Effects on the reionization history from the primordial perturbations

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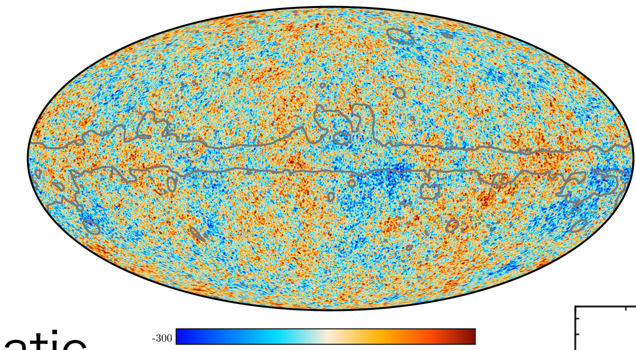
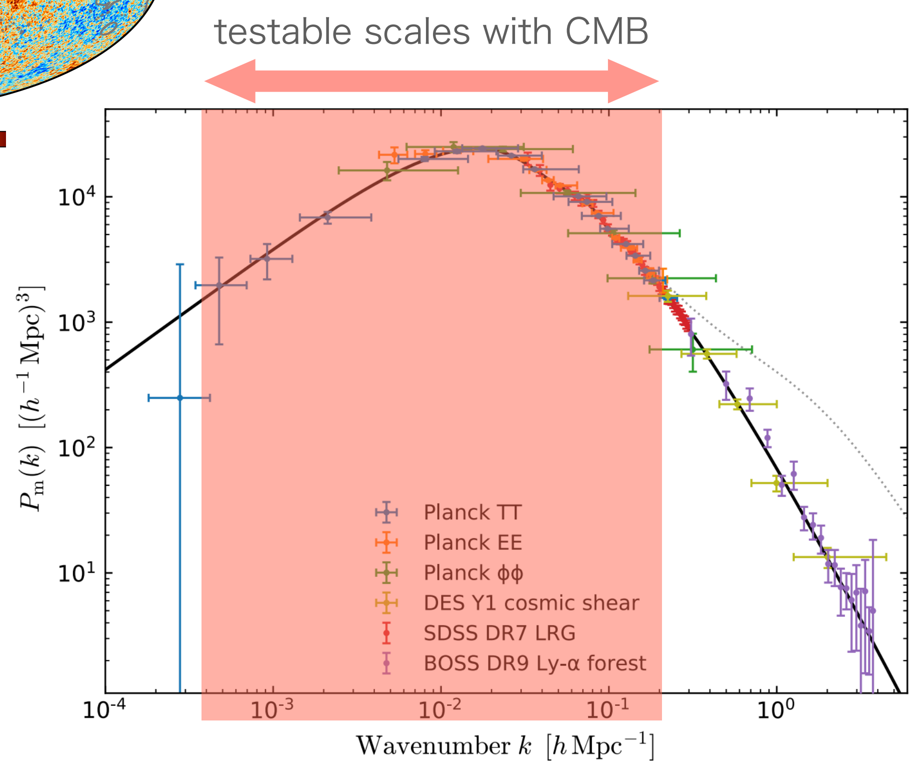
Planck image-gallery (https://www.cosmos.esa.int/web/planck/picture-gallery)

Primordial curvature perturbations



- CMB anisotropy, galaxy distributions suggest the primordial fluctuations
- Explained very well by adiabatic (curvature) perturbations with a single power-law power spectrum
- Testable scales of primordial fluctuations with CMB are finite
- Larger scales? > Causality limit, GW?



Planck 2018 results (2020), A&A, 641, A1

Power spectrum of the curvature perturbations

Different inflation models,
different features on primordial spectrum

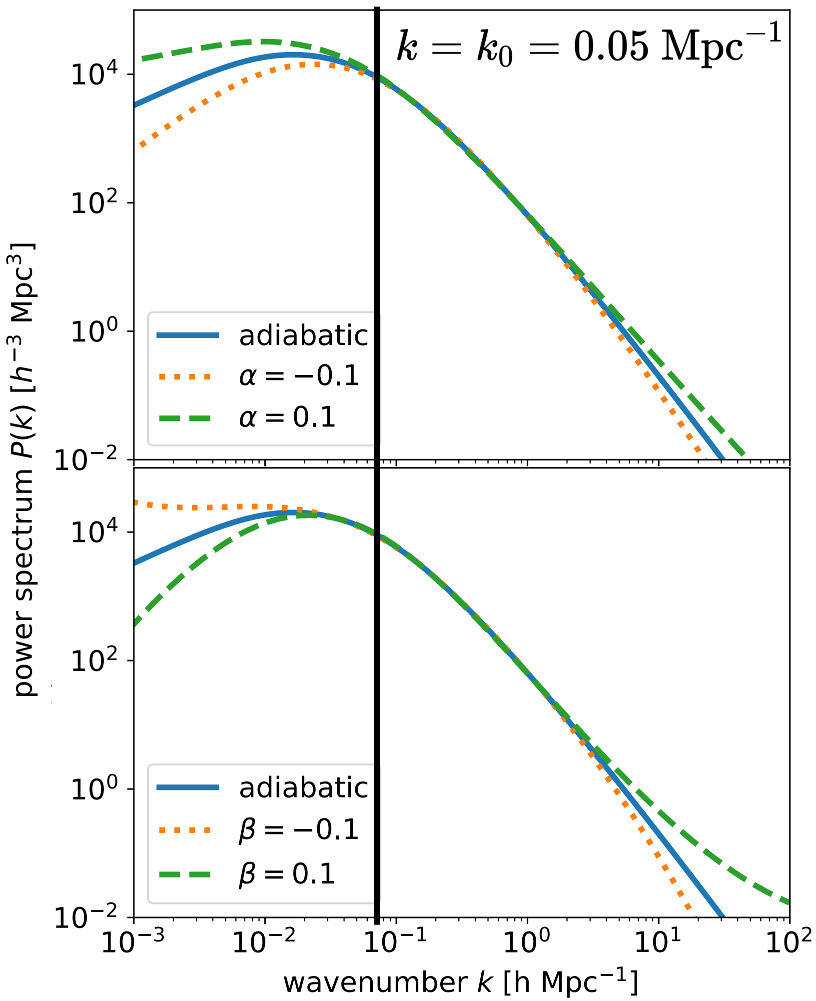
Top-down approaches (physical motivation): Potential of inflaton, slow-roll parameters

Bottom-up approaches (phenomenological):

(1) running indices:

$$\mathcal{P}(k) = A_s \left(\frac{k}{k_0}\right)^{n_s - 1 + \frac{1}{2}\alpha_s \ln\left(\frac{k}{k_0}\right) + \frac{1}{6}\beta_s \left[\ln\left(\frac{k}{k_0}\right)\right]^2}$$

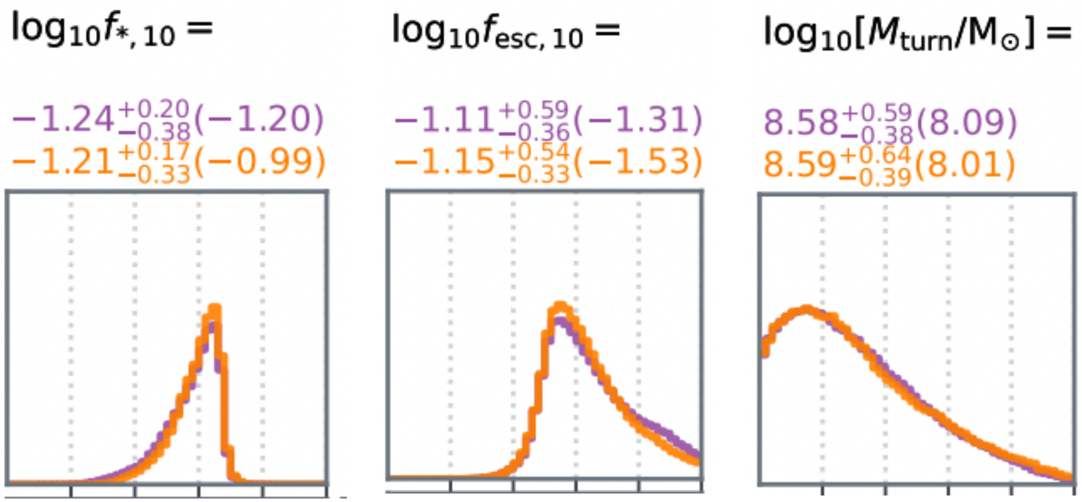
Power spectrum of the adiabatic perturbations



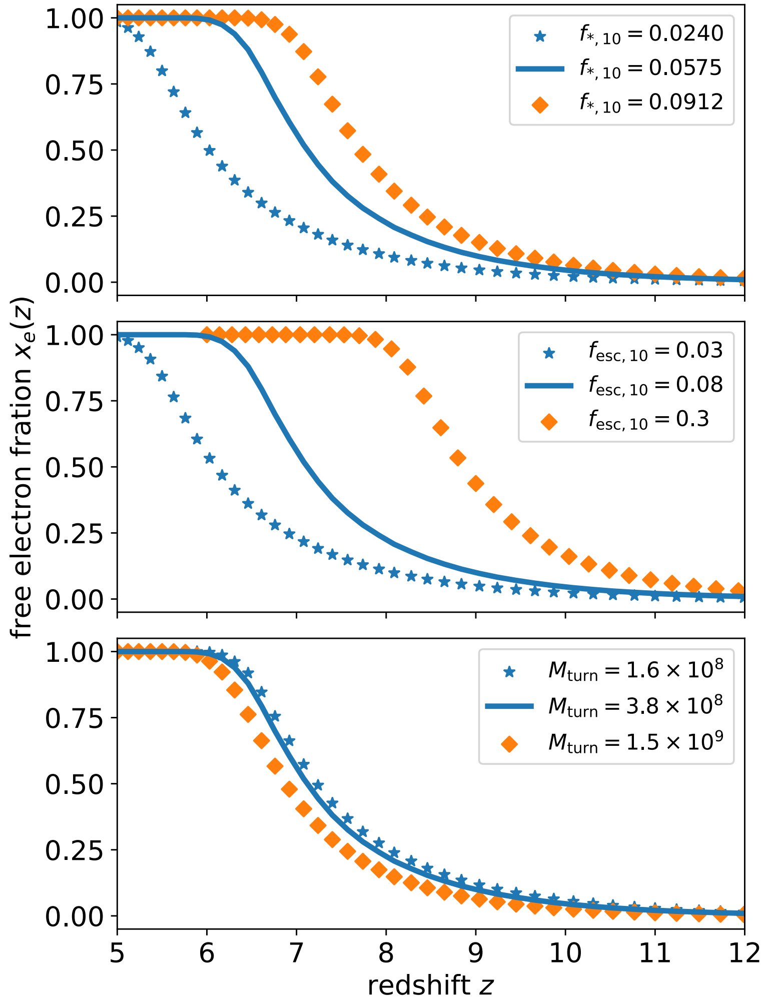
Astrophysical effects on the reionization history

Previous constraints on 21cmFAST parameters

HERA 21cm PS + galaxy UV LFs
+ QSO dark fraction + CMB optical depth



Abdurashidova, Z. et al. 2022, ApJ, 924, 51.



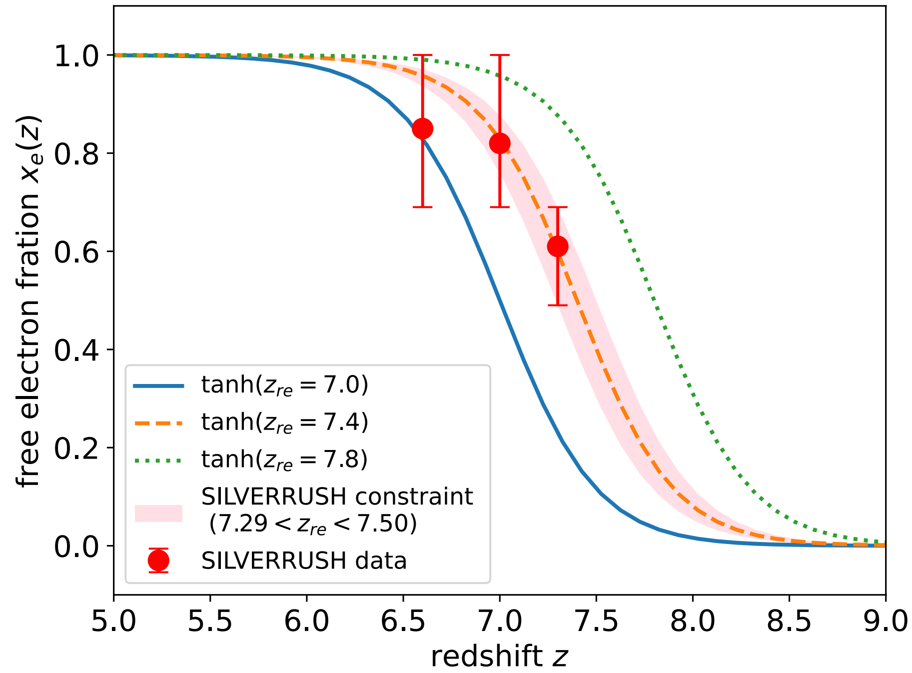
Minoda, Yoshiura, and Takahashi, Phys. Rev. D 108, 123542 (2023)

Fitting function of 21cmFAST results

$$x_{\rm e}(z=7.3) = \min(1.0, \tilde{x}_{\rm e,7.3}),$$

$$\tilde{x}_{\rm e,7.3} = \left\{0.421{\rm e}^{A} + B\left[\left(\frac{f_{*,10}}{0.058}\right)^{C} - 1.0\right] + D\log\left(\frac{M_{\rm turn}}{3.8\times10^{8}M_{\odot}}\right)\right\}\left(\frac{f_{\rm esc,10}}{0.078}\right)^{E},$$

$$A = 8.43\alpha_s + 11.41\beta_s,$$
$$B = 4.00\alpha_s + 7.75\beta_s + 0.38,$$
$$C = -5.24\alpha_s - 12.04\beta_s + 1.34,$$
$$D = -0.7\alpha_s - 1.20\beta_s - 0.07,$$
$$E = -3.11\beta_s + 1.08.$$



Mean fitting error: ~0.02

Observation error of SILVERRUSH: ~0.2

$$0.49 \le x_{\rm e} \le 0.69 \text{ at } z = 7.3.$$

$$7.29 \le z_{\rm re} \le 7.50$$

Minoda, Yoshiura, and Takahashi, Phys. Rev. D 108, 123542 (2023)

MCMC analysis (only running)

Flat prior:
-0.2 < alpha < 0.2
-0.2 < beta < 0.2

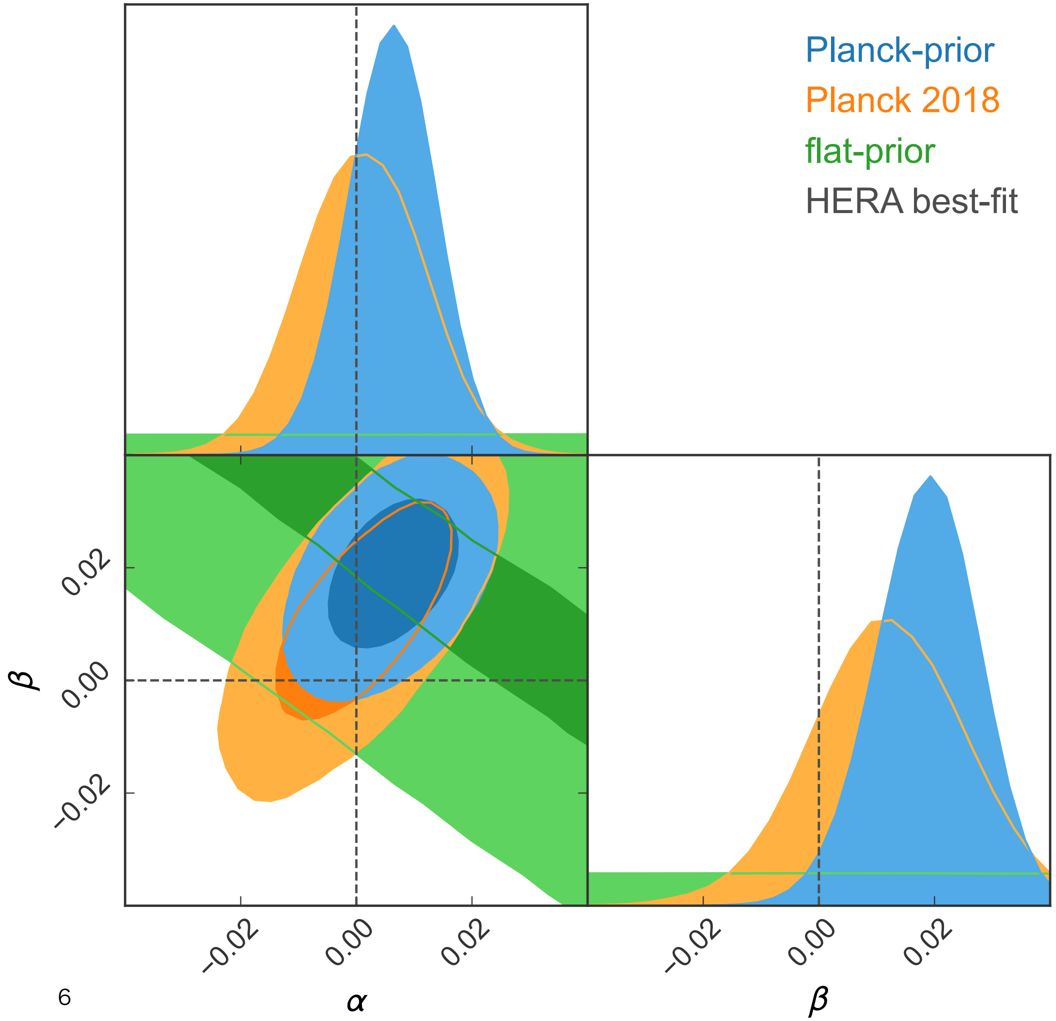
Planck prior:
2D gaussian on alpha and beta,
with Planck 2018 covariance matrix

Planck 2018

$$\alpha_s = 0.0011 \pm 0.0099,$$
$$\beta_s = 0.009 \pm 0.012,$$

Our results

$$\alpha_s = 0.006^{+0.007}_{-0.007}$$
$$\beta_s = 0.019^{+0.008}_{-0.009}$$



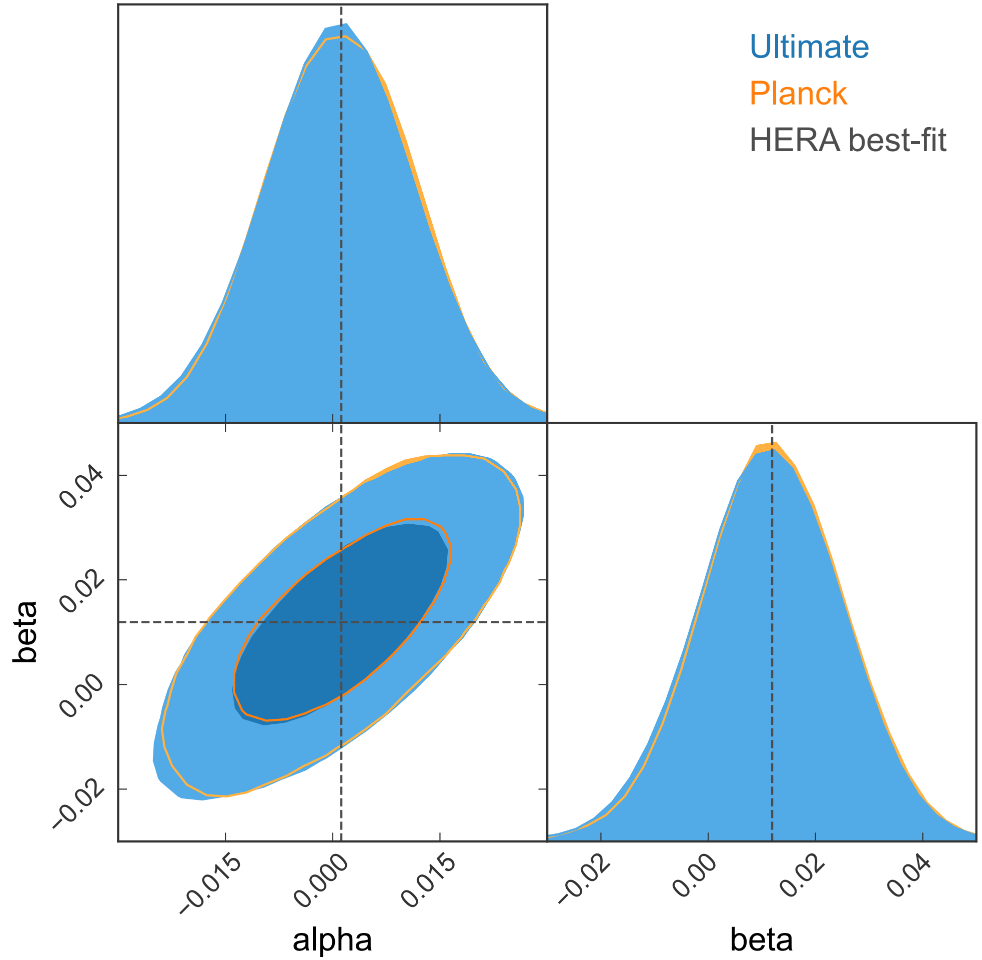
Minoda, Yoshiura, and Takahashi, Phys. Rev. D 108, 123542 (2023)

MCMC analysis (with astro)

Flat prior:
-0.2 < alpha < 0.2
-0.2 < beta < 0.2
0.001 < fesc < 0.4
0.001 < fstar < 0.4
7.0 < logM < 10.5

Planck prior:
2D gaussian on alpha and beta

- Almost same with the Planck-only constraint



Summary

- We calculate the effects of the primordial perturbations on the reionization history, and put constraints on running power spectrum from SILVERRUSH observation.
- We also discuss the degeneracy between uncertainty of astrophysical parameters and primordial perturbations.
- For the future prospects, the further severe constraint would be given by the combined analysis of the 21-cm line signal and the reionization, and/or the other observables (21-cm power spectrum, CMB distortion, Lyman alpha forest, and so on)