Accelerating Expansion of the Universe by Porcupinefish spacetime

Yoshiyuki WATABIKI
watabiki@th.phys.titech.ac.jp
(in collaboration with Jan Ambjørn)

Talk @ KEK-PH22
held at KEK
on 30/11/2022

Conclusion

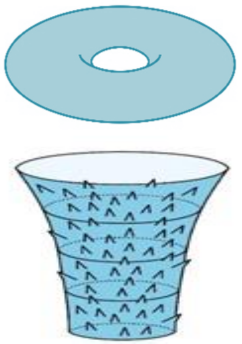
- The topology of universe is 3D torus.

  → The space has the flat curvature.

- Accelerating expansion of universe is caused by Porcupinefish spacetime.

  → No tensions in (H_0, BAO, $f_m \sigma_8$, S_8).
  (The late time observables are obtained from CMB.)

- No Dark Energy exists.



MENU

1. **Quantum Gravity based on $\mathcal{W}$ and $\mathcal{J}$ algebra**
   a. Definition of our Theory
   b. From the birth of universe to the Big Bang

2. **Modified Friedmann Equation**
   a. The derivation of Modified Friedmann equation
   b. The origin of accelerating expansion of Universe

3. **Tensions in Accelerating Expansion of Universe**
   a. The comparison with theories and observations from the viewpoint of cosmic tensions (H_0, BAO, $f_{\mathrm{m}}\sigma_8$, S_8)

4. **Conclusions**

1. Quantum Gravity based on *W* algebra and Jordan algebra

a. Definition of our Theory

- **Transfer Operator**

The partition fun. is derived by the expectation value of $\Theta^\star$.

Our model is described by the transfer operator $\Theta^\star$

$$\Theta^\star \stackrel{\text{def}}{=} \mathrm{e}^{W_{-2}^{(3)}} \qquad W_n^{(3)} \stackrel{\text{def}}{=} \frac{1}{3} \sum_{k+l+m=n} \mathrm{Tr} : \alpha_k \alpha_l \alpha_m :$$

$$\alpha_n \stackrel{\text{def}}{=} \sum_\mu E_\mu \, \alpha_n^\mu \qquad [\alpha_m^\mu, \alpha_n^\nu] = m \delta_{m+n,0} \delta^{\mu,\nu}$$

where E_μ is the 3×3 octonian Hermitian matrices.

(m, n are modes [$m, n \in \boldsymbol{Z}$], μ, ν are flavors [$\mu, \nu = 0, 1, \ldots, 26$].)

- **The emergence of time**

We shift α_n and introduce $\phi_n^\dagger$ and ϕ_n as

$$(\alpha_{-n})^\star = 3\lambda_3\delta_{n,3} + \lambda_1\delta_{n,1} + n\phi_n \qquad (\alpha_n)^\star = \phi_n^\dagger$$

$$3\lambda_3 = \frac{1}{2g} \qquad \lambda_1 = -\frac{\mu}{2g} \qquad (\alpha_0)^\star = 1$$

α_0 is commutative with all operators.

Physical vacuum $|\mathrm{vac}\rangle$ is a coherent state,

$$\phi_n|\mathrm{vac}\rangle = 0 \qquad [\phi_m, \phi_n^\dagger] = \delta_{m,n} \qquad [m, n \in \boldsymbol{N}]$$

Under the physical vacuum, the scale symmetry is broken!

$$\alpha_n \to (gT)^{-n/2}\alpha_n \ \text{ leads to } \ W_{-2}^{(3)} \to gT\, W_{-2}^{(3)}$$

⇨ T **appears in front of** $W_{-2}^{(3)}$
and starts to play the role of time.

b. From the birth of universes to Big Bang

- **Hamiltonian for the evolution of Universe**

$$H_W \stackrel{\text{def}}{=} -gW_{-2}^{(3)} = -\frac{g}{3}\sum_{k+l+m=-2} \mathrm{Tr} : \alpha_k \alpha_l \alpha_m :$$

$$\begin{cases} \alpha_n = \phi_n^\dagger \\ \alpha_0 = 1 \\ \alpha_{-n} = n\phi_n \\ \qquad +\frac{1}{2g}\delta_{n,3} \\ \qquad -\frac{\mu}{2g}\delta_{n,1} \end{cases}$$

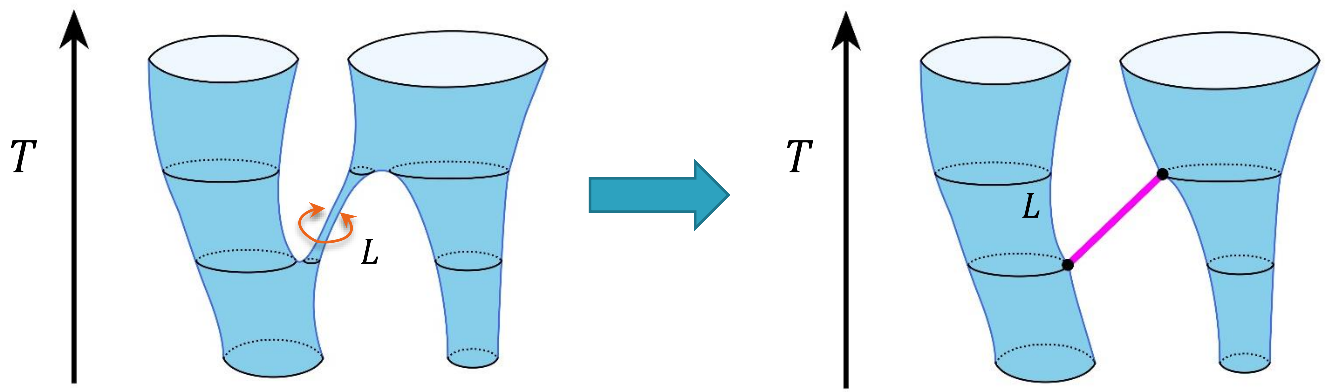
$$\left.\begin{aligned} &= -g\sum_{n=4}^{\infty}\sum_{k=1}^{n-3}\phi_k^\dagger \phi_{n-k-2}^\dagger n\phi_n \\ &\quad - g\sum_{n=4}^{\infty}\sum_{k=\max(3-n,1)}^{\infty}\phi_{n+k-2}^\dagger k\phi_k n\phi_n \end{aligned}\right\} \text{Knitting Mechanism}$$

$$\underbrace{-\sum_{n=1}^{\infty}\phi_{n+1}^\dagger n\phi_n + \mu\sum_{n=2}^{\infty}\phi_{n-1}^\dagger n\phi_n - 2g\sum_{n=3}^{\infty}\phi_{n-2}^\dagger n\phi_n}_{\text{Expansion of Universes}}$$

$$+\left(\mu\phi_1 - 2g\phi_2 - g\phi_1\phi_1\right) \underbrace{-\left(\frac{1}{4g}\phi_4^\dagger - \frac{\mu}{2g}\phi_2^\dagger + \phi_1^\dagger\right)}_{\text{Creation of Universes}} - \frac{\mu\mu}{4g}$$

Tr is omitted.

- **Knitting mechanism (Dimension Enhancement)**

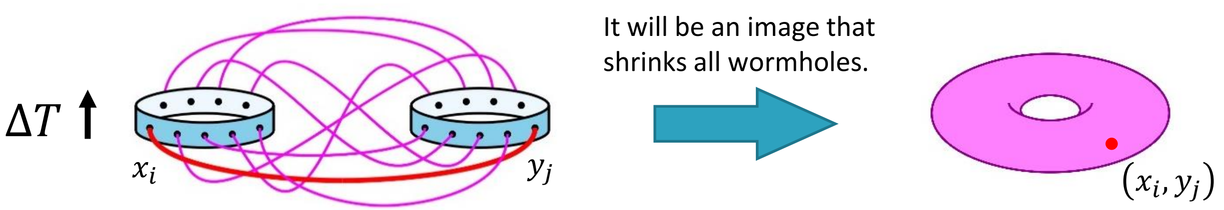


(A wormhole with small L is shown by purple line.)

High−dimensional space is formed after the birth of space.

Contributions by tiny wormholes are dominant. $G(L, L; T) \sim \dfrac{1}{\sqrt{4\pi LT}}$

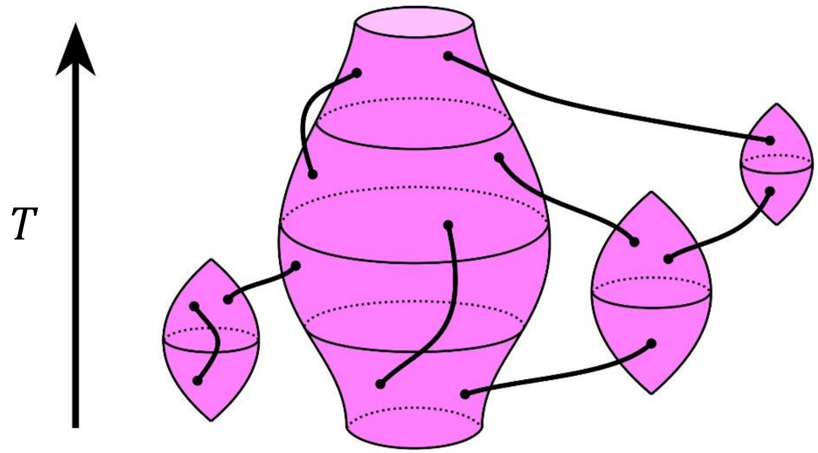
$[T \sim 0]$



(The set of tiny wormholes gives a torus topology.)

- **Coleman mechanism** **(Vanishing cosmo const.)**

Connection by wormholes with finite T gives vanishing the cosmological constant μ.



Vanishing the cosmological constant μ gives the Big Bang energy and denies the existence of dark energy.

2. Modified Friedmann Equation

a. The derivation of Modified Friedmann equation

- The classical Hamiltonian obtained from

$$-\sum \phi_{n+1}^{\dagger} n \phi_n + \mu \sum \phi_{n-1}^{\dagger} n \phi_n - 2g \sum \phi_{n-2}^{\dagger} n \phi_n$$

is

$$\mathcal{H}_c = -L\left(\Pi^2 - \mu + \frac{2g}{\Pi}\right) \qquad \{L\,,\Pi\} = 1$$

then, we have

$$\boxed{\left(\dot{L}/L\right)^2 = \frac{\kappa\rho}{3} + \frac{B}{\dot{L}/L}\,\frac{1+3F(x)}{(F(x))^2}}$$

μ is replaced by Matter Energy by Coleman mechanism.

$$4\mu \rightarrow \frac{\kappa\rho}{3}$$

$$(F(x))^2 - (F(x))^3 = x \qquad x \stackrel{\text{def}}{=} \frac{B}{\left(\dot{L}/L\right)^3} \qquad B \stackrel{\text{def}}{=} -8g$$

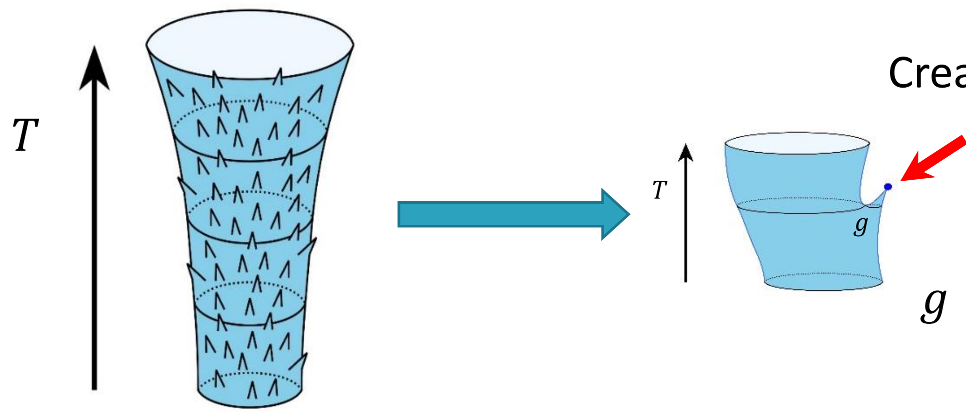
b. The origin of accelerating expansion of Universe

● The geometrical meaning of $-2g\alpha_0 \sum \phi^{\dagger}_{n-2} n \phi_n$

This term comes from the leading term of disk amplitude $F(L)$

$$F(L) = \delta(V) + \cdots \quad \Leftarrow \quad \tilde{F}(\xi) = \xi^{-1} + \cdots = \frac{1}{\xi + \sqrt{\mu}}$$

Negative g gives accelerating expansion of Universe.



Porcupinefish spacetime

Creation of baby universe

$F^{(\mathrm{baby})} = \delta(V)$

$$g = -\frac{B}{8} < 0$$

3. Tensions in Accel. Expansion of Univ.

- **Boundary Condition 1** (CDM is assumed)

Data from Planck satellite

$$t_0^{(\mathrm{CMB})} = 13.8 \times 10^9 \text{ [year]}$$

$$H_0^{(\mathrm{CMB})} = 67.3 \pm 0.6 \text{ [km/sec/Mpc]}$$

$$z_{\mathrm{LS}}^{(\mathrm{CMB})} = 1089.95$$

$$\frac{L_{\Lambda(\mathrm{CMB})}\left(t_0^{(\mathrm{CMB})}\right)}{L_{\Lambda(\mathrm{CMB})}\left(t_{\mathrm{LS}}^{(\mathrm{CMB})}\right)} = 1 + z_{\mathrm{LS}}^{(\mathrm{CMB})} \qquad H_{\Lambda(\mathrm{CMB})}\left(t_0^{(\mathrm{CMB})}\right) = H_0^{(\mathrm{CMB})}$$

$t_{\mathrm{LS}}^{(\mathrm{CMB})}$ and $\Lambda^{(\mathrm{CMB})}$ are determined.

- **Boundary Condition 2** (CDM is assumed)

Data from Standard candles

$H_0^{(\mathrm{SC})}$ = 73.0 $\pm$1.0 [km/sec/Mpc] ⟵ 5σ from Planck Satellite

(ArXiv:2112.04510)

We also use $t_{\mathrm{LS}}^{(\mathrm{CMB})}$ and $z_{\mathrm{LS}}^{(\mathrm{CMB})}$. ⟵ No difference between ΛCDM model and our model before $t_{\mathrm{LS}}^{(\mathrm{CMB})}$

$$\frac{L_{\Lambda^{(\mathrm{SC})}}\left(\boldsymbol{t}_{\boldsymbol{0}}^{(\mathrm{SC})}\right)}{L_{\Lambda^{(\mathrm{SC})}}\left(t_{\mathrm{LS}}^{(\mathrm{CMB})}\right)} = 1 + z_{\mathrm{LS}}^{(\mathrm{CMB})} \qquad H_{\Lambda^{(\mathrm{SC})}}\left(\boldsymbol{t}_{\boldsymbol{0}}^{(\mathrm{SC})}\right) = H_0^{(\mathrm{SC})}$$

$$\frac{L_{\boldsymbol{B}}\left(\boldsymbol{t}_{\boldsymbol{0}}^{(\mathrm{B})}\right)}{L_{\boldsymbol{B}}\left(t_{\mathrm{LS}}^{(\mathrm{CMB})}\right)} = 1 + z_{\mathrm{LS}}^{(\mathrm{CMB})} \qquad H_{\boldsymbol{B}}\left(\boldsymbol{t}_{\boldsymbol{0}}^{(\mathrm{B})}\right) = H_0^{(\mathrm{SC})}$$

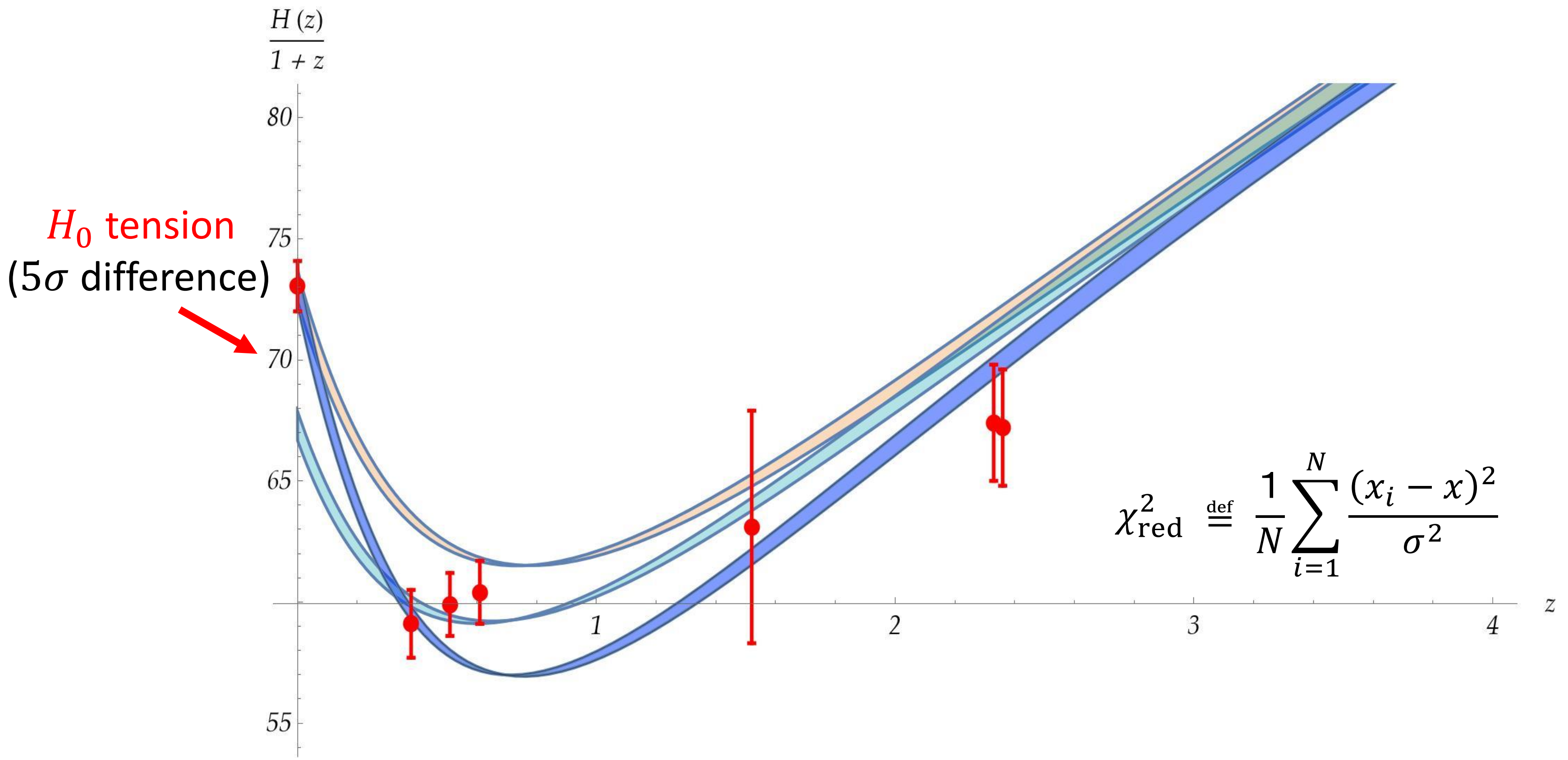
$t_0^{(\mathrm{SC})}$, $\Lambda^{(\mathrm{SC})}$, $t_0^{(\mathrm{B})}$, B are determined.

=13.3 =13.9

3- b

- $\dfrac{H(z)}{1+z}$

Blue is our model using Standard Candle data.
Orange is ΛCDM model using Standard Candle data.
Green is ΛCDM model by Planck satellite data only.



$$\chi_{\mathrm{red}}^{(\mathrm{B})2} = 1.3^2 \qquad \chi_{\mathrm{red}}^{(\mathrm{SC})2} = 1.9^2 \qquad \chi_{\mathrm{red}}^{(\mathrm{CMB})2} = 2.3^2$$

(⇒ Standard Candle data represents the accel. expansion well.)

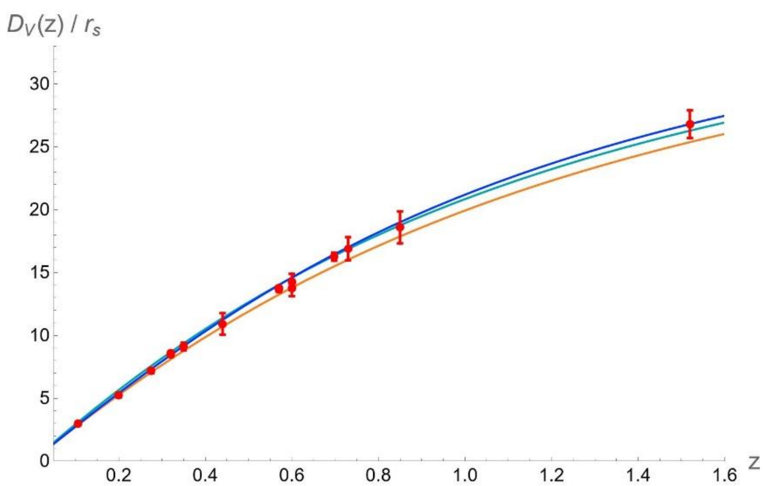
Blue is our model using Standard Candle data.
Orange is ΛCDM model using Standard Candle data.
Green is ΛCDM model by Planck satellite data only.

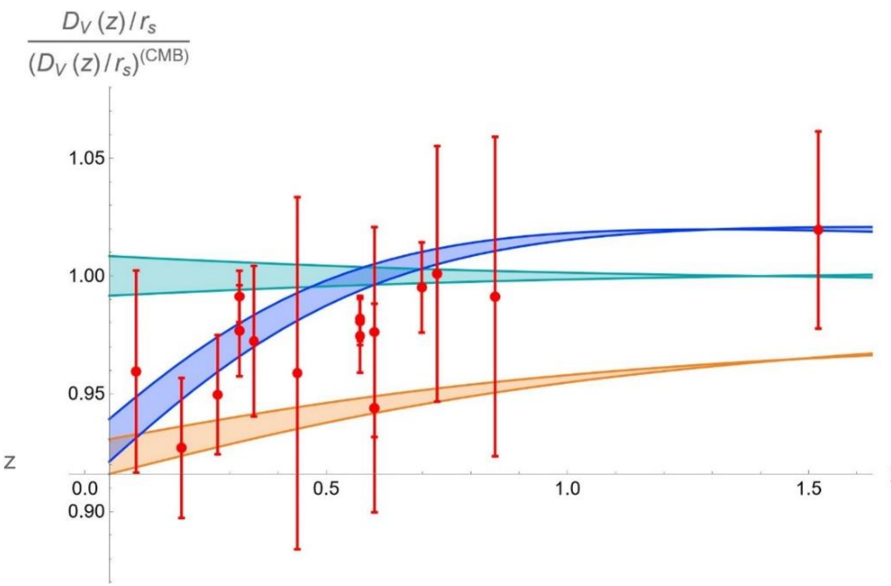
- $\dfrac{D_V(z)}{r_s}$ **(BAO)**

$$r_S^{(B)} \backsim r_S^{(SC)} \sim r_S^{(CMB)} = 147.05 \pm 0.30 \text{ [Mpc]}$$

Data from Planck satellite

r_s is the sound horizon at $z = z_{\mathrm{drag}}$





$$\chi_{\mathrm{red}}^{(B)2} = 1.0^2 \qquad \chi_{\mathrm{red}}^{(SC)2} = 2.1^2 \qquad \chi_{\mathrm{red}}^{(CMB)2} = 1.3^2$$

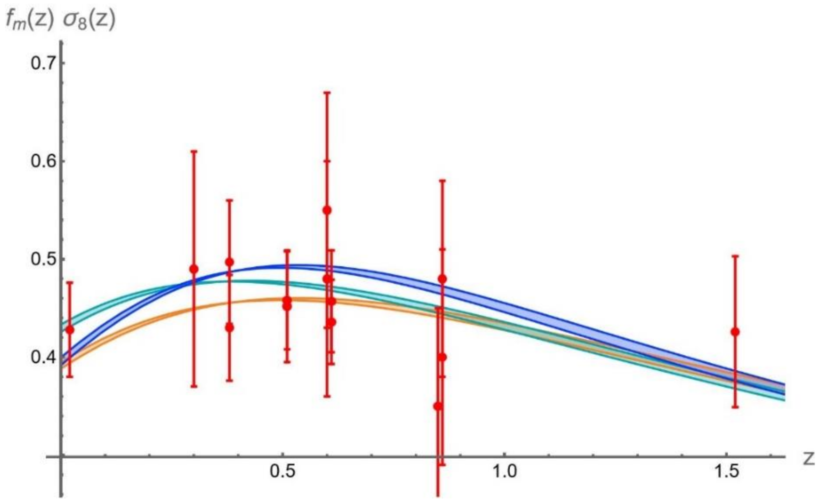
(⇒ BAO is related with the early stage of Universe.)

Blue is our model using Standard Candle data.
Orange is ΛCDM model using Standard Candle data.
Green is ΛCDM model by Planck satellite data only.

3- b

- $\boldsymbol{f_{\mathrm{m}}(z)\,\sigma_8(z)}$

$$\sigma_8^{(\mathrm{B})}(z_0) \sim \sigma_8^{(\mathrm{SC})}(z_0) \sim \sigma_8^{(\mathrm{CMB})}(z_0) = 0.8120 \pm 0.0073$$



Data from Planck satellite

(⇒ Error bars are large.)

$$\chi_{\mathrm{red}}^{(\mathrm{B})2} = 0.70^2 \qquad \chi_{\mathrm{red}}^{(\mathrm{SC})2} = 0.51^2 \qquad \chi_{\mathrm{red}}^{(\mathrm{CMB})2} = 0.54^2$$

- $\boldsymbol{S_8} \overset{\mathrm{def}}{=} S_8(0),\quad S_8(\mathrm{z}) \overset{\mathrm{def}}{=} \sigma_8(z)\sqrt{\Omega_{\mathrm{m}}(z)/0.3}$

S_8 tension

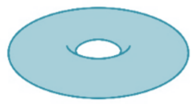
$$\chi_{\mathrm{red}}^{(\mathrm{B})2} = 0.75^2 \qquad \chi_{\mathrm{red}}^{(\mathrm{SC})2} = 0.75^2 \qquad \chi_{\mathrm{red}}^{(\mathrm{CMB})2} = 3.35^2$$

(⇒ S_8 looks related with the late stage of Universe.)

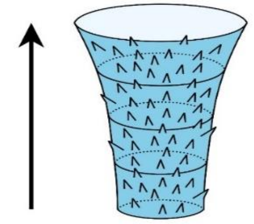
4. Conclusions

a. Emergence of space

- **High-dimensional space is formed by the direct product of several 1D loop spaces S^1.**
- **The topology of our universe is 3D torus. Therefore, the spacetime is flat.**



b. Identity of Dark energy



- **Accelerating expansion of Universe is caused by Porcupinefish spacetime.**
- **No tensions appear in (H_0, BAO, $f_m \sigma_8$, S_8).**
- **Dark energy does not exist.** (because of Coleman mechanism)

SUMMARY

The history of our universe.

- **From WAW (W-alg. world) to Big Bang**

The $\mathcal{W}$−algebra world (WAW) is described by the static picture or the picture using fictitious time.