The Hubble constant in the axi-Higgs universe

Luu Hoang Nhan

in collaboration with

Leo WH Fung, Lingfeng Li, Tao Liu, Yucheng Qiu, S.-H.Henry Tye

(**arXiv:2102.11257** and **arXiv:2105.01631**)

New Perspectives 2021

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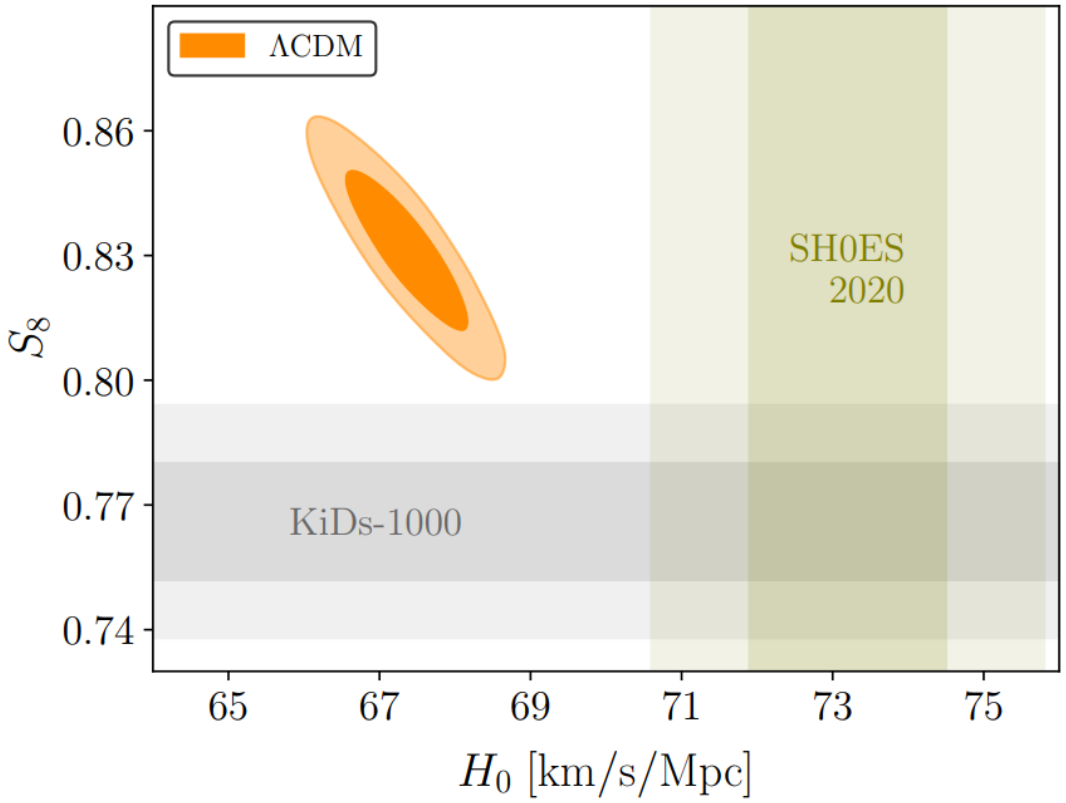
H_0 and S_8 tensions in ΛCDM



Planck 2018 (1807.06209)

$H_0 = 67.36 \pm 0.54$ (ΛCDM)

$H_0 = 73.2 \pm 1.3$ (SH0ES)

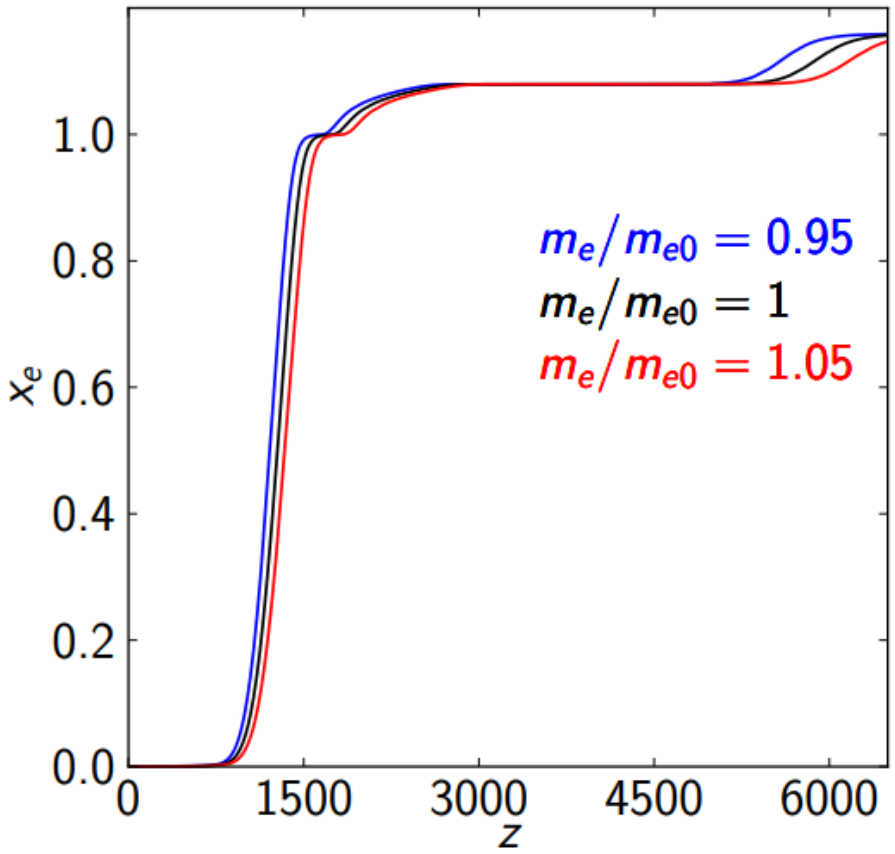
$\rightarrow 4.1\sigma$ discrepancy

$S_8 = 0.832 \pm 0.013$ (ΛCDM)

$S_8 = 0.766^{+0.020}_{-0.014}$ (KiDs-1000)

$\rightarrow 2.8\sigma$ discrepancy

$\Lambda\mathrm{CDM} + \mathrm{m_e}$ model



Planck 2015 (1406.7482)

When m_e increases

→ electrons recombine faster

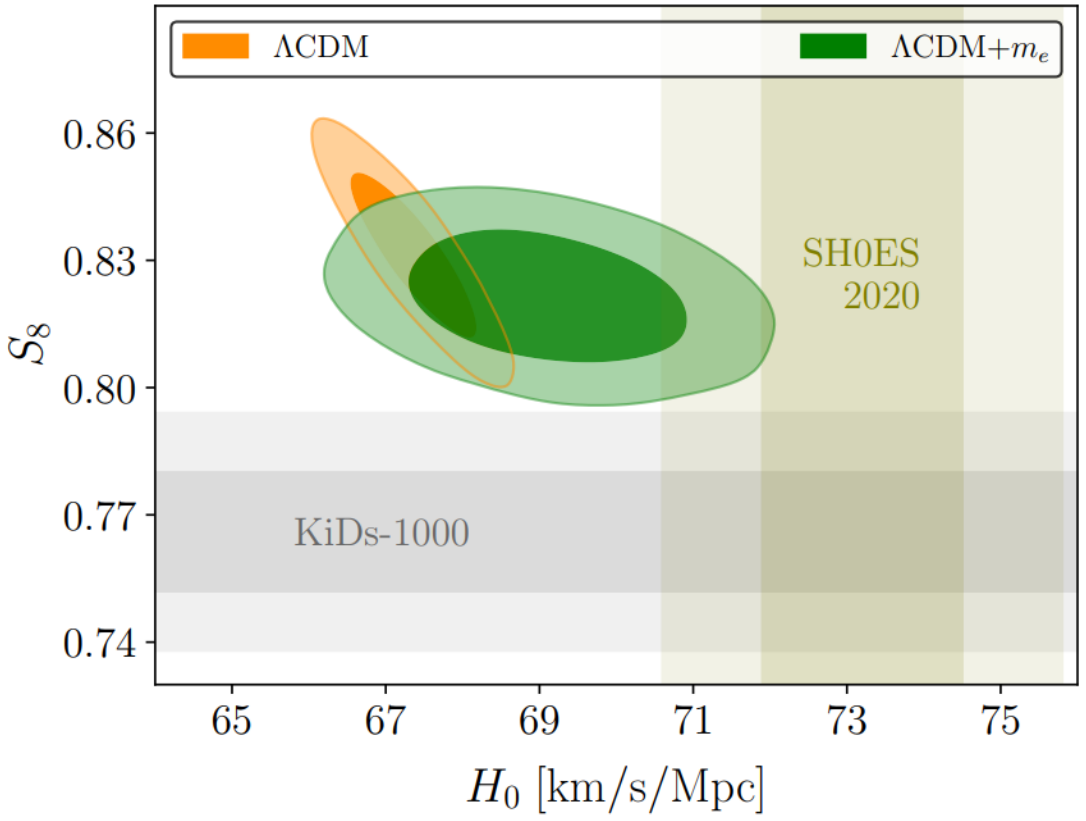
→ earlier recombination

→ reduced sound horizon

$$r_s(z_*) = \int_{z_*}^{\infty} \frac{c_s(z)}{H(z)}$$

→ increasing H_0

H_0 and S_8 in $\Lambda\mathrm{CDM} + \mathrm{m_e}$



Hart & Chluba (1912.03986)

$H_0 = 69.1 \pm 1.2\ (\Lambda\mathrm{CDM} + \mathrm{m_e})$

$H_0 = 73.2 \pm 1.3$ (SH0ES)

$\rightarrow 2.2\sigma$ discrepancy

$S_8 = 0.821 \pm 0.010\ (\Lambda\mathrm{CDM} + \mathrm{m_e})$

$S_8 = 0.766^{+0.020}_{-0.014}$ (KiDs-1000)

$\rightarrow 2.5\sigma$ discrepancy

Axi-Higgs theoretical model

- The Higgs field coupled to an ultralight axion

$$V = m_a^2 f_a^2 \left(1 - \cos\frac{\phi}{f_a}\right) + |K(\phi)(m_s^2 F(\phi) - \kappa h^+ h)|^2$$

- The axion evolves following misalignment mechanism:

$$\ddot{\phi} + 3H\dot{\phi} + m_a^2\phi = 0$$

Axi-Higgs effective model

- The Higgs VEV is driven by the axion

$$v = v_0(1 + \delta v) = 246\ \mathrm{GeV}\left(1 + \frac{C\phi^2}{2M_{Pl}^2}\right)$$

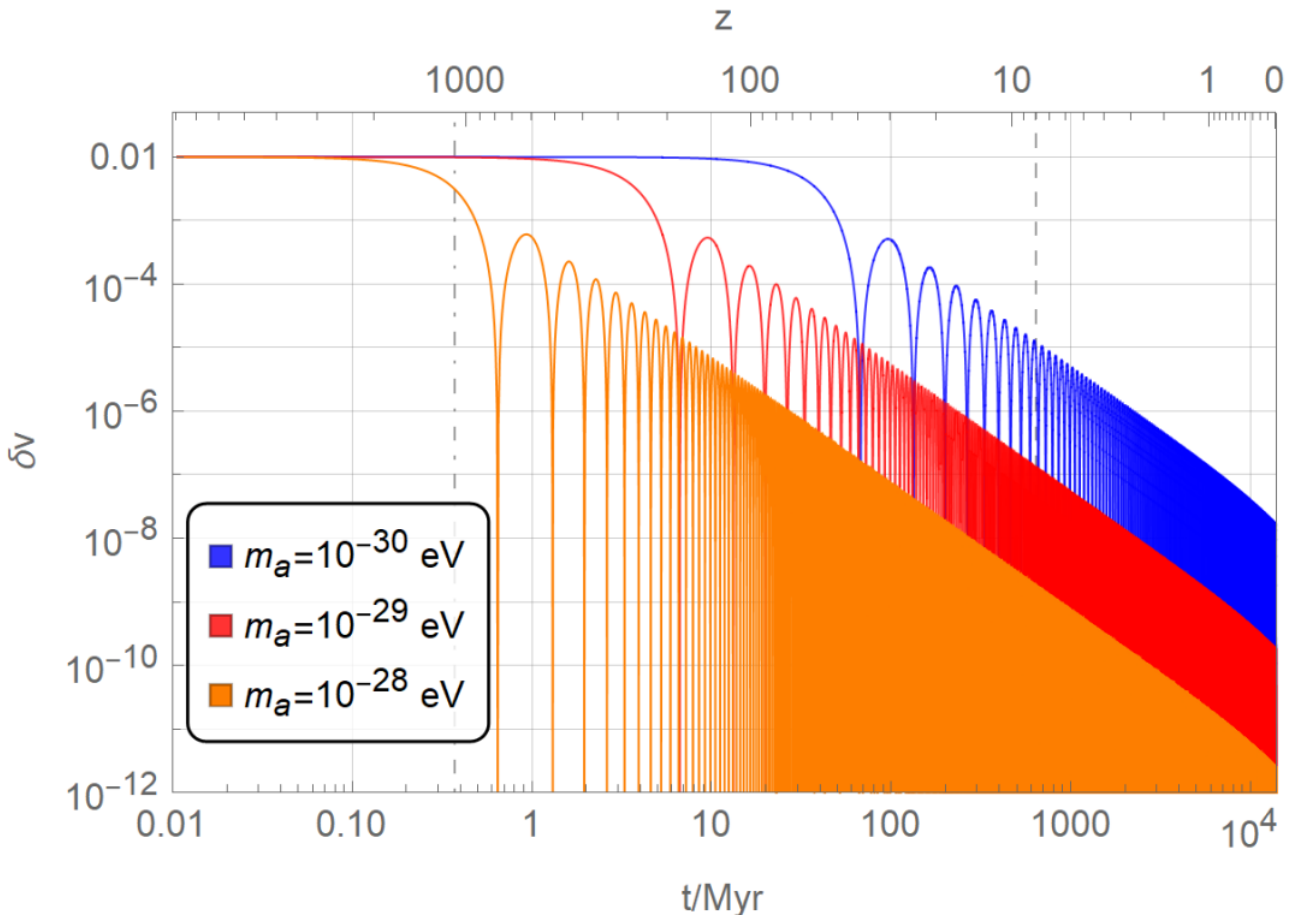
- Axion density is given by

$$\delta v \propto \rho_a \sim \mathrm{const} \text{ at early times } z \gg z_a$$

$$\delta v \propto \rho_a \propto (1+z)^3 \text{ at late times } z \ll z_a$$

with z_a depending on m_a

Higgs-VEV evolution



Axi-Higgs with $m_a \simeq 10^{-30}$ eV

- similar to $\Lambda\mathrm{CDM} + m_e$ before recombination
- similar to axion cosmology after recombination

Axi-Higgs is approximately equivalent to $\Lambda\mathrm{CDM} + m_e + \omega_a$

Axion perturbative cosmology

Axion has finite Jeans scale

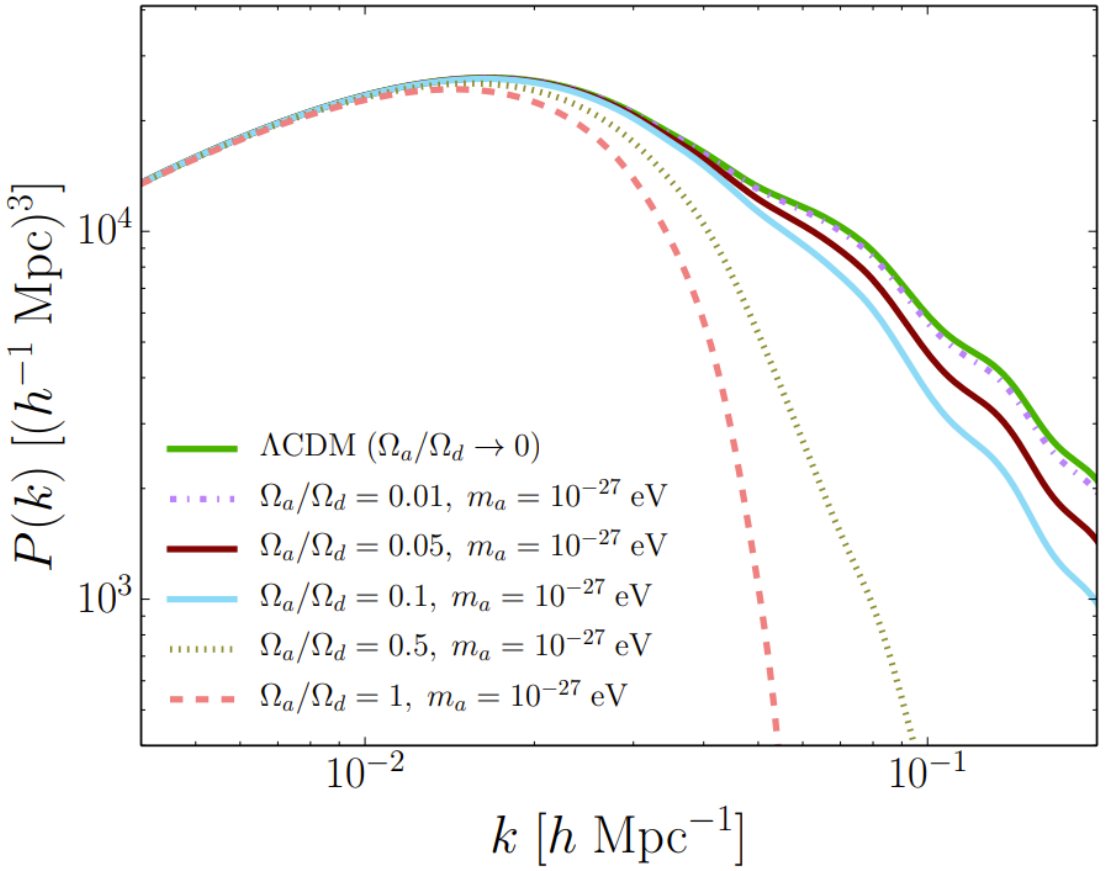
→ Suppress small-scale structures

→ Reduce σ_8 by definition

$$\sigma_8^2 = \int_0^\infty P(k)\, W^2(kR_8) dk$$

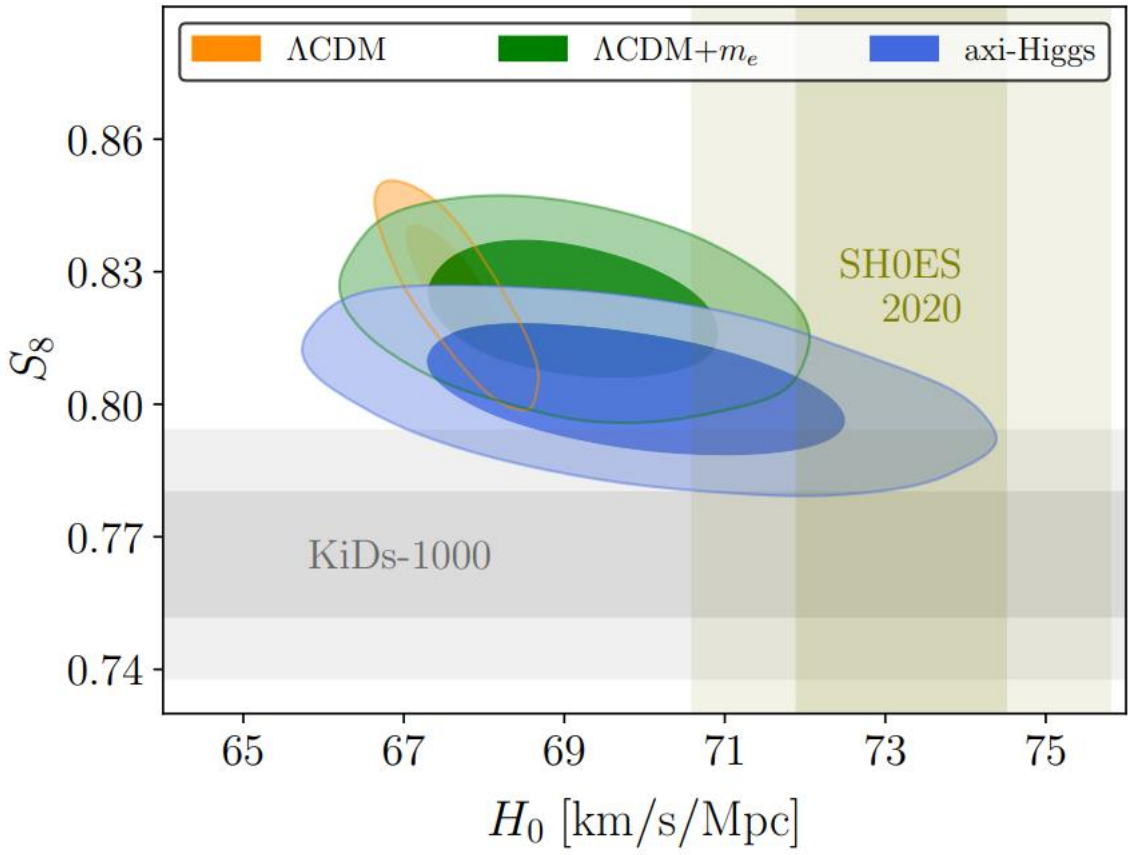
→ Reduce S_8 as a consequence

$$S_8 = \sigma_8 (\Omega_m / 0.3)^{0.5}$$



HGMF (1410.2896)

H_0 and S_8 in axi-Higgs



$H_0 = 69.9 \pm 1.8$ (axi-Higgs)

$H_0 = 73.2 \pm 1.3$ (SH0ES)

$\rightarrow 1.5\sigma$ discrepancy

$S_8 = 0.8031 \pm 0.0098$ (axi−Higgs)

$S_8 = 0.766^{+0.020}_{-0.014}$ (KiDs-1000)

$\rightarrow 1.7\sigma$ discrepancy

Summary and Discussion

- Axi-Higgs can alleviate H_0 and S_8 tensions simultaneously
- Axi-Higgs also alleviates the well-known Lithium puzzle in BBN
- Axi-Higgs could be tested by quasar absorption lines