Gravity-induced Vacuum Dominance:
an Overview

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Support: FAPESP

■ VACUUM ENERGY

Vacuum: the "emptiest" state

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In classical physics

Complete absence of particles and radiation

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In Relativistic Quantum Physics

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- Fields (not particles) are the fundamental building blocks;
- Particles are only excitations of field modes (not even observer independent — Unruh effect)

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In this scenario:

Vacuum state of field Φ

$\Downarrow$

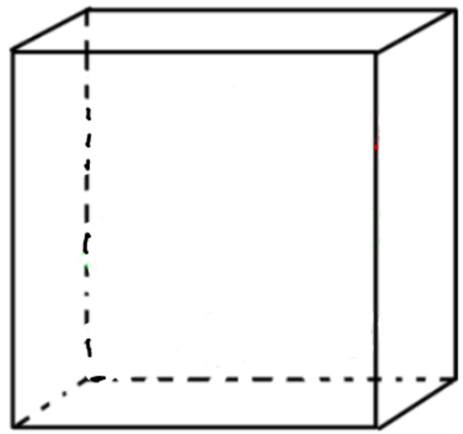
No excitations

$\Downarrow$

All field modes in their ground state

VACUUM ENERGY

- Field in a box



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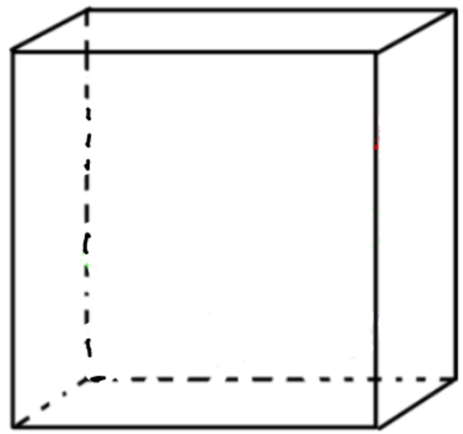
• Field in a box

Classical field : $(-\Box + m^2)\Phi = 0$

$$\Phi = \sum_{\mathbb{k}} q_{\mathbb{k}}(t)\, S_{\mathbb{k}}(\mathbb{x})$$



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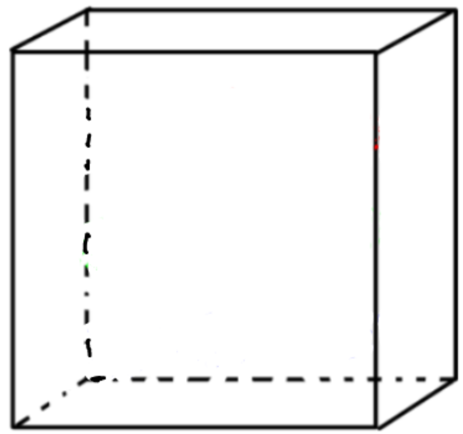

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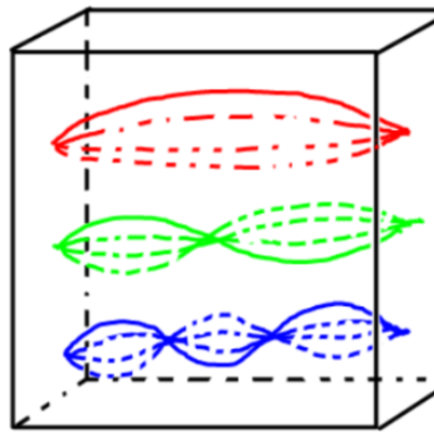

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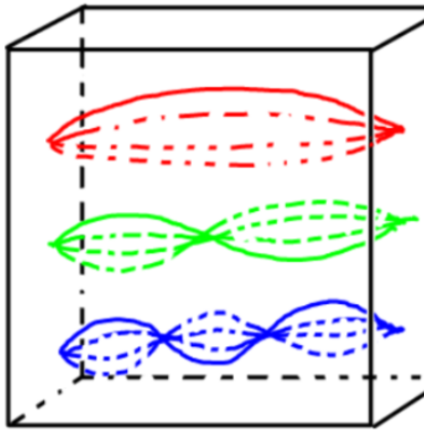

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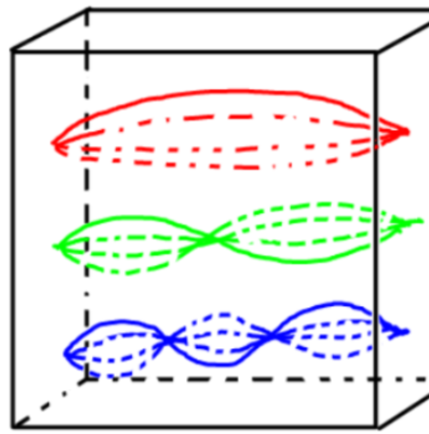

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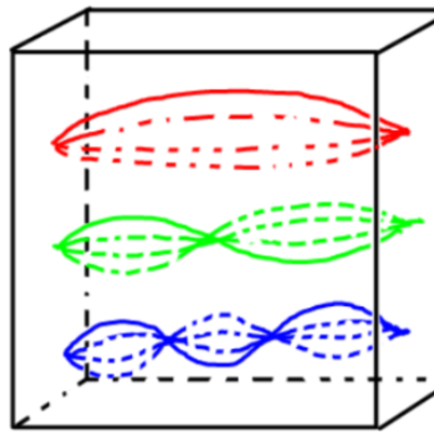

(Free) Field ⟷ Collection of Harmonic Oscillators (one for each mode)

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Quantize the field $\longrightarrow$ Collection of quantized harmonic oscillators

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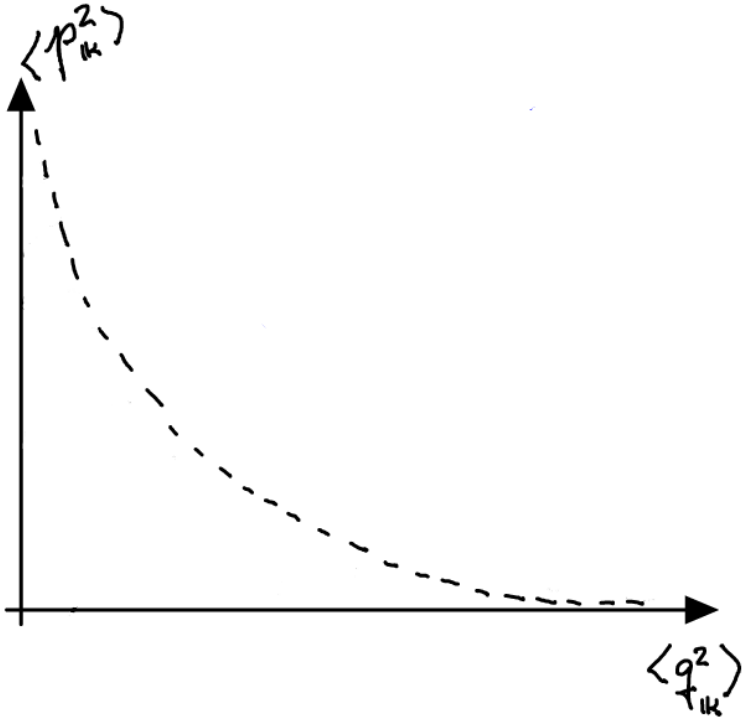

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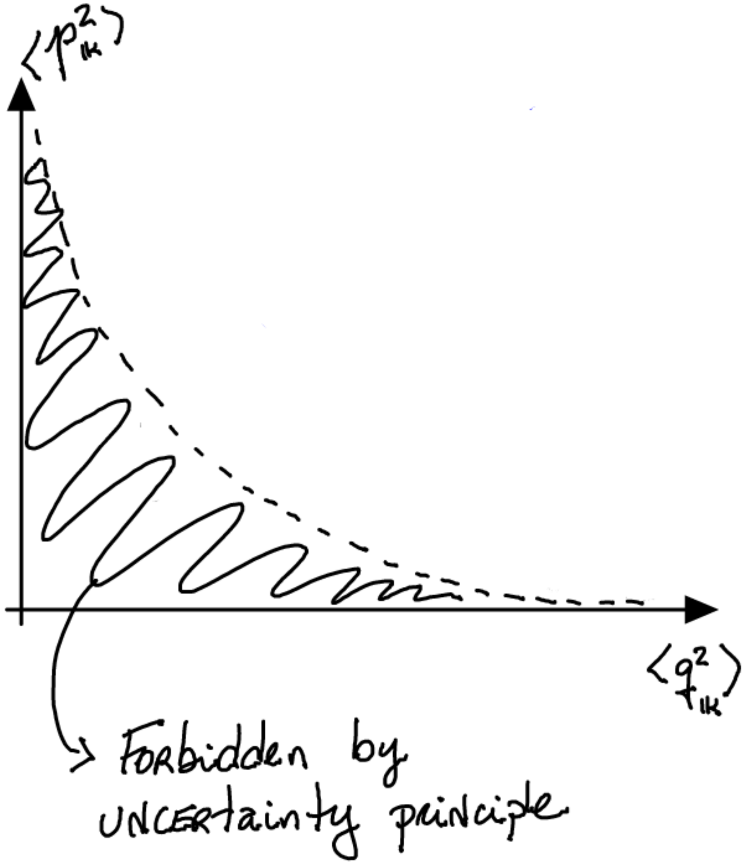

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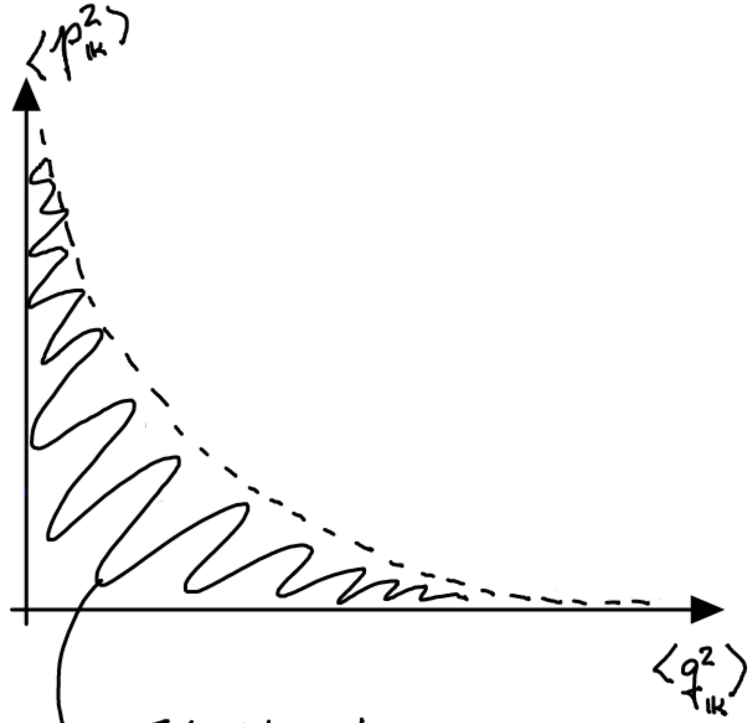

Forbidden by uncertainty principle

Energy stored in each mode:

$$\langle \mathcal{E}_{\mathbf{k}}\rangle = \frac{\langle p_{\mathbf{k}}^2\rangle}{2} + \frac{\omega_{\mathbf{k}}^2}{2}\langle q_{\mathbf{k}}^2\rangle$$

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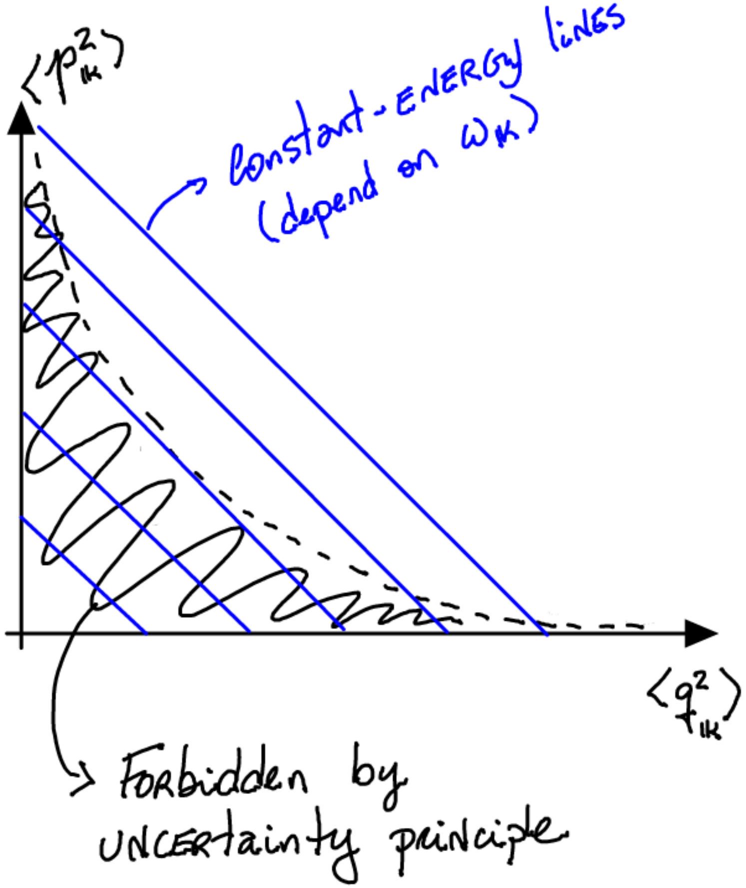

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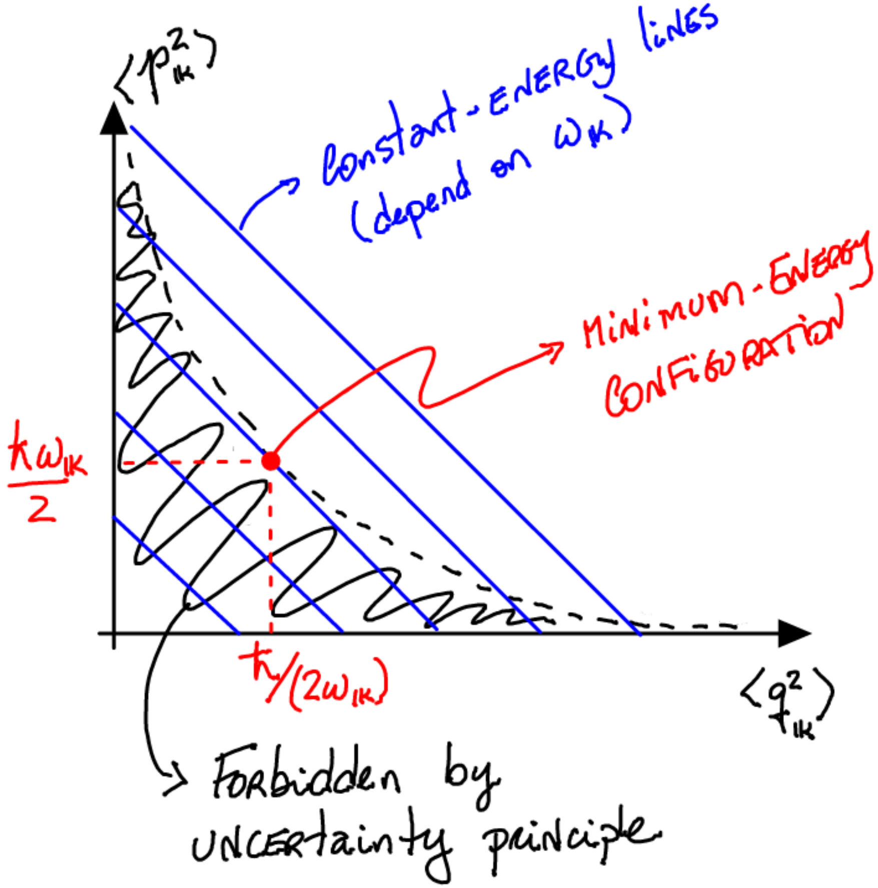

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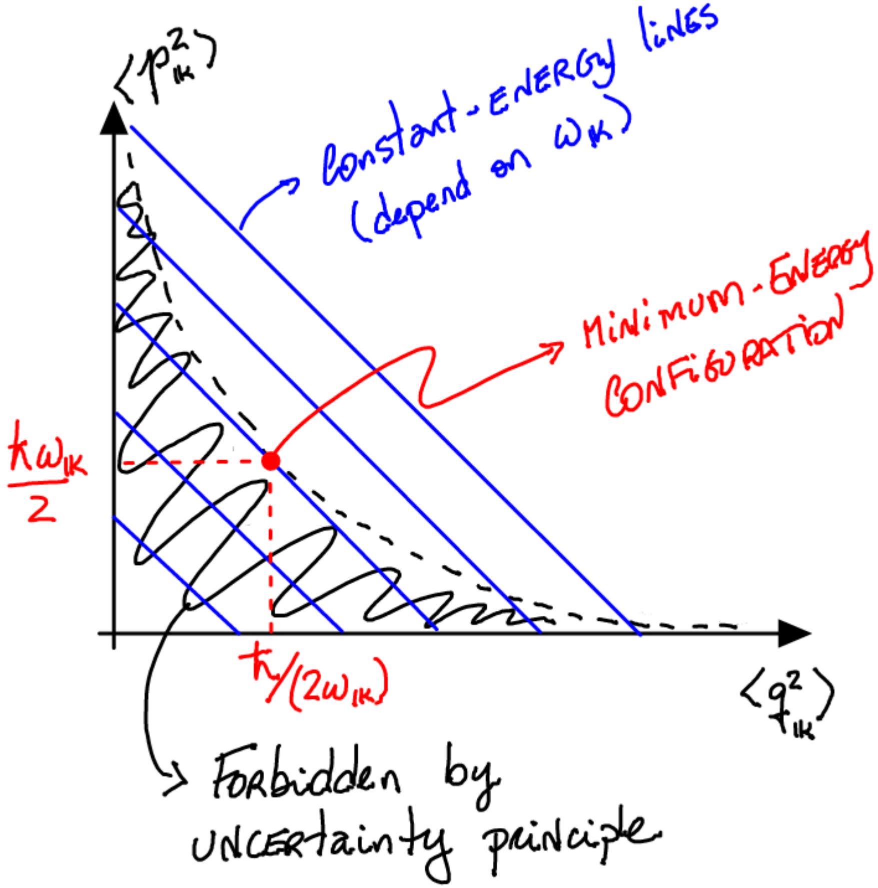

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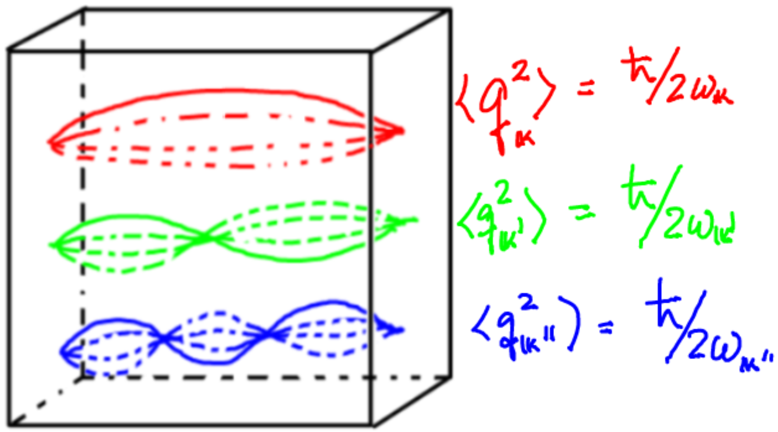

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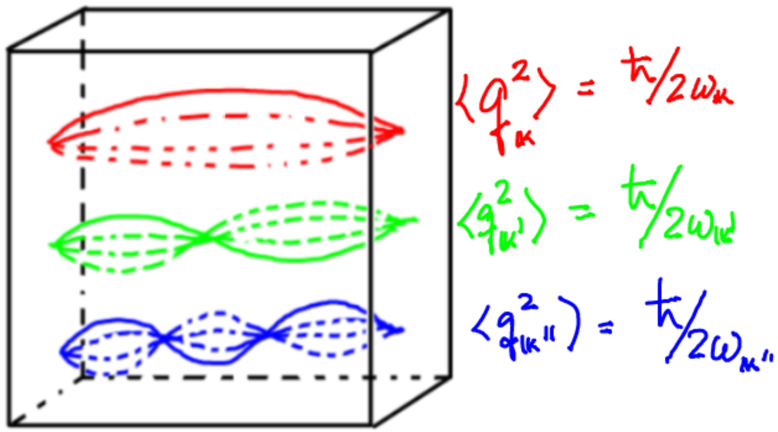

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$$\langle \mathcal{E}_{\mathbf{k}}\rangle_{min} = \frac{\hbar\omega_{\mathbf{k}}}{2} \Longrightarrow \mathcal{E}_{min} = \sum_{\mathbf{k}} \langle \mathcal{E}_{\mathbf{k}}\rangle_{min} = \infty \text{ (due to high-frequency modes)}$$

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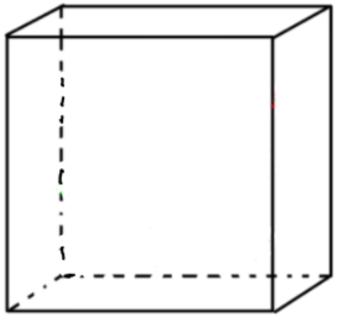
Compare with

$\rho_{CMB} \sim 10^{-27}\ g/cm^3$

Vacuum energy in curved spacetimes



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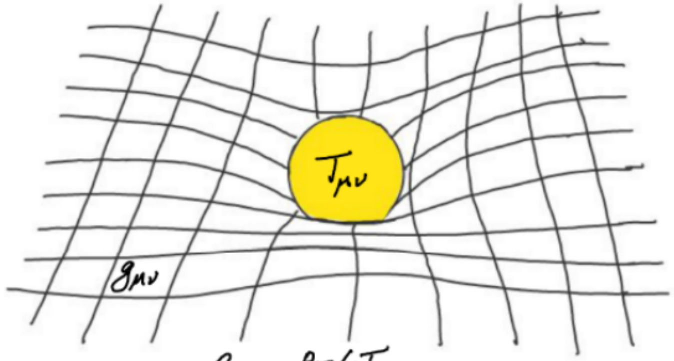

$$G_{\mu\nu} = 8\pi G T_{\mu\nu}$$

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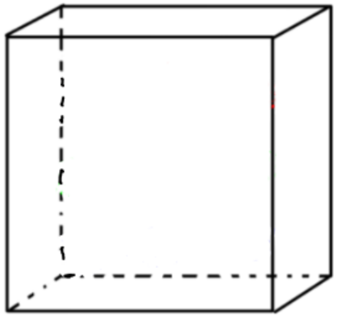

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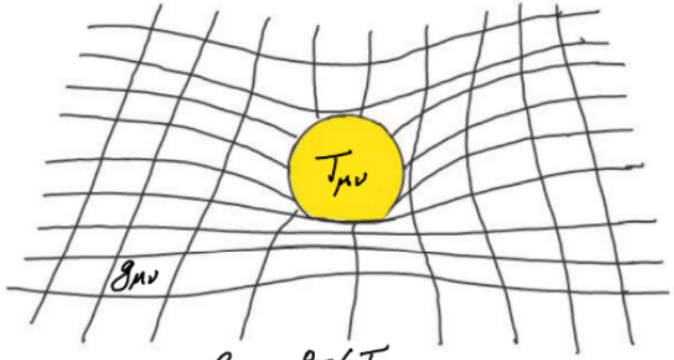

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Boundary conditions on the field Φ → Background-geometry influence on the field Φ:

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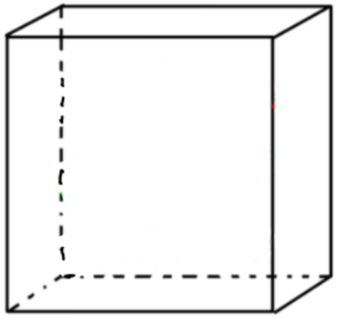

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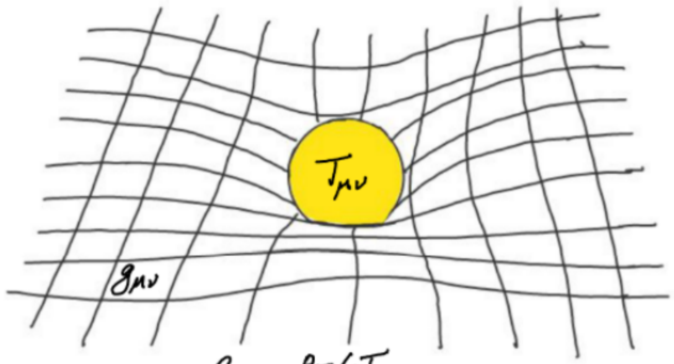

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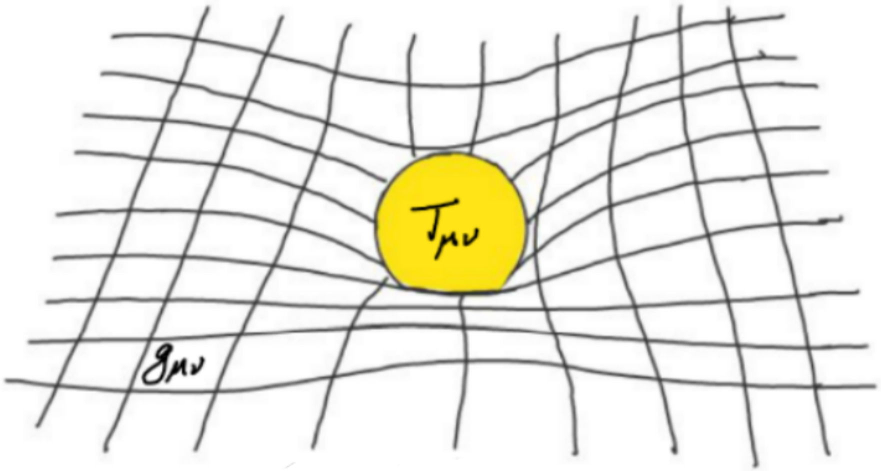

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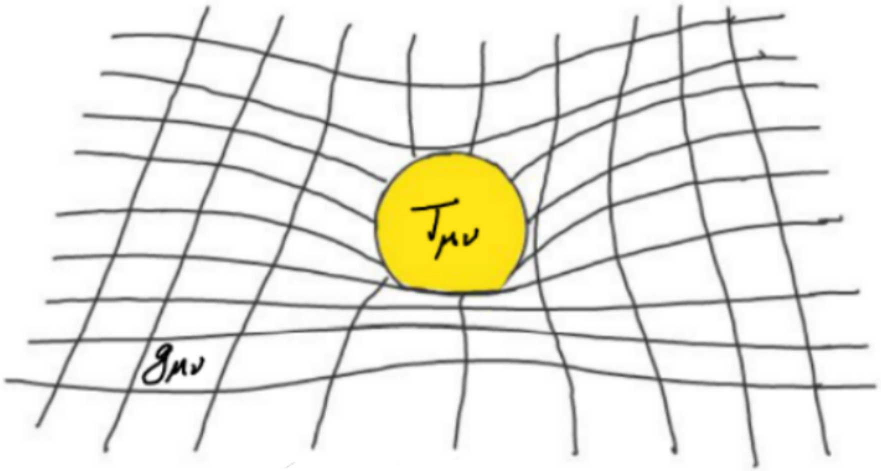

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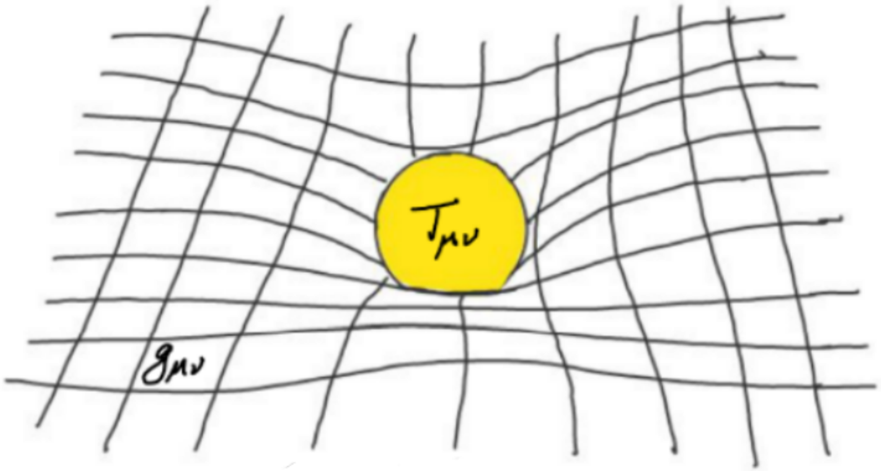

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Eigenfunctions of an elliptic (usually positive) dif. operator with eigenvalues ω_α^2

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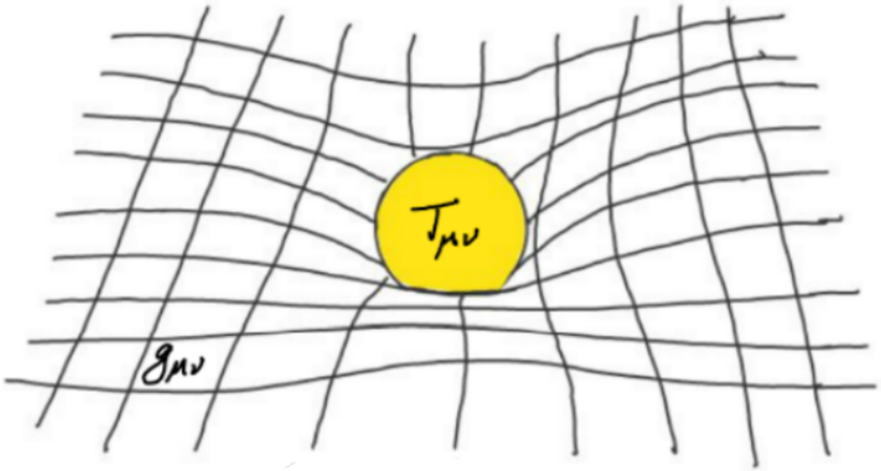

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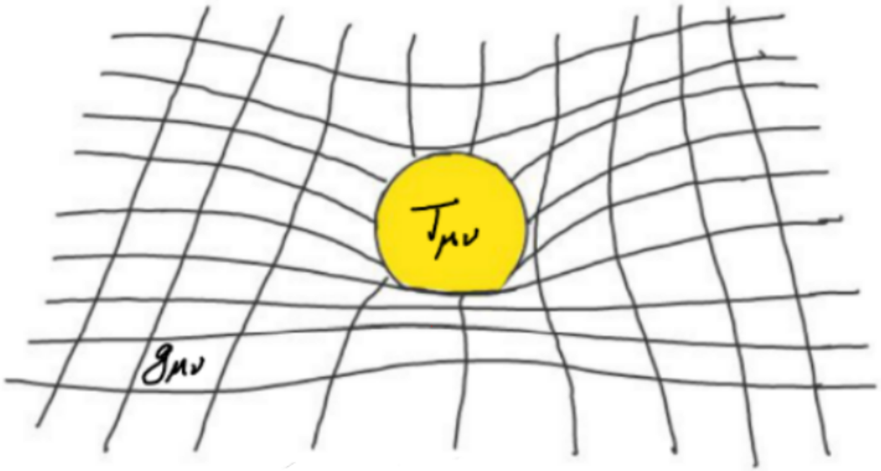

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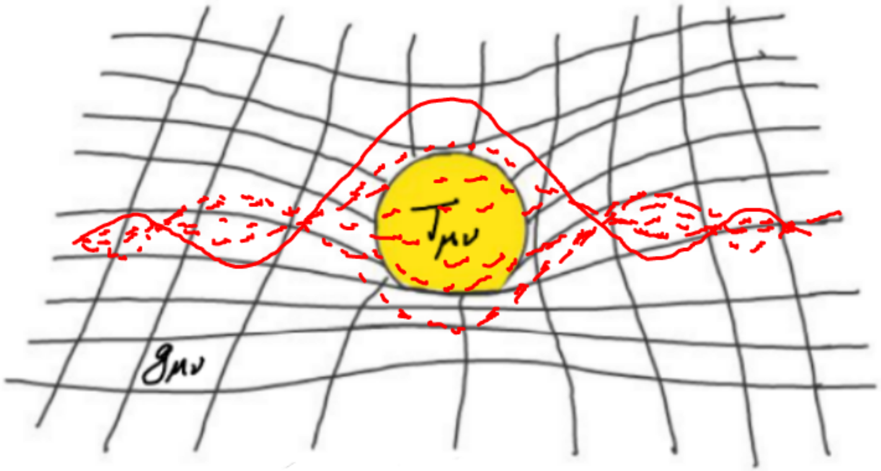

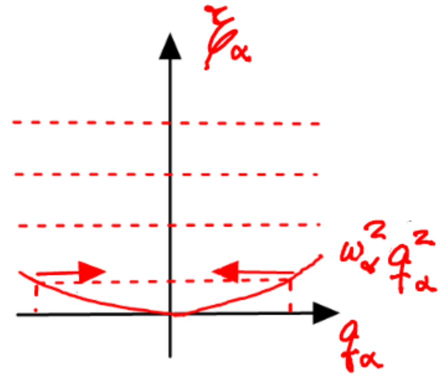

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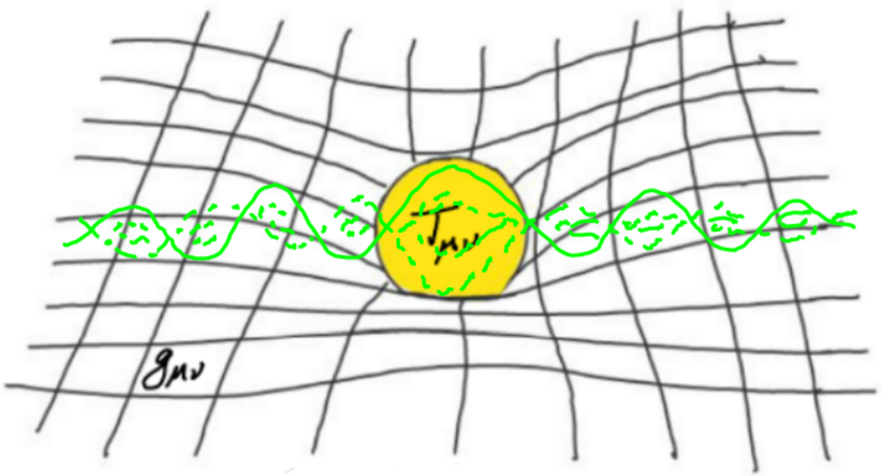

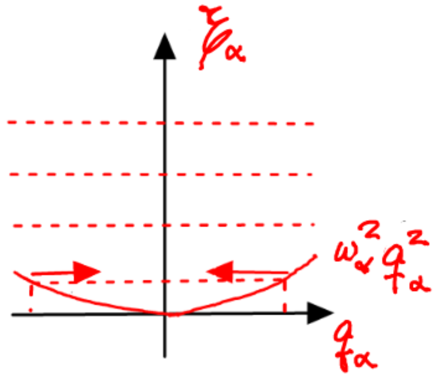

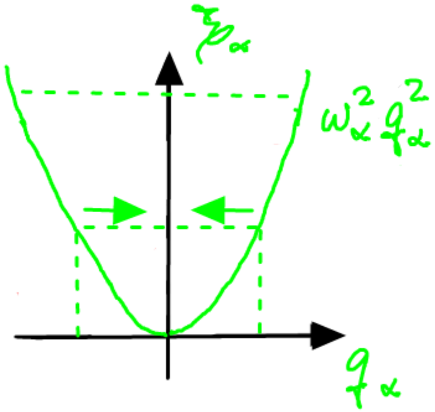

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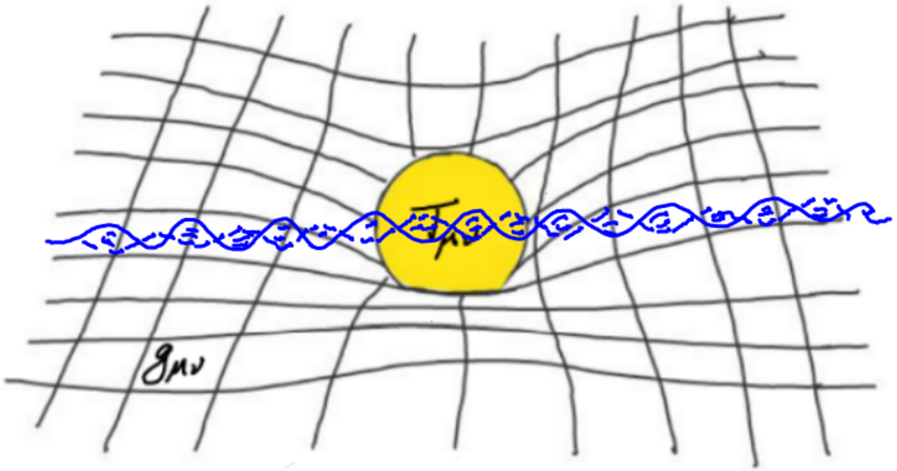

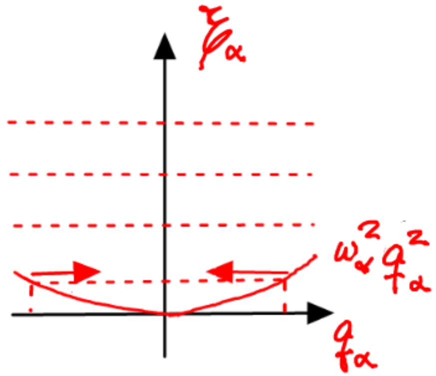

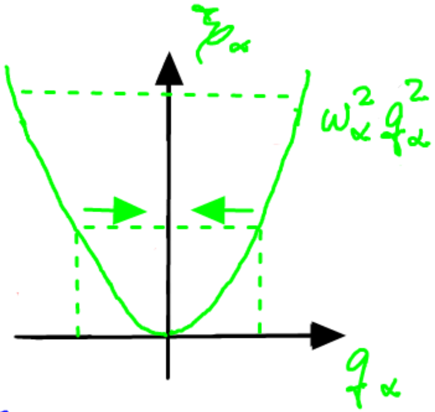

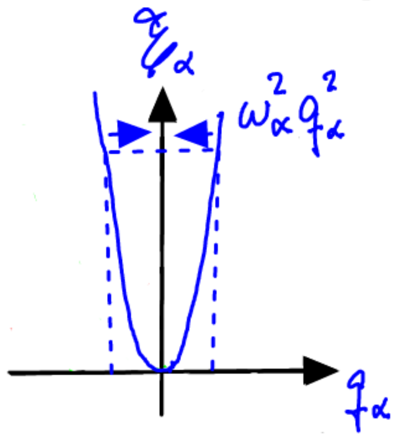

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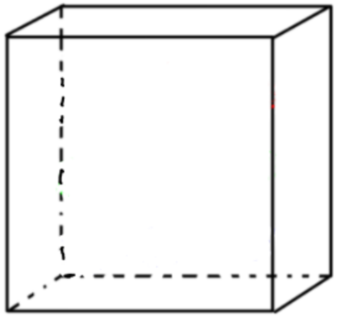

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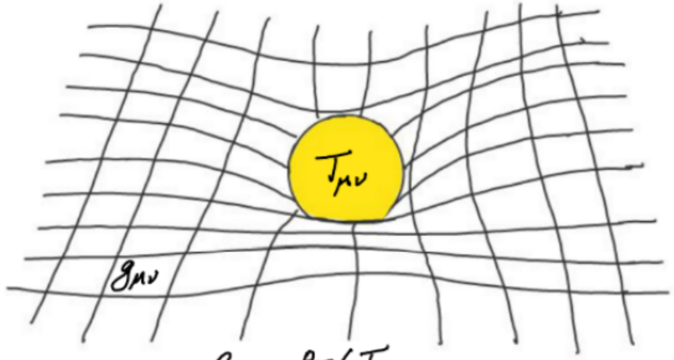

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Boundary conditions on the field Φ

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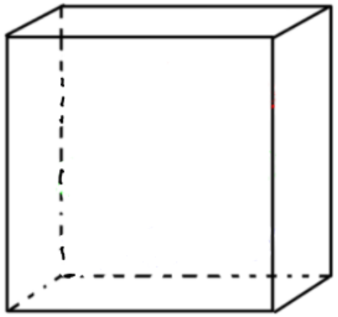

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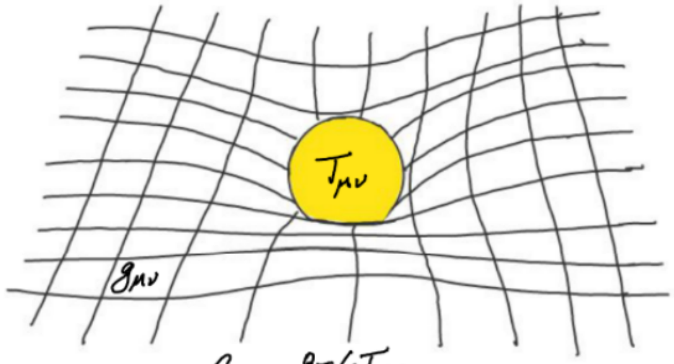

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(Naive) Infinite-constant subtraction scheme

Point-splitting renormalization (infinite renormalization of cosmological constant, Newton's constant, and quadratic-curvature constants — for free fields)

Vacuum energy in curved spacetimes

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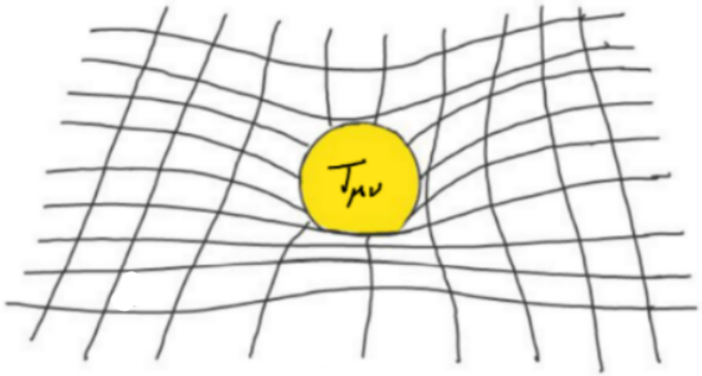

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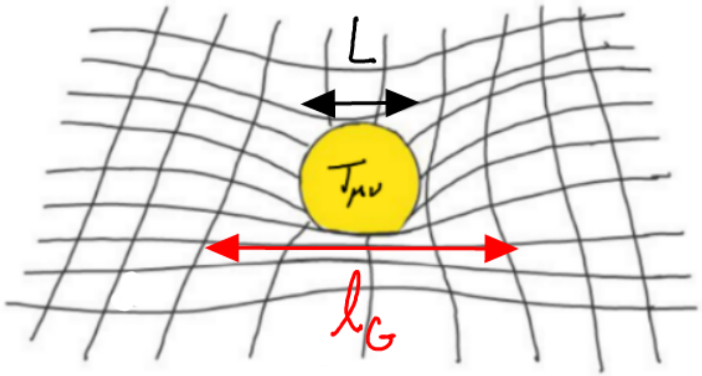

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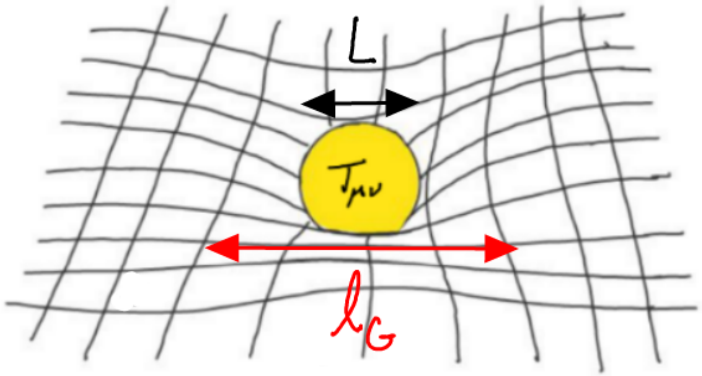

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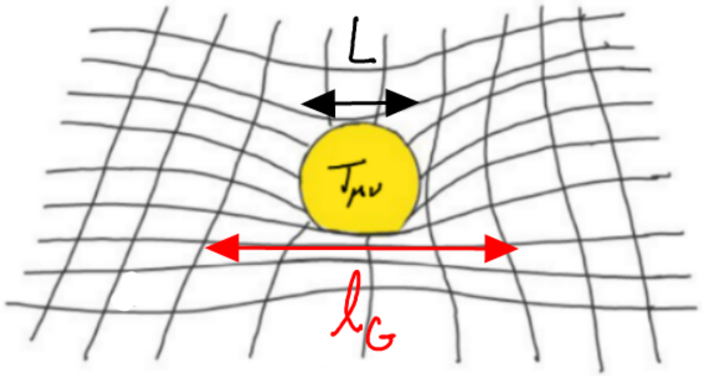

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However...

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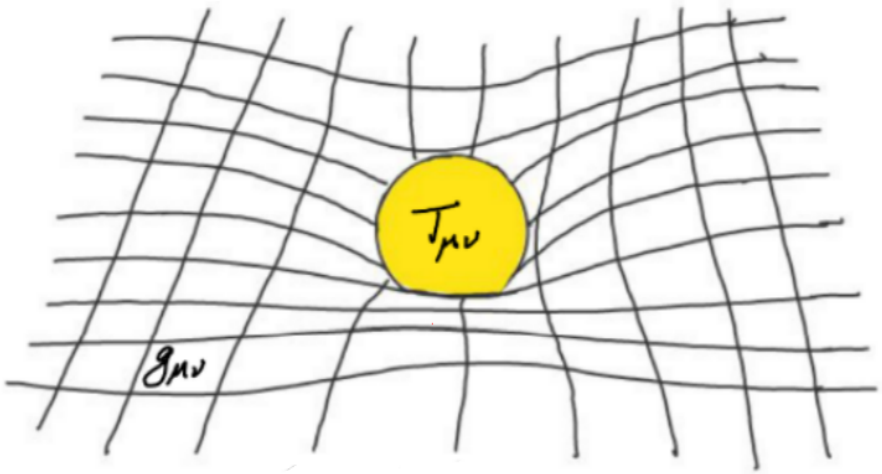

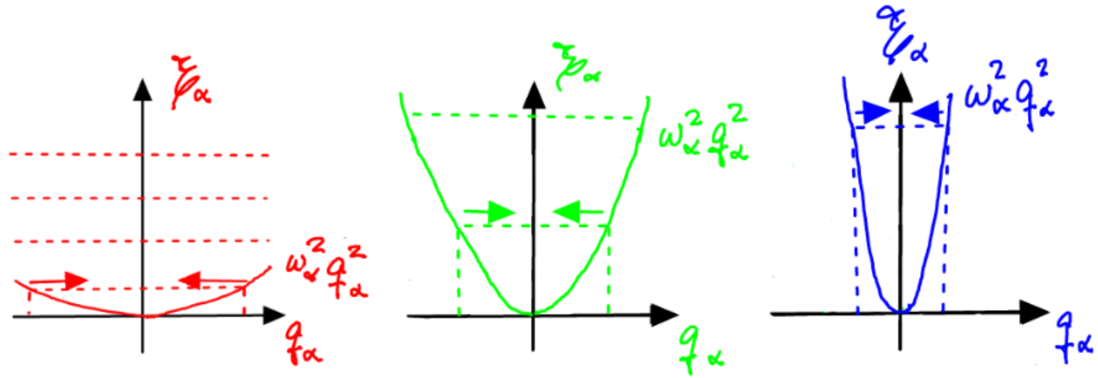

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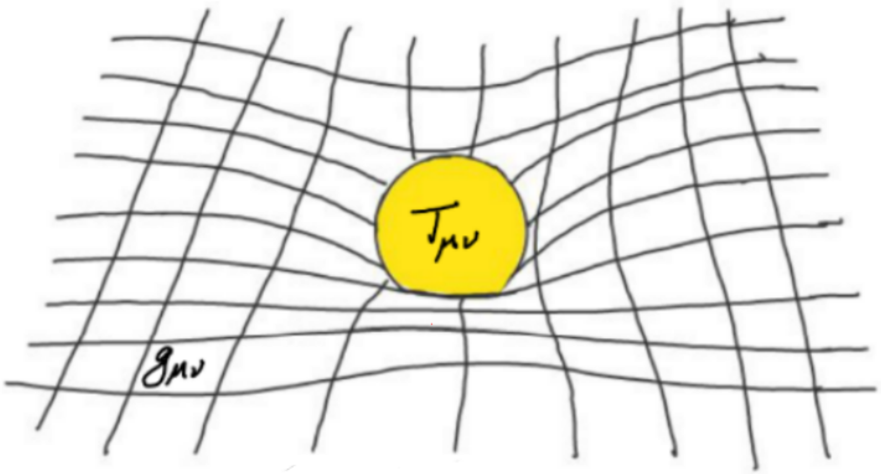

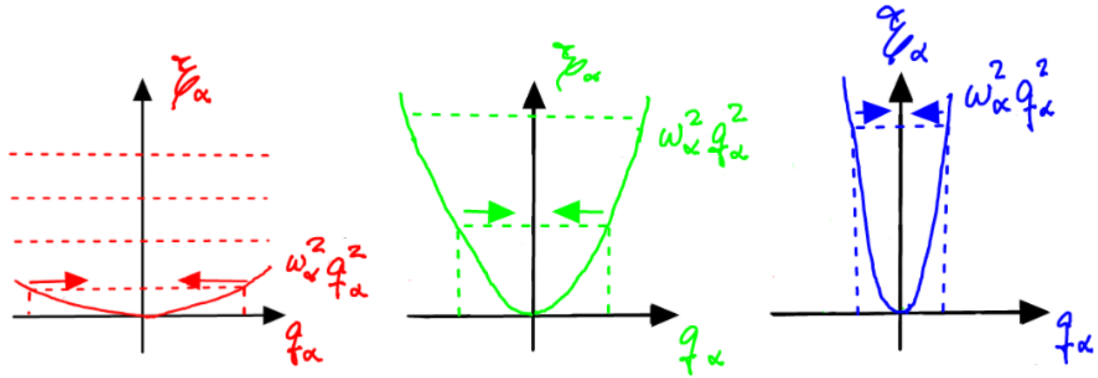

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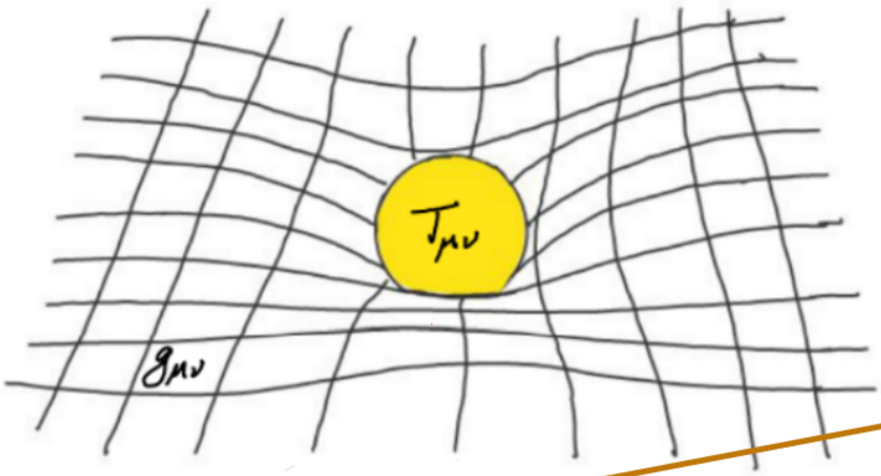

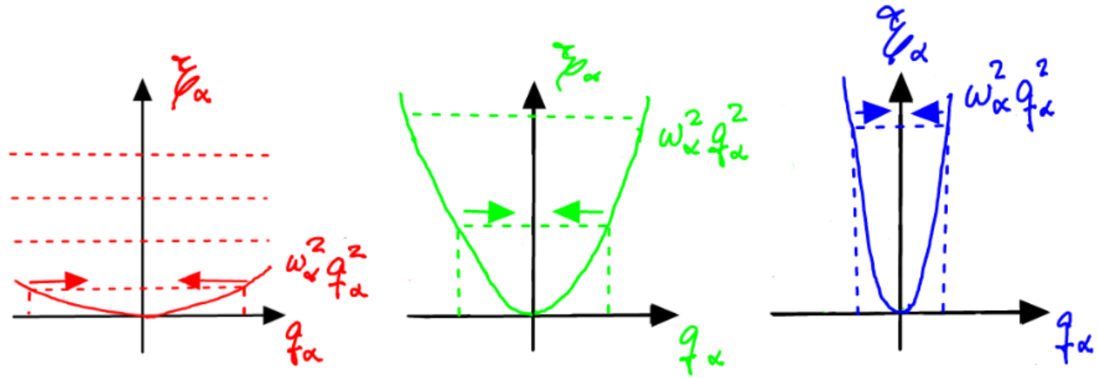

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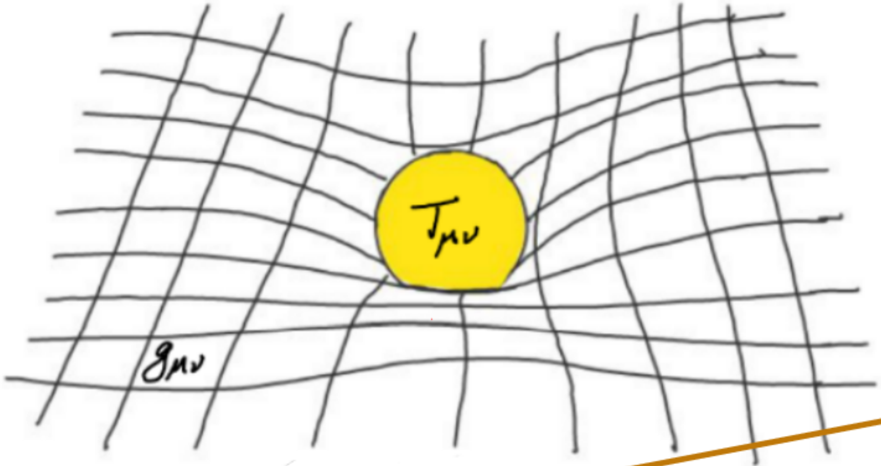

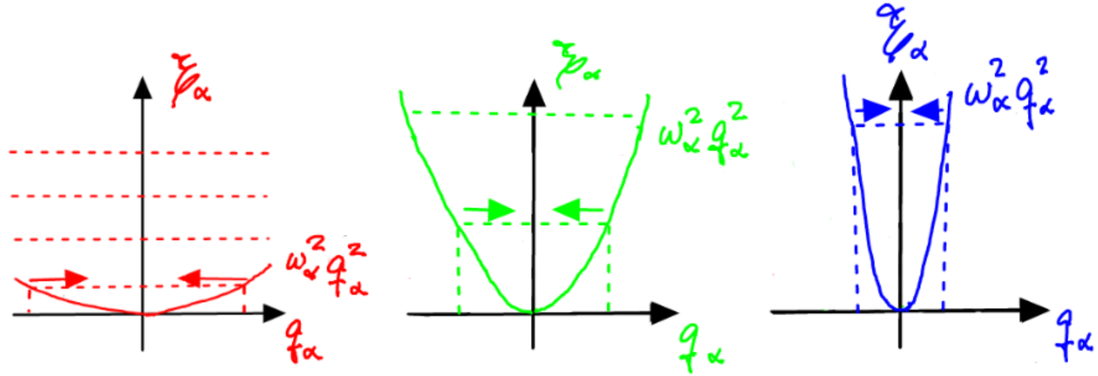

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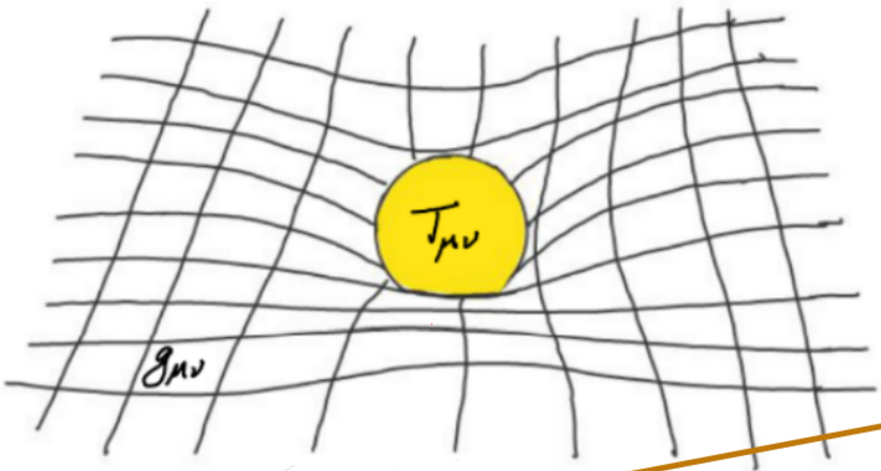

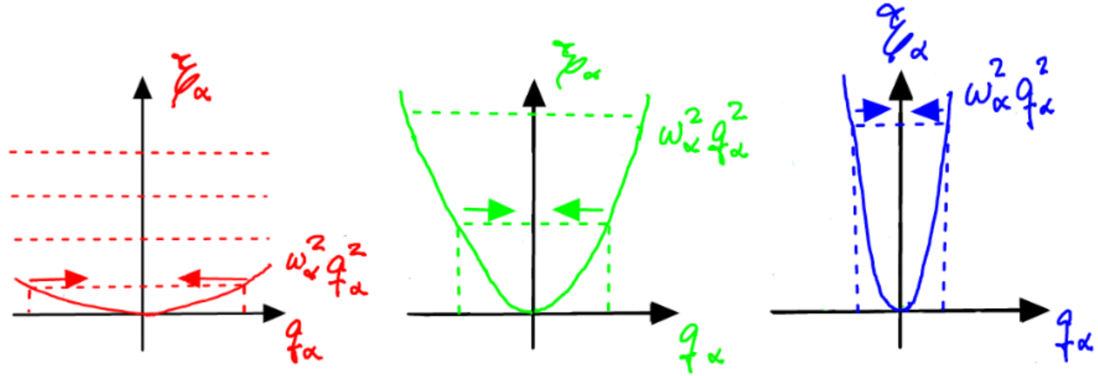

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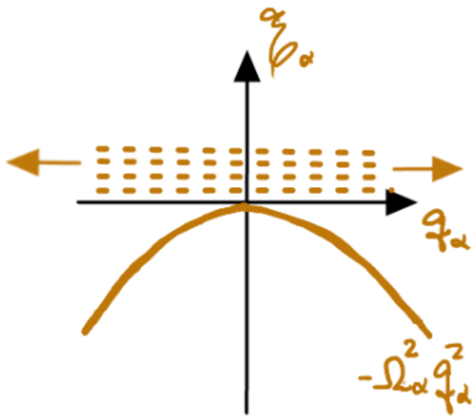

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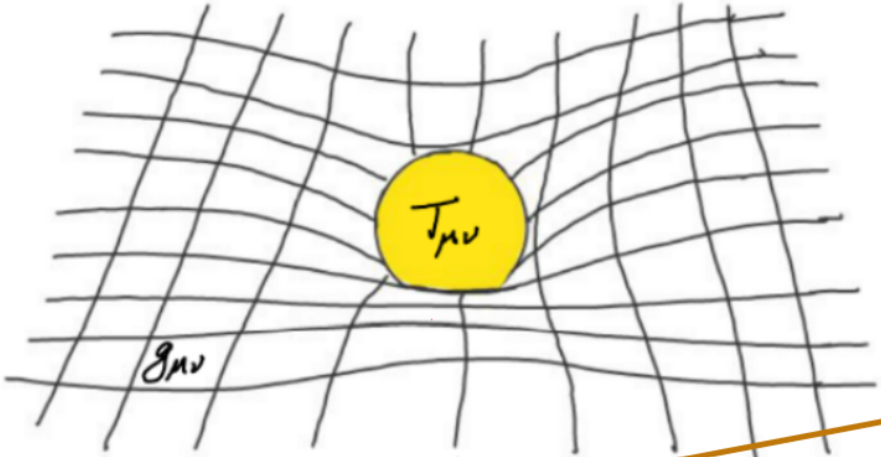

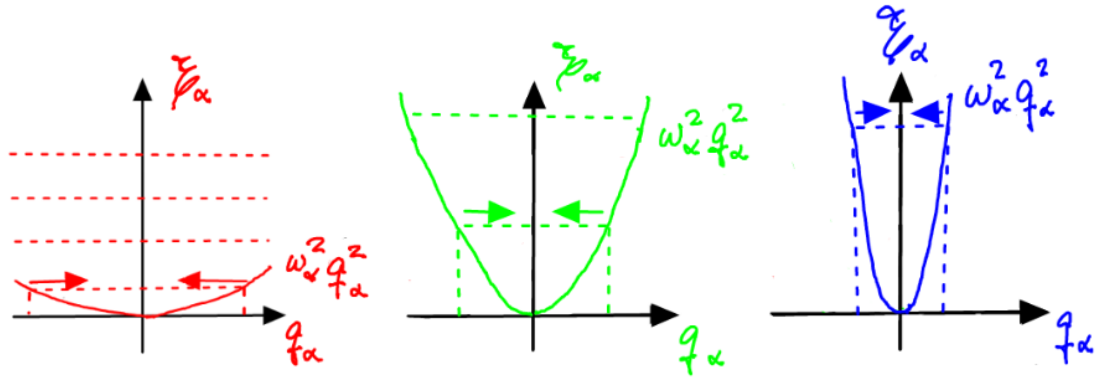

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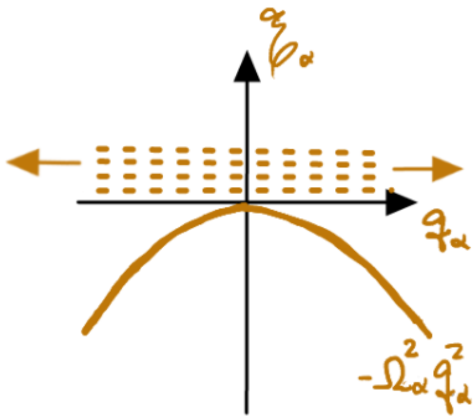

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UNSTABLE (TACHYONIC) MODE

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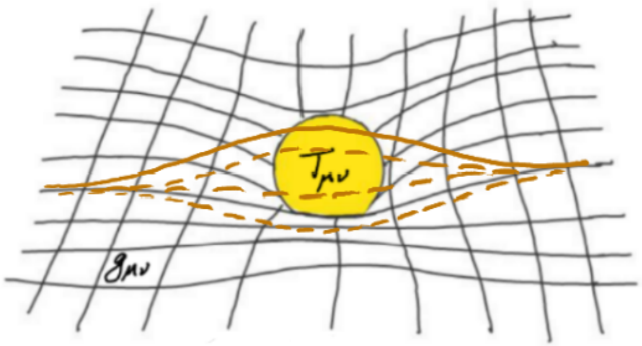

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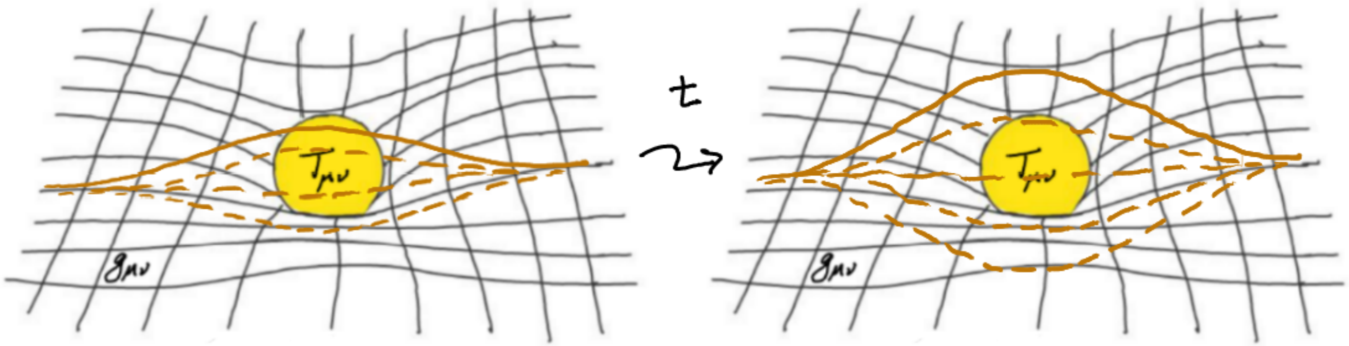

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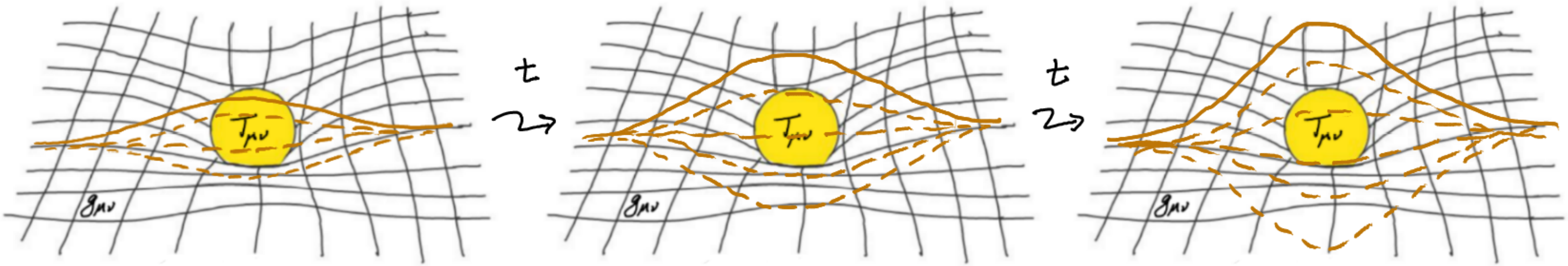

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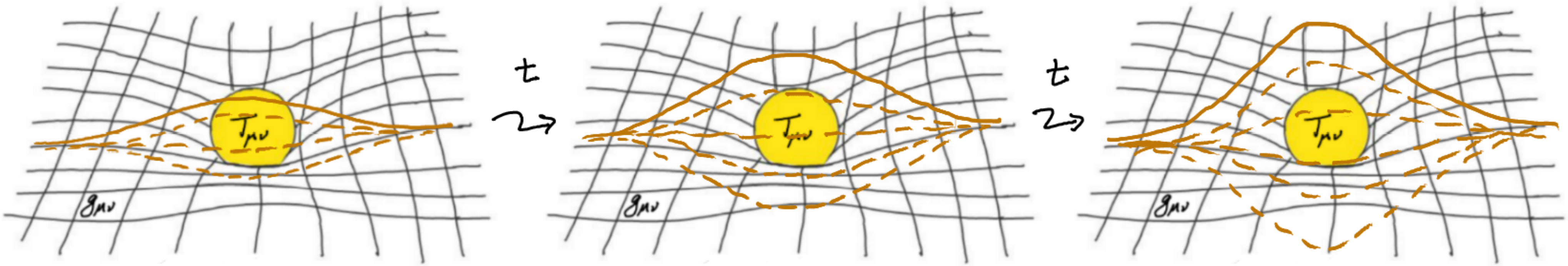

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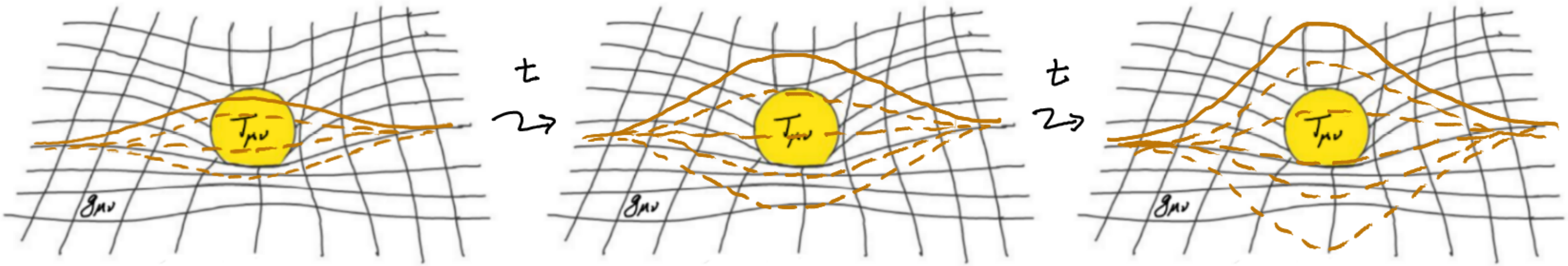

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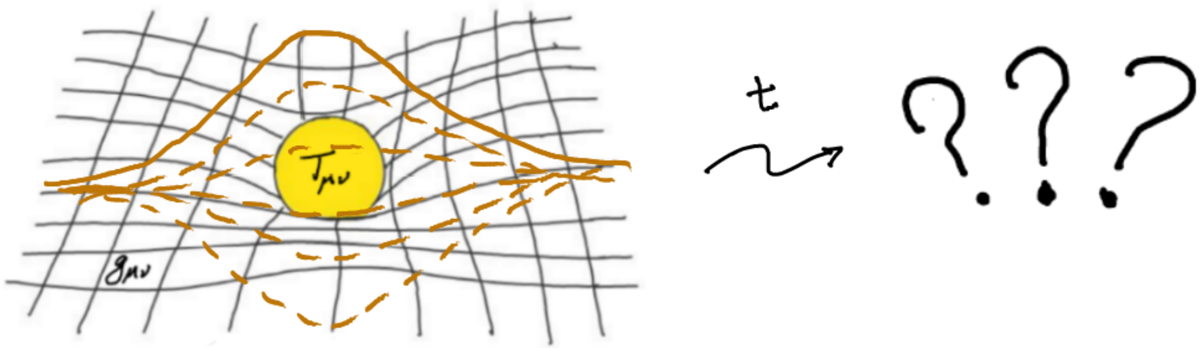

Awaking the vacuum in an Astrophysical scenario

[WCC Lima, GEA Matsas & DATV, PRL 105, 151102 (2010)]

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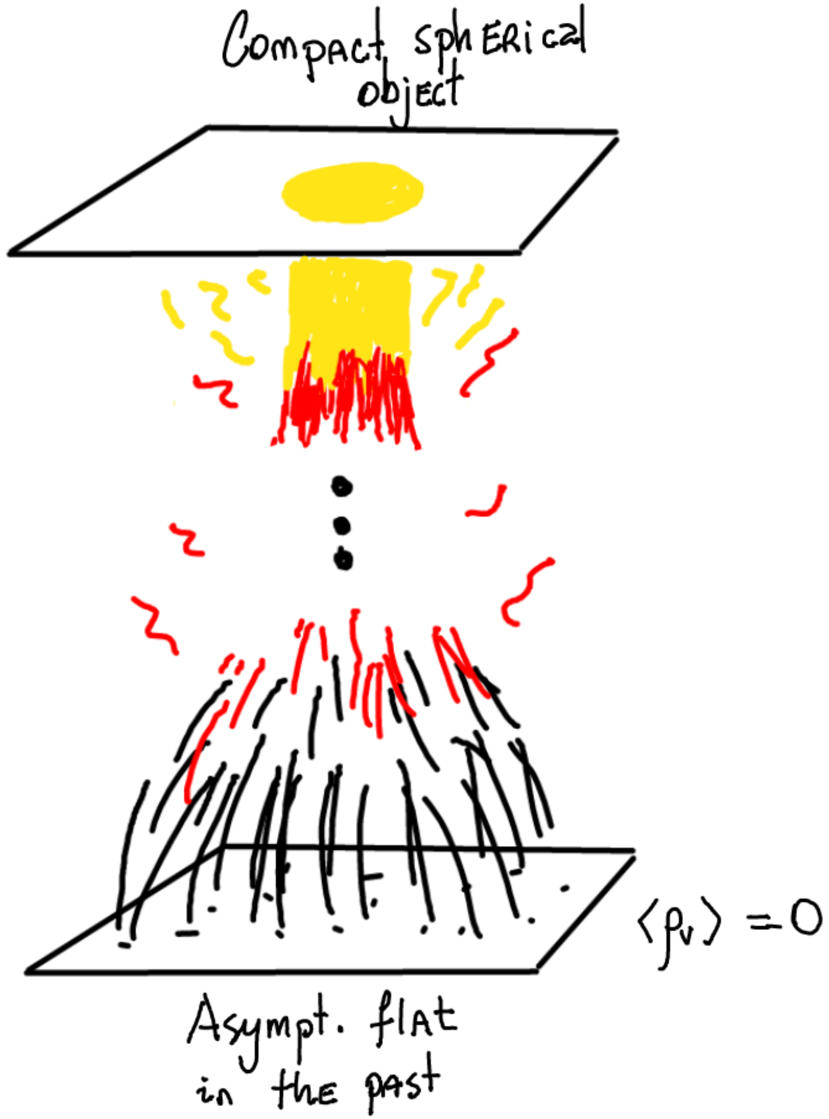

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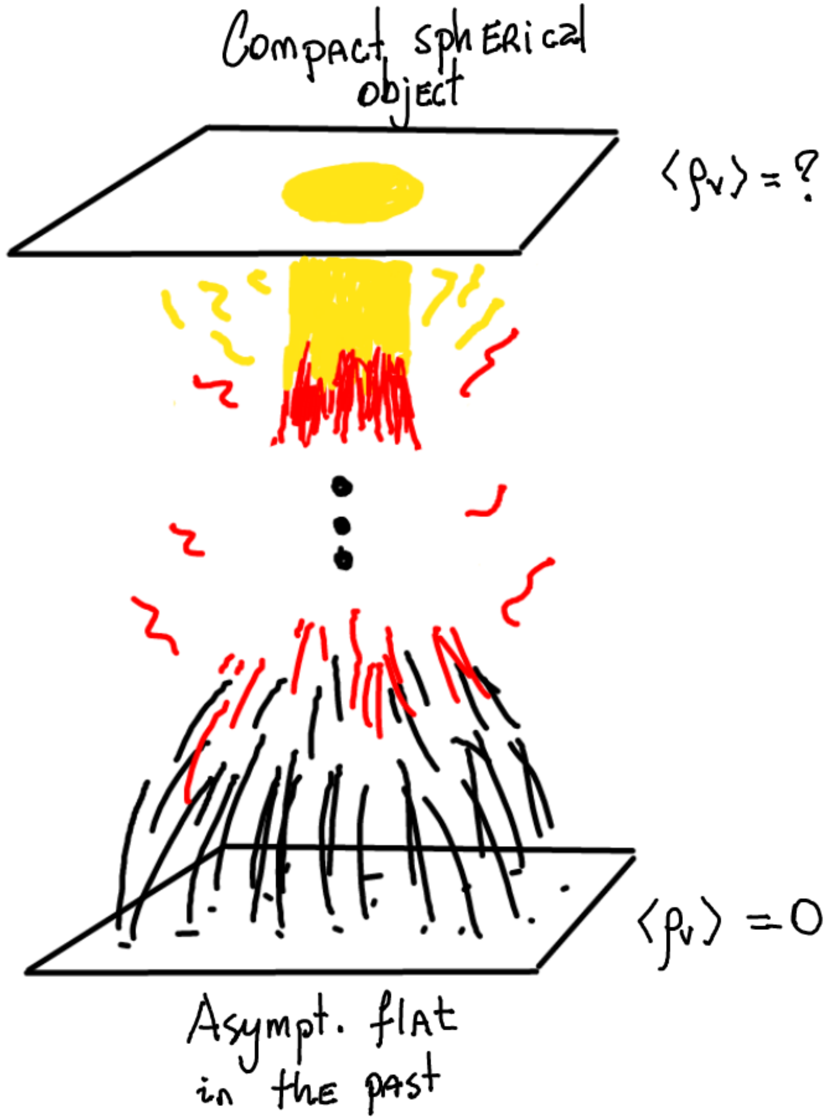

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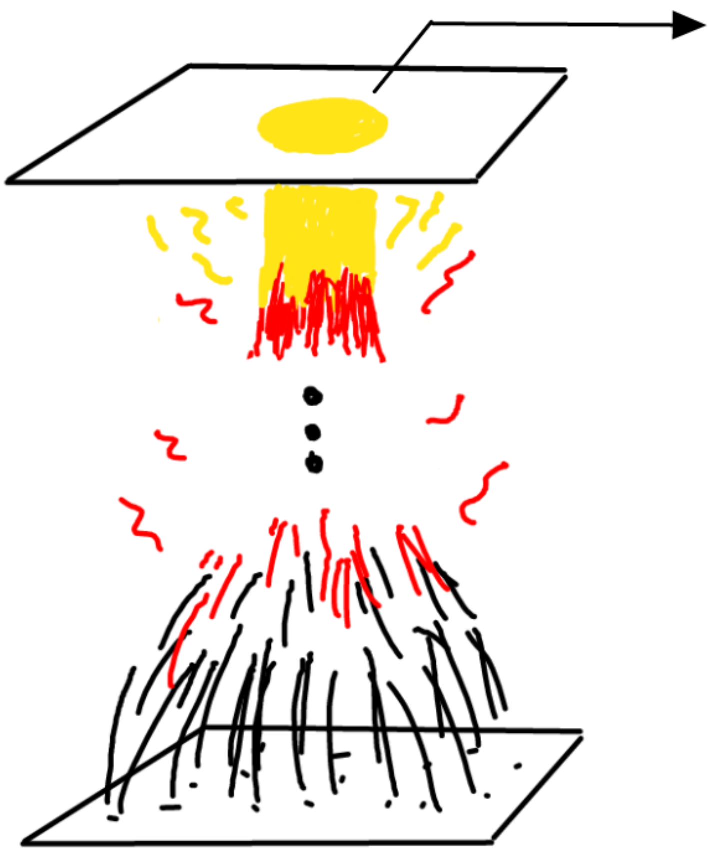

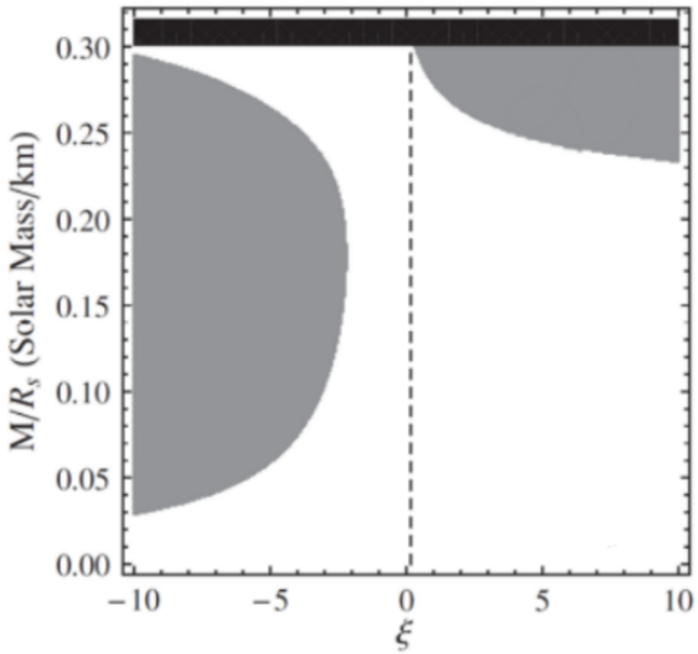

Values of $(\xi, M/R)$ for which at least one mode of the field is unstable

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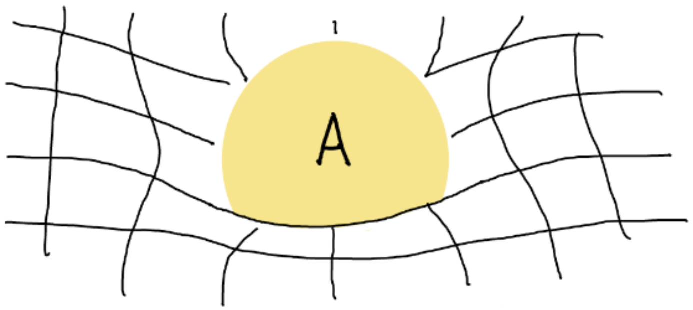

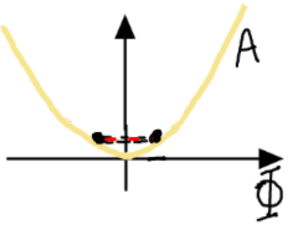

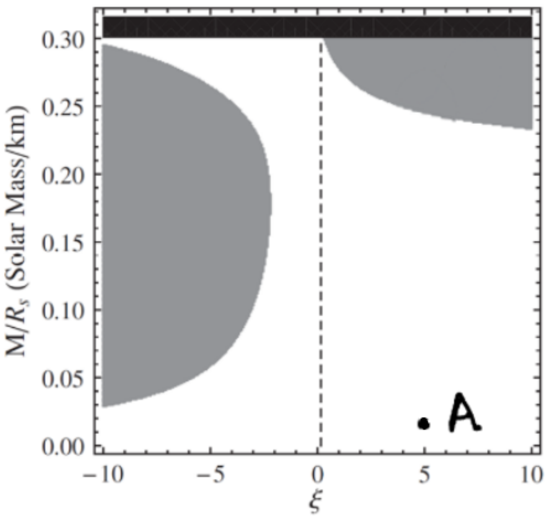

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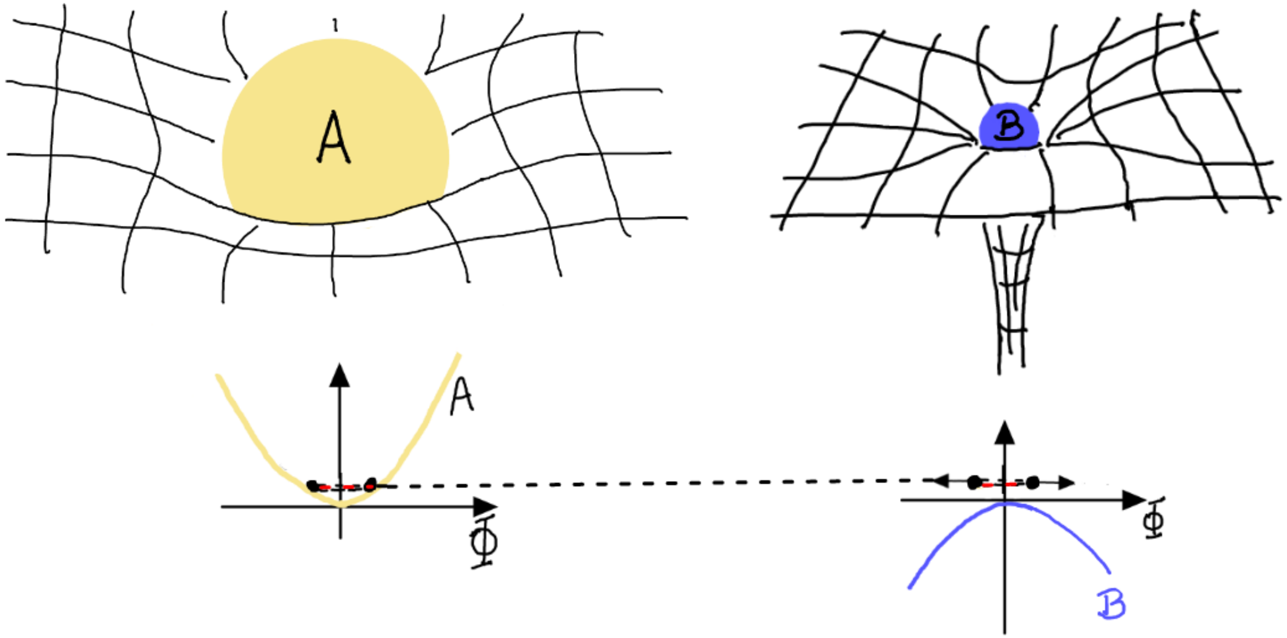

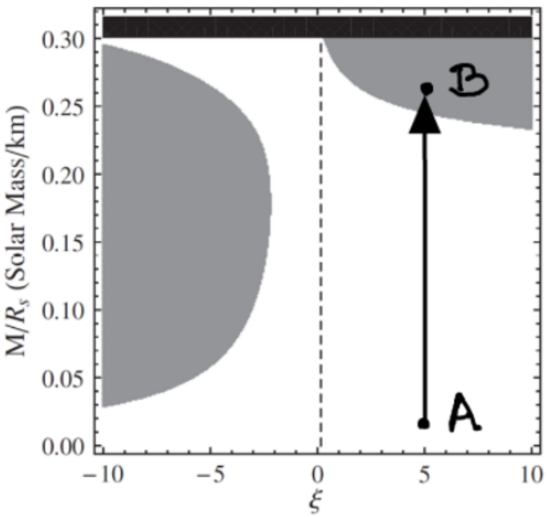

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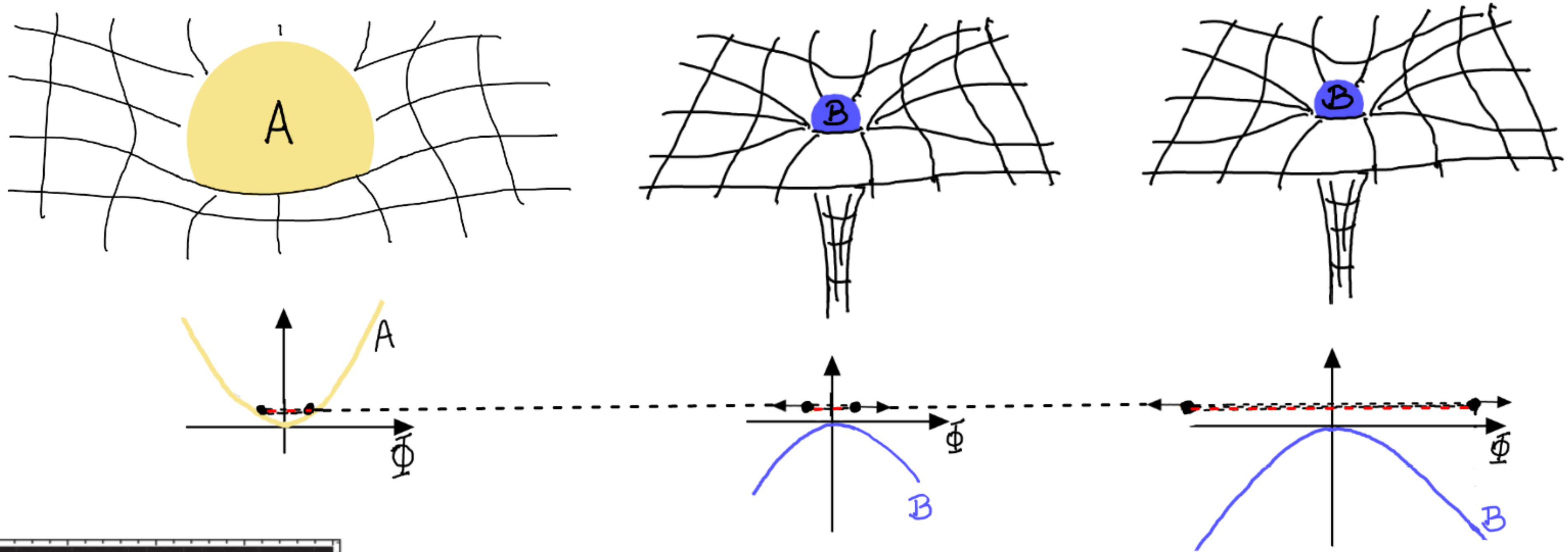

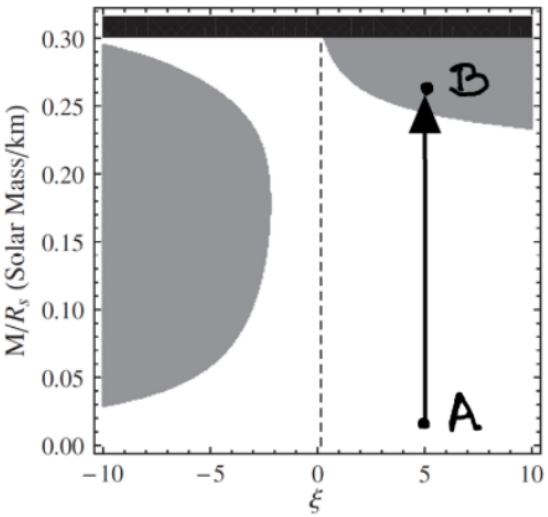

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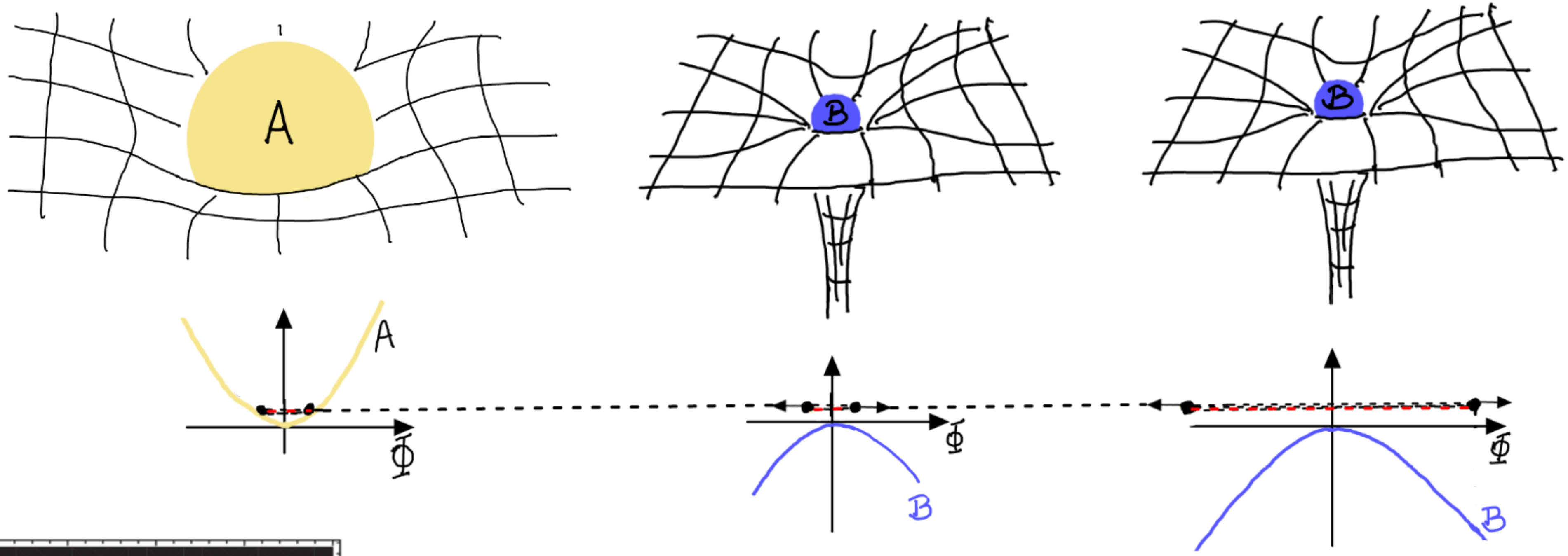
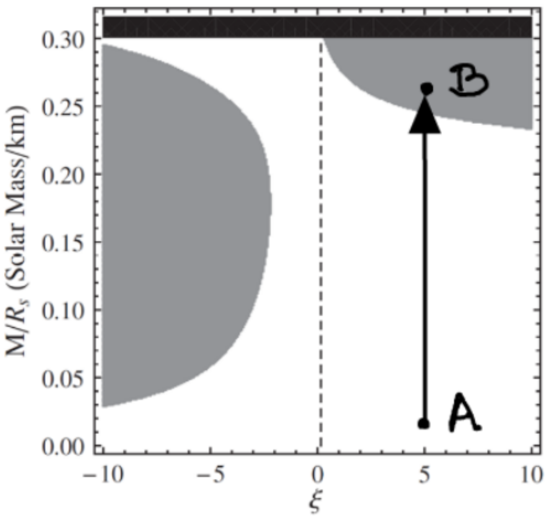


$\langle \rho_v \rangle \sim 10^{-62}\, g/cm^3 \xrightarrow[\Delta t \sim 1ms]{} \langle \rho_v \rangle \sim 10^{14}\, g/cm^3$



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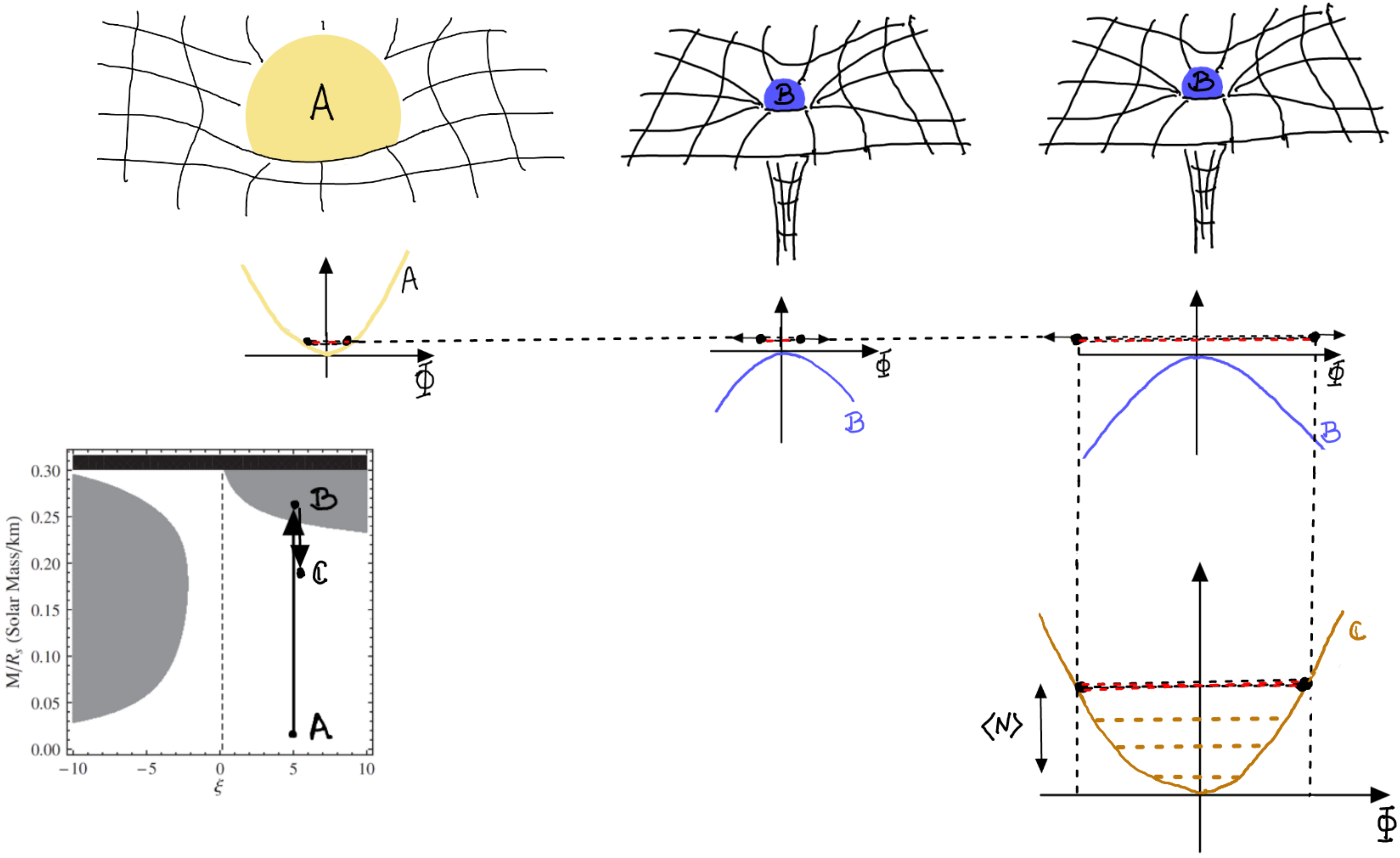

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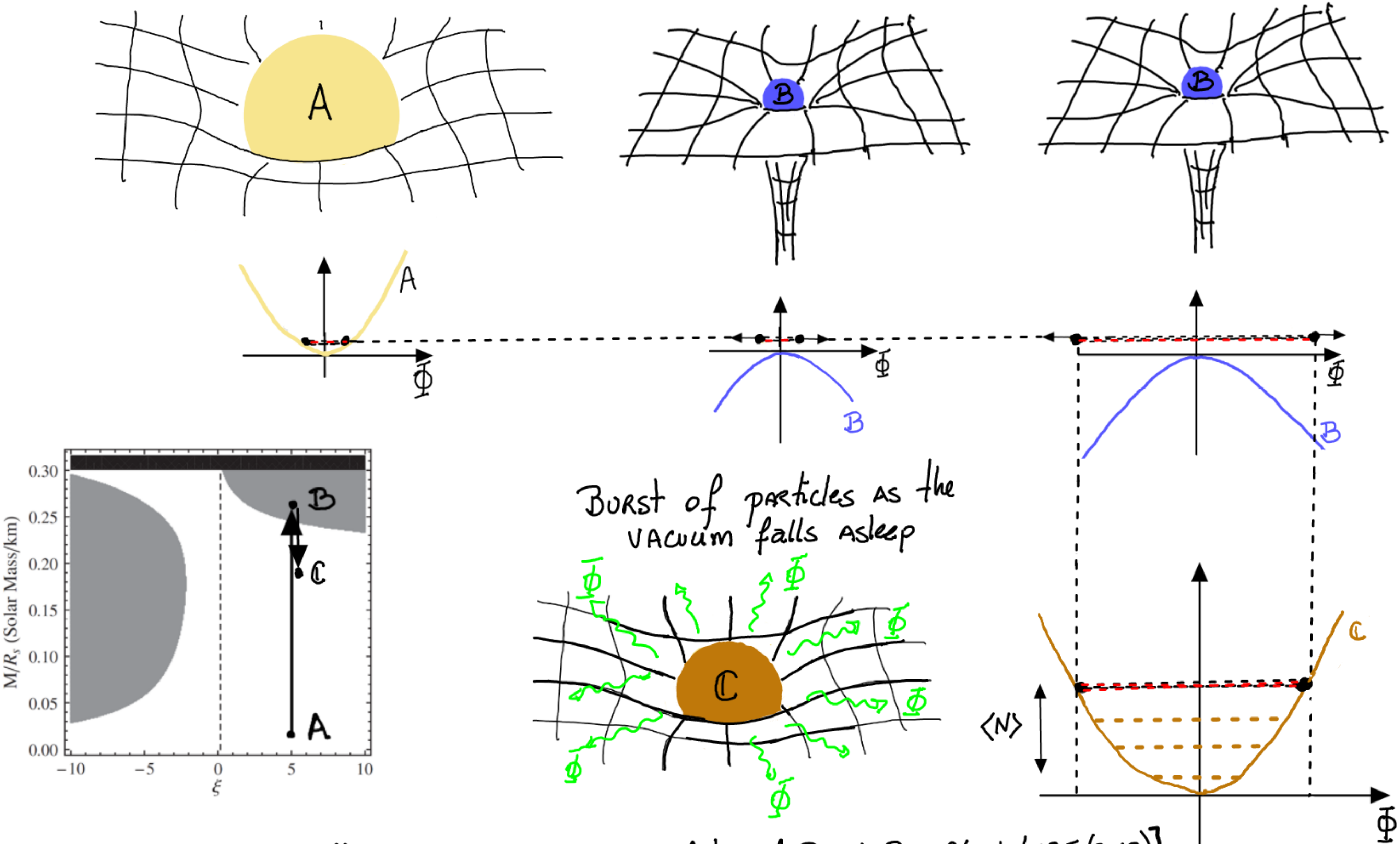

[A. Landulfo, W. Lima, G. Matsas & DATV, PRD 86, 104025 (2012)]

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