Is a new cosmological tension emerging from the (Lyman-α) forest?

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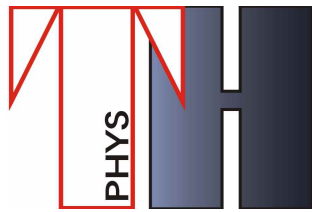
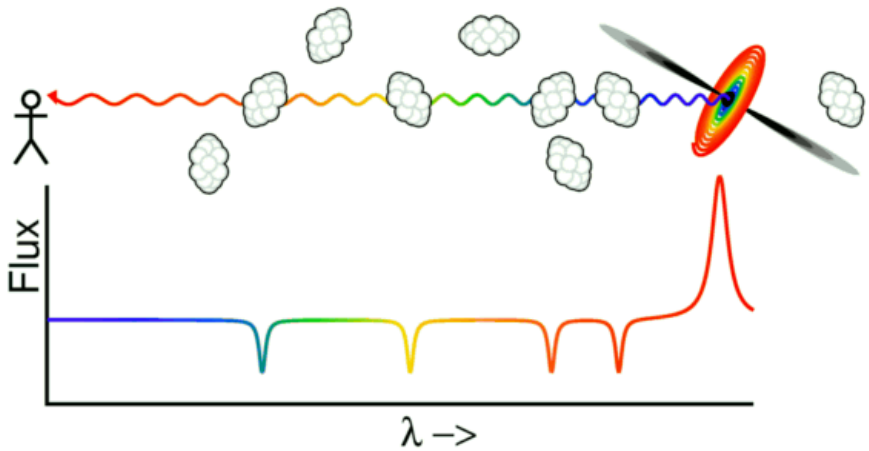
Presentation for the
"Tensions in cosmology" workshop



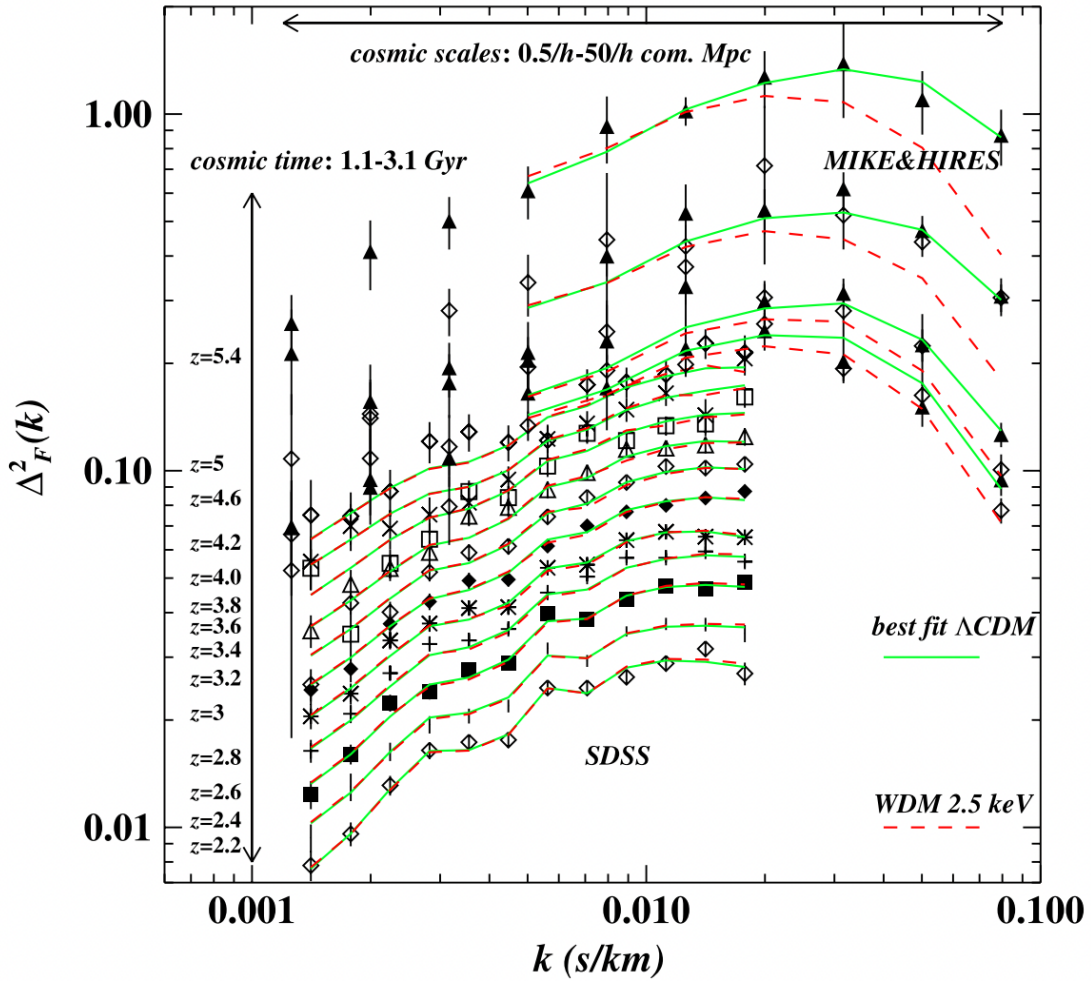
The Lyman-α flux power spectrum

- Photons from quasars 1) travel through H clouds, 2) get absorbed and 3) re-emitted in other direction
- Since clouds are at lower redshifts than source, features are shifted towards lower wavelengths $\rightarrow$ Lyα forest
- Density and temperature of clouds determine depth and width of absorption features

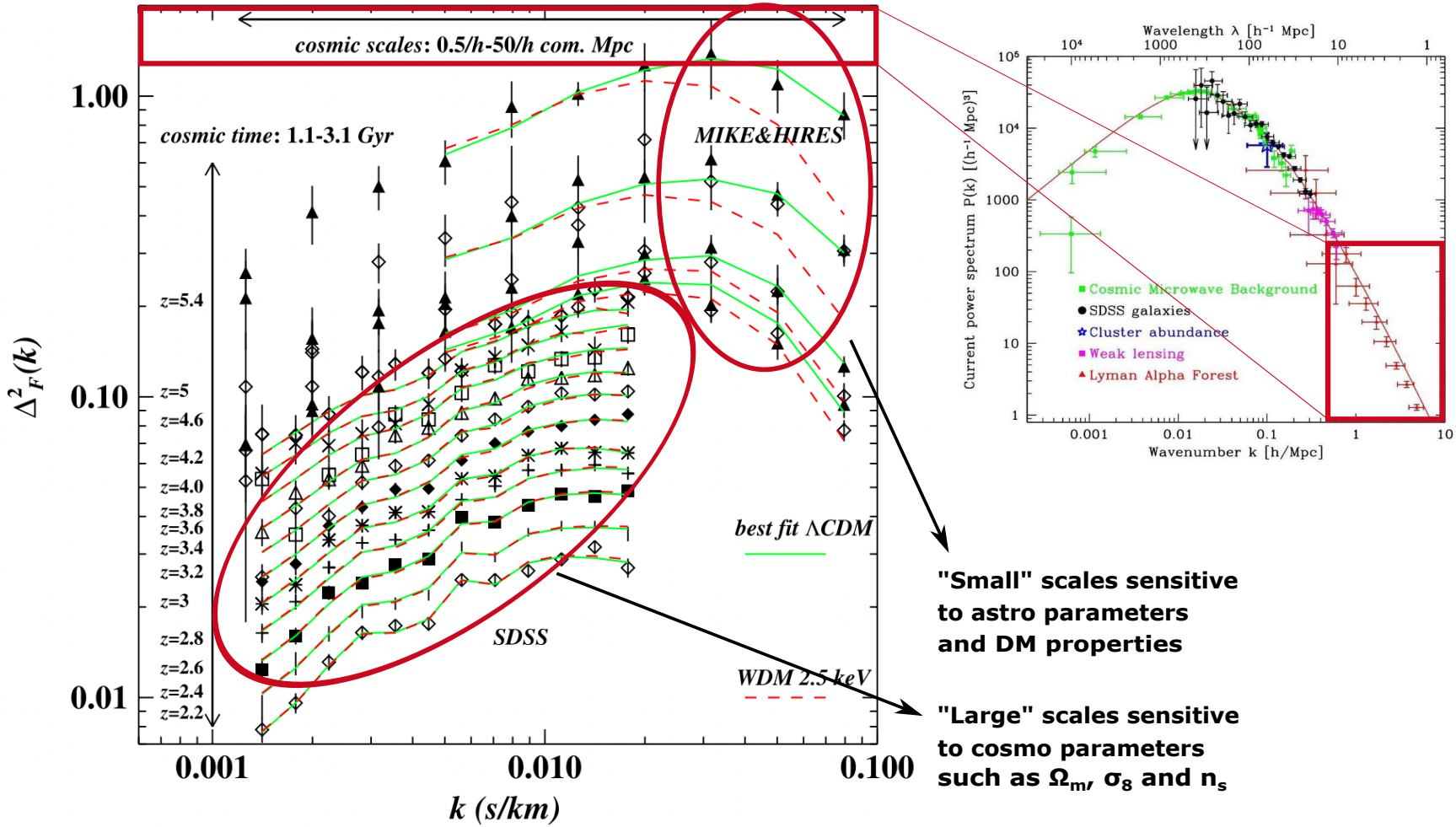


Adapted from `www.astro.ucla.edu`

- Calculate normalized "transmission", Fourier transform, ensemble average, get flux PS (see e.g. Garzilli et al. 2019 for pedagogical introduction)



Adapted from Viel et al. 2013

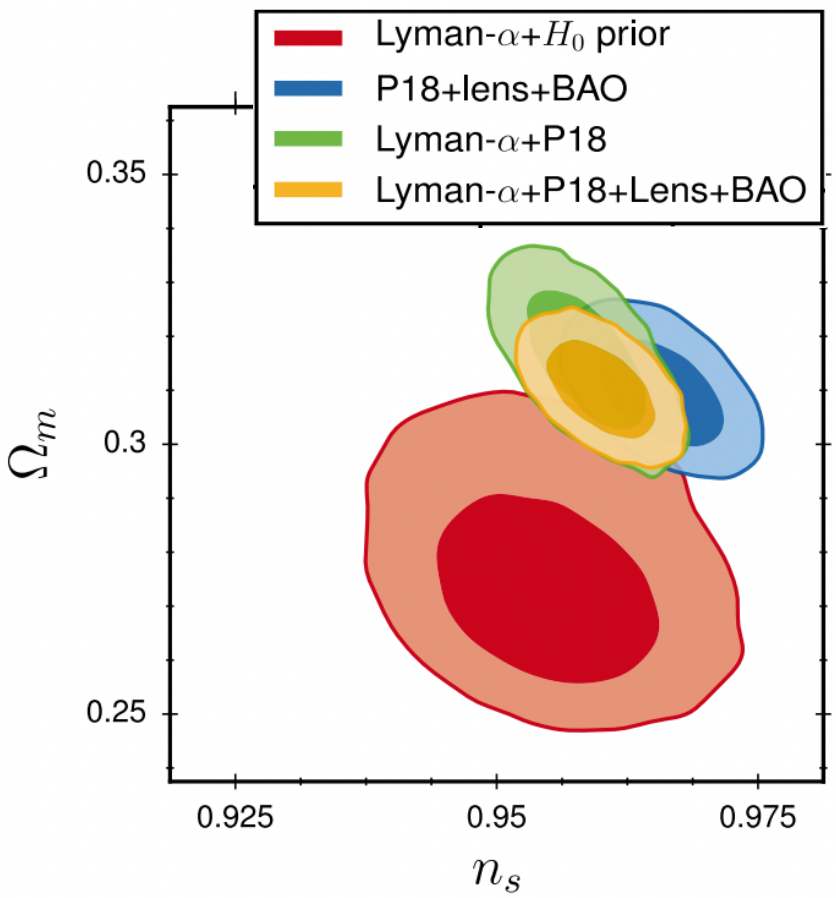


Adapted from Viel et al. 2013 (left) and Tegmark et al. 2004 (right)

State of the art: ΛCDM

At large scales (SDSS):

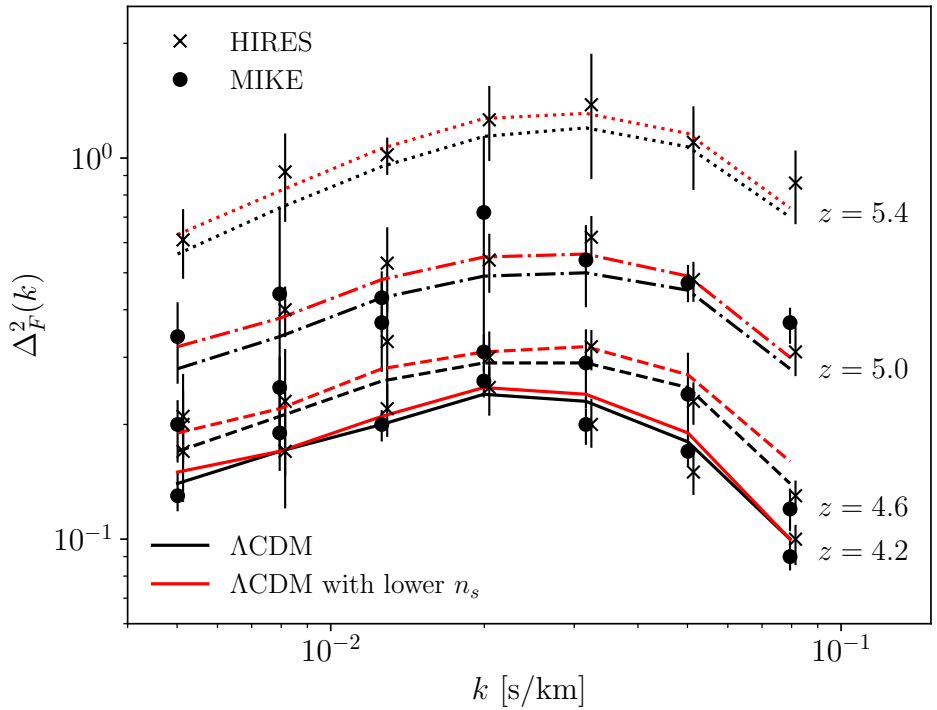
- Overall good agreement with weak lensing measurements
- $2.5 - 3.5\sigma$ tension with early-time measurements in the determination of the PS tilt
- Analysis with two independent slopes at CMB and Lyα scales
  $\rightarrow n_s(\mathrm{CMB}) = 0.967 \pm 0.004$
  vs. $n_s(\mathrm{Ly}\alpha) = 0.941 \pm 0.006$
  $\rightarrow \Delta\chi^2 \simeq -14$
- Preference for a PS more strongly falling off than CMB would like



Adapted from Palanque-Delabrouille et al. 2019

At small scales (MIKE/HIRES+XQ-100):

- Visually clear that ΛCDM prediction (black) lays below MIKE/HIRES data points and that a lower n_s (red) can improve the fit



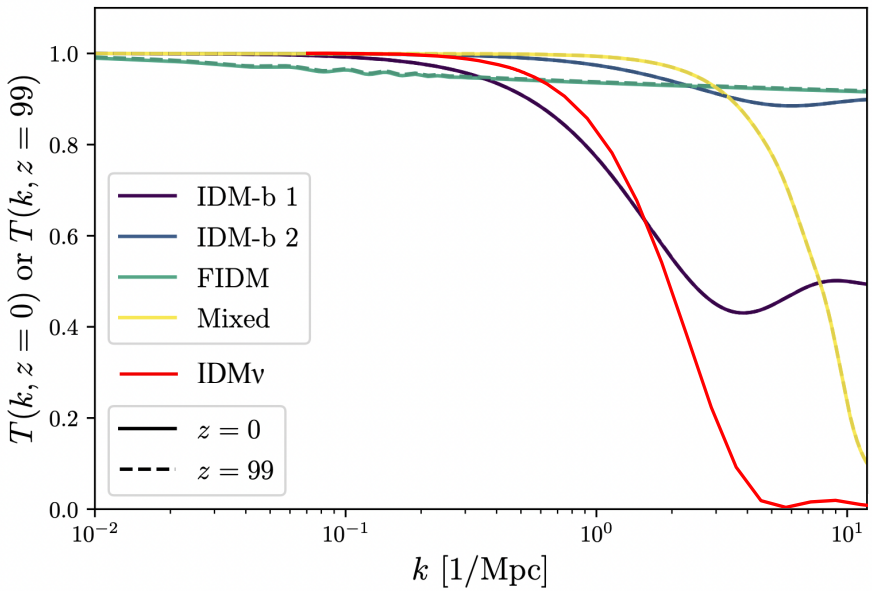
- More quantitative analysis in progress (Piga, Murgia et al. 2022)

Adapted from Hooper & Lucca 2021

State of the art: dark matter

Generalities on the role of (light/warm and interacting) DM:

- If the DM is 1) light/warm ($m_{\rm DM} \simeq \mathcal{O}$(few keV)) or 2) interacting (with e.g. baryons, γ, ν and dark radiation), high velocity dispersion/ interactions act as pressure/dragging effect countering the gravitational collapse
- Suppression of the MPS
- Shape of the suppression encapsulates the model dependence



$\rightarrow$ Many DM models predict a suppression of the PS at Lyα scales, but which ones can correctly adjust its tilt?

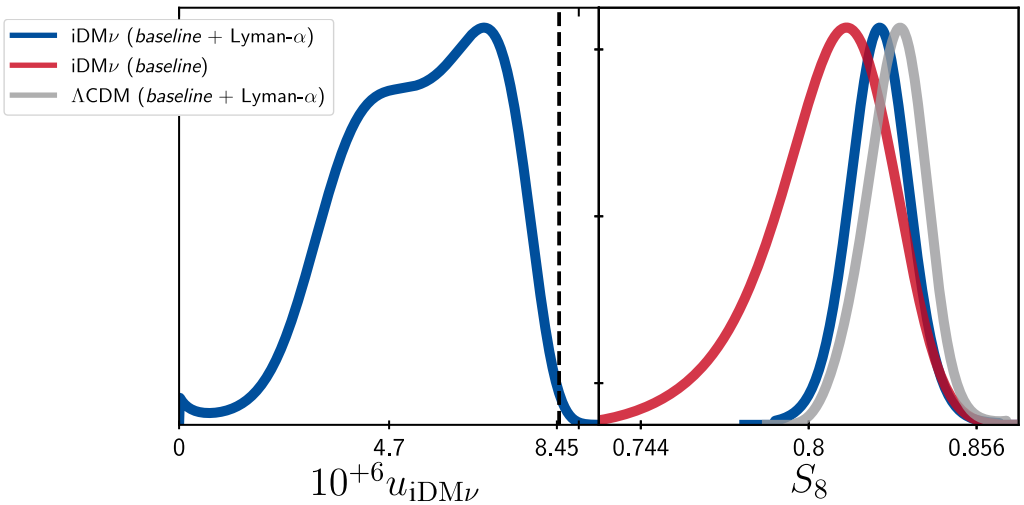
Adapted from Hooper et al. 2022 (with info from Hooper & Lucca 2021)

Hints of new physics?

(Hooper & Lucca 2021 and Hooper et al. 2022)

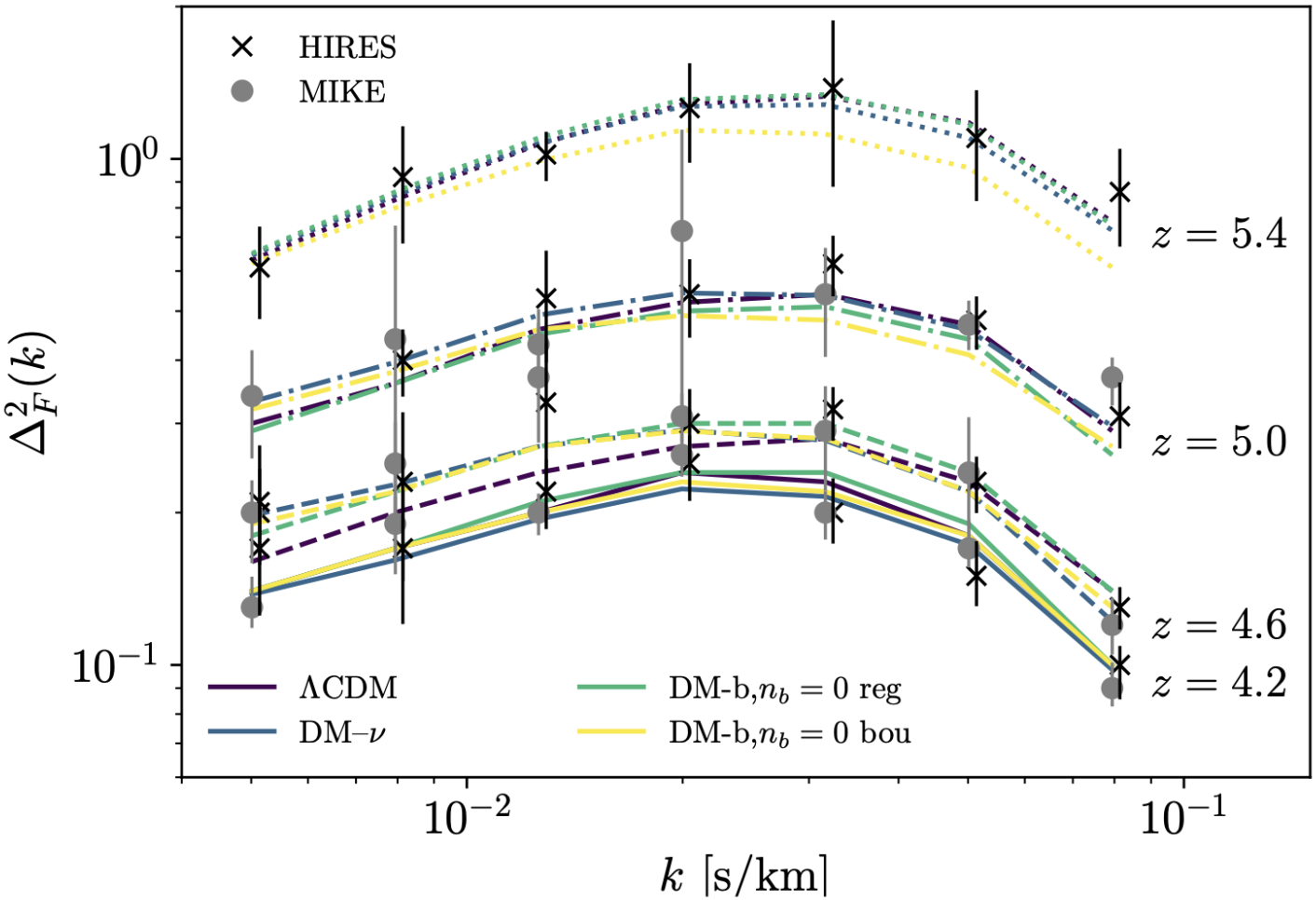
Case-by-case study in the context of MIKE/HIRES data:

- WDM and FIDM show no preference
  $\rightarrow$ indicative for sharpest and softest suppression
- DM-b interactions show a slight preference for
  $\sigma_{\rm DMb} \simeq 4 - 6 \times 10^{-27}$ cm^2 and $f_{\rm DMb} \simeq 0.06 - 0.2$
- DM-ν interactions show a preference for $\sigma_{\rm DM\nu}$ 3σ away from zero
  (with the requirement of a relatively cold thermal history)



Adapted from Hooper & Lucca 2021

Visual confirmation:



Adapted from Hooper et al. 2022

Final thoughts and take-home message

What we know:

- There is a $2-3\sigma$ tension in the determination of the PS's tilt between early-time and Lyman-α measurements
- Many DM models predict a suppression of the PS at Lyman-α scales, but only few seem to be "correctly" adjusting the PS's tilt (DM-ν and DM-b interactions are two such examples)

What we do not know (yet):

- Is the tension real?
  $\rightarrow$ Need for combined analyses to cover as many scales as possible
  $\rightarrow$ Fundamental role of upcoming data
- Is this tension actually *new*? Could it just be a small-scale extension of the σ_8 tension?
- What would it take to solve the tension?