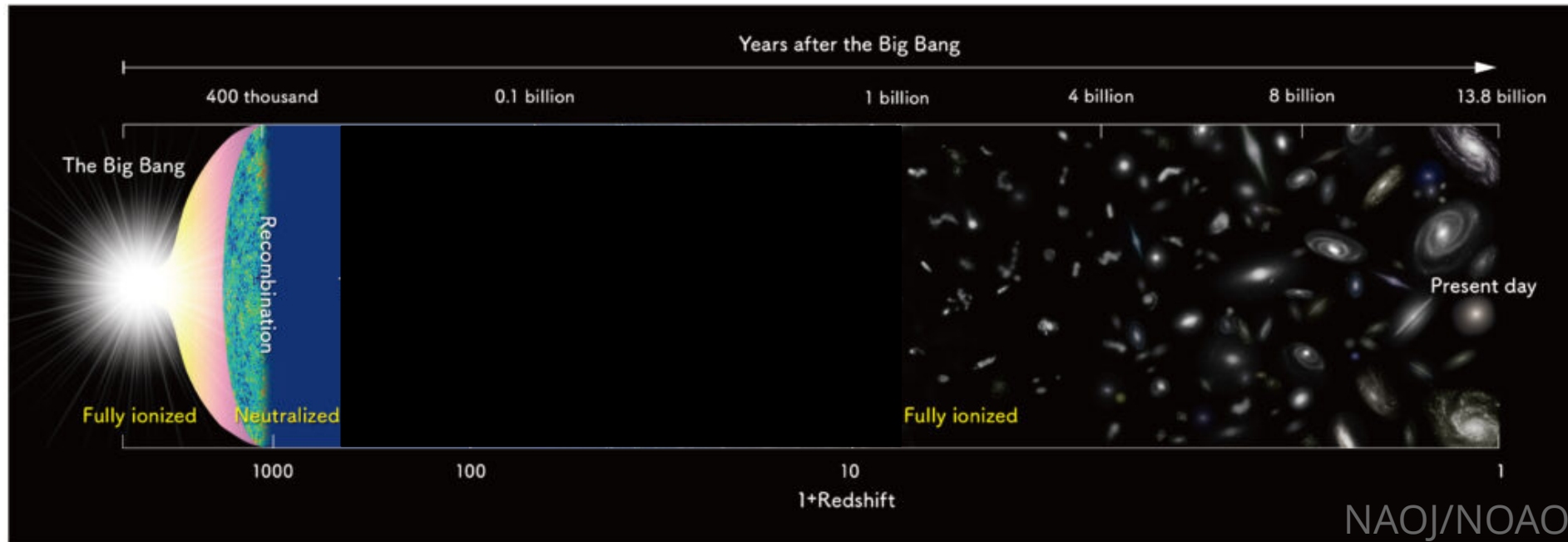
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- What redshifts have we directly measured?
 - $z \sim \text{few}$: e.g. galaxy surveys



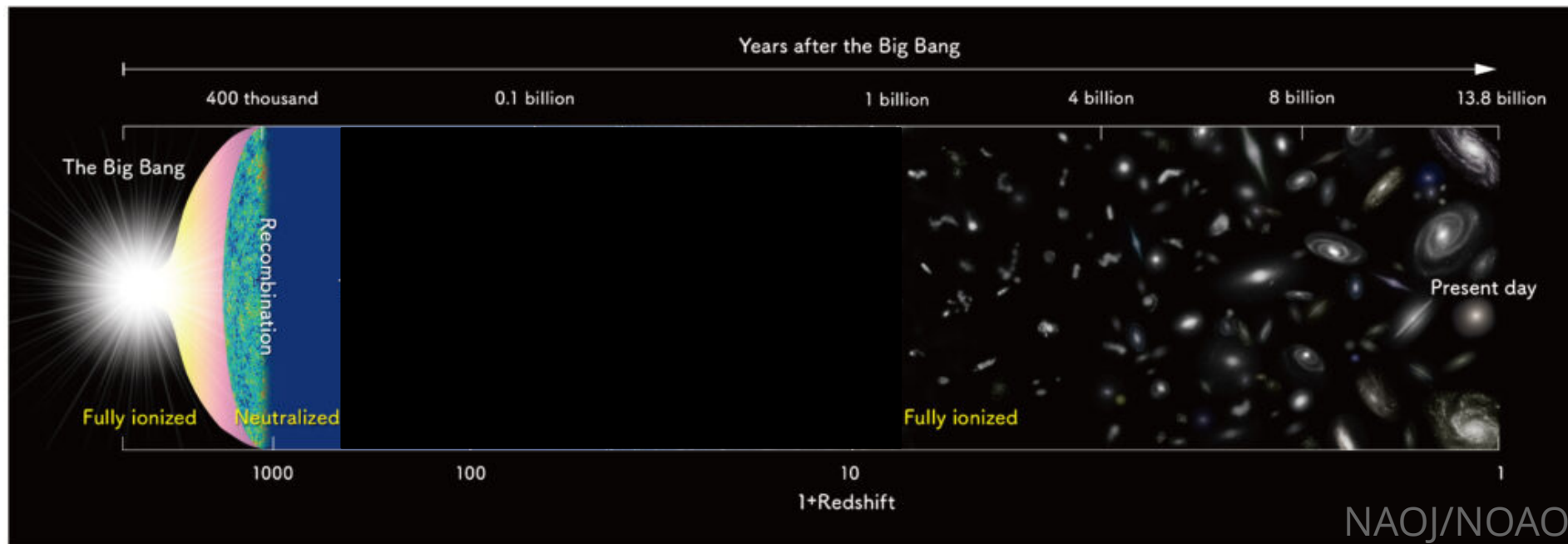
WHAT IS 21CM COSMOLOGY?

- What redshifts have we directly measured?
 - $z \sim \text{few}$: e.g. galaxy surveys
 - $z = 1100$: cosmic microwave background



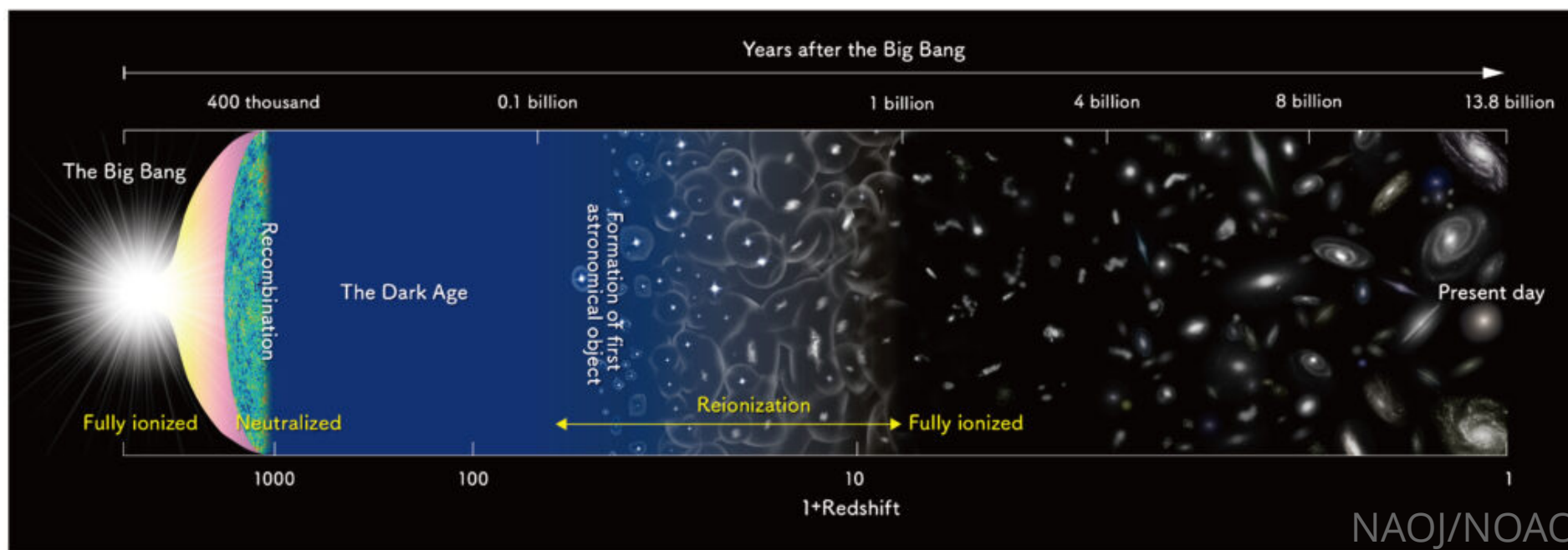
WHAT IS 21CM COSMOLOGY?

- In between, there are few stars/galaxies, only diffuse hydrogen



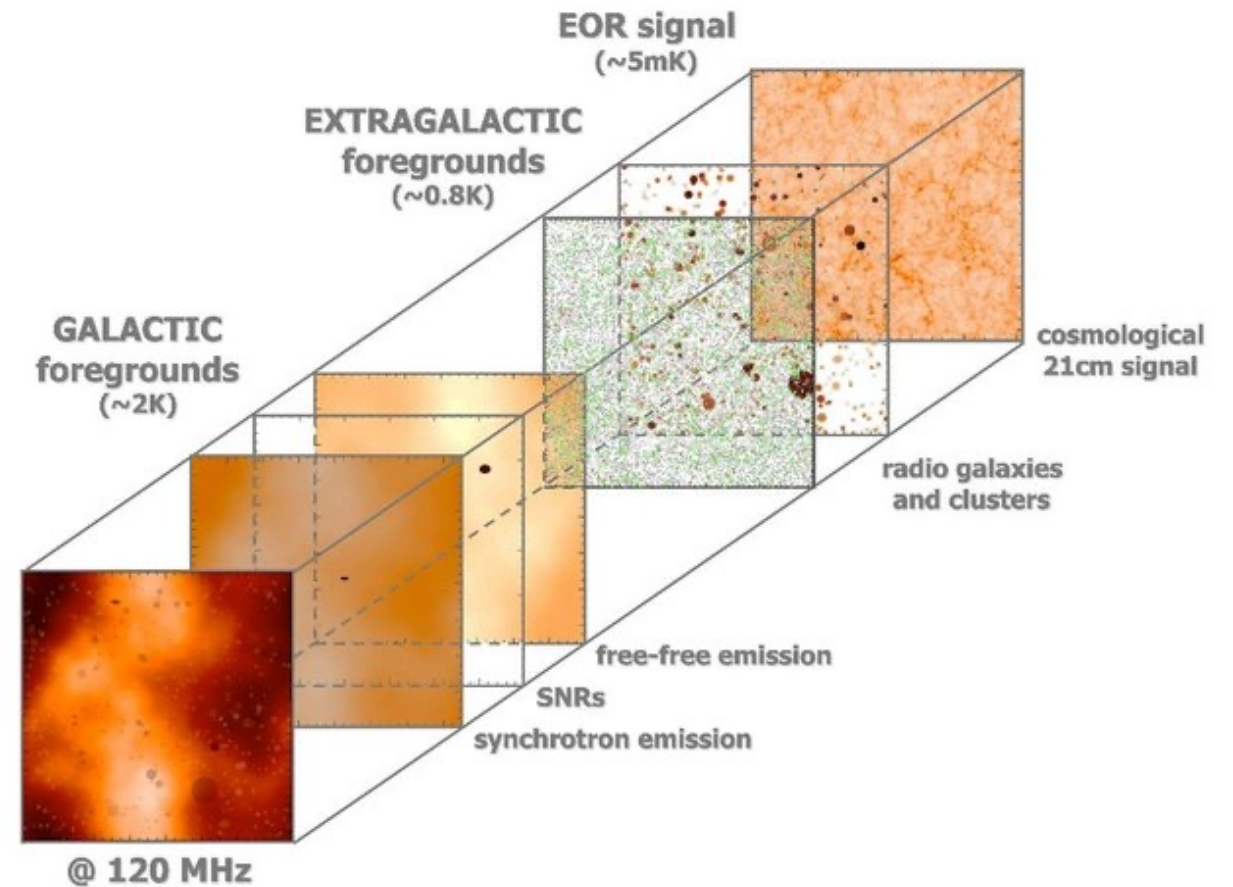
WHAT IS 21CM COSMOLOGY?

- In between, there are few stars/galaxies, only diffuse hydrogen
 - Search for the hyperfine transition of neutral hydrogen → 21cm



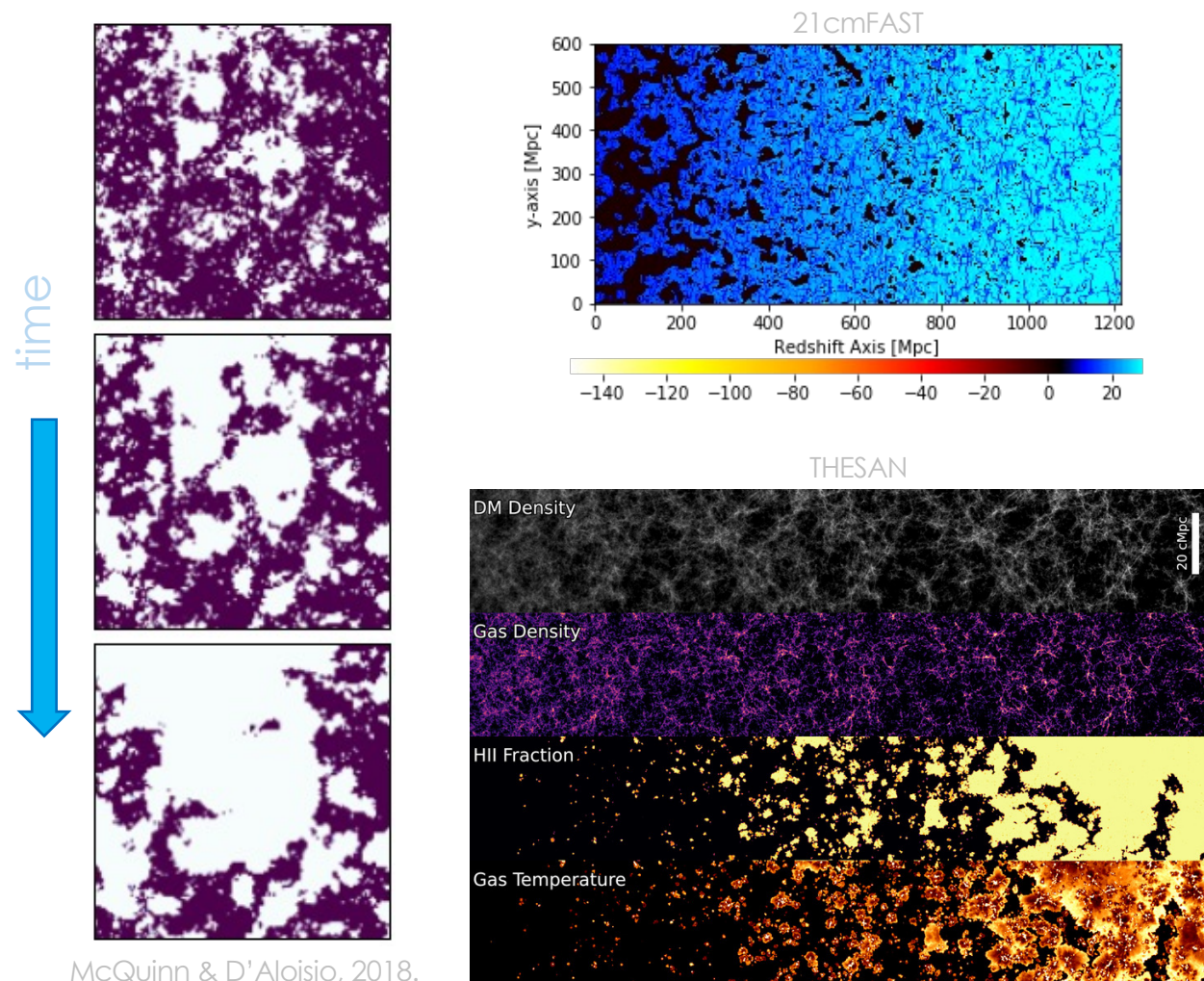
WHAT'S THE CATCH?

- Experimentally: huge foregrounds, e.g. synchrotron radiation



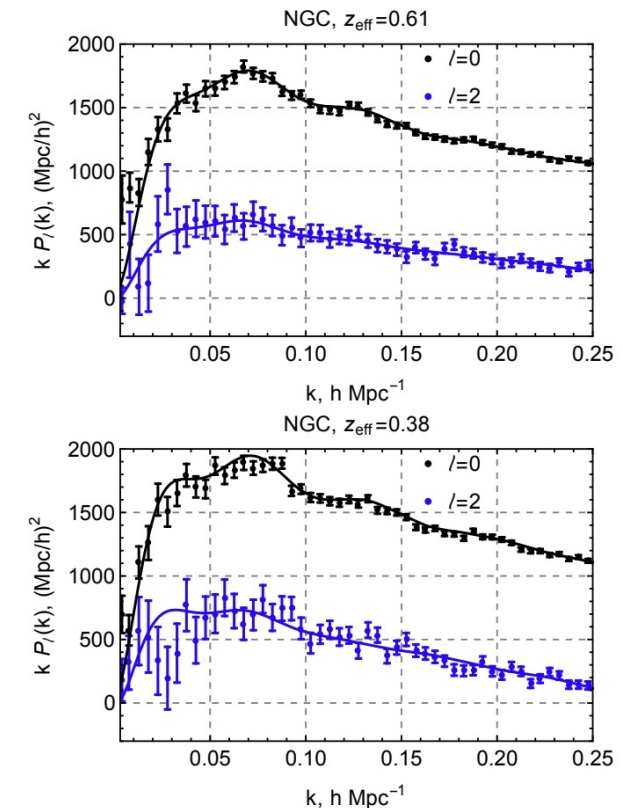
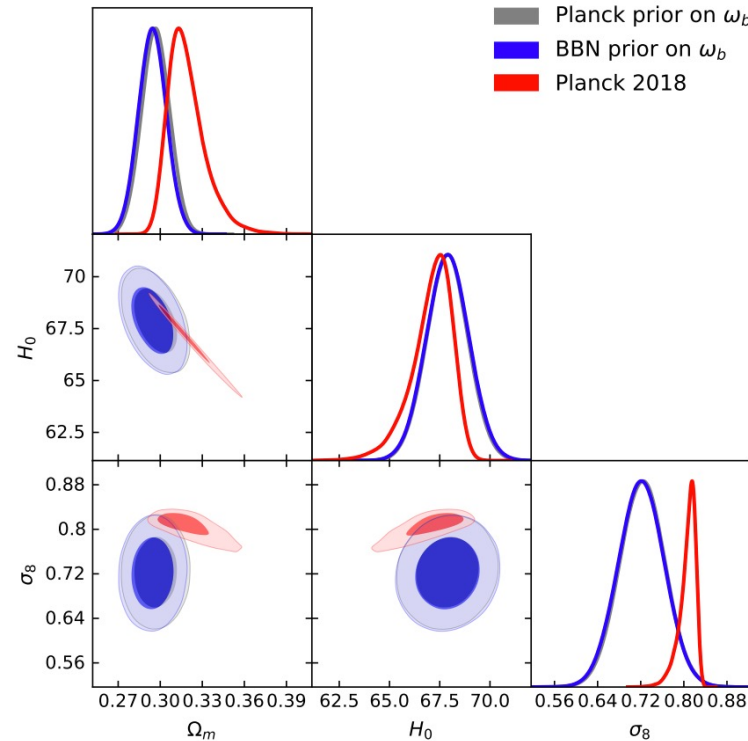
WHAT'S THE CATCH?

- Experimentally: huge foregrounds, e.g. synchrotron radiation
- Theoretically: Prevailing view is that analytic/perturbative methods won't work
 - Reionization is very patchy/nonlinear
 - Instead rely on computationally expensive simulations



COSMOLOGICAL EFFECTIVE FIELD THEORIES

- Some scales are only mildly nonlinear
- Perturbative method
 - Systematically treat nonlinearities
 - Only needs a few parameters
- Applied with great success to galaxy data
- Extracted cosmological parameters at % level



21 CM SIGNAL IS PERTURBATIVE

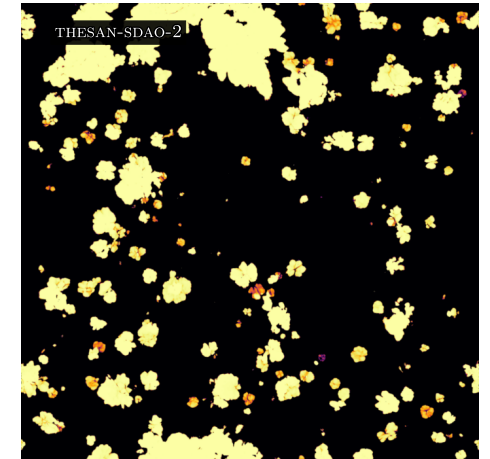
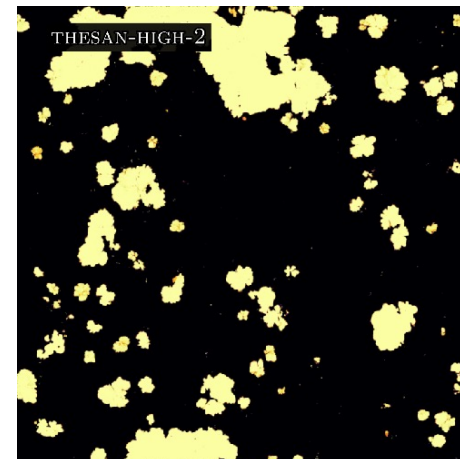
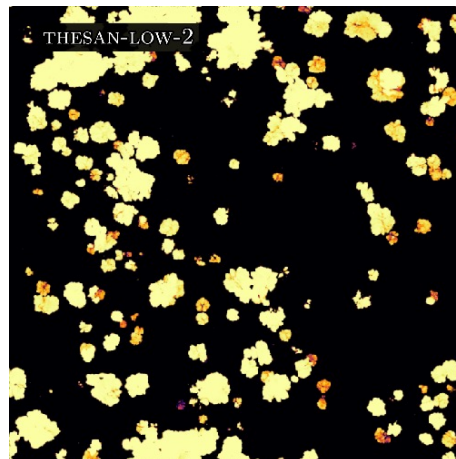
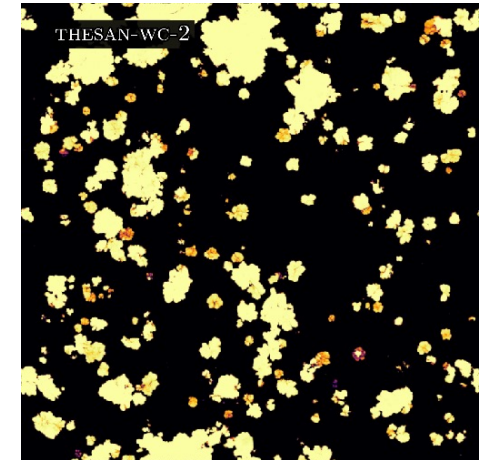
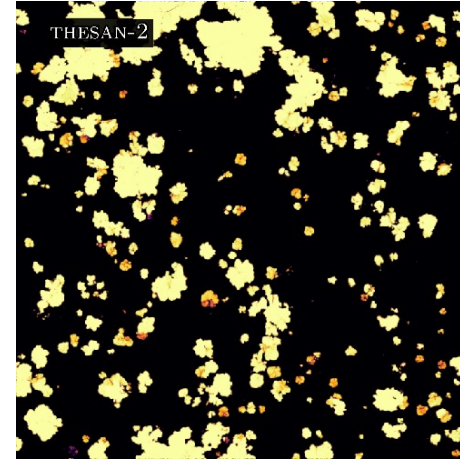
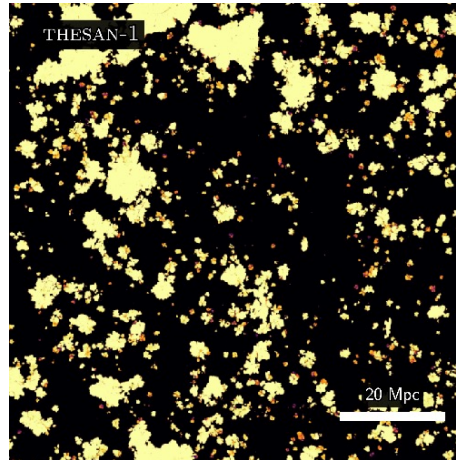
- Recent papers have shown that effective field theory (EFT) methods may work on observable scales
- We showed that EFT is a very good description even when including realistic observational effects
- Steps in building up our EFT:
 - Relating 21 cm to matter density?
 - Dealing with small nonlinear scales?
 - Redshift space distortions?



FITTING TO THE *THESAN* SIMULATIONS

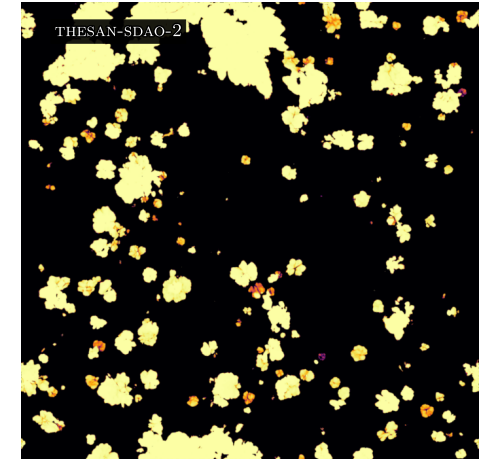
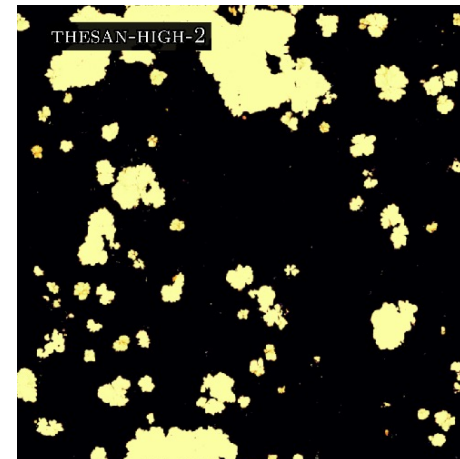
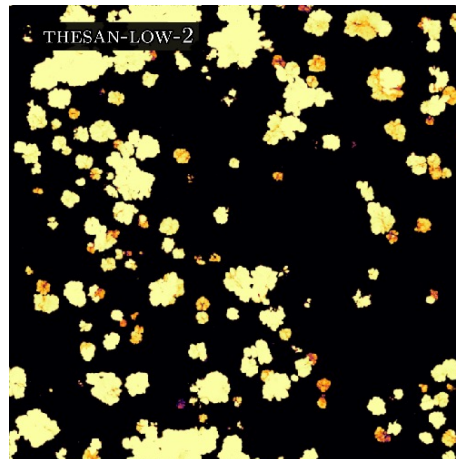
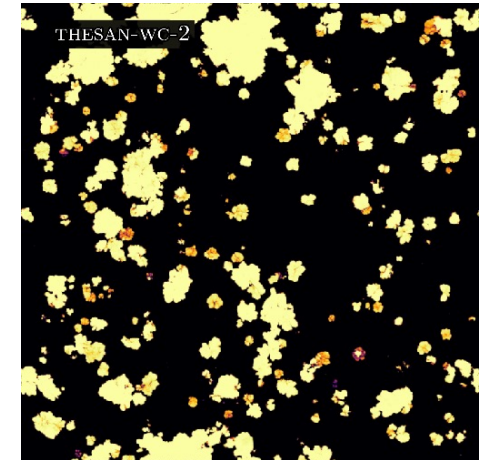
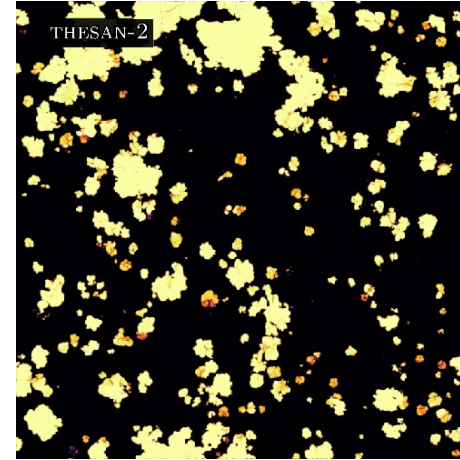
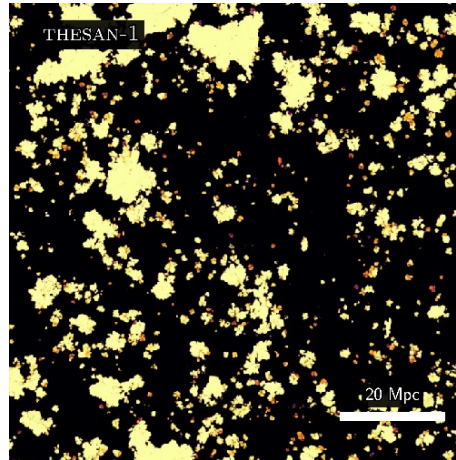
THESAN

- Radiation-magneto-hydrodynamical simulations to study reionization
- Neutral fraction is ~ 0.7 for each simulation shown

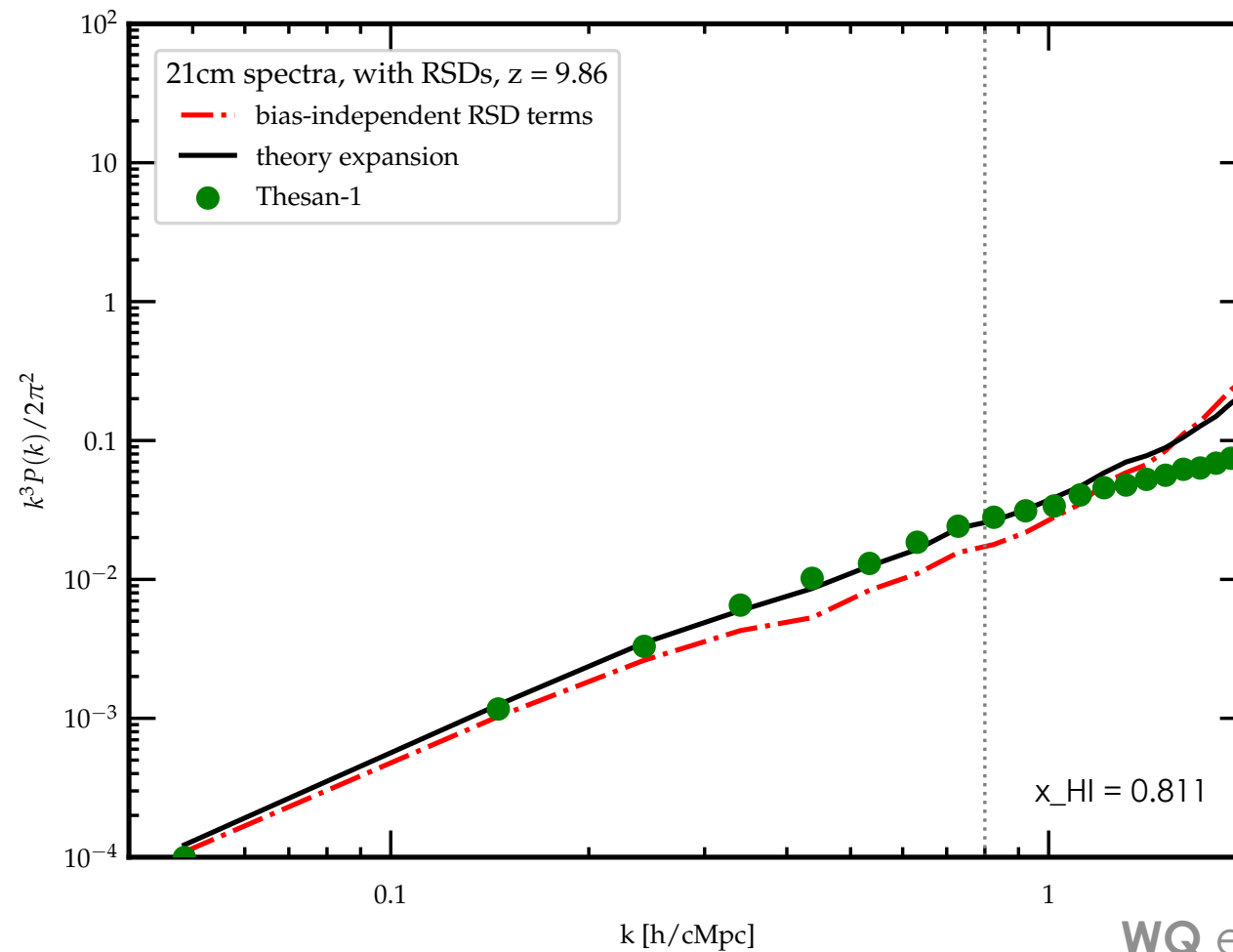


THESAN

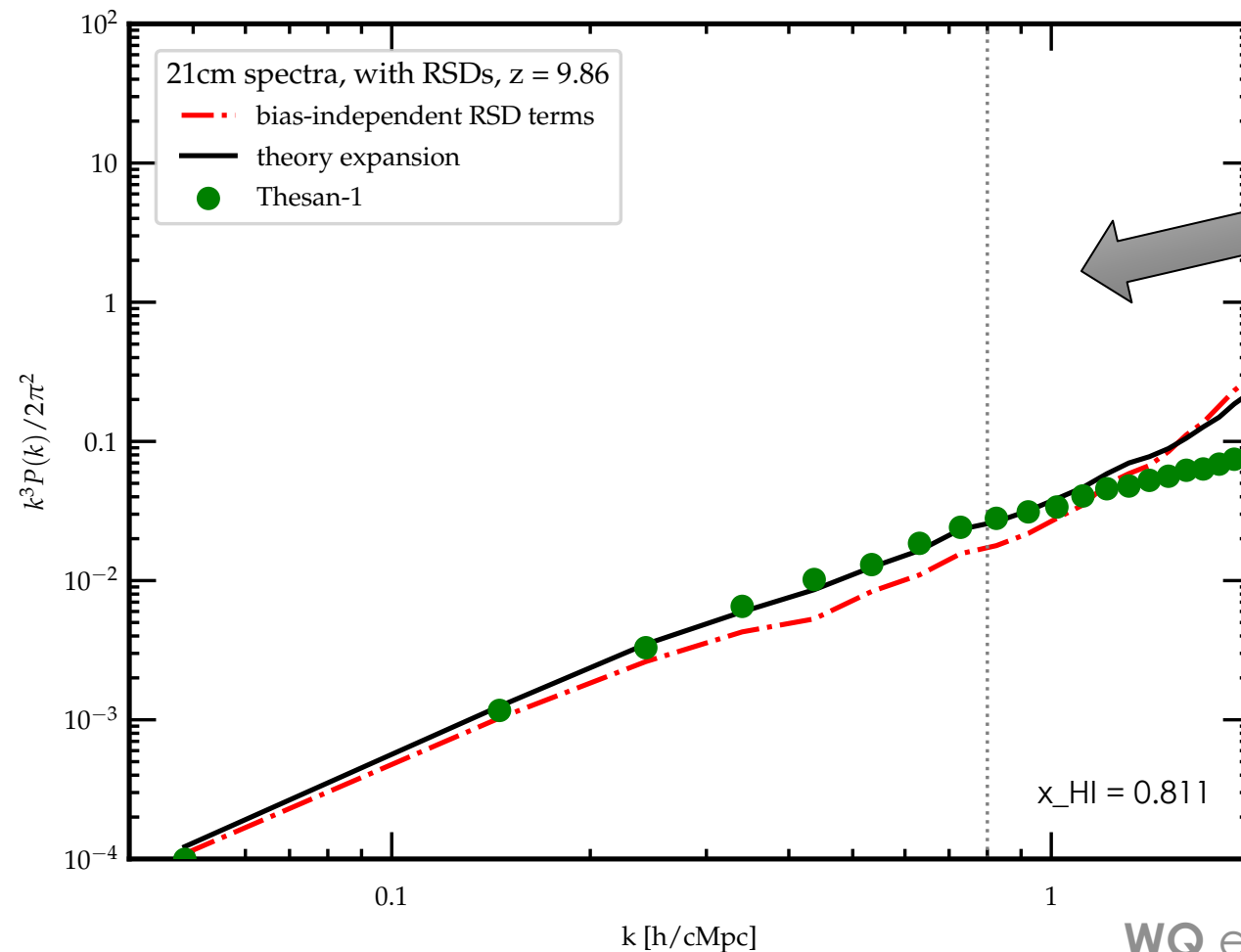
- Thesan-1: High resolution
- Thesan-2: Medium resolution
- Thesan-WC-2: Compensates for lower star formation due to less resolution
- Thesan-Low-2: Small haloes contribute to reionization
- Thesan-High-2: Large haloes contribute to reionization
- Thesan-SDAO-2: Non-standard dark matter model



POWER SPECTRUM

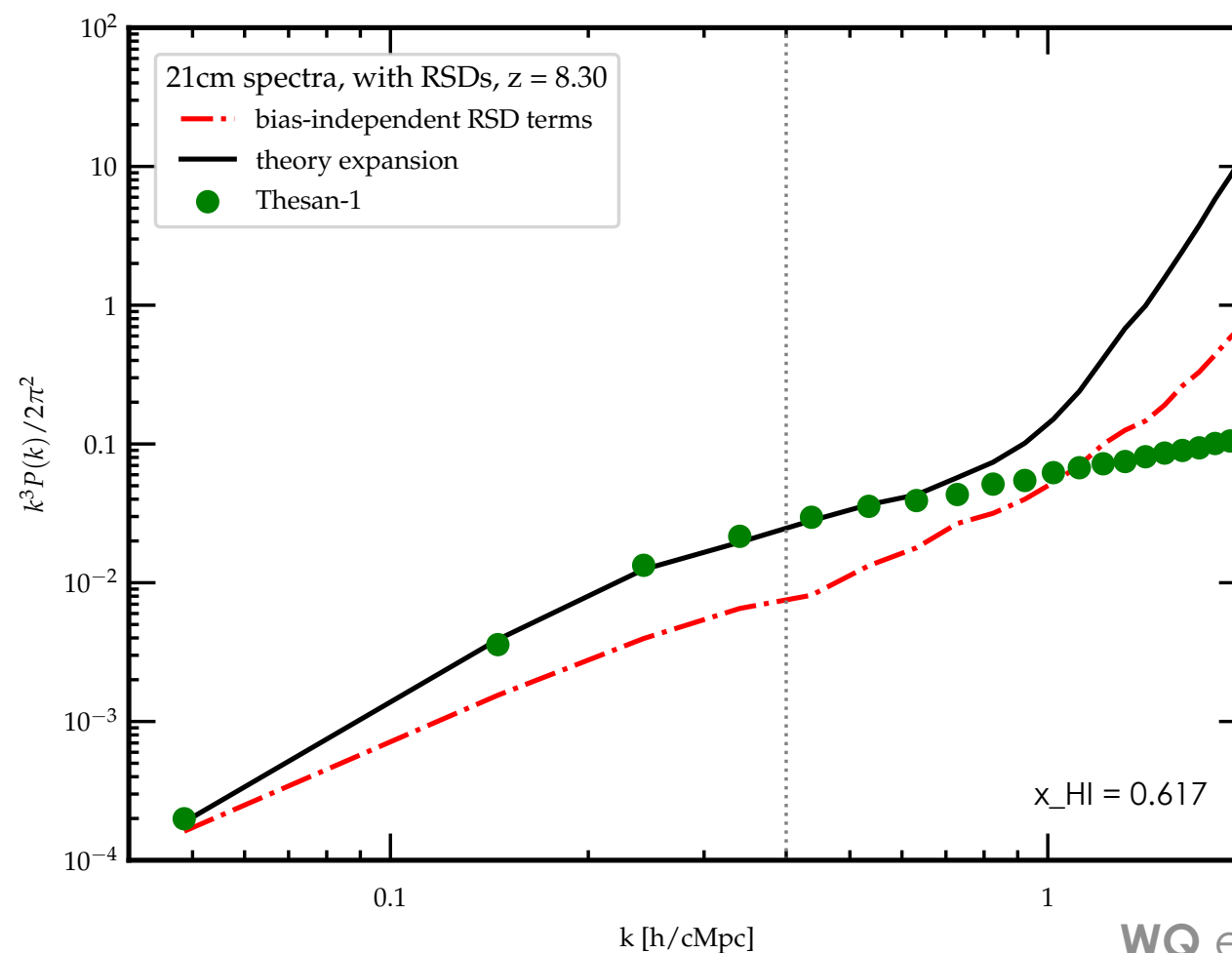


POWER SPECTRUM

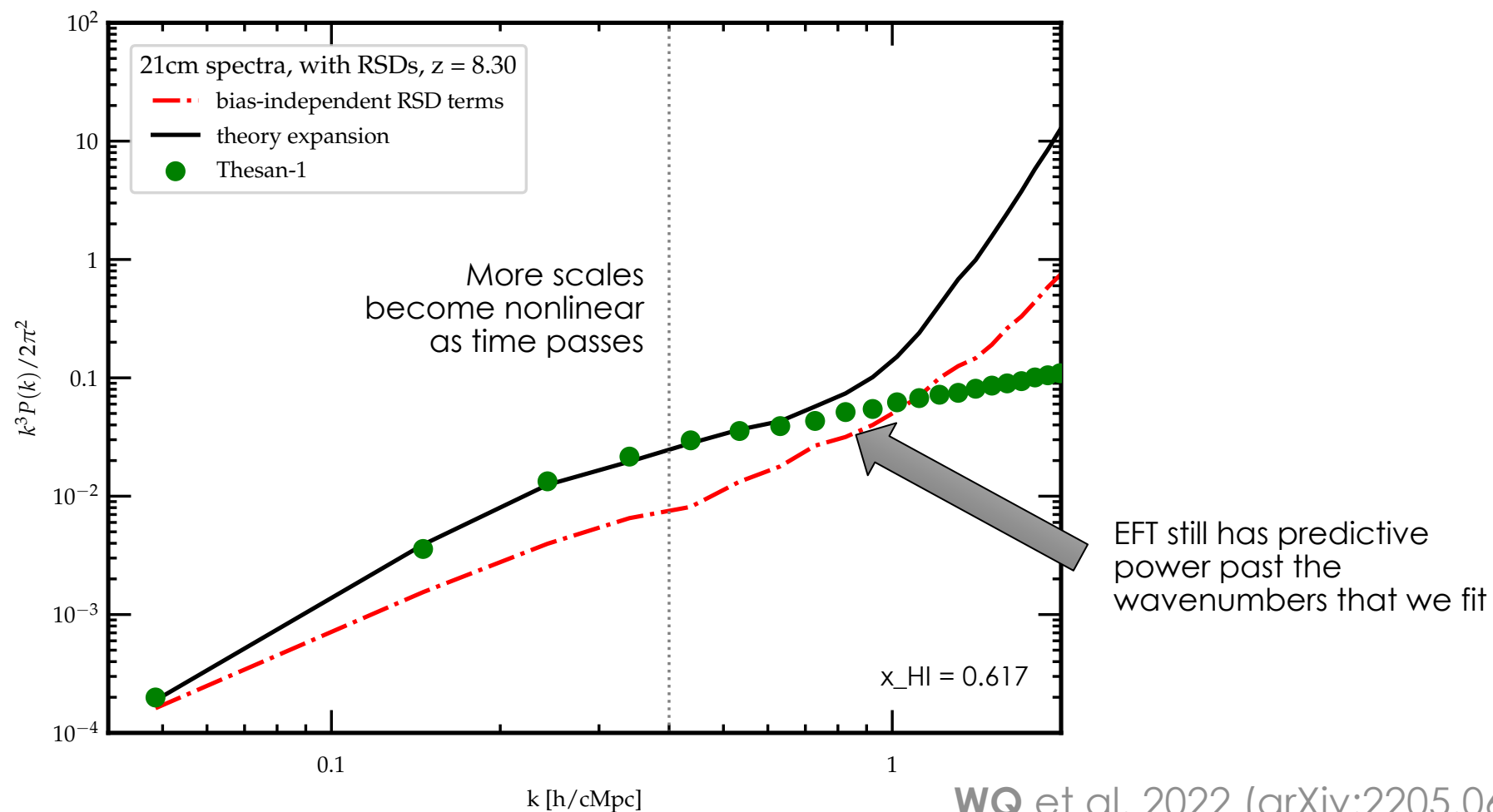


Wavenumber at which
the density field
becomes nonlinear

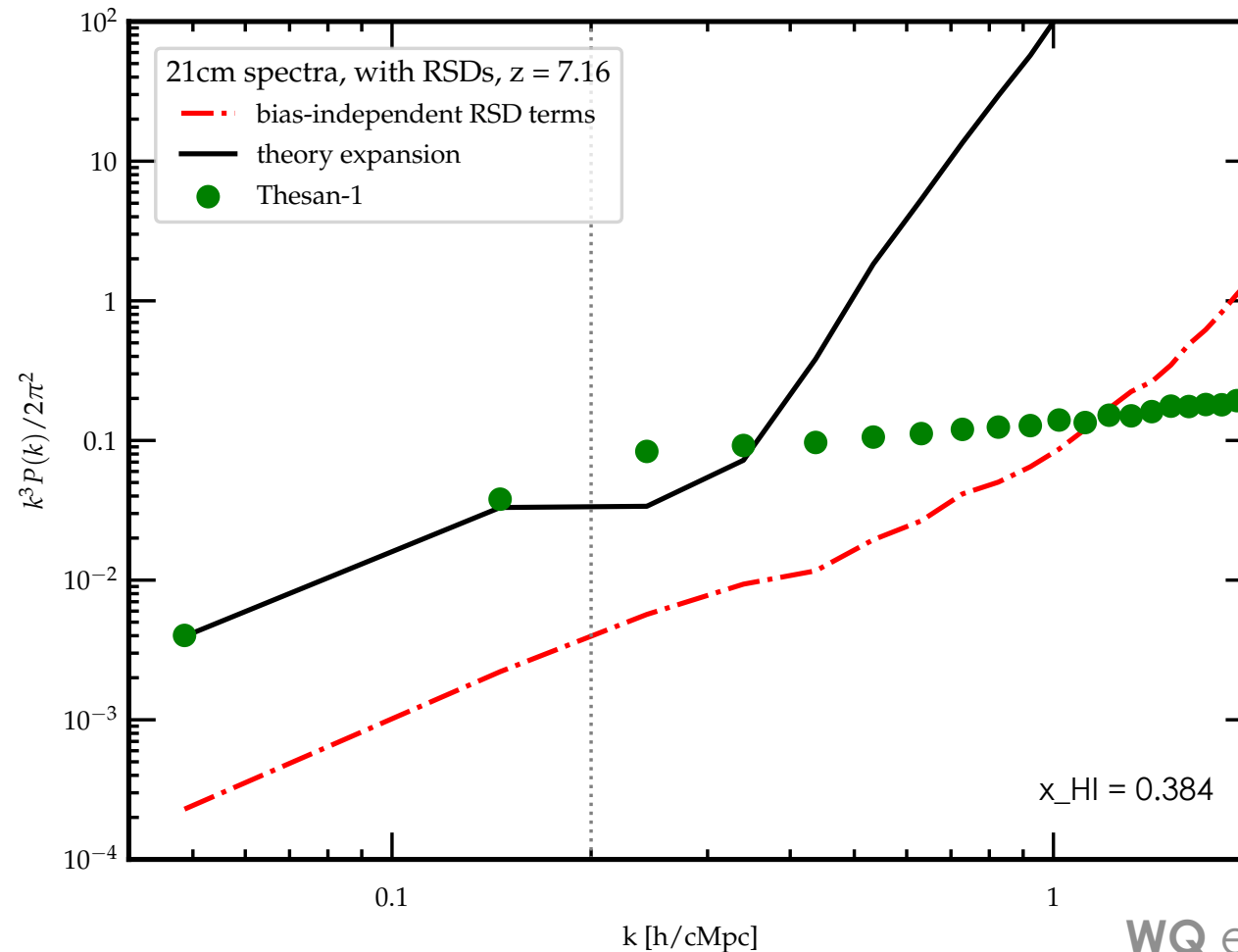
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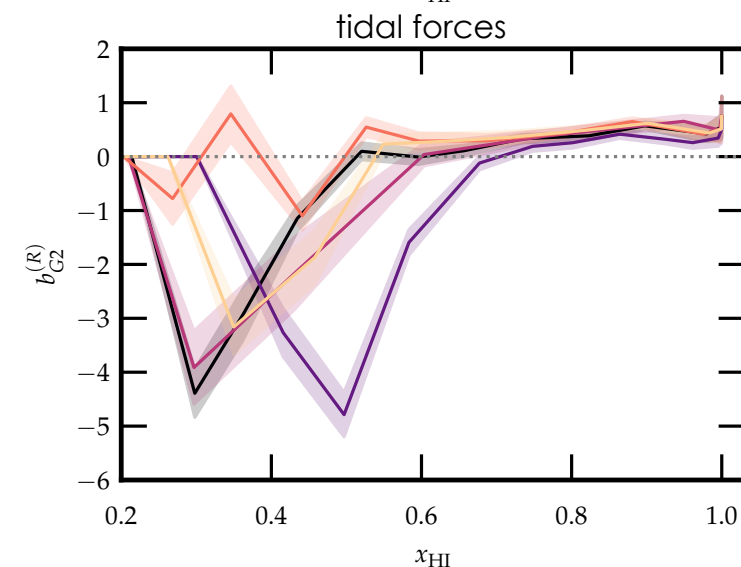
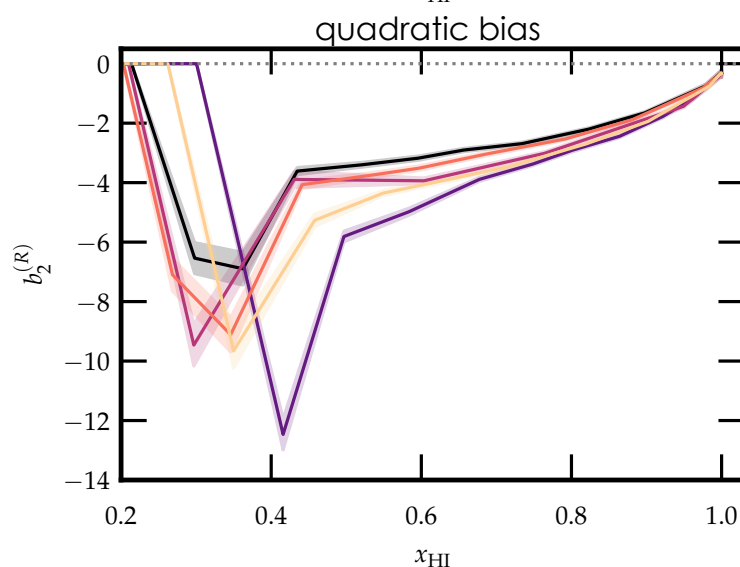
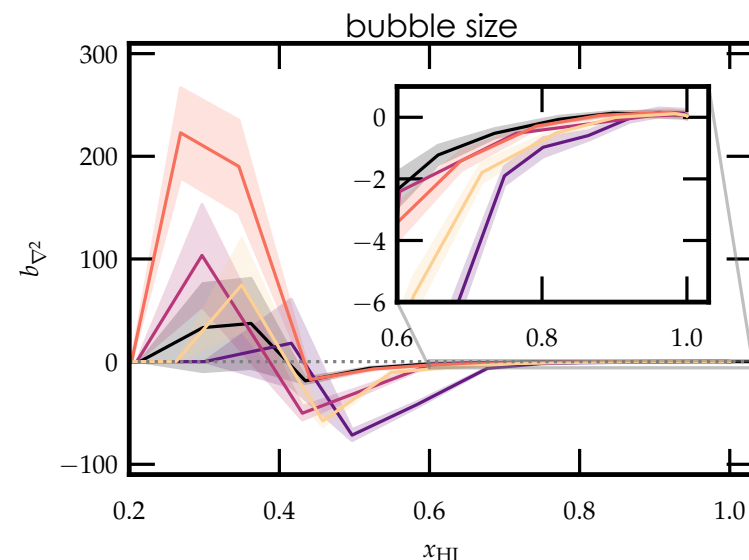
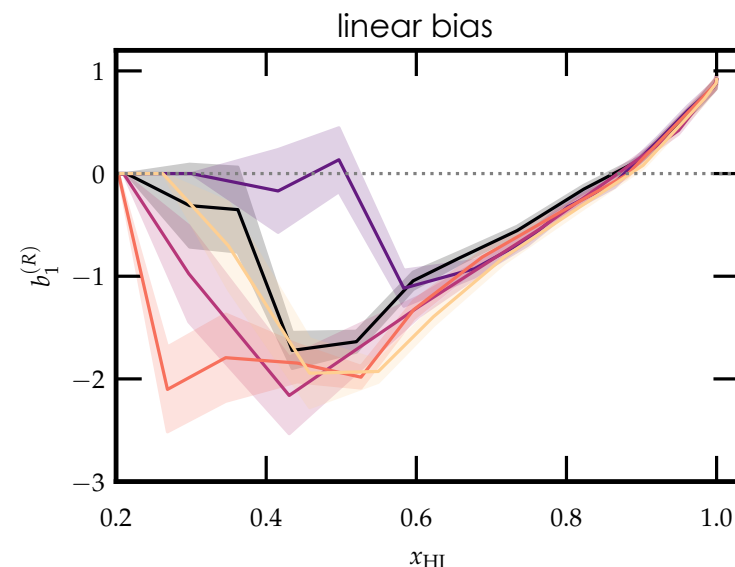
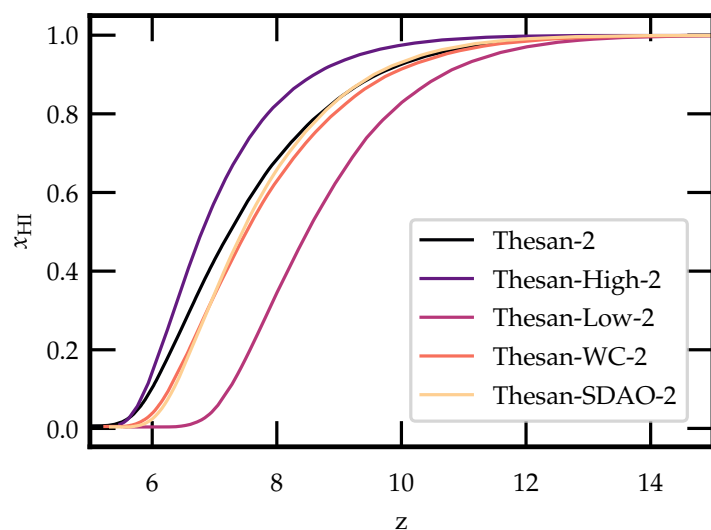


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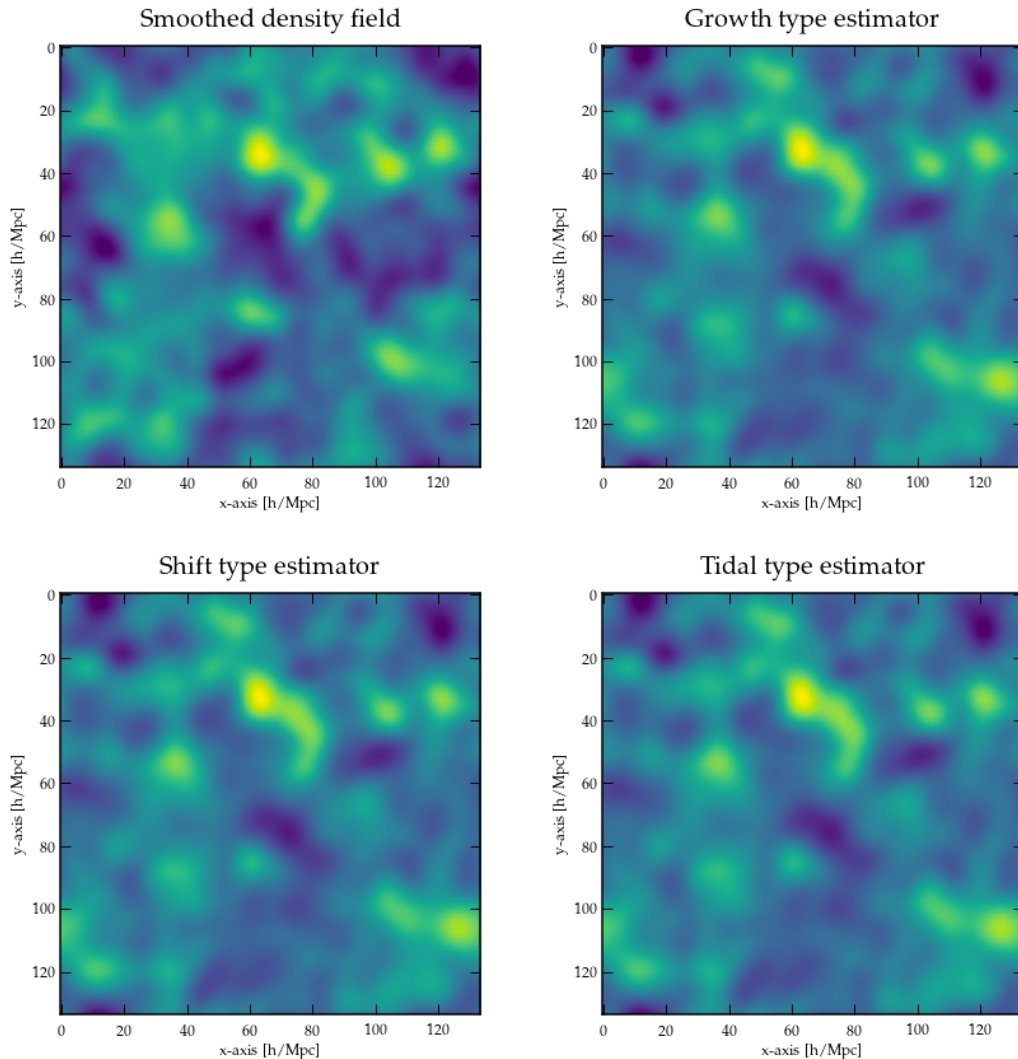


At this level of ionization,
perturbative theory
breaks down

SIMULATION DIFFERENCES



SNEAK PREVIEW



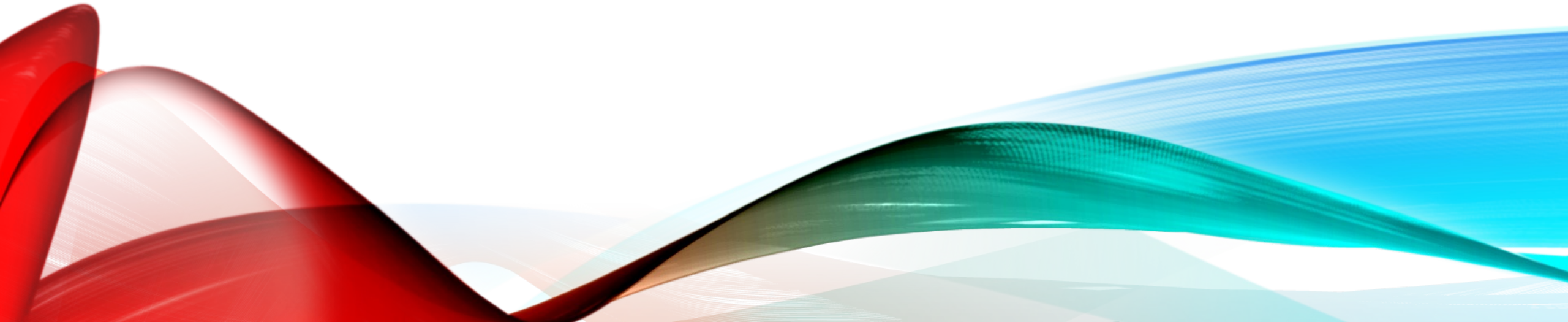
- Large scale 21cm measurements suffer from spectrally smooth foregrounds
- Can we reconstruct these large scale modes through small-scale couplings?
- Leveraging EFT may be less computationally expensive than other methods
- *Preliminary work with Kai-feng Chen, Adrian Liu, and Katelin Schutz*



SUMMARY

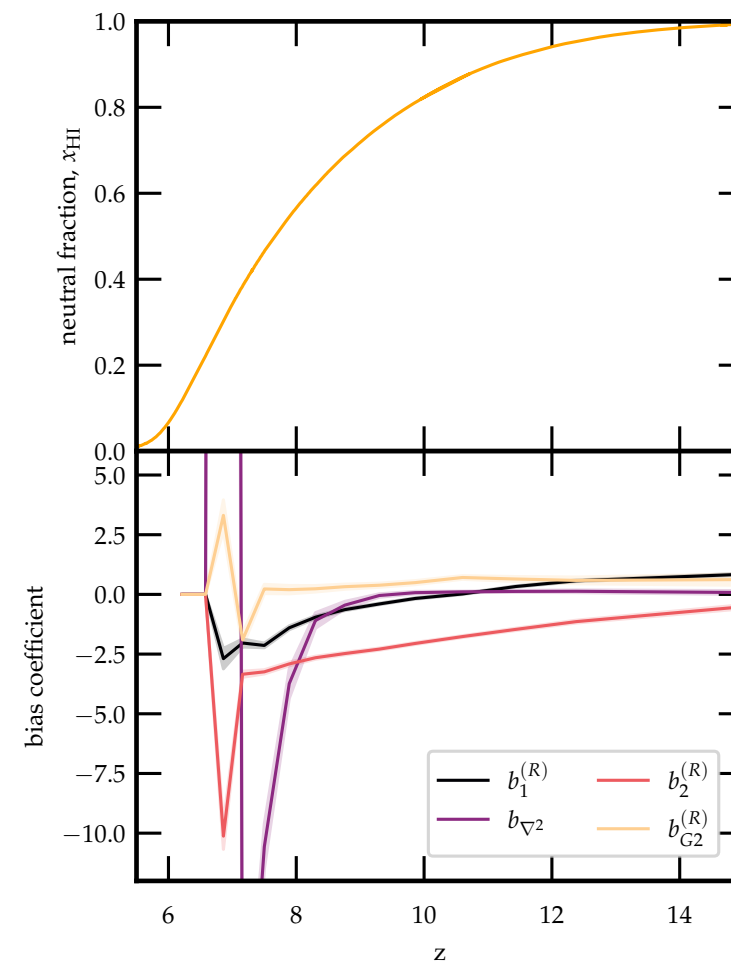
- On observable scales, we can use perturbative methods
- We've extended these EFT methods, e.g. including RSDs
- Theory expansion is a good fit to simulations, at early enough redshifts and large length scales
- Evolution of coefficients reflects different physics
- Next: reconstructing modes in the foreground wedge

BACKUP

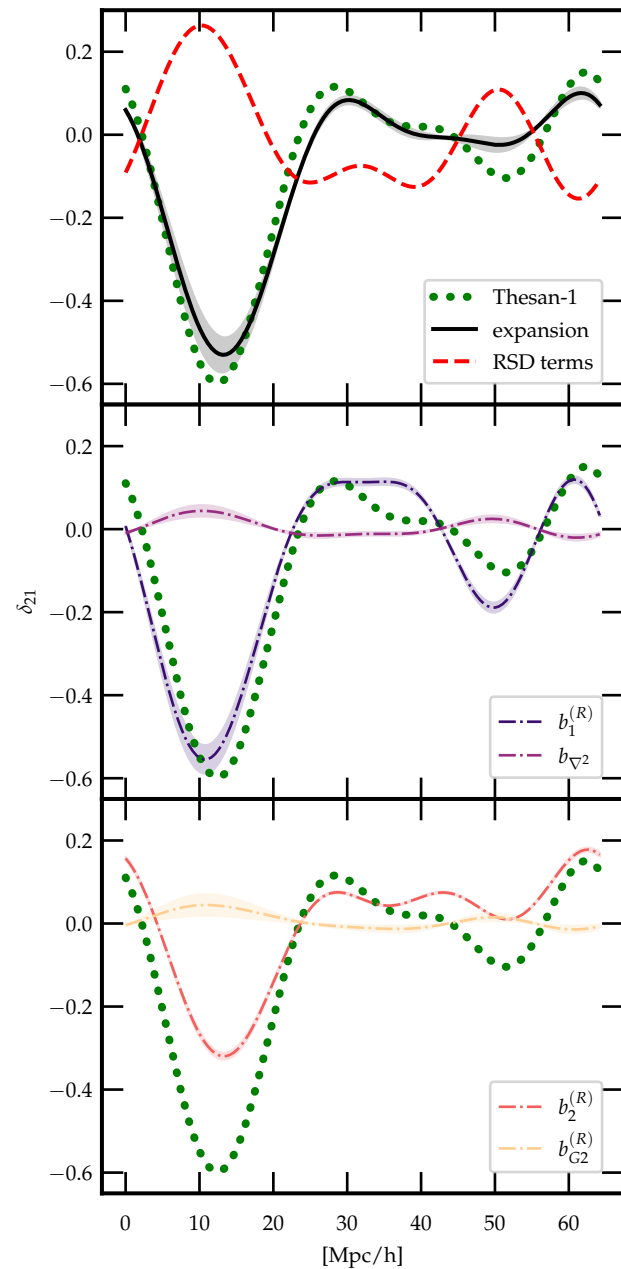


EVOLUTION OF COEFFICIENTS

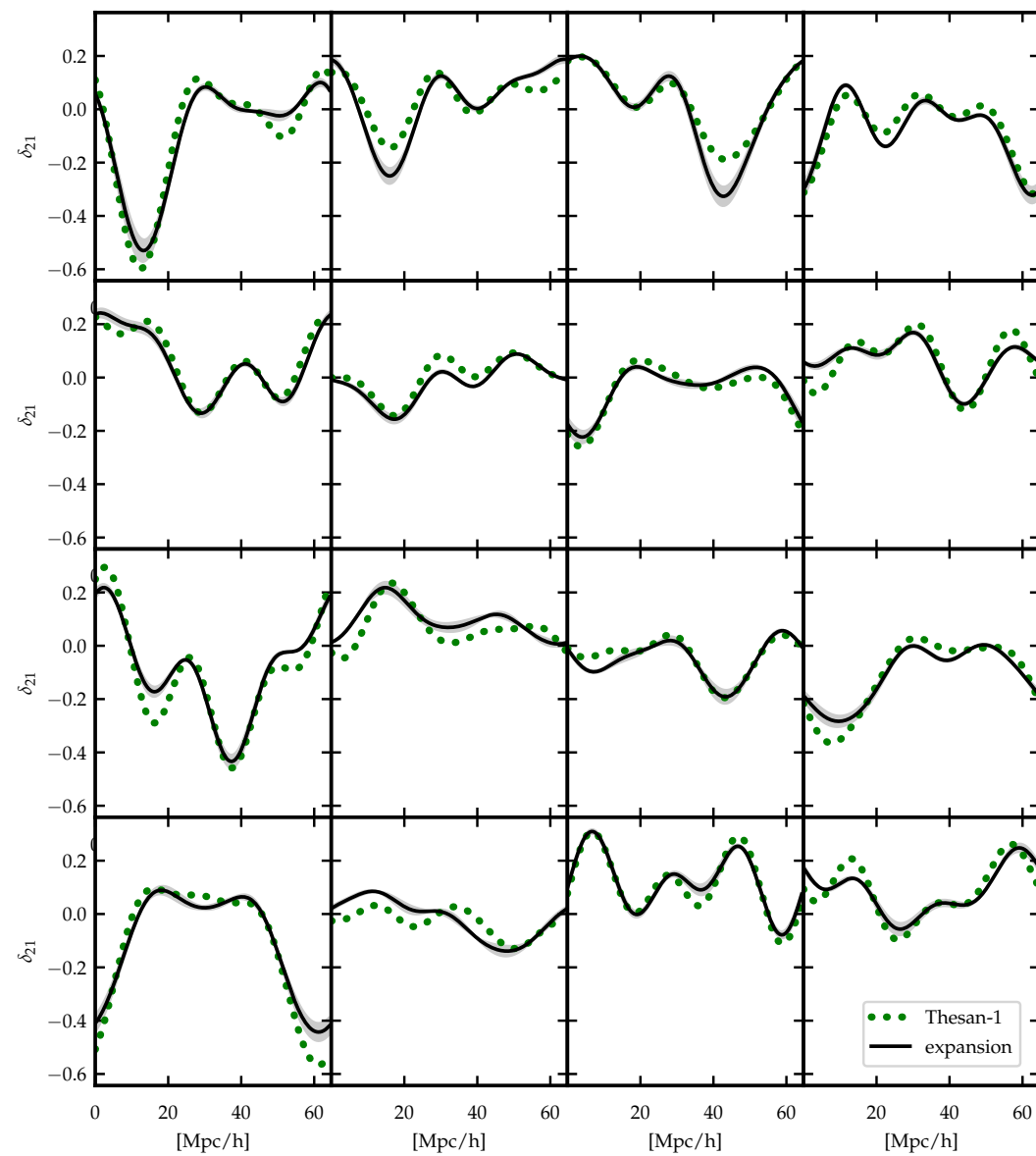
- How do these coefficients evolve with time?
- Evolution becomes rapid/jagged after a certain time --- theory is breaking down
- Physical interpretations:
 - $b_1^{(R)}$ is linear bias
 - $b_2^{(R)}$ is quadratic bias
 - b_{∇^2} is related to bubble size
 - $b_{G2}^{(R)}$ quantifies anisotropic stresses



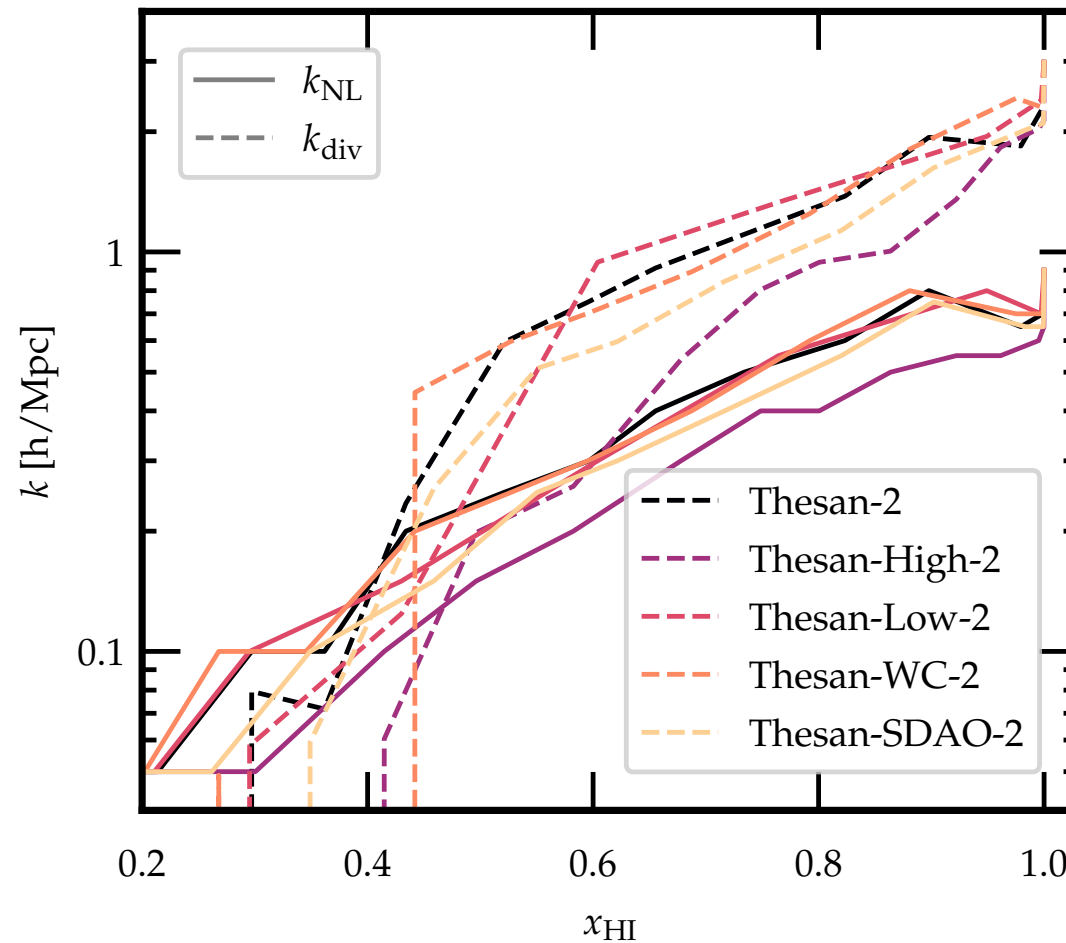
COMPARISON IN CONFIGURATION SPACE



- 1D slices of 21 cm brightness temperature at $z = 8.30$, $x_{\text{HI}} = 0.617$
- Smoothed over $k = 0.4 \text{ h/cMpc}$



WHEN PERTURBATIVITY BREAKS DOWN



EFT SHAPES AS FUNCTION OF ANGLE

