Title: The Big Bang as a Mirror

Speakers: Latham Boyle

Collection/Series: Charting the Future Symposium

Subject: Cosmology, Particle Physics, Strong Gravity

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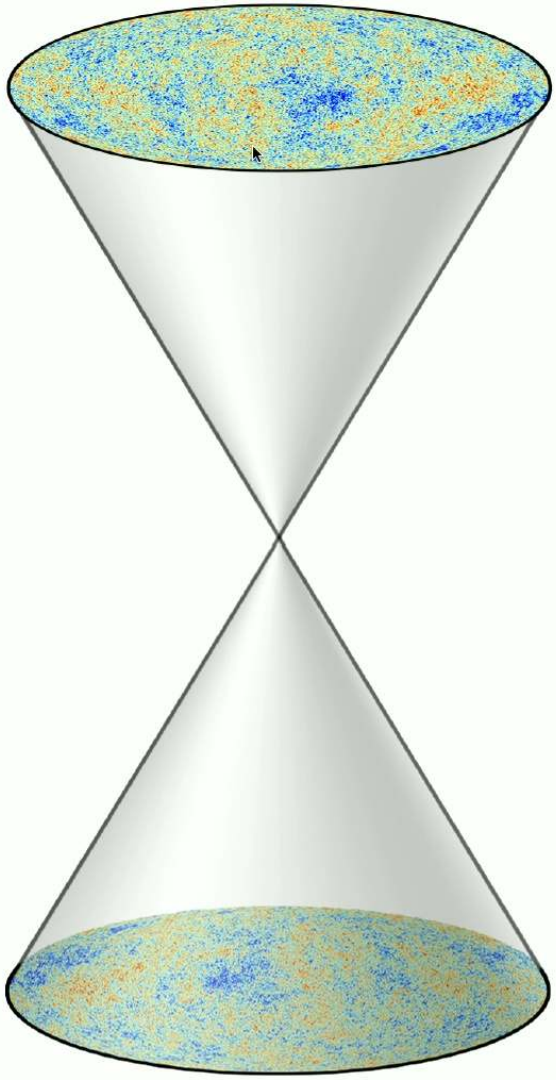


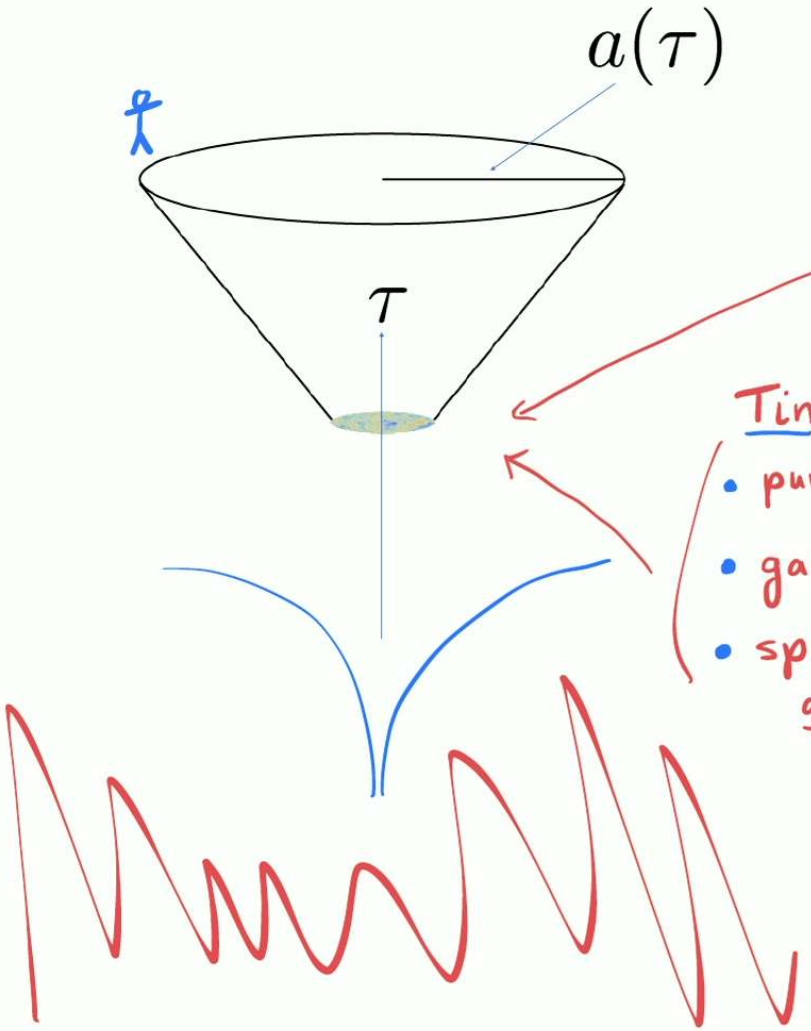
The Big Bang as a Mirror

(What is the Simplicity of the Early Universe Trying to Tell Us?)

Latham Boyle
(Higgs Centre, U. of Edinburgh)

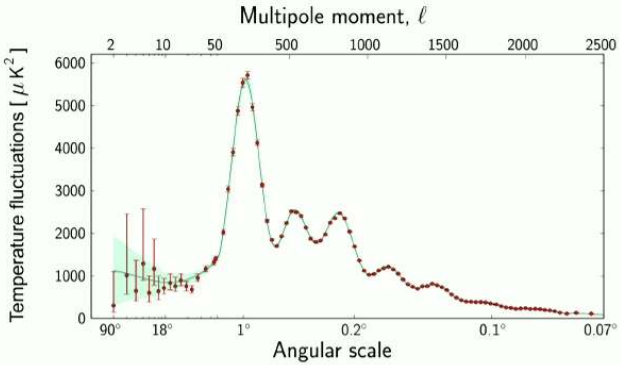
with Neil Turok

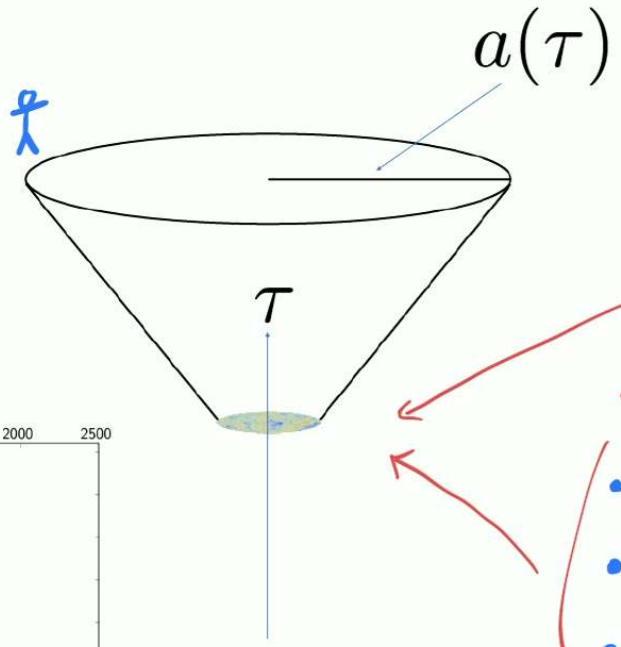
Charting the Future (PI 25th Anniversary)



Background:
- Homogeneous
- Isotropic
- Spatially Flat

Tiny (10^{-5}) random perturbations:
- purely "scalar" (no vorticity or gravitational waves)
- gaussian, nearly scale invariant
- special phases (synchronized as if Big Bang is a mirror!)





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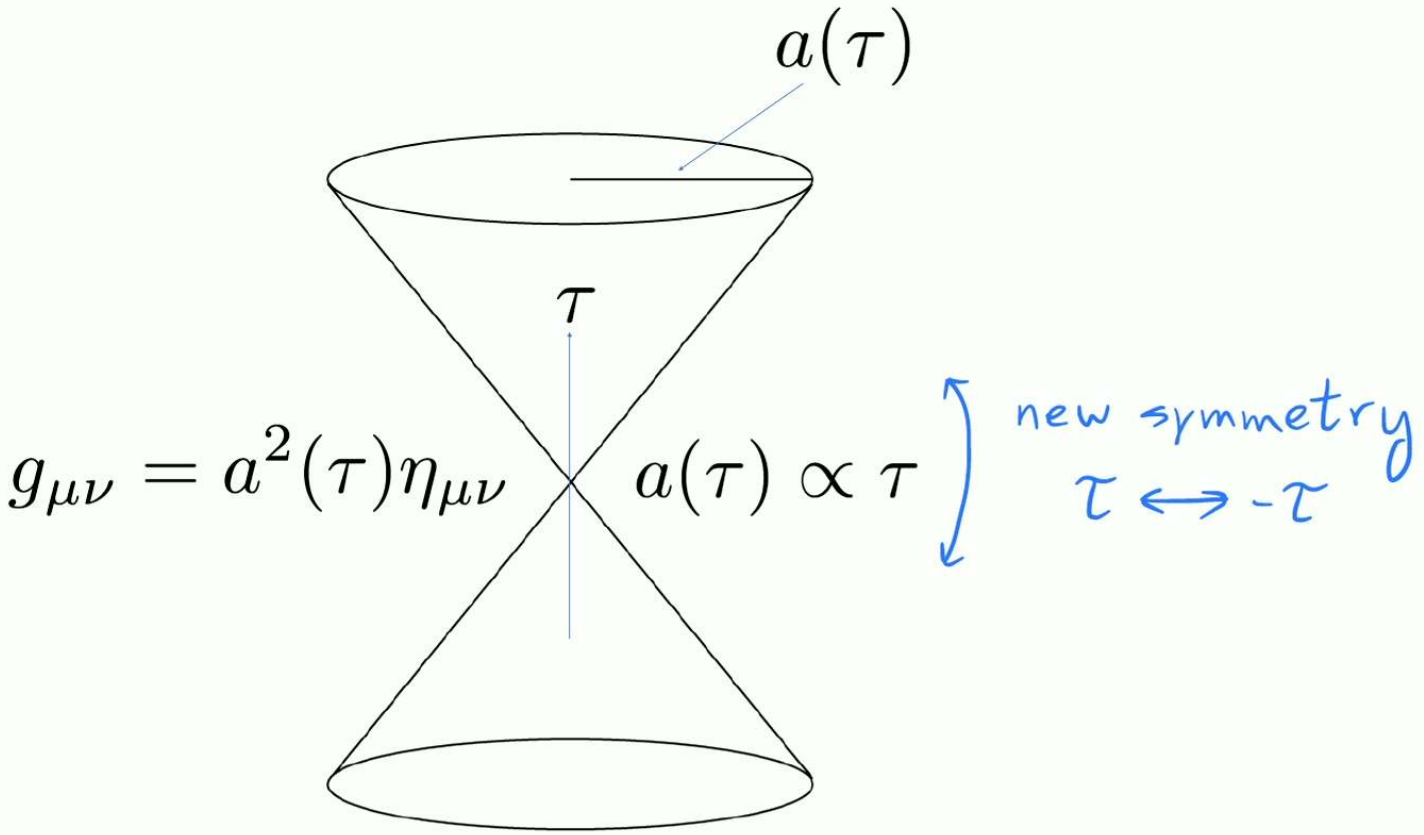
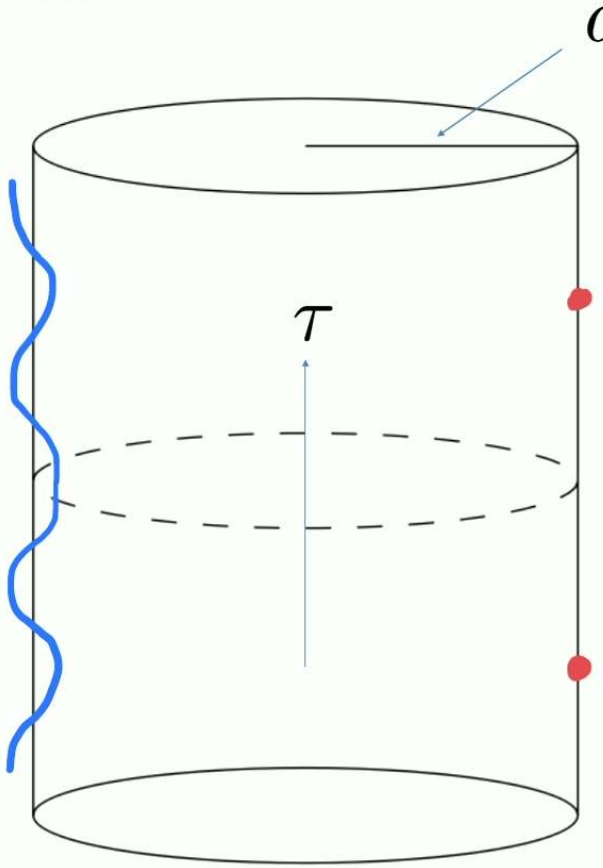

$a(\tau)$
τ
$g_{\mu\nu} = a^2(\tau)\eta_{\mu\nu}$
$a(\tau) \propto \tau$
new symmetry
$\tau \leftrightarrow -\tau$

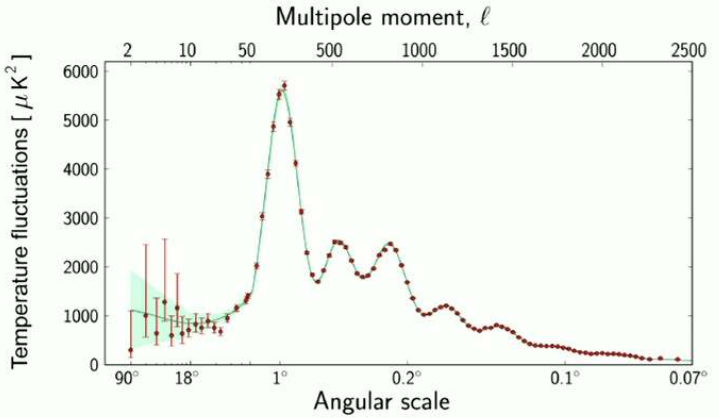
Primordial Perturbations



The Big Bang is a Mirror!

Explains:

1) "Ringing" CMB spectrum:

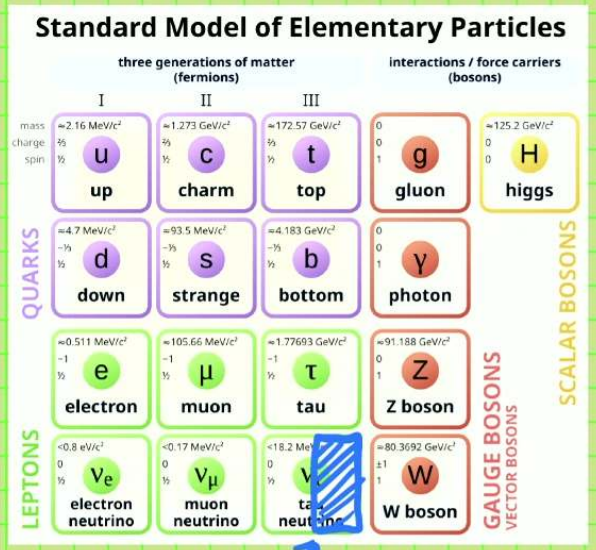


2) No primordial vorticity

3) No singular perturbations

(LB+N.Turok PRL 2018)

Dark Matter



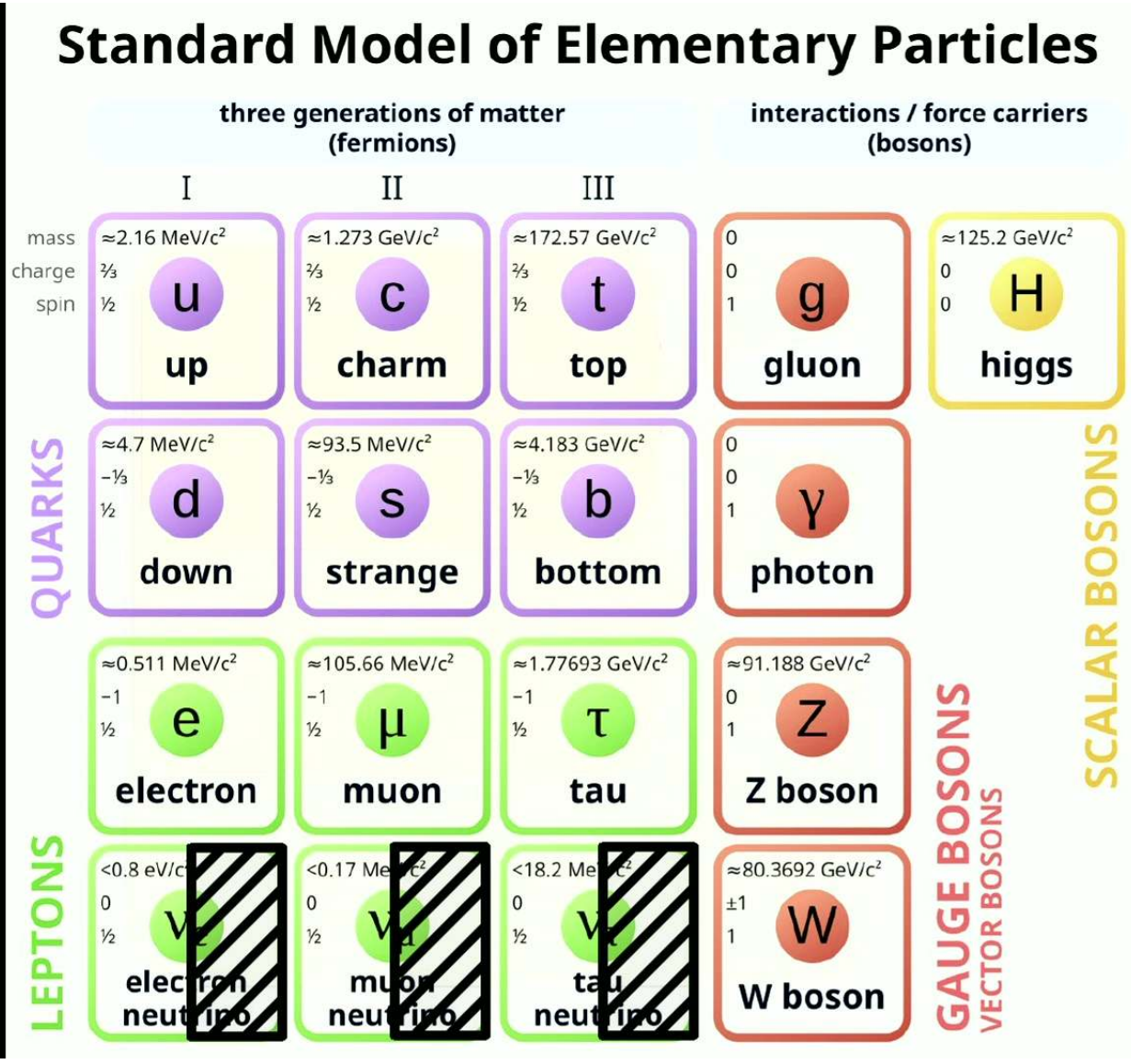
- Dark matter radiated from Big Bang
- Just like Hawking radiation from Black Hole

Predictions:

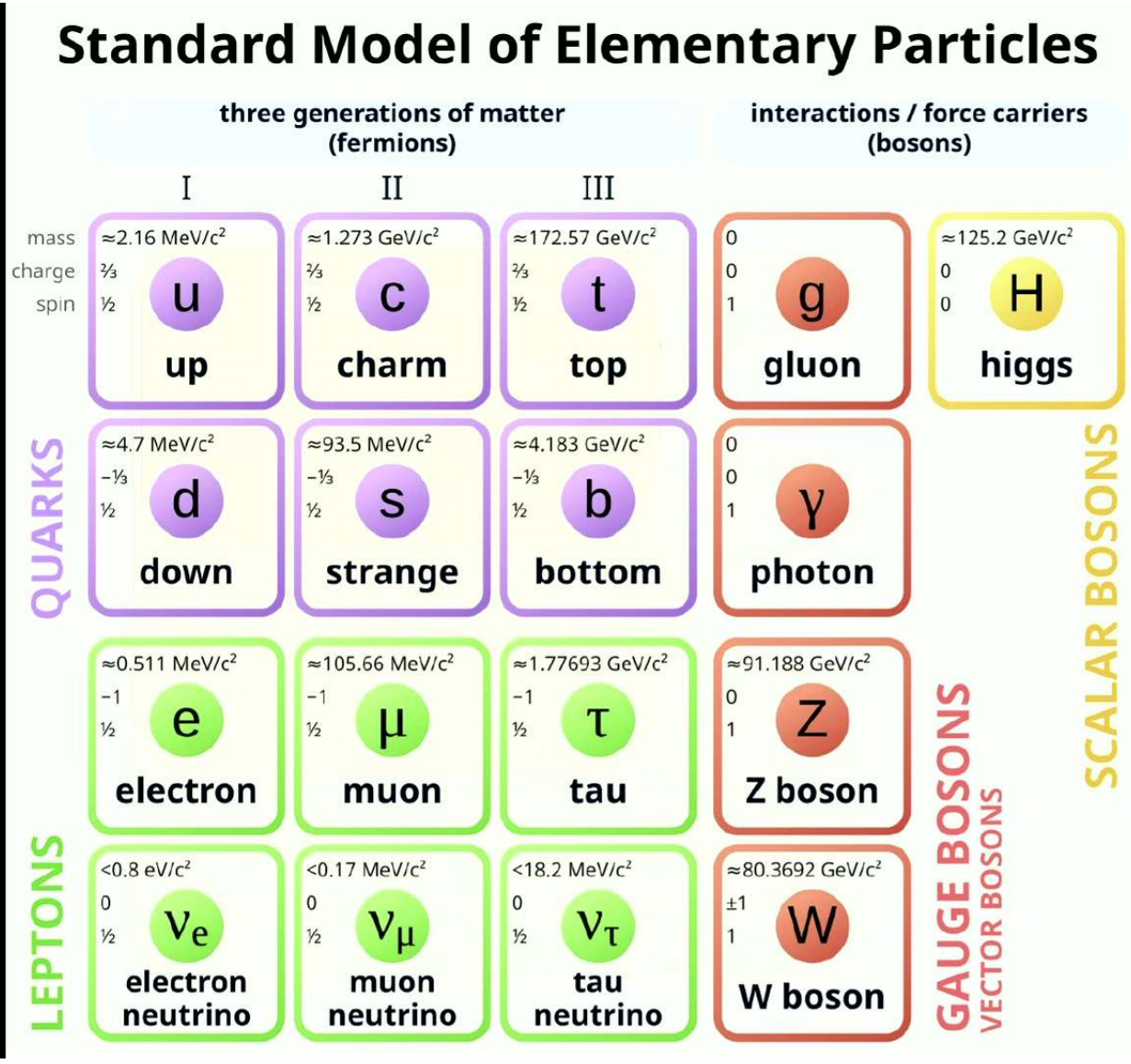
1) $m_{DM} = 4.8 \times 10^8$ GeV $\approx 5 \times 10^8 \, m_{proton}$
2) Dark matter is cold + adiabatic
3) lightest neutrino is massless
4) neutrinoless double beta decay rate (still a decade or two away)
5) no primordial gravitational waves (in contrast to inflation, tested by CMB polarization expts.)

(LB + N. Turok PRL 2018)

Standard Model of Elementary Particles



Standard Model of Elementary Particles



The gravitational entropy of the universe

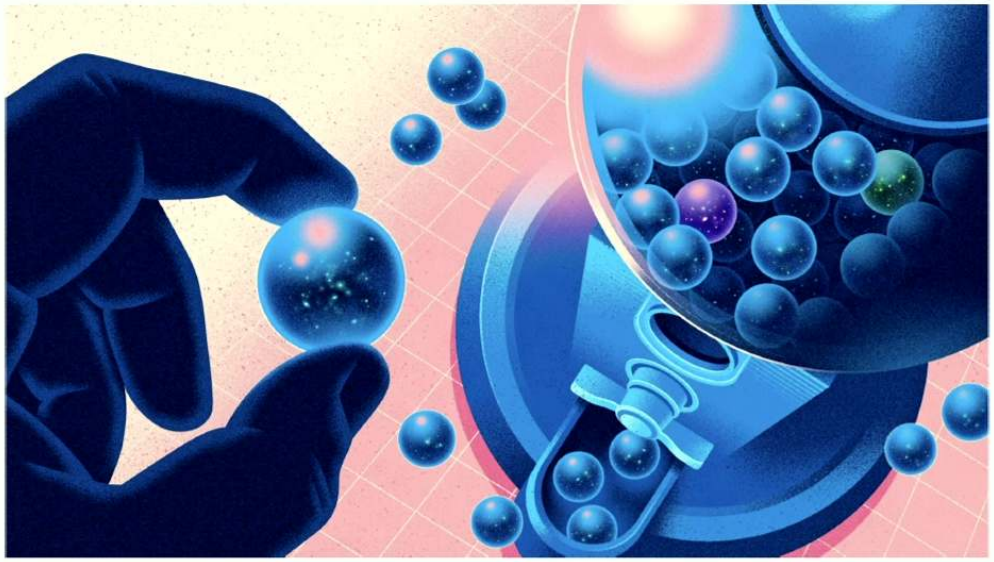


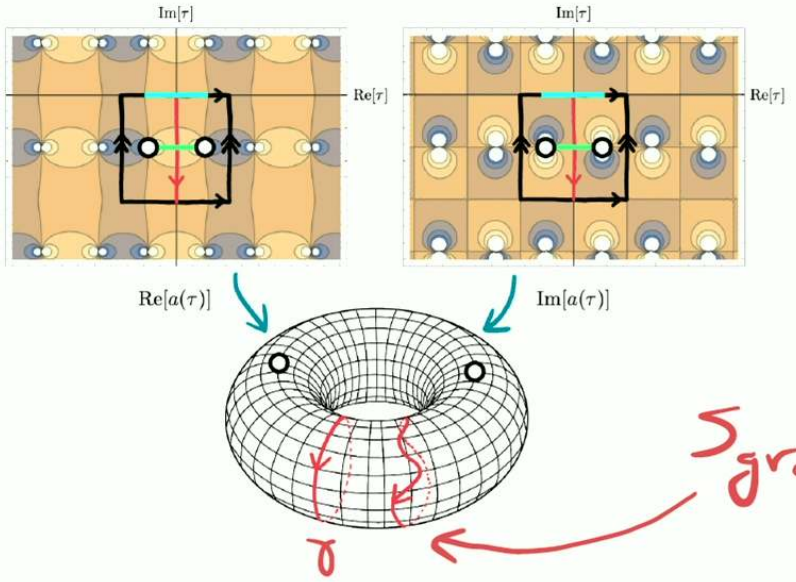
Image Credit: Quanta Magazine

Explains: cosmic flatness, homogeneity, isotropy, and tiny positive cosmological constant

(LB+N. Turok PLB 2024)

Step 1. Obtain general solution for the cosmic scale factor:

$$H^2 = \frac{8\pi G}{3}\left(\frac{r}{a^4} + \frac{\mu}{a^3} + \lambda\right) - \frac{\kappa}{a^2}$$



Step 2. Obtain general formula for the *gravitational* entropy of an FRW universe: $S_{grav}(r, u, \lambda, \kappa)$

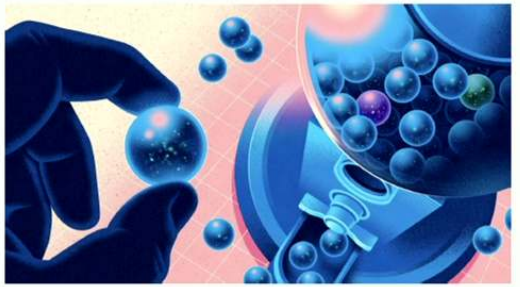
Flat universes and tiny positive Lambda are favoured!

Step 3. Add cosmological perturbations (small inhomogeneities and isotropies):

If the Big Bang is a mirror, these *cost* entropy!

Grav. entropy is largest for universes like ours: homogeneous, isotropic and flat (with tiny positive Lambda)!

A measure on the space of universes.



Primordial Power Spectrum (arXiv:2302.00344)

$$\mathcal{P}_{\mathcal{R}}(k) = \mathcal{P}_{\mathcal{R}}(k_{pl})(k/k_{pl})^{n_s-1}$$

$$\mathcal{P}_{\mathcal{R}}(k_{pl}) = \frac{3^2 5^3}{7(2\pi)^4}\frac{1}{\mathcal{N}_{eff}^2}\left(\frac{125}{108}\alpha_Y^2 - \frac{95}{72}\alpha_2^2 - \frac{49}{6}\alpha_3^2\right)^2$$

$$n_s - 1 \approx -\frac{7\alpha_3}{\pi}$$

$$\mathcal{P}_{\mathcal{R}}(k_*) = 12.9 \pm 4.5 \times 10^{-10} \quad (\text{Planck}: \ \mathcal{P}_{\mathcal{R}}(k_*) = 21 \times 10^{-10})$$

$$n_s = 0.958 \qquad (\text{Planck}: \ n_s = 0.9587 \pm 0.0056)$$