

The background of the slide is a deep blue image showing the cosmic web, with intricate filaments of matter and numerous bright, distant galaxies scattered throughout.

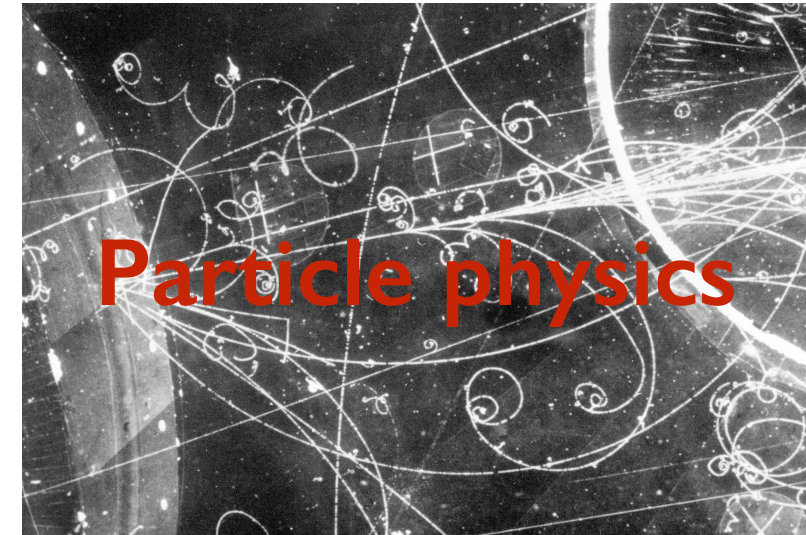
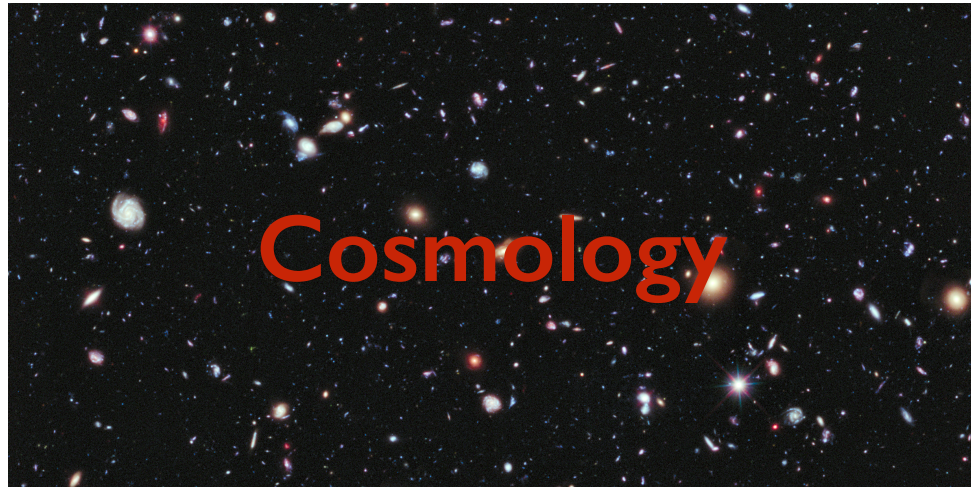
# TESTING THE PARADIGM OF COLD DARK MATTER WITH THE SMALL-SCALE UNIVERSE

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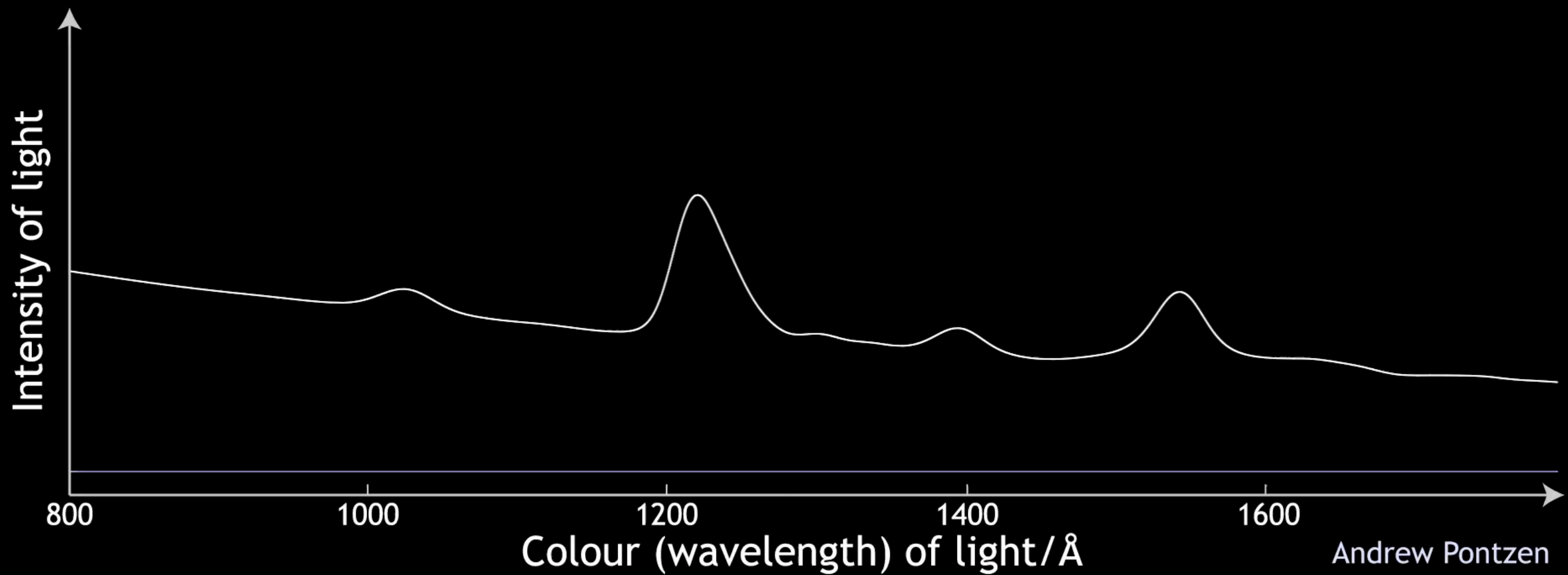
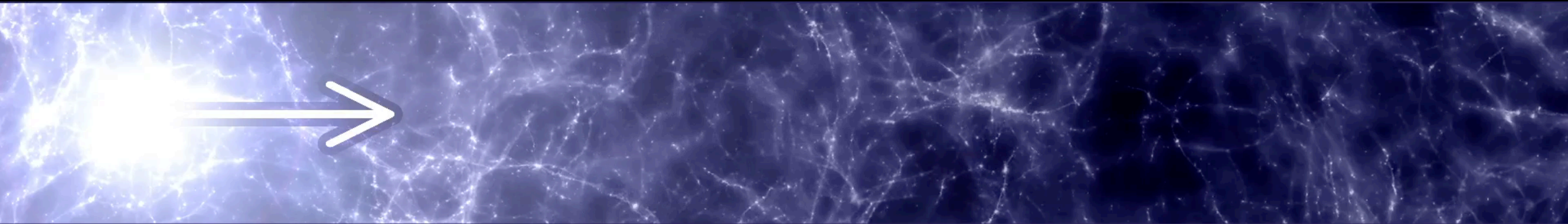


# Beyond the Standard Models of...



- **Lyman-alpha forest** can probe early Universe on **small scales**
- Need “emulator” for **statistical inference with cosmological simulations**
- **Synergy with other astrophysical probes & direct detection**

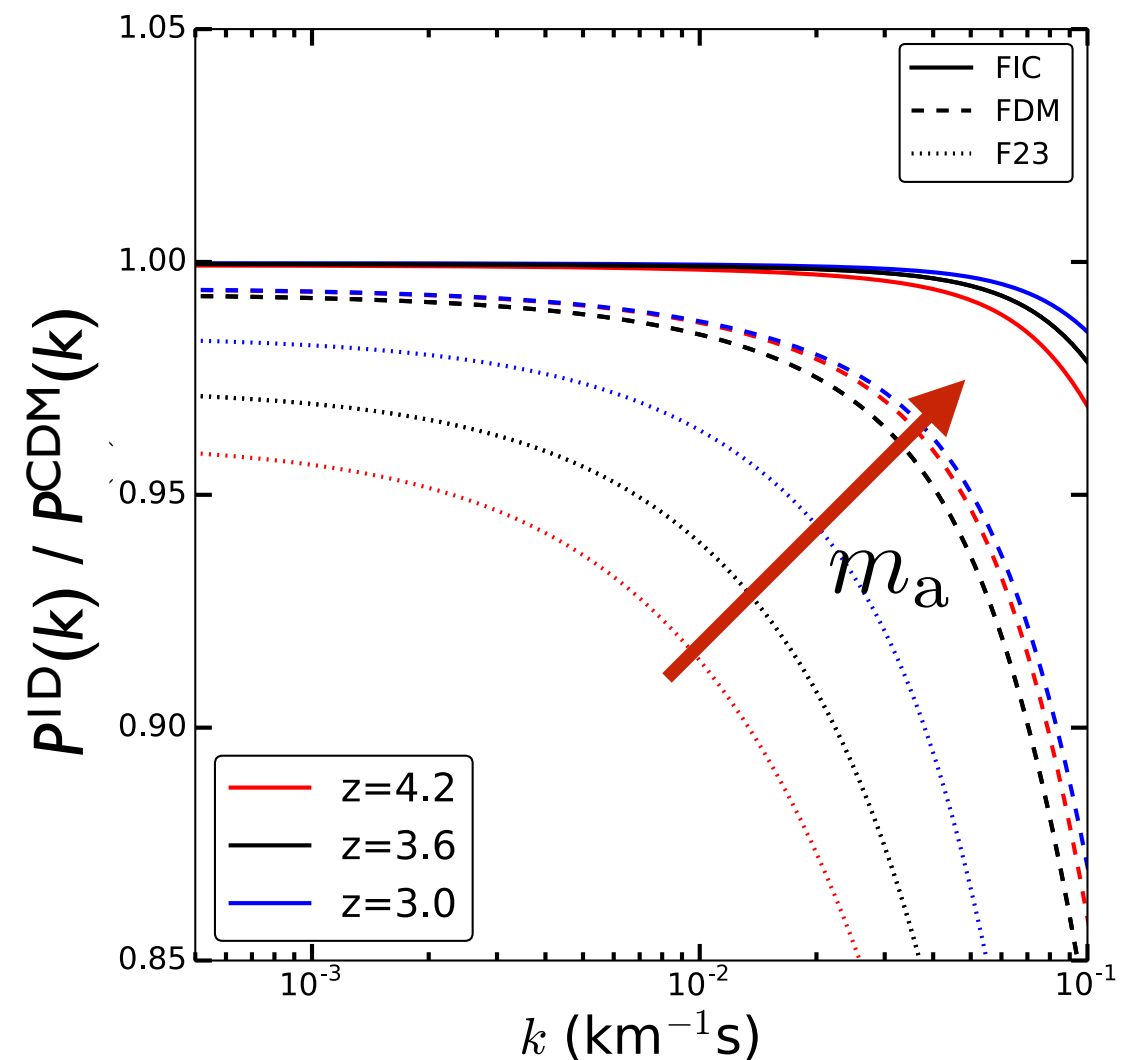
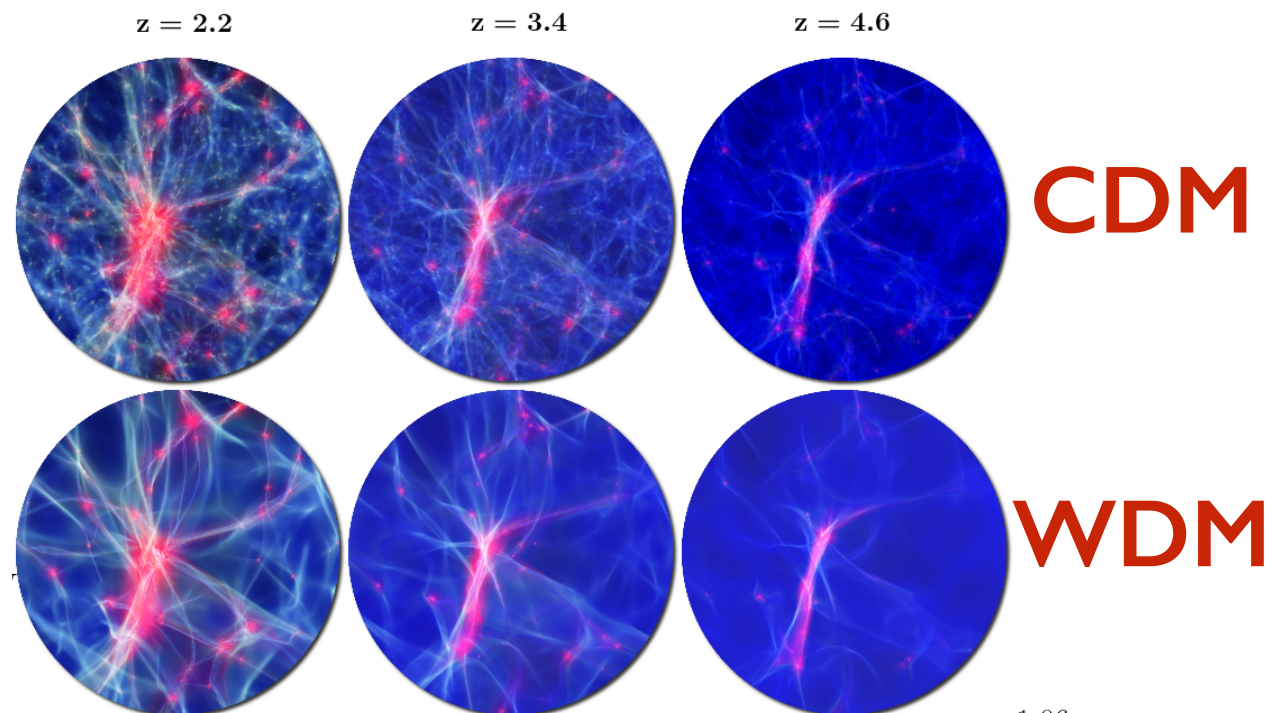
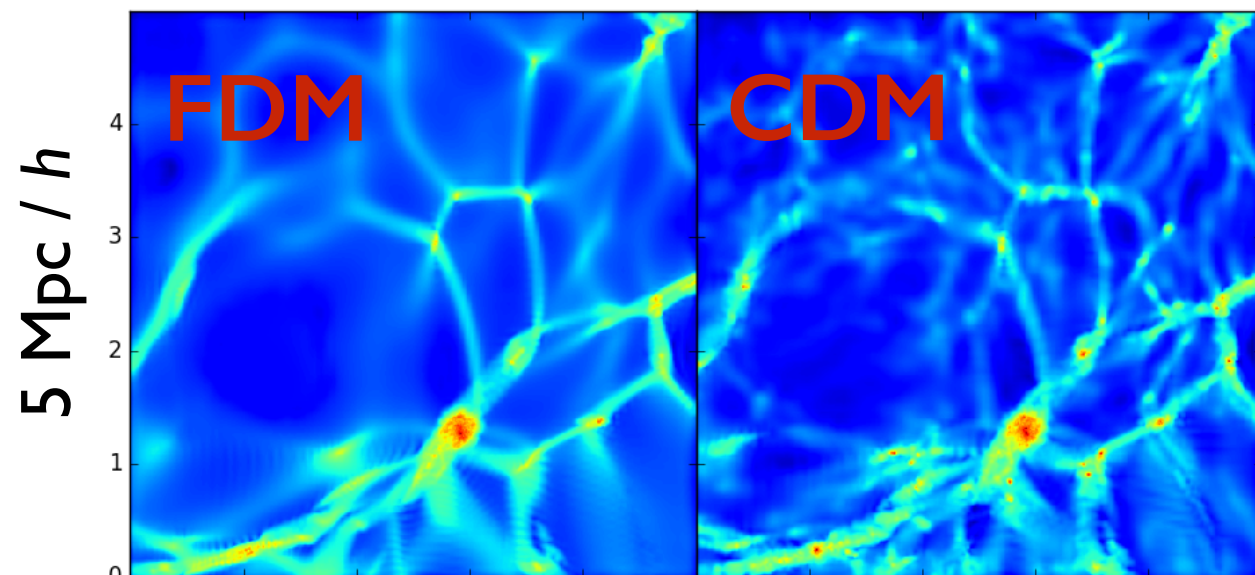
# The Lyman-alpha forest





# Ultra-light axion (fuzzy) dark matter [FDM]

+ warm dark matter [WDM] / interacting dark matter







# BAYESIAN EMULATOR OPTIMISATION

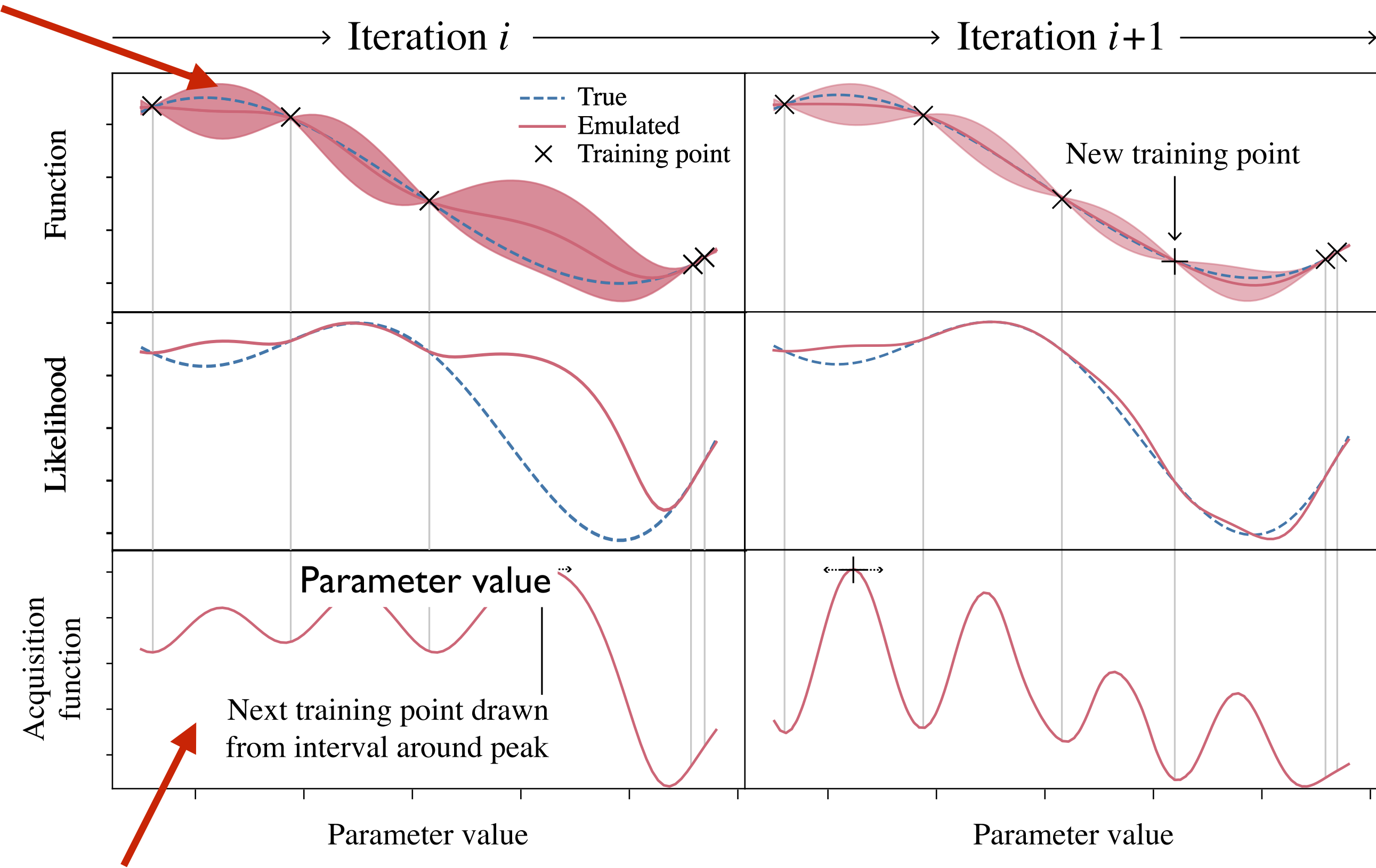
JCAP, 02, 031, 2019

JCAP, 02, 050, 2019

*with Peiris, Bird, Pontzen, Verde, Font-Ribera*

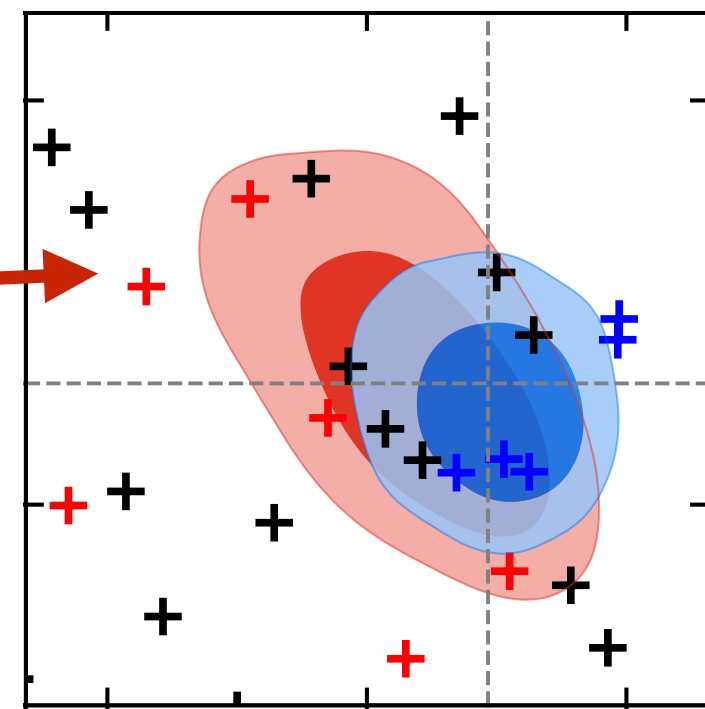
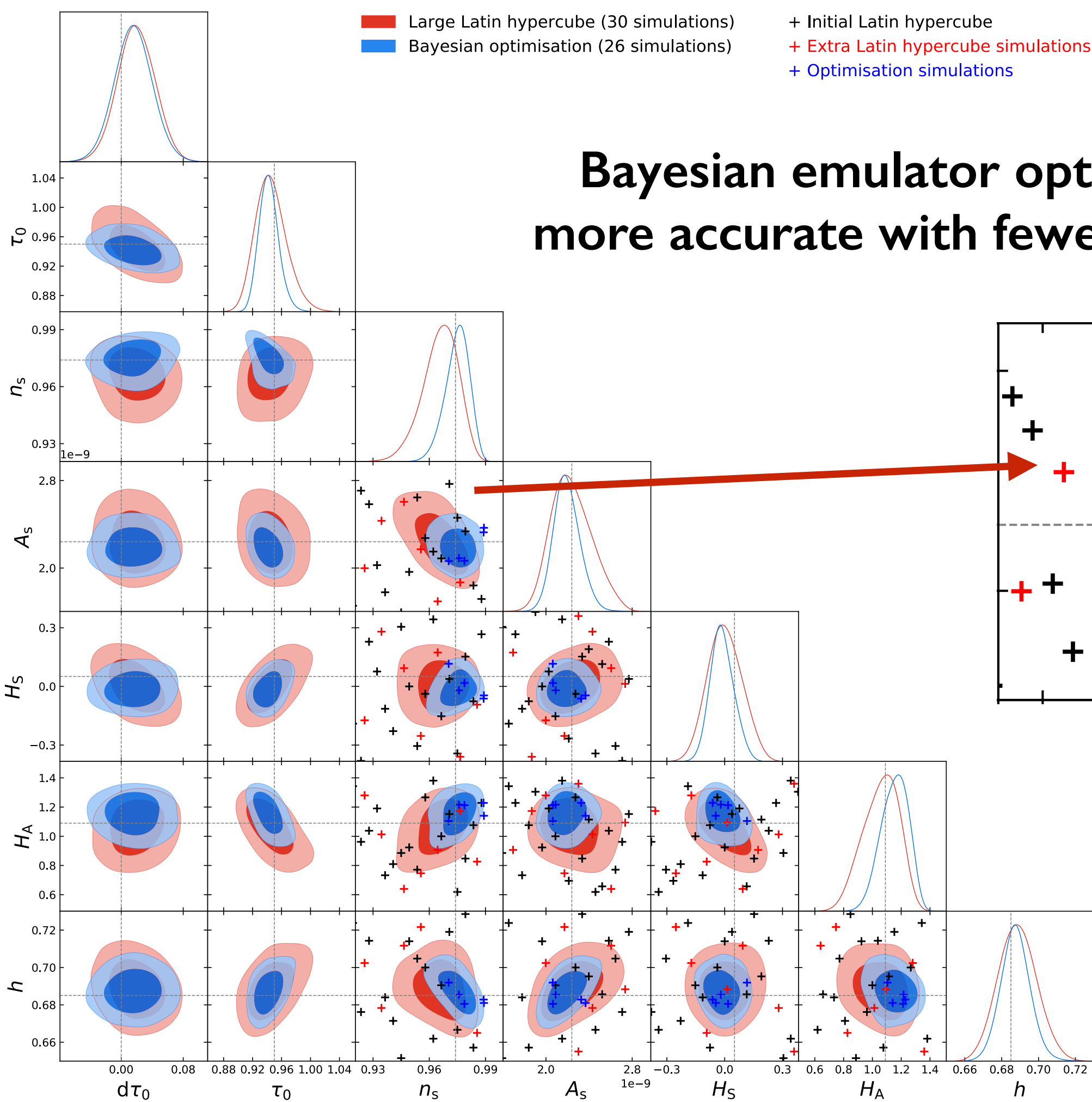


Gaussian process smoothly & probabilistically interpolates between training sims



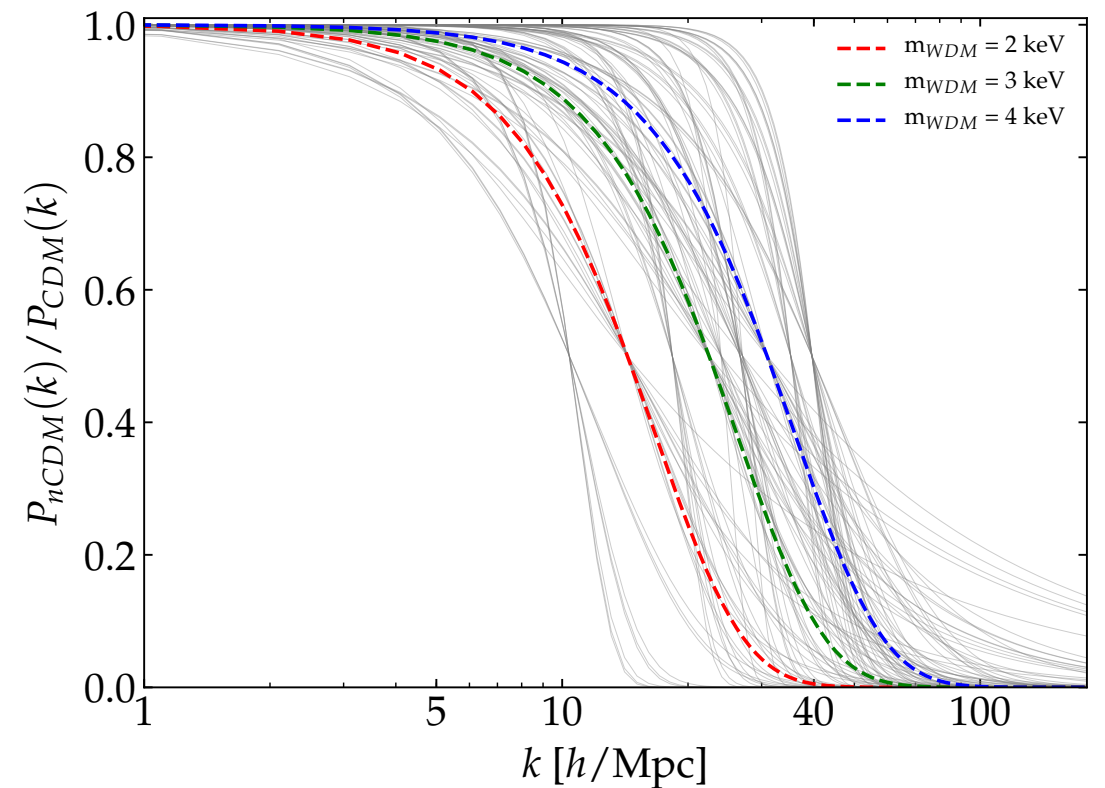
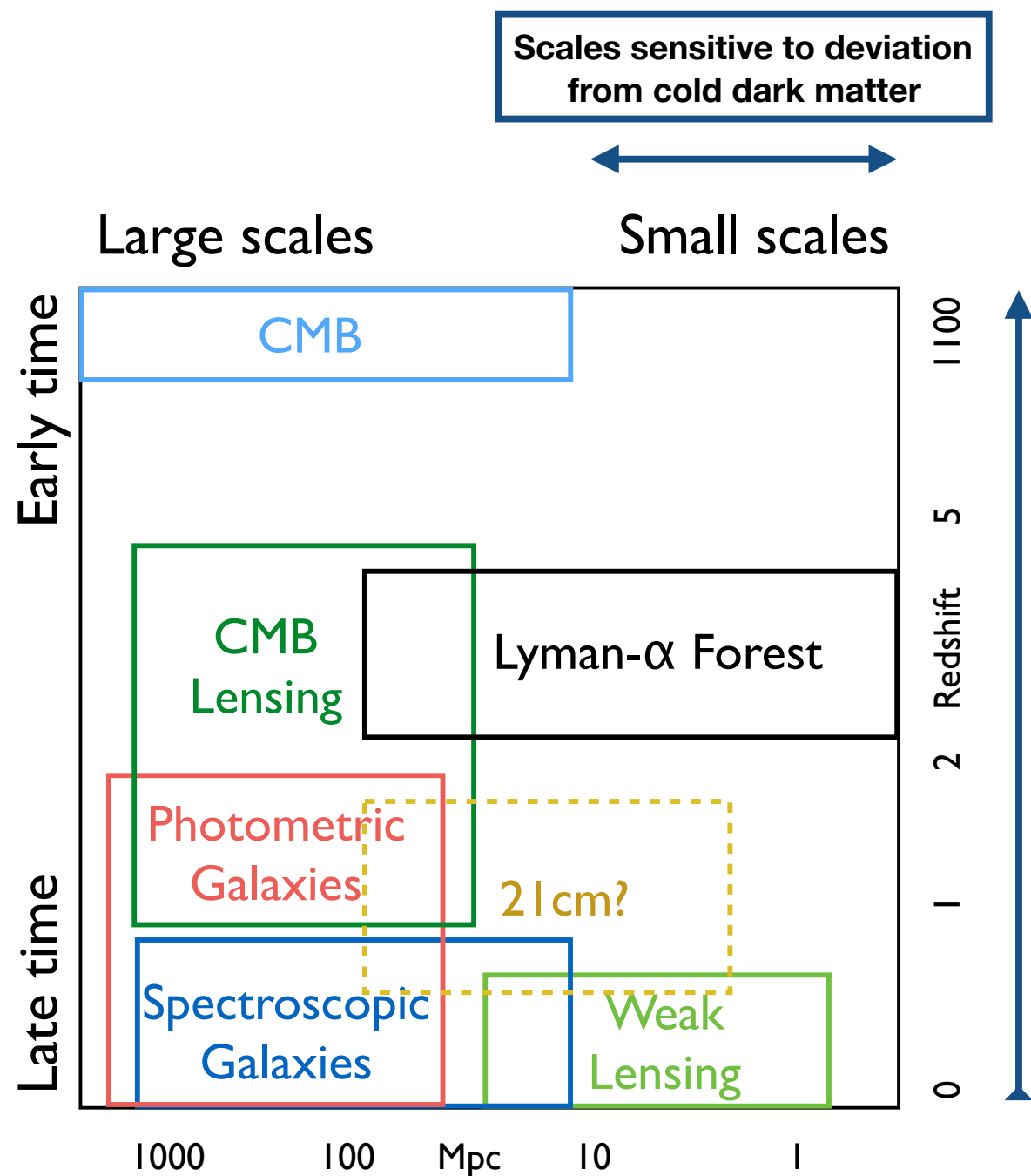
Bayesian optimisation actively constructs training set & tests for convergence







# TESTING THE PARADIGM OF COLD DARK MATTER

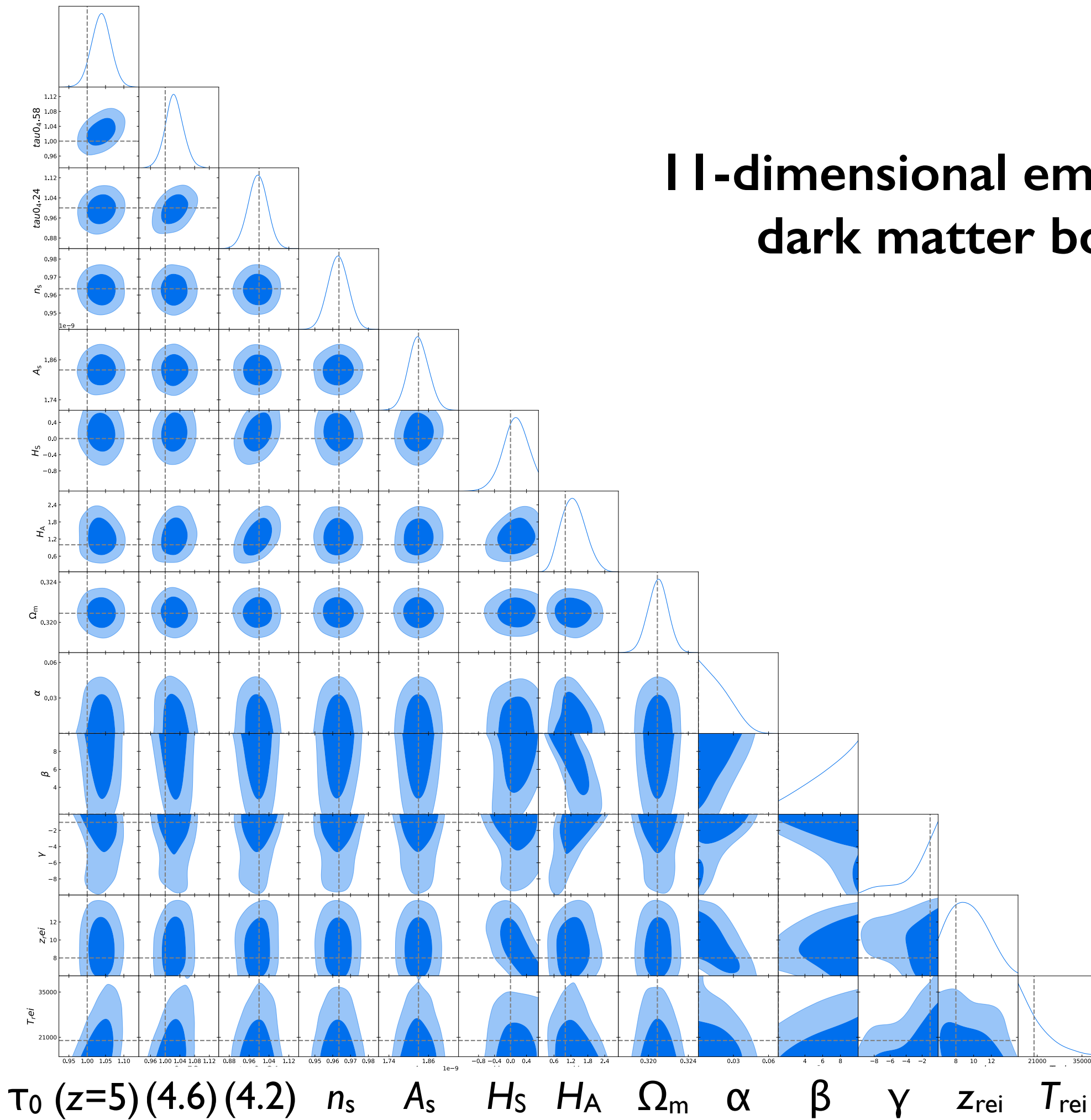


$$T^2(k) = \frac{P_{\text{nCDM}}(k)}{P_{\text{CDM}}(k)}$$

$$T(k) = [1 + (\alpha k)^\beta]^\gamma$$

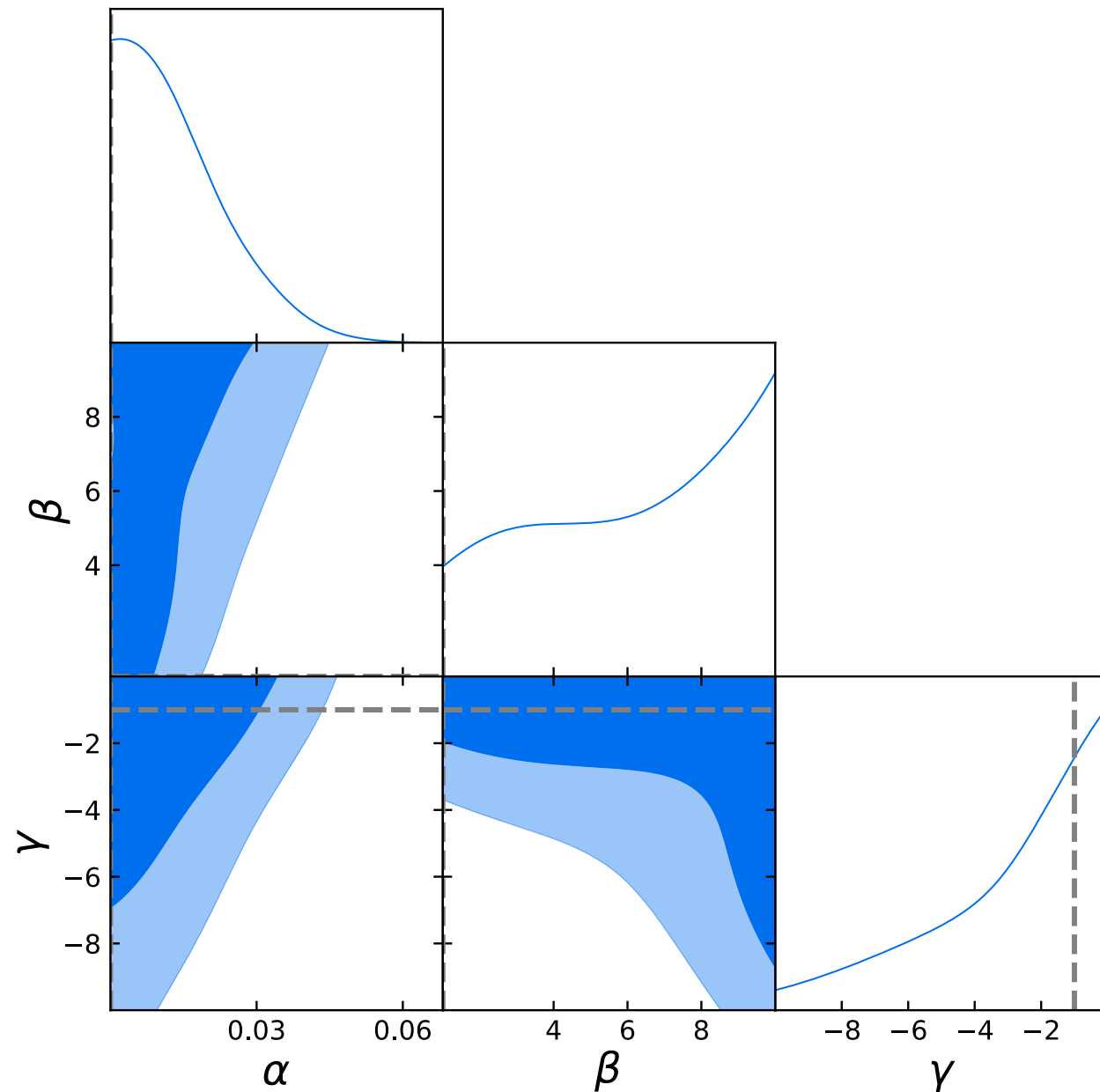


# 11-dimensional emulator for dark matter bounds

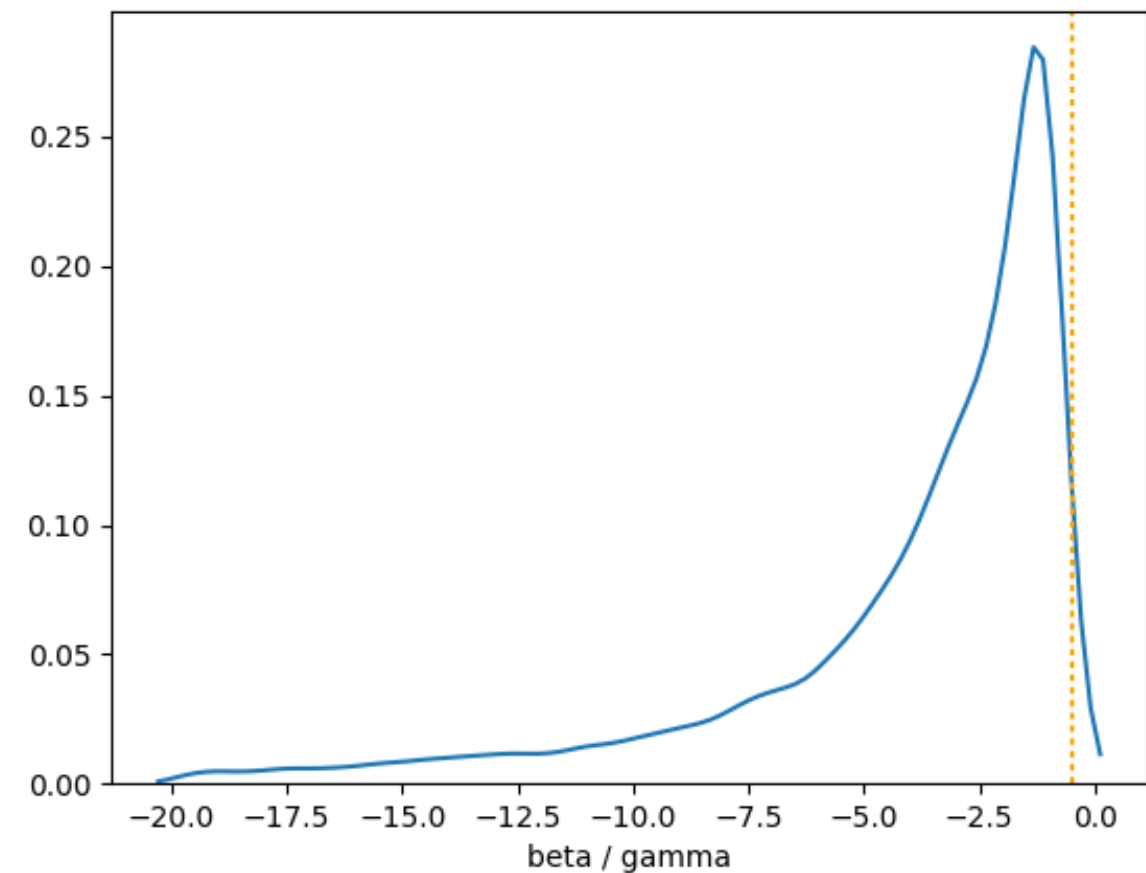




# The Lyman-alpha forest constrains dark matter model space by scale and shape of power spectrum suppression



$$m_{\text{ULA}} \geq 10^{-21} \text{ eV}$$



# Synergy

- Lyman-alpha forest sensitive to **light DM - baryon cross sections**  
unaccessible by traditional direct detection (e.g., CRESST)
- Ultra-light axion bounds **complementary to potential future direct detection** (CASPEr-ZULF)
- DM self-interaction bounds from Lyman-alpha forest arise from **scales intermediate to astro probes** (galaxy clusters/dwarf galaxies)

