A new method to determine H_0 from cosmological energy-density measurements

8 May 2024, Future Spectroscopic Surveys, Berkeley
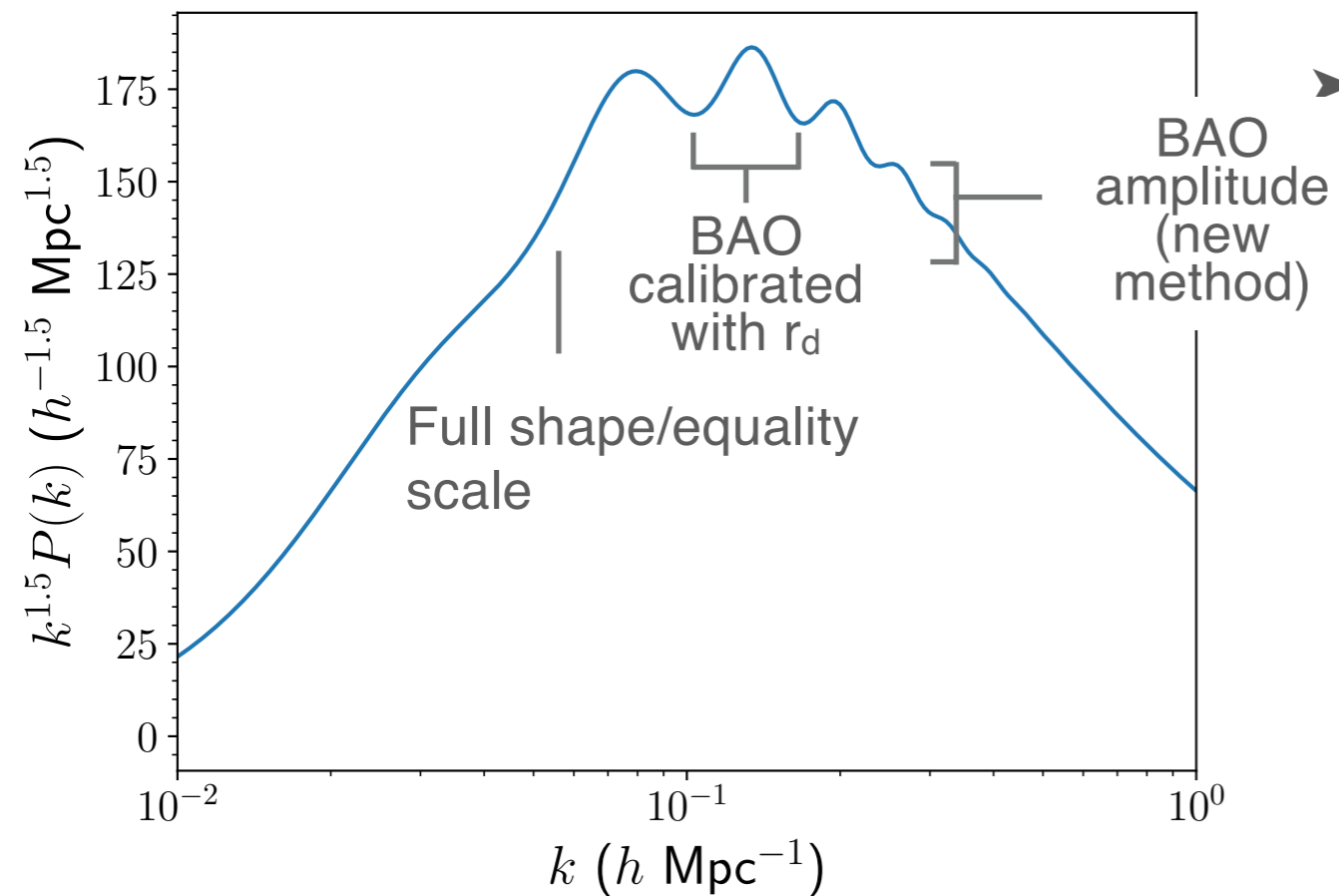
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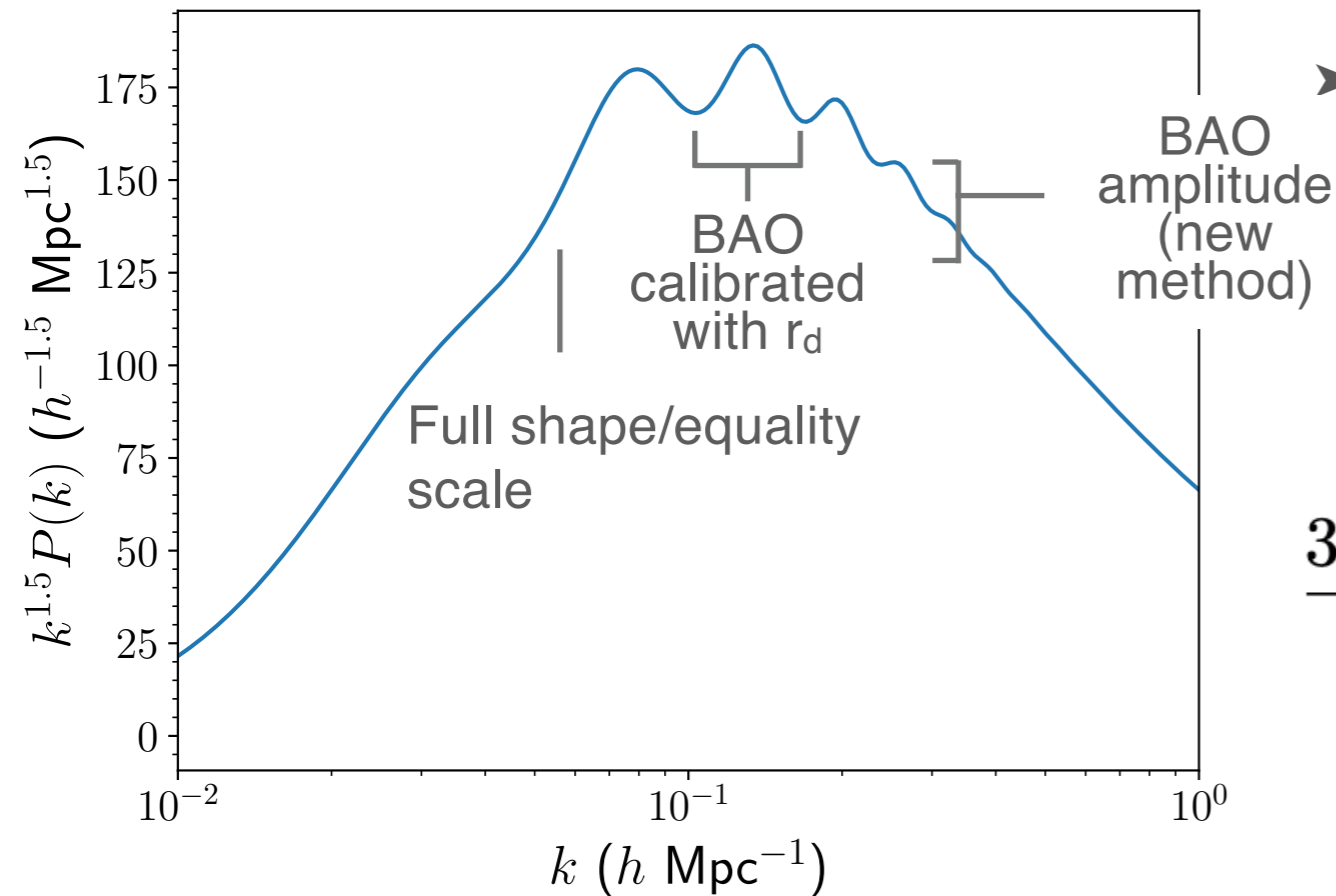
2403.19227 and 2403.19236

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A new sound horizon free H$_0$ measurement

Plot axes: $k^{1.5} P(k)$ ($h^{-1.5}$ Mpc$^{1.5}$) vs k (h Mpc^{-1})

Labels on plot:
- BAO calibrated with r$_d$
- BAO amplitude (new method)
- Full shape/equality scale

➤ Can we measure H$_0$ without any reference to standard rulers (equality or sound horizon)?

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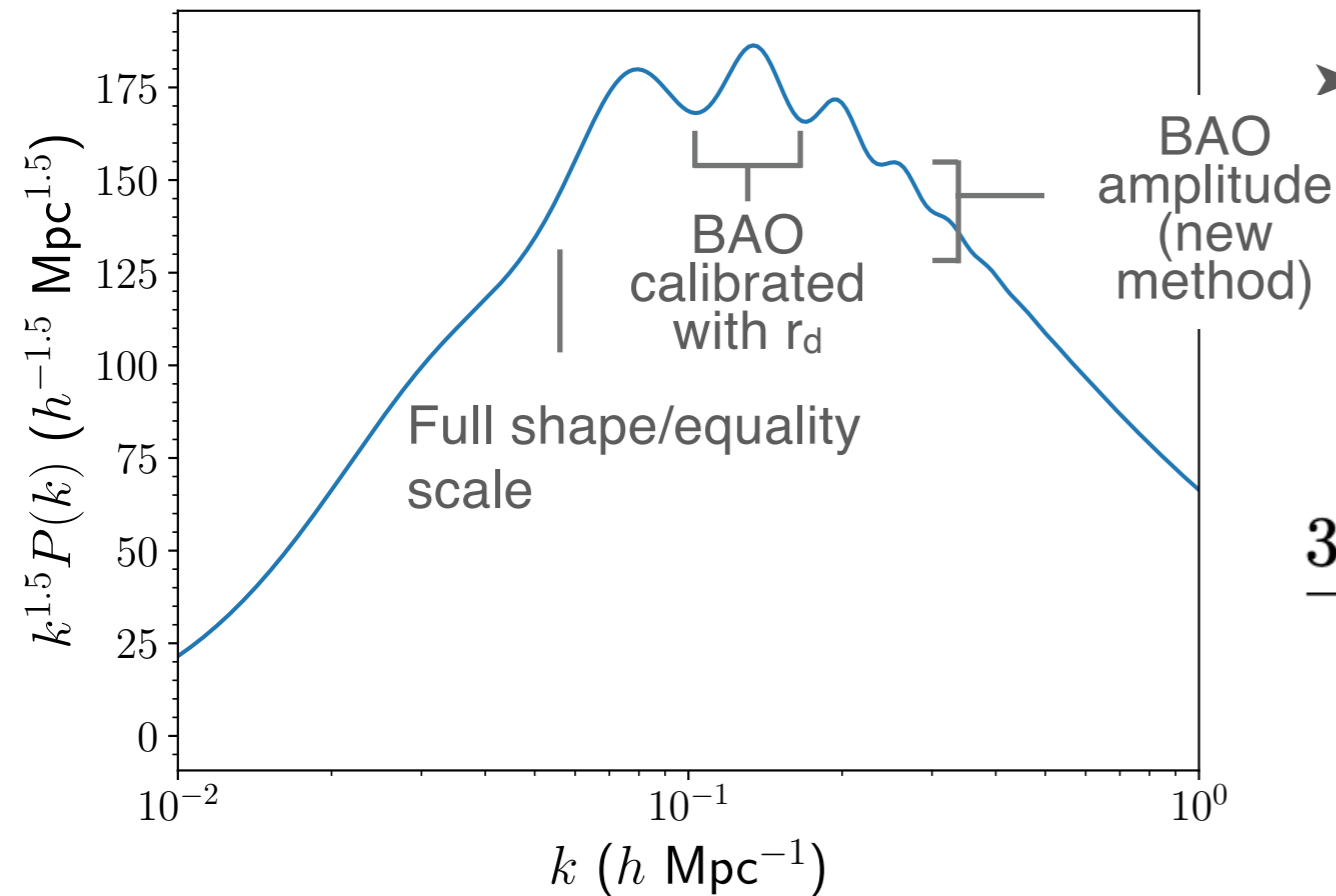WATERLOO

A new sound horizon free H_0 measurement
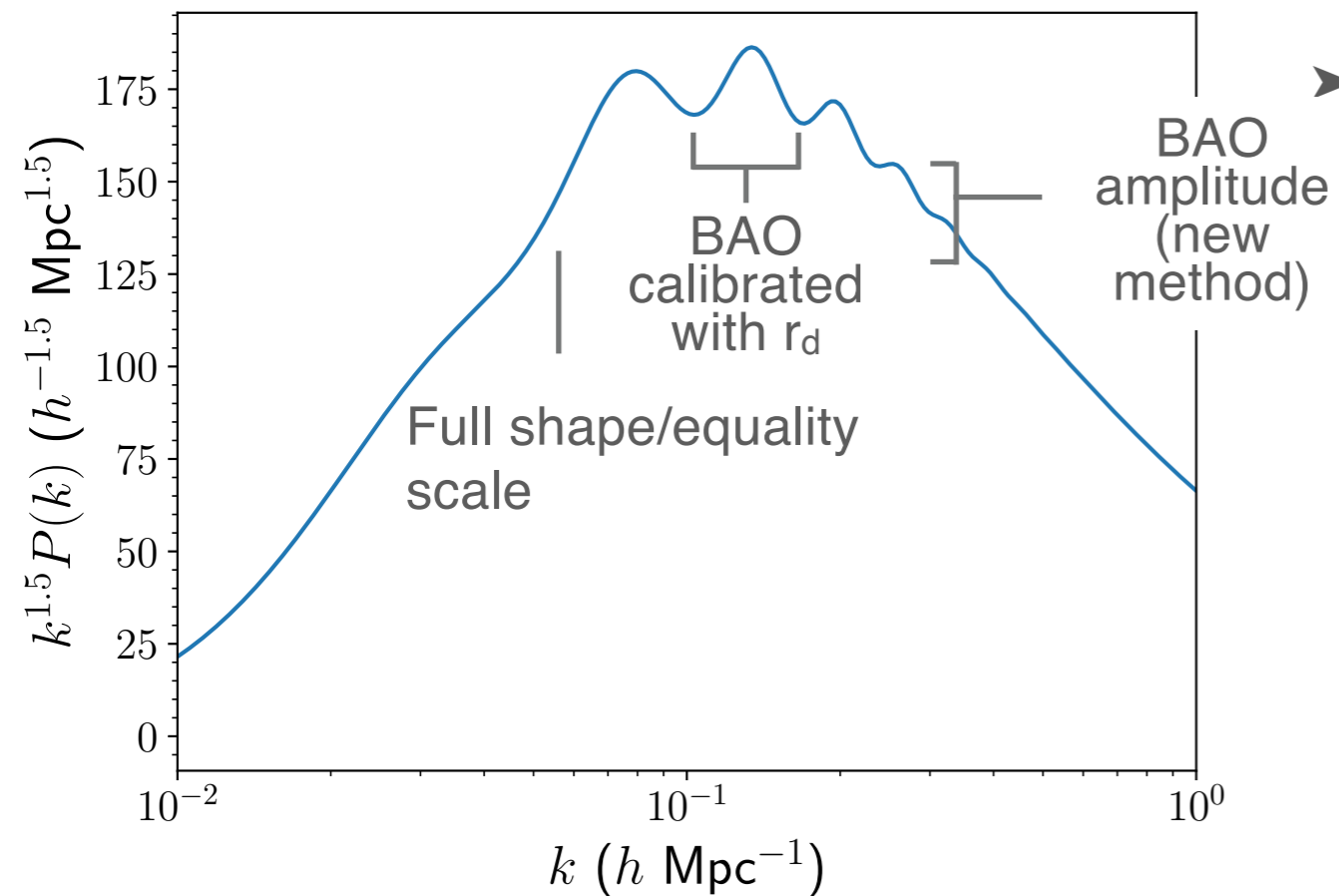

➤ Can we measure H_0 without any reference to standard rulers (equality or sound horizon)?

➤ Yes!

$$\frac{3c^2 H_0^2}{8\pi G} = \epsilon_c = \epsilon_{\gamma,0} \times \frac{\epsilon_{b,0}}{\epsilon_{\gamma,0}} \times \frac{\epsilon_{m,0}}{\epsilon_{b,0}} \times \frac{1}{\Omega_{m,0}}.$$

CMB Temp.   BBN   Amp. of
                    baryon
                    signal   Geometry

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A new sound horizon free H₀ measurement

Plot with y-axis labeled $k^{1.5} P(k)$ ($h^{-1.5}$ Mpc$^{1.5}$) and x-axis labeled k (h Mpc^{-1}).

Labels on plot: "BAO calibrated with r_d", "BAO amplitude (new method)", "Full shape/equality scale"

➤ Can we measure H₀ without any reference to standard rulers (equality or sound horizon)?

  ➤ Yes!

$$\frac{3c^2 H_0^2}{8\pi G} = \epsilon_c = \epsilon_{\gamma,0} \times \frac{\epsilon_{b,0}}{\epsilon_{\gamma,0}} \times \frac{\epsilon_{m,0}}{\epsilon_{b,0}} \times \frac{1}{\Omega_{m,0}}.$$
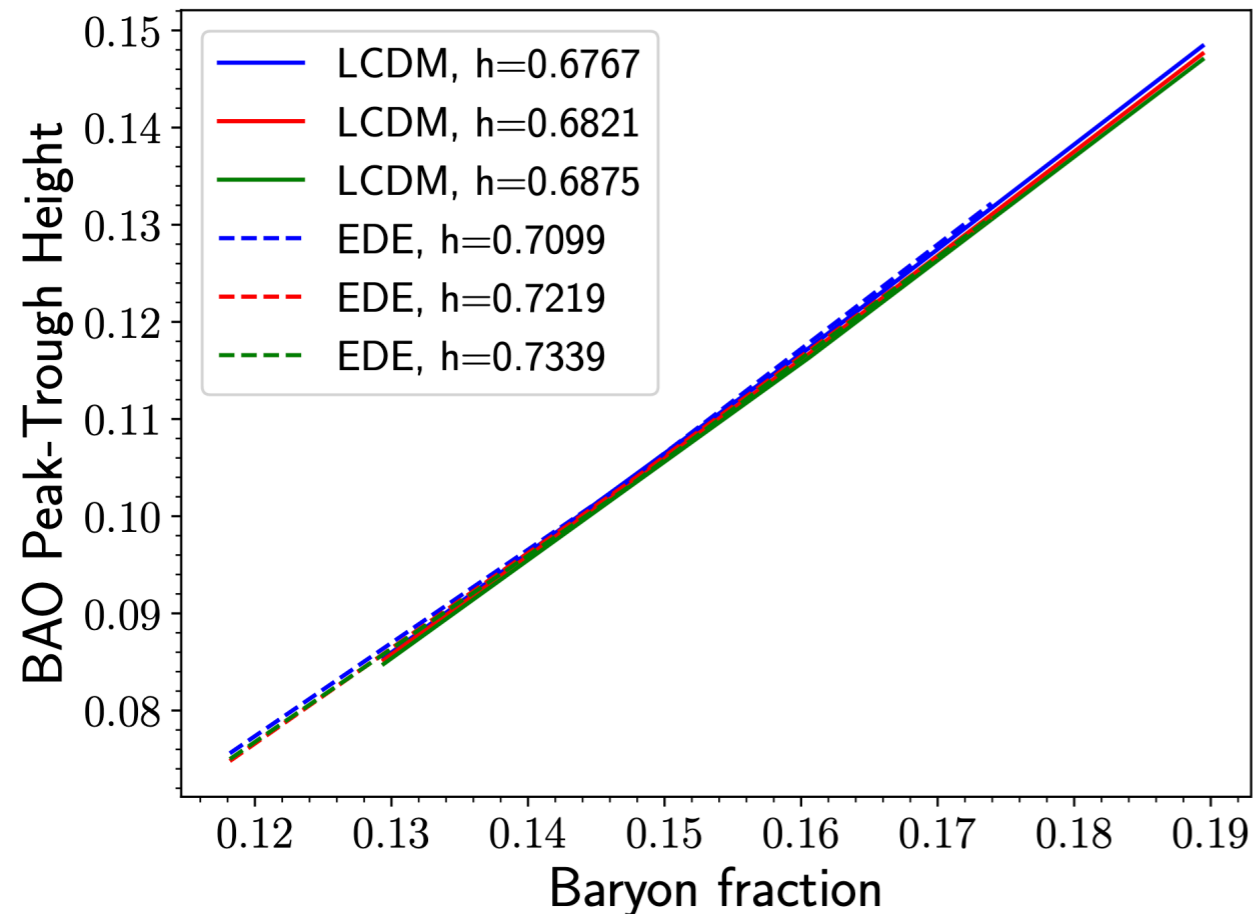
CMB Temp.   BBN   Amp. of baryon signal   Geometry

➤ Goals: model-independent constraints on Hubble-changing cosmologies; decomposing parameter constraints into their constituent physics

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A new sound horizon free H_0 measurement

Plot: $k^{1.5}P(k)$ ($h^{-1.5}$ Mpc$^{1.5}$) versus k (h Mpc^{-1}). Labels: "Full shape/equality scale", "BAO calibrated with r_d", "BAO amplitude (new method)".

➤ New method is complementary to

  ➤ Standard H_0 constraints calibrated by the sound horizon

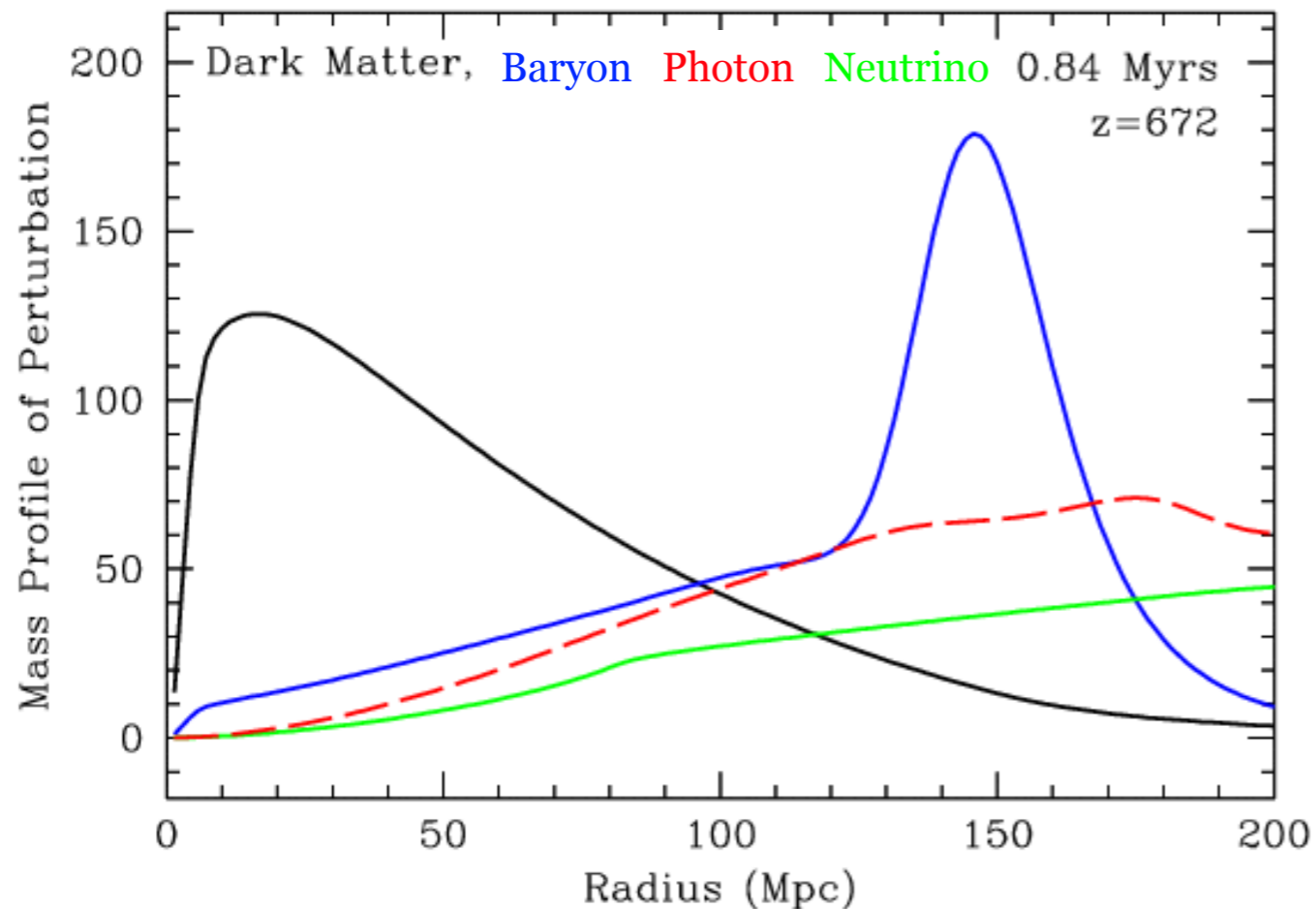 ➤ Equality scale standard ruler measurements (Baxter & Sherwin 2021)

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A new sound horizon free H₀ measurement

Legend:
- LCDM, h=0.6767
- LCDM, h=0.6821
- LCDM, h=0.6875
- EDE, h=0.7099
- EDE, h=0.7219
- EDE, h=0.7339

X-axis: Baryon fraction
Y-axis: BAO Peak-Trough Height

➤ BAO amplitude is *very robust* to P(k) changes from Early Dark Energy

$$\frac{3c^2 H_0^2}{8\pi G} = \epsilon_c = \epsilon_{\gamma,0} \times \frac{\epsilon_{b,0}}{\epsilon_{\gamma,0}} \times \frac{\epsilon_{m,0}}{\epsilon_{b,0}} \times \frac{1}{\Omega_{m,0}}.$$

CMB Temp.　　BBN　　Amp. of baryon signal　　Geometry

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Measuring the baryon fraction

credit: Daniel Eisenstein

➤ Split the transfer function into baryonic and CDM components with new parameter γ_B

$$P(k) \propto (\gamma_B T'_b(k) + (1 - \gamma_B)T'_c(k))^2$$

➤ Use both template-based and full-shape methods to fit data

  ➤ Template based: fits pre-recon and post-recon correlation functions

 ➤ Full-shape based: add γ_B as extra parameter in CLASS-PT

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Template and full-shape fits

|	Template Fits	Full-shape fits
Cosmological Parameters?	Fixed ❌	Varied ✔
Reconstruction?	✔	❌
Nonlinear parameters?	❌	✔
Speed	✔	❌
Model independent?	✔	❌

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Tests on N-body mocks

➤ Test recovery of γ_B on mean of 84 Nseries mocks

   ➤ Large-volume N-body mocks matching the geometry of CMASS NGC

➤ γ_B recovered within 0.4σ (0.3σ for full-shape)
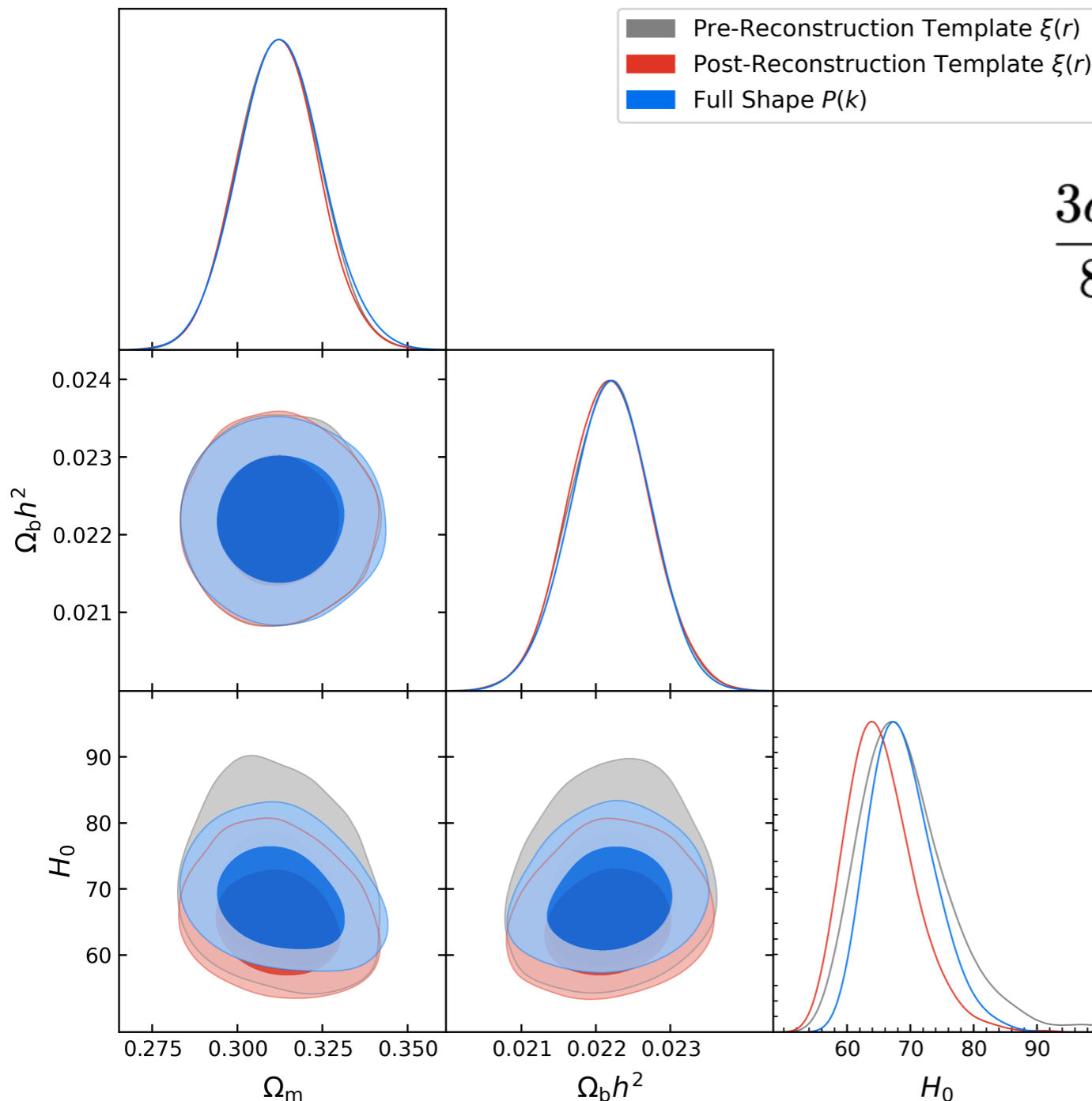

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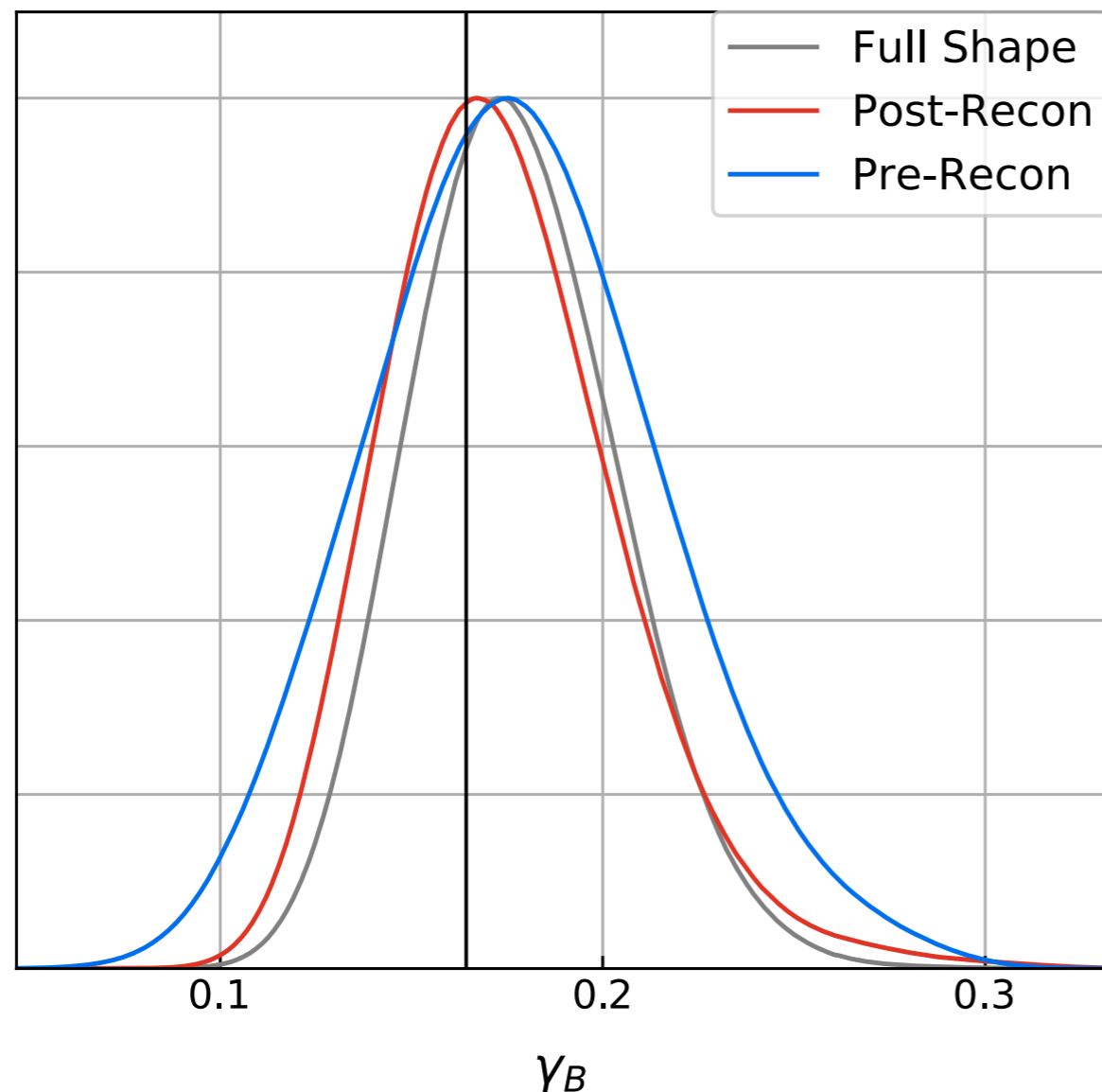
Noiseless theory vector tests: full-shape fits

➤ γ_B recovery similar between ΛCDM, EDE, and Nseries mocks
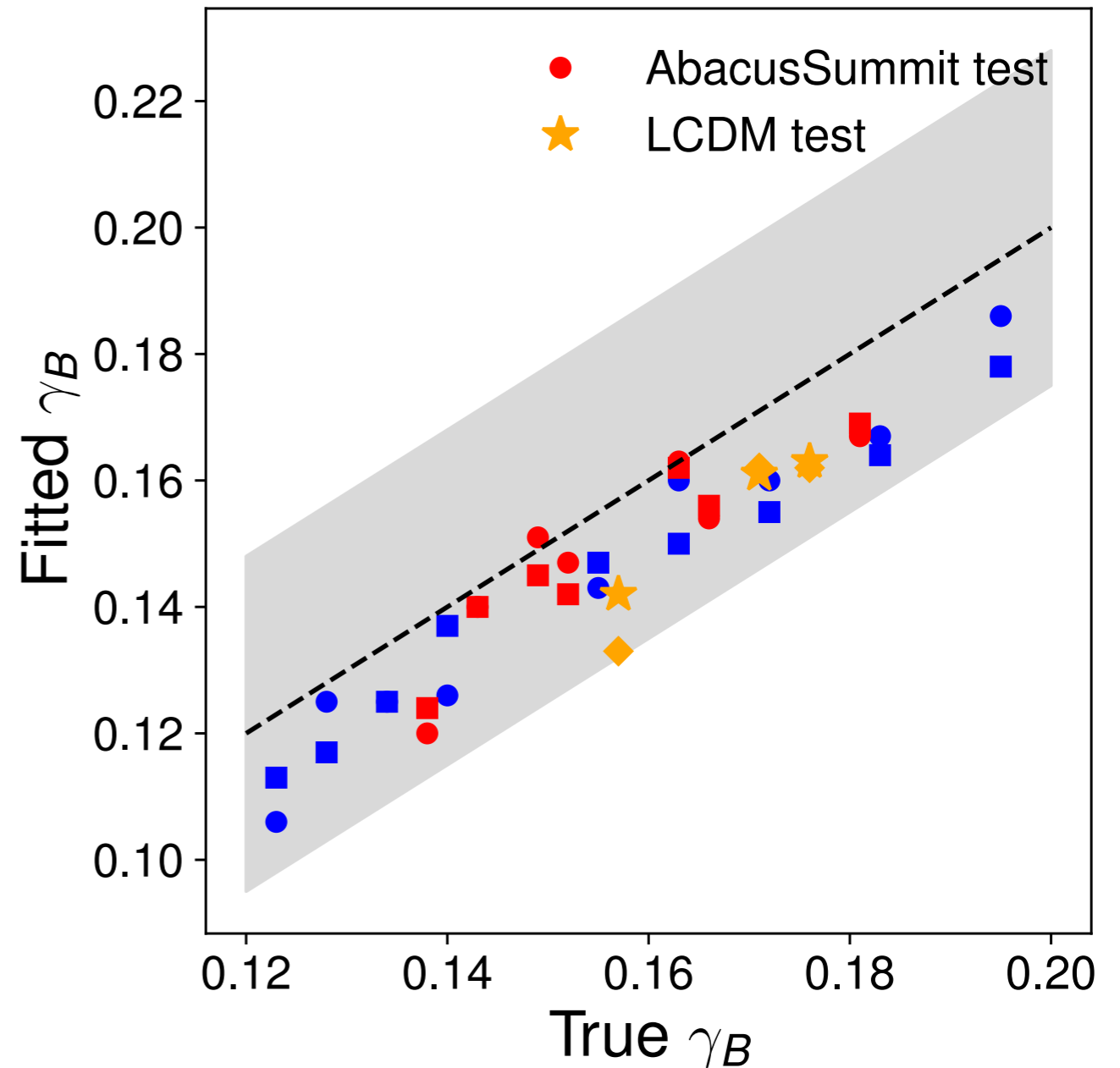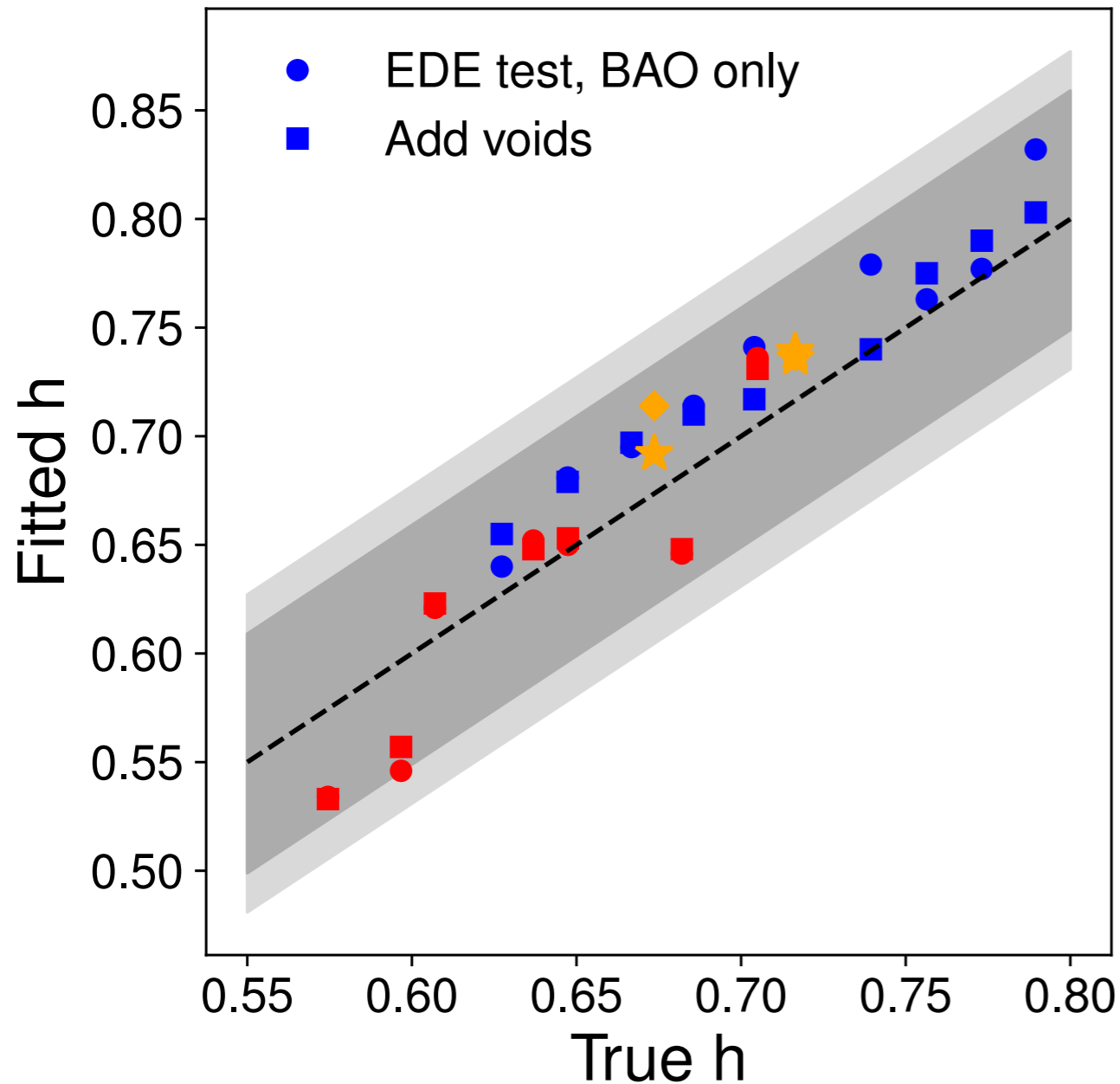
Combining with BBN and uncalibrated standard rulers to measure H_0

➤ Datasets: BOSS baryon amplitude + BBN (Schoeneberg et al. (2024)) + BOSS distances marginalizing over r_d + Type Ia Supernovae + void AP constraints

$$\frac{3c^2 H_0^2}{8\pi G} = \epsilon_c = \epsilon_{\gamma,0} \times \frac{\epsilon_{b,0}}{\epsilon_{\gamma,0}} \times \frac{\epsilon_{m,0}}{\epsilon_{b,0}} \times \frac{1}{\Omega_{m,0}}.$$

CMB Temp.   BBN   Amp. of   Geometry
                      baryon
                      signal

Legend:
- Pre-Reconstruction Template $\xi(r)$
- Post-Reconstruction Template $\xi(r)$
- Full Shape $P(k)$

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Energy density H$_0$ constraint

➤ Current constraints are rather weak (BOSS detects BAO at ~8σ)

➤ DESI-Y1 constraints ongoing; DESI-Y5+Euclid will allow σ$_{H0}$ ~ 1.5 km/s/Mpc

➤ Constraining power scales similarly to BAO: DESI-2 & Spec-S5 are ideal for this measur