The Hubble Tension and the Magnetic Universe

with new constraints from ACTDR4 and SPT-3G Year 1 data

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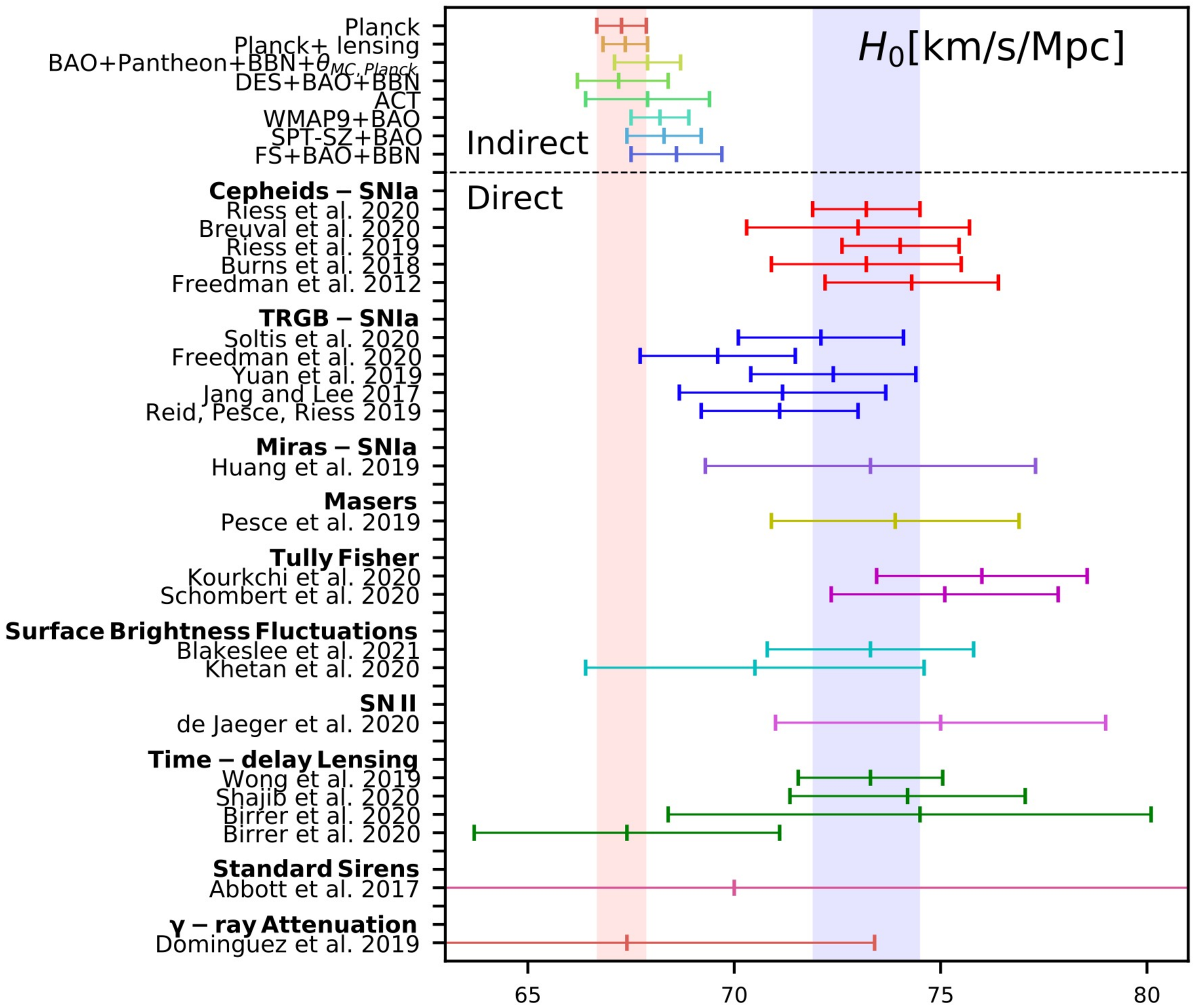
KJ and LP, arXiv:2004.09487, Phys. Rev. Lett.
SG, KJ and LP, in preparation

The Hubble tension



from E. Di Valentino, arXiv:2011.00246

The tension is between measurements that rely on a model to determine *the sound horizon at recombination* and those that do not

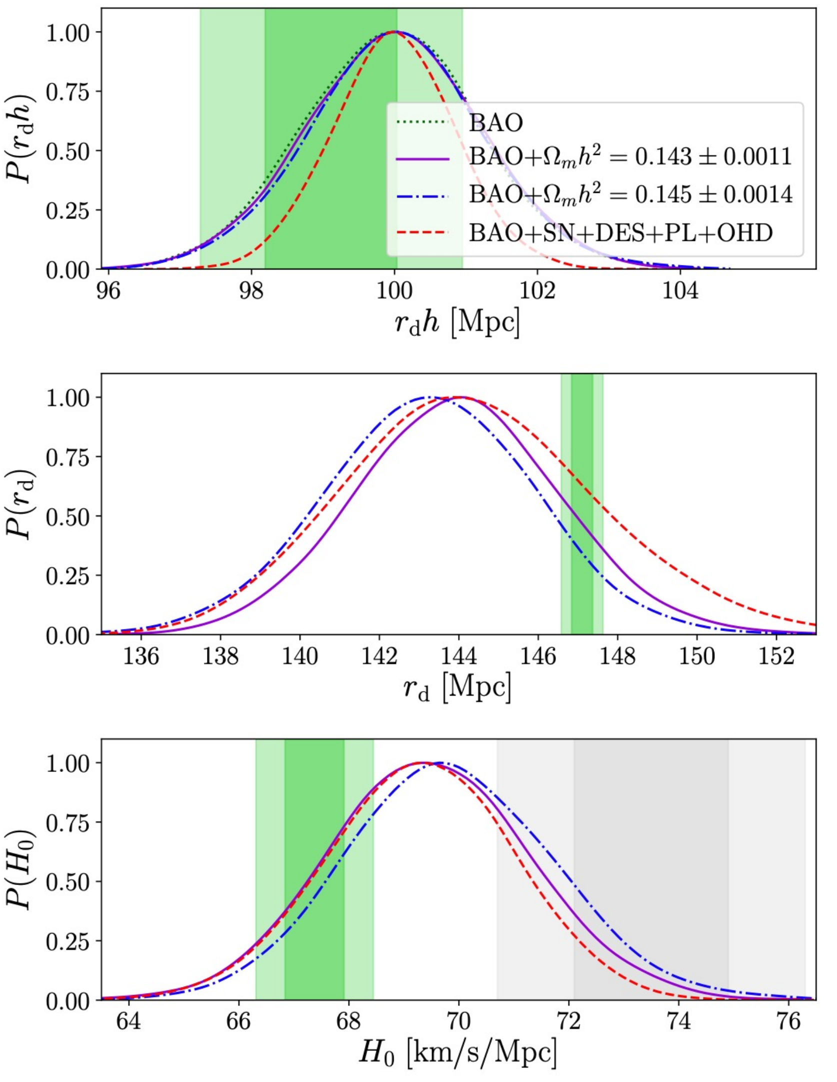
The sound horizon and H_0 determined from BAO in a recombination-independent way

Treat r_d as an independent parameter

Combine BAO (eBOSS DR16+) with CMB lensing, galaxy weak lensing and cosmic chronometers

or

Combine BAO with a prior on $\omega_m = \Omega_m h^2$



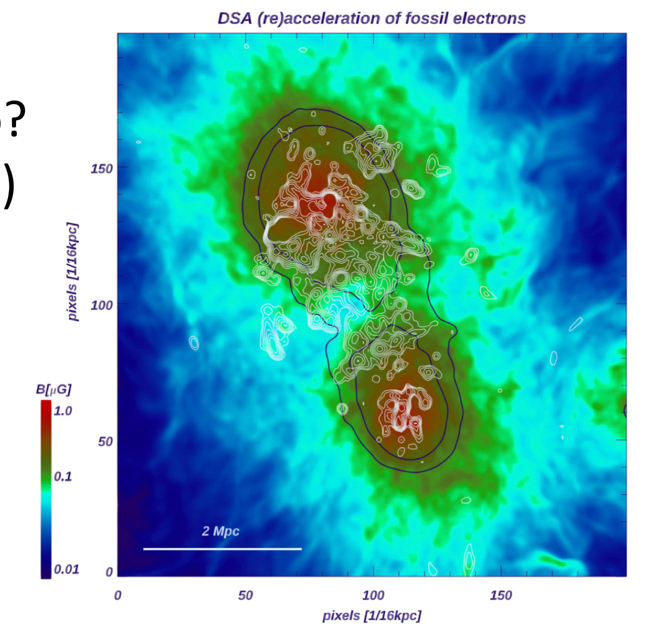
LP, G.-B. Zhao, K. Jedamzik, arXiv:2009.08455, Ap. J. Lett

What kind of new physics can help reduce the sound horizon?

- Many models proposed with the aim of solving the Hubble tension
- Primordial Magnetic Fields

Cosmic Magnetic Fields

○ Micro-Gauss (μG) fields in galaxies and clusters
- produced during galaxy formation via dynamo?
- primordial origin? (need 0.01-0.1 nano-Gauss)
- μG fields seen in proto-galaxies that haven't turned enough times for the dynamo to work!



○ Evidence of magnetic fields in voids
- missing GeV γ-ray halos around TeV blazars

A. Neronov and I. Vovk, arXiv:1006.3504, Science (2010)

○ Magnetic fields in filaments
- LOFAR observation of a ~3-10 Mpc radio emission ridge connecting two merging galaxy clusters suggests ~0.1-0.3 μG fields in the filament

F. Govoni et al, arXiv:1906.07584, Science (2019)

○ Generated in the early universe – not "if", but "how much"
- phase transitions
- inflationary mechanisms
- a window into the early universe

See a recent review by T. Vachaspati, arXiv:2010.10525

How do magnetic fields help to reduce the sound horizon and, hence, relieve the Hubble tension?

In two sentences:

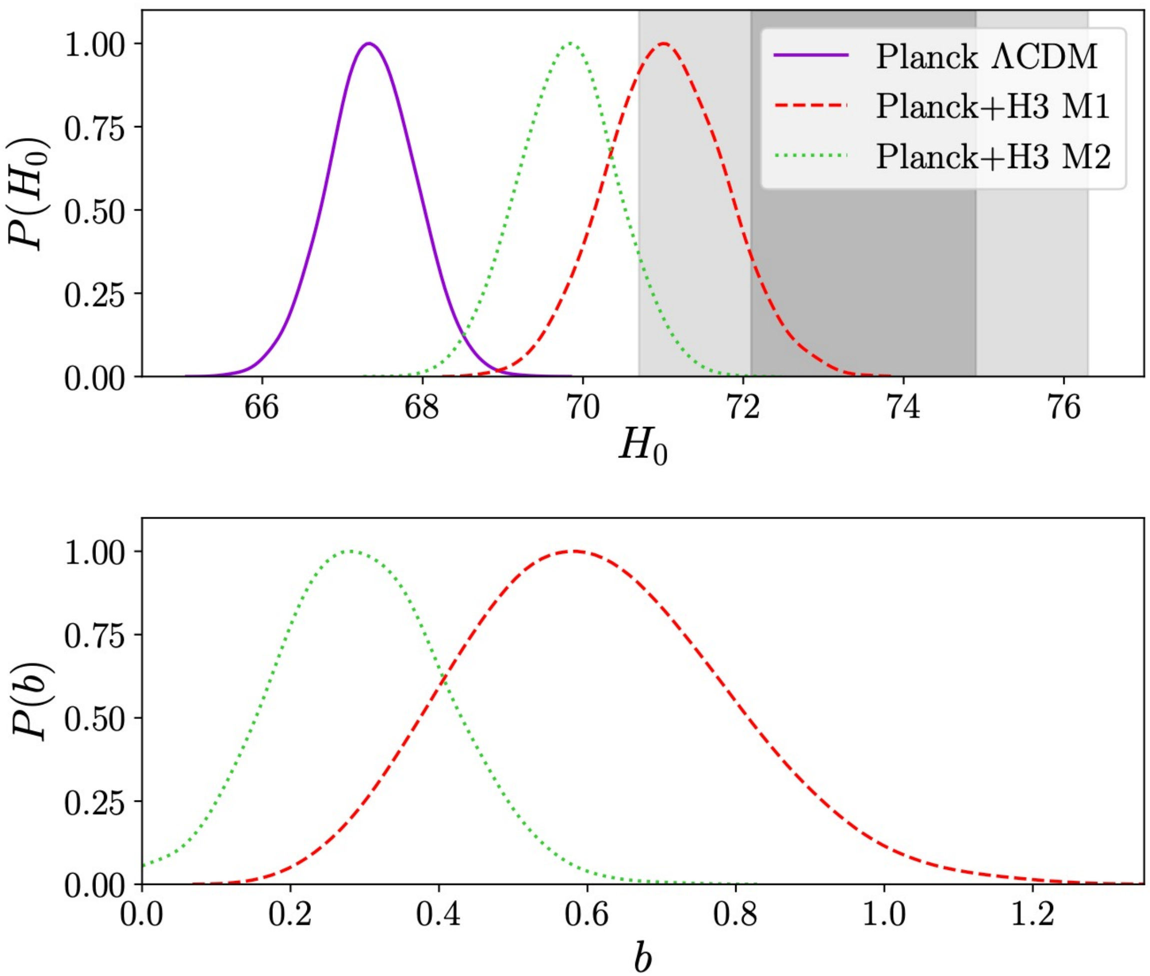
- A stochastic magnetic field present in the plasma prior to recombination induces baryon inhomogeneities (clumping) on very small (~1kpc) scales, speeding up the recombination
  Jedamzik & Abel, arXiv:1108.2517, JCAP (2013); Jedamzik & Saveliev, arXiv:1804.06115, PRL (2019)

- An earlier completion of recombination results in a smaller sound horizon at decoupling, helping to relieve the H_0 tension
  Jedamzik & LP, arXiv:2004.09487, PRL (2020)

A new parameter, baryon clumping:

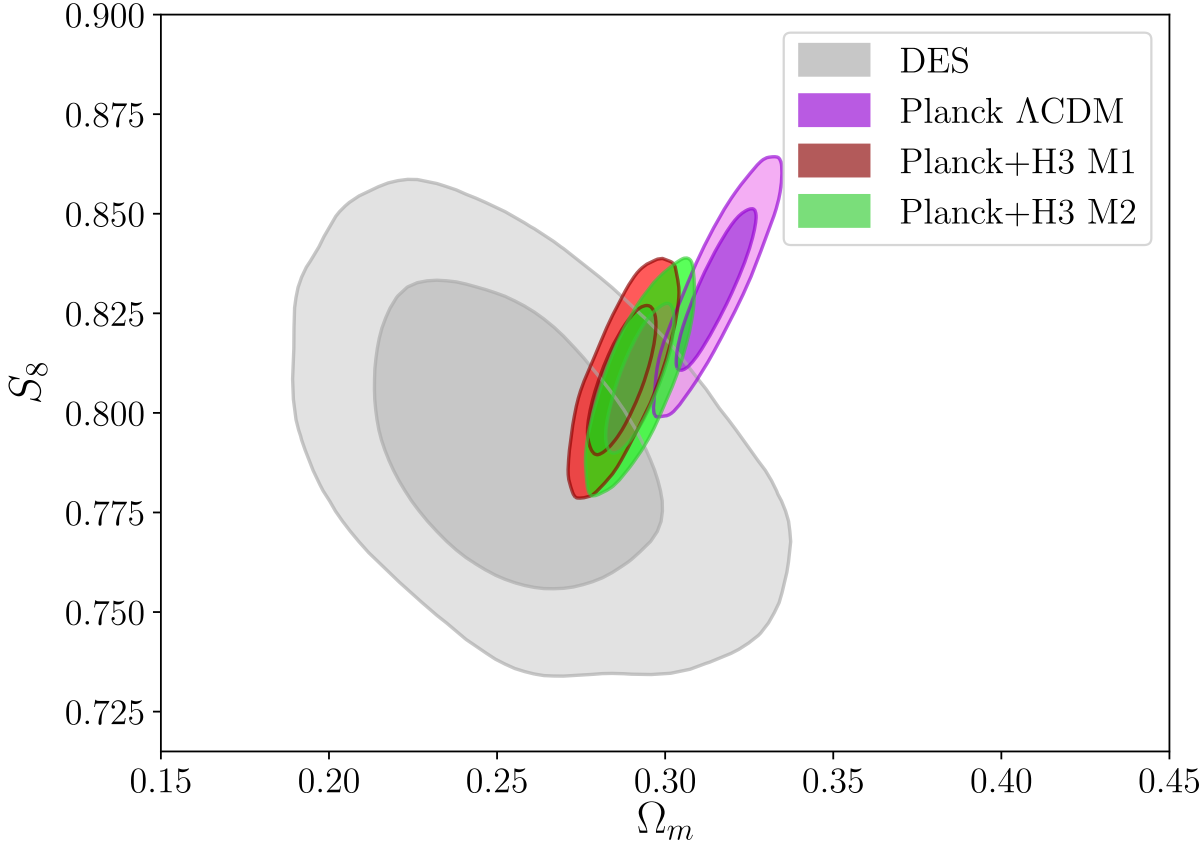
$$b = (\langle n_b^2 \rangle - \langle n_b \rangle^2)/\langle n_b \rangle^2$$

Relieving the Hubble tension



K. Jedamzik and L. Pogosian, arXiv:2004.09487, PRL

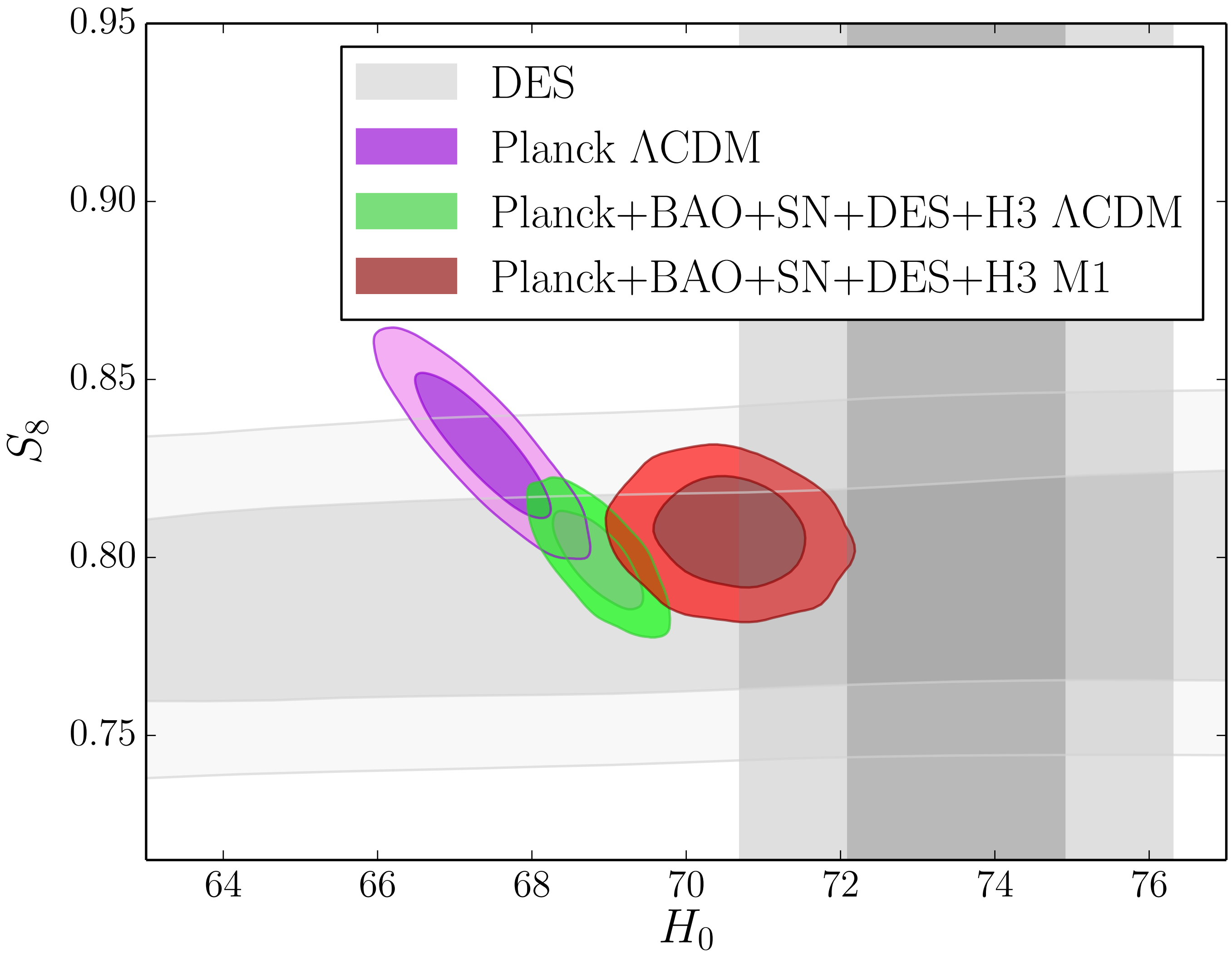
Relieving the S_8-Ω_m tension



As a byproduct, clumping models also relieve the S_8-Ω_m tension

K. Jedamzik and L. Pogosian, arXiv:2004.09487, PRL

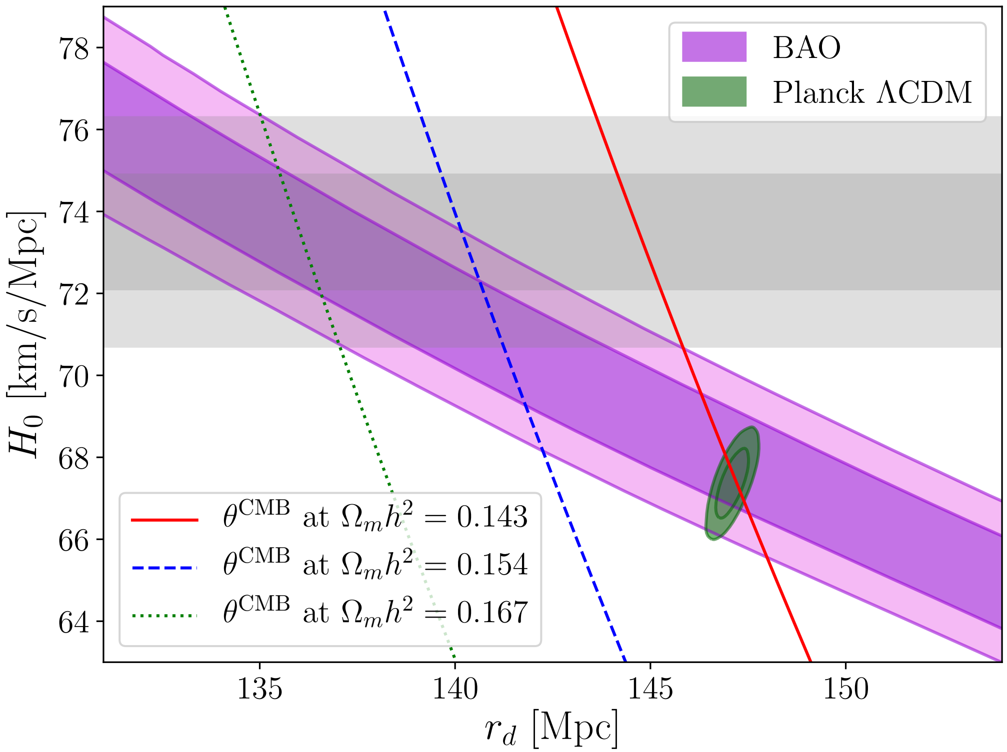
Fitting to all data

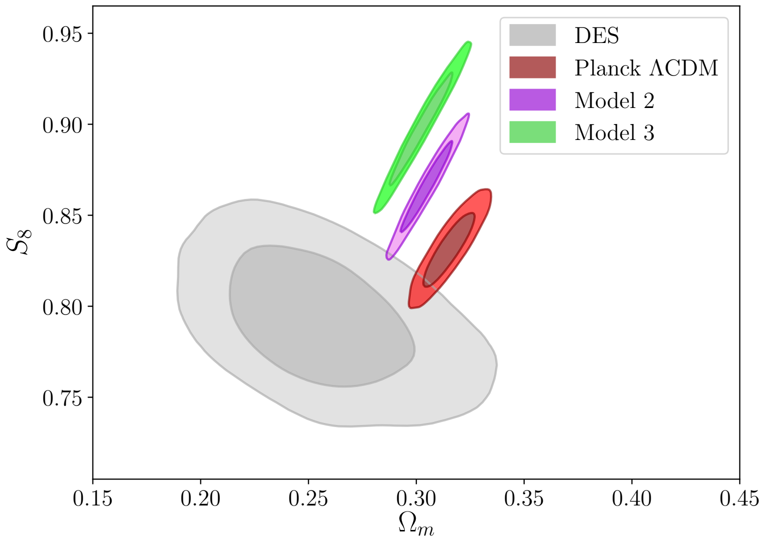


K. Jedamzik and L. Pogosian, arXiv:2004.09487, PRL

Why reducing the sound horizon cannot (by itself) fully relieve the Hubble tension

- The free parameters are r_d, h and $\Omega_m h^2$
- To make the CMB line pass through the BAO/SH0ES overlap region one needs to increase $\Omega_m h^2$
- A larger $\Omega_m h^2$ creates tension with weak lensing data, e.g. DES and KiDS



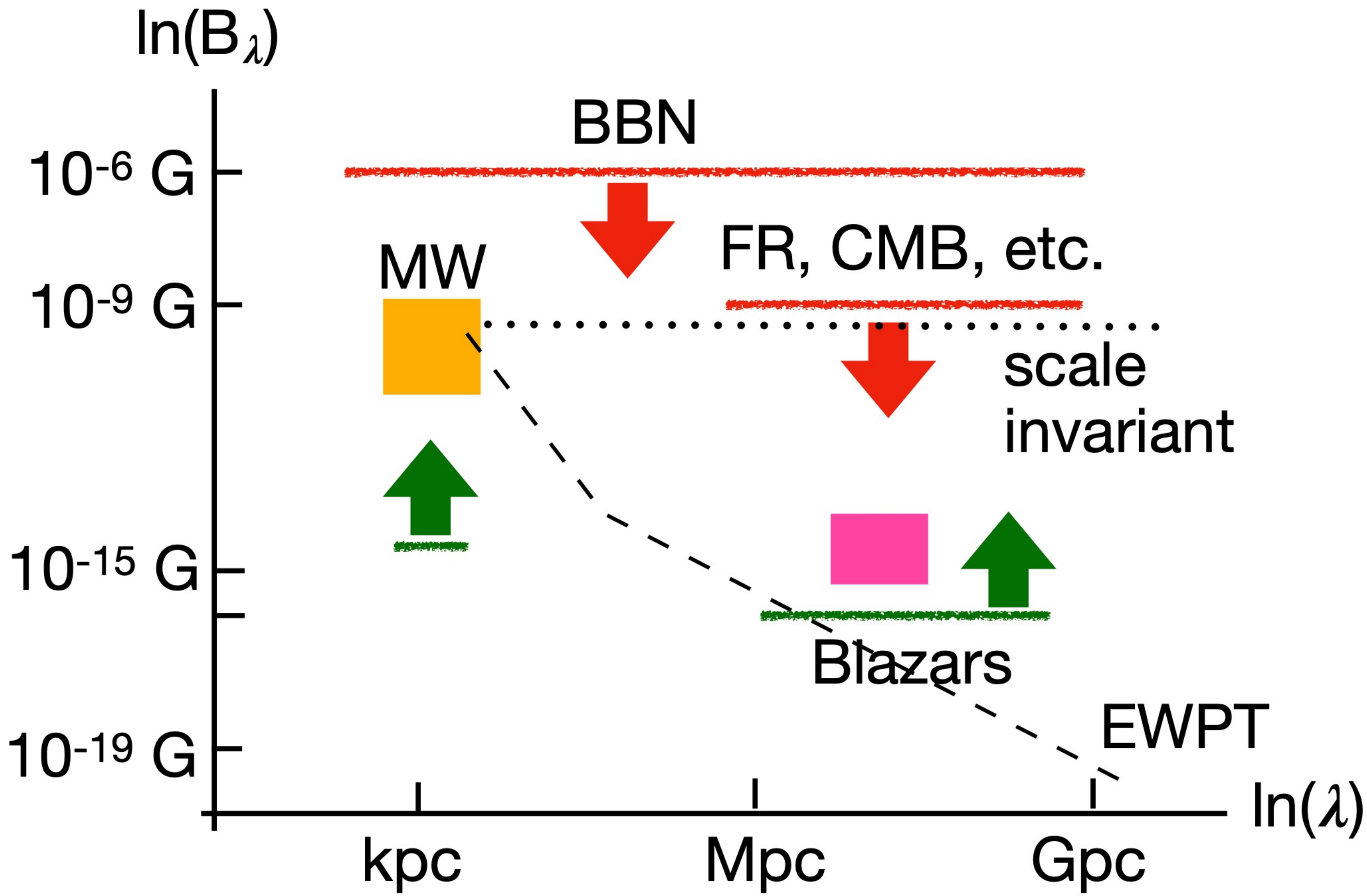


K. Jedamzik, LP, G.-B. Zhao, arXiv:2010.04158

Implications

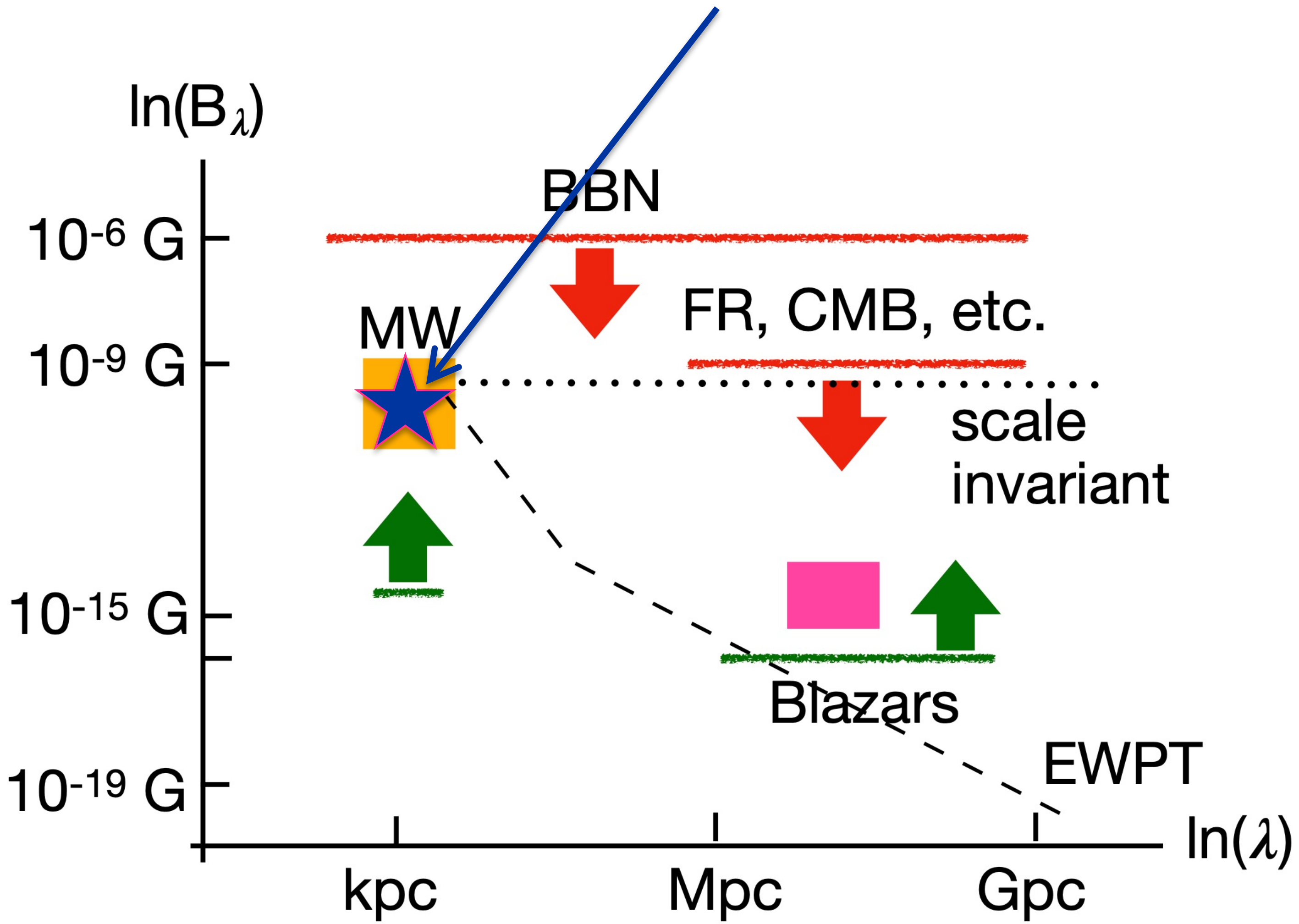
- Magnetic fields can raise the CMB+BAO inferred H_0 to $\sim$70 km/s/Mpc
- The amount of clumping needed for this corresponds to $\sim$0.05-0.1 nano-Gauss pre-recombination magnetic field

Cosmological Magnetic Fields



Plot from T. Vachaspati, arXiv:2010.10525

Clumping required to relieve the H_0 tension



Plot from T. Vachaspati, arXiv:2010.10525

Implications

- Magnetic fields can raise the CMB+BAO inferred H_0 to ~70 km/s/Mpc

- The amount of clumping needed for this corresponds to ~0.05-0.1 nano-Gauss pre-recombination magnetic field, which is what one would need to explain the observed galactic, cluster and intergalactic fields

- This is a highly falsifiable proposal -- future observations will rule it out or land further support

- Clumping affects the amount of Silk damping that determines the anisotropy power at the high-l end of CMB spectra

- How about the recent high resolution CMB data from ACT and SPT-3G?
  (see also Thiele et al, arXiv:2105.03003, for ACT DR4 constraints on clumping)

The new data (since Spring 2020)

- New BAO from eBOSS DR16

  Alam et al, arXiv:2007.08991

- New SH0ES, H_0=73.2 +/- 1.3 km/s/Mpc

  Riess et al, arXiv:2012.08534

Do not notably change clumping constraints based on DR12 BAO and 2019 SH0ES

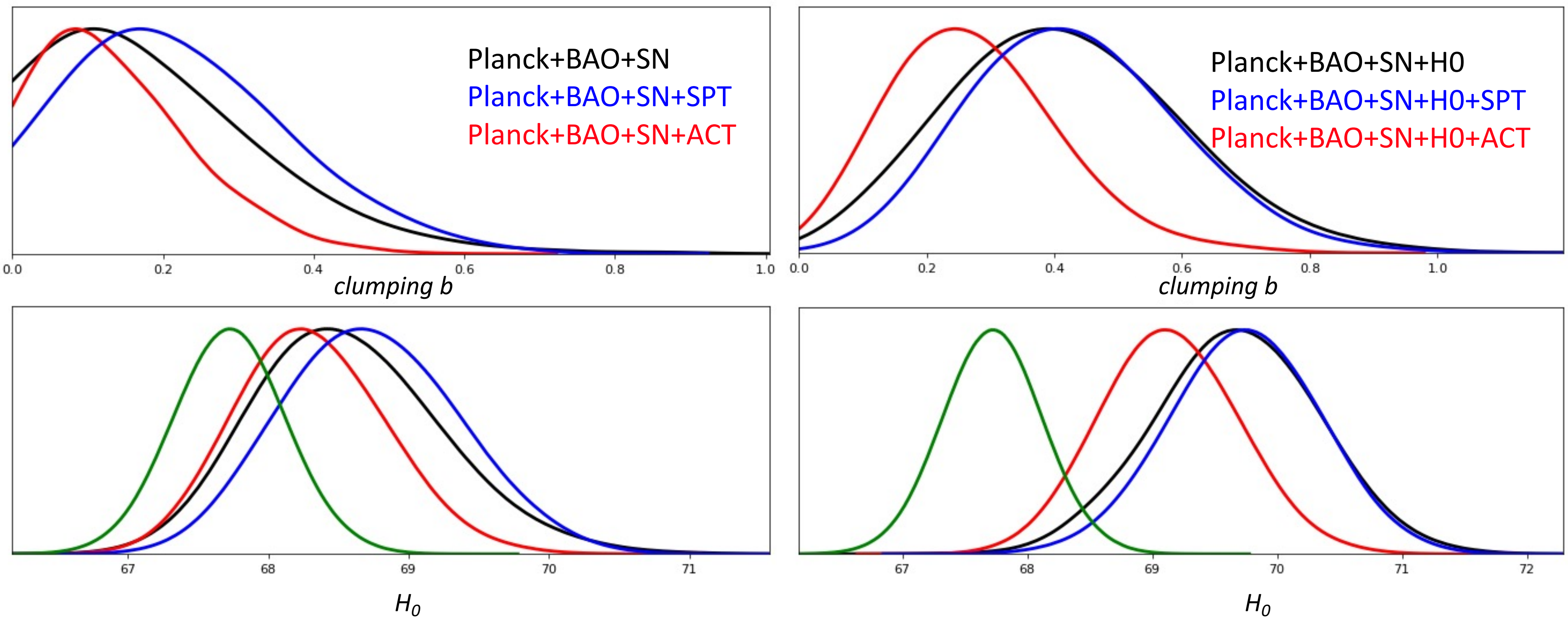
- ACT DR4 TT (600<l<4000), TE and EE (350<l<4000)

  Choi et al, arXiv:2007.07289

- SPT-3G Year 1, TE and EE (300<l<3000)

  Dutcher et al, arXiv:2101.01684

New constraints on clumping



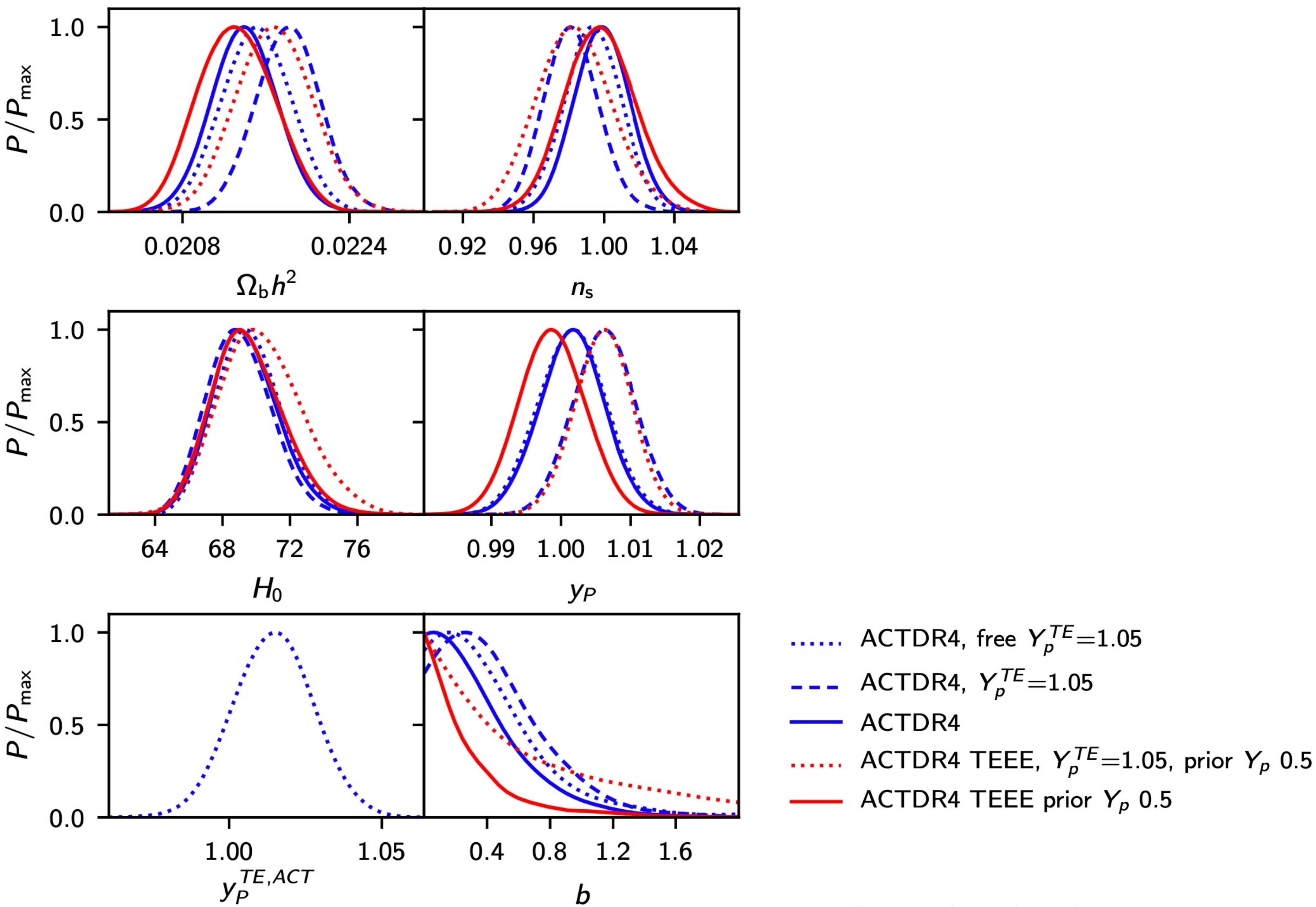
	without SH0ES	with SH0ES
Planck+BAO+SN	b<0.47 (95%CL), H_0=68.57 ± 0.68	b=0.42 ± 0.18, H_0=69.68 ± 0.66
with SPT	b < 0.50 (95%CL), H_0=68.73 ± 0.64	b = 0.43 ± 0.17, H_0=69.74 ± 0.61
with ACT	b < 0.34 (95%CL), H_0=68.30 ± 0.55	b = 0.28 ± 0.14, H_0=69.14 ± 0.56

S. Galli, K. Jedamzik and LP, in preparation

Why is ACT DR4 so much more constraining compared to SPT-3G Y1?

- Not the $3000<l<4000$ band powers
- Not the TT: ACT constraints on b get stronger when TT is removed
- LCDM based mock simulations show that ACT and SPT-3G TE+EE spectra should yield comparable constrains on b, while adding ACT TT should make them tighter
- Anomalously strong constraints coming from ACTDR4 TE+EE
- Minor (~2σ) inconsistencies between Planck and ACT DR4 in LCDM can be resolved by a 5% re-calibration of TE ($Y^{TE}_{p}=1.05$, *Aiola et al, arXiv:2007.07288*)
- While there is no apparent physical reason for recalibrating TE, doing so significantly relaxes the ACTDR4 constraints on clumping

S. Galli, K. Jedamzik and LP, in preparation



S. Galli, K. Jedamzik and LP, in preparation

Conclusions

- The Hubble tension hints at a missing ingredient in the physics of recombination. That missing ingredient could be a primordial magnetic field of strength that happens to be of the right order to also explain the observed galactic, cluster and intergalactic fields
- This can only raise the value of H_0 up to 70 km/s/Mpc (it could be all we need!)
- Primordial magnetic fields were not invented to solve the Hubble tension. A detection of clumping is important by itself, as a solution of a much older puzzle and a tantalizing evidence of new physics in the early universe
- Future high resolution CMB temperature and polarization anisotropy data (Simons Observatory, CMB=S4) will provide a stringent test of this scenario (*S. Galli, K. Jedamzik and LP, in preparation)*