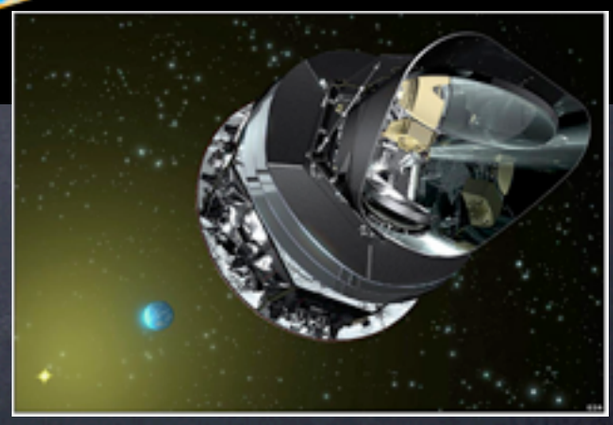
Summary of group B

Cosmology

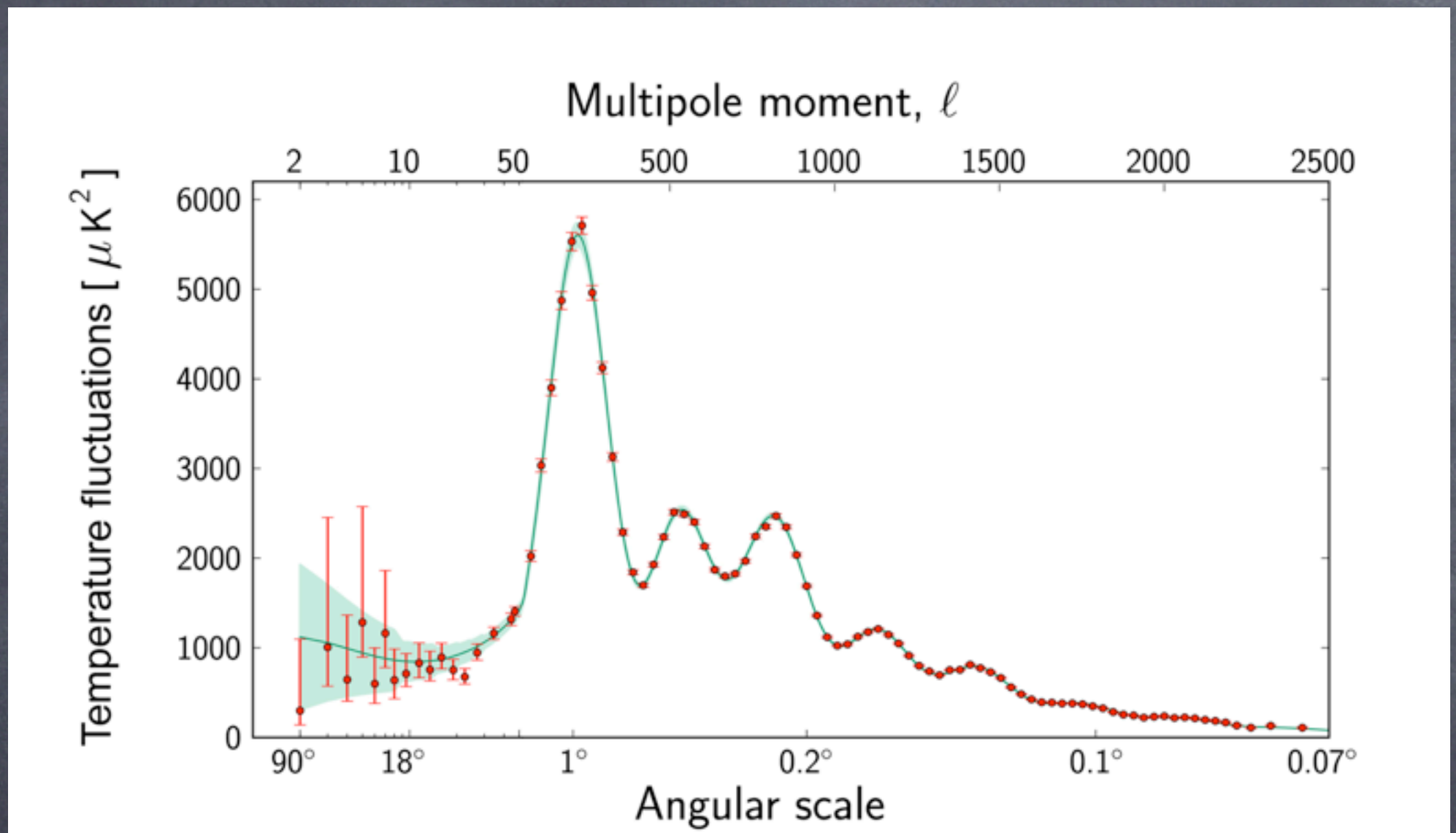
@Tohoku forum for creativity
25th October

Fuminobu Takahashi (Tohoku)

Cosmology is now a precision science.



We have the standard Lambda CDM cosmology.



Perfect agreement with the standard LCDM model with 6 parameters. $(\Omega_b h^2, \Omega_c h^2, \theta_{\rm MC}, \tau, n_s, \ln(A_s))$

The rationale for precision measurements

"The whole history of physics proves that a new discovery is quite likely lurking at the next decimal place."

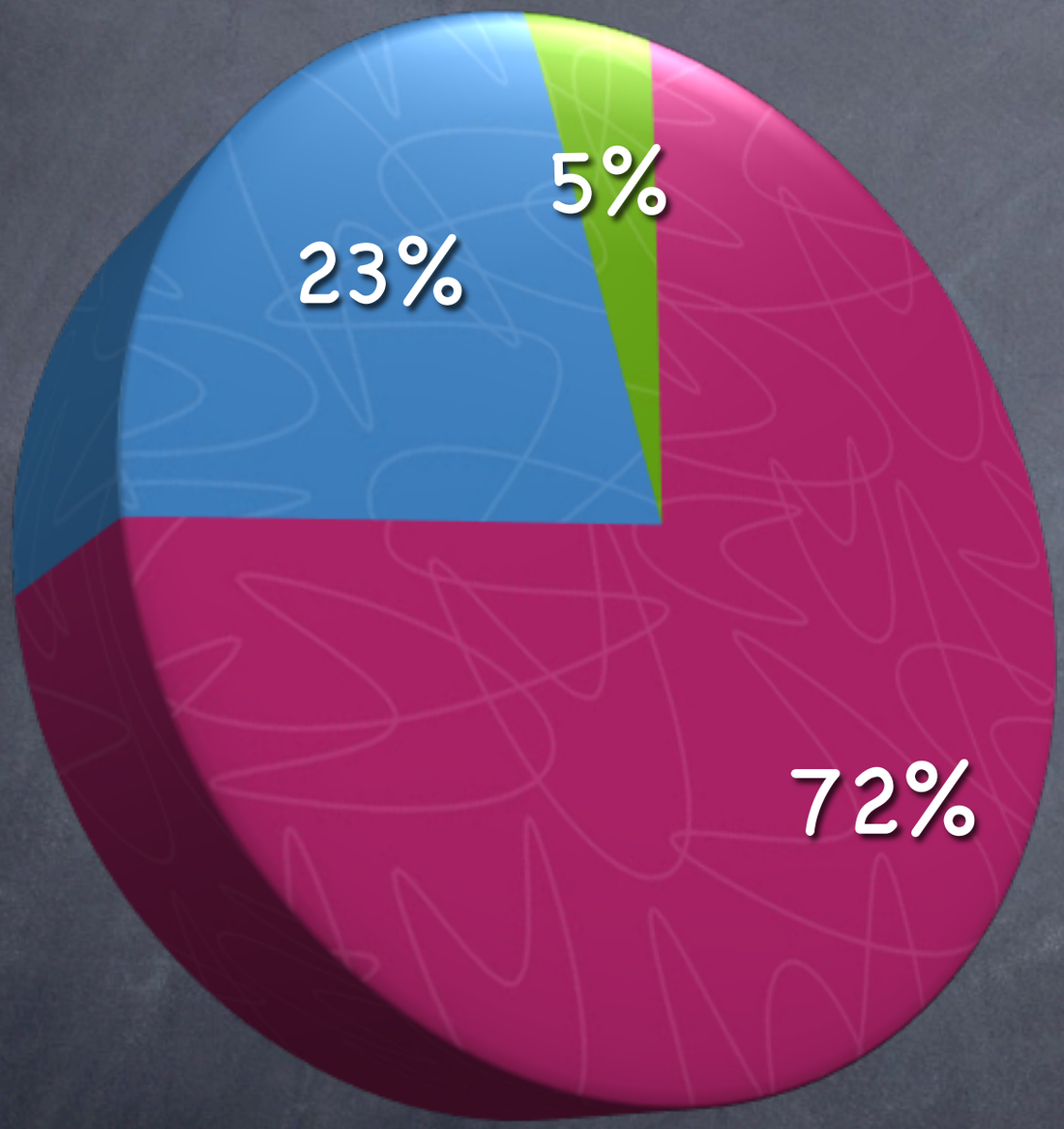
F.k. Richtmeyer (1931)

"A precision experiment is justified if it can reveal a flaw in our theory or observe a previously unseen phenomenon, not simply because the experiment happens to be feasible..."

S. L. Glashow, 1305.5482

Then where to look for?

The present Universe is dominated by dark sector



- Dark energy
- Dark matter
- Ordinary matter

Dark matter and dark energy clearly call for new physics beyond standard model.

We had many interesting talks in this workshop.

Hypercharged DM

Direct detection

Dark energy

Dark matter

Massive gravity

R-xions

Sterile nu

Dark radiation

axions

WISPy DM

Moduli decay

CMB

Inflation

muon g-2 SUSY

Reheating

Gravitational waves

BSM

Density perturbations

- The dark sector provides us with a hint for new physics beyond SM. There may be something unexpected.
- In the discussion session, we focused on a hot dark matter component recently favored by a set of different cosmological observations.

$$\Delta N_{\rm eff} = 0.61 \pm 0.30,$$

$$m^{\rm eff}_{\rm HDM} = (0.41 \pm 0.13)\,{\rm eV},$$

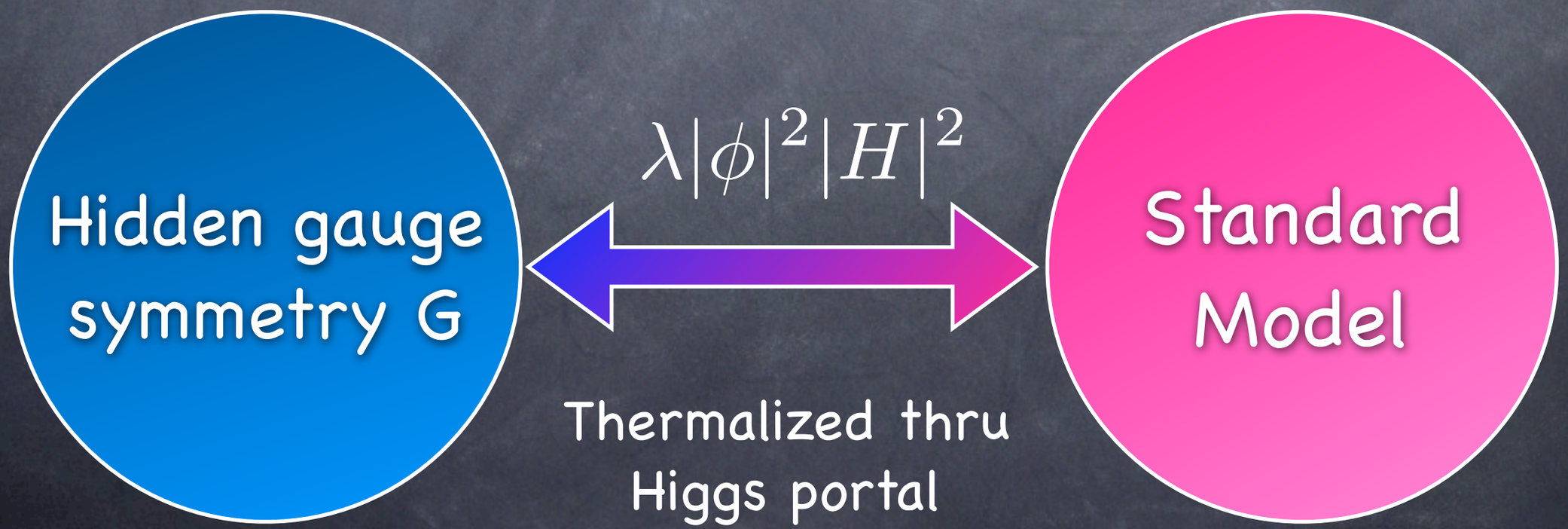
- The dark sector provides us a hint for new physics beyond SM. There may be something unexpected.
- In the discussion session, we focused on a hot dark matter component recently favored by a set of different cosmological observations.
- We have found an interesting possibility:
  - Non-Abelian hidden gauge group through Higgs portal

Consider a non-Abelian hidden gauge symmetry G, which is thermalized thru Higgs portal and gets strong at a scale of O(0.1)eV.

$$\mathcal{L} = -\frac{1}{4} F'_{\mu\nu} F'^{\mu\nu} + |D\phi|^2 + \frac{\lambda}{4} |\phi|^2 |H|^2 + \mathcal{L}_{\rm SM}$$

ϕ : scalar charged under G G=U(1), SU(N), etc.

H : SM Higgs doublet



The hidden sector remains coupled to the SM sector at temperatures below the mass of ϕ.

$$\mathcal{L}_{\rm eff} = \frac{1}{\Lambda_\phi^2} F'_{\mu\nu} F'^{\mu\nu} |H|^2, \quad \text{for} \;\; m_h < T < m_\phi$$

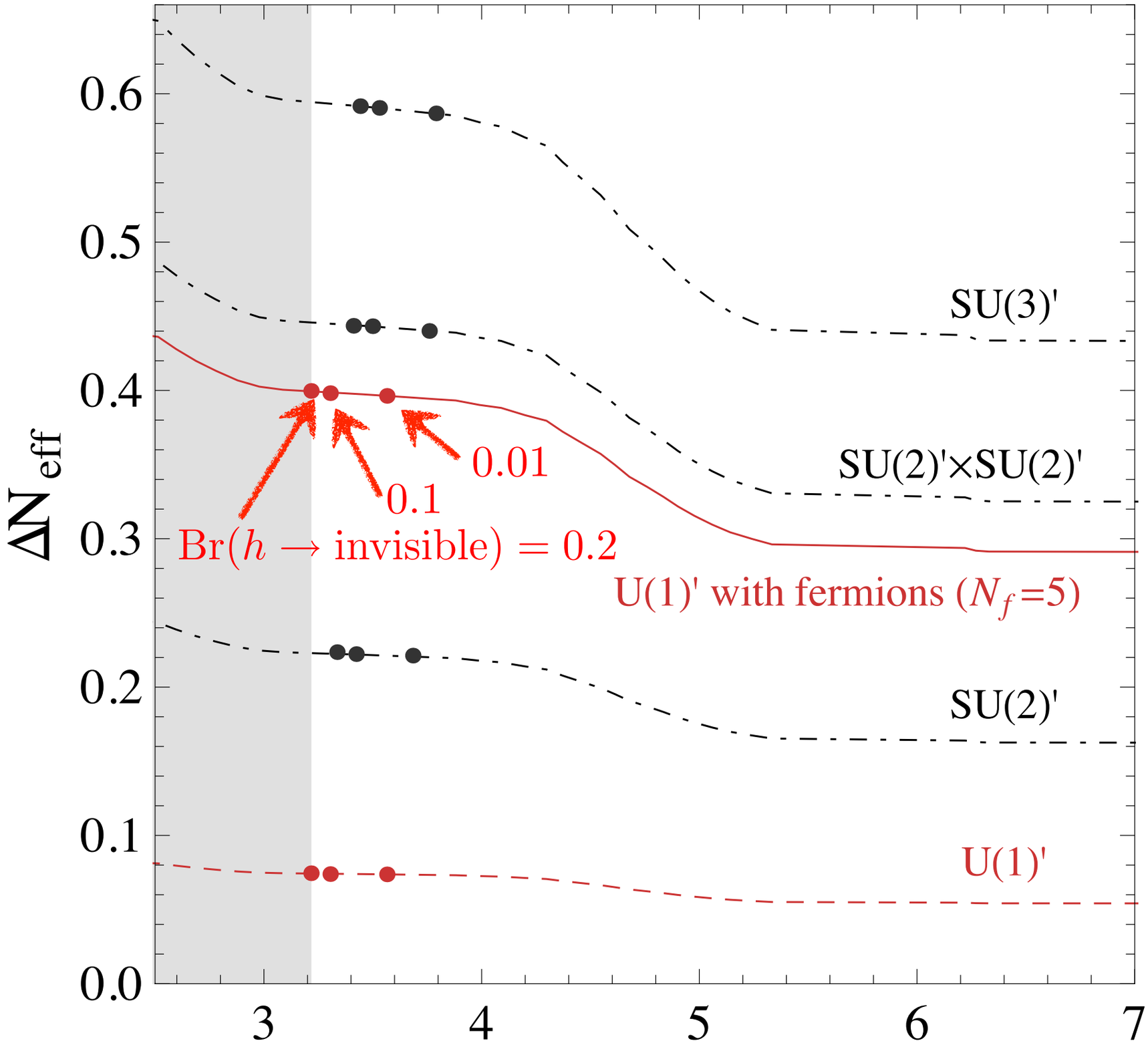
cf. Higgs decays into hidden sector after EW breaking.

$$\Lambda_\phi \sim \left(\frac{\lambda g'^2}{8\pi^2} \right)^{-1/2} m_\phi,$$

$$\mathcal{L}_{\rm eff} = \frac{1}{\Lambda_\phi^2} \frac{m_f}{m_h^2} F'_{\mu\nu} F'^{\mu\nu} \bar{f} f, \quad \text{for} \;\; T < m_h$$

f: SM quarks, leptons

The hidden sector is decoupled when the interaction rate becomes equal to the Hubble parameter.



$$\Lambda_\phi \sim \left(\frac{\lambda g'^2}{8\pi^2}\right)^{-1/2} m_\phi,$$

K-S. Jeong, FT 1305.6521

- When the hidden gauge group becomes strong at T = O(0.1)eV, the hidden gluons will form hidden glueballs, which become HDM.

- The thermal relic of the scalars may annihilate into Higgs due to the hidden strong interactions.

- Some parameter space can be searched by the invisible Higgs decay search at ILC.