Cosmic Tsunamis in Modified Gravity

scalar waves wrecking screening mechanisms

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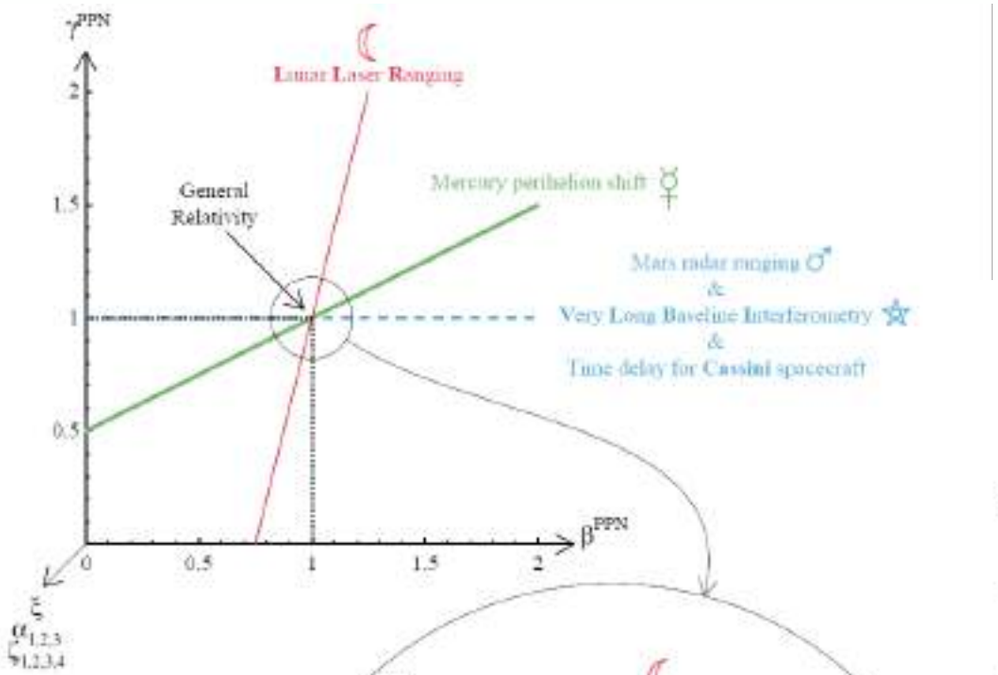
Extending General Relativity

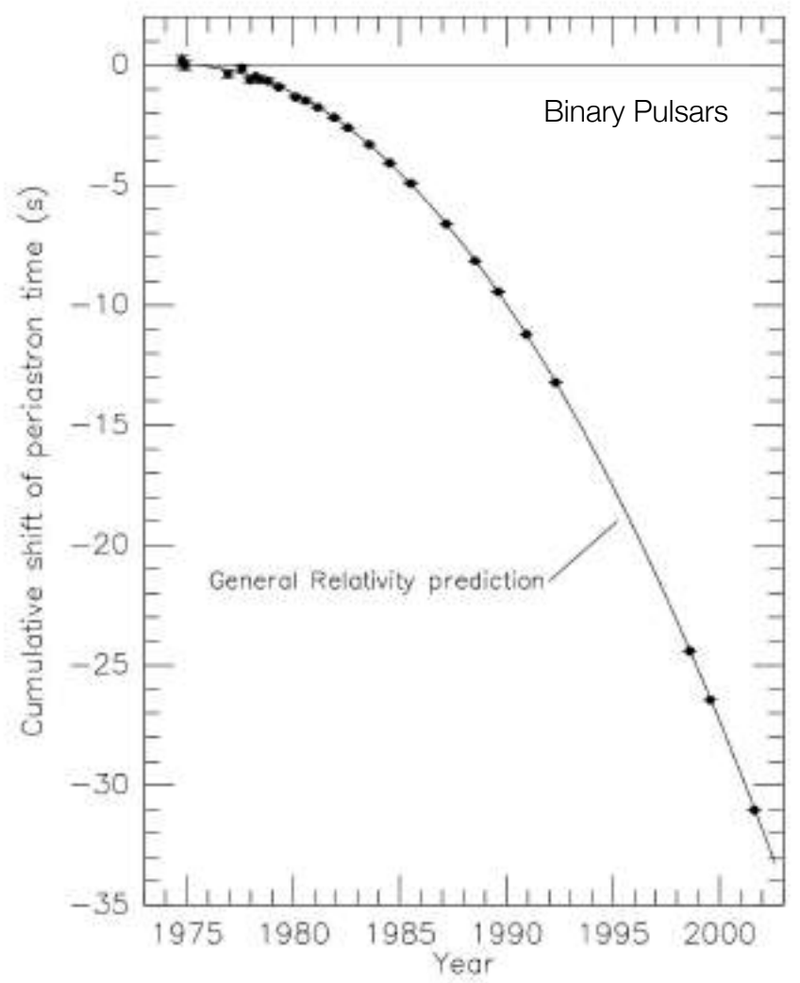
Light degree of freedom driving acceleration

Screening Mechanisms!

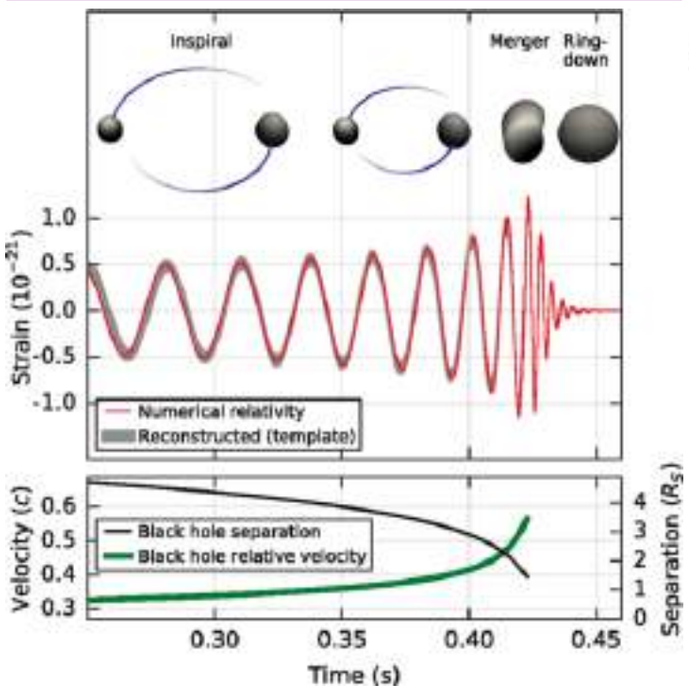
Solar System Bounds



Astrophysical Bounds



Strong field Bounds



Screening Mechanisms in Scalar-Tensor Gravity

Suppressing the Yukawa Potential

$$\mathcal{L} = -\frac{1}{2} Z^{\mu\nu}(\phi, \partial\phi, ...)\partial_\mu\phi\partial_\nu\phi - V(\phi) + g(\phi)T^\mu_\mu$$

1. Weak coupling

2. Large mass

3. Large inertia

$$V(r) = -\frac{g^2(\bar{\phi})}{Z(\bar{\phi})c_s^2(\bar{\phi})} \frac{e^{-\frac{m(\bar{\phi})}{\sqrt{Z(\bar{\phi})}c_s(\bar{\phi})}r}}{4\pi r}\mathcal{M}$$

Efficiency crucial to evade gravity constraints

Constrains on Modified Gravity

Post-Newtonian Parameter

$$\mathrm{d}s^2 = (-1 + 2\frac{GM}{r})\,\mathrm{d}t^2 + (1 + 2\gamma\frac{GM}{r})\,\mathrm{d}x^2$$

"How much space is curved by a unit rest mass"

$$\gamma - 1 = (2.1 \pm 2.3) \times 10^{-5}$$

$$\gamma - 1 = 0, \qquad \text{GR}$$

$$\gamma - 1 = -\frac{\phi^2}{M^2}\,\frac{2}{\frac{\phi^2}{M^2} + 2\Psi(1 + \frac{\phi^2}{M^2})}$$

Computing the profile of the field in the solar system

$$S = \int \mathrm{d}^4x\sqrt{-g}\left(\frac{M_{\rm Pl}^2}{2}R - \frac{1}{2}(\partial\phi)^2 - V(\phi)\right) + S_{\rm matter}\left[A^2(\phi)g_{\mu\nu}, \psi\right]$$

- Scalar field equation of motion

$$\ddot{\phi} + 3H\dot{\phi} - \frac{1}{a^2}\nabla^2\phi = \quad -V_{\text{eff},\phi}(\rho, \phi)$$

- A damped **wave equation**

Quasi-static approximation

Field profile does not change in virialised/quasi-static systems

- Scalar field equation of motion

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- **Quasi-static** approximation

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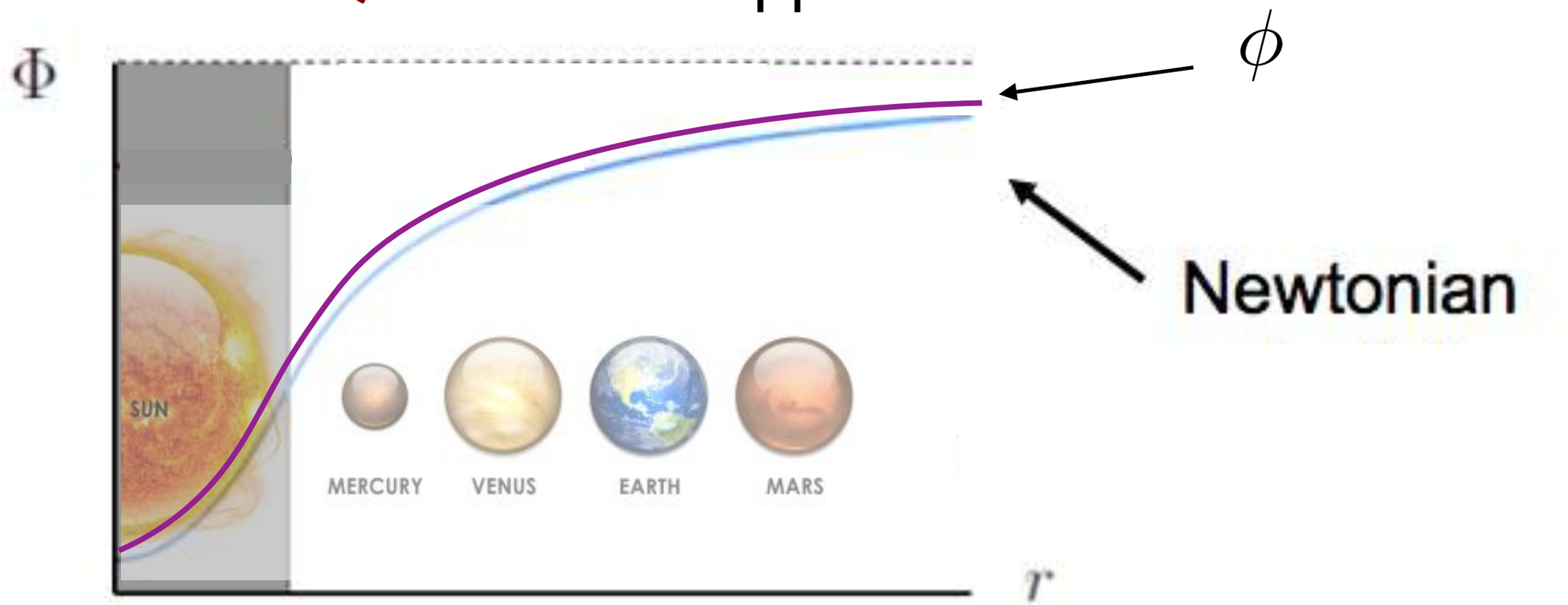
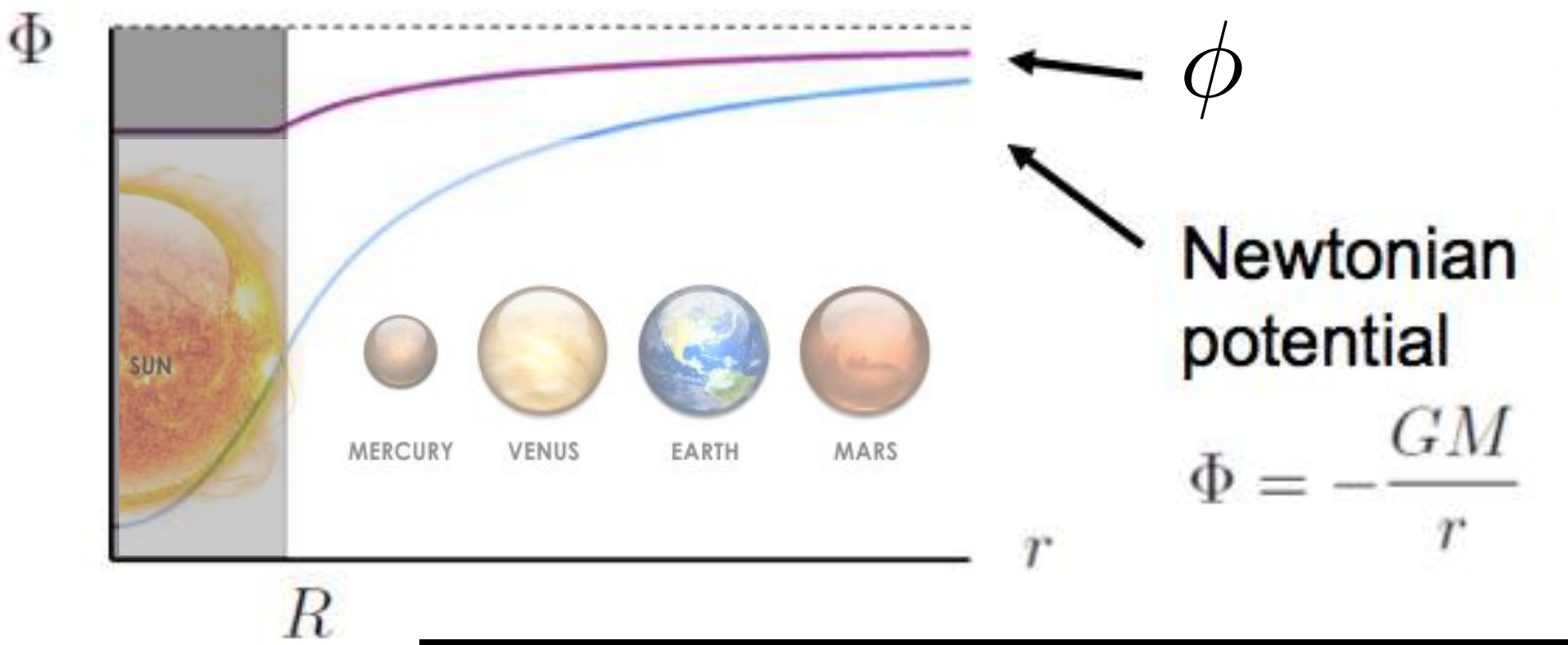


$$\gamma - 1 = -\frac{\phi^2}{M^2}\frac{2}{\frac{\phi^2}{M^2} + 2\Psi(1 + \frac{\phi^2}{M^2})} \ll 1$$

Screening mechanism suppress field value and gradient

$$\vec{a} = -\vec{\nabla}\Phi - \frac{\mathrm{d}\ln A(\phi)}{\mathrm{d}\phi}\vec{\nabla}\phi$$

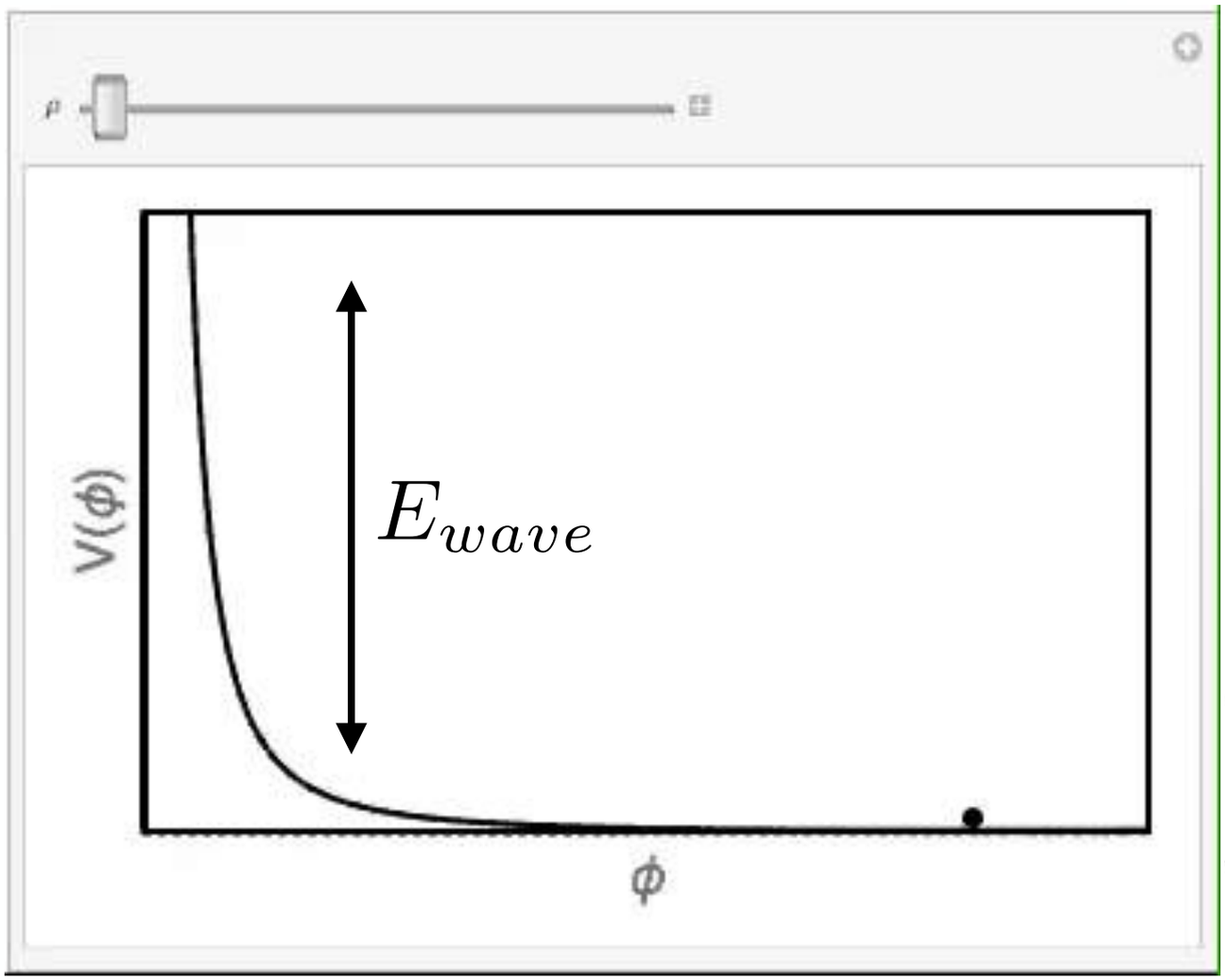
$$F_\phi \ll F_N$$



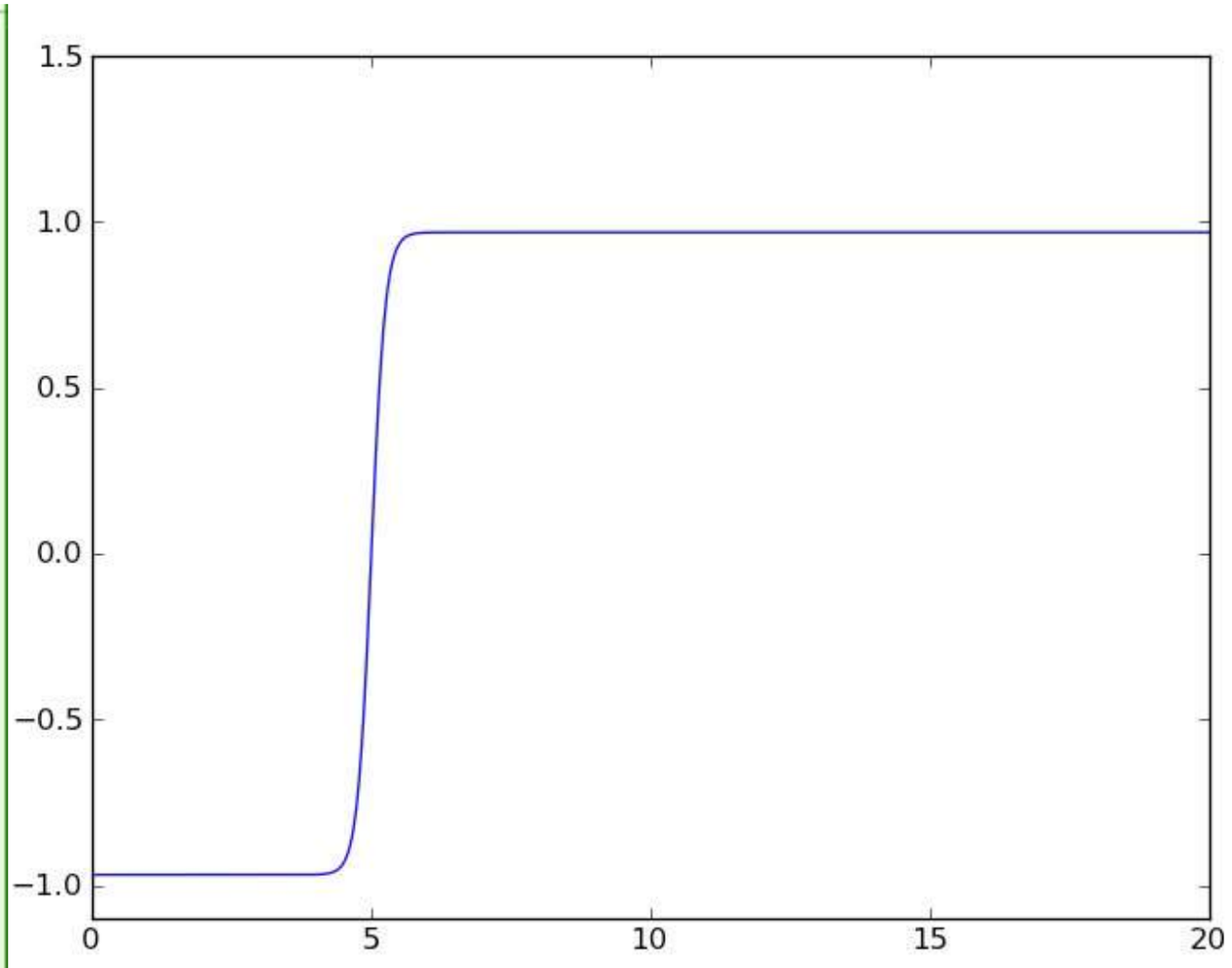
$$\gamma - 1 = -\frac{\phi^2}{M^2}\frac{2}{\frac{\phi^2}{M^2} + 2\Psi(1+\frac{\phi^2}{M^2})} \ll 1$$

Waves from Supernovae

Chameleon Potential



Profile of field



Waves from collapse of domain walls

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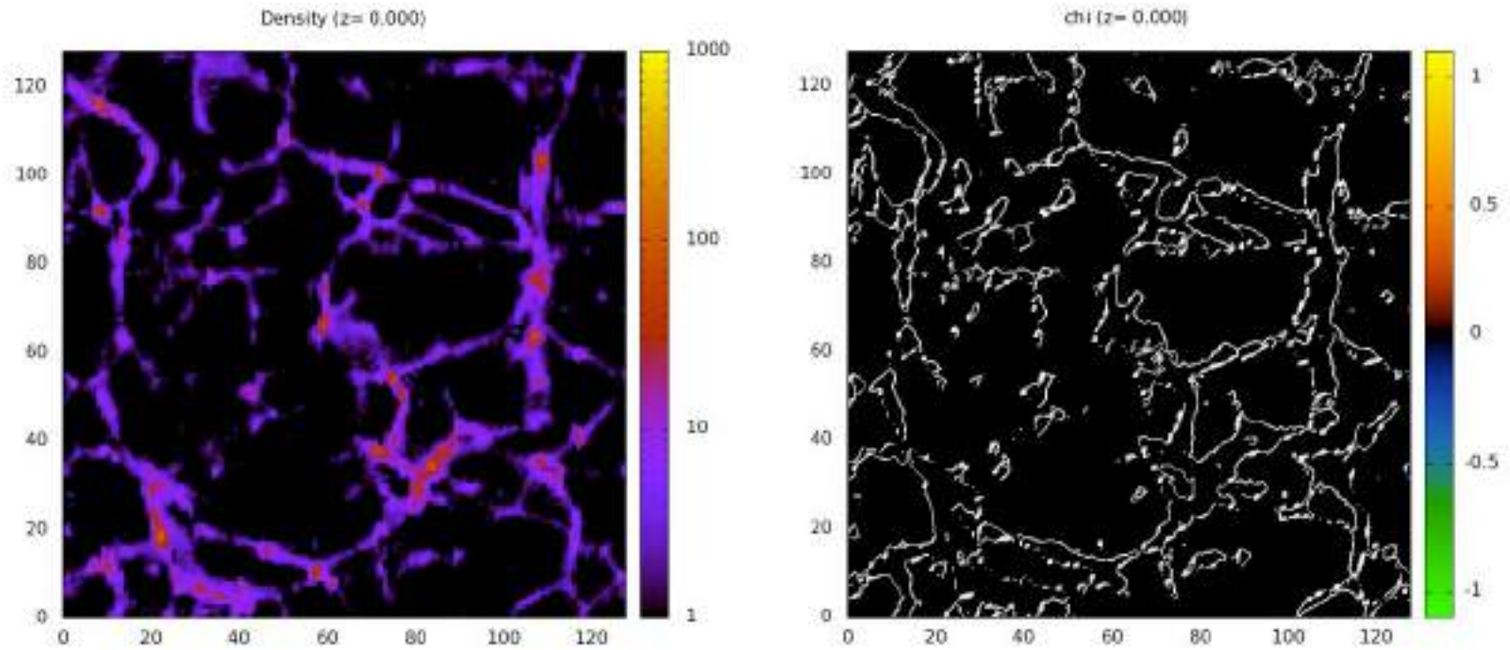

Profile of field

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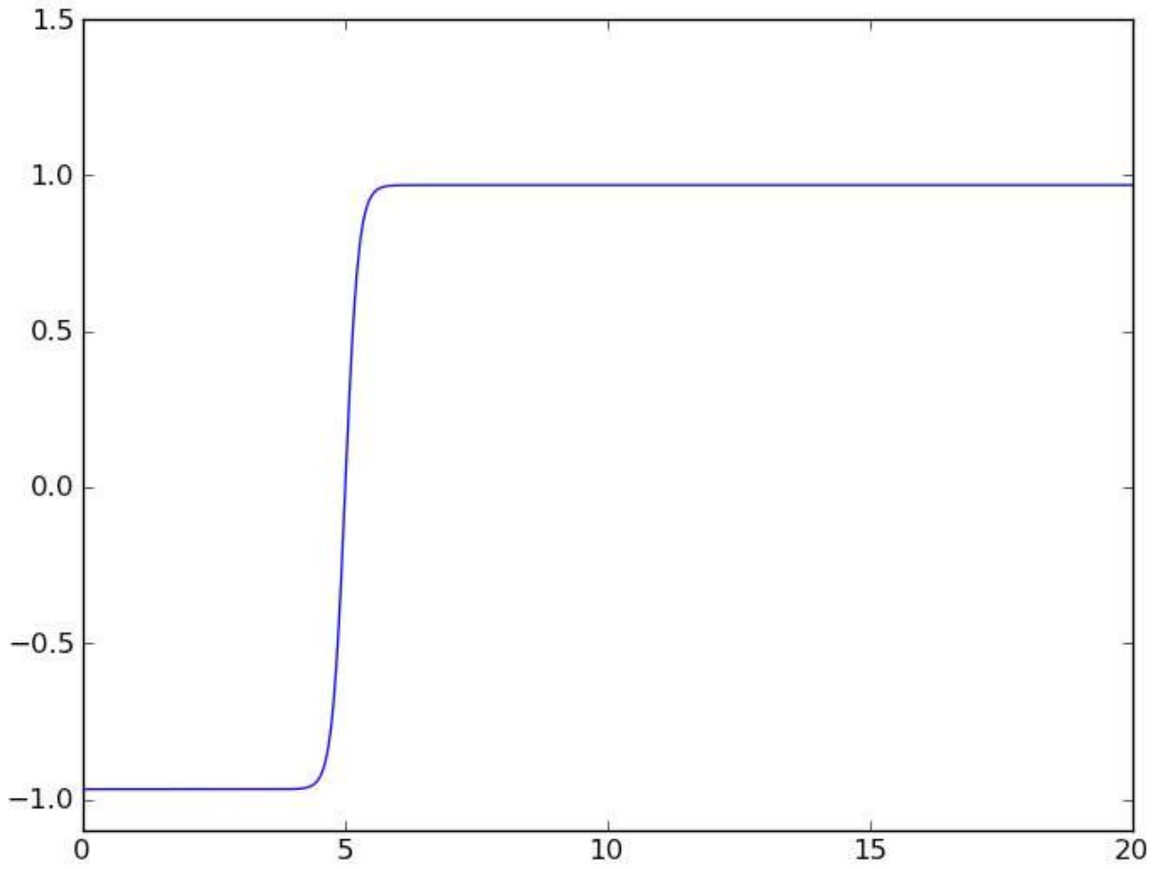
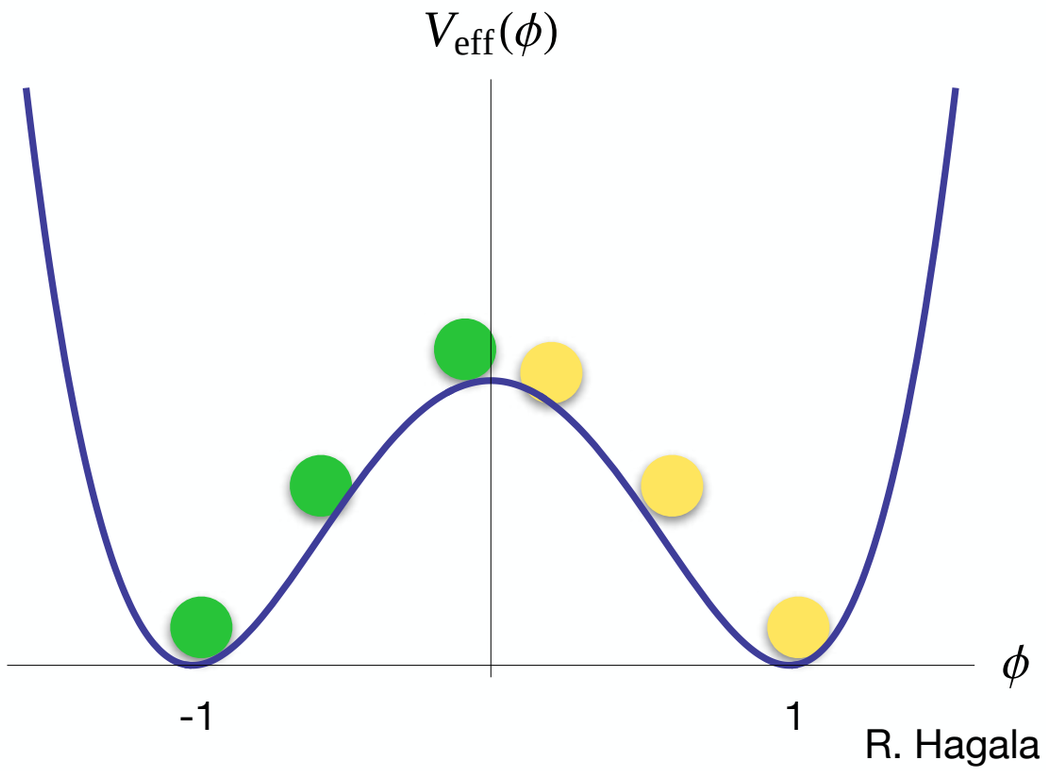
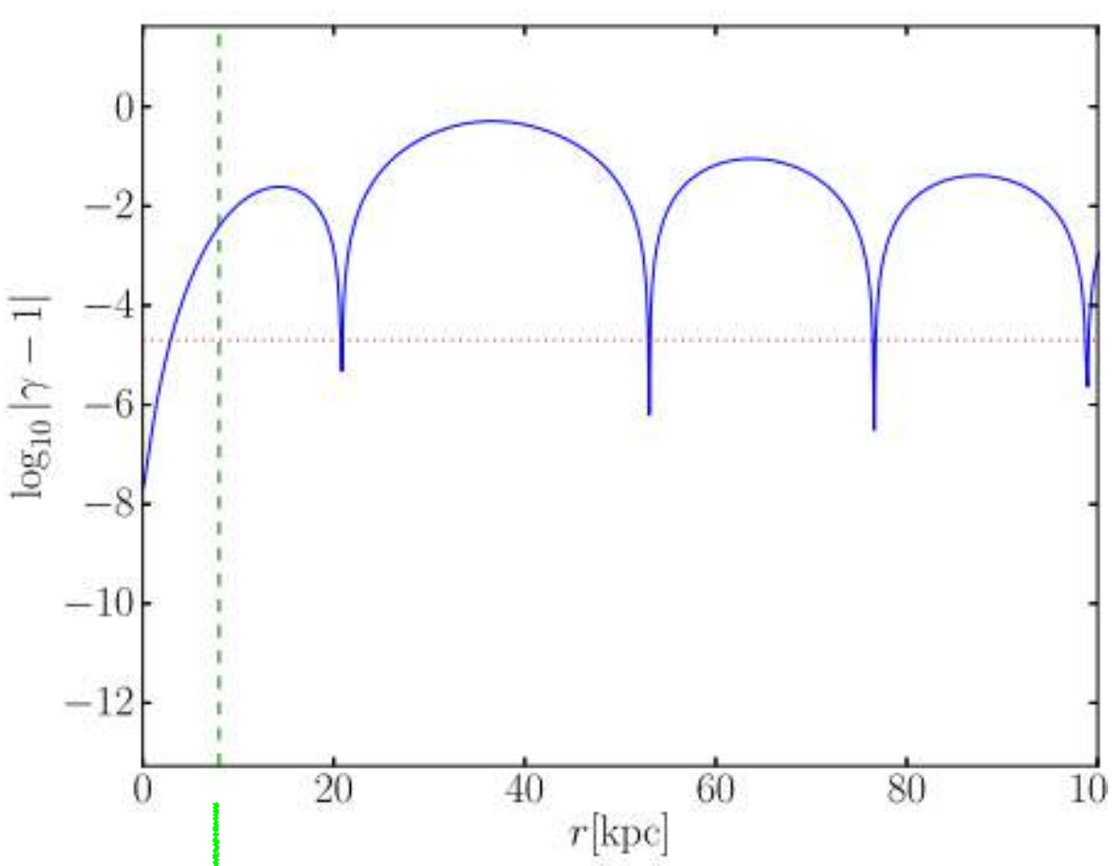




R. Hagala



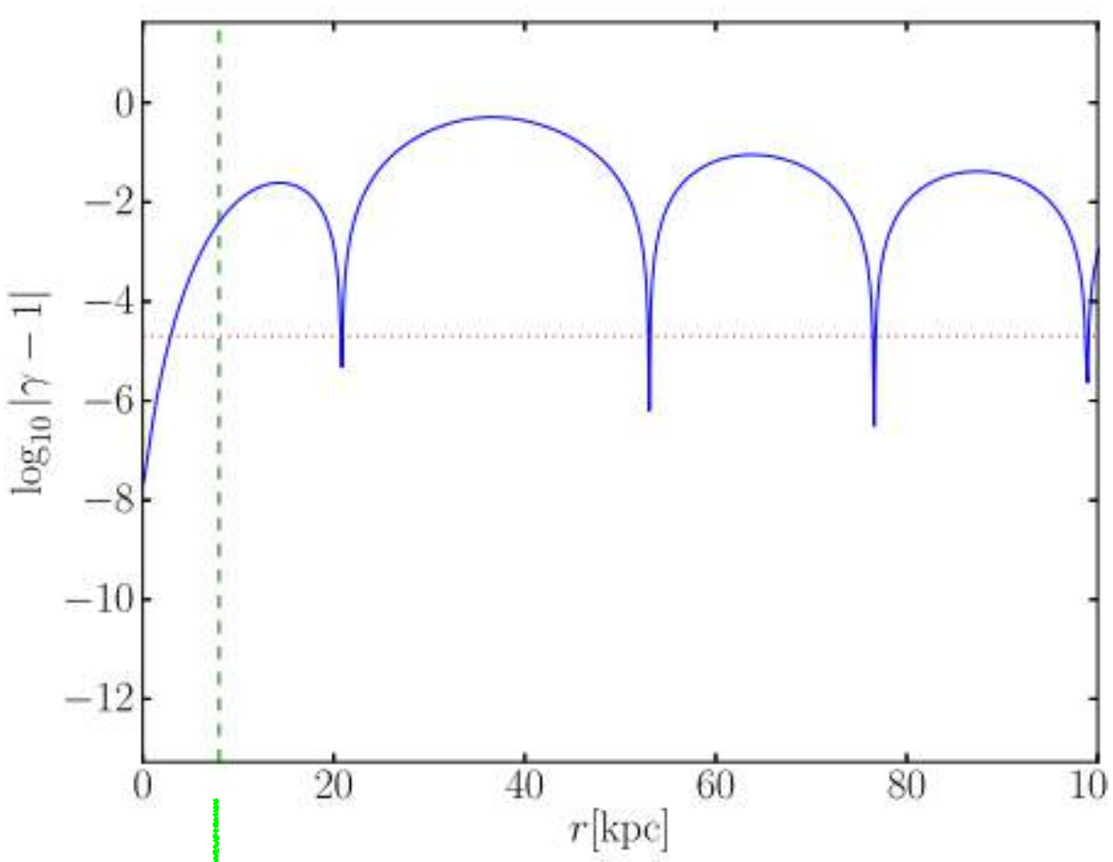
Distance from milky way centre

Solar System

Cassini bound

$$\gamma - 1 = -\frac{\phi^2}{M^2}\frac{2}{\frac{\phi^2}{M^2} + 2\Psi(1+\frac{\phi^2}{M^2})}$$

Hagala, Llinares, DFM, PRL



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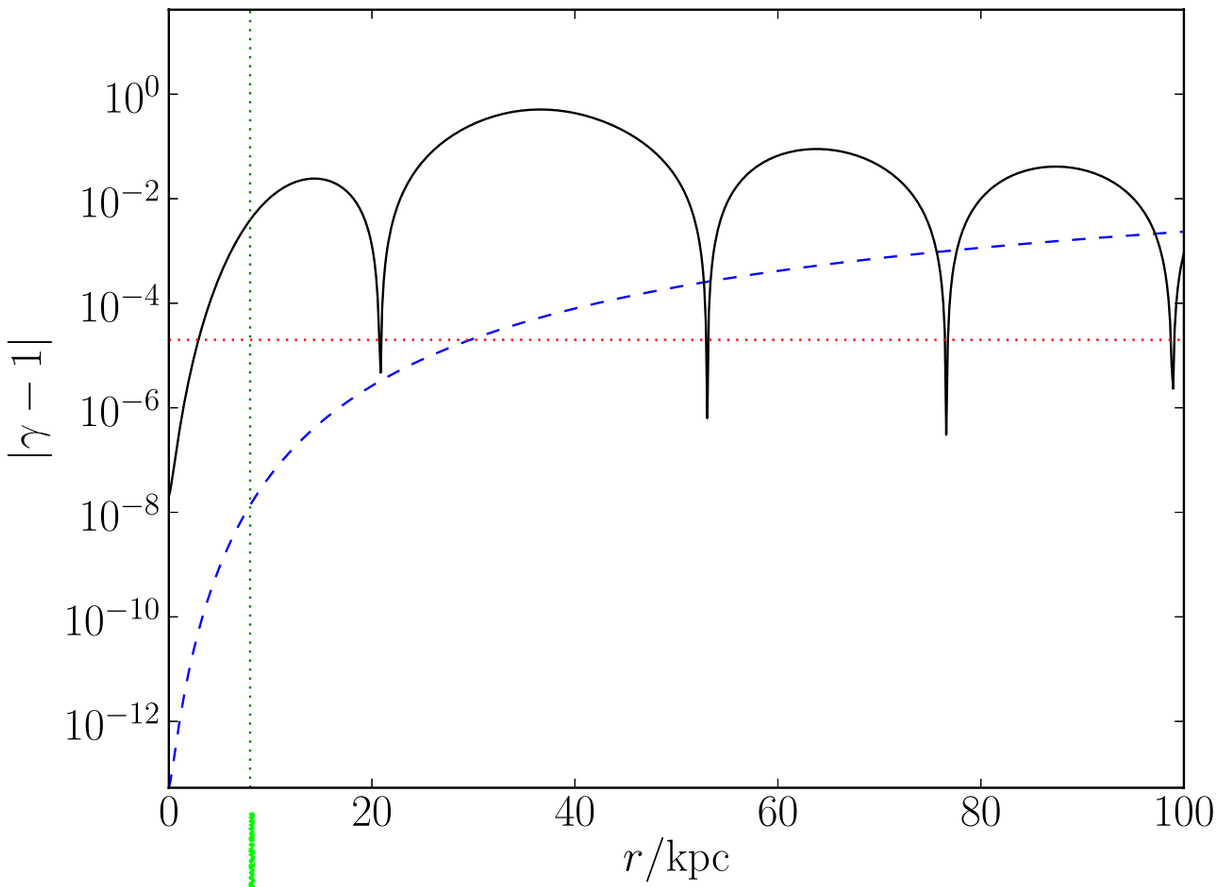

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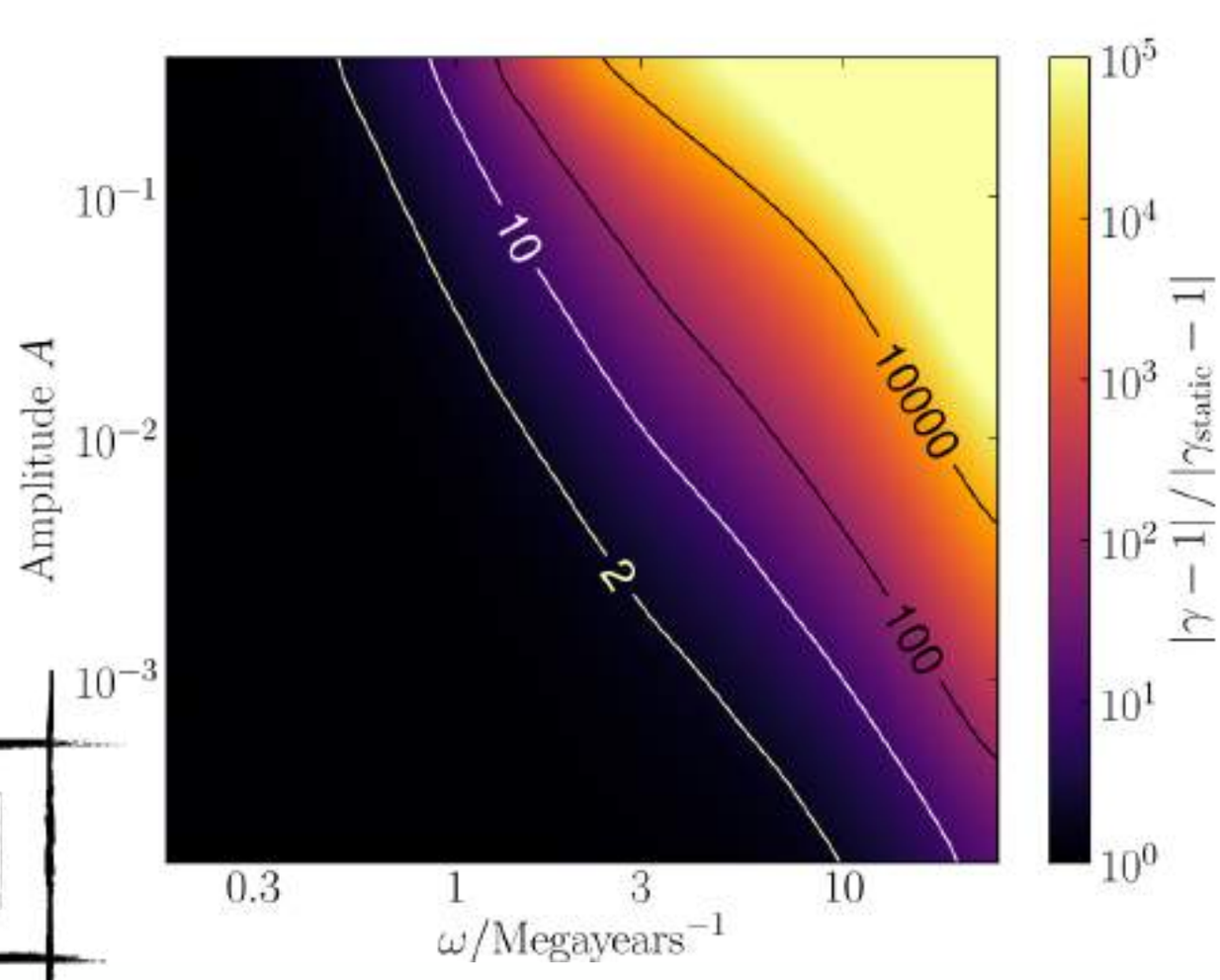
Screening disrupted!

Scalar waves increase the PPN parameter and fifth force several orders in magnitude!

Oscillations are a smoking gun!



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Summary

- A light extra degree of freedom in the gravity sector is viable only if a screening mechanism is efficient to suppress it at local scales

- The viability and efficiency of screening mechanism generally relies on the quasi-static approximation

- Astrophysical events can create waves and the quasi-static approximation is no longer valid

- Waves diminish the screening mechanism efficiency in several orders of magnitude reducing the viability of many modified gravity theories