



Towards a Pre-geometric Quantum Gravity

Spacetime from Spontaneous Gauge Symmetry Breaking

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Quantum Gravity

“The Sanctum Graal” of Theoretical Physics



Quantum Mechanics

$$\phi, \quad \psi^a, \quad A_\mu^a$$

$$[\hat{a}, \hat{a}^\dagger] = \mathbb{I}$$

$$S = \mathbb{I} + iT$$

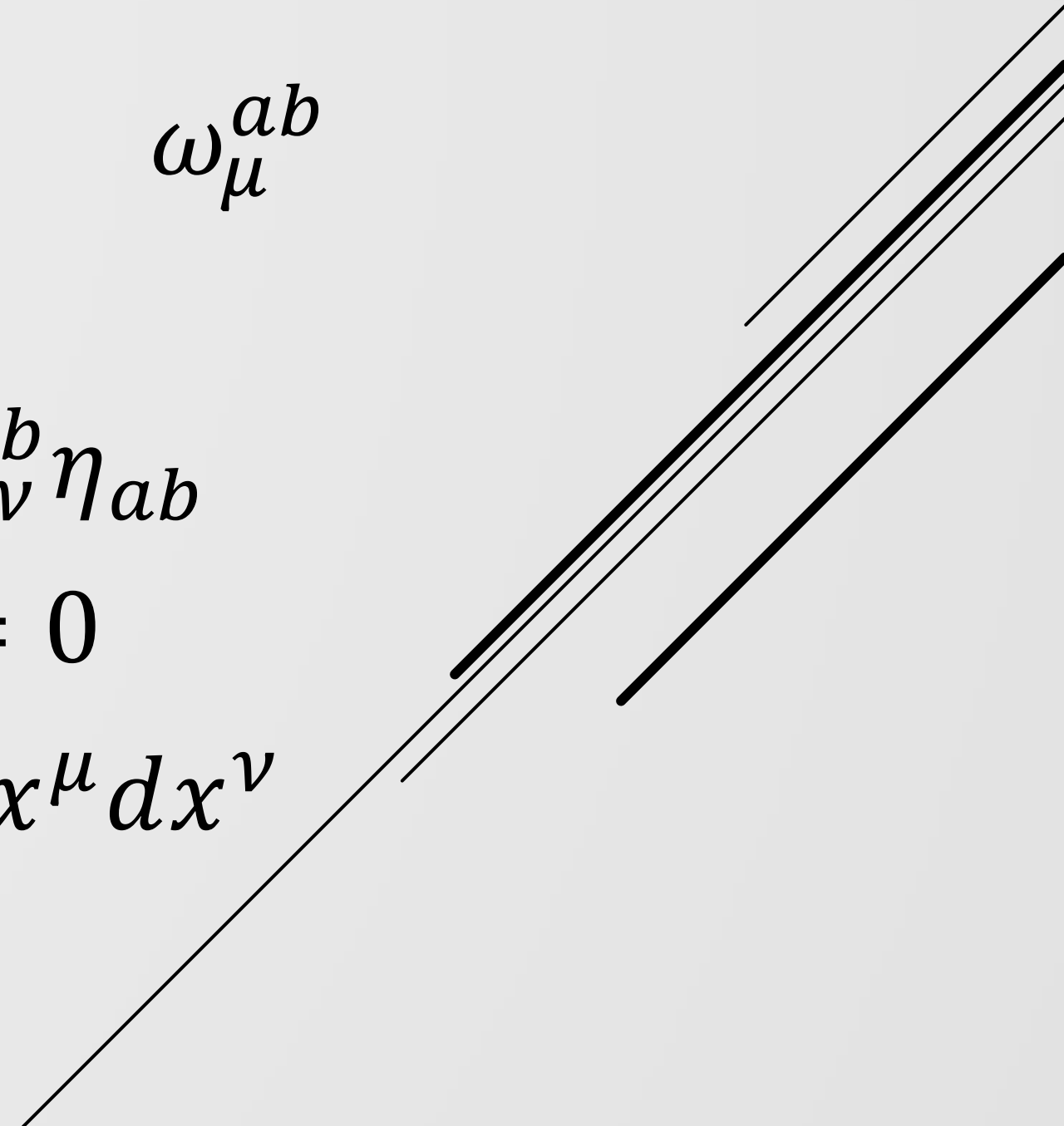
$$\frac{d}{dt} \langle \hat{O} \rangle = \frac{1}{i\hbar} \langle \hat{O}, \hat{H} \rangle + \left\langle \frac{\partial}{\partial t} \hat{O} \right\rangle$$

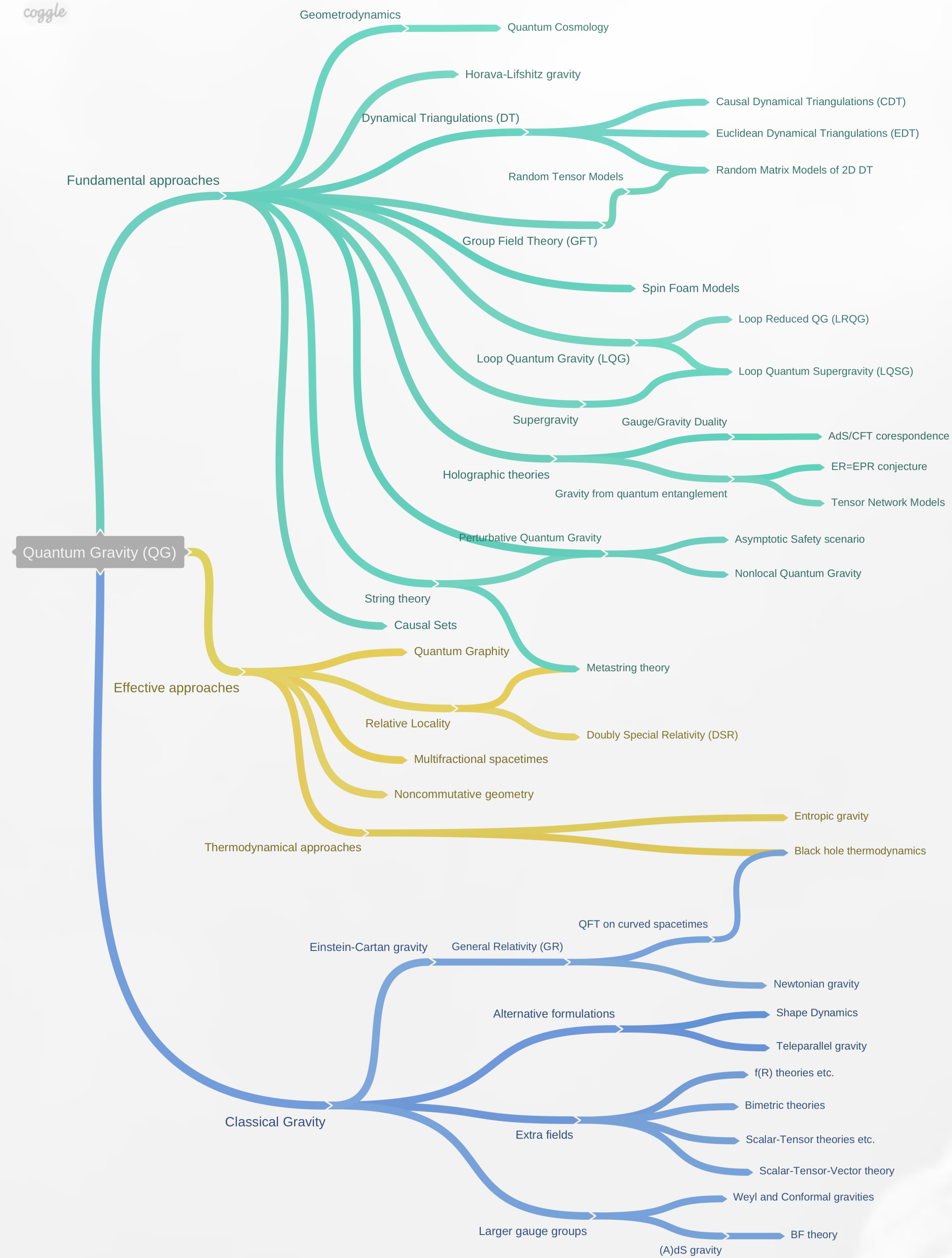
General Relativity

$$g_{\mu\nu}, \quad e_\mu^a, \quad \omega_\mu^{ab}$$

$$g_{\mu\nu} = e_\mu^a e_\nu^b \eta_{ab}$$

$$\nabla_\lambda g_{\mu\nu} = 0$$

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu$$
A series of parallel diagonal lines extending from the bottom right towards the top right, crossing the General Relativity section.



... See “Quantum gravity phenomenology at the dawn of the multi-messenger era—A review”, A. Addazi et al, European COST Action, Prog.Part.Nucl.Phys. 125 (2022) 103948 • e-Print: 2111.05659...

Classical gravity

$$\mathcal{L}_{\text{EH}} = \frac{M_P^2}{2} e e_a^\mu e_b^\nu R_{\mu\nu}^{ab}$$

$R_{\mu\nu}^{ab} = 2(\partial_{[\mu} \omega_{\nu]}^{ab} + \omega_{c[\mu}^a \omega_{\nu]}^{cb})$

$g_{\mu\nu} = e_\mu^a e_\nu^b \eta_{ab}$

$e \equiv \det e_\mu^a$

$$\mathcal{G} = R^2 - 4R_{\mu\nu}R^{\mu\nu} + R_{\mu\nu\rho\sigma}R^{\mu\nu\rho\sigma} = (e_a^\mu e_b^\nu e_c^\rho e_d^\sigma - 4e_a^\mu e_d^\nu e_c^\rho e_b^\sigma + e_c^\mu e_d^\nu e_a^\rho e_b^\sigma) R_{\mu\nu}^{ab} R_{\rho\sigma}^{cd}$$

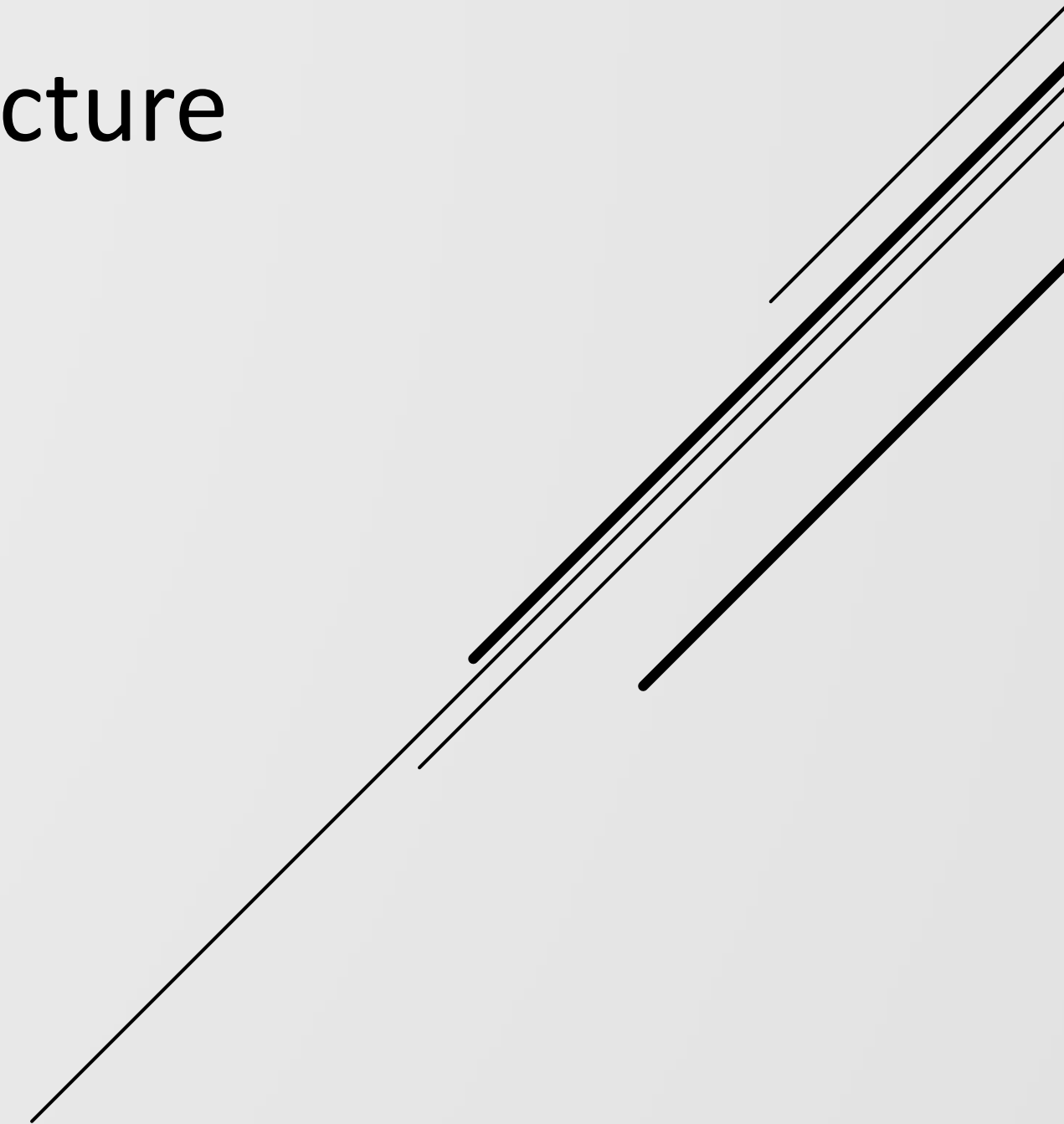
Quantum Mechanics

General Relativity

gauge theory

metric structure

spontaneous symmetry breaking



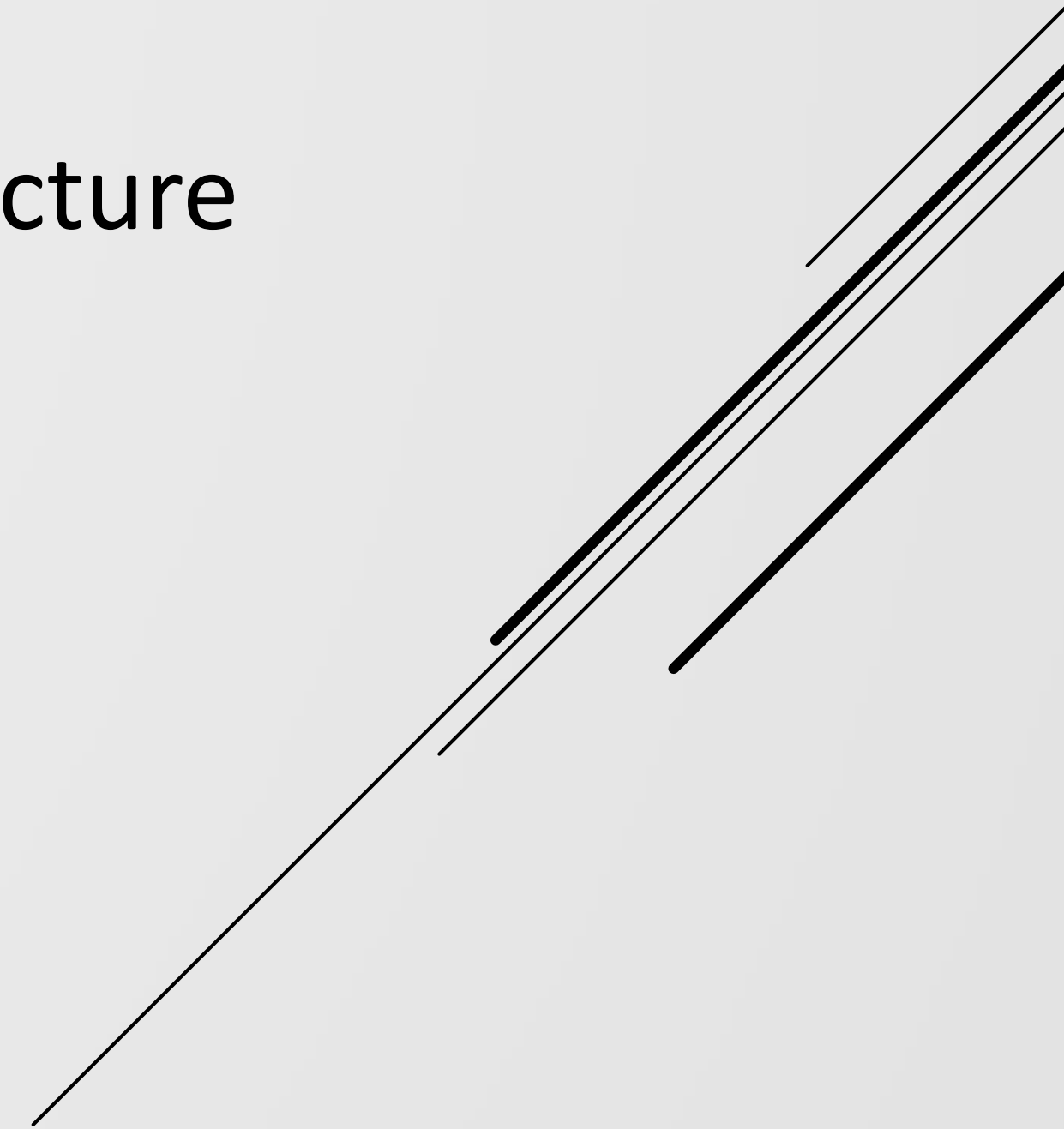
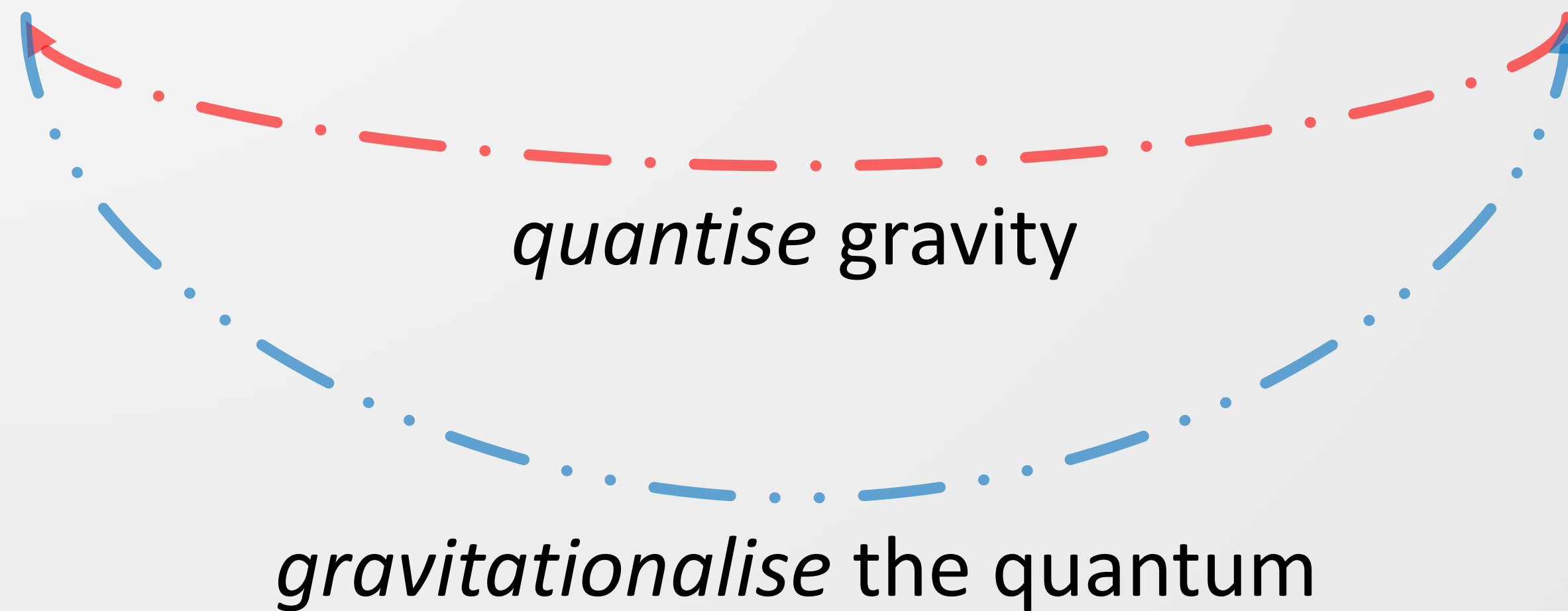
local Lorentz transformation $\Lambda_b^a(x)$

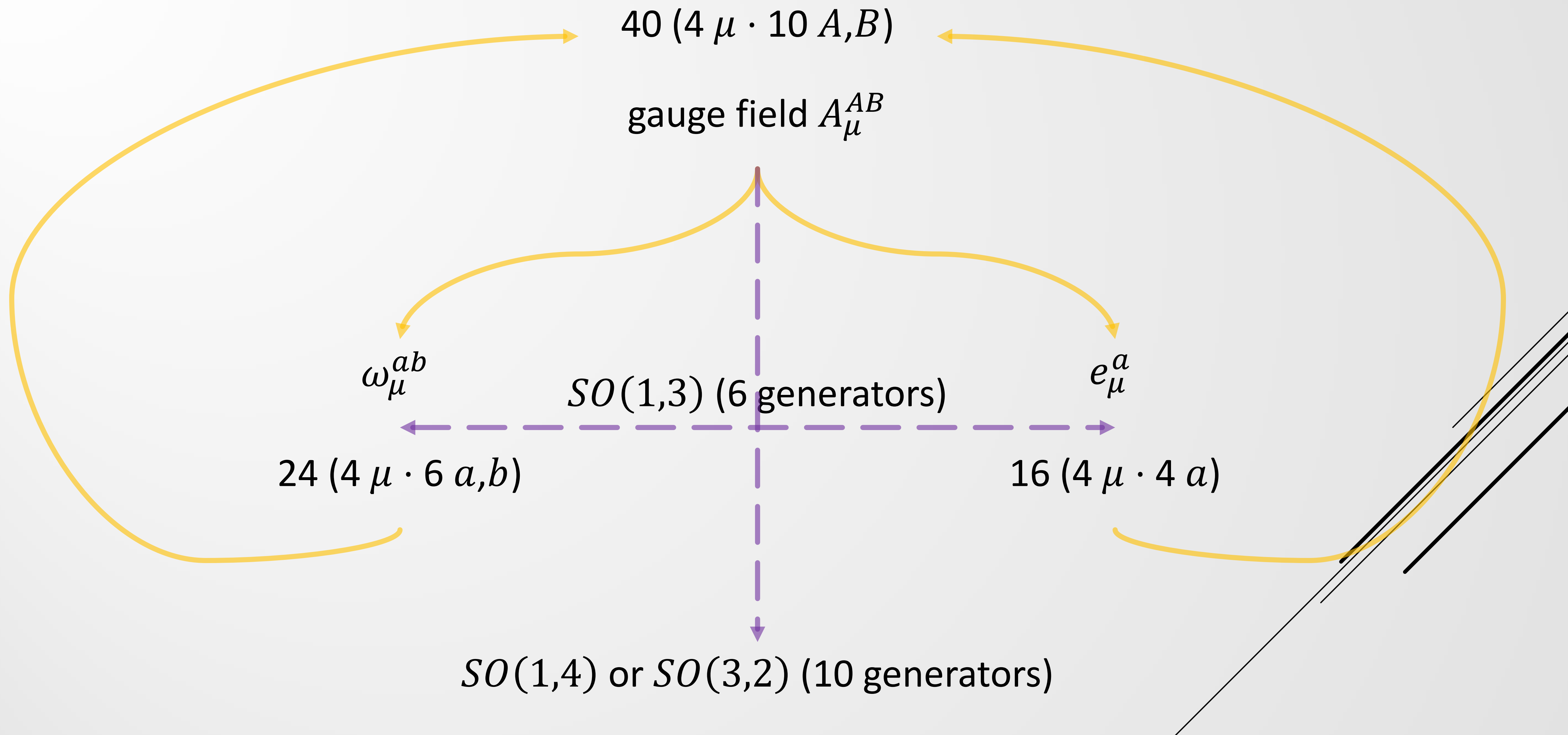
$$\omega_\mu^{ab} \rightarrow \Lambda_c^a \omega_\mu^{cd} (\Lambda^{-1})_d^b + \eta^{cd} \Lambda_c^a \partial_\mu (\Lambda^{-1})_d^b$$

$$e_\mu^a \rightarrow \Lambda_b^a e_\mu^b$$

gauge theory

metric structure





SSB

internal-space generalised
Minkowski metric η_{AB}

tangent-space
Minkowski metric η_{ab}

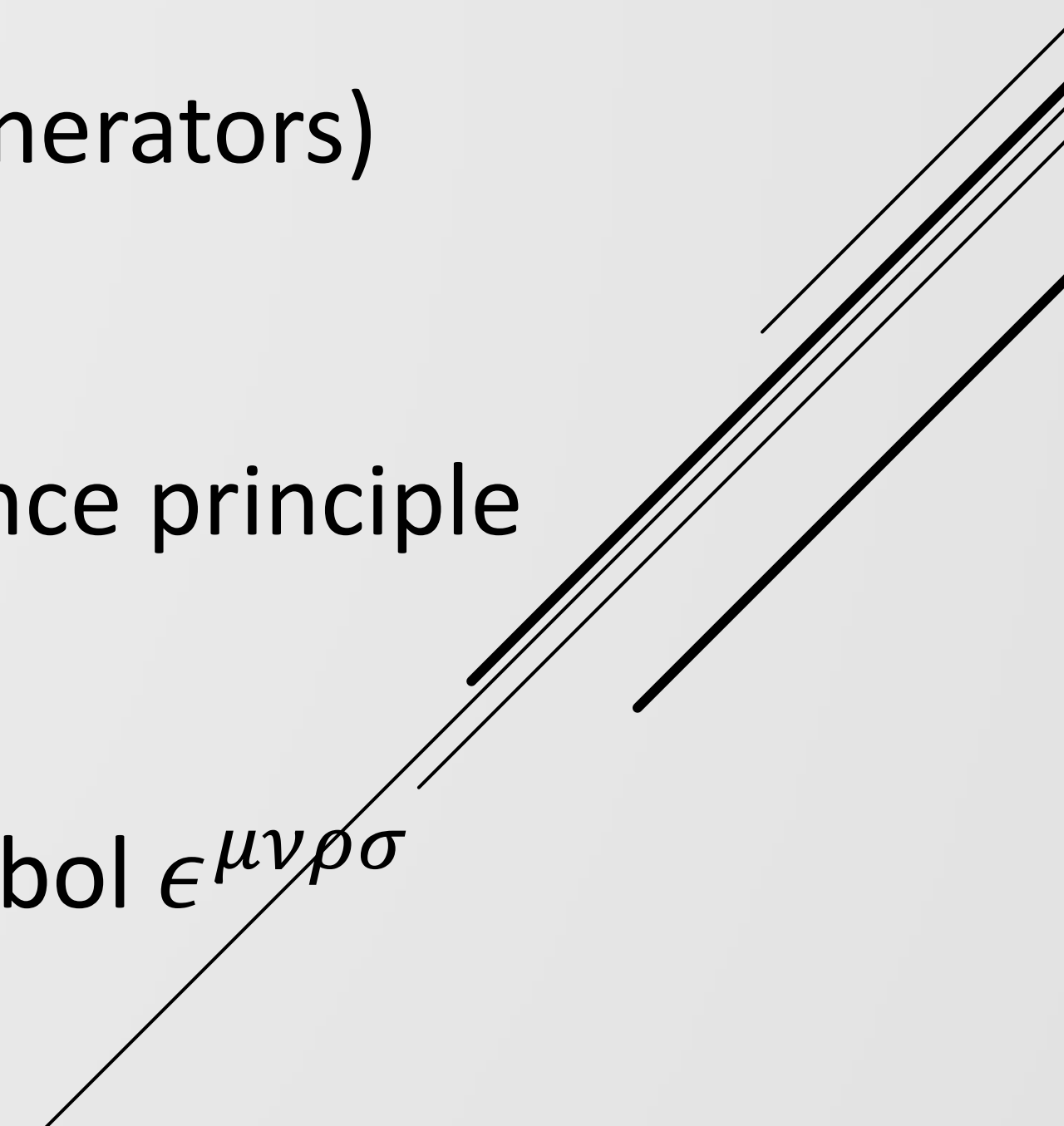
$SO(1,4)$ or $SO(3,2)$ (10 generators)

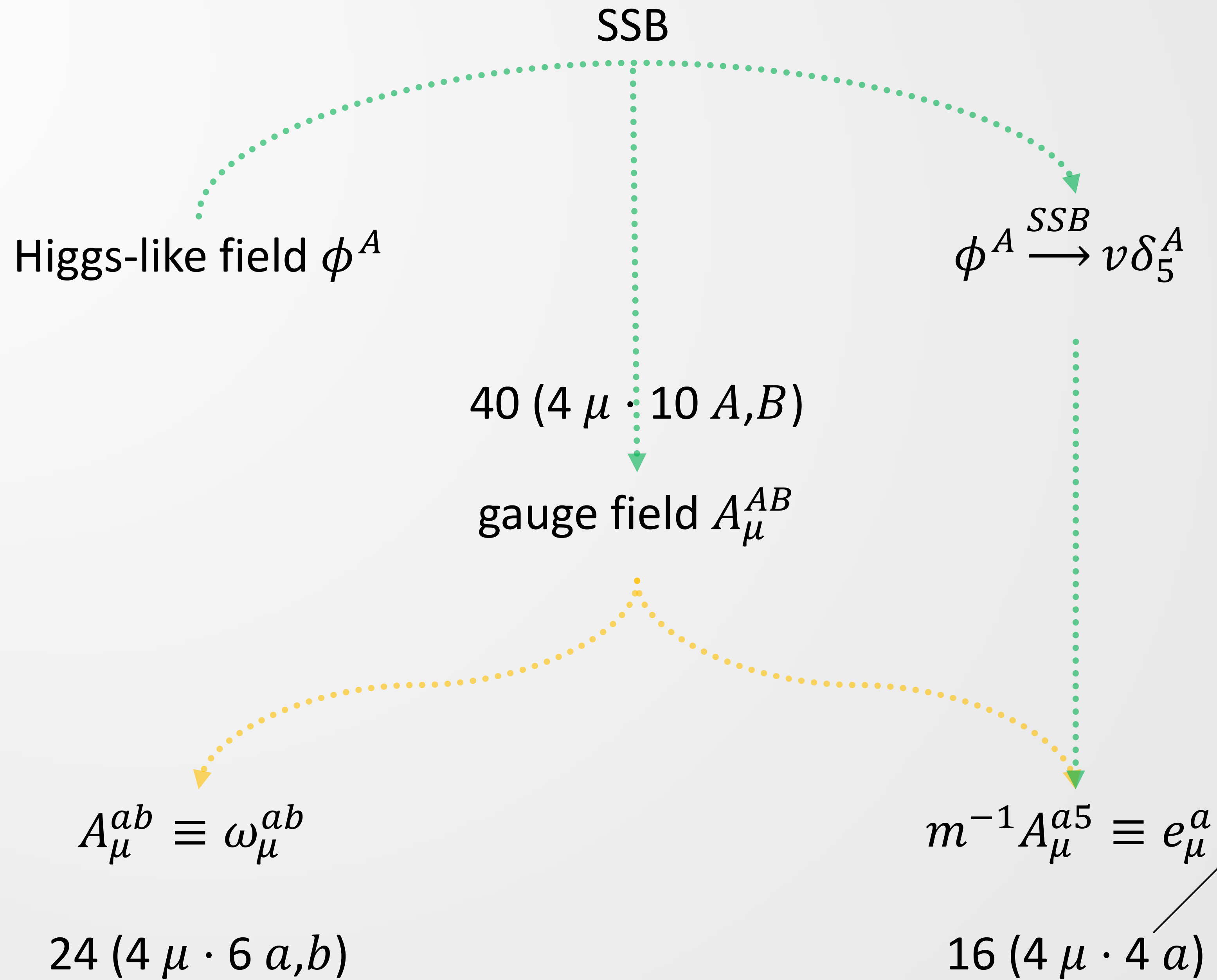
$SO(1,3)$ (6 generators)

Einstein equivalence principle

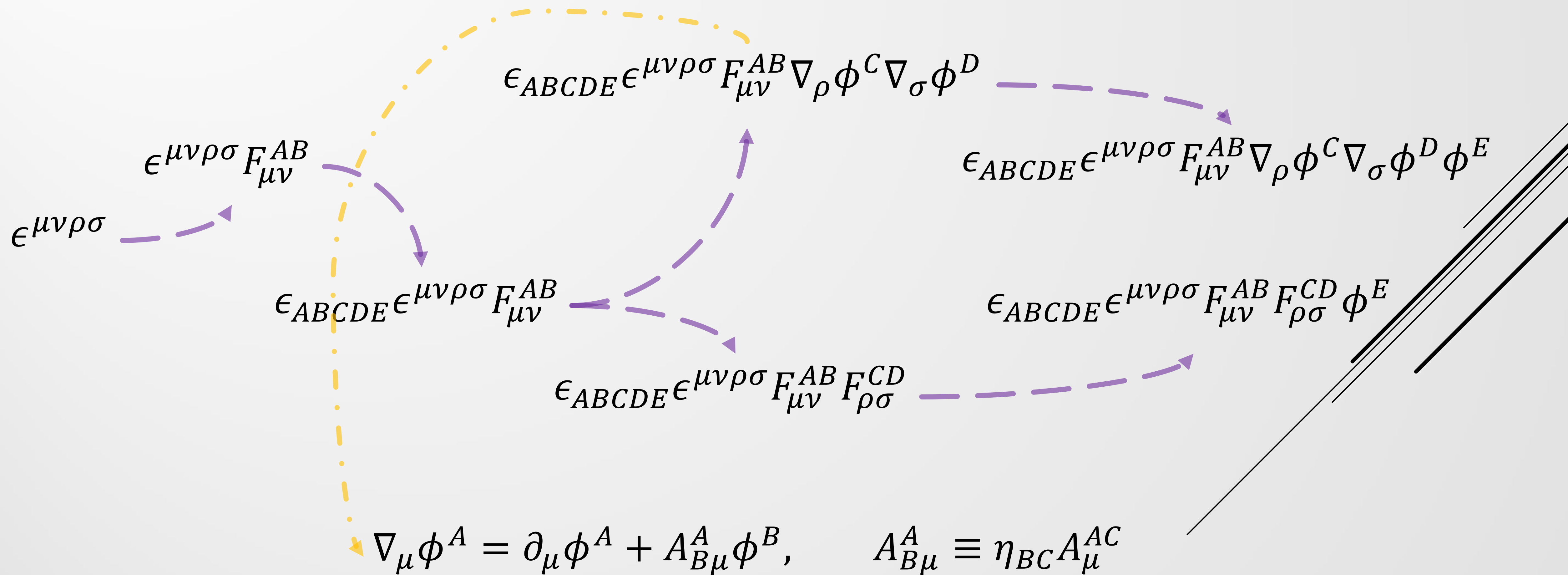
no metric structure ~~$g_{\mu\nu}$~~

Levi-Civita symbol $\epsilon^{\mu\nu\rho\sigma}$





Constructing the theory



Two possible Lagrangians

$$\mathcal{L}_W = k_W \epsilon_{ABCDE} \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu}^{AB} \nabla_\rho \phi^C \nabla_\sigma \phi^D \phi^E$$

$$\mathcal{L}_{MM} = k_{MM} \epsilon_{ABCDE} \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu}^{AB} F_{\rho\sigma}^{CD} \phi^E$$


 $\mathcal{L}_W \xrightarrow{SSB} \mathcal{L}_{EH} - M_P^2 \Lambda e$


 $\mathcal{L}_{MM} \xrightarrow{SSB} \mathcal{L}_{EH} - M_P^2 \Lambda e + \lambda e \mathcal{G}$

$$M_P^2 \equiv -8k_W v^3 m^2$$

$$\Lambda \equiv \pm 6m^2 = \mp \frac{3M_P^2}{4k_W v^3}$$

$$k_W \sim -1 [\phi]^{-3} \Rightarrow v \sim 10^{40} [\phi]$$

$$M_P^2 \equiv \pm 32k_{MM} v m^2$$

$$\Lambda \equiv \pm 3m^2 = \frac{3M_P^2}{32k_{MM} v}$$

$$\lambda \equiv -4k_{MM} v$$

$$k_{MM} \sim \pm 1 [\phi]^{-1} \Rightarrow v \sim 10^{119} [\phi]$$

Note: + or - for SO(1,4) or SO(2,3)

Spontaneous symmetry breaking

symmetry-breaking potential

unitary gauge

$$\mathcal{L}_{\text{SSB}} = -k_{\text{SSB}} v^{-4} |J| (\eta_{AB} \phi^A \phi^B \mp v^2)^2$$

$$\phi^A = v \delta_5^A$$

$$\phi^A \xrightarrow{\text{SSB}} (v + \rho) \delta_5^A$$

Pre-geometric form, after SSB will become the $\det(e)$

Hamiltonian formulation

conjugate momenta

$$\Pi_A = \frac{\delta(\mathcal{L}_W + \mathcal{L}_{SSB})}{\delta \dot{\phi}^A} = 2\epsilon_{ABCDE}\epsilon^{0ijk}\nabla_k\phi^D\phi^E \left[k_W F_{ij}^{BC} - \frac{2k_{SSB}}{v^4|J|} J \nabla_i\phi^B \nabla_j\phi^C (\eta_{FG}\phi^F\phi^G \mp v^2)^2 \right],$$

$$\Pi_{AB}^i = \frac{\delta(\cancel{\mathcal{L}_W + \mathcal{L}_{SSB}})}{\delta \dot{A}_i^{AB}} = 2k_W\epsilon_{ABCDE}\epsilon^{0ijk}\nabla_j\phi^C\nabla_k\phi^D\phi^E, \quad \Pi_{AB}^0 = \frac{\delta(\cancel{\mathcal{L}_W + \mathcal{L}_{SSB}})}{\delta \dot{A}_0^{AB}} = 0$$

Lagrangian density

$$\mathcal{L}_W + \mathcal{L}_{SSB} = \Pi_{AB}^i F_{0i}^{AB} + \Pi_A \nabla_0 \phi^A$$

Hamiltonian density

$$\mathcal{H}_W = \Pi_{AB}^i \dot{A}_i^{AB} + \Pi_A \dot{\phi}^A - \mathcal{L}_W - \mathcal{L}_{SSB} = \Pi_{AB}^i (\partial_i A_0^{AB} - 2A_{C[0}^A A_{i]}^{CB}) - \Pi_A A_{B0}^A \phi^B$$

Hamiltonian

$$H_W = - \int A_0^{AB} (\partial_i \Pi_{AB}^i + 2 \Pi_{BC}^i A_{Ai}^C + \eta_{BC} \Pi_A \phi^C) d^3x + \int \partial_i (\Pi_{AB}^i A_0^{AB}) d^3x$$



$$H_W \xrightarrow{SSB} \frac{M_P^2}{4} \epsilon_{abcd} \epsilon^{0ijk} \left\{ \int [\omega_0^{ab} \partial_i (e_j^c e_k^d) + 2 \omega_{e0}^a \omega_i^{eb} e_j^c e_k^d] d^3x \right. \\ \left. + \int [\mp 4m^2 e_0^a e_i^b e_j^c e_k^d + e_0^a e_i^b R_{jk}^{cd} - \partial_i (\omega_0^{ab} e_j^c e_k^d)] d^3x \right\}$$

$$\Pi_A \xrightarrow{SSB} \Pi_a = \pm 2k_W v^2 m \epsilon_{abcd} \epsilon^{0ijk} e_k^d (R_{ij}^{bc} \mp 2m^2 e_i^b e_j^c), \\ \Pi_{AB}^i \xrightarrow{SSB} \Pi_{ab}^i = 2k_W v^3 m^2 \epsilon_{abcd} \epsilon^{0ijk} e_j^c e_k^d, \quad \Pi_{AB}^0 \xrightarrow{SSB} 0$$

$$\Pi_{AB}^i \dot{A}_i^{AB} + \Pi_A \dot{\phi}^A = \Pi_{ab}^i \dot{A}_i^{ab} + 2m \Pi_{a5}^i \dot{A}_i^{a5} + \Pi_A \dot{\phi}^A$$

$$\xrightarrow{SSB} \Pi_{ab}^i \dot{\omega}_i^{ab} + \cancel{2m \Pi_{a5}^i \dot{e}_i^a} + \cancel{i \Pi_A \dot{\delta}_5^A}$$

$$\mathcal{L}_W \xrightarrow{SSB} \mathcal{L}_{EH} + \mathcal{L}_\Lambda$$

$$\mathcal{L}_{SSB} \xrightarrow{SSB} 0$$

$$\mathcal{H}_W \xrightarrow{SSB} \Pi_{ab}^i \dot{\omega}_i^{ab} - \mathcal{L}_{EH} - \mathcal{L}_\Lambda$$

ADM formalism

$$\mathcal{H}_{ADM} = \pi_{ab}^i \dot{\omega}_i^{ab} - \mathcal{L}_{EH} - \mathcal{L}_\Lambda$$

$$\Pi_{ab}^i = \pi_{ab}^i \Leftrightarrow \text{time gauge}$$

recovery of the canonical formulation of General Relativity after SSB

recovery of the canonical formulation of General Relativity after SSB

$$\begin{aligned}
 H_W &\xrightarrow{SSB} \frac{M_P^2}{4} \epsilon_{abcd} \epsilon^{0ijk} \left\{ \int \left[\omega_0^{ab} \partial_i (e_j^c e_k^d) + 2\omega_{e0}^a \omega_i^{eb} e_j^c e_k^d \right] d^3x \right. \\
 &\quad \left. + \int \left[\mp 4m^2 e_0^a e_i^b e_j^c e_k^d + e_0^a e_i^b R_{jk}^{cd} - \partial_i (\omega_0^{ab} e_j^c e_k^d) \right] d^3x \right\} \\
 &\quad \mathcal{H}_\Lambda = M_P^2 \Lambda e \qquad N\mathcal{H}_\perp + N^i \mathcal{H}_i \qquad \partial_i (\pi_{ab}^i \omega_0^{ab}) \\
 &\quad H_{\text{ADM}} = \int \left[N\mathcal{H}_\perp + N^i \mathcal{H}_i + \omega_0^{ab} \mathcal{J}_{ab} + \mathcal{H}_\Lambda + \partial_i (\pi_{ab}^i \omega_0^{ab}) \right] d^3x
 \end{aligned}$$

Loop Quantum Gravity and BF theories

$$\Pi_{A0}^i \xrightarrow{SSB} \Pi_{a0}^i = \frac{M_{\text{P}}^2}{4} \epsilon_{0abc} \epsilon^{0ijk} e_j^b e_k^c = \frac{M_{\text{P}}^2}{2} \tilde{E}_a^i = \frac{M_{\text{P}}^2}{2} \sqrt{h} E_a^i \text{ Ashtekar's "electric field"}$$

$$S_{\text{EH}} = \frac{M_{\text{P}}^2}{2} \int \text{tr}(B \wedge F) = \frac{M_{\text{P}}^2}{4} \int \epsilon_{abcd} e^c \wedge e^d \wedge R^{ab}$$

$$\Leftrightarrow B_{ab}^{(\text{EH})} = \frac{M_{\text{P}}^2}{4} \epsilon_{abcd} e^c \wedge e^d \text{ simplicity constraint}$$

$$H_{\text{W}} \xrightarrow{SSB} H_{\text{ADM}} \Leftrightarrow \text{time gauge}$$

$$S_{\text{W}} = \int \text{tr}(B \wedge F) = -2k_{\text{W}} \int \epsilon_{ABCDE} \nabla \phi^C \wedge \nabla \phi^D \phi^E \wedge F^{AB}$$

$$\Leftrightarrow B_{AB}^{(\text{W})} = -2k_{\text{W}} \epsilon_{ABCDE} \nabla \phi^C \wedge \nabla \phi^D \phi^E \xrightarrow{SSB} B_{ab}^{(\text{W})} = B_{ab}^{(\text{EH})}$$

Algebra of constraints

extended Hamiltonian density

$$\begin{aligned}\mathcal{H}_W^{ext} &= -A_0^{AB} \left(\partial_i \Pi_{AB}^i + 2\Pi_{BC}^i A_{Ai}^C + \eta_{BC} \Pi_A \phi^C \right) + \lambda^A Z_A + \lambda_i^{AB} Z_{AB}^i + \lambda_0^{AB} Z_{AB}^0 \\ &= \lambda^A Z_A + \lambda_i^{AB} Z_{AB}^i + \lambda_0^{AB} Z_{AB}^0 + \tilde{\lambda}_0^{AB} \dot{Z}_{AB}^0\end{aligned}$$

 A_0^{AB} is a *gauge* degree of freedom (λ_0^{AB} is undetermined)

constraint	first-class	second-class
primary	Z_{AB}^0	Z_A, Z_{AB}^i
secondary		$\dot{Z}_{AB}^0$

Degrees of freedom

► 90 dynamical variables: $10 A_0^{AB}$, $30 A_i^{AB}$, $5 \phi^A$, $10 \Pi_{AB}^0$, $30 \Pi_{AB}^i$ and $5 \Pi_A$

► 20 gauge choices: $-10 A_0^{AB}$ and $-10 \Pi_{AB}^0$

► 10 independent first-class constraints: $10 Z_{AB}^0$

► 44 independent second-class constraints: $30 Z_{AB}^i$, $5 Z_A$, $10 \dot{Z}_{AB}^0$ and $-1 H_W^{ext}$

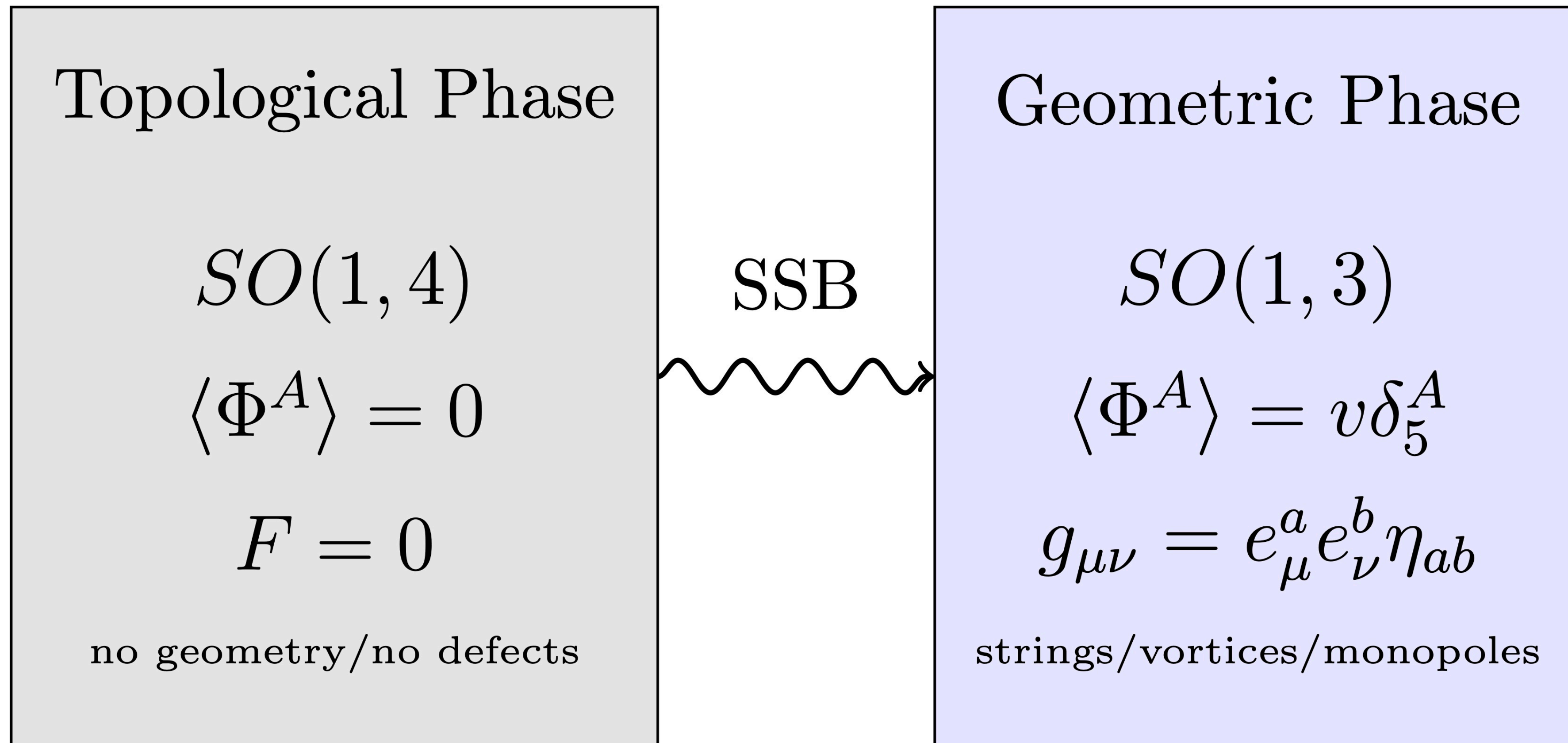
2#degrees of freedom

= #variables – 2#first class constraints – #second class constraints

$$= 90 - 20 - 20 - 44 = 6$$

3 degrees of freedom: $h_{\mu\nu}$ and ρ (like in scalar-tensor *metric* theories)

Main Idea of The Meta-Geometric Gravity Program



Phase Transitions and Metrogenesis: SSB from $SO(1, 4)$ to $SO(1, 3)$

Topological Quantization, Not Only A Gauge Phase Transitions but also a Topological Phase transitions *Berezinskii-Kosterlitz-Thouless, Haldane, Wu*

Part I: Conclusions and Remarks

I) We start from a 1+3 Topological Space-Time, without any background metric, not even Minkowski. Equipped only with Levi-Civita Symbol
— **Axi-Topological Manifold**.

In this sense, Space-time coordinates are just “labels” in Pre-geometric phase.

II) We consider **a Gauge-Higgs Theory $SO(1,4)$ — or $SO(2,3)$ —**
as Higher Dimensional Gauged Lorentz Group.

The Pre-geometric Gravitational Fields are Gauge Potentials and “Gravi-Higgs”

III) After SSB down to $SO(1,3)$ — gauged Lorentz Group. We obtain:

i) **emergent metric tensor** (emergent space distances and “clocks”)
and emergent Diffeomorphism Symmetries

In this sense, the **Graviton is not a Fundamental Field**

ii) **emergent Scales**: Planck Scales and Cosmological Constants are not fundamental, they are re-combination of fundamental couplings of the theory.

iii) Hamiltonian Analysis: **3 degrees of freedom!** After SSB 2 for gravitons, 1 for a massive scalaron field, the “Planckion”.

The background is a complex, layered composition. On the left, a large, semi-circular clock face is visible, with numbers 1 through 12. Inside this clock is a smaller clock face, which in turn contains an even smaller one. To the right of the clock is a globe showing clouds and a bright light source. The entire scene is overlaid with a dense network of white, glowing lines and dots, resembling a neural network or a complex data structure. The word "FRONTIERS" is written in a large, elegant, black serif font across the center of the image.

FRONTIERS

Implications in Cosmology

- **Big Bang Singularity Problem,**

NON-SINGULAR EMERGENT QUANTUM COSMOLOGY

A. Addazi et al CQG (2025), G. Meluccio PRD (2025),

A. Addazi et al PRD (2025)

A. Addazi et al in preparation (2026)

125 Mpc/h

- **New Scalar Higgs Field as Inflaton.**

Or Einstein-Cartan Hybrid Composite Inflation *A. Addazi, P. Chen, A. Marciano EPJC 2017*

Bounce or Cyclic Cosmology, CPT Mirror Universe? *See P. Chen talk —PRD 2026*

Ultra High Energy Phase Transitions

A. Addazi et al CQG (2025)

- **Topological Phase Transitions and Relic Defects:**

Gravitational Monopoles, Strings, Domain Walls, New Exotic Compact Objects

Rich Dark Matter Spectrum

A. Addazi et al in Preparation (2026)

- **Cosmological Constant: Topological Protection mechanisms, Naturalness, Relaxation and Dynamical Dark Energy, DESI data**

A. Addazi, G. Meluccio, S. Capozziello MDPI (2025)

A. Addazi, Y. Aldabergonov, Y. Cai et al (2026) on arXiv

See-Saw for CC and GB

$$\alpha_{\text{GB}} = -4Y_{\text{MM}}v = -\frac{3M_{\text{P}}^2}{8\Lambda}.$$

Prediction: GB coupling proportional to VEV
Inverse proportional to CC, proportional to dS Entropy!

$$|\alpha_{\text{GB}}| \sim S_{\text{dS}} \sim \frac{R_{\text{H}}^2}{L_{\text{P}}^2}, \quad |\alpha_{\text{GB}}| \sim \frac{1}{\alpha_G(\Lambda)}, \quad \alpha_G(\Lambda) = \frac{\Lambda}{M_{\text{P}}^2}.$$

Hints of Deep Relations of Information, Entropy and Topology

$$|\alpha_{\text{GB}}|\alpha_G(\Lambda) \sim 1 \rightarrow S_{\text{dS}} \sim |\alpha_{\text{GB}}| \sim \frac{1}{\alpha_G(\Lambda)} \sim N.$$

Analogy with Electric-Magnetic Dualities *Dirac, Keith-Olive, Seidberg-Witten, ...*

$$\theta = -cY_{\text{MM}}v \qquad \frac{1}{32\pi^2} \int_M e\mathcal{G} \, d^4x = \chi(M) \, ,$$

$$\Psi = \int \mathcal{D}A \mathcal{D}\phi e^{iS[A,\phi]}$$

$$\xrightarrow{SSB} \int \mathcal{D}g \mathcal{D}\omega e^{iS_{\text{EH}}[g,\omega]} e^{32\pi^2 i\alpha_{\text{GB}}\chi(M)} \, ,$$

$$\theta \rightarrow \theta + 2\pi k \quad \Rightarrow \quad e^{i\theta\chi(M)} \rightarrow e^{i\theta\chi(M)+2\pi i k\chi(M)} = e^{i\theta\chi(M)}$$

$$\begin{aligned} V &= Y_{\text{SSB}}|J| \left[1 - \cos \left(cY_{\text{MM}}(|\phi| - v) \right) \right]^p \\ &= Y_{\text{SSB}}|J| \left[2 \sin^2 \left(\frac{c}{2} Y_{\text{MM}}(|\phi| - v) \right) \right]^p \, , \end{aligned}$$

**Large Transformation Group,
Theta-angle, CC quantization,
Infinite vacua in topological sectors,
Periodic Potential with Large Barriers
Similarities with the Axion**

$\Lambda_k / \Lambda_{\text{obs}}$

Pre-geometric phase

$$\Lambda_k \sim 1/k$$

1

2

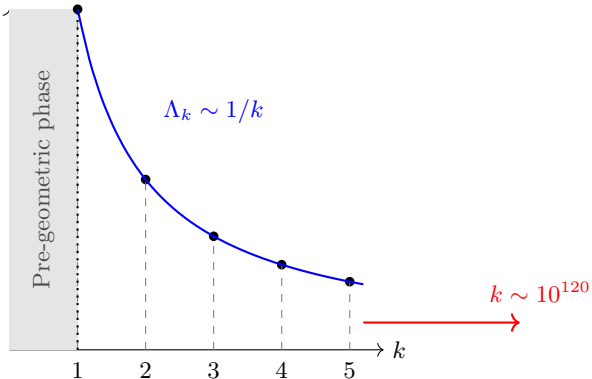
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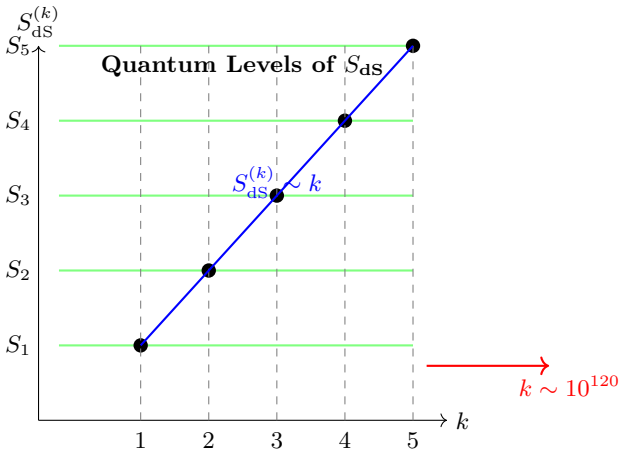
4

5

k

$$k \sim 10^{120}$$





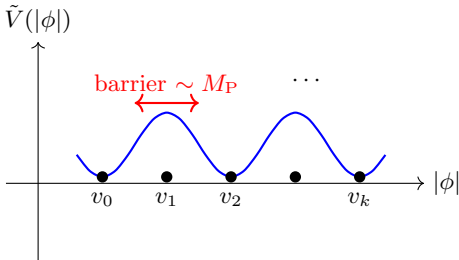


FIG. 2. The periodic Higgs potential $\tilde{V}(|\phi|) = V(|\phi|)/|J|$

$$\mathcal{L}_{f\text{MM}} = Jf(J^{-1}\mathcal{O}_{\text{MM}}), \quad \mathcal{L}_{f\text{W}} = Jf(J^{-1}\mathcal{O}_{\text{W}}),$$

where

$$J = \epsilon_{ABCDE}\epsilon^{\mu\nu\rho\sigma}\nabla_\mu\phi^A\nabla_\nu\phi^B\nabla_\rho\phi^C\nabla_\sigma\phi^D\phi^E.$$

$$J \xrightarrow{SSB} e, \quad \mathcal{L}_{f\text{MM}} \xrightarrow{SSB} ef(L), \quad \mathcal{L}_{f\text{W}} \xrightarrow{SSB} ef(R-2\lambda),$$

$$\theta = \frac{\alpha_{\text{GB}}}{32\pi^2} \longrightarrow \frac{b}{F} = \frac{\alpha_{\text{GB}}}{32\pi^2} e^{\sqrt{2/3}\varphi} = \frac{\alpha_{\text{GB}}}{32\pi^2} f',$$

**The Theta-angle becomes a Dynamical Field,
Gravi-Axion;**

**Adding Corrections Which Preserve
The Pre-geometric Volume Structure
and Covariance;**

DE becomes Dynamical!

Dualities with Horndeski and Galileons

$$\begin{aligned} \frac{\mathcal{L}}{\sqrt{-g}} = & \frac{1}{2}R - \frac{3}{4f'^2}\partial f'\partial f' - \frac{1}{2f'}\left(Z + 2\lambda - \frac{Z}{f'}\right) \\ & + \frac{\alpha_{\text{GB}}}{2}\left[f'\mathcal{G} + \frac{4}{f'}G^{\mu\nu}\partial_\mu f'\partial_\nu f' \right. \\ & \left. - \frac{3}{f'^2}\partial f'\partial f'\square f' + \frac{3}{f'^3}(\partial f'\partial f')^2\right]. \end{aligned}$$

Quadratic Corrections fit DESI with Bare GB-CC Relation!

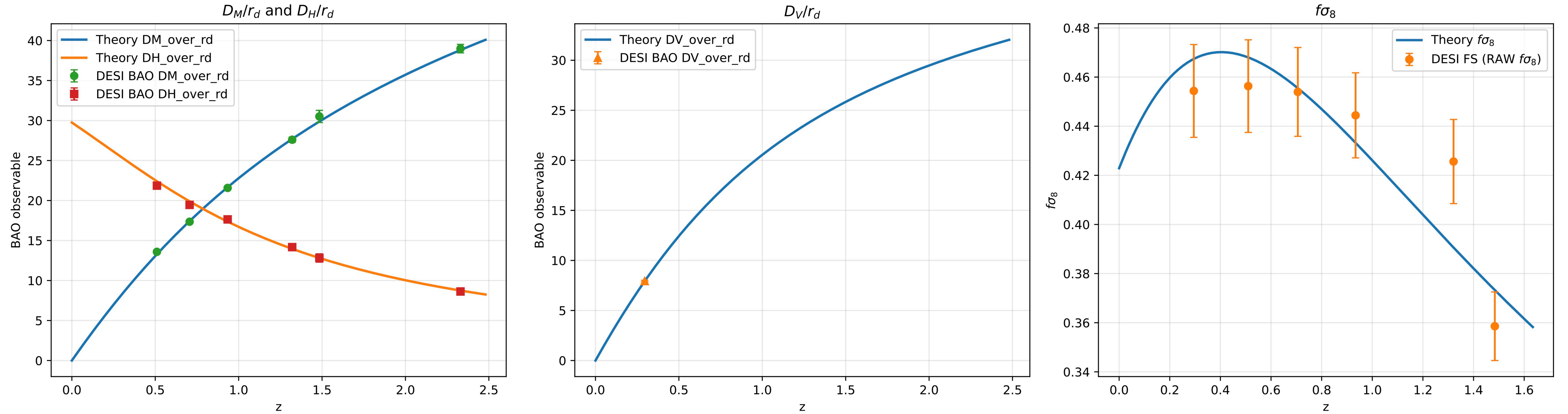


FIG. 1. Best-fit free- $\bar{\alpha}$ solution vs. DESI BAO+FS data. *Left:* anisotropic BAO observables D_M/r_d (comoving angular diameter distance) and D_H/r_d (Hubble distance). *Middle:* isotropic BAO observable D_V/r_d . *Right:* growth-rate data $f\sigma_8(z)$. Theory curves (solid lines) use the best-fit background with profiled amplitudes S and A . The fit describes both the expansion history and the structure growth simultaneously.

* $rd=147$ Mpc It is the physical scale (in megaparsecs, Mpc) that the baryon–photon acoustic oscillations could travel before the universe cooled enough for baryons to decouple from photons (the drag epoch).

** $f\sigma_8$ is a combined observable that measures the growth rate of cosmic structure, weighted by the amplitude of matter fluctuations.

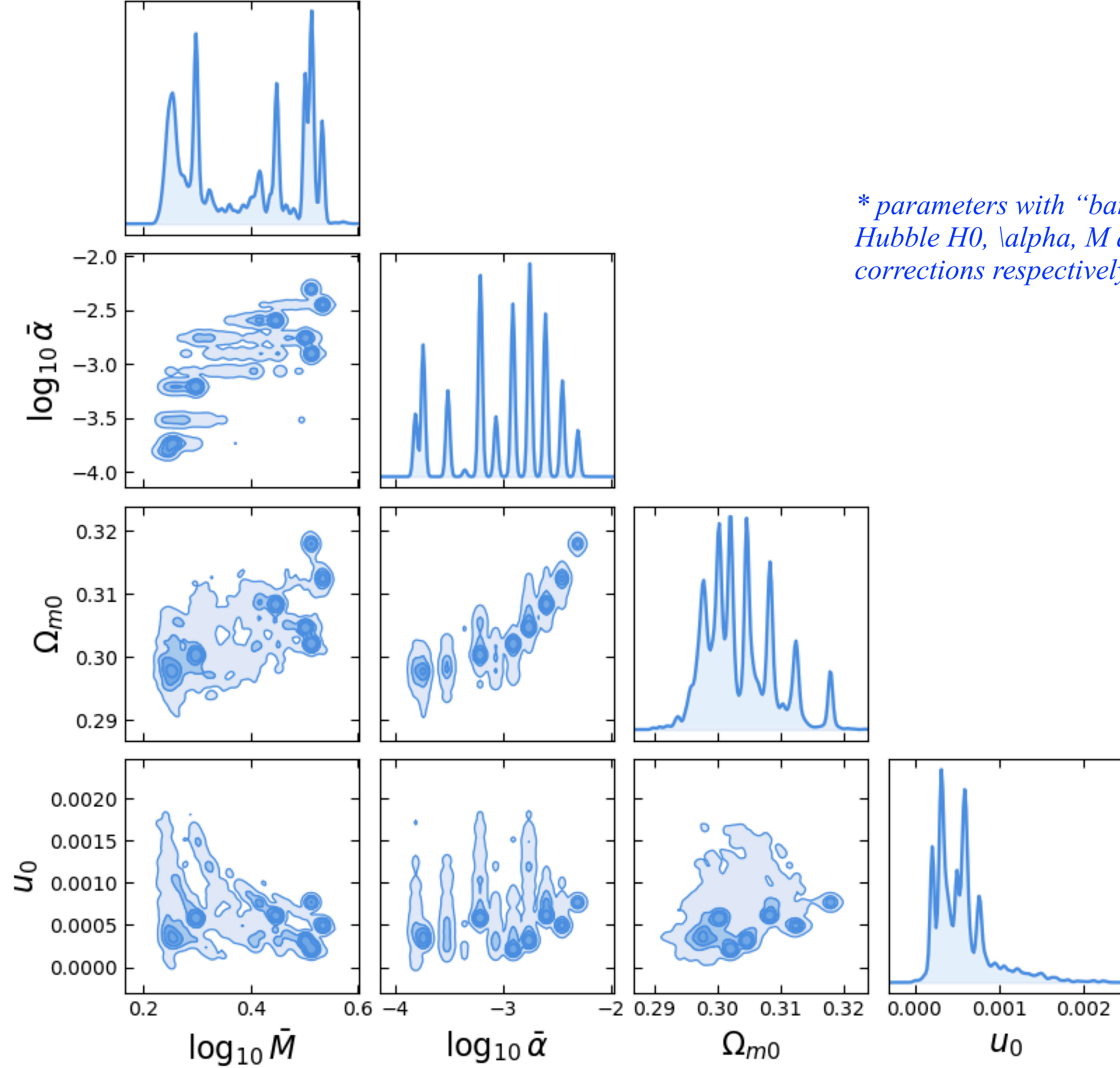


FIG. 3. Accepted-region map from the free- $\bar{\alpha}$ scan, showing one- and two-dimensional projections of the four-dimensional parameter space $(\log_{10} \bar{M}, \log_{10} \bar{\alpha}, \Omega_{m0}, u_0)$. Darker regions indicate more strongly preferred parts of the scan. Ω_{m0} remains confined to a narrow interval around ~ 0.31 , while u_0 is concentrated near zero, confirming that viable solutions require the scalar dynamics to be already close to the vacuum configuration today. The $\log_{10} \bar{\alpha}$ direction exhibits several islands, reflecting the non-trivial geometry of the likelihood surface.

Unification: Theta-angle, Immirzi Parameter and Cosmological Constant

$$S_{\theta}^{(\text{pre})} = \frac{\Theta_{\text{MM}}}{32\pi^2} \int d^4x \epsilon^{\mu\nu\rho\sigma} (\eta_{MQ}\eta_{NP} - \eta_{MP}\eta_{NQ}) F_{\mu\nu}^{MN} F_{\rho\sigma}^{QP},$$

After Spontaneous Symmetry Breaking

$$\text{Tr}(F \wedge F).$$

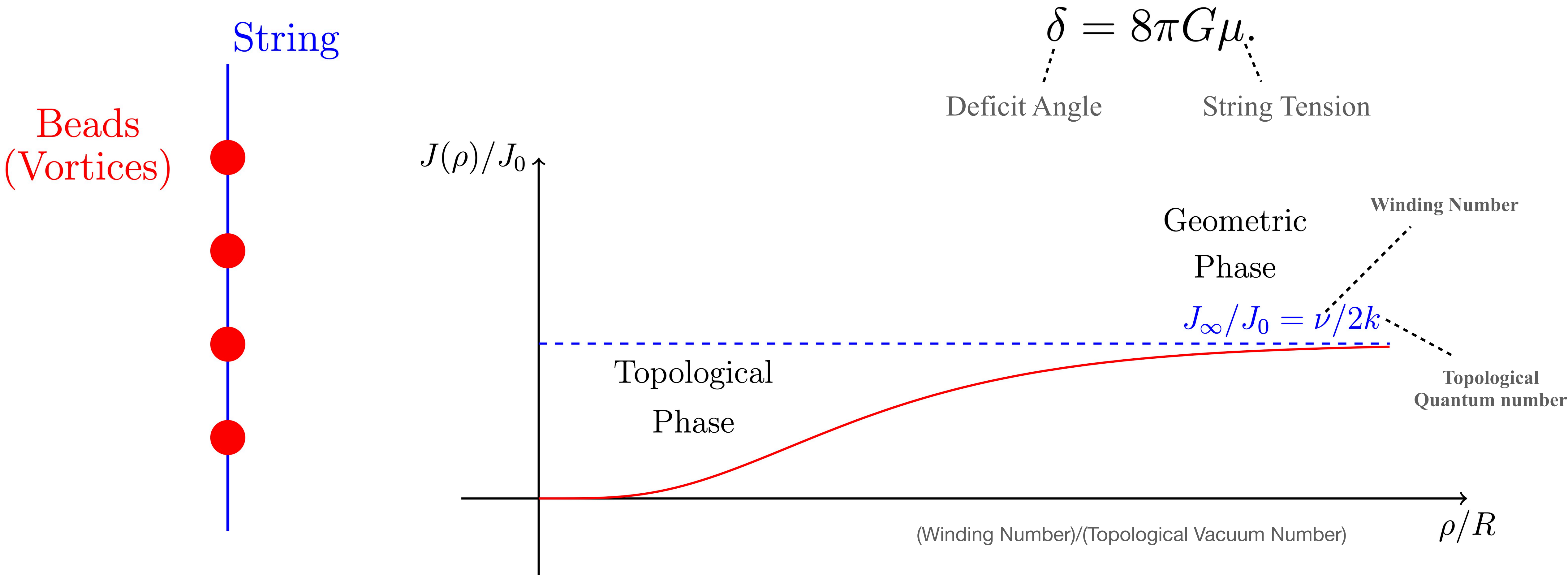
$$S_{\text{Holst}} = \frac{1}{2\gamma} \int e^m \wedge e^n \wedge R_{mn}, \quad \frac{1}{\gamma} = \frac{\Theta_{\text{MM}}\Lambda}{12\pi^2}.$$

$$\frac{\theta_G}{\alpha_{GB}} = -\frac{32\pi^2}{\gamma} \implies \gamma = -32\pi^2 \frac{\alpha_{GB}}{\theta_G},$$

Topological Defects: the example of Cosmic Strings

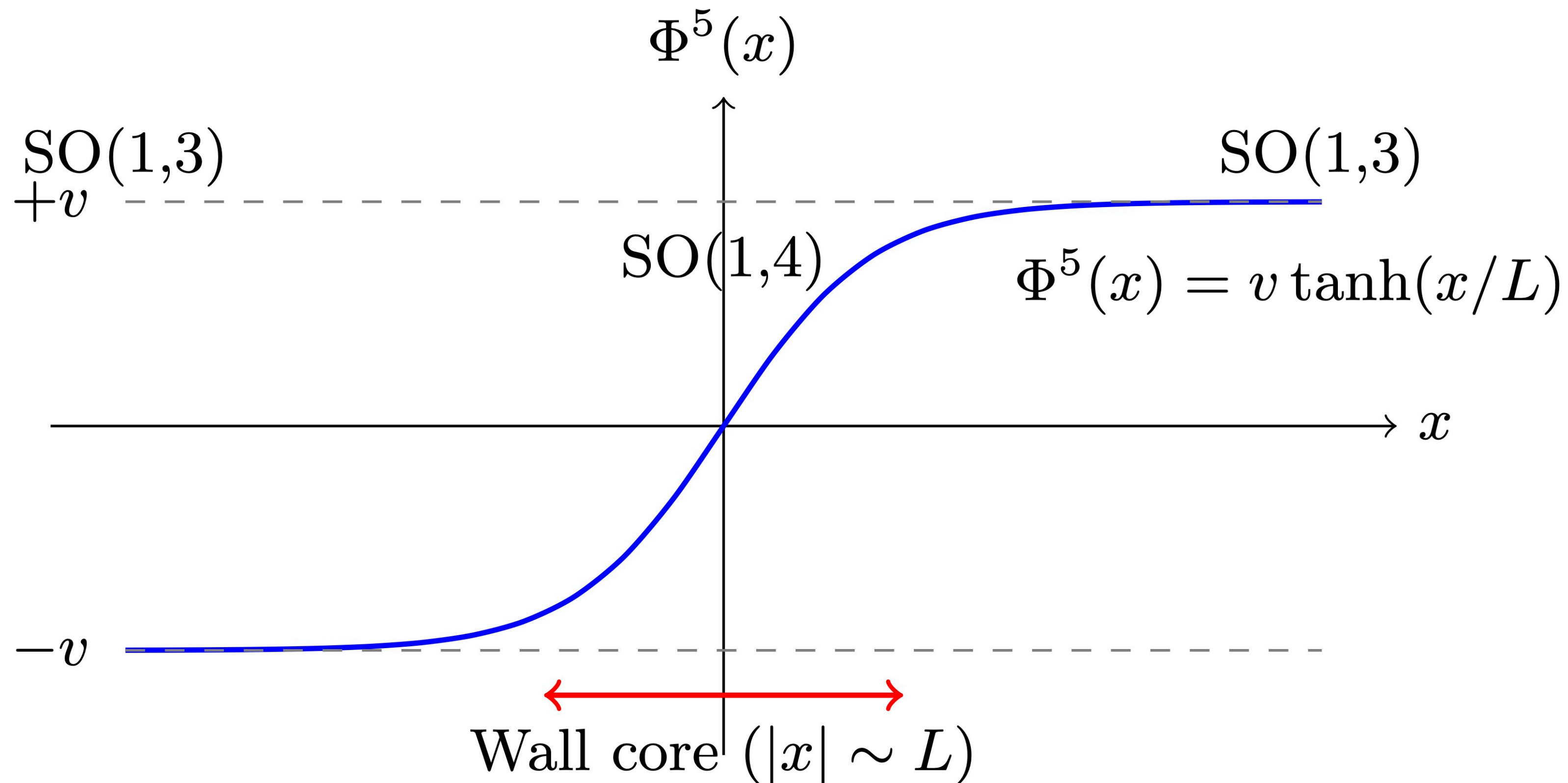
$$\Phi^A(\rho) = \phi(\rho) \delta_5^A = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \phi(\rho) \end{pmatrix}.$$

$$ds^2 = -dt^2 + dz^2 + d\rho^2 + \left(1 - \frac{\delta}{2\pi}\right)^2 \rho^2 d\phi^2,$$



Domain Walls

$$\Phi^A(x) = \phi(x)\delta_5^A,$$



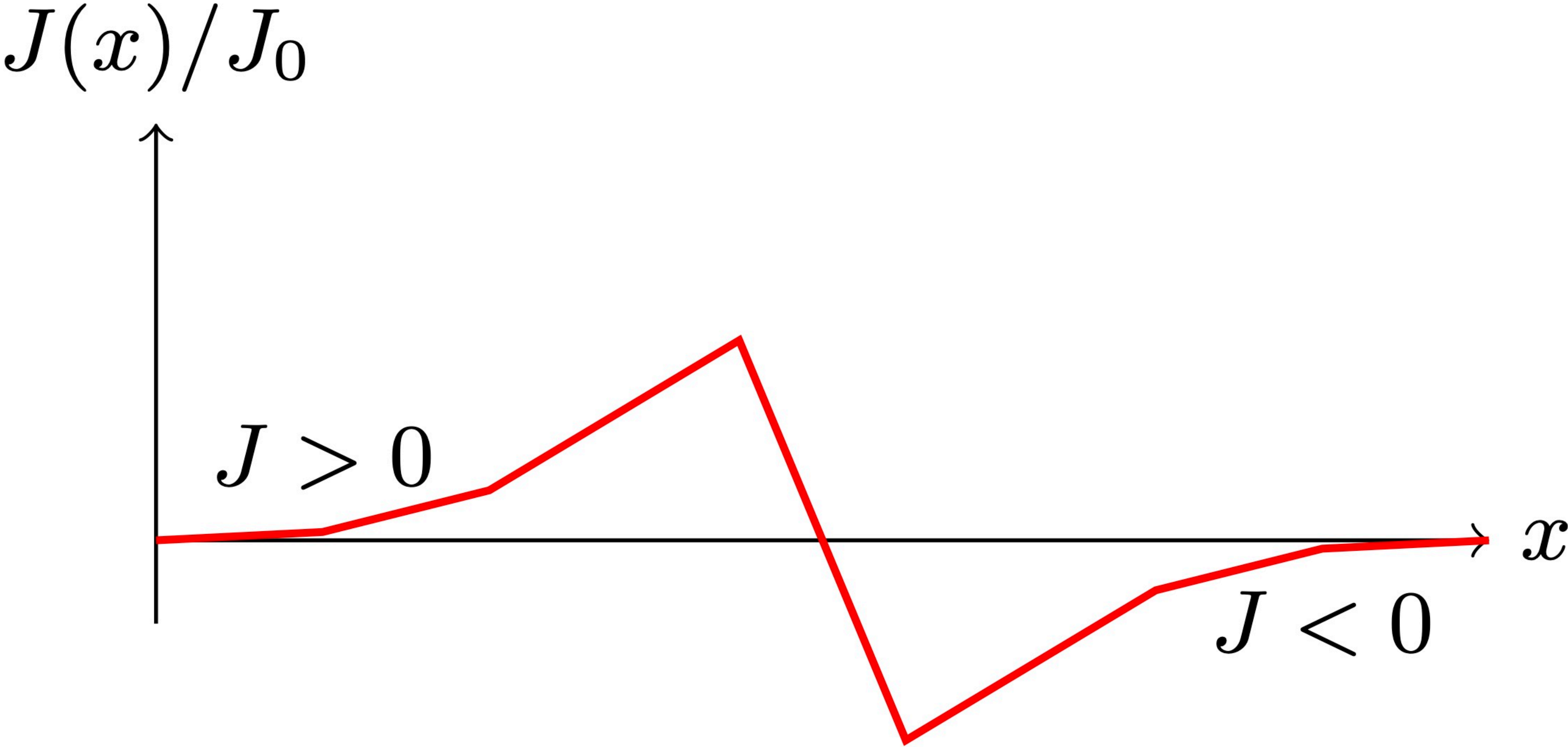
Emergent Vilenkin metric *Vilenkin PLB '83*

$J(x)$ localized at core, sourcing $K = 4\pi G\sigma$

$\langle \Phi^5 \rangle = \pm v$ breaks $SO(1,4) \rightarrow SO(1,3)$

$$J = \epsilon_{01235} \epsilon^{txyz} (\nabla_t \Phi^0) (\nabla_x \Phi^1) (\nabla_y \Phi^2) (\nabla_z \Phi^3) \Phi^5.$$

$$J(x) = m^4 v^6 e^{-2K|x|} e^{Kt} \frac{1}{L} \operatorname{sech}^2 \left(\frac{x}{L} \right) \tanh^5 \left(\frac{x}{L} \right).$$



Gravitational Instantons and Gravitational Monopoles

Euclidean Taub/NUT Solutions

$$ds^2 = U(r)(d\tau + 2n \cos \theta \, d\phi)^2 + \frac{dr^2}{U(r)} + (r^2 + n^2)(d\theta^2 + \sin^2 \theta \, d\phi^2),$$

$$U(r) = 1 - \frac{2(Mr + n^2)}{r^2 + n^2},$$

$$\Phi^A(r) = f(r) \, \delta_5^A = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ f(r) \end{pmatrix}.$$

$$J = \zeta \, \epsilon^{\tau r \theta \phi} \, (\nabla_\tau \Phi^0)(\nabla_r \Phi^1)(\nabla_\theta \Phi^2)(\nabla_\phi \Phi^3) \, \Phi^5,$$

$$A_\tau^{05} = m \sqrt{U(r)},$$

$$A_\phi^{05} = 2m \sqrt{U(r)} \, n \cos \theta,$$

$$A_r^{15} = \frac{m}{\sqrt{U(r)}},$$

$$A_\theta^{25} = m \sqrt{r^2 + n^2},$$

$$A_\phi^{35} = m \sqrt{r^2 + n^2} \sin \theta.$$

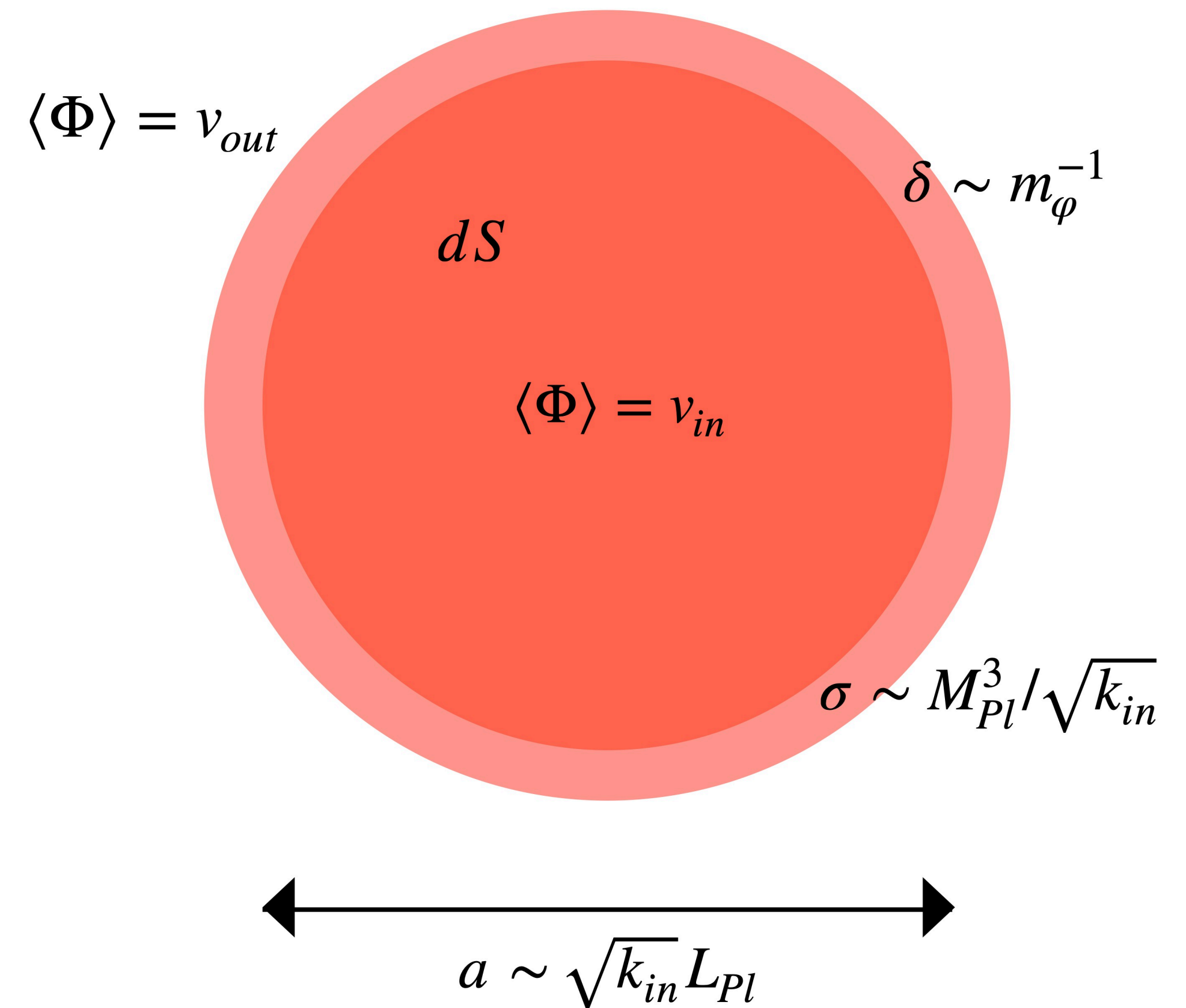
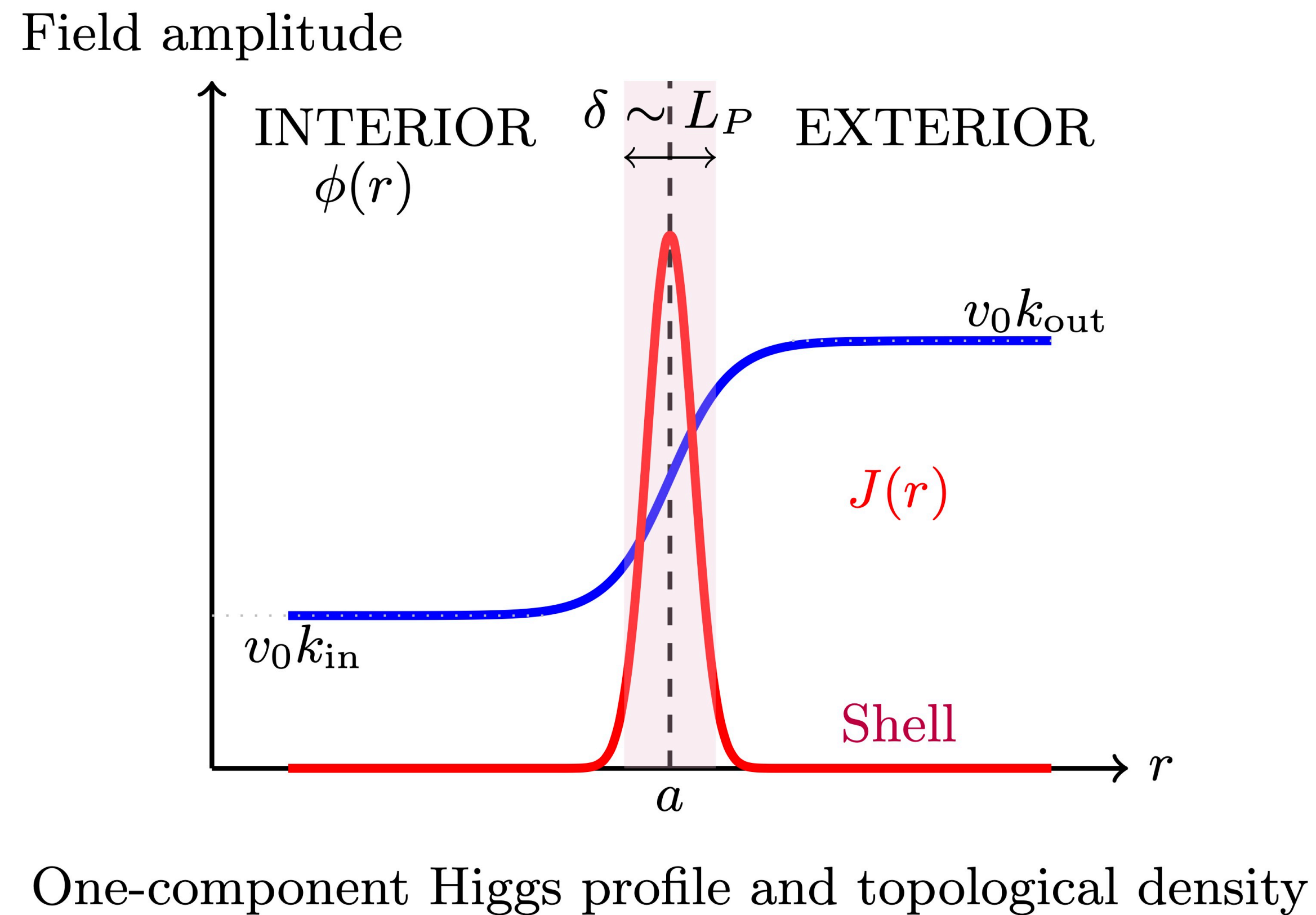
$$J(r, \theta) = \zeta \, m^4 \, (r^2 + n^2) \, \sin \theta \, f(r)^5.$$

NUT MONOPOLE CHARGE

Top-Star

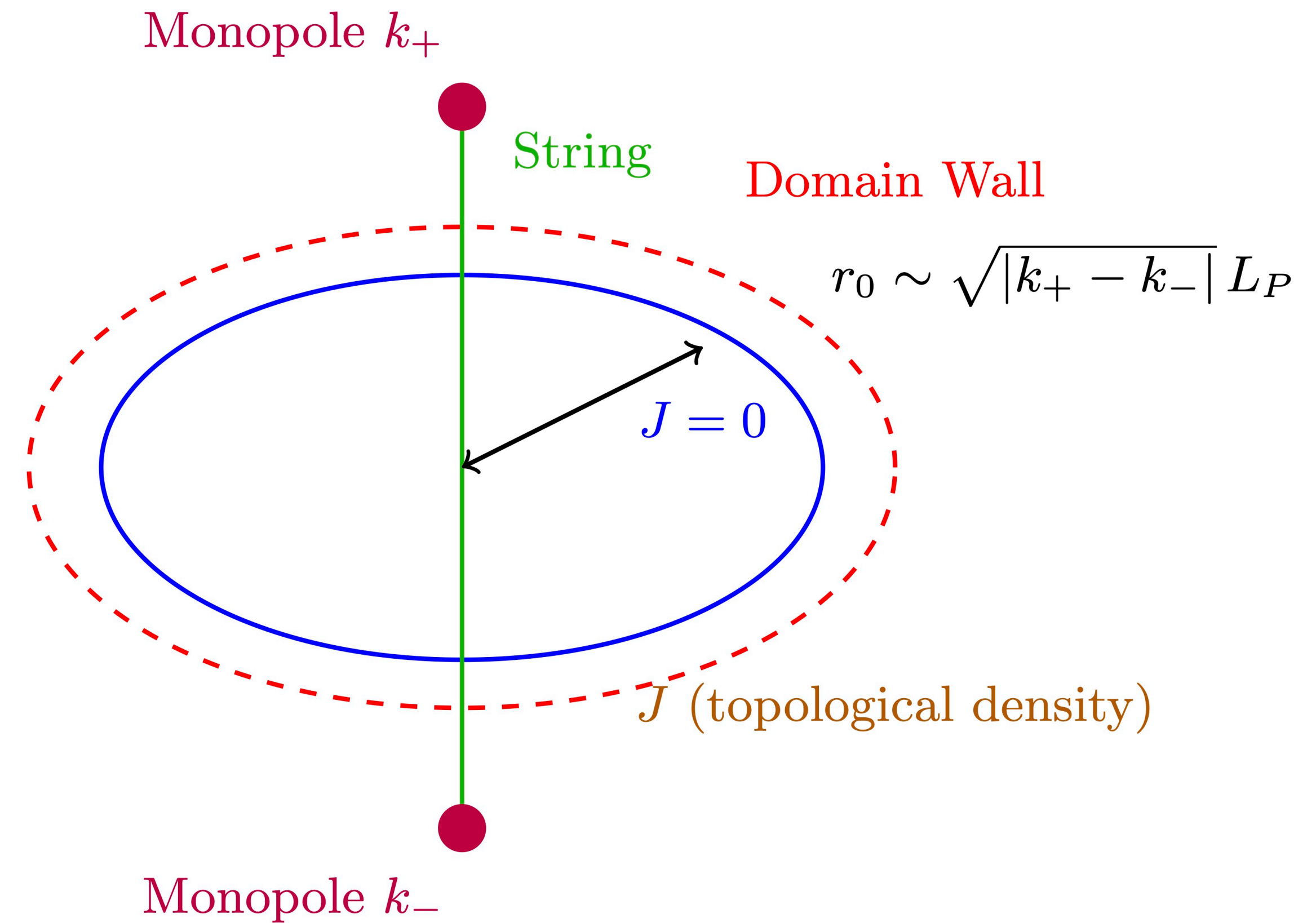
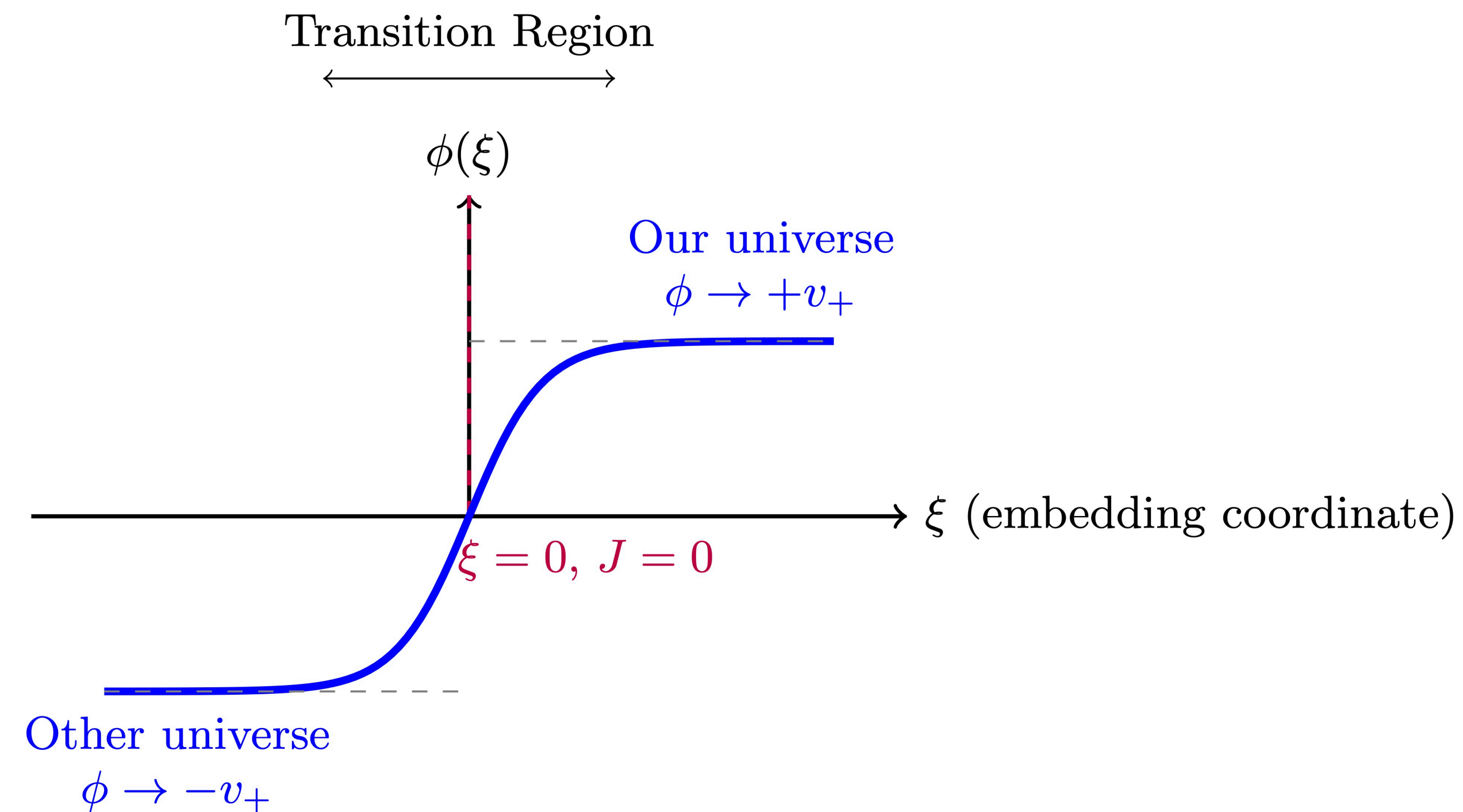
Topological Gravastar

Exotic Compact Objects Predicted by the theory, Stabilized by Topological Conserved Numbers, Remnants, Natural Dark Matter candidates with “Topological Memory Burden”



Top-Wormhole

Topological Charge Conservation Stabilizes the Object against perturbations,
no need for exotic matter like “ghosts”, NEC is not violated but “saturated”,
But Topological Burden does not stabilize Close Time Curves (CTC)



Morris-Thorne solution '88

**Gravitational Waves, Supermassive BH merging, Tidal Love Number,
LISA, TianQing, TAIJI projects**

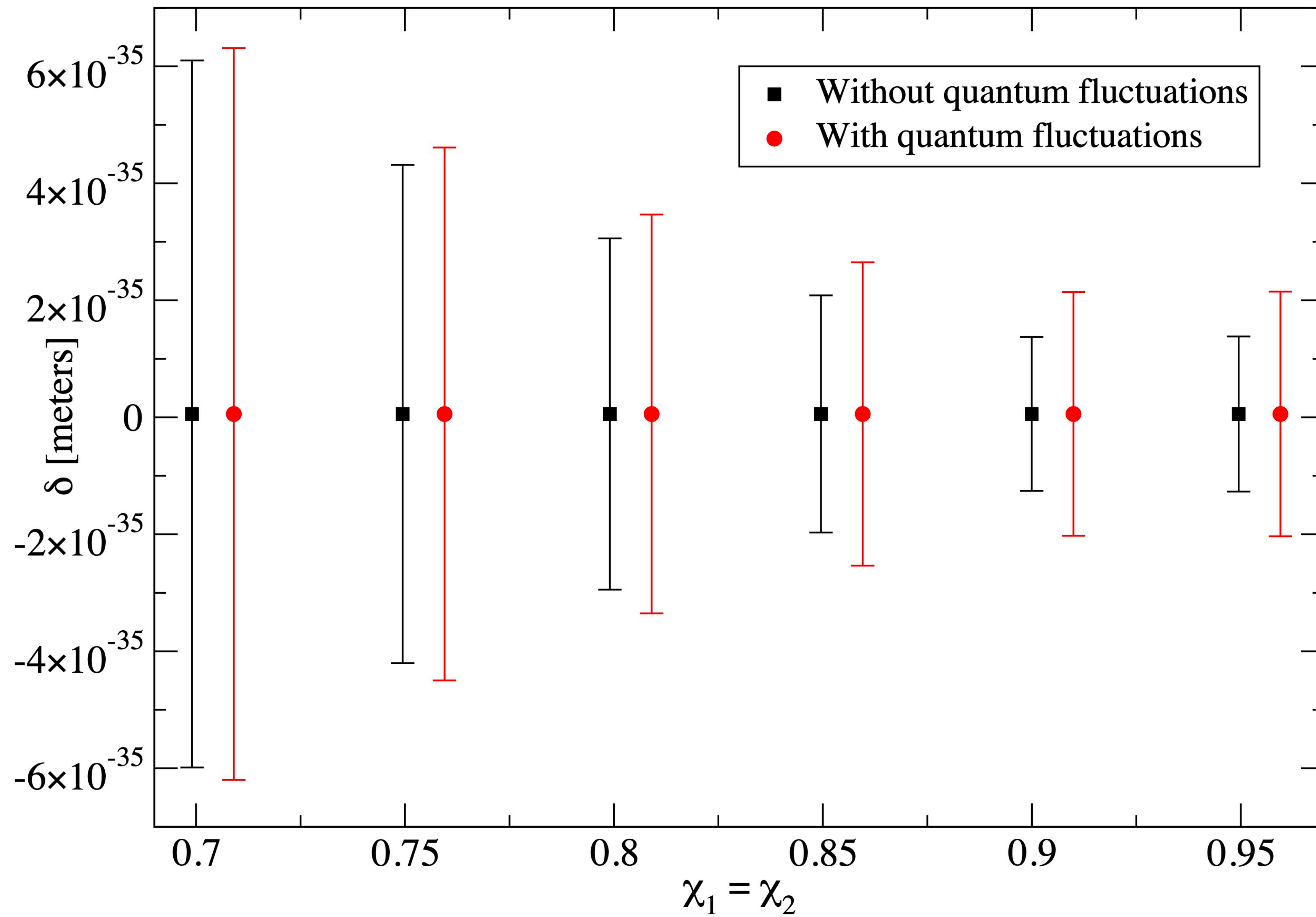
$$\delta = r_0 - r_H = r_H e^{-1/k} \, ,$$

$$\tilde{h}(f) = \mathcal{A}(f) e^{i\psi_1(f)+i\psi_2(f)+i\psi_3(f)} \, ,$$

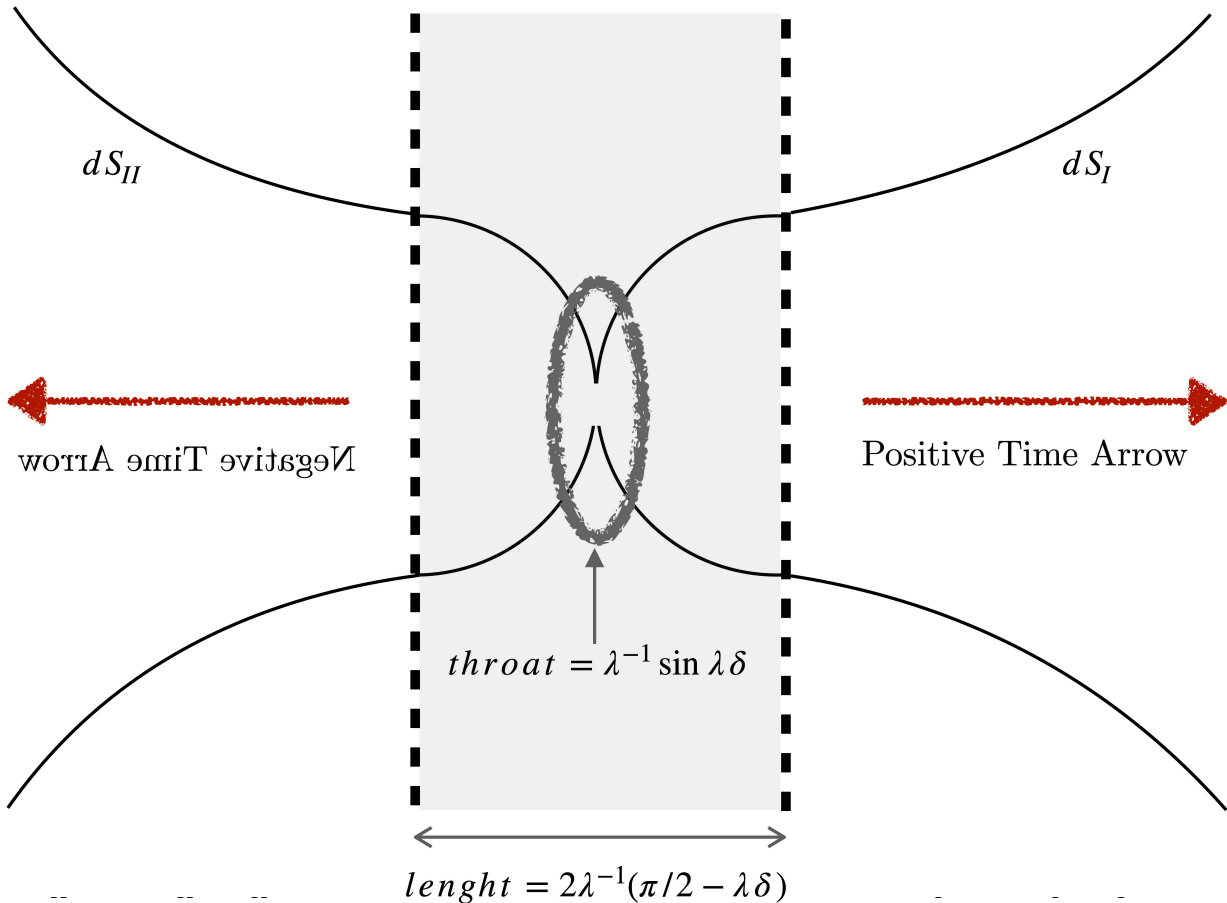
$$\psi_3(f) = -\psi_N \frac{\Lambda}{6m^5} v^{10} \frac{(1+q)^2}{q} \, ,$$

$$\psi_N = (3/128) \eta^{-1} v^{-5}$$

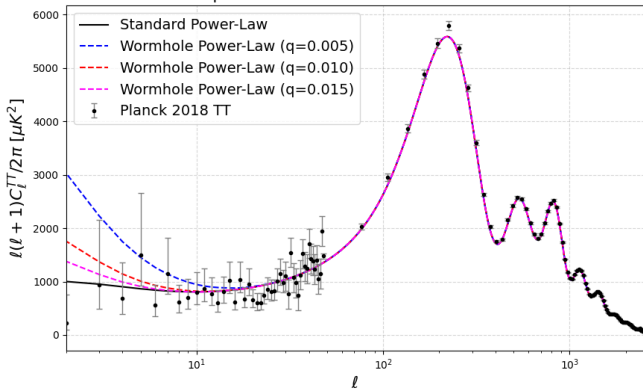
$$v = (\pi m f)^{1/3} \quad \eta = m_1 m_2 / m^2 \quad \Lambda = (1 + 12/q) m_1^5 k_1 + (1 + 12q) m_2^5 k_2 \, ,$$



Mirror Twin Entangled Universes



CMB TT Spectrum: Wormhole vs Standard Power-Law



Aspects of Meta-Geometric Quantization

New Meta-Geometric Wheeler-de Witt (WdW) Equation

A. Addazi et al PRD 2025 and work in progress

Gradient Flow and Stochastic Quantization à la Parisi-Wu or alternative Schwinger-Keldysh

A. Addazi et al PLB 2026 and work in progresses

Spin/String Network Correspondence (H-duality)

E. Bianchi CQG 09', A. Addazi SCPMA and IJGGMP et al 17' and work in progress

Embedding Matter as “Emergent”: Larger Meta-GUT groups such as $SO(1,2N)$ — and Special Supersymmetric Gauge Group $OsP(32|R)$ can include Emergent Supergravity and M-theory

A. Addazi, In preparation

Topological Protection of Vacuum Energy

A. Addazi, G. Meluccio 2026 on arXiv and works in preparation

Pre-geometric Wheeler deWitt

$$\hat{\mathcal{H}}|\Psi\rangle = 0,$$

$$\Psi[A_{\lambda}^{AB}(x^{\mu}), \phi^C(x^{\nu})] \quad (\text{instead of } \Psi[h_{ij}(x^k)])$$

TIME HERE IS PRESENT, CONTRARY TO ADM WdW, WHAT DOES IT MEAN WITH RESPECT TO THE PROBLEM OF TIME?

$$\hat{A}_{\mu}^{AB}(x) \rightarrow A_{\mu}^{AB}(x), \quad \Pi_{AB}^{\mu}(x) \rightarrow -i \frac{\delta}{\delta A_{\mu}^{AB}(x)},$$

$$\hat{\phi}^A(x) \rightarrow \phi^A(x), \quad \Pi_A(x) \rightarrow -i \frac{\delta}{\delta \phi^A(x)}.$$

$$\mathcal{H}_W \xrightarrow{SSB} \mathcal{H}_{\text{ADM}},$$

Meta-QG and BF with constraint

$$S_{\text{BF}} = \int \text{tr}(B \wedge F), \quad F = dA + A \wedge A,$$

$$\mathcal{D}B^{AB} = 0, \quad F^{AB} = 0,$$

Topological Phase:
No propagating d.o.f,
Exact Quantization

$$B_{AB}^{(\text{W})} = -2k_{\text{W}} \epsilon_{ABCDE} \nabla \phi^C \wedge \nabla \phi^D \phi^E. \quad \text{Meta-Geometric Wilczek}$$

SSB

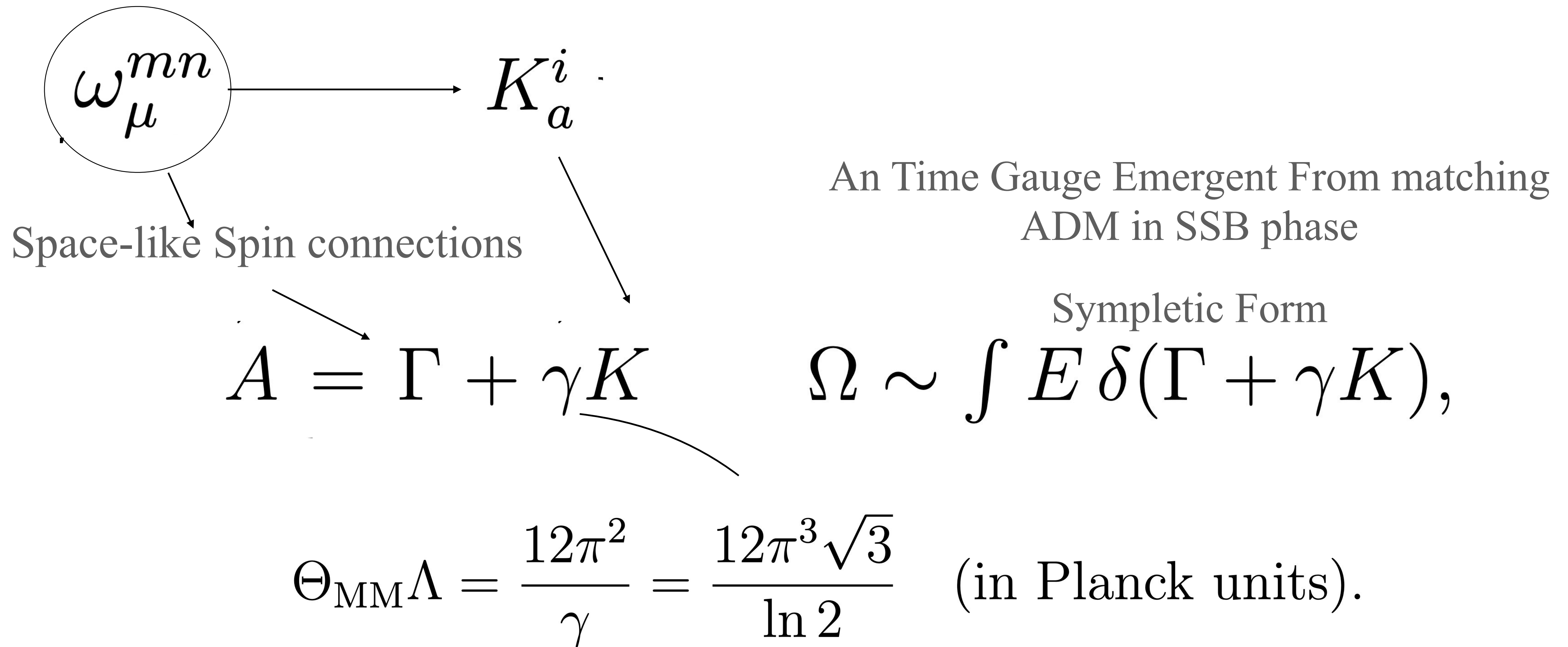
$$B_{ab}^{(\text{EH})} = \frac{M_{\text{P}}^2}{4} \epsilon_{abcd} e^c \wedge e^d.$$

Geometric Phase

From $\langle \text{Higgs} \rangle = 0$ to $\langle \text{Higgs} \rangle$ Non-Zero, There is the interpolation between the Topological Phase and Geometric Phase: Topological Phase Transition!

“Emergent” Ashtekar-Barbero Variables

MM/W + Theta-term



Hamiltonian and Simplicity Constraints: From Meta-QG to LQG

Simplicity Constraints: before SSB not a “grasping”,
Acting on connecting two vertices and Higgs dependent

$$B_{AB}^{(W)} = -2k_W \epsilon_{ABCDE} \nabla \phi^C \wedge \nabla \phi^D \phi^E. \quad B_{ab}^{(EH)} = \frac{M_P^2}{4} \epsilon_{abcd} e^c \wedge e^d.$$

Hamiltonian Constraints: polynomial in variables

$$\mathcal{H} = -A_0^{AB} [\partial_i \Pi_{AB}^i(\phi, A) + 2\Pi_{BC}^i(\phi, A) A_{Ai}^C + \eta_{BC} \Pi_A(\phi, A) \phi^C] + \lambda^A Z_A + \lambda_i^{AB} Z_{AB}^i + \lambda_0^{AB} Z_{AB}^0, \quad \mathcal{H} = \frac{1}{\sqrt{\det q}} \left(\epsilon^{ijk} F_{ab}^i E_j^a E_k^b - 2(1 + \gamma^2) K_{[a}^i K_{b]}^j E_i^a E_j^b \right)$$

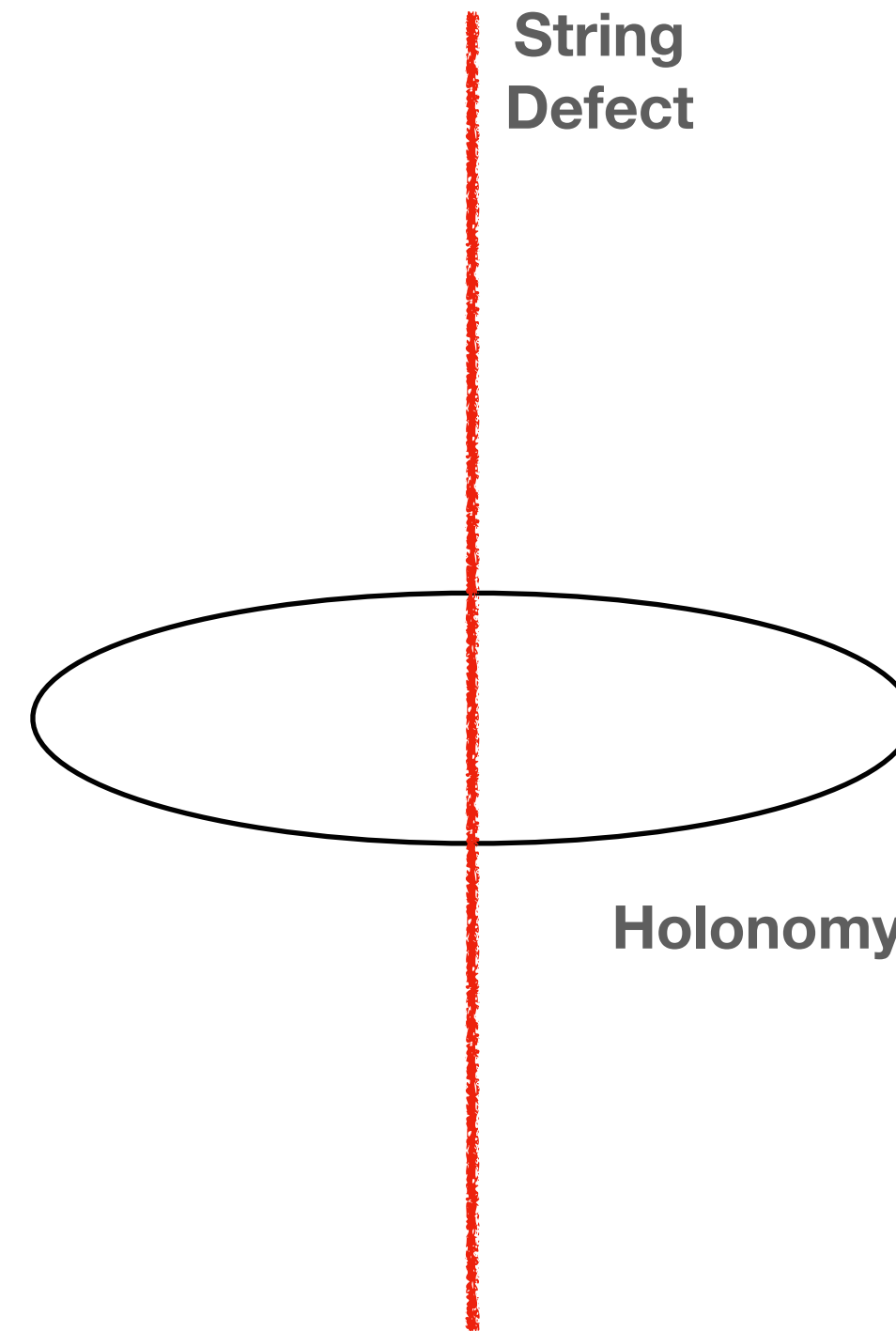
*Meta-Geometric Networks? Holonomies on all towers of Topological
Spaces Summing on Genus* A. Addazi 2026 in preparation

String/Spin Duality

Aharonov-Bohm Effect

String Networks

Winding number



Spin Networks

Quantum Spin

I) Classical General Relativity from flat connections closing on a “solenoid defect”

II) Our Strings are not Fundamental (No String Theory) but Composite Topological States)

iii) One-to-One Correspondence of the Moduli Space of Strings with LQG Hilbert space

E. Bianchi CQG '09', A. Addazi et al SCPMA and IJGMMP 2017, A.Addazi 2026 in preparation

Parisi-Wu Stochastic Quantization: Langevin System

$$\frac{\partial A^{AB}}{\partial s} = \underbrace{-i\mathcal{D}B^{AB} + \xi_g A^{AB}}_{\text{Drift Terms}} + \underbrace{\xi_f B^{AB}}_{\text{Stochastic Noise}},$$

$$\frac{\partial B^{AB}}{\partial s} = -iF^{AB} - i\epsilon^{AB}{}_{CDE} B^{CD} \phi^E + \xi_f B^{AB},$$

$$\frac{\partial \phi^A}{\partial s} = -i\epsilon^A{}_{BCDE} B^{BC} \wedge B^{DE} + \xi_s \phi^A,$$

IN DEEP UV, QUANTUM NOISE DOMINATES: APPROXIMATED SOLUTION LEADS TO TOPOLOGICAL UV FIXED POINT

$$\frac{\partial \phi^A}{\partial s} - \xi_s \phi^A \approx 0. \qquad \phi^A(s) \approx e^{-\frac{\sigma_{\xi_s}^2}{2}(s-s_0)} \phi_0^A(s),$$

Part II. Frontiers. Conclusions

Re-interpretation and attempt of solution of the Cosmological Constant Problem:

I) CC as manifestation of Topological Complexity *in vacuo*

II) CC is quantized, our Universe “trapped” in a large topological number
— 120th digits

III) Natural “See-Saw” mechanism with the VEV scale of the new Gravi-Higgs;

The Large Higgs barrier stabilizes the CC to “flow” towards UV — tunneling suppression.

And also Entropic Barrier: “Entropic Naturalness” rather than “Anthropic Principle” .

Dynamical Dark Energy Vs DESI.

Exploration of New “Exotica” predicted: Gravitational Cosmic Strings, Gravitational Monopoles, Gravitational Domain Walls,...

Dark Matter and Gravitational Waves

Aspects of Quantization: LQG as low energy limit of a Meta-QG which UV fixed point “lives” on a Topological Quantum Phase;

Ideas: Meta-Networks, Spin/String Duality, Larger Unifying Groups, Parisi-Wu Stochastic Gradient Flow, Emergent Supergravity and M-theory from $Osp(R | 32)_L \times Osp(R | 32)_R$



And... the journey just began
Thanks for the attention!