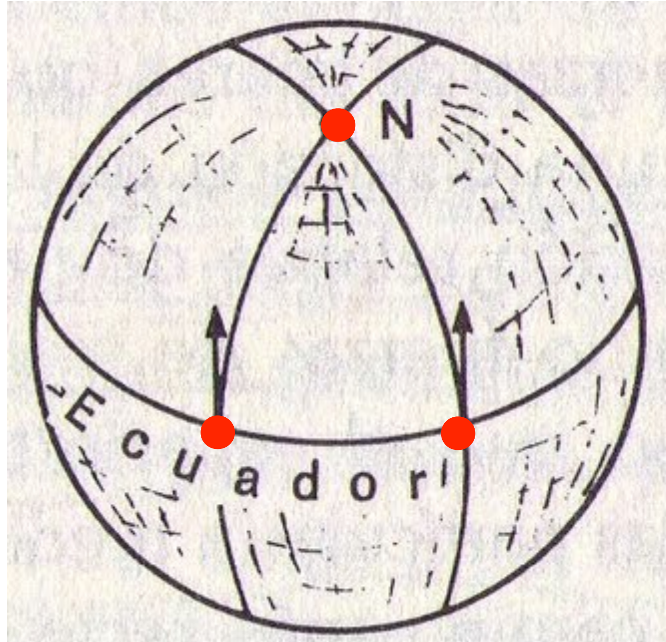
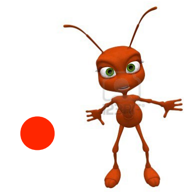
Departamento de Física
División de Ciencias e Ingenierías del Campus León
Universidad de Guanajuato

“SUPERSIMETRIA Y ESCALAMIENTO ANISOTRÓPICO; DOS MANERAS DE GENERALIZAR LA FÍSICA”

Dr. Octavio Obregón

$\Rightarrow$





$$\text{NO} \;\Rightarrow\; x^2 + y^2 + z^2 = cte$$

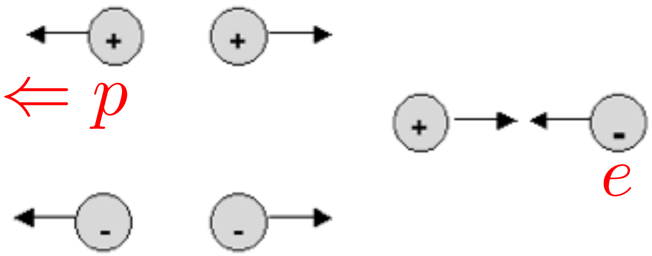
$$(\;)x^2 + (\;)y^2 + (\;)z^2 = cte$$

$$ds^2 = -dt^2 + dx^2 + dy^2 + dz^2$$

$$ds^2 = \underbrace{g_{\mu\nu}}_{\substack{\text{Interacción}\\ \text{gravitacional}}} dx^\mu dx^\nu \;\Rightarrow\; \begin{cases} \mu, \nu = 0, \dots, 3 \\ x^0 = t \\ x^1 = x \\ x^2 = y \\ x^3 = z \end{cases}$$

Fuerzas

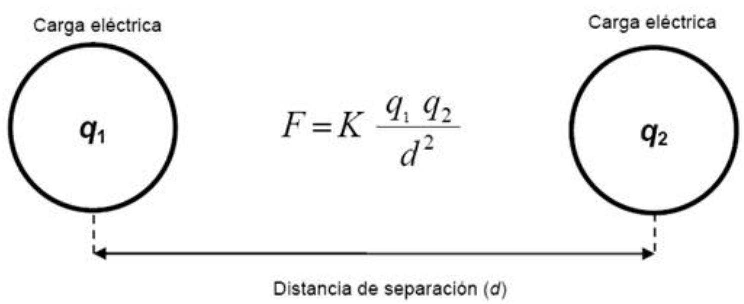
Fuerza eléctrica



protón $\Leftarrow p$

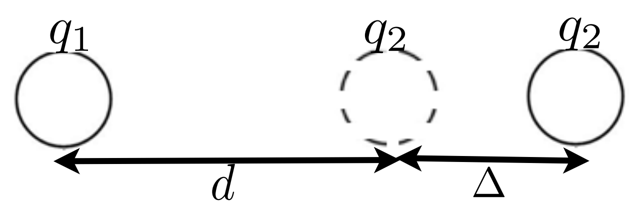
$e \Rightarrow$ electrón

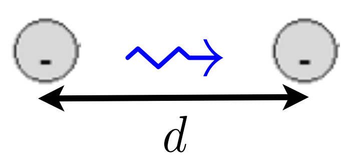
Fuerza de Coulomb



$$F = K\frac{q_1\, q_2}{d^2}$$

$$F = K\frac{q_1 q_2}{(d+\Delta)^2}$$ ✕





fotón $\rightsquigarrow$

"Interacciones"

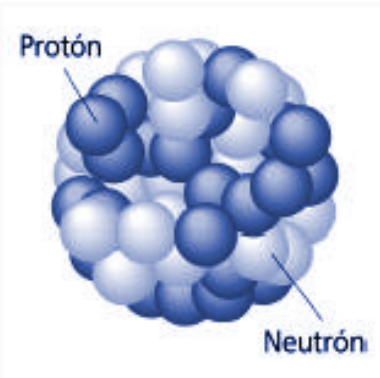
En General:

 Fermiones (Ψ)

$\rightsquigarrow$ Bosones (A_μ)

Simetrías

Núcleo



N ...

P ... +

pero

$N \stackrel{?}{=} P$

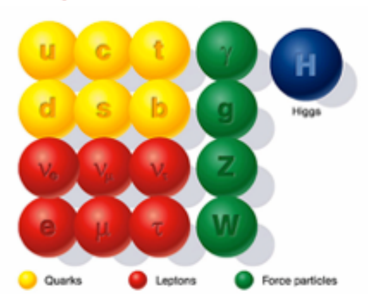
isospín

Ahora que tal si $F \sim B$

$\ominus$ = $\rightsquigarrow$ no tan fácil

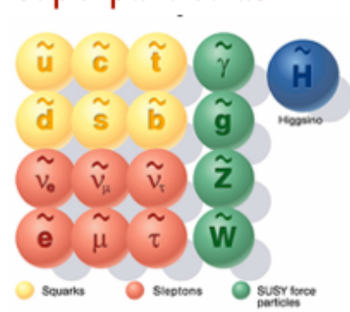
pero nuevas partículas

partículas



$\Rightarrow$

superpartículas



$\underset{B}{\rightsquigarrow}$ . . . . . . $\underset{F}{\text{Fotino}}$

$\underset{F}{\ominus}$ . . . . . . $\underset{B}{\text{Selectrón}}$

Regresamos a

$$g_{\mu\nu} \left\{ \begin{array}{l} \text{Interacción} \\ \text{gravitacional} \end{array} \right.$$

$\vdots$

B si Supersimetría... F

$g_{\mu\nu}$ ... Ψ_μ

sistemas gravitatorios $g_{\mu\nu}$

El UNIVERSO

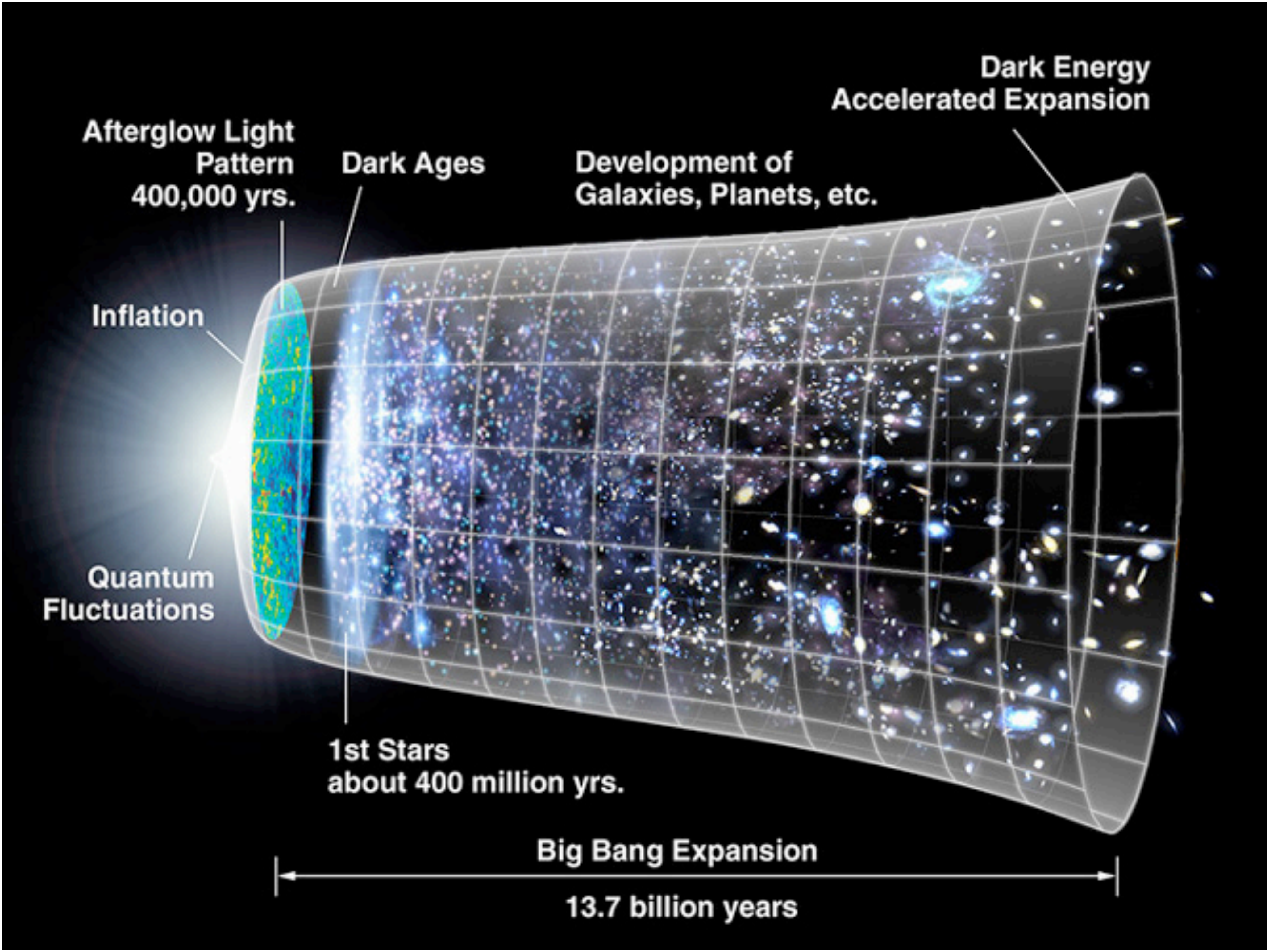
$$\boxed{ds^2 = -dt^2 + a(t)^2 \left[dr^2 + r^2 d\Omega^2\right]}$$

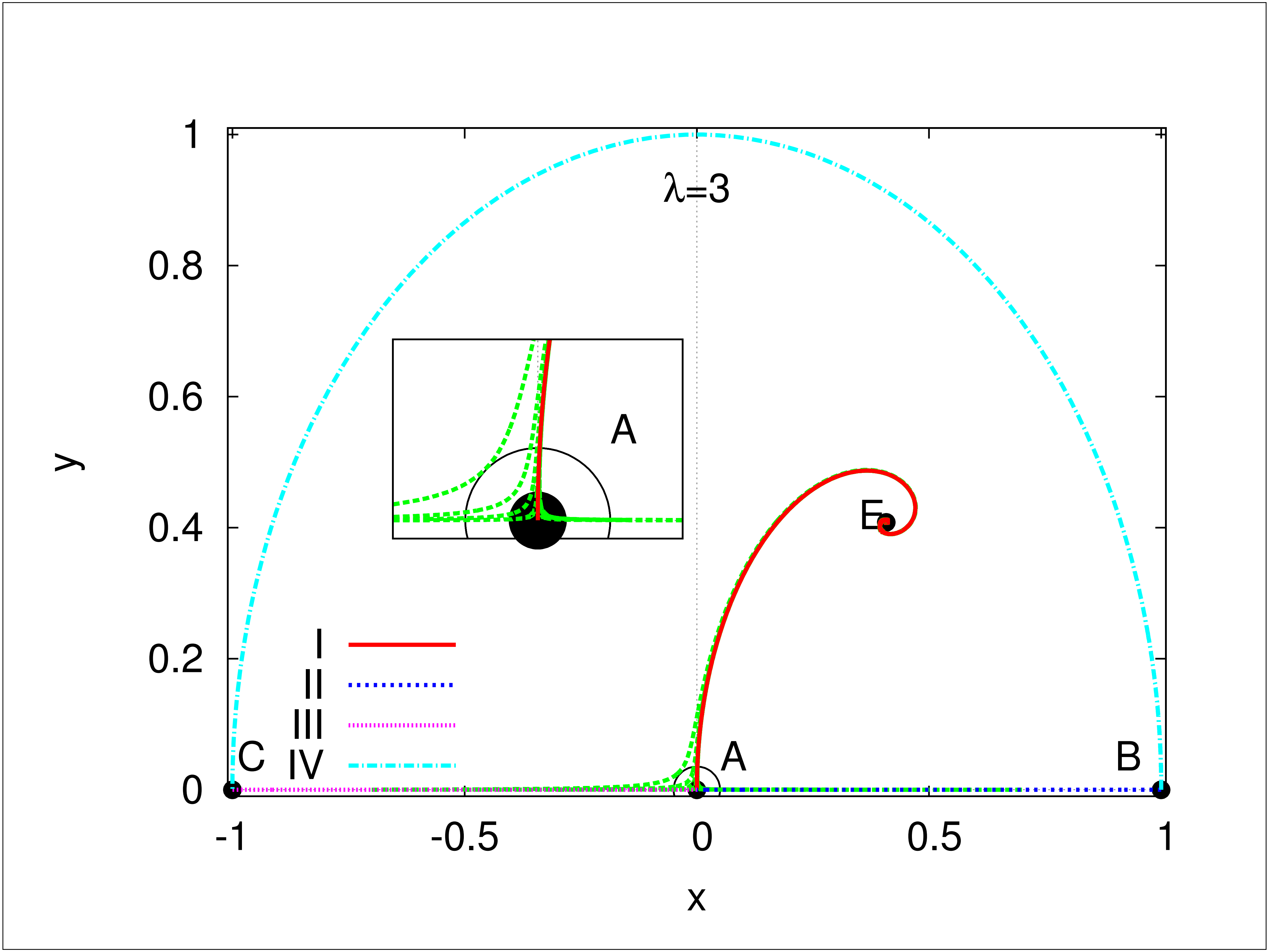
$*\ a(t)$ radio del UNIVERSO

$*$ Además ϕ (o Λ)

"EL SUPERUNIVERSO"

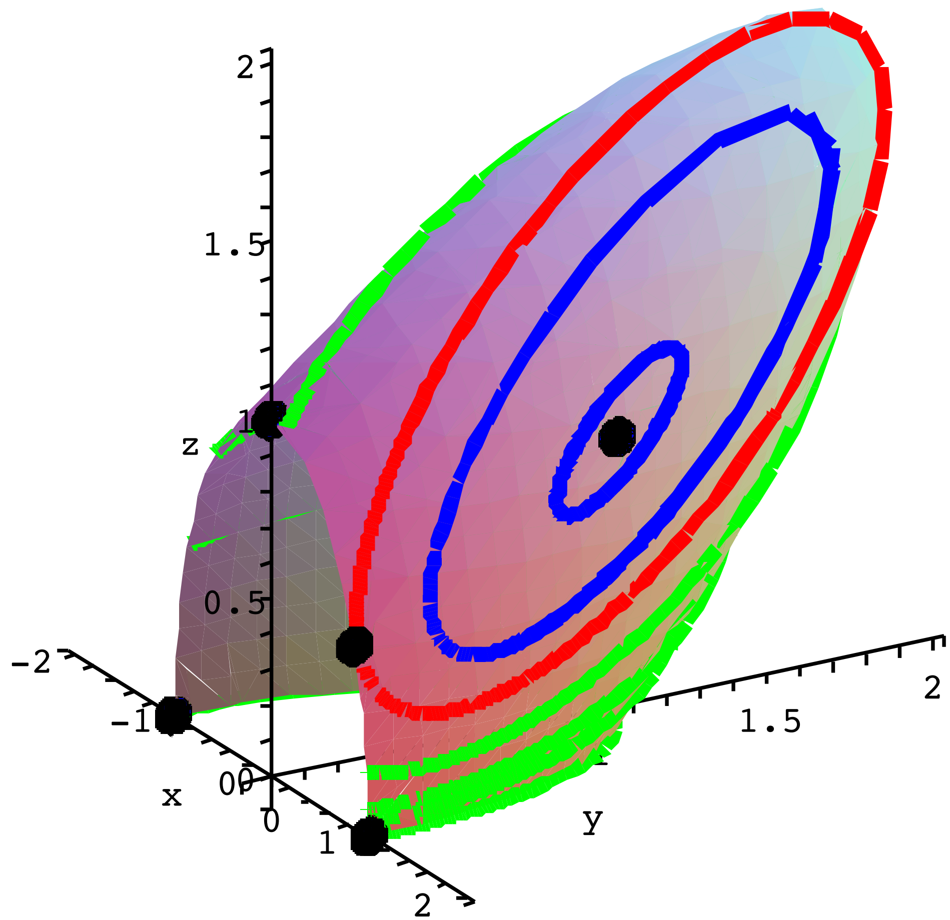
$$(g_{\mu\nu}, \Psi_\mu) \quad \& \quad (\phi, -)$$


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

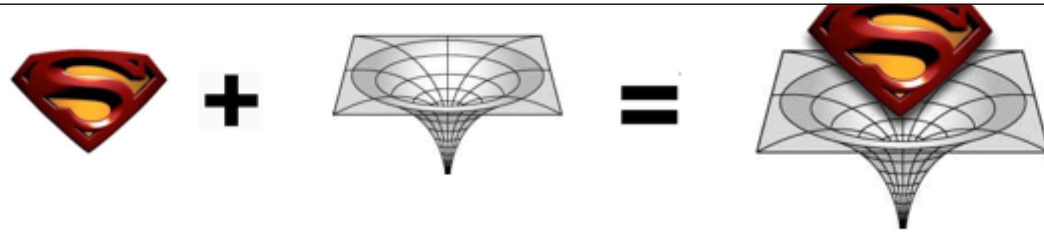


λ=3
A
E
C
A
B
I
II
III
IV
y
x
1
0.8
0.6
0.4
0.2
0
-1
-0.5
0
0.5
1

JCAP 1012:011,2010



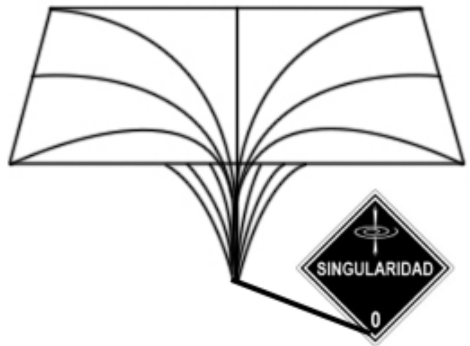
Agujeros negros supersimétricos;



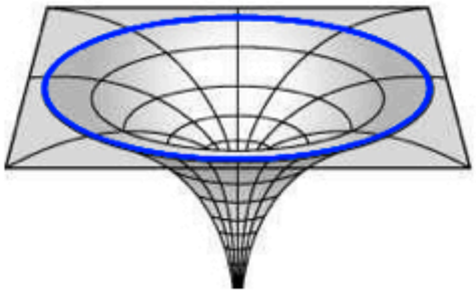
Phys. Rev. D 80, 104020 (2009)

Phys. Rev. D 84, 024015 (2011)

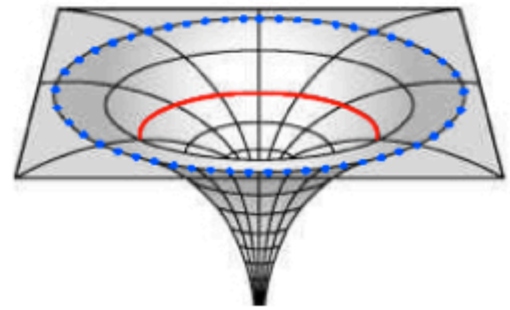
solución general



límite bosonico

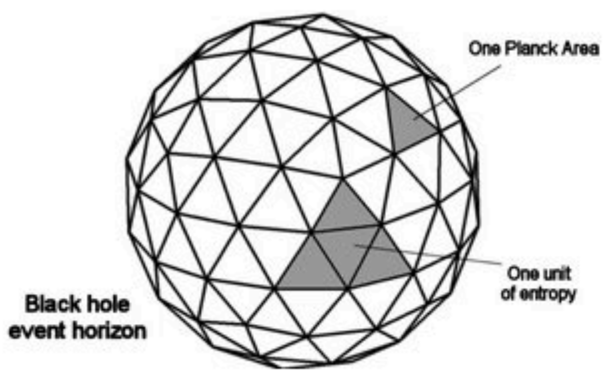


límite fermionico



Entropía

Desde el punto de vista cuántico, los agujeros negros son los objetos con el mayor número posible de microestados (no sabemos aún lo que son) del universo. Su entropía es la máxima posible.



Bekenstein-Hawking

$$S_{bh} \sim m^2$$

Región Supersimétrica

$$S_{bh} \sim M^6$$

Quantum Cosmology in Hořava-Lifshitz Gravity

O. Obregón

Motivation

- Self-consistent framework for quantum gravity
- Applications
    1. Gravity duals (AdS/CFT)
    2. Mathematical (Ricci Flows)

- Reproduce the observed gravitation phenomena

¿How close can we get with this idea?

Additional Motivation

- Unification
- Cosmology and BH
- Problem of time

Hořava Gravity (Minimal Version)

- Power-counting Renormalizable

Ingredients

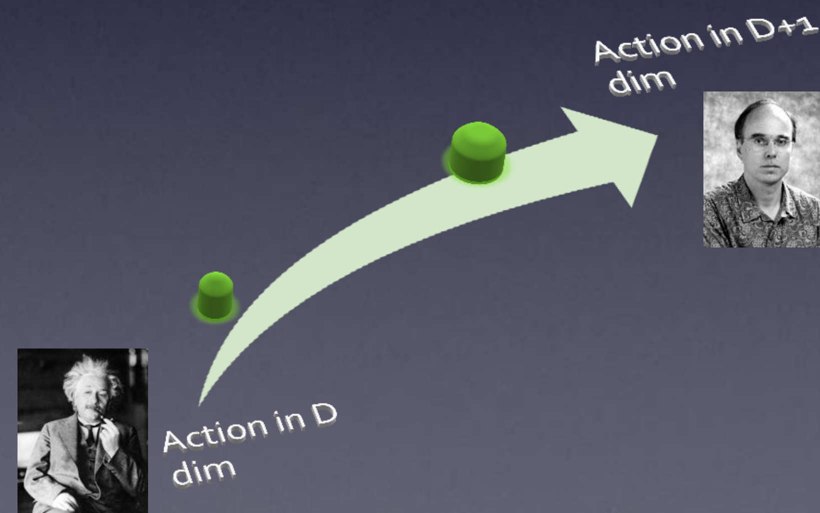
- Anisotropic Scaling

$$\mathbf{x} \to b\mathbf{x}, \qquad t \to b^z t.$$

- Symmetries - Diff$_F$(M)

$$\tilde{x}^i = \tilde{x}^i(x^i, t), \quad \tilde{t} = \tilde{t}(t)$$

- Projectable metric $N = N(t)$
- ***Detailed Balance***



Gravity with Anisotropic Scaling

The Action:

$$S = \frac{1}{2}\int dt d^D\mathbf{x}\left\{(\dot{\phi})^2 - \mathcal{V}\right\}$$

Kinetic term

- Quadratic in first time derivatives of g_{ij}
- Invatiant under $\mathrm{Diff}_F(M)$

$$S_K = \frac{2}{\kappa^2}\int dt d^3x\sqrt{g}N(K_{ij}K^{ij} - \lambda K^2)$$

$$[\kappa] = \frac{z-3}{2}$$

Potential term

- Of order 2z in spatial derivatives of g_{ij}
- Invariant under $\mathrm{Diff}_F(M)$

$$S_V = \frac{\kappa^2}{2}\int dt d^3x\sqrt{g}N\mathcal{V}(R_{ijkl})$$

$$(\text{dim } 6): R^3, \quad RR_{ij}R^{ij}, \quad R^i{}_jR^j{}_kR^k{}_i$$
$$R\nabla^2R, \quad \nabla_iR_{jk}\nabla^iR^{jk}$$

$$(\text{dim } 4): R^2, \; R^{ij}R_{ij},$$

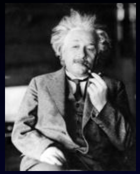
$$(\text{dim } 2): R,$$

$$(\text{dim } 0): 1$$

Detailed Balance

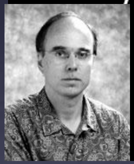
$$\mathcal{V} = \frac{\delta W}{\delta g_{ij}} \mathcal{G}_{ijkl} \frac{\delta W}{\delta g_{kl}}$$

Action in 3 dim



$$W = \frac{1}{w^2} \int_{\Sigma} \omega_3(\Gamma) + \mu \int d^3\mathbf{x} \sqrt{g}(R - 2\Lambda_W) \longrightarrow \frac{1}{\sqrt{g}} \frac{\delta W}{\delta g_{ij}} = \frac{2}{w^2} C^{ij} - \mu \bar{G}^{ij}$$

Action in 3+1 dim



$$S = \int dt d^3\mathbf{x} \sqrt{g} N \left\{ \frac{2}{\kappa^2} (K_{ij}K^{ij} - \lambda K^2) - \frac{\kappa^2}{2w^4} C_{ij}C^{ij} + \frac{\kappa^2 \mu}{2w^2} \varepsilon^{ijk} R_{il} \nabla_j R^l_k + \frac{\kappa^2 \mu^2}{8(1-3\lambda)} \left[\frac{1-4\lambda}{4} R^2 - (1-3\lambda) R_{ij} R^{ij} + \Lambda_W R - 3\Lambda_W^2 \right] \right\}.$$

κ, λ, μ. w and Λ_W are coupling constants, and comparing the terms in **yellow** with GR

$$c = \frac{\kappa^2 \mu}{4} \sqrt{\frac{\Lambda_W}{1-3\lambda}}, \qquad G_N = \frac{\kappa^2}{32\pi c}, \qquad \Lambda = \frac{3}{2}\Lambda_W, \qquad \lambda = 1$$

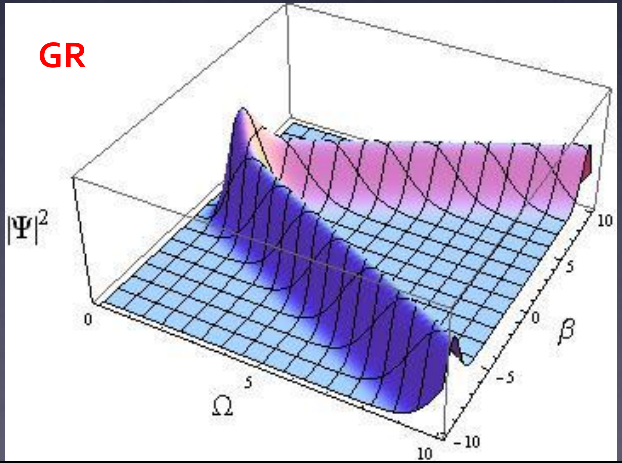
Kantowski-Sachs Quantum Cosmological Model

Misner parametrization

$$ds^2 = -N(t)^2 dt^2 + e^{2\sqrt{3}\beta(t)} dr^2 + e^{-2\sqrt{3}\beta(t) - 2\sqrt{3}\Omega(t)}(d\theta^2 + \sin^2\theta d\varphi^2)$$

Wheeler-DeWitt Equation

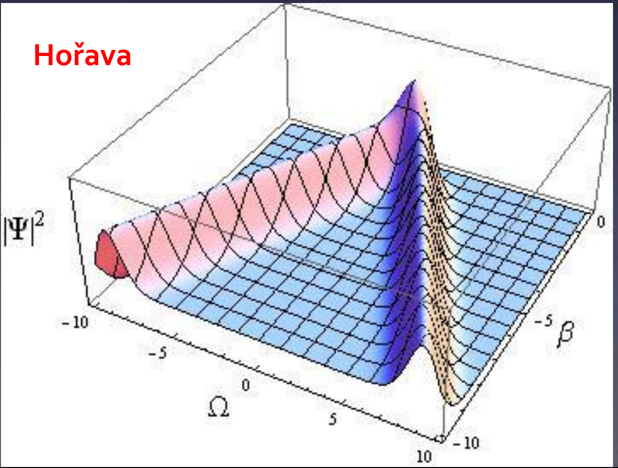
$$\Big\{ -(2\lambda - 1)\frac{\partial^2}{\partial\beta^2} + 2(\lambda - 1)\frac{\partial}{\partial\beta}\frac{\partial}{\partial\Omega} - \frac{1}{2}(\lambda - 3)\frac{\partial^2}{\partial\Omega^2} + 3\mu^2 e^{-2\sqrt{3}\Omega}\left[2\Lambda_W - 3\Lambda_W^2 e^{-2\sqrt{3}\beta - 2\sqrt{3}\Omega} + (2\lambda - 1)e^{2\sqrt{3}\beta + 2\sqrt{3}\Omega}\right]\Big\}\psi(\beta, \Omega) = 0$$



$$\psi_\nu^\pm(\beta, \Omega) = e^{\pm i\nu\sqrt{3}\beta} K_{i\nu}(4e^{-\sqrt{3}\Omega})$$

$$\beta \longrightarrow \Omega$$

$$\Omega \longrightarrow -\beta$$



$$\psi_\nu(\beta, \Omega) = e^{\pm i\nu\sqrt{3}\Omega} K_{i\nu}(\mu e^{\sqrt{3}\beta})$$

WKB Approximation

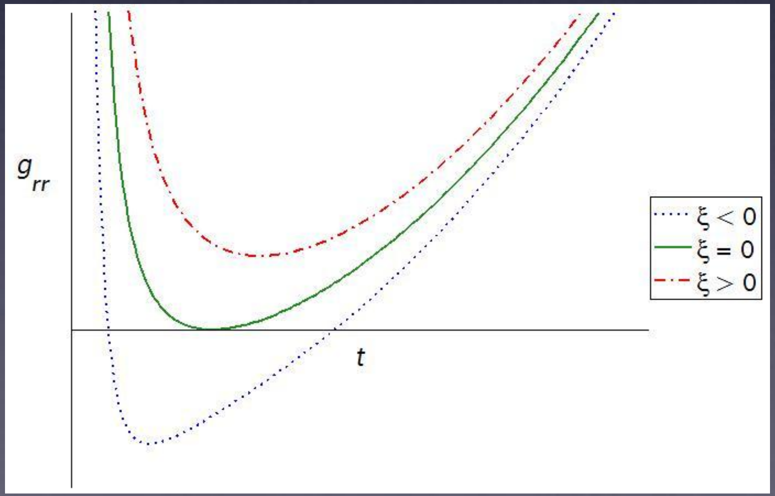
$$ds^2 = -\left(\frac{\Lambda t^2}{3} + \frac{2\xi}{t} + \frac{3}{4\Lambda t^2} - 1\right)^{-1} dt^2 + \left(\frac{\Lambda t^2}{3} + \frac{2\xi}{t} + \frac{3}{4\Lambda t^2} - 1\right) dr^2 + t^2 d\Omega^2$$

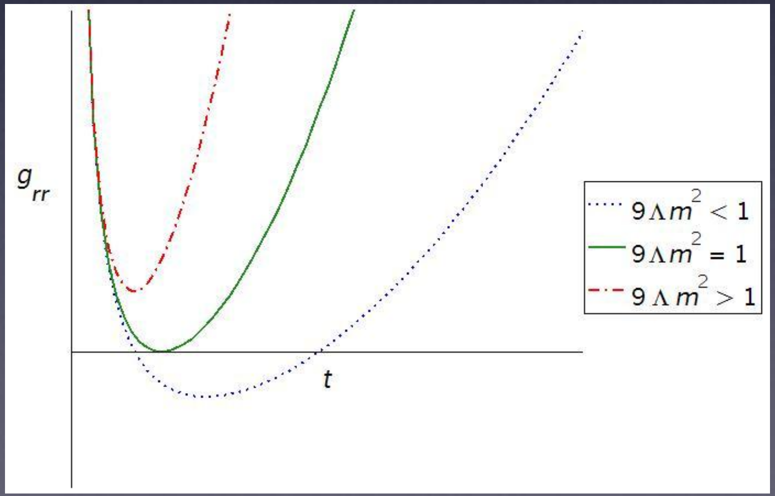
SdS (Hořava)

- Singularity $t = 0$
- $\xi > 0$, non-singular
- $\xi = 0$, $t_s = \sqrt{\frac{3}{2\Lambda}}$ (singularity)
- $\xi < 0$, 2 singularities

SdS (GR)

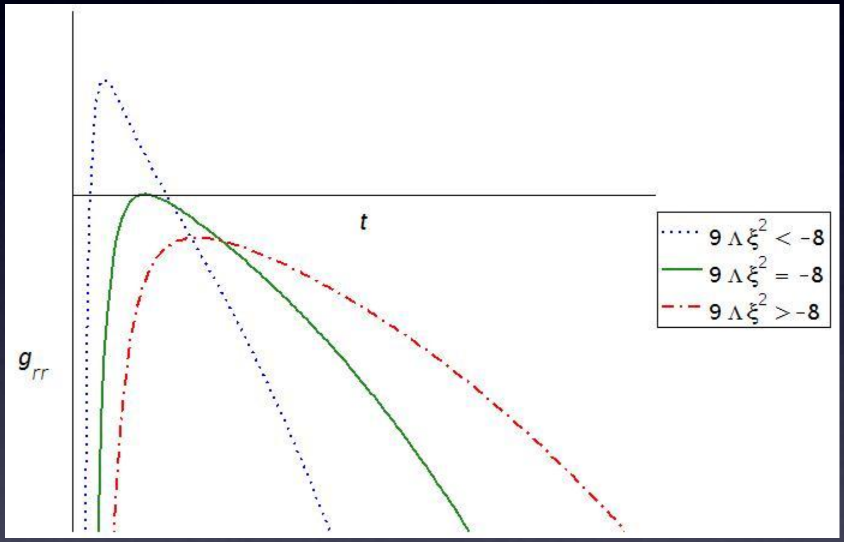
- Singularity $t = 0$
- $m = 0$, $t_h = \sqrt{\frac{3}{\Lambda}}$ (horizon)
- 2 horizons with $0 < \Lambda m^2 < \frac{1}{9}$





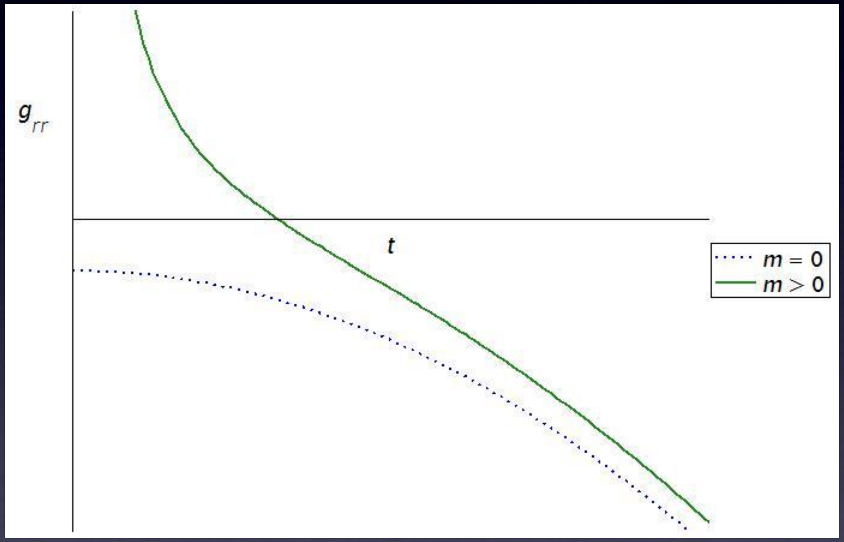
SAdS (Hořava)

- Singularity $t = 0$
- $-8 > 9\Lambda\xi^2$, 2 singularities
- $-8 \leq 9\Lambda\xi^2 \leq 0$, unphysical



SAdS (GR)

- Singularity $t = 0$
- $m > 0$, 1 Horizon
- $m < 0$, Unphysical



Results available in...

- **Quantum cosmology in Horava-Lifshitz gravity**

  Phys. Rev. D 86, 063502 (2012)

- A quantum cosmological model in Horava-Lifshitz gravity

  AIP Conf. Proc. 1396, pp. 151-155 (2011)