Exploring Mirror Twin Higgs Cosmology with Present and Future Weak Lensing Surveys

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第二届地下和空间粒子物理与宇宙物理前沿问题研讨会

Exploring Mirror Twin Higgs Cosmology with Present and Future Weak Lensing Surveys

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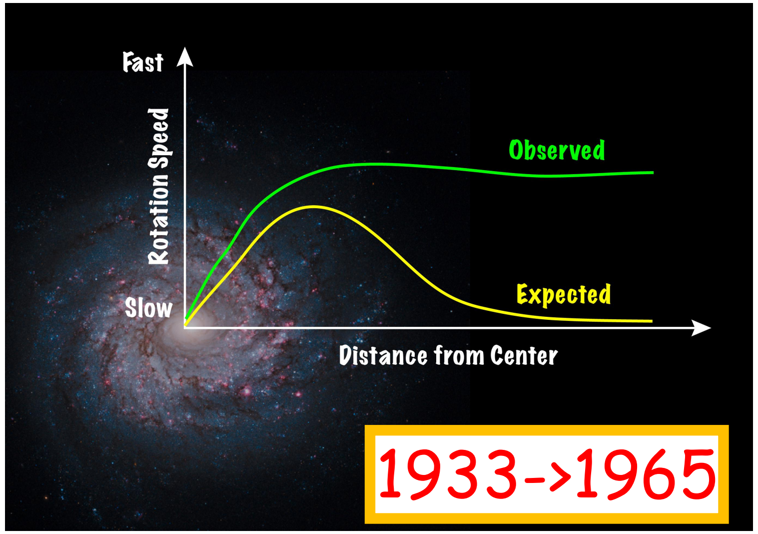
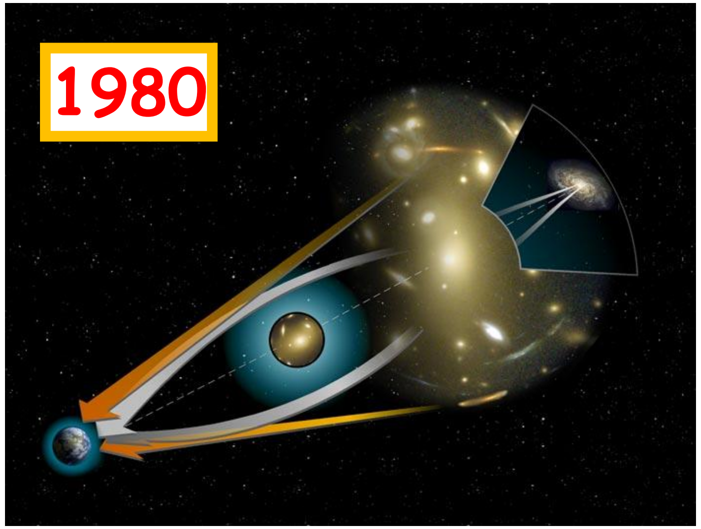
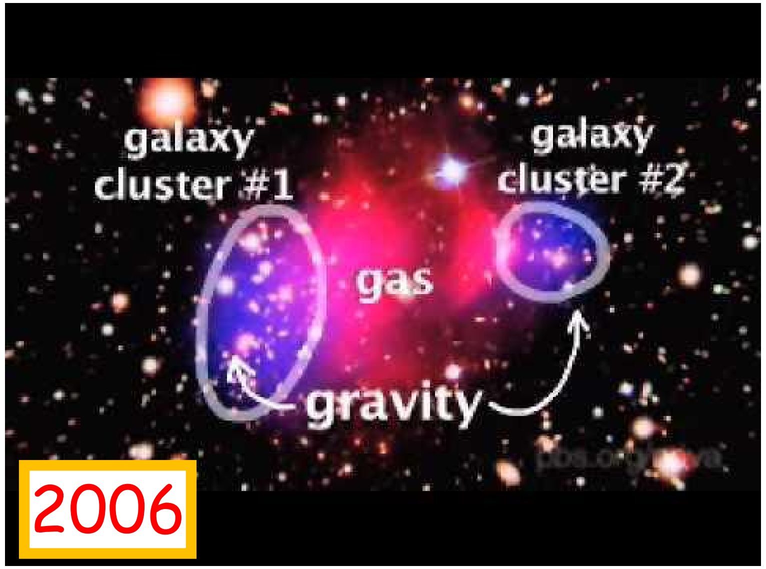
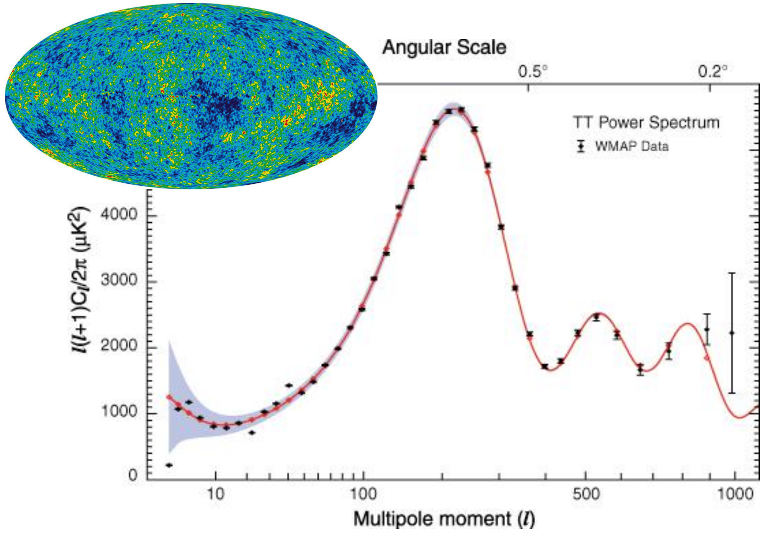
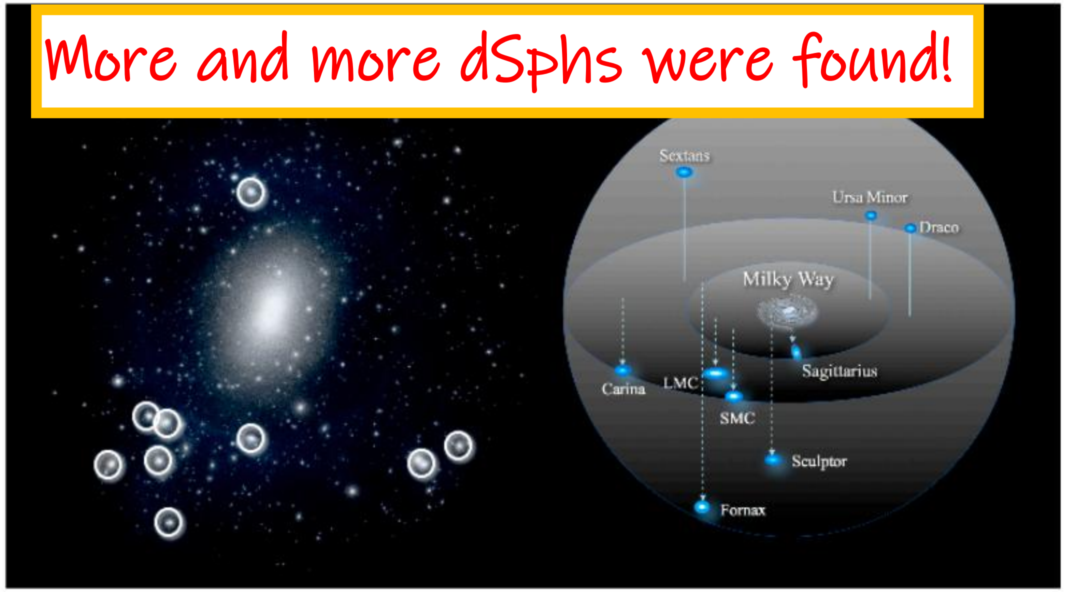
What is Dark Matter?



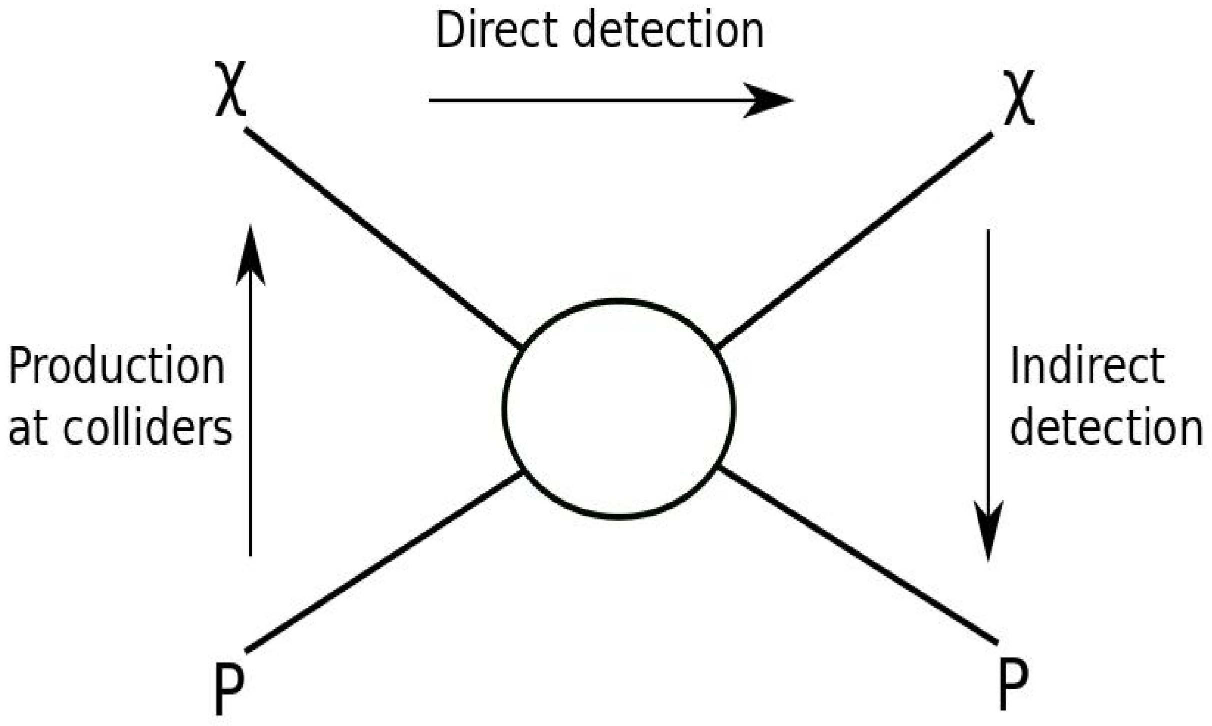


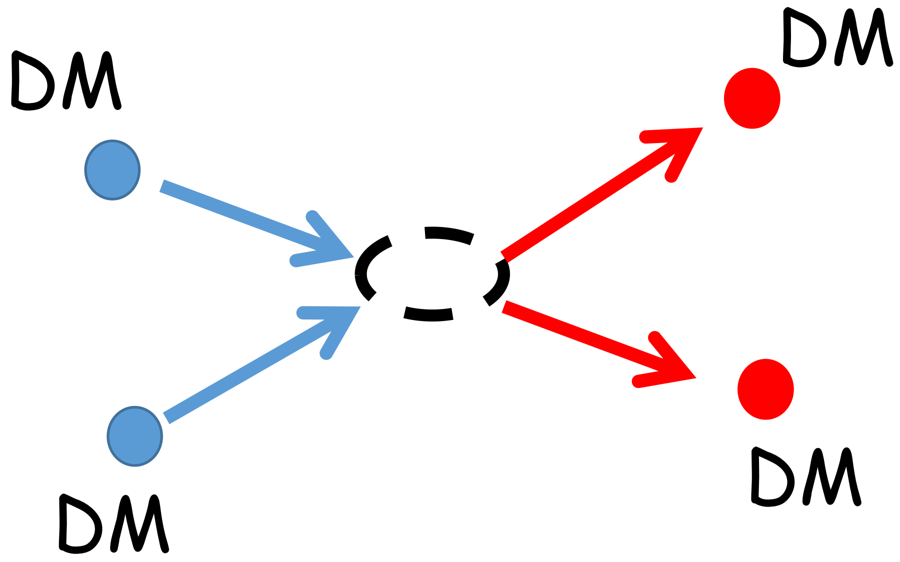




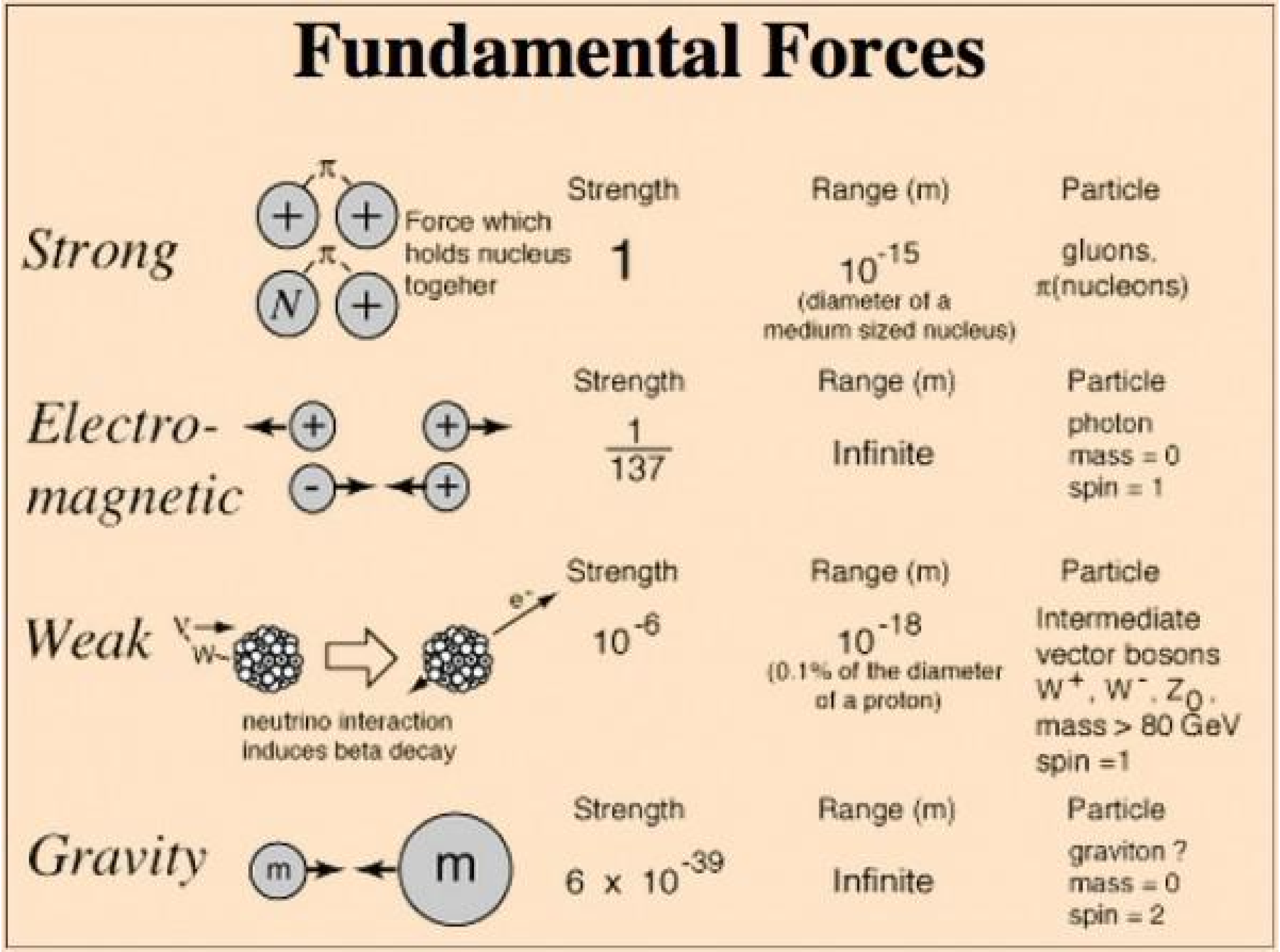


It will be difficult to explain the universe without DM assumption.





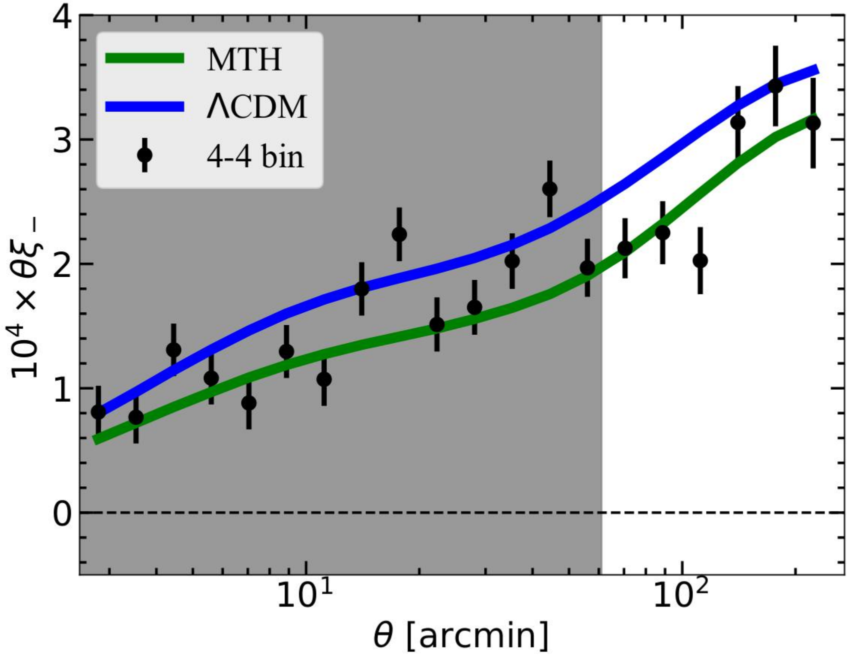
However, all the evidence are all based on gravitational interaction.
Can we see any non-gravitational interaction from gravitational evidence?



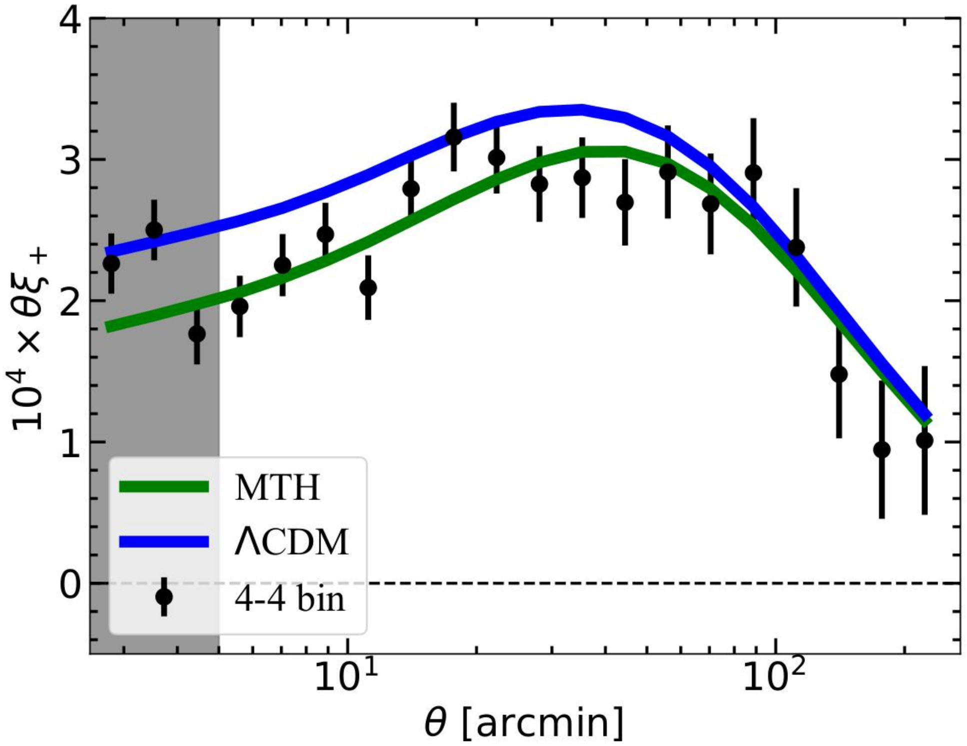
What is the DM-SM interaction strength?

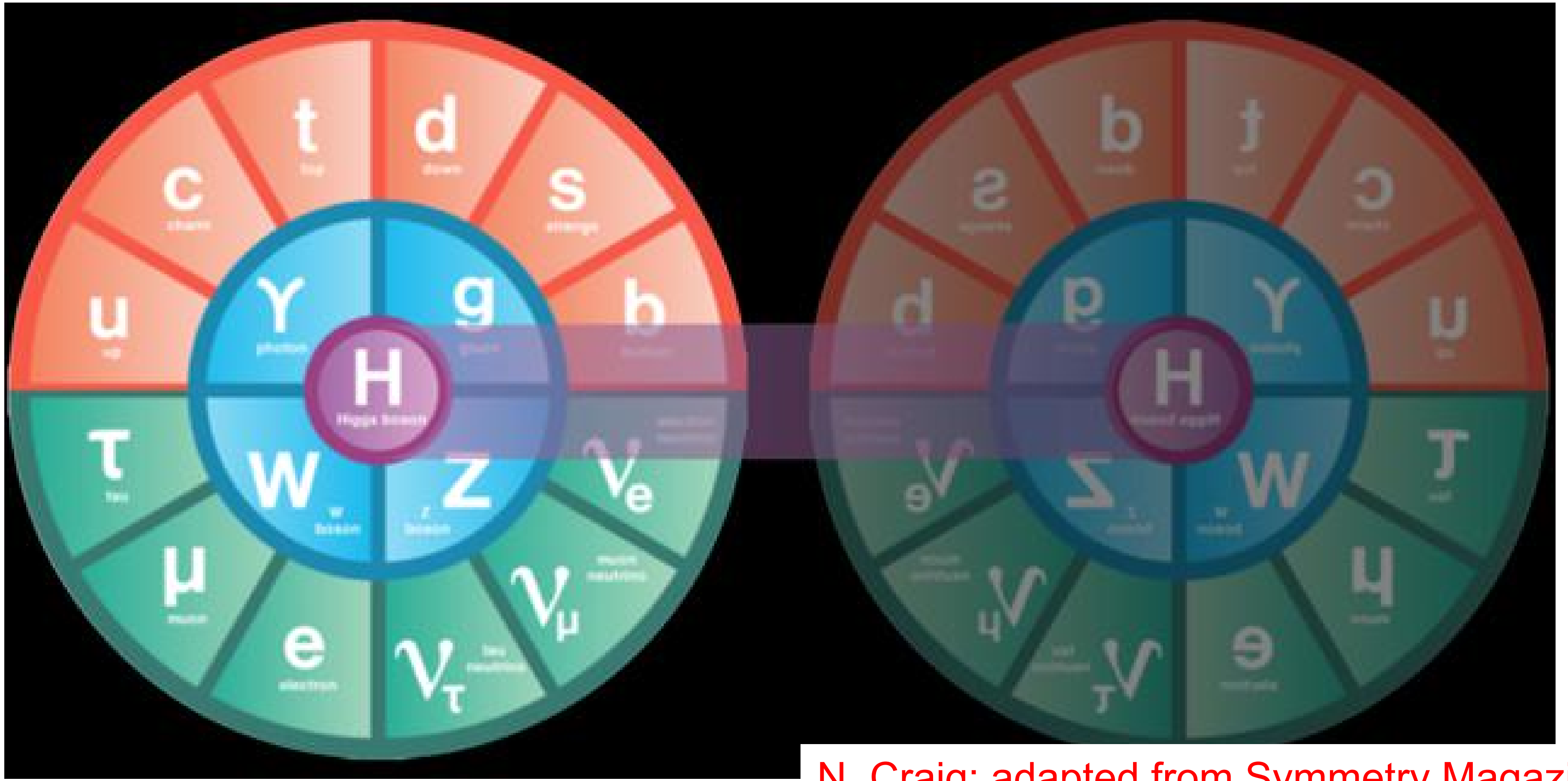
How is possible that no interaction between 1e-6 and 1e-39?

Only gravitational interaction?



We shall be able to see non-gravitational interactions from precise cosmological measurements.





N. Craig; adapted from Symmetry Magazine

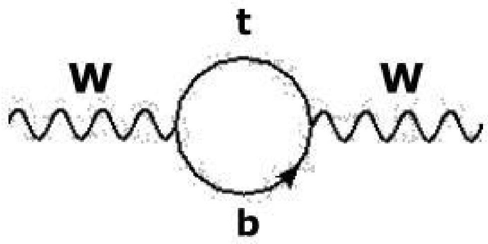
Mirror Twin Higgs

A solution of the Higgs hierarchy problem.

The hierarchy problem in the SM

- Success of radiative corr. in the SM:

	predicted	observed
top quark	179^{+12}_{-9}	172.7 ± 2.9
Higgs boson	91^{+45}_{-32}	?



- Failure of radiative corr. in Higgs sector:

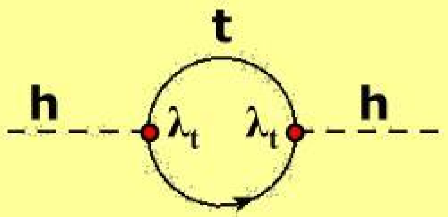
$$m_h = m_{h_{bare}} + \delta m_{h,top} + \ldots$$

150 = 135429433658723515 0
−135429433658723500 0

Hierarchy problem:

→ 'Conspiracy' to get $m_h \sim M_{EW}$ ($\ll M_{PL}$)
→ Biggest troublemaker is the top quark!

Radiative corrections from top quark



$$\delta m^2_{h,top} = -\frac{3}{8\pi^2}\lambda_t^2 \Lambda^2$$

Popular solutions of the Higgs hierarchy problem: SUSY, Mirror Twin Higgs, and so on.

The Hidden Naturalness solution

A concrete example: **Twin Higgs**

Chacko, Goh, Harnik (2005), (up to 10 TeV)

Mirror twin Higgs		
$\hat{r}$	Flat	$[10^{-3}, 1]$
$\hat{v}/v$	Flat	$[2, 15]$
$\Delta\hat{N}$	Flat	$[10^{-3}, 1]$

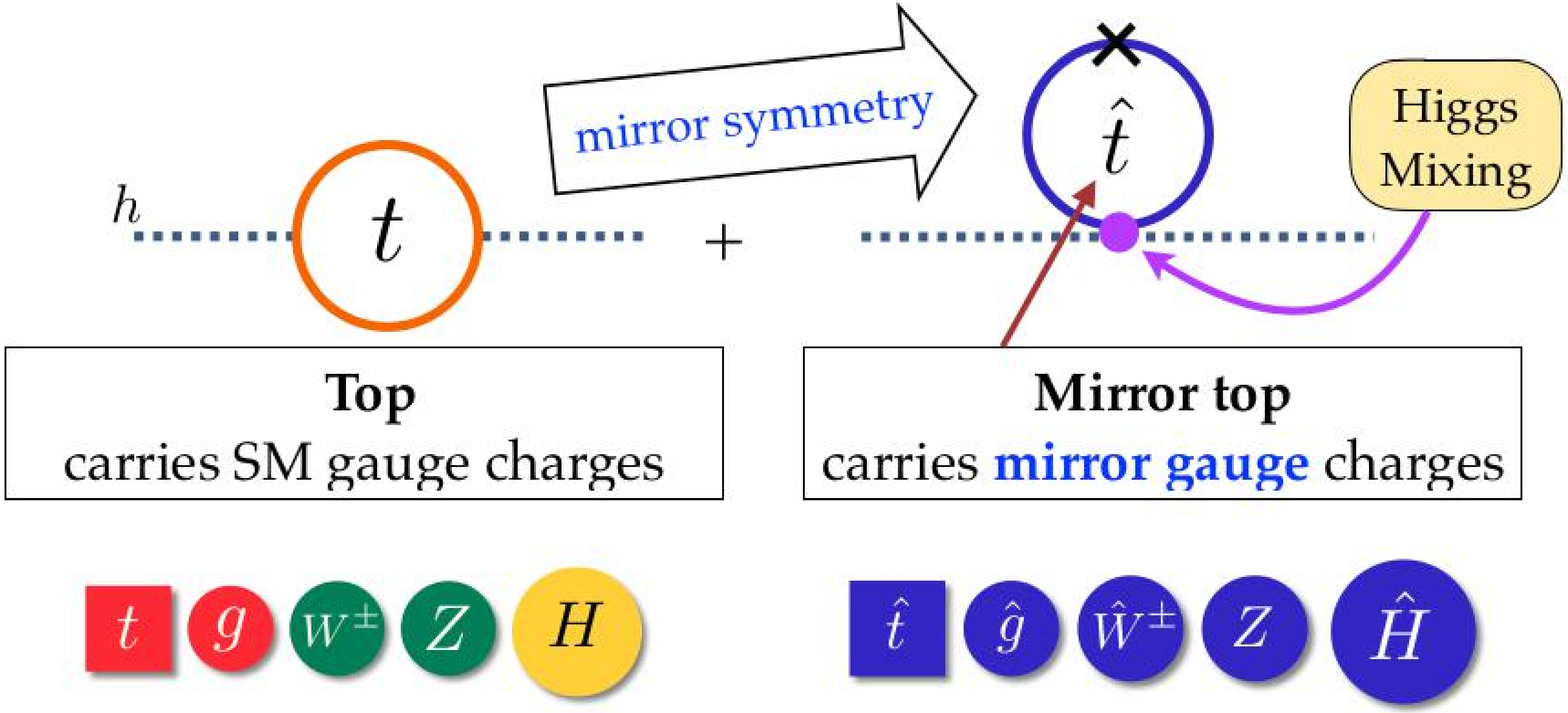
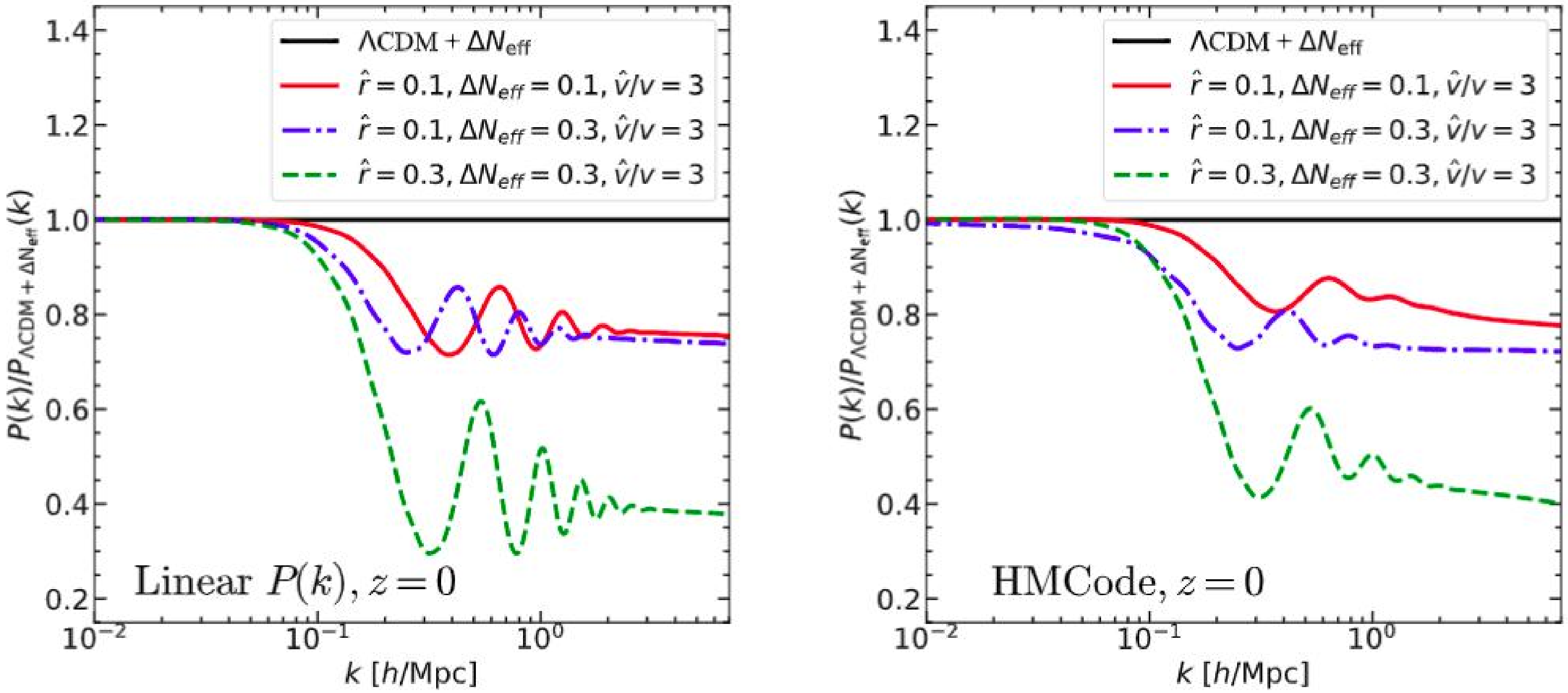


Image credit: Yusin Tsai

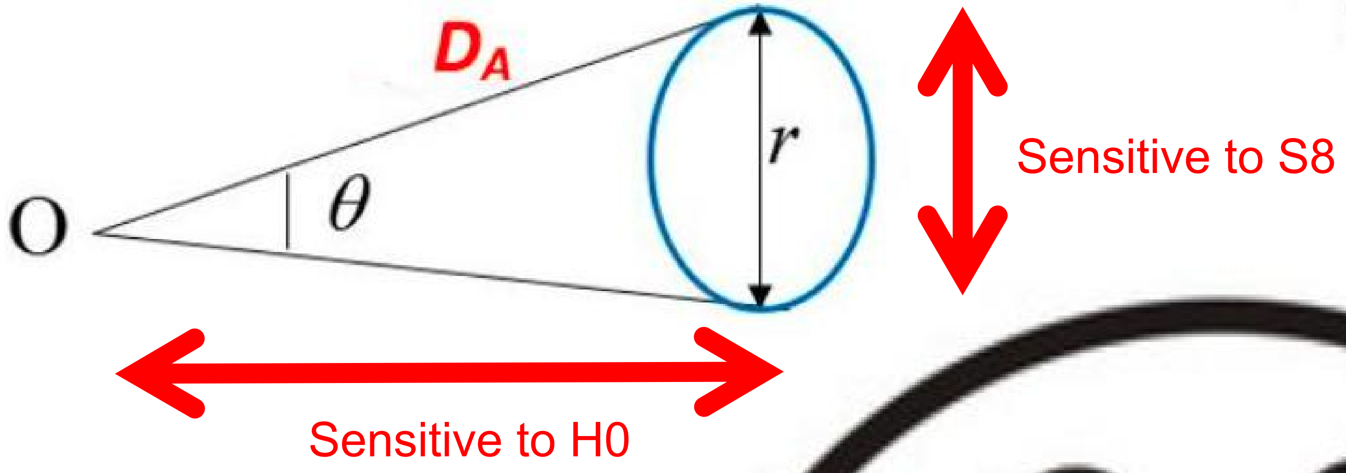
- We only introduce three parameters for a cosmological study.
- DR includes twin neutrinos and photons.

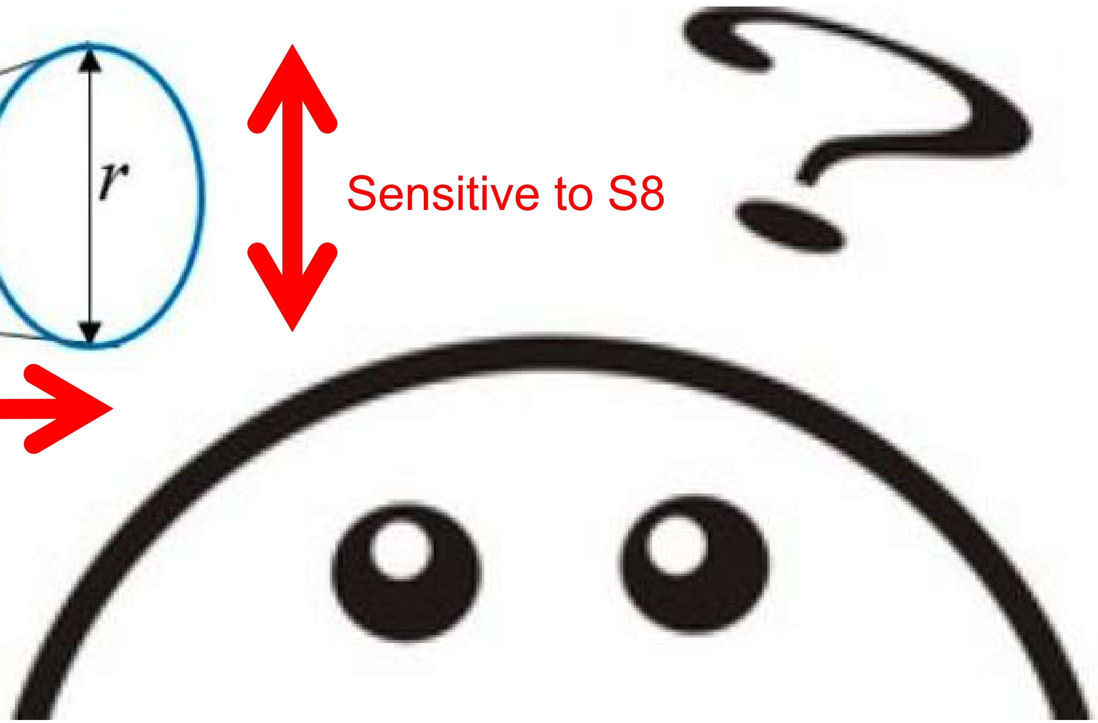
The Mirror Twin Higgs



Parameter	Prior distribution	Prior range
Cosmology		
$\Omega_b h^2$	Flat	[0.022, 0.023]
$\Omega_{\rm cdm} h^2$	Flat	[0.112, 0.128]
$100 \cdot \theta_s$	Flat	[1.039, 1.043]
$\ln\left(A_s \times 10^{10}\right)$	Flat	[2.955, 3.135]
n_s	Flat	[0.941, 0.991]
$\tau_{\rm reio}$	Flat	[10^{-2}, 0.7]
Mirror twin Higgs		
$\hat{r}$	Flat	[10^{-3}, 1]
$\hat{v}/v$	Flat	[2, 15]
$\Delta\hat{N}$	Flat	[10^{-3}, 1]
Intrinsic alignment		
$A_{\rm IA}$	Flat	[-6, 6]
η	Flat	[-6, 6]

- Matter power spectra are suppressed at a large k region.
- Non-linear effects wash out the DAO features.



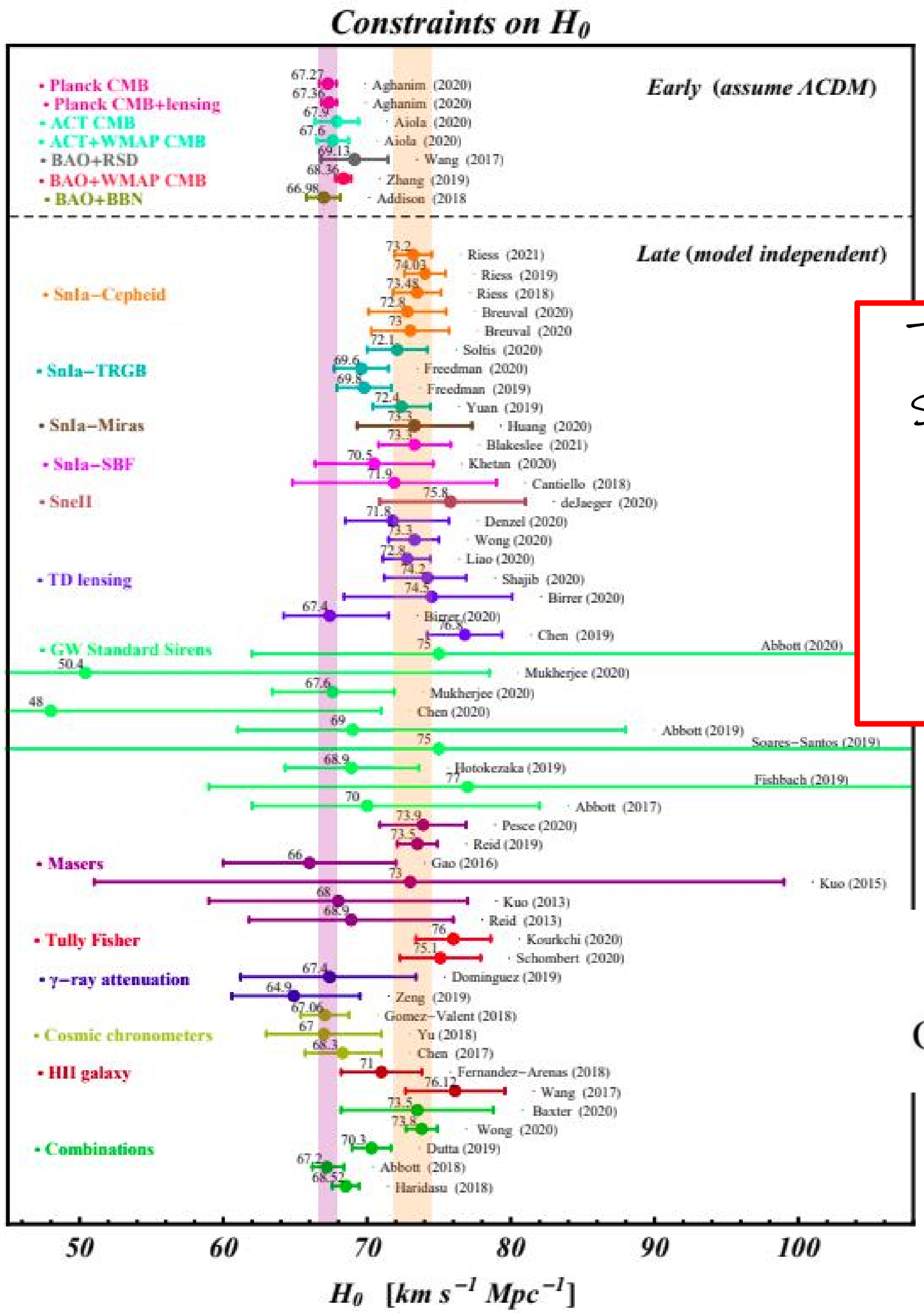


$$\theta_s = \frac{r_s(z^\star)}{D_A(z^\star)}$$

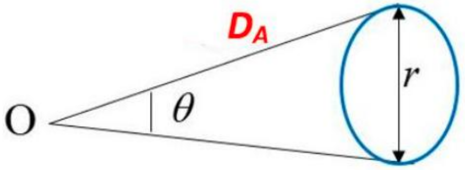
$$r_s(z^\star) = \int_{z^\star}^{\infty} \frac{dz}{H(z)} c_s(z)$$

$$D_A(z^\star) = \int_0^{z^\star} \frac{dz}{H(z)}$$

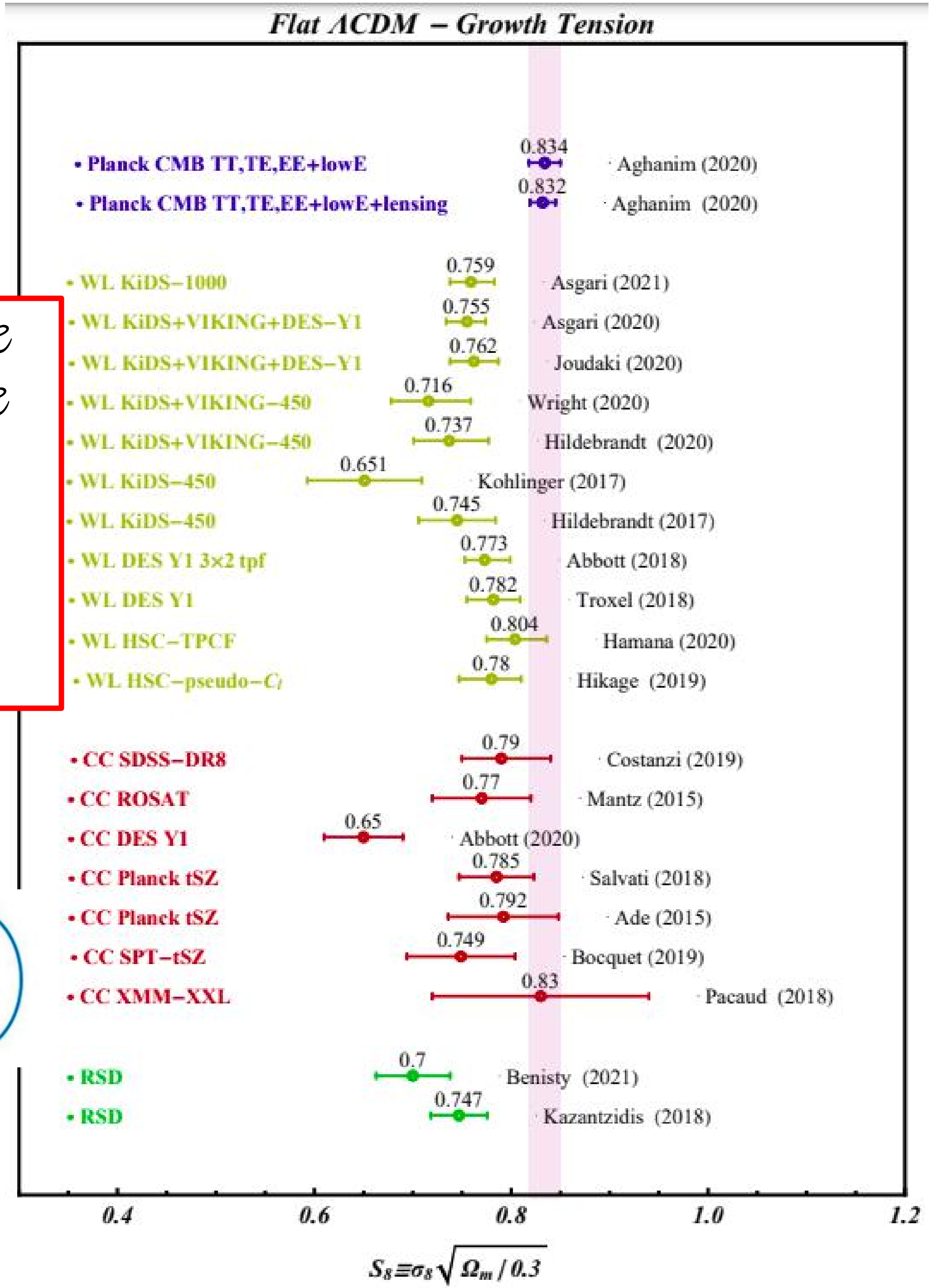
H0 and S8 problem

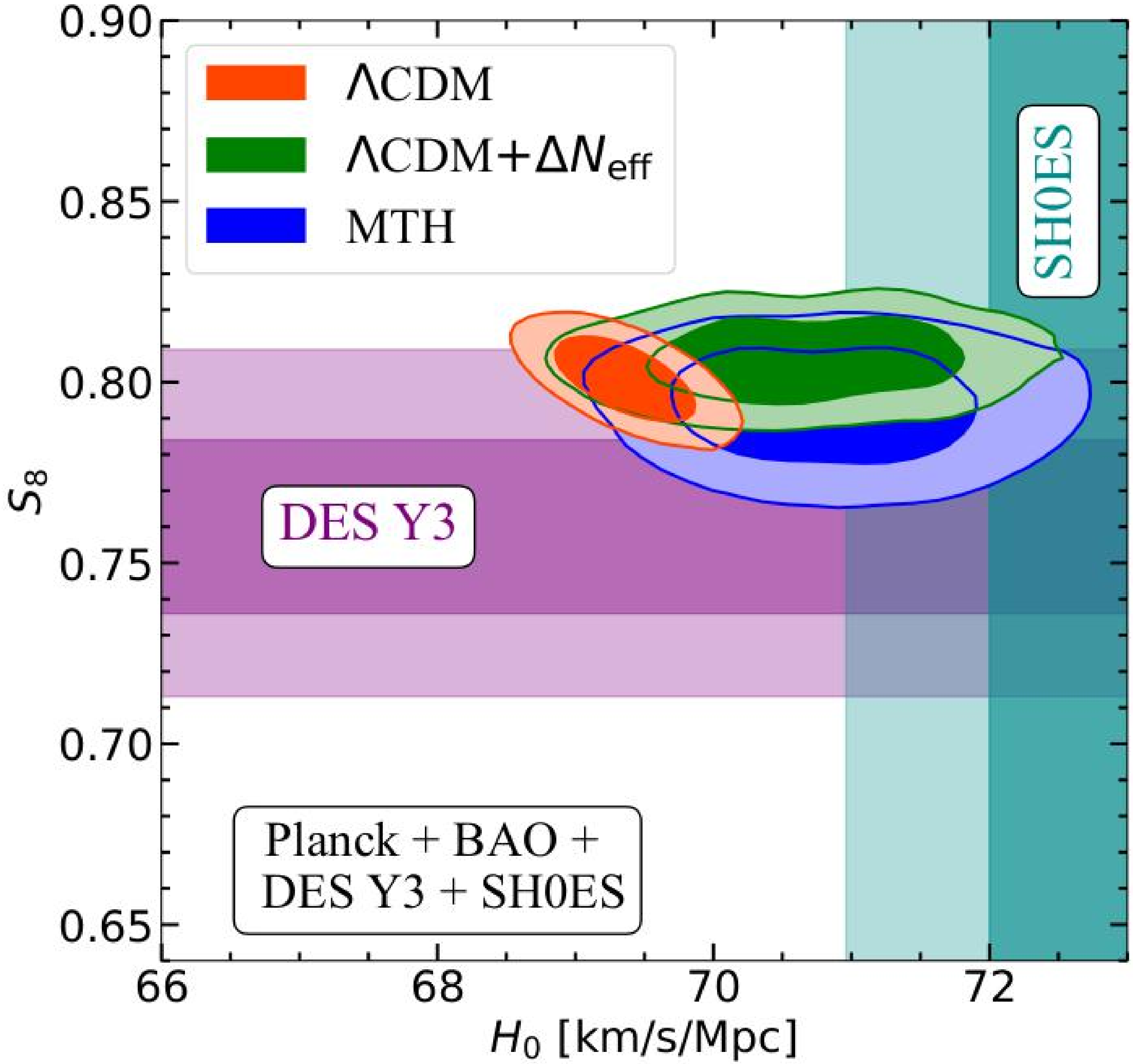


The LCDM large sclae results are smaller Ho but larger S8 than the small scale measurements.



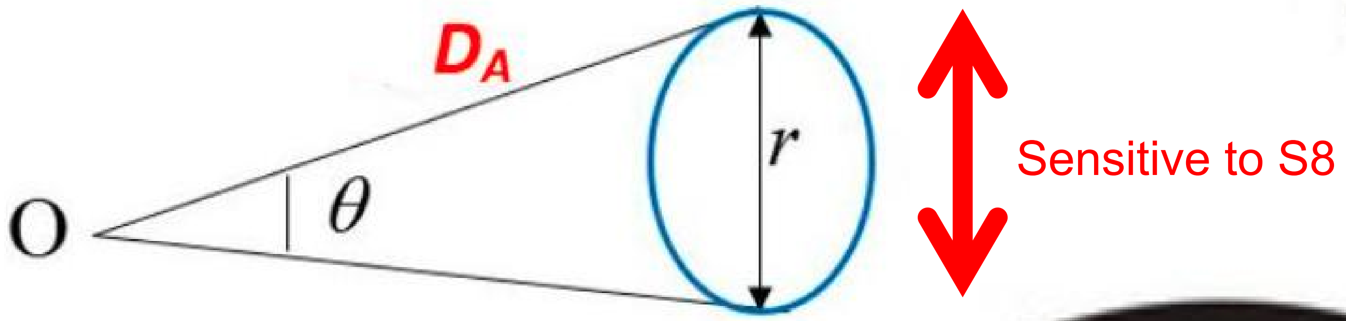
L. Perivolaropoulos, and F. Skara (2105.05208)

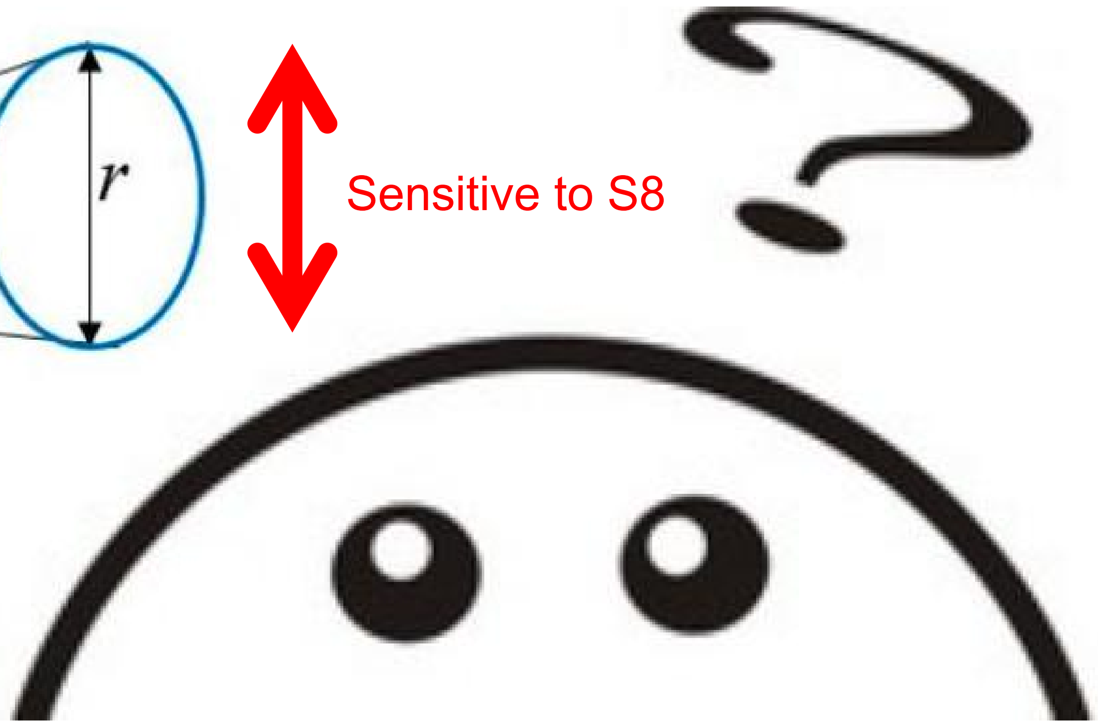




Small Ho but large S8?

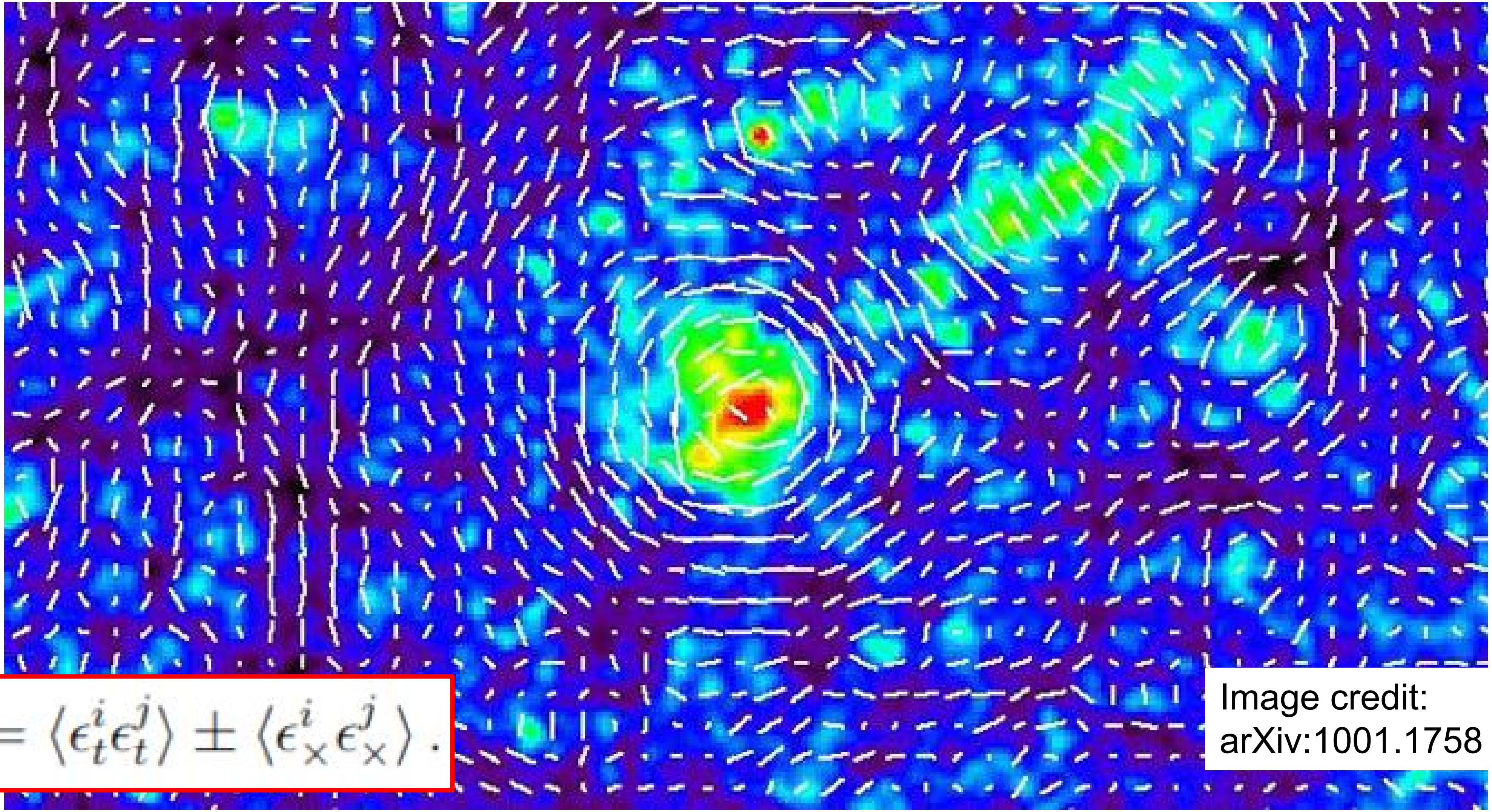
If adding a dark radiation component to the Universe, H0 can be increased while S8 is still large!





Cosmic Shear measurement

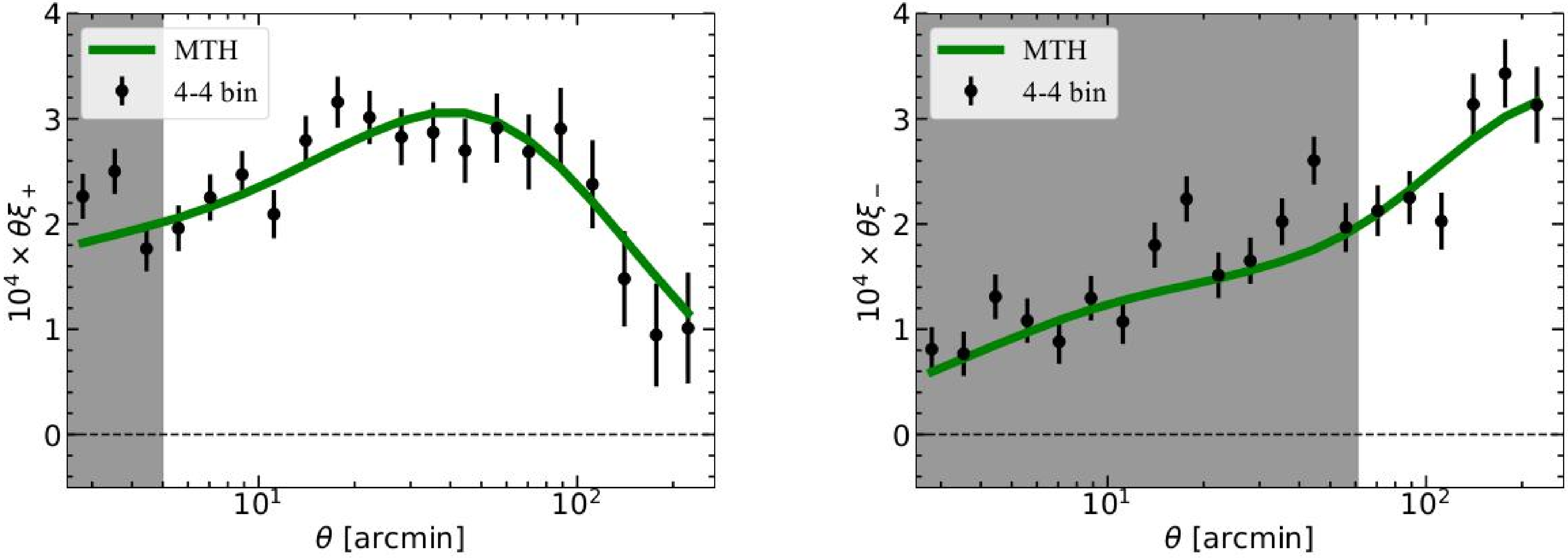
shape-shap 2 points-correlation: Cosmic Shear



$$\xi_{\pm}^{ij}(\theta) = \langle \epsilon_t^i \epsilon_t^j \rangle \pm \langle \epsilon_\times^i \epsilon_\times^j \rangle \, .$$

Image credit: arXiv:1001.1758

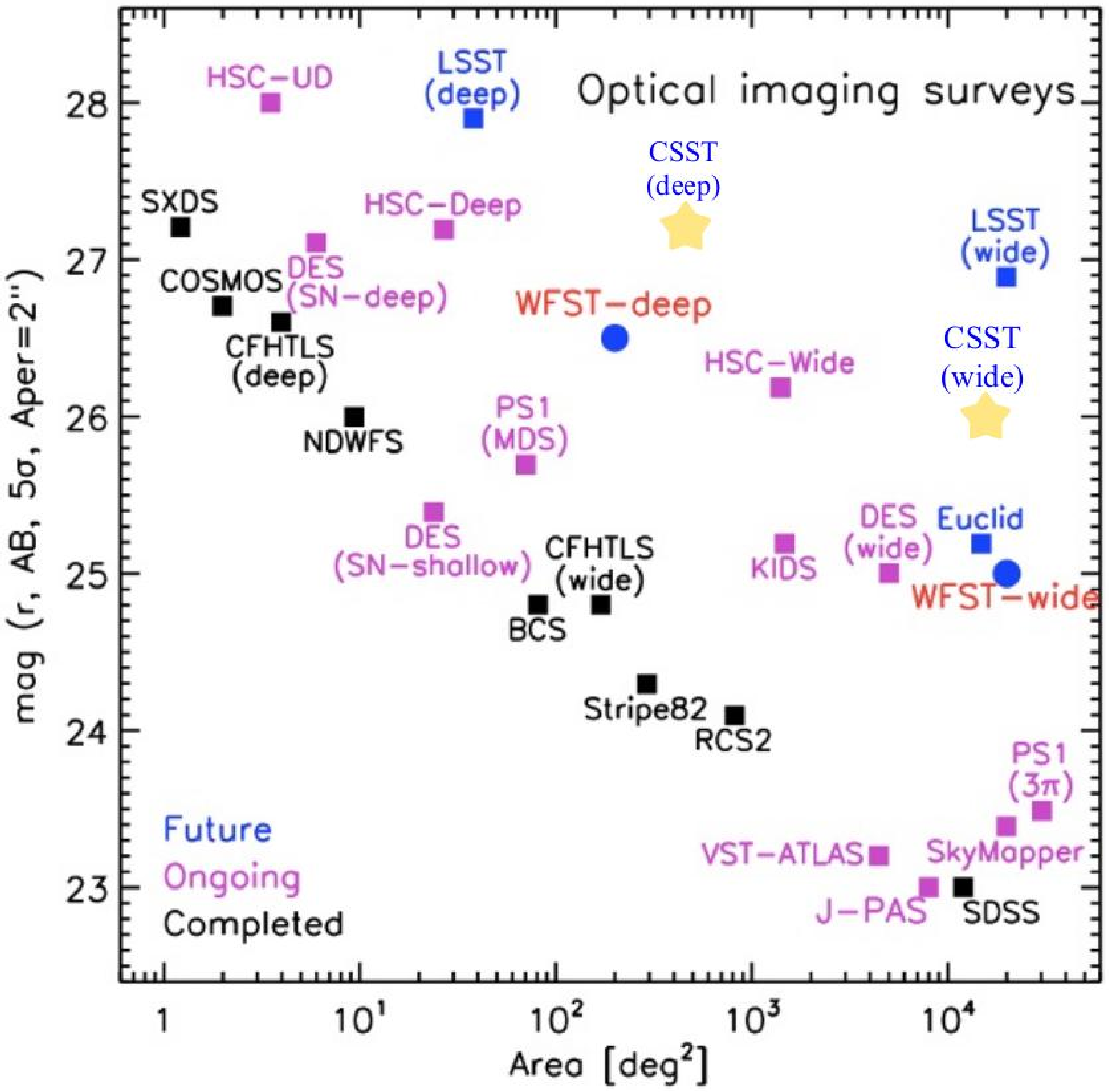
shape-shap 2 points-correlation: Cosmic Shear

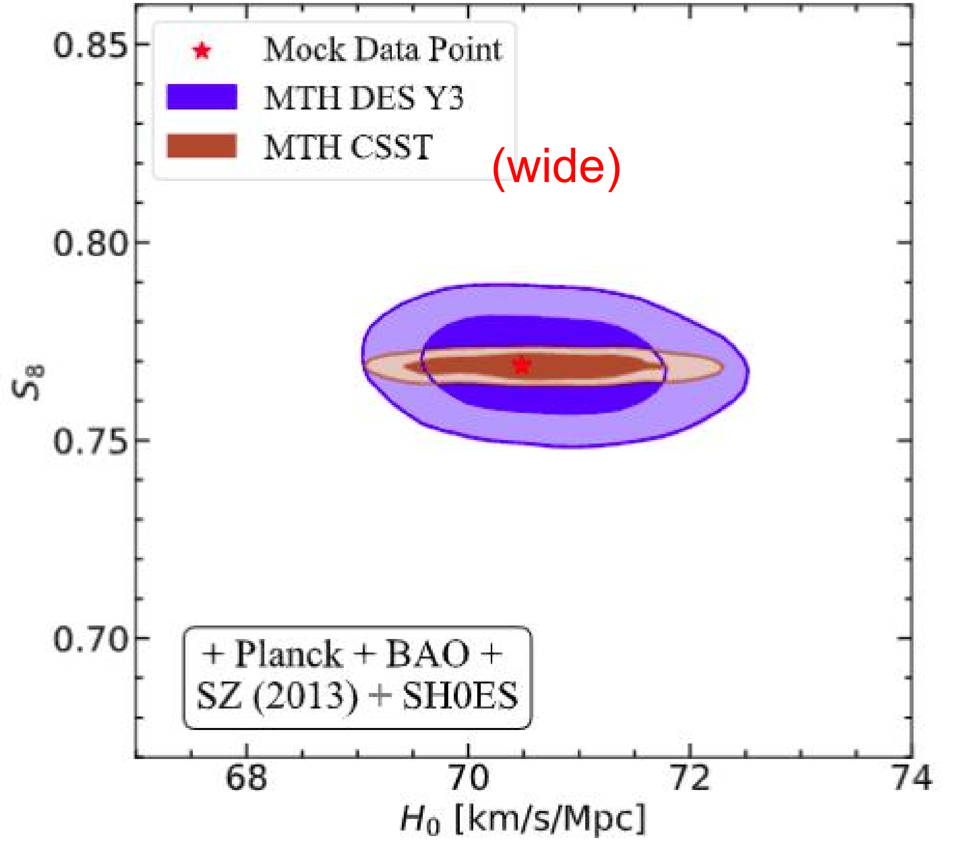


$$\xi_{\pm}^{ij}(\theta) = \frac{1}{2\pi}\int_0^{\infty} C_{\rm tot}^{ij}(\ell) J_{0/4}(\ell \cdot \theta)\ell d\ell$$

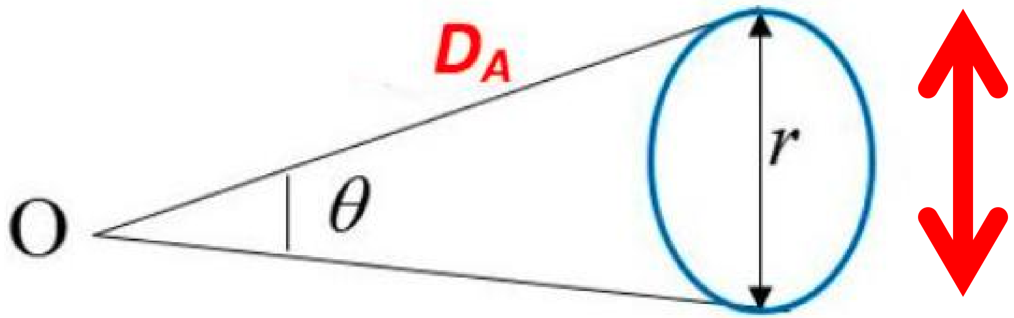
$$C_{GG}^{ij}(\ell) = \int_0^{\chi_{z_{\max}}} d\chi \frac{W^i(\chi)W^j(\chi)}{\chi^2} P_\delta\left(k = \frac{\ell + 1/2}{\chi}, z(\chi)\right)$$

Telescopes for Cosmic Shear





References: HSC website, Chi Zhang, [Chinese Science Bulletin 66, 1290 (2021)], and 2301.03068



Basic likelihoods:

1. Cosmic shear (DES Y3, shape-shape).
2. CMB (TT, TE, EE, lensing).
3. BAO (BOSS DR12).

Results

When studying how MTH can relax the H_0 and S_8 tensions, we further include two datasets one by one

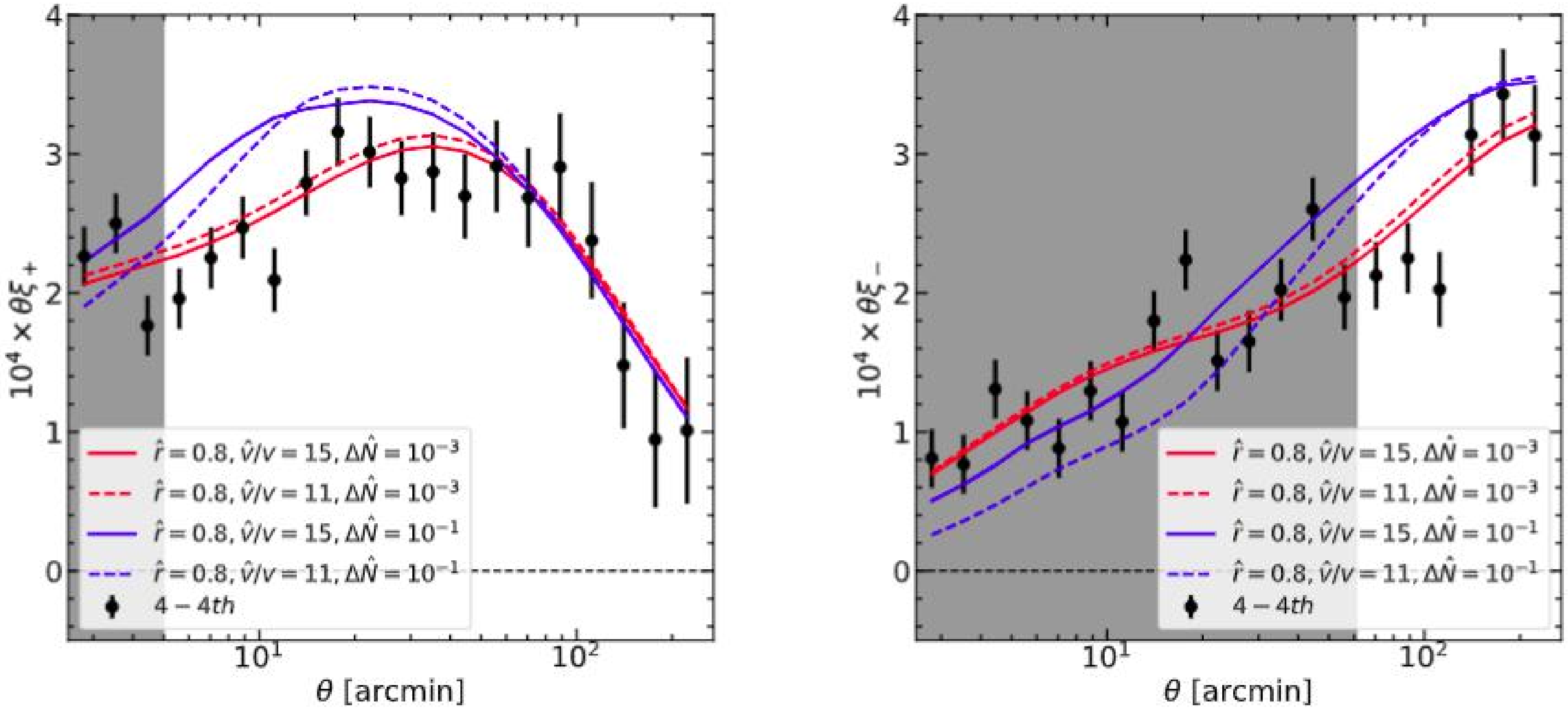
(iv) The SH0ES likelihood is also a Gaussian distribution with the measurement [74]

$$H_0 = 73.04 \pm 1.04 \text{ km s}^{-1}\text{Mpc}^{-1}.$$

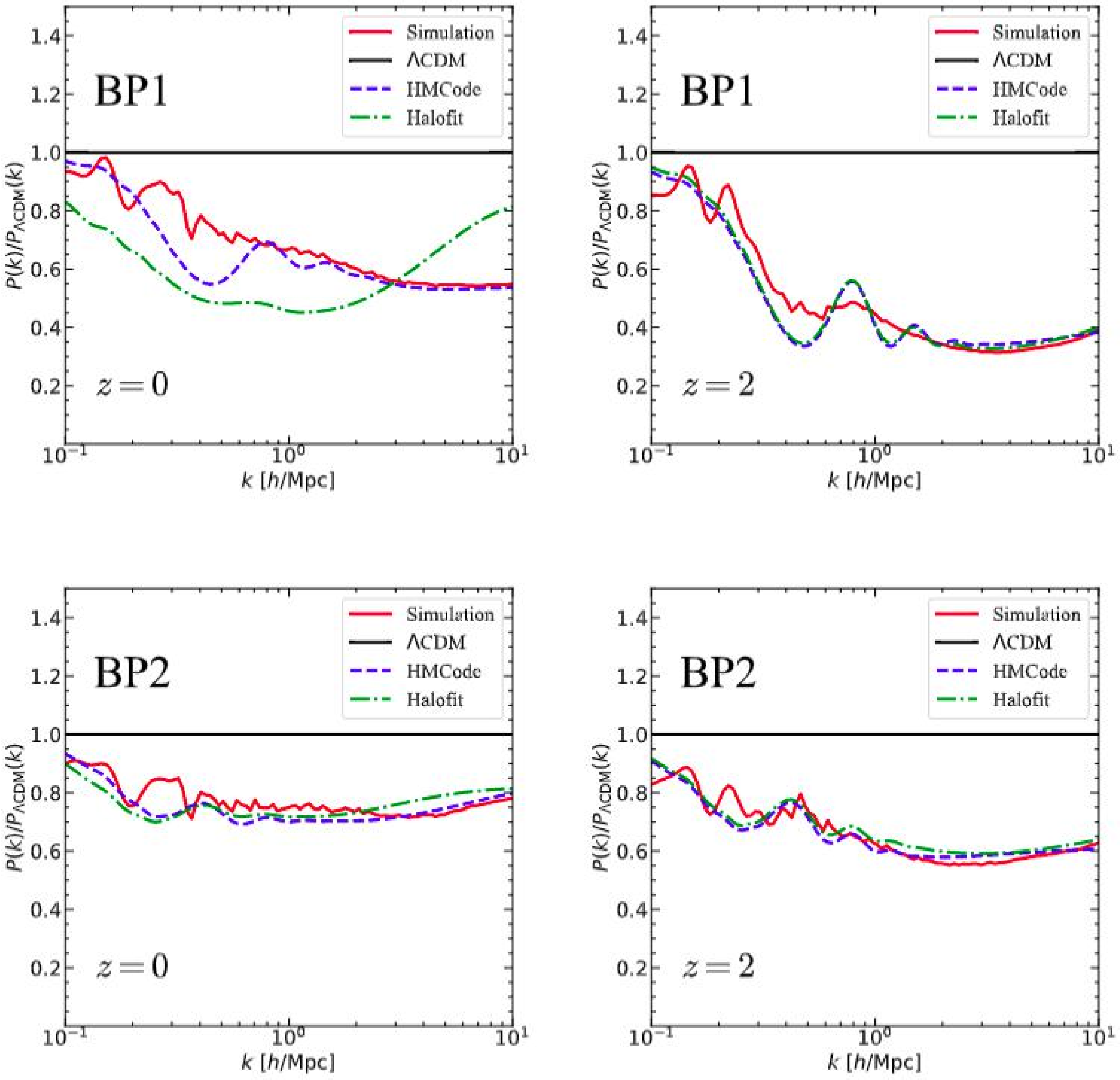
(v) The Planck SZ (2013) likelihood[4] is described by a Gaussian distribution with the measurement [45]

$$S_8^{\rm SZ} \equiv \sigma_8 \left(\Omega_{\rm m}/0.27\right)^{0.3} = 0.782 \pm 0.010.$$

The impact of vev and Delta N



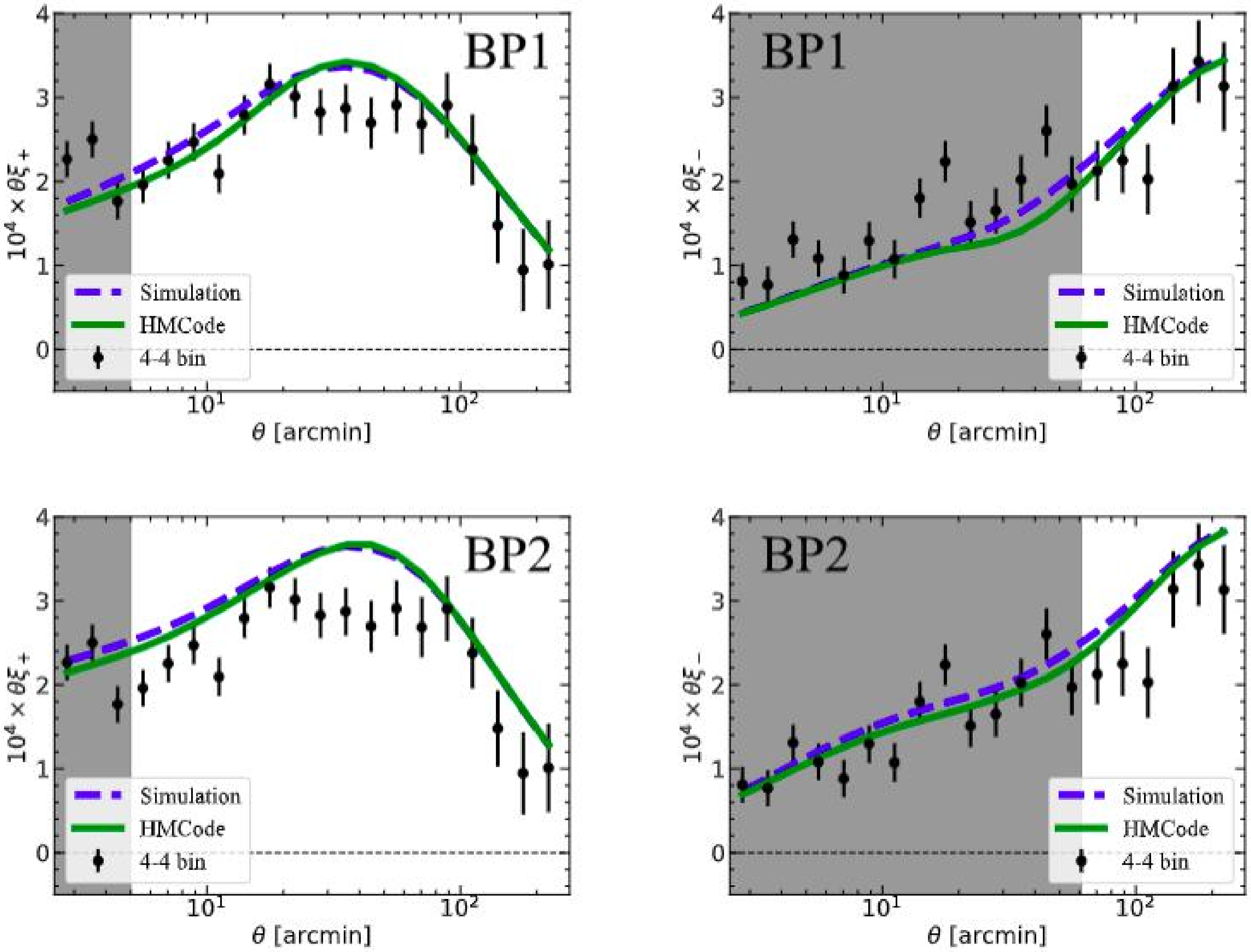
- DES Y3 cannot probe a small scale.
- A large r-hat and small Delta N can escape from DES due to mask.



Systematic study

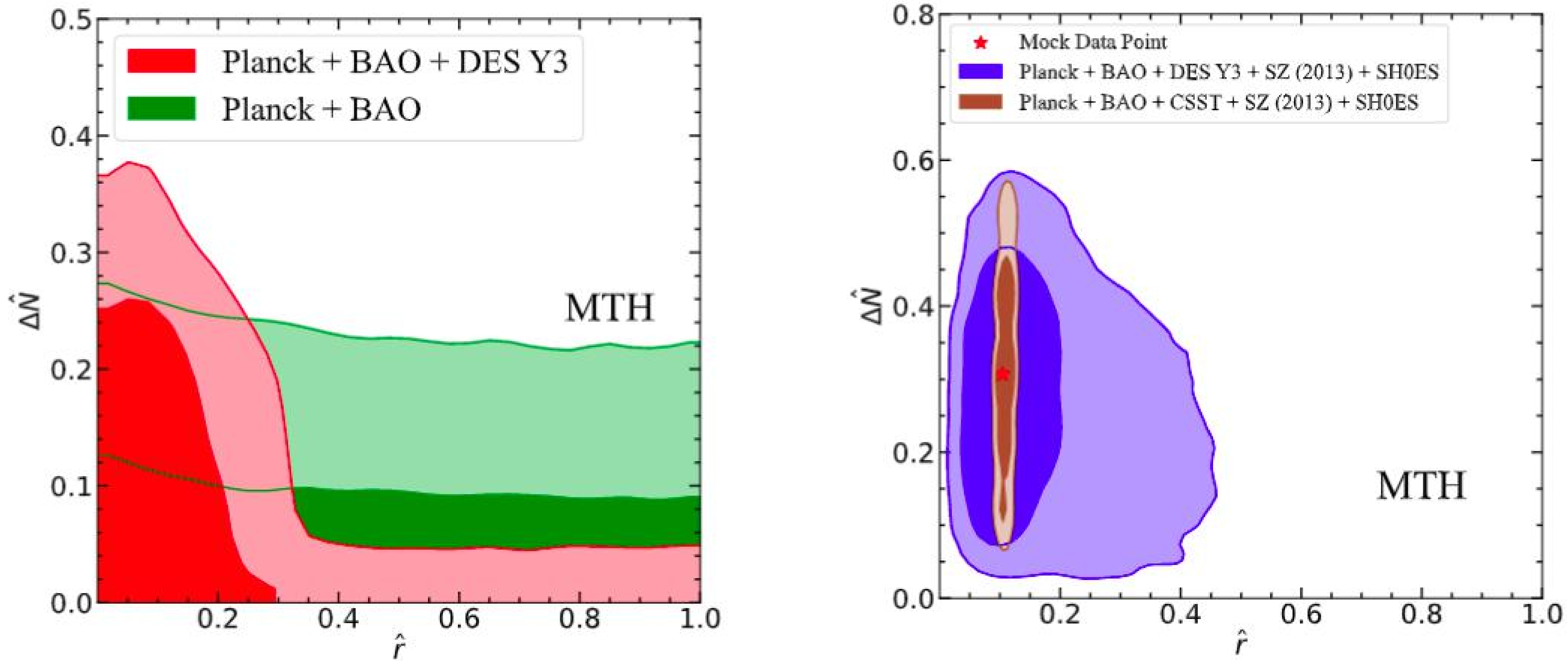
- Non-linear effects for THM are still very similar to LCDM.
- The largest discrancy is from the small scale which is already been masked.

Systematic study

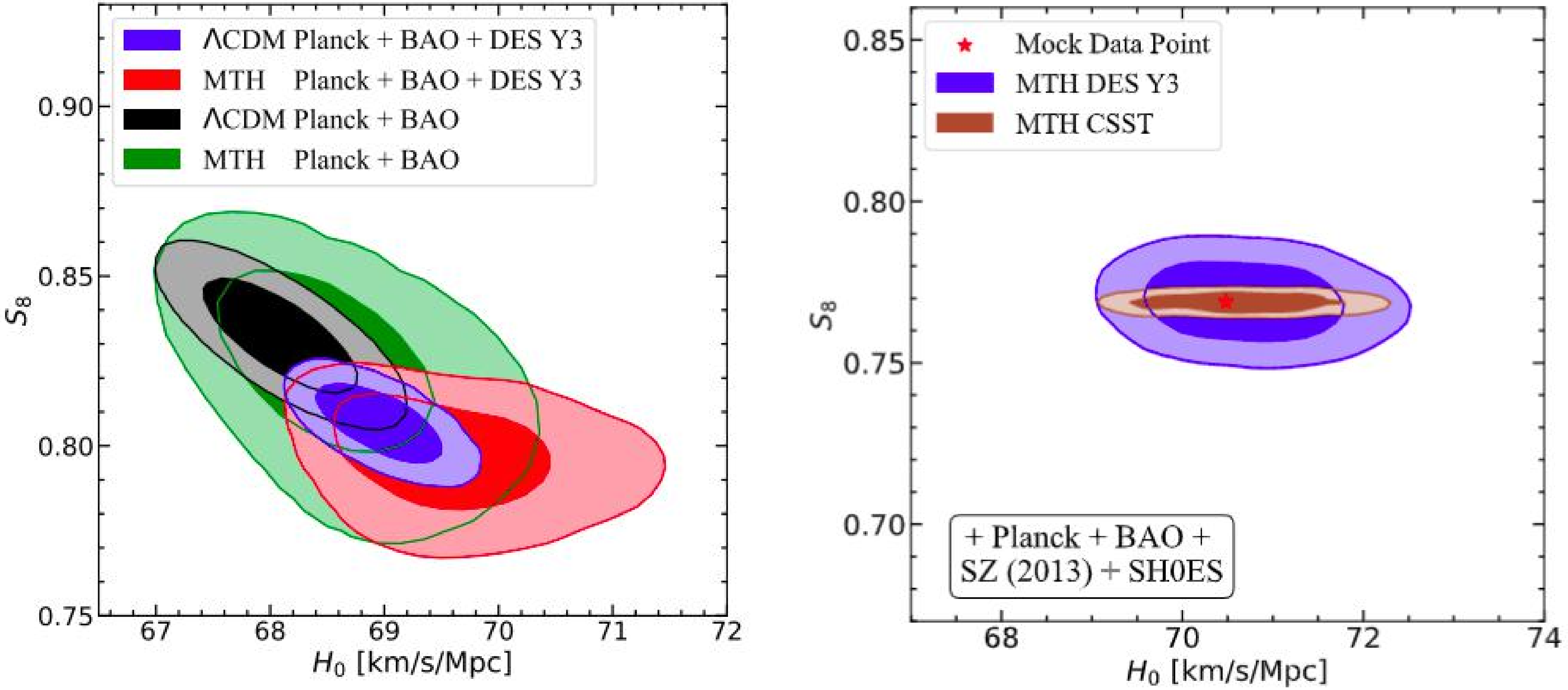


- The shear power spectra computed by HMCode (the IC given by the LCDM) and N-body simulation are similar.
- The main differences are hidden at the small angle region.
- They are hard to statistically distinguished.

MTH with SZ (2013) and SHOES



- DES Y3 strongly disfavour the region of large r-hat.
- The future telescopes like CSST can pin down the range of r-hat.



MTH can pull the parameter space to a lower S8.

Summary

- While the MTH model is presently not a superior solution to the observed H0 tension compared to the ΛCDM+ΔNeff model, we demonstrate that it has the potential to alleviate both the H0 and S8 tensions, especially if the S8 tension.

- The MTH model can relax the tensions while satisfying the DES power spectrum constraint up to k~10 h Mpc−1.

- We show that the future China Space Station Telescope (CSST) can determine the twin baryon abundance with a 10% level precision.