Kinetic screening and scalar radiation in K-Essence

Ramiro Cayuso September 17th

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MARIE CURIE ACTIONS

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K-essence

$$S = \int d^4x\sqrt{-g}\left(\frac{M_{pl}^2}{2}R + K(X)\right) + S_m\left(A(\phi)g_{\mu\nu}, u_m\right)$$

Conformal factor

$$K(X) = -\frac{1}{2}X + \frac{\beta}{4\Lambda^4}X^2 + \frac{\tilde{\gamma}}{8\Lambda^8}X^3$$

$$A(\phi) = exp(-\sqrt{2}\alpha\frac{\phi}{M_{pl}})$$

Conformal coupling

$$X = \nabla_\mu\phi\nabla^\mu\phi$$

$$\gamma^{\mu\nu}\nabla_\mu\nabla_\nu\phi = \frac{T}{4\mathrm{M_{pl}}\,\mathrm{K_X}}$$

K-essence: motivation

Cosmology: To explain accelerated cosmic expansion. Phys.Rev.Lett.85:4438-4441,2000

$\Lambda \approx 2 \times 10^{-3} eV$

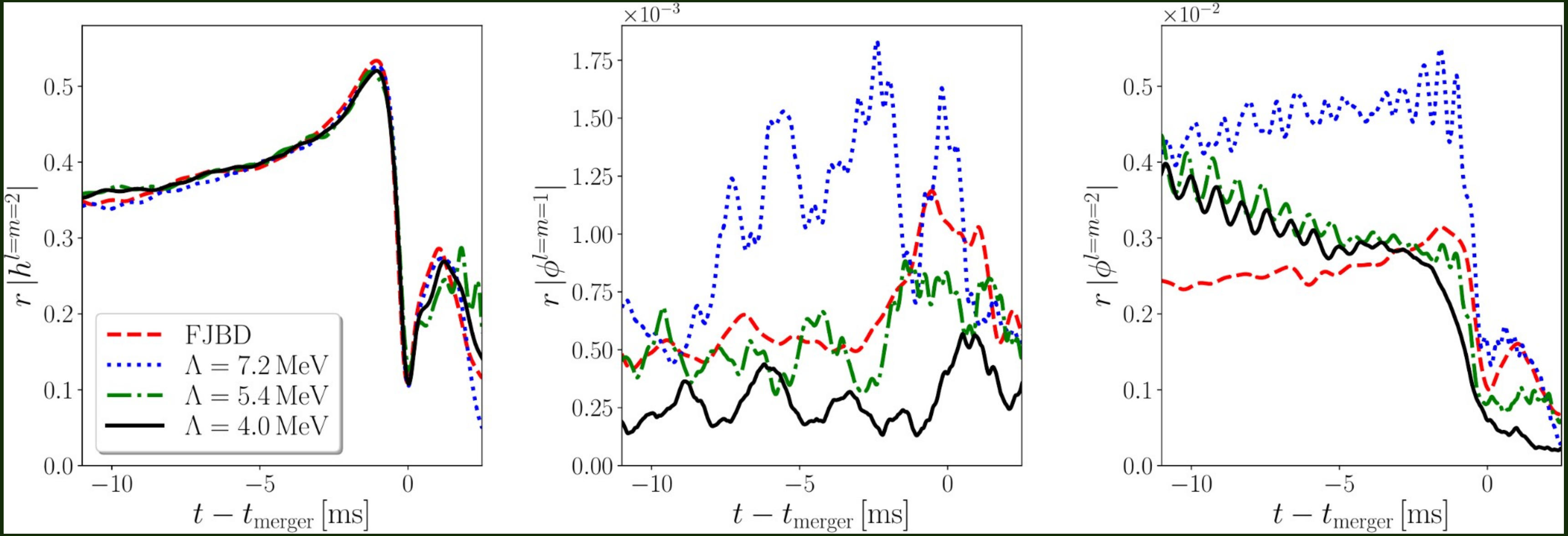
Interesting: Posses Kinetic screening mechanism

$\nabla_\mu \phi$ Unseen by local tests of gravity → Does it hold in Binaries?

Non-Linear terms dominate | Linear terms dominate

Screening : Looks like GR | r_V | Looks like FJBD

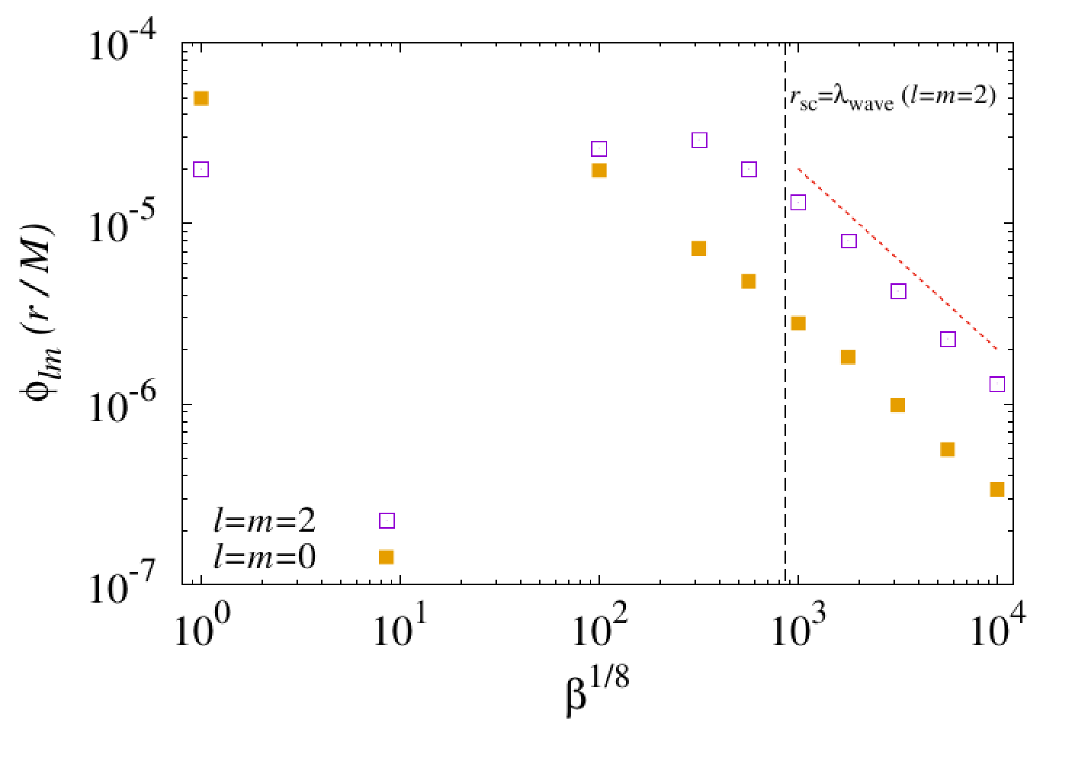
K-essence: BNS simulations



Miguel Bezares, et all: Phys.Rev.Lett. 128 (2022) 9, 091103

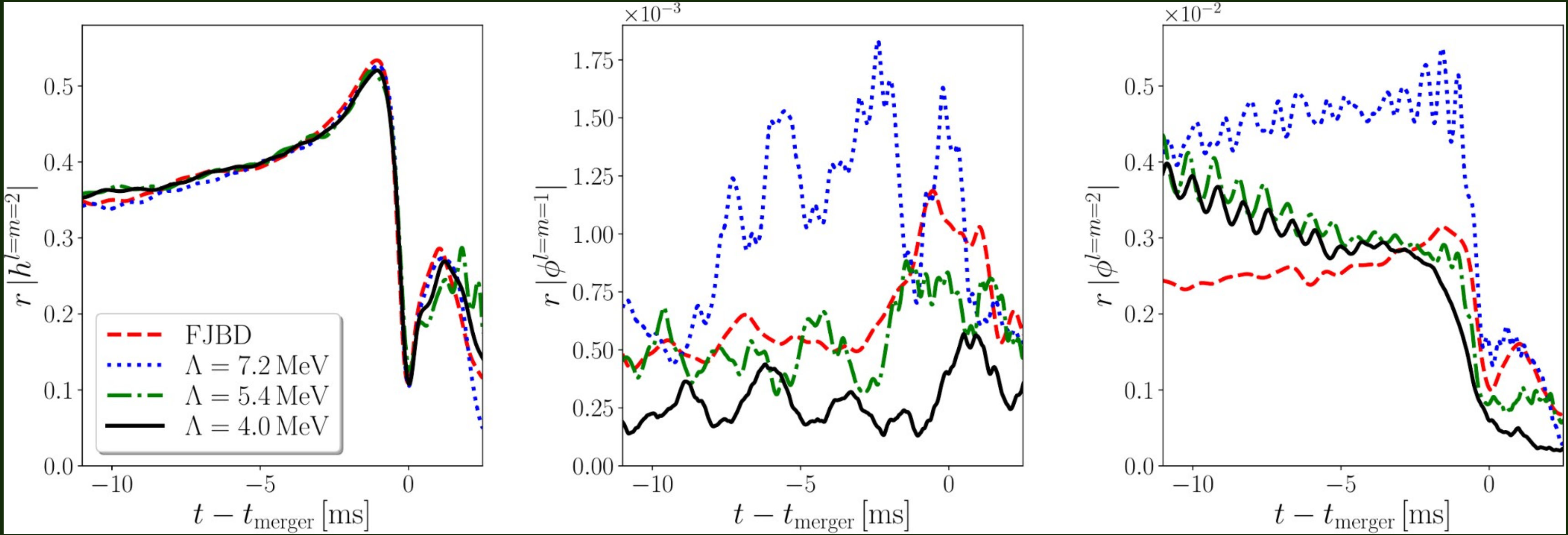
No evidence of screening in Late-inspiral/Merger

K-essence: single NS simulations



Masaru Shibata & Dina Traykova: Phys. Rev. D 107, 044068

K-essence: BNS simulations



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No evidence of screening in Late-inspiral/Merger

Perhaps too far away from the regime $\lambda_r < r_V$ Quite hard to do Numerics

K-essence: The equations

$$\gamma^{\mu\nu}\nabla_\mu\nabla_\nu\phi = \frac{T}{4\mathrm{M_{pl}\,K_X}}$$

$$\gamma^{\mu\nu} \equiv \eta^{\mu\nu} + \frac{2K_{XX}}{K_X}\nabla^\mu\phi\nabla^\nu\phi \qquad K(X) = -\frac{1}{2}X + \frac{\beta}{4\Lambda^4}X^2 + \frac{\tilde{\gamma}}{8\Lambda^8}X^3$$

Characteristic speeds Dynamics can break the IVP

$$\lambda^i_\pm = \frac{1}{K_X - 2\partial_t\phi^2 K_{XX}}\left[2\Pi\partial^i\phi K_{XX} \pm \sqrt{K_X(K_X + 2K_{XX}X)}\right]$$

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$$\gamma \equiv \frac{\tilde{\gamma}}{\Lambda^8} \approx 10^{20} \to \Lambda = 4\mathrm{MeV}$$

Let us try to get closer to that regime: Simplified set up.

Flat Spacetime

Prescribed matter source in Keplerian orbits

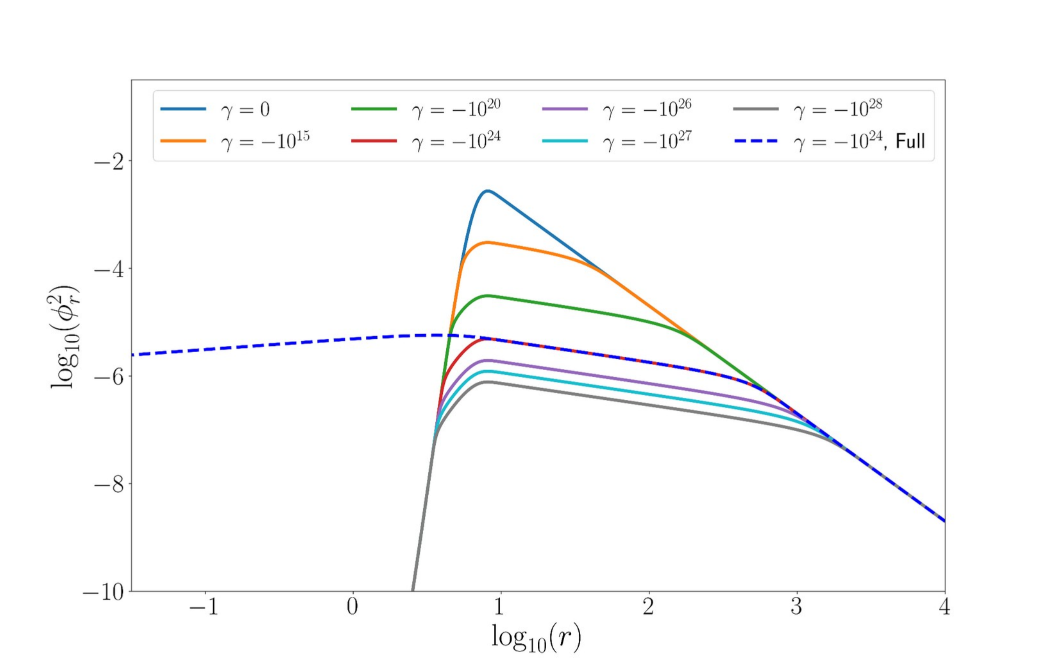
$$T = -\frac{1}{(2\pi\sigma)^{3/2}}\left(r_1^2 \exp\left[-\frac{1}{2}\left(\frac{\vec{r}_1(t)}{\sigma}\right)^2\right] + r_2^2 \exp\left[-\frac{1}{2}\left(\frac{\vec{r}_2(t)}{\sigma}\right)^2\right]\right)$$

$$\Omega = \sqrt{\frac{2M}{(2r_{orbit})^3}}$$

Radiation: $\lambda_r = \frac{2\pi}{\Omega}$

Lessons from Initial data: You have to be careful

$$T = -\frac{1}{(2\pi\sigma)^{3/2}}\left(r_1^2 \exp\left[-\frac{1}{2}\left(\frac{\vec{r}_1(t)}{\sigma}\right)^2\right] + r_2^2 \exp\left[-\frac{1}{2}\left(\frac{\vec{r}_2(t)}{\sigma}\right)^2\right]\right)$$



$$M = 1M_\odot$$

$$r_{star} \approx 13.5\text{Km}$$

$$\gamma = 10^{28}$$

↓

$$\Lambda = 0.4\text{MeV}$$

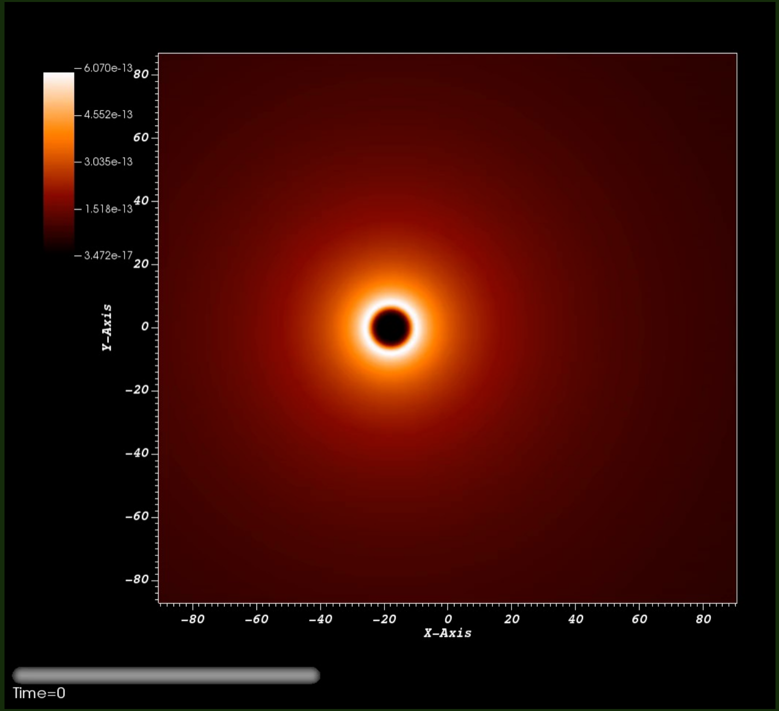
$$R_v \approx 2000\text{Km}$$

Single star source: Black hole companion

$$T = -\frac{1}{(2\pi\sigma)^{3/2}}\left(r_1^2 \exp\left[-\frac{1}{2}\left(\frac{\vec{r}_1(t)}{\sigma}\right)^2\right]\right)$$

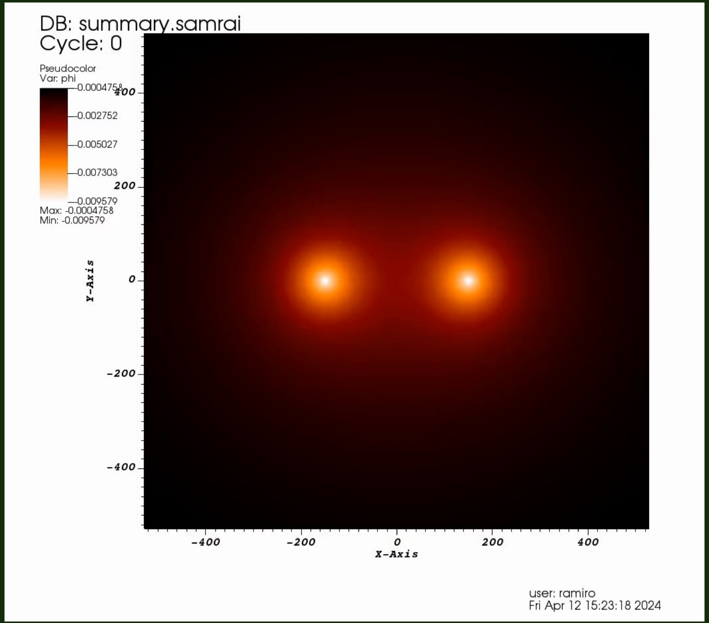
- Start from static-configuration
- Slowly increase the Ω_orbit

$$R_{orbit} = 27\mathrm{Km}$$



Binary star source

$$T = -\frac{1}{(2\pi\sigma)^{3/2}} \left(r_1^2 \exp\left[-\frac{1}{2} \left(\frac{\vec{r}_1(t)}{\sigma} \right)^2 \right] + r_2^2 \exp\left[-\frac{1}{2} \left(\frac{\vec{r}_2(t)}{\sigma} \right)^2 \right] \right)$$



- For binary, superposition is not good enough. Slowly bring together.
- Slowly increase Ω_{orbit} .
- No practical for large couplings.

Single star source: Black hole companion

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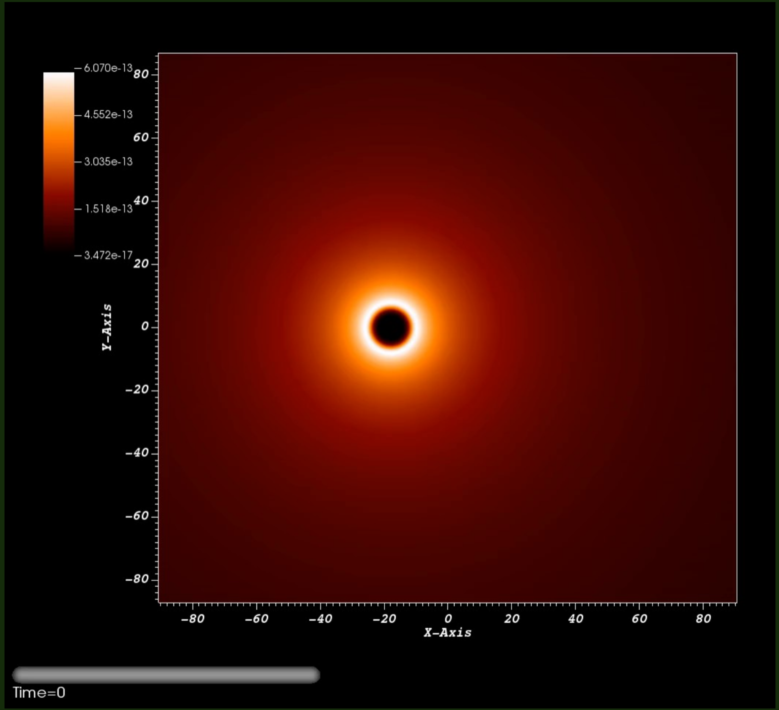
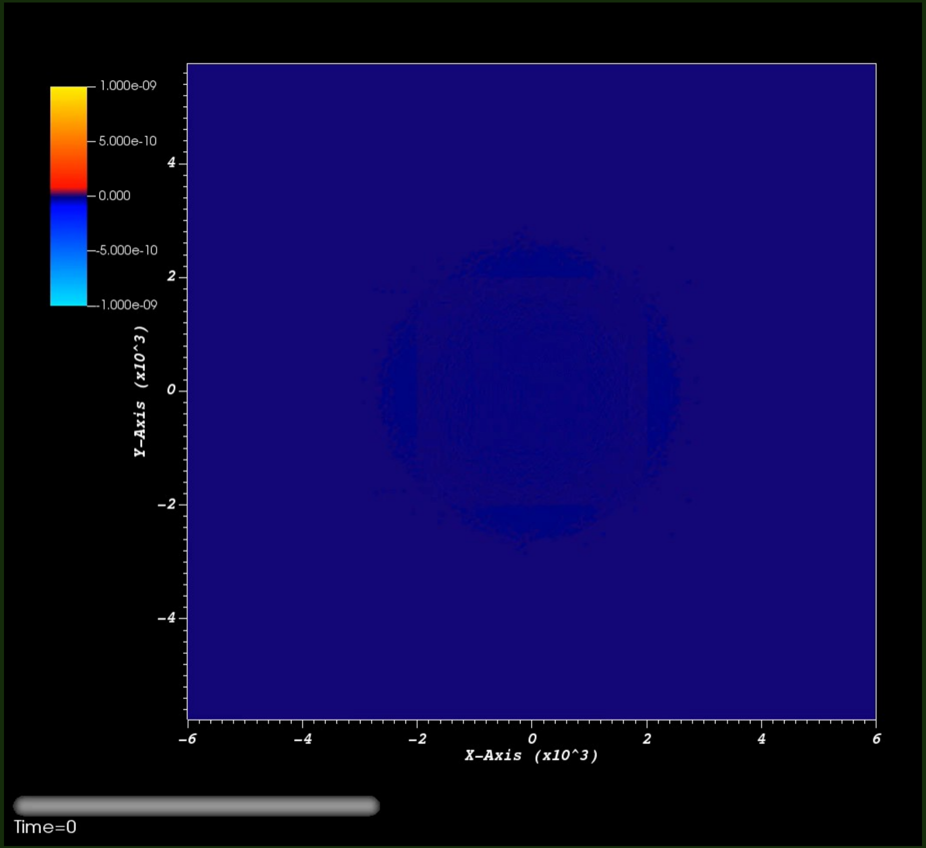


Scalar Radiation : Single star



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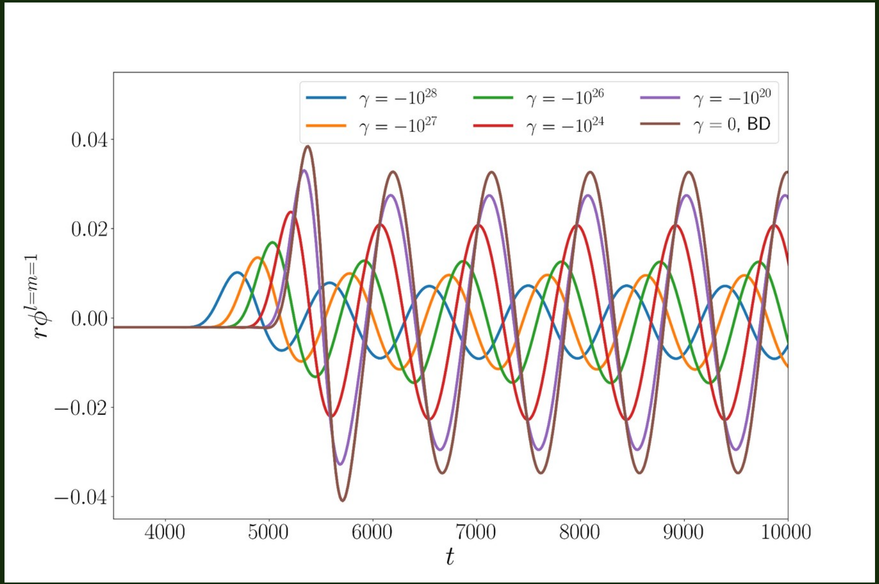
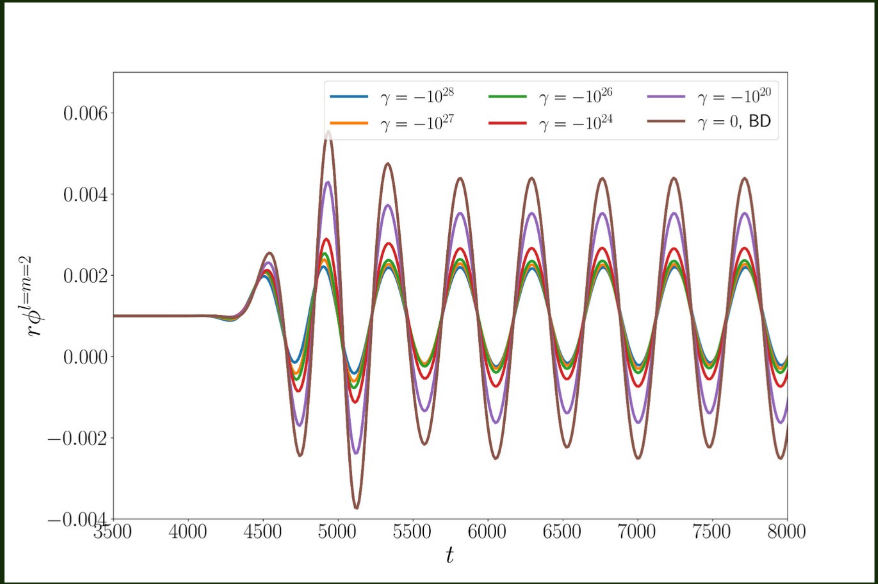
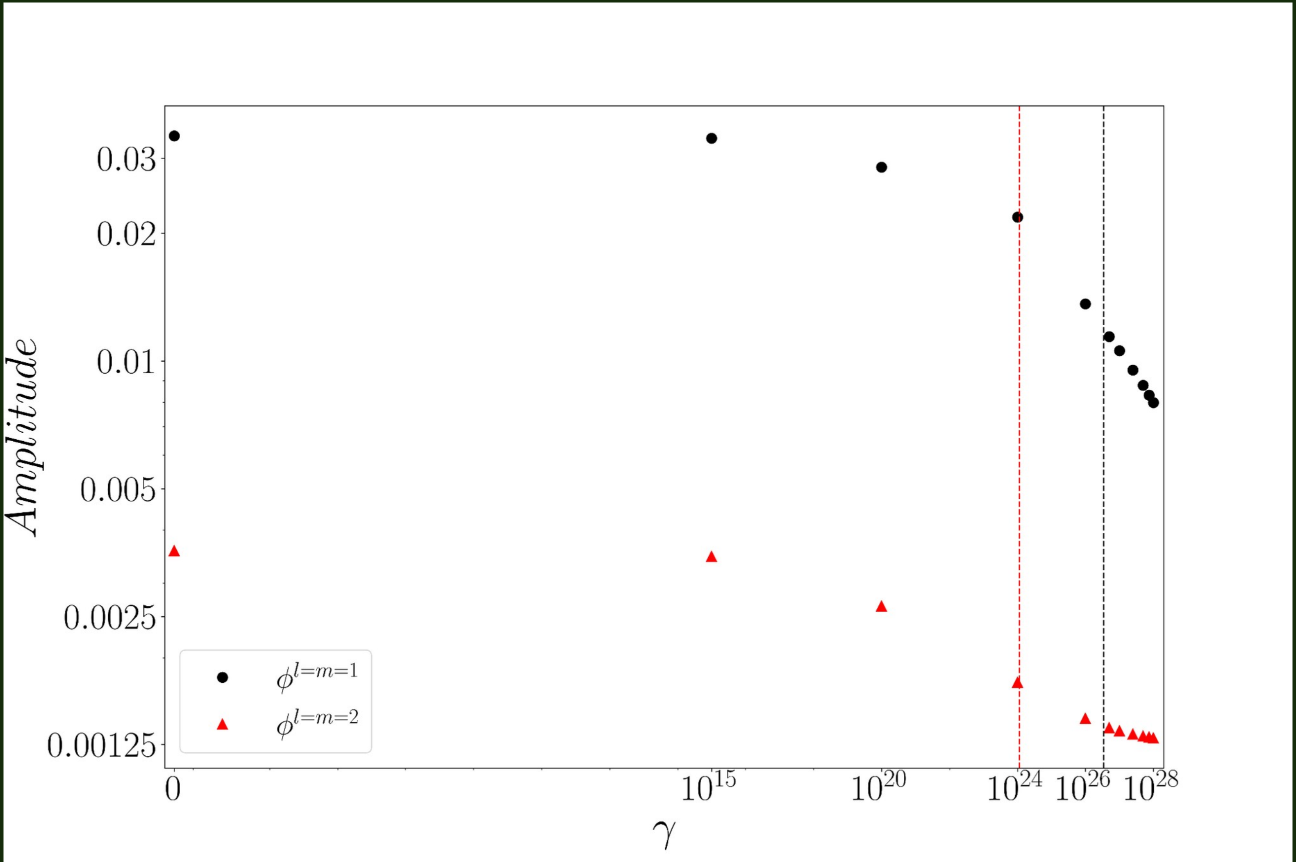




$$\lambda_{dipole} \approx \frac{2}{3} r_V$$

$$\lambda_q \approx \frac{1}{3} r_V$$

Scalar Radiation : Scaling



Conclusion:

- Performed simulations in simplified scenario, achieving a better hierarchy of scales.
- Screening seems to be effective throughout the parameter space.

No amplification

GR terms ?
Binary ?

Inflection point in Quadrupole

Questions ?