

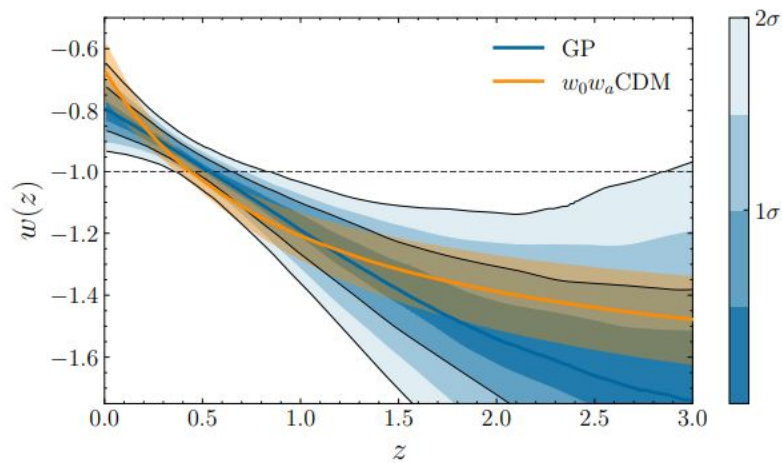
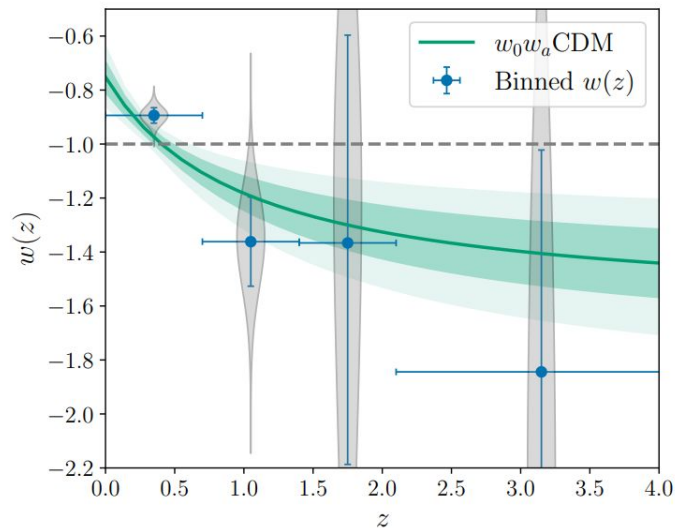
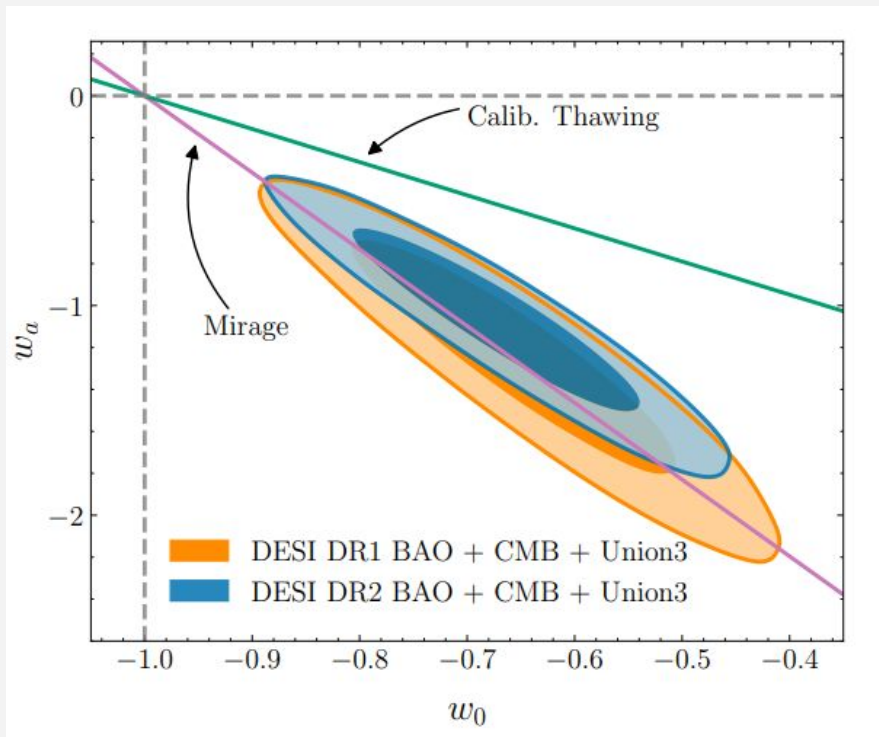
# Interface between string theory and cosmology

An open discussion

# Dark Energy

- Theoretical constraints on **bulk dark energy**?
- Acceleration in the **asymptotics**?
- Updates on **dS constructions**?
- Dynamical dark energy:
  - DESI systematics?
  - Is the **phantom crossing** real? Thawing vs crossing?
  - DESI / SNeIa **cross-checks**? Cosmic chronometers, quasars?
  - Is measured discrepancy the **expected signal** of dynamical DE? Does it look like something else?
  - Interplay with **Hubble tension** (other tensions) ?
  - Neutrinos?
- SNe systematics:
  - Agreement between **different SNe datasets** (Dovekie recalibration)
  - SNe and progenitor **age/host correlation**?

# DESI plots



# SNe consistency

DES-SN5YR (no external priors)

Flat- $\Lambda$ CDM

$0.352 \pm 0.017$

DES-Dovekie (SN-only)

Flat- $\Lambda$ CDM

$0.330 \pm 0.015$

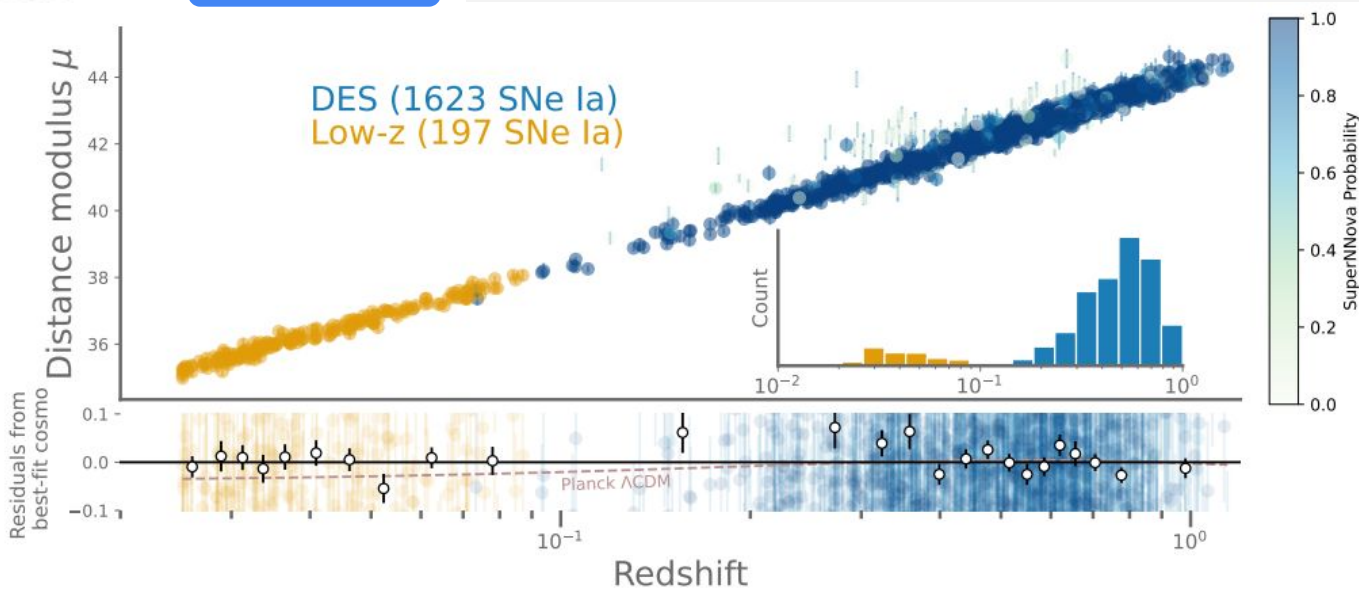
## Unity 3

Probes	$\chi^2$ (DoF)	$h$	$\Omega_m$
SNe	24.0 (20)	...	Flat $\Lambda$ CDM $0.356^{+0.028}_{-0.026}$

Pantheon+ & SHOES - All Models

Flat $\Lambda$ CDM

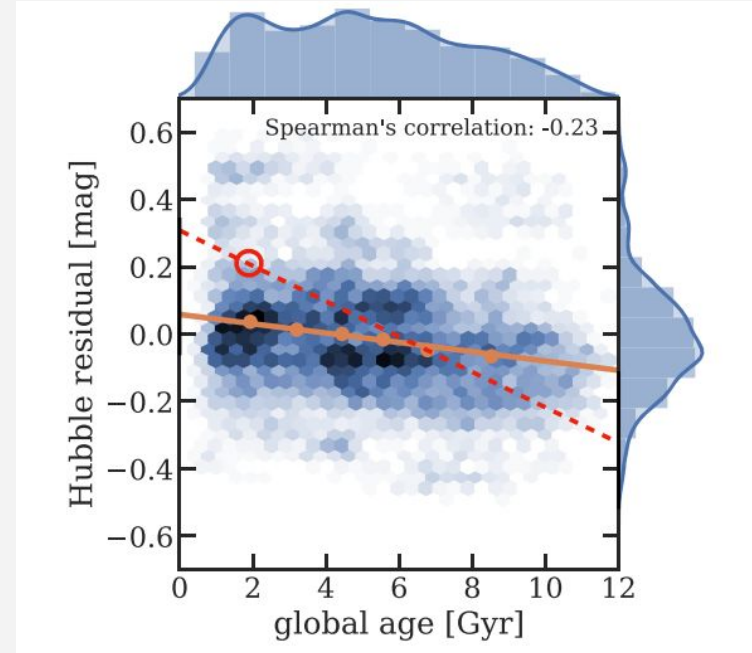
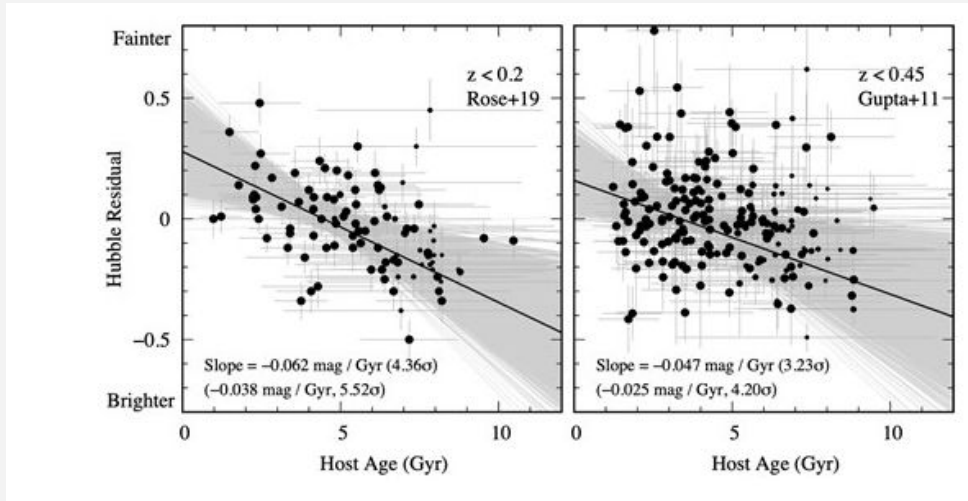
$0.334 \pm 0.018$



# Host relevance

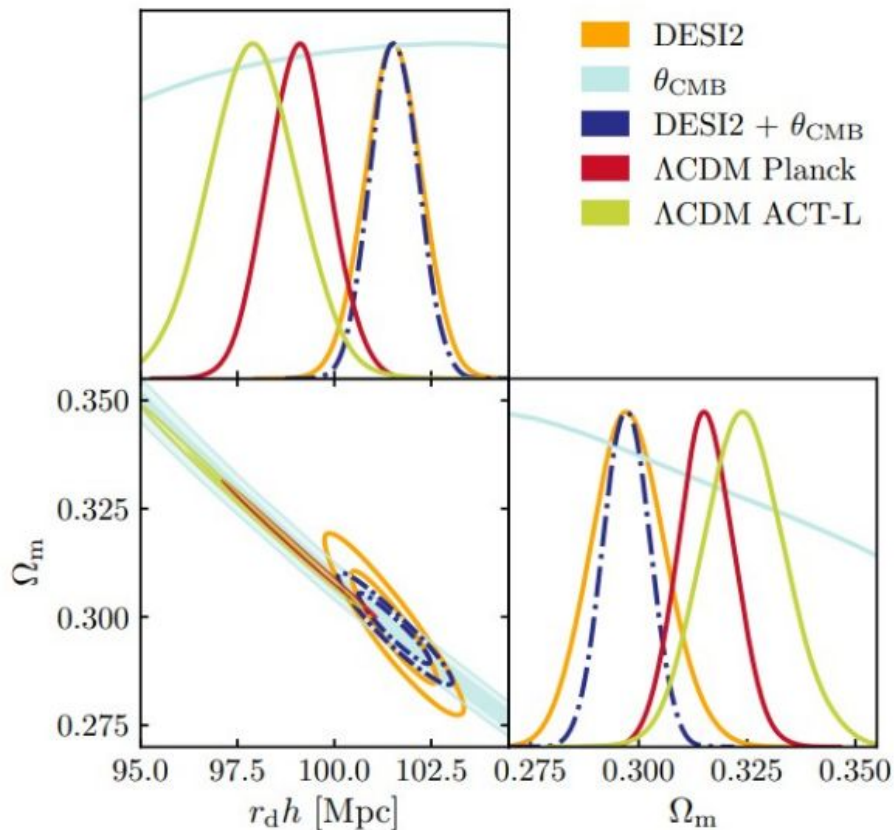
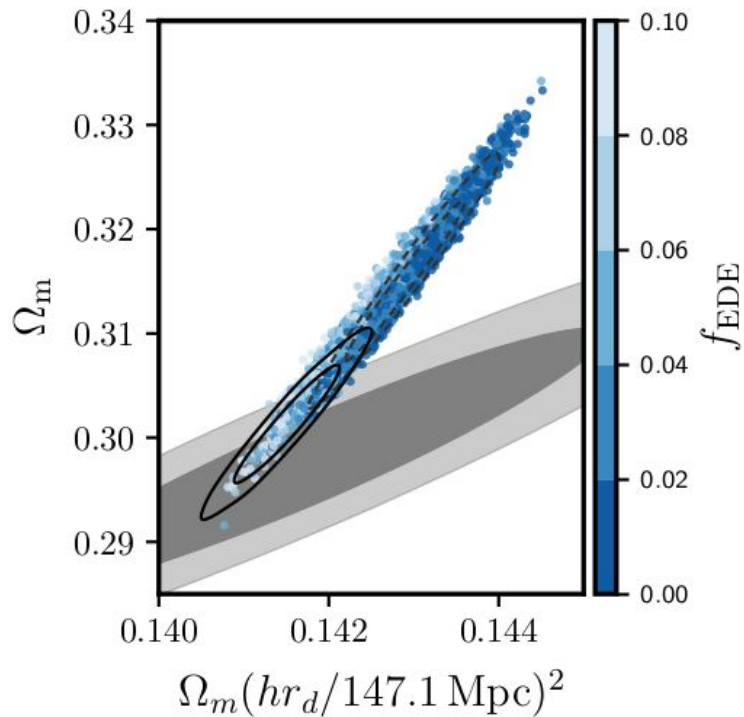
Left: 2510.13121, Right: 2002.12382

See also: 2408.07175



# Early universe & DESI

---  $\Lambda$ CDM: CMB-SPA     $\bullet\bullet$  EDE: CMB-SPA  
—  $\Lambda$ CDM: DESI        — EDE: CMB-SPA + DESI



# Surprising statements

0708.0024

## The Mirage of $w = -1$

Eric V. Linder

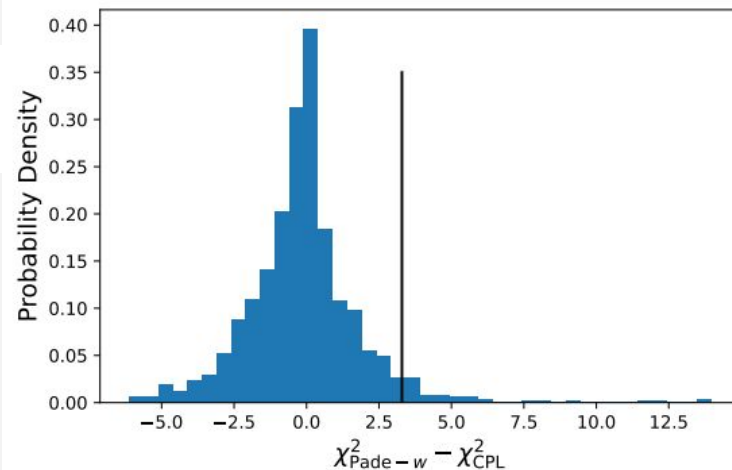
Thus low redshift data pointing to  $w = -1$  does not truly argue for a cosmological constant. Even the simplest question of whether the equation of state of dark energy is equal to the cosmological constant therefore requires experiments able to sensitively constrain time variation  $w(z)$  and not merely a constant  $w$ .

2506.15091

### Could We Be Fooled about Phantom Crossing?

The first result we obtain is that, for the real data, CPL is preferred over the Pade- $w$  model at a  $\Delta\chi^2 = 3.3$ .

This level of preference, or higher, for CPL over Pade- $w$  in the actual data occurs in 3% of mock cases, even though all the mock data are generated using the best-fit Pade- $w$  as the true model. This is our key result.



# Theory solutions – Which one do you prefer?

- Late-time
  - DE/DM coupling  $\Delta\chi^2=8$  (P-LBS) 2506.18477
  - ↳ Dark Dimension  $\Delta\chi^2=12$  (P-LBS) 2507.03090
  - Scalar field DE  $\Delta\chi^2=8$  (estimate) 2506.15091
  - Monodromic k-ess.  $\Delta\chi^2=11$  (P-LBS) 2408.14628
  - Stringy constructions?
- Early-time (also solve Hubble tension?):
  - EDE  $\Delta\chi^2=7$  (P-ACT-LBS) 2505.08051
  - modified recombination  $\Delta\chi^2=9$  (P-LBS) 2504.15274
- Spatial curvature?

Reference:

w0wa has  $\Delta\chi^2=11$  (P-LBS) or  $\Delta\chi^2=20$  (Union3)

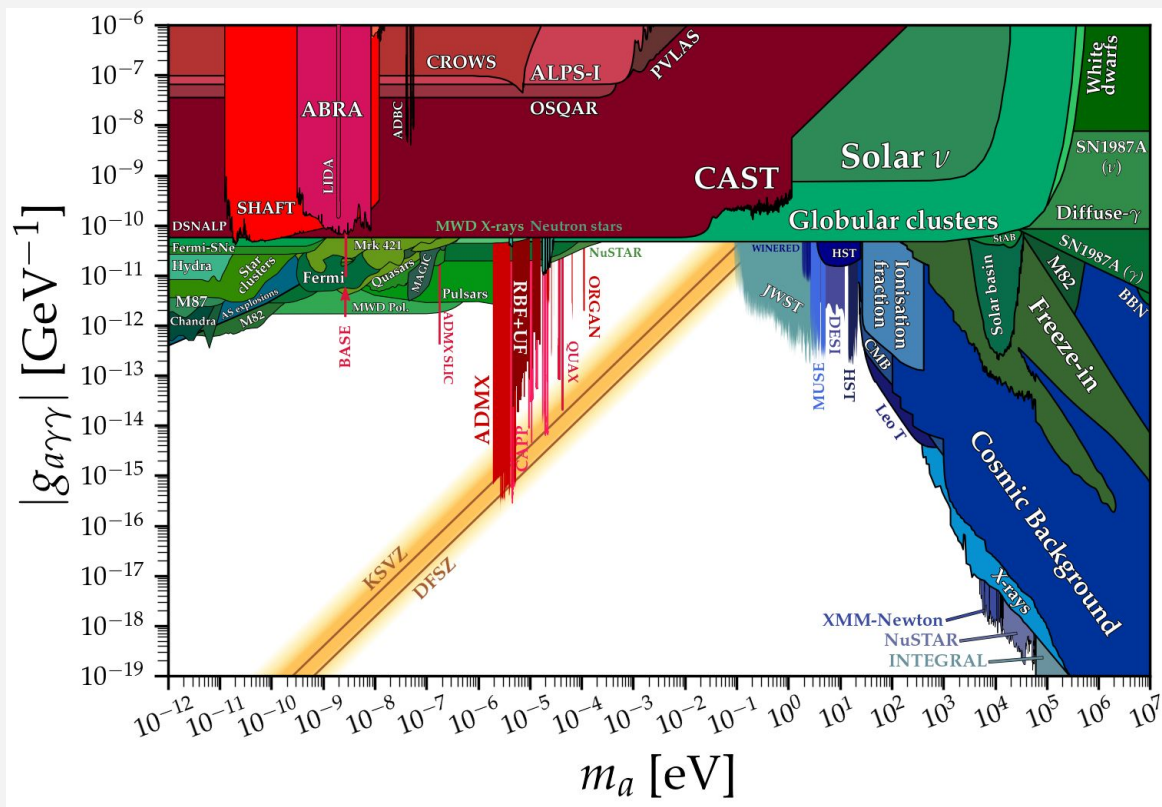
# The first moments...

- Inflation
  - What have we learned from model building?
  - Constructions? Phenomenologically viable or toy models?
  - Single- vs multi-field?
  - Theoretical constraints?
    - Transplanckian problem/Kontsevich-Segal/scalar field range?
  - New constraints from data?
- Kination
  - How generic?
  - Observational evidence? Gravitational waves?
  - Varying tensions strings?
- Baryogenesis
  - What models are preferred/plausible? Any theoretical constraints?
- Experimental constraints on kination/early matter domination/warm inflation?

# Axions and other light particles

- What axions can we get in string theory?
  - Axion/scalar systems in string theory. Cosmology applications?
  - ALPs above the QCD line with gauge coupling unification?
  - Are there axions for DE? EDE?
  - Explaining birefringence?
- Observational Status of birefringence?
- Other predictions from string theory? Photoverse?

# Axion parameter space



# Birefringence evidence

Npipe: 2502.07654

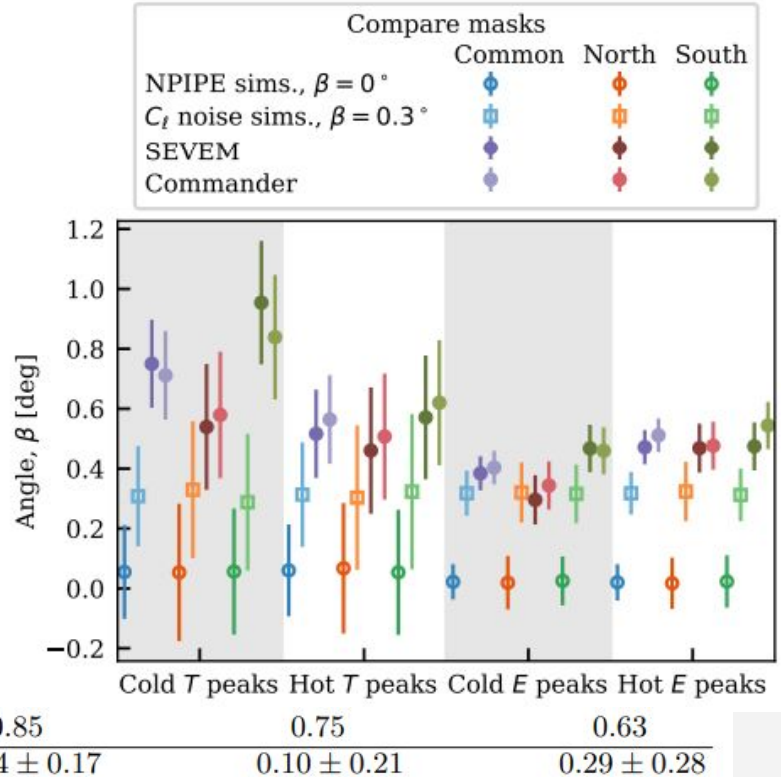
ACT DR6: 2503.14452

$$\hat{\psi}_{\text{ACT}} = 0.20^\circ \pm 0.08^\circ \quad (\text{stat} + \text{optics}),$$

Planck DR 4: 2201.07682

We apply two independent approaches to assess the foreground impact. The first model for  $C_\ell^{EB, \text{dust}}$  is based on filaments of hydrogen clouds producing the thermal dust emission and polarization [55, 59]. We use this model because it is the only physical model for the foreground  $EB$  available today. When the filaments and

Spur, with potentially higher synchrotron variations. The power asymmetry between the two hemispheres could also be a contributor [75]. The result is subtle and only present in the  $T$  peaks, so we cannot draw any strong conclusions about the foreground production of  $EB$  or  $TB$ , but we do recommend further investigation before attributing any cosmological origin to a detection of  $\beta$ .



$f_{\text{sky}}$	0.93	0.90	0.85	0.75	0.63
$\beta$	$0.36 \pm 0.11$	$0.26 \pm 0.14$	$0.14 \pm 0.17$	$0.10 \pm 0.21$	$0.29 \pm 0.28$

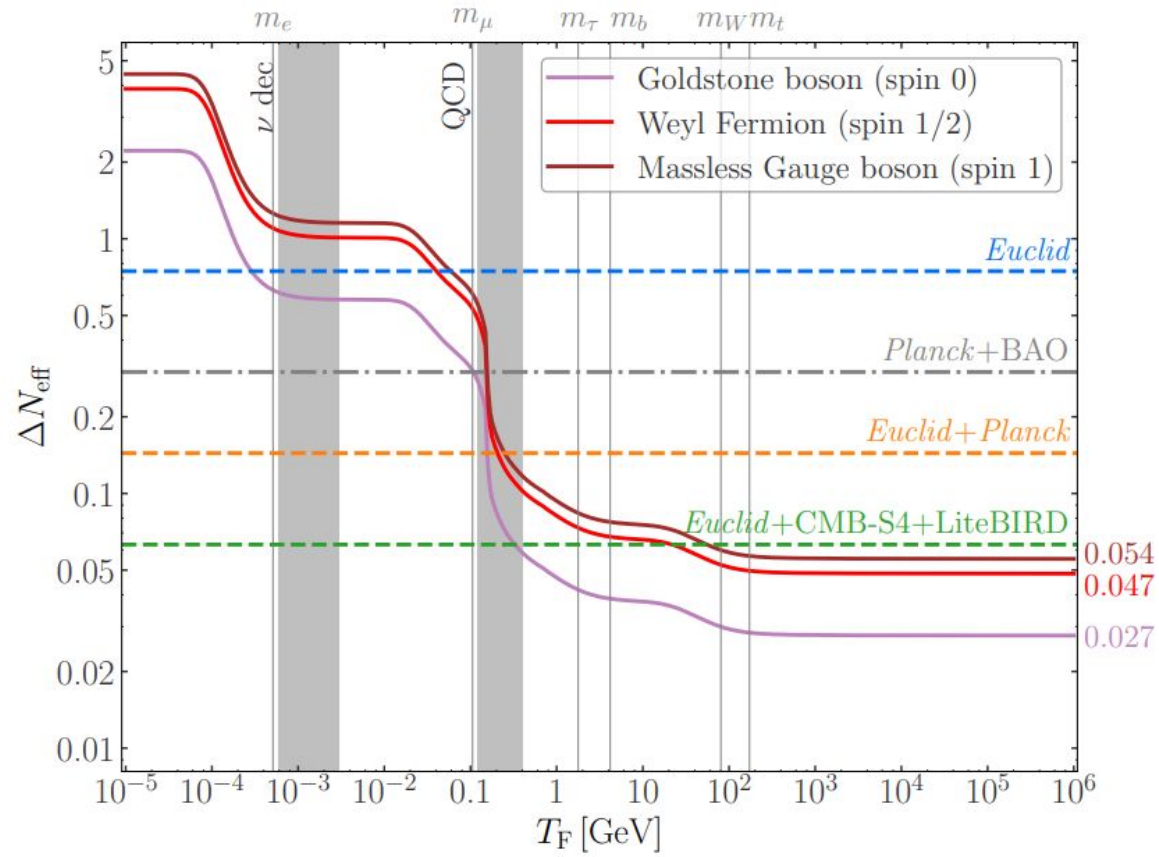
# Light towers

- Are there light towers?
- What do they do in early/late-time cosmology? During inflation? Dark sector?
- Free-streaming / light particles constraints? (CMB, BBN, structure formation)

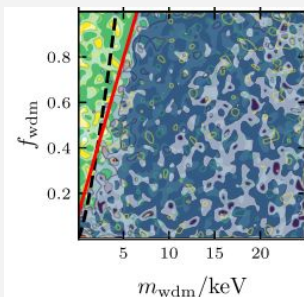
# Extra dimensions

- Models with changing extra dimensions?
- Dark dimension: AdS distance conjecture is not satisfied ?  
Cancellations? Scale separation?

# Light particle constraints

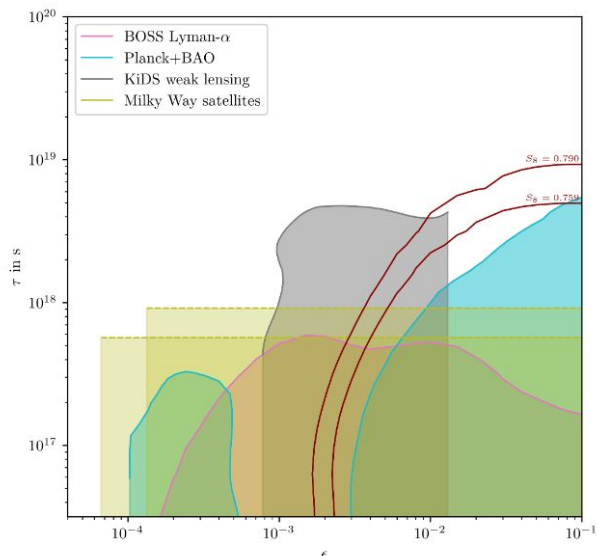


# Warm dark matter, decaying DM



Non-relativistic transition far before recombination ( $z > 40000$  for  $f=1$ )

2206.08188



Cannot decay into EM particles (tight constraints)

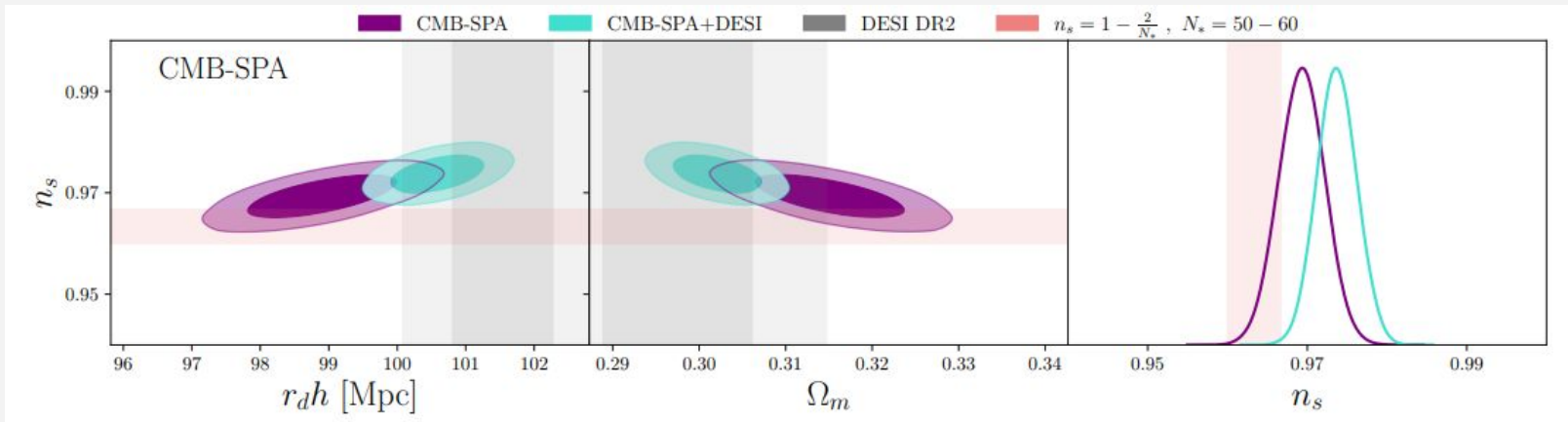
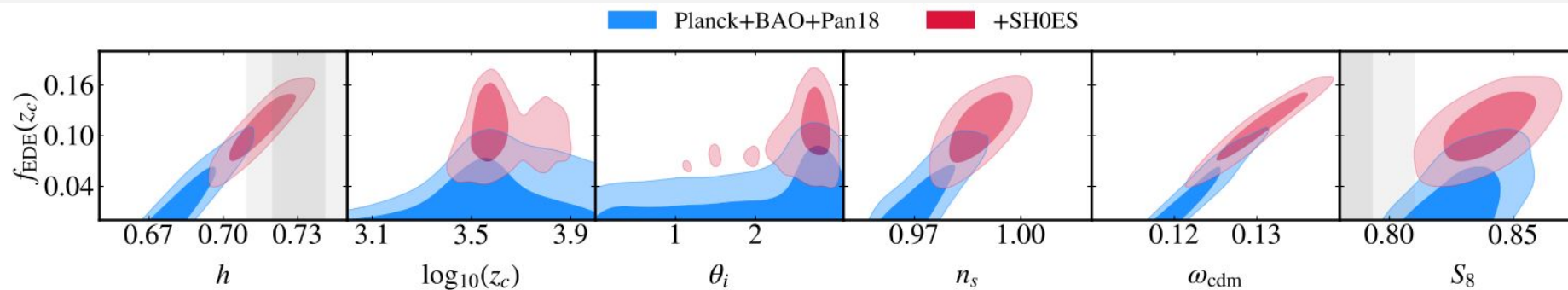
Can not decay too much ( $< 3\%$ ) 1606.02073

Cannot decay too warm  $v < 100 \text{ km/s}$  (1503.05682)

# Observational prospects

- Other observations **beyond birefringence/DE** that might interest you?
  - Can cosmology/astrophysics constrain **fifth forces / light scalars / extra dimensions** (short distance vs long distance)
- What will be best constrained by cosmology in the **coming decade(s)**?
- **Variations of constants** locally vs cosmologically (screening?)
- **$n_s$  constraints** -> running of  $n_s$ ? Scale influence?

# EDE 2302.09032 , SPA 2512.05108



## Other interesting points

- What happens to calculations within string theory at the **high curvature region** (small black hole? Initial spacetime singularity?)
- Alternatives to dS? Bubble cosmology?
- Anything we missed?