Gravitons as Goldstone particles and Cosmology

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Outline:

1) Introduction
2) Lorentz Non-Invariant condensates
3) Tenzor condensate oscilations → graviton_goldstones
4) Interaction ; Universality
5) Cosmology with goldstone_gravitons
6) Bigravity cosmology

Spontaneous breacking of Lorentz Invariance (LI)

$\Longrightarrow$ nonscalar goldstone particles

$\Longrightarrow$ restoration of $\simeq$ LI at long distances ?

Photons : D. Bjorken (1963)

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Gravitons: R. Phylips (1966)

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P. Kraus, E. Tomboulis (2002)

$$\langle \bar{\Psi} \gamma_\mu \Psi \rangle_0 = n_\mu \neq 0 \longrightarrow n_\mu + A_\mu(x) , \quad n_\mu A_\mu(x) = 0$$

$$\langle \bar{\varphi} \partial_\mu \partial_\nu \varphi + B_\mu^\lambda B_{\lambda\nu} + \ldots \rangle_0 = n_{\mu\nu} \neq 0 \rightarrow t_{\mu\sigma}(x) = n_{\mu\sigma} + h_{\mu\sigma}(x)$$

$$\mathrm{Tr}\, h(x) = c_1 , \quad \mathrm{Tr}(n.h) = c_2 , \quad \mathrm{Tr}(nnh) = c_3 , \quad \mathrm{Tr}(nnnh) = c_4$$

Model and general definitions

$$\mathcal{L}\left[\, SU(N) \otimes \boxplus \,\right]$$

Stand. Model Fields

(B, χ, φ) — interactions becomes strong on scale Λ

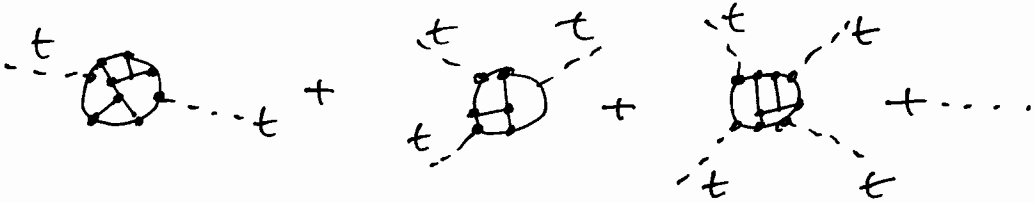
$$\hat{\tau}_{\mu\nu}(x) = \mathrm{Tr}\left[a_1\left(B_\mu^{\lambda} B_{\lambda\nu}\right) + a_2\left(\bar{\varphi}\,\partial_\mu\partial_\nu \phi\right) + a_3\left(\bar{\chi}\,\partial_\mu\partial_\nu \chi\right) + a_4\left(B_\mu^{\lambda} B_\lambda^{\sigma} B_{\sigma\nu}\right) + \dots\right]$$

$$\langle \hat{\tau}_{\mu\nu} \rangle_0 = \int \mathcal{D}(B,\chi,\phi)\, \hat{\tau}_{\mu\nu} \exp\left(i \int \mathcal{L}\right) = \eta_{\mu\nu} \neq 0 \sim \Lambda^4$$

$$i \int L\left(t_{\mu\nu}(x)\right) d^4x = \ln\left[\int \mathcal{D}(B,\chi,\phi) \exp\left(i\int \mathcal{L}\right) \delta_x\left(t_{\mu\nu}(x) - \hat{\tau}_{\mu\nu}(B,\chi,\phi)\right)\right]$$

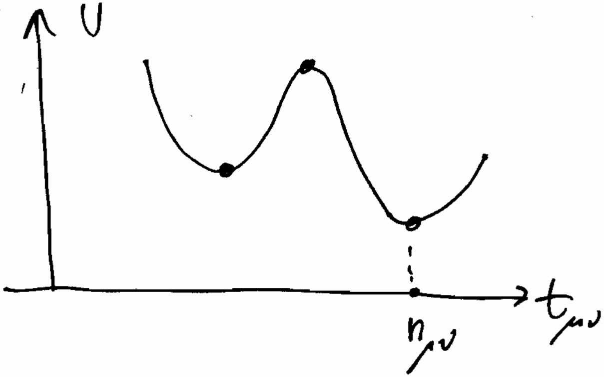
$$L(t_{\mu\nu}) = -\underline{V(t_{\mu\nu})} + \underline{\Gamma^{\alpha\beta\gamma\delta\rho\sigma}\, t_{\alpha\beta,\gamma}\, t_{\delta\rho,\sigma}} + W^{\cdots\cdots\cdots}\, t_{\cdot\cdot,\cdot}\, t_{\cdot\cdot,\cdot}\, t_{\cdot\cdot,\cdot} + \dots$$

Potential and $n_{\mu\nu}$ condensation

$V(t_{\mu\nu}) \sim$ 

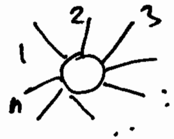
$$V(t_{\mu\nu}) \simeq g_2 t_{\mu\nu}^2 + g_3 t_{\mu\nu}^3 + \dots$$

$$\frac{\partial V}{\partial t_{\mu\nu}} = 0 \quad \text{at } t_{\mu\nu} = n_{\mu\nu} \quad , \quad |n_{\mu\nu}| \sim \Lambda^4$$



$$\left(\frac{\partial^2 V}{\partial t_{\mu\nu} \partial t_{\lambda\sigma}} \right)$$

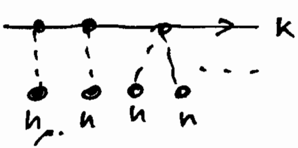
LI violation in observable

at $k_i \ll \Lambda$ amplitudes 

$= A_n(k_1, \dots k_n, n_{\mu\nu})$

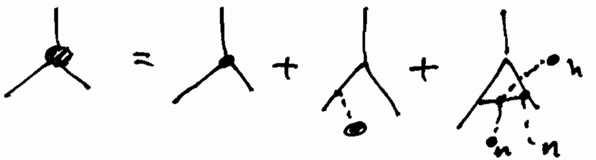
can depend from $n_{\mu\nu}$.

Effective vertexes: $\phi \partial_\mu \partial_\nu \phi \, n_{\mu\nu}$, $\phi^k \partial_\mu \partial_\nu \phi \, n_{\mu\lambda} n_{\lambda\nu}, \dots$



$$G^{-1}(k) = k^2 - m^2 + k_\mu k_\nu N_{\mu\nu} + O(k^4) \; ; \; N_{\mu\nu} = c_1 n_{\mu\nu} + c_2 n_{\mu\lambda} n_{\lambda\nu} + \dots$$

$$\hookrightarrow g_{\mu\nu} k_\mu k_\nu - m^2$$



$$\to \Gamma_3 = \Gamma_3^{(0)} + \frac{k_{1\mu} k_{2\nu}}{\Lambda^2} g^{(2)}_{\mu\nu} + \dots$$

Universality: $g_{\mu\nu} = g^{(2)}_{\mu\nu} = g^{(n)}_{\mu\nu} = \dots$

Low energy universality: $g^{(i)}_{\mu\nu} = g_{\mu\nu} + \frac{k^2}{\Lambda^2} Z^{(i)}_{\mu\nu} + \frac{k_\alpha k_\beta n_{\mu\nu}}{\Lambda^2} Y^{(i)}_{\mu\nu} + \dots$

Condensate $n_{\mu\nu}$ oscilations $\rightarrow$ goldstone_gravitons

$$t_{\mu\nu}(x) = \Omega^{\lambda}_{\mu}(x)\, n_{\lambda\sigma}\, \Omega^{\sigma}_{\nu}(x)$$

Local Lorentz rotations $\quad \Omega^{\nu}_{\mu}(x) = \left[\exp\left(\frac{1}{2}\omega_{ab}(x)\Sigma^{ab}\right)\right]^{\nu}_{\mu}$

$$(\Sigma^{ab})^{\nu}_{\mu} = \eta^{a\nu}\delta^{b}_{\mu} - \eta^{b\nu}\delta^{a}_{\mu} \quad ; \qquad \omega_{ab}(x) = -\omega_{ba}(x)$$

$$V(t_{\mu\nu}(x)) = V(n_{\mu\nu})$$

Decomposition:

$$t_{\mu\nu}(x) = \sum_{a=1}^{4} \underbrace{w_{\mu}^{a}(x)}\,(\lambda^{a} + \underline{\underline{\rho^{a}(x)}})\,\underbrace{w_{\nu}^{a}(x)}$$

massive fields

$$w_{\mu}^{a}(x) = \underline{\Omega^{\lambda}_{\mu}}(x)\,\delta^{a}_{\lambda}$$

massless fields (g_gravitons)

Configurations of tenzor condensate

$$\eta_{\mu\nu} S_\nu^a = \lambda^a S_\mu^a \longrightarrow \eta_{\mu\nu} = \sum_a \lambda^a S_\mu^a S_\nu^a$$

$$\eta_{\mu\nu} \Rightarrow \begin{pmatrix} \lambda_1 & 0 & 0 & 0 \\ 0 & \lambda_2 & 0 & 0 \\ 0 & 0 & \lambda_3 & 0 \\ 0 & 0 & 0 & -\lambda_0 \end{pmatrix},$$

$$\begin{pmatrix} \lambda_1 & 0 & 0 & 0 \\ 0 & \lambda_2 & 0 & 0 \\ 0 & 0 & \lambda_4 & \lambda_5 \\ 0 & 0 & \lambda_5 & -\lambda_4 \end{pmatrix}, \qquad \begin{pmatrix} \lambda_1 & 0 & 0 & 0 \\ 0 & \lambda_2 & 0 & 0 \\ 0 & 0 & \lambda_4 - \lambda_5 & \lambda_5 \\ 0 & 0 & \lambda_5 & -\lambda_4 - \lambda_5 \end{pmatrix}$$

Potential in terms of invariants

$$V(t_{\mu\nu}) \Longrightarrow V(S_i) = \sum_{n_i=0}^{\infty} a_{n_1 n_2 n_3 n_4} \cdot S_1^{n_1} \cdot S_2^{n_2} \cdot S_3^{n_3} \cdot S_4^{n_4}$$

$$S_1 = t_{\mu\mu}\,, \quad S_2 = t_{\mu\nu} t_{\nu\mu}\,; \quad S_3 = t_{\mu\nu} t_{\nu\lambda} t_{\lambda\mu}\,; \quad S_4 = t_{\mu\nu} t_{\nu\lambda} t_{\lambda\sigma} t_{\sigma\mu}$$

$$S_i = \sum_{k=1}^{4} \lambda_k^i \quad ; \quad \partial V / \partial t_{\mu\nu} = 0 \longrightarrow \frac{\partial V}{\partial S_i} = 0$$

Simple model: $V(S_i) = v_0 \sum_{i=1}^{4} \left(-a_i S_i + \frac{1}{2} S_i^2 \right)$

$$\frac{\partial V}{\partial S_i} = 0 \longrightarrow \quad S_i = a_i\,, \quad V(a_i) = -\frac{1}{2} v_0 a_i\,, \quad \frac{\partial^2 V}{\partial S_i^2} = v_0$$

Weak fields : $h_{\mu\nu}(x) \longrightarrow \omega_{ab}(x)$

$$t_{\mu\nu}(x) \simeq n_{\mu\nu} + h_{\mu\nu}(x) \qquad ; \; \Omega \simeq 1 + \frac{1}{2}\omega\Sigma$$

$$\underline{h_{\mu\nu}} \simeq \omega_{\mu\beta} n_{\beta\nu} - \omega_{\nu\beta} \cdot n_{\beta\mu}$$

$$\underline{\omega_{ab}} \simeq h_{a\beta} \tilde{n}_{\beta b} - h_{b\beta} \tilde{n}_{\beta a} \qquad \tilde{n} = n^{-1}$$

Lagrangian for goldstone gravitons

$$\mathcal{L}_2 = \Gamma^{\alpha\beta\gamma\delta\rho\sigma}(t) \cdot t_{\alpha\beta,\gamma} \cdot t_{\delta\rho,\sigma} \quad ; \; t = \Omega n \Omega$$

For weak fields: $t_{\alpha\beta} = \tilde{t}_{\alpha\beta} + \omega_{\alpha\gamma}\tilde{t}_{\gamma\beta} + \tilde{t}_{\alpha\gamma}\omega_{\gamma\beta}$ $\Bigg|$ $\tilde{t}_{\alpha\beta} = n_{\alpha\beta} + \zeta^a_\alpha \zeta^a_\beta \, \varphi_a(x)$

$$\mathcal{L}_2 \simeq \left(P^{\gamma\alpha\beta\sigma\delta\rho} + \omega_{ab} Q^{ab\,\gamma\alpha\beta\sigma\delta\rho}\right) \partial_\gamma \tilde{t}_{\alpha\beta} \, \partial_\sigma \tilde{t}_{\delta\rho} +$$

$$+ \left(\partial_\gamma \omega_{ab} \cdot \partial_\sigma \omega_{mn}\right)\left(\tilde{t}_{\alpha\beta} \tilde{t}_{\delta\rho}\right)\left(H_1^{\gamma ab \dots \rho} + \omega_{pk} H_2^{pk\gamma \dots \rho}\right) +$$

$$+ \partial_\gamma \omega_{ab} \left(\tilde{t}_{\alpha\beta} \, \partial_\gamma \tilde{t}_{\delta\rho}\right) U^{\gamma ab\alpha \dots} \quad + \dots$$

Example with degenerate condensate case

$$h_{\mu\nu} = \begin{pmatrix} \lambda_0 & & & 0 \\ & -\lambda_1 & & \\ & & -\lambda_1 & \\ 0 & & & -\lambda_1 \end{pmatrix} \rightarrow \begin{array}{l} t_{\mu\nu}(x) = -\lambda_1 \eta_{\mu\nu} + (\lambda_0 + \lambda_1) v_\mu(x) v_\nu(x) \\ ds^2 = dt^2 - 2v_i\, dx^0 dx^i - (\delta_{ij} + v_i v_j) dx^i dx^j \end{array} \quad \Bigg|\ v_\mu = (1, \vec{v})$$

For week fields: $h_{i0} \simeq \omega_{i0}(\lambda_0 - \lambda_1)$; $R^{0i0k} \sim \partial^0(\partial^i h^{0k} + \partial^k h^{0i})$

Static mass $\partial^0 \partial^i h_{0i} \sim m_p^{-2} M \delta^3(\vec{x}) \rightarrow$

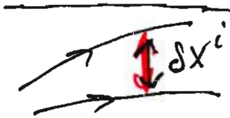
$$\rightarrow \omega^{i0} \simeq h^{i0} \simeq \frac{M}{m_p^2} \frac{x^0 x^i}{|\vec{x}|^3}, \quad f^k \sim \Gamma^k_{00} \sim \partial^0 h^{k0} \sim x^k / |x|^3$$

$\nwarrow$ force

Cosmology $T^{00} = \rho_0 \rightarrow R^{00} \sim \partial^0 \partial^i h^{0i} \sim \rho_0 \rightarrow$

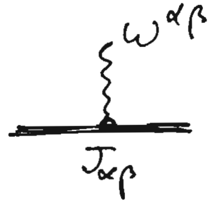
$$\rightarrow h^{0i} \sim \rho_0 x^i (x^0 \pm c_1) \rightarrow g_{ik} \simeq \eta_{ik} + h_{0i} h_{0k} = \eta_{ik} + \frac{x^i x^k}{a^2(x^0)}$$

$$a(x^0) \sim \frac{m_p^2}{(c_1 \pm x^0)\rho_0} \sim a_0\left(1 \pm \frac{\rho_0}{m_p^2} a_0 x^0 + \ldots\right.$$



$$\partial^0 \partial^0 \delta x^i \sim R^{0i0k} \delta x^k \rightarrow \frac{\partial^0 \partial^0 \delta x^i}{\delta x^i} \sim R^{\cdots\cdot} \sim \frac{\rho_0}{m_p^2} \leftarrow \frac{\partial^0 \partial^0 a}{a}$$

Interaction



$$\omega^{\alpha\beta} J_{\alpha\beta}$$

$$J_{\alpha\beta} = (S^a_\alpha \partial_\beta \rho^a - S^a_\beta \partial_\alpha \rho^a)(S^a_\mu \partial_\mu \rho^a) + \partial_{[\alpha} \omega_{\cdot\cdot} h_{\cdot\cdot} \partial_\cdot \omega_{\cdot\beta]}$$

$$h^a_{\mu\nu} (\partial_\mu \rho^a \partial_\nu \rho^a) \; ; \; h^a_{\mu\nu} = S^a_\mu S^a_\alpha \omega_{\alpha\nu} + S^a_\nu S^a_\alpha \omega_{\alpha\mu}$$

$\partial_\mu \omega J_\mu$ –

– only derivative interactions for scalar goldstones

When $\mathcal{L}_2 = \Gamma^{\alpha\beta\gamma\mu\nu\lambda}\partial_\alpha t_{\beta\gamma}\,\partial_\mu t_{\nu\lambda} \Longrightarrow$ GR Lagrangian $R\sqrt{-g}$?

1) $\Gamma^{\alpha\beta\gamma\delta\rho\sigma}(t)$ – functions only from 'covariant' = inverse $t^{\alpha\beta}$

$$t^{\alpha\beta} = \epsilon^{\alpha\lambda\rho\gamma}\epsilon^{\beta\sigma\mu\nu}\, t_{\lambda\sigma} t_{\rho\mu} t_{\gamma\nu}/4!\,t$$

$t = \det t_{\mu\nu} = \lambda_1\lambda_2\lambda_3\lambda_4 = \mathrm{const}$

2) In the week field limit for $t_{\mu\nu}$:

$$\mathcal{L} \longrightarrow \text{massless Pauli-Fierz } \mathcal{L}$$

$$\mathcal{L}_2 \sim t_{\alpha\beta,\gamma}\, t_{\delta\sigma,\rho}\left(2t^{\alpha\delta}t^{\beta\rho}t^{\gamma\sigma} - t^{\alpha\delta}t^{\beta\sigma}t^{\gamma\rho}\right)$$

$\updownarrow$ $\quad t_{\mu\nu} \leftrightarrow g_{\mu\nu}$

$\mathcal{L}_2 =$ GR Lagrangian $R\sqrt{-g}$ in gauge

$\mathrm{Sp}\, t_{\mu\nu} = a_1$, $\mathrm{Sp}(tt) = a_2$, $\mathrm{Sp}(ttt) = a_3$, $\mathrm{Sp}(tttt) = a_4$

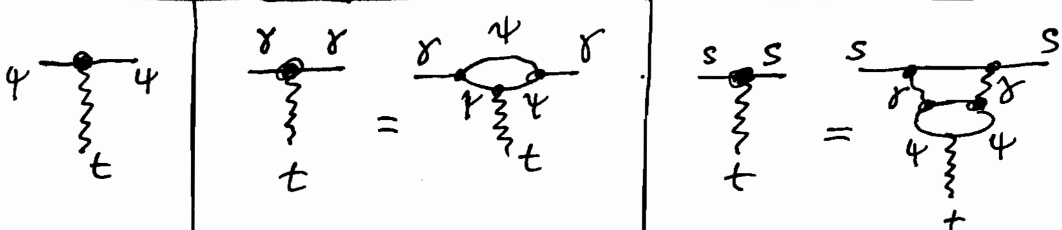
$a_i = \sum_a (\lambda^a)^i$; $\det t_{\mu\nu} = \mathrm{const}.$

Coupling of G–G to particles (Universality ?)

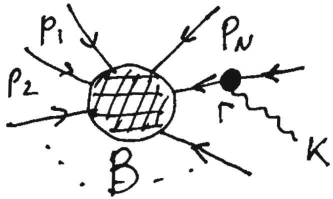
$$\omega_{ab} \frac{\partial \mathcal{L}_2}{\partial \omega_{ab}} \sim \omega_{ab}\, C^{\mu\nu}_{ab} \cdot \left(\partial_\mu \rho^{(n)}\, \partial_\nu{}^{(n)}\right)$$

1) On scale $\sim \Lambda$ coupling is non universal (Only particles ρ)

2) On distances $\gg \Lambda^{-1}$ operators in $\partial \mathcal{L}_2 / \partial \omega_{ab}$ renormalize →
→ this can lead to universality in soft limit.



$g_{\psi\psi t} \sim 1$ $\qquad$ $g_{\gamma\gamma t} \sim e^2$ $\qquad$ $g_{sst} \sim e^4$



$$= A^{(N)}_{\mu\nu}(p_1,..p_n,K) = B^{(N)}(p_1,\ldots p_n)\sum_{i=1}^{N}\frac{\Gamma^{(i)}_{\mu\nu}(p_i)}{(2p_{i\alpha}K_\beta g^i_{\alpha\beta})}$$

$$\Gamma^{(i)}_{\mu\nu}(p) = C^i p_\mu p_\nu + (H_1^i)_{\mu\nu} + p_\mu (H_2^i)_{\nu\lambda} p_\lambda + p_\lambda (H_2^i)_{\lambda\mu} p_\nu + (H_3^i)_{\lambda\mu}\cdot p_\lambda\,(H_3^i)_{\nu\beta}\cdot p_\beta \,.$$

$$(H^i_K)_{\mu\nu} = \left(C^i_K n + \overset{\frown}{C}{}^i_K\cdot n\cdot n + \hat{C}^i_K\, n\cdot n\cdot n + \check{C}^i_K\cdot n\,n\,n\,n\right)_{\mu\nu}$$

$$K_\mu A^{(N)}_{\mu\nu} = 0 \longrightarrow (H_1)^i_{\mu\nu} = 0\,;\ (H_2)^i_{\mu\nu} = a_i g^i_{\mu\nu}\,;\ (H_3)^i_{\mu\nu} = b_i g^i_{\mu\nu} = b_i \eta_{\mu\nu};$$

$$c^i + 2a_i + (b_i)^2 = C \longrightarrow$$

$$\Gamma^{(i)}_{\mu\nu}(p_i, K) = \underline{C p_\mu p_\nu} + \frac{K^2}{\Lambda^2}\,\underline{\hat{\Gamma}^i_{\mu\nu}(p)} + \ldots$$

univers. non univers.

$$\left|\frac{K}{\Lambda}\right| \sim \frac{10^{-12}}{10^{19}} \sim 10^{-31}$$

$$\left(\frac{K}{m_p}\right)_{exp} \lesssim 10^{-15}$$

Supersymmetric case $[V^i, \Phi^i]$

* | SS is also brocken on scale $\Lambda \sim m_p$

** | SS is brocken on scale $\ll \Lambda$

$$H_{\mu\nu} \sim \exp(\xi \bar{Q} + \dot{Q}\bar{\xi})\tau_{\mu\nu}(x) \longrightarrow H_{\mu\nu} = \tau_{\mu\nu} + \theta\chi_{\mu\nu} + \theta\theta f_{\mu\nu}$$ | only chiral $H_{\mu\nu}$

$$H_{\mu\nu} = U_\mu^a U_\nu^a \longrightarrow U_\mu^a = S_\mu^a + \theta\chi_\mu^a + \theta\theta\sigma_\mu^a$$

$$\hat{H}_{\mu\nu} = P_1(\Phi)\partial_\mu\phi^i\partial_\nu\phi^i + P_2(\Phi)W_\alpha^i\sigma_\mu^{\alpha\dot{\beta}}\partial_\nu W_{\dot{\beta}}^i + \dots$$ $|W_\alpha^i = \bar{D}\bar{D}D_\alpha V^i$

$$\hookrightarrow \int \mathcal{D}\phi^i \mathcal{D}V^i \exp(iL(\phi^i, V^i))\delta_x(H_{\mu\nu} - \hat{H}_{\mu\nu}(\phi^i, V^i)) \longrightarrow \mathcal{L}(H_{\mu\nu}) \leftarrow$$ effect. Lagrang.

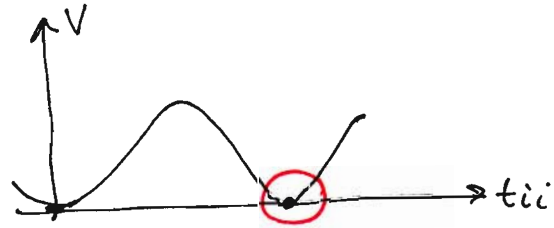
$$\mathcal{L}(H_{\mu\nu}) = F^{(0)}(H)_{\theta\theta} + F^{(1)}(H\cdot H^+)_{\theta\theta\theta\theta} + \partial_\alpha\partial_\beta F^{(2)}_{\alpha\beta}(HH^+)_{\theta\theta\theta\theta} + \dots$$

$\hookrightarrow$ Corresp. potent. energy $V(t_{\mu\nu}) = f_{\alpha\beta}(t) f^+_{\alpha\beta}(t)/\mathcal{F}(tt^+)$ | $\mathcal{F} = \partial F^{(1)}_{(2)}/\partial z$

| $f_{\alpha\beta} = a_1 t_{\alpha\beta} + a_2 t_{\alpha\gamma} t_{\gamma\beta} + \dots$

$V = \sum_i (f(t_{ii}))^2$, $f = \sum_1^\infty a_n t^n$

$\nwarrow$ in diagonal basis for $f_{\alpha\beta}$



Gauge for Goldstone Gravitino $\chi_\mu \approx (\exp(iQ\xi(x)) - 1)\sigma_a S_\mu^a$

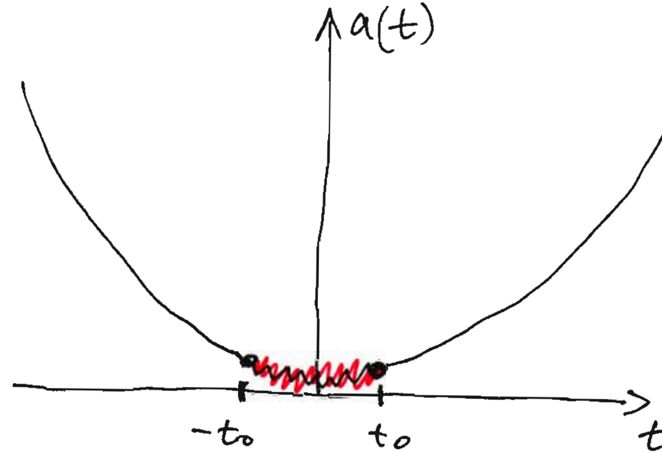
Nonsingular Cosmology — only Goldstone_Gravitons

Flat FRW cosmolog:

$$ds^2 = -dt^2 + a^2(t)\,(d\vec{x}_3)^2$$

t:

$$[-\infty, -t_0]\ \underbrace{[-t_0, t_0]}_{\text{Inertial behaviour}}\ [t_0, \infty]$$



1) Initial conditions at $t = -\infty$

2) No Inflation period

3) Spectra of cosmological perturbations at $t > t_0$

Bigravity Cosmology

[Geometrical $g_{\mu\nu}$] $+$ [Goldstone_Grav $g^{(gold)}_{\mu\nu} = t_{\mu\nu}$]

Two 'Planck' scales $M_p \sim \Lambda_s$; $m_p \sim \Lambda$

$$M_p \gg m_p \simeq 10^{19}\,\text{GeV}$$

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1) $g_{\mu\nu}$ interacts with full $T_{\mu\nu}$
2) $t_{\mu\nu}$ interacts with part of $T_{\mu\nu}$ at distances $\sim \Lambda^{-1}$,
   and with $T_{\mu\nu} - \langle T_{\mu\nu}\rangle_0$ at distances $\gg \Lambda^{-1}$.

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1). $g_{\mu\nu}$ interacts with $\langle T_{\mu\nu}\rangle_0 \longrightarrow$ dS behaviour

2) $t_{\mu\nu}$ – no interact wiht $\langle T_{\mu\nu}\rangle_0 \longrightarrow$ no inflation

Suppose that theory is supersymmetr. up to $\Lambda_c \sim m_p$ (supergr
strings/

Geometric grav. interacts with $\langle T_{\mu\nu} \rangle_0 \sim \Lambda^4$ and leads to cosmolog. acseleration:

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 \sim \Lambda^4 / M_p^2 \longleftrightarrow \text{Compare with } \frac{\rho_{exper.}(today)}{m_p^2}$$

$$\frac{m_p}{M_p} \simeq \left(\frac{\rho_{exper}(today)}{m_p^4}\right)^{1/2} \simeq \left(\frac{10^{-12}\,GeV}{10^{19}\,GeV}\right)^2 \simeq 10^{-62} \rightarrow$$

$$\rightarrow M_p \simeq 10^{81}\,GeV \gg m_p \simeq 10^{19}\,GeV$$

1.) Supersym. is brocken at $\sim \Lambda_c \sim m_p$

2.) Inflation $\rightarrow$ is possible only in pre BB stage

Bigravity and Gold_Grav. with supersym.

Super. Sym. breaking at scale $\mu \sim 10^4 \div 10^{12}$ GeV $\ll m_p$

$$\xi \equiv \frac{m_p}{M_p} = \left(\frac{\rho_{exper}(\text{today})}{\mu^4} \right)^{1/2} \Rightarrow \simeq \underset{\uparrow}{10^{-48}} \div \underset{\uparrow}{10^{-32}}$$

$$\mu \sim 10^{12} \div 10^4 \text{ GeV}$$

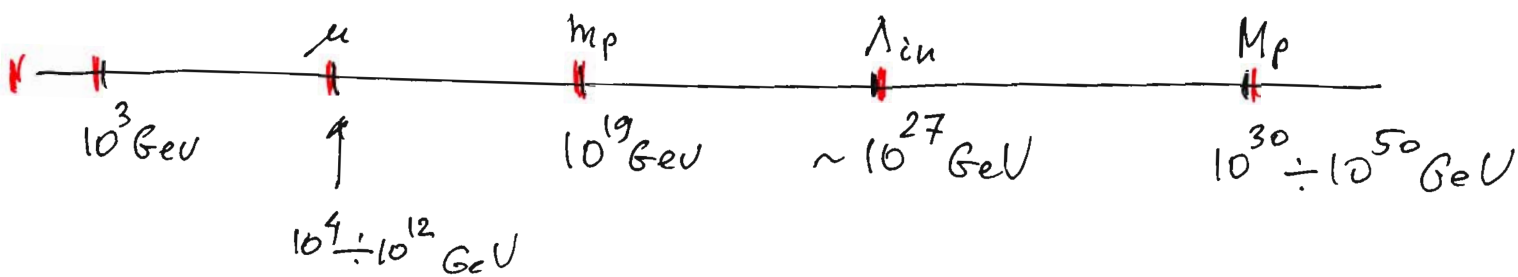
Inflation

initiated by a coherent fluctuation of inflaton field Φ_{in} with mean $\langle \Phi_{in} \rangle = \Lambda_{in}$ in the primary bubble:

$$H_{inf} \sim \Lambda_{in}^2/M_p \sim \xi\, m_p \left(\frac{\Lambda_{in}}{m_p}\right)^2$$

To have $H_{inf} \sim 10^{12}$ GeV we need Λ_{in}:

$$\Lambda_{in} \gtrsim m_p \cdot 10^{8\div10} \ll M_p$$

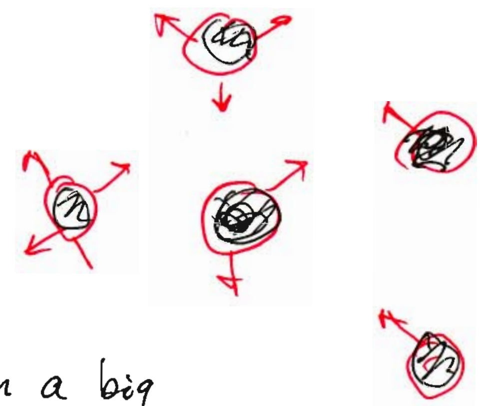


General scenario

1. Slow dS expansion of 'background', comming from geometrical $g_{\mu\nu}$ with

$$H = \frac{\dot a}{a} \sim 10^{-43}\,\text{GeV} \sim \text{'modern value of } H\text{'}$$

2. This background is rarely 'populated' by bubbles (Univerces) of standard model, created by a inflation fluctuations on scale Λ_{in}



3. The probability for creation of such a big primary bubble (to reproduce our Univerce size) can be very small. So the mean number of such a Univ. inside the geometrical dS horizon $\ll 1$.

Single bubble – stages of grow

1) Creation of bubble (primary) by fluctuation at scale Λ_{in}

2) Inflation grow of bubble; relaxation, creation of particles, ... ; high $T \sim \Lambda_{in}$

3) Goldstone_Gravity switches on at $T \sim \Lambda$

4) FRW – expansion – all stages

5) When partices density ρ becomes $\sim \Lambda_{geom}^4$ –
– geometrical gravity will be more essential on a cosmological scales

6) When $\rho \ll \Lambda_{geom}^4$ bubbles gradually dissolve and disappeare.