Spinorial Perturbations in Galileon Black Holes

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Goal and Motivation

♣ Stability of the geometry.

♣ Fermion fields have unique features that boson fields do not have.

♣ Gauge/gravity conjecture: spinorial perturbations describe matter fields at the boundary CFT.

Galileon Black Hole Solution

The action is given by [M. Rinaldi, Phys. Rev. D86, 084048 (2012)]

$$S = \frac{1}{2} \int dx^4 \sqrt{-g} \left[\beta R - \left(g^{\mu\nu} - \bar{z} G^{\mu\nu} \right) \partial_\mu \phi \partial_\nu \phi \right] . \tag{1}$$

where

$$\beta = m_P^2 , \qquad \bar{z} = \frac{z}{m_P^2} . \tag{2}$$

For $z > 0$ a black hole solution can be found to be

$$ds^2 = -F(r)dt^2 + H(r)dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2) , \tag{3}$$

with

$$F(r) = \frac{3}{4} + \frac{r^2}{L^2} - \frac{2M}{m_P^2 r} + \frac{\sqrt{\bar{z}}}{4r} \arctan\left(\frac{r}{\sqrt{\bar{z}}}\right), \quad (4)$$

$$H(r) = \frac{(r^2 + 2\bar{z})^2}{4(r^2 + \bar{z})^2 F(r)},$$

$$\left[\phi'(r)\right]^2 = -\frac{m_P^2 r^2 (r^2 + 2\bar{z})^2}{4\bar{z}(r^2 + \bar{z})^3 F(r)}, \quad (5)$$

being $l^2 = 12\bar{z}$. Clearly, $\bar{z}$ is a nonperturbative parameter that interpolates between S ($z \to \infty$) and SAdS solutions.

Fermionic Field Perturbations

The spinorial field must obey Dirac equation

$$i\gamma^{(a)} e^{\mu}_{(a)} \nabla_{\mu} \Psi - \mu_s \Psi = 0\,, \tag{6}$$

where

$$\nabla_{\mu} = \partial_{\mu} + \frac{1}{4}\omega_{\mu}^{(a)(b)} \gamma_{[a}\gamma_{b]}\,, \qquad \omega_{\mu}^{(a)(b)} = e_{\nu}^{(a)} \partial_{\mu} e^{(b)\nu} + e_{\nu}^{(a)} \Gamma^{\nu}_{\mu\sigma} e^{\sigma(b)}\,. \tag{7}$$

Decoupling the radial part of Dirac equation and after some coordinate transformations the 2-spinors $Z_{\pm}$ obey the following equation,

$$\left(\frac{d^2}{d\hat{r}_*^2} + \omega^2\right) Z_{\pm} = V_{\pm} Z_{\pm}\,, \tag{8}$$

with the superpartner potentials

$$V_{\pm} = W^2 \pm \frac{dW}{d\hat{r}_*}\,, \tag{9}$$

given in terms of the so-called superpotential

$$W = \frac{\left[F\left(K^2/r^2 + \mu_s^2\right)\right]^{1/2}}{1 + \frac{\mu_s K}{2\omega(K^2+\mu_s^2 r^2)}\sqrt{\frac{F}{H}}}\,. \tag{10}$$

The coordinate $\hat{r}_*$ can be calculated exactly in terms of a tortoise coordinate r_* both given by

$$\hat{r}_* = r_* + \frac{1}{2\omega}\arctan\left(\frac{\mu_s r}{K}\right)\,, \qquad dr_* = \sqrt{\frac{H(r)}{F(r)}}\,dr\,. \tag{11}$$

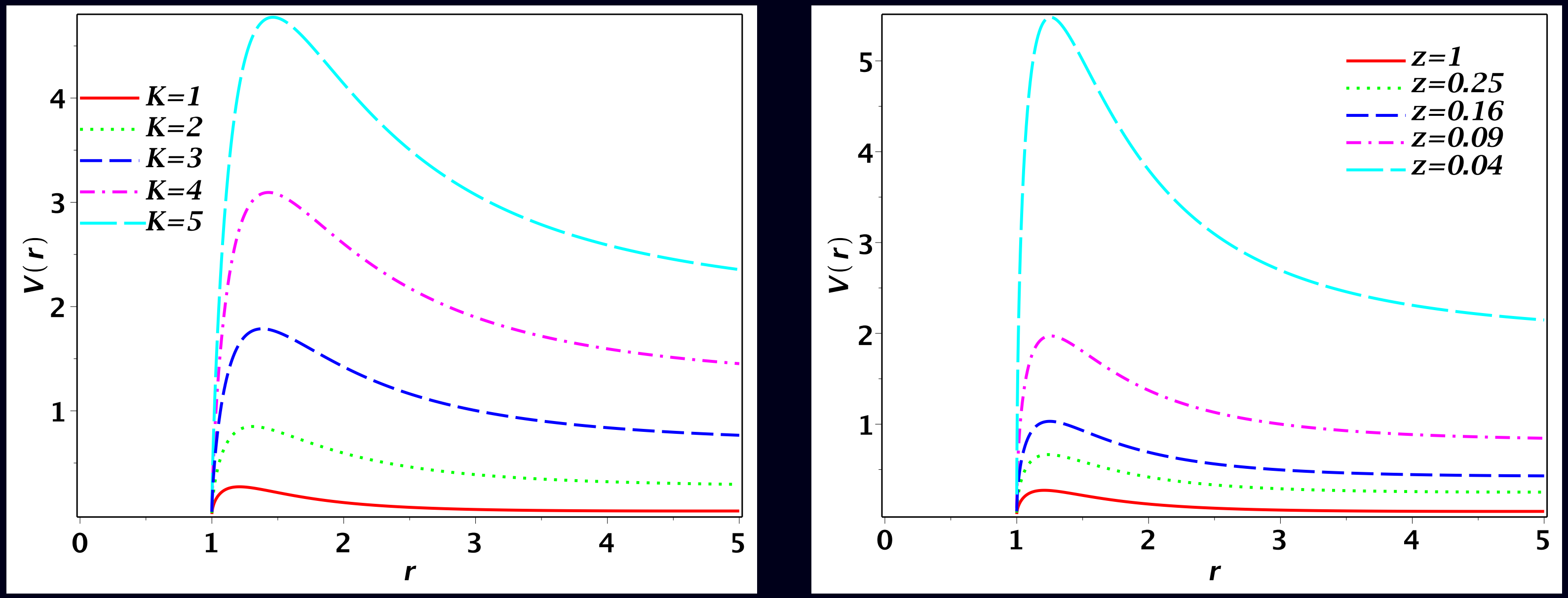


Figure 1: Effective potential V_+ for fermion perturbations for different K and $\bar{z}$.

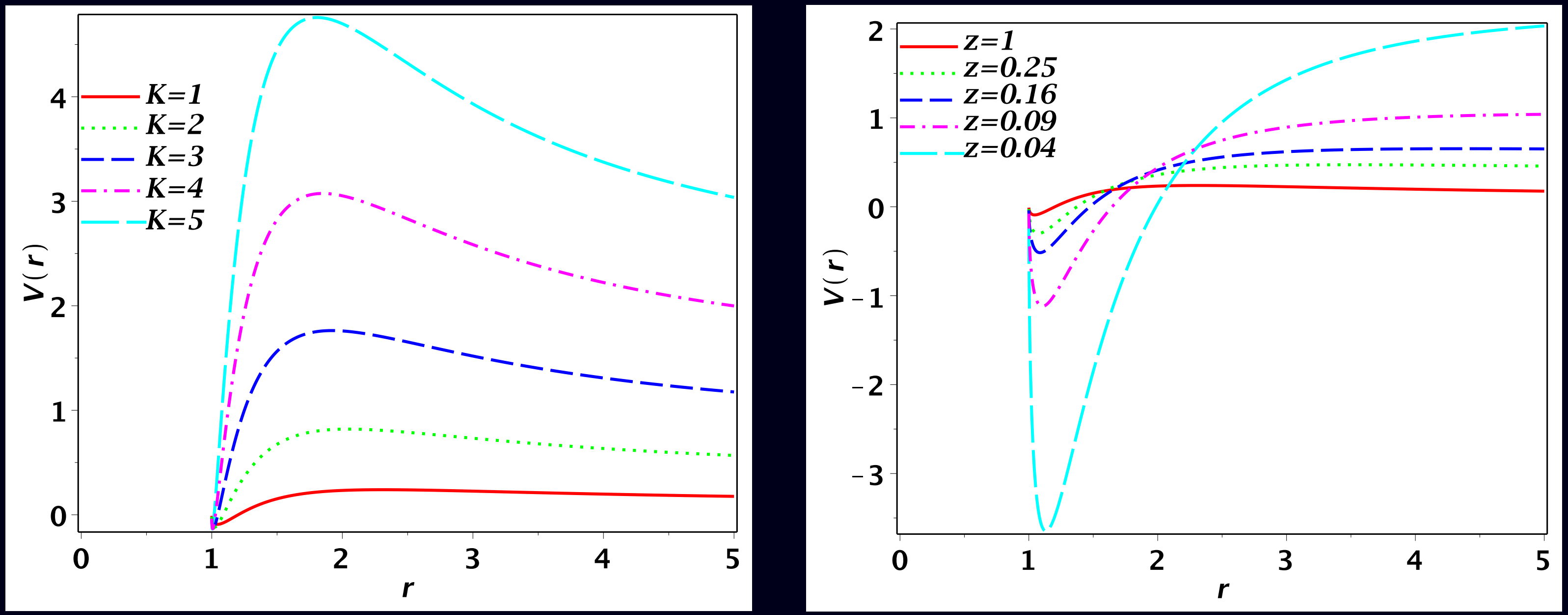


Figure 2: Effective potential V_{-} for fermion perturbations for different K and $\bar{z}$.

WKB results

	$\sqrt{\bar{z}} = 1$		$\sqrt{\bar{z}} = 0.8$		$\sqrt{\bar{z}} = 0.6$	
K	$Re(\omega)$	$-Im(\omega)$	$Re(\omega)$	$-Im(\omega)$	$Re(\omega)$	$-Im(\omega)$
1	0.420	0.357	0.394	0.495	0.124	1.250
2	0.832	0.340	0.858	0.410	0.461	0.776
3	1.273	0.326	1.361	0.379	1.290	0.475
4	1.712	0.321	1.845	0.371	1.988	0.440
5	2.148	0.319	2.321	0.369	2.593	0.450

Table 1: Dirac quasinormal frequencies with fixed horizon radius $r_+ = 1$ computed using the WKB technique.

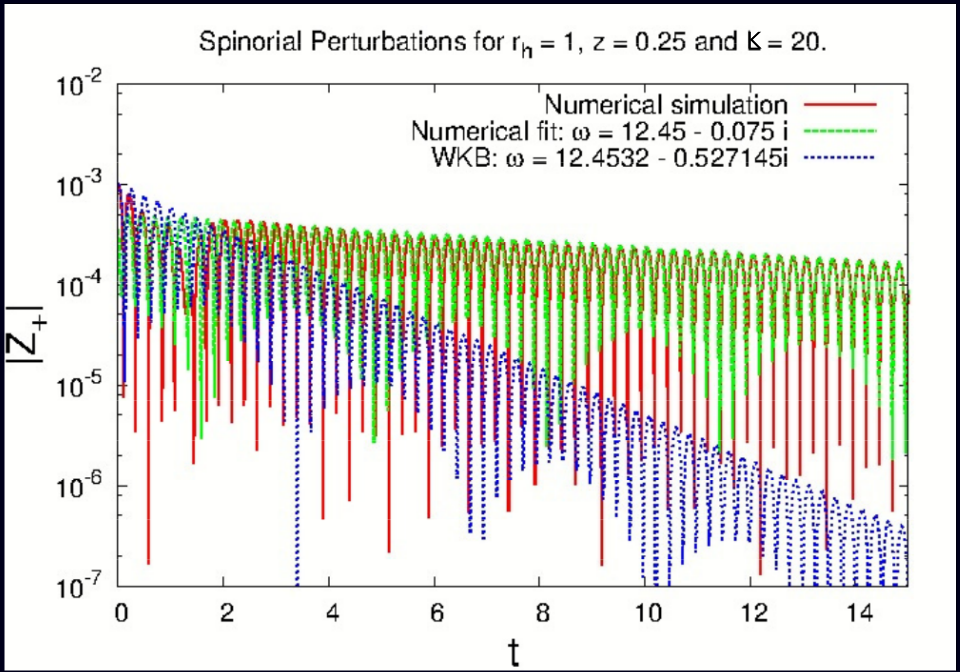
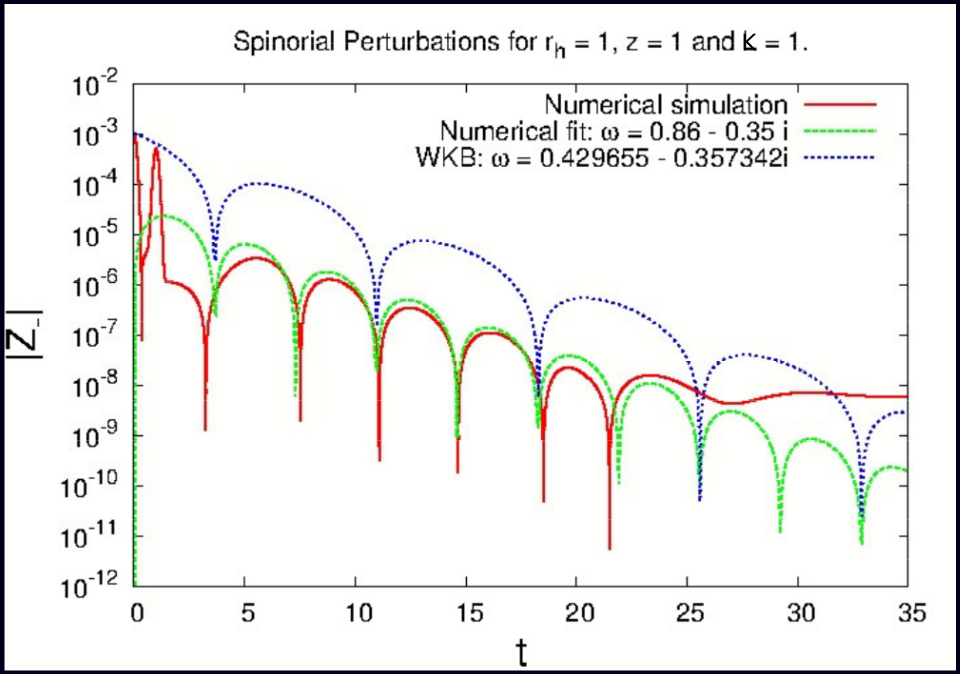


Figure 3: Perturbations evolution for a superpartner potential V_+.



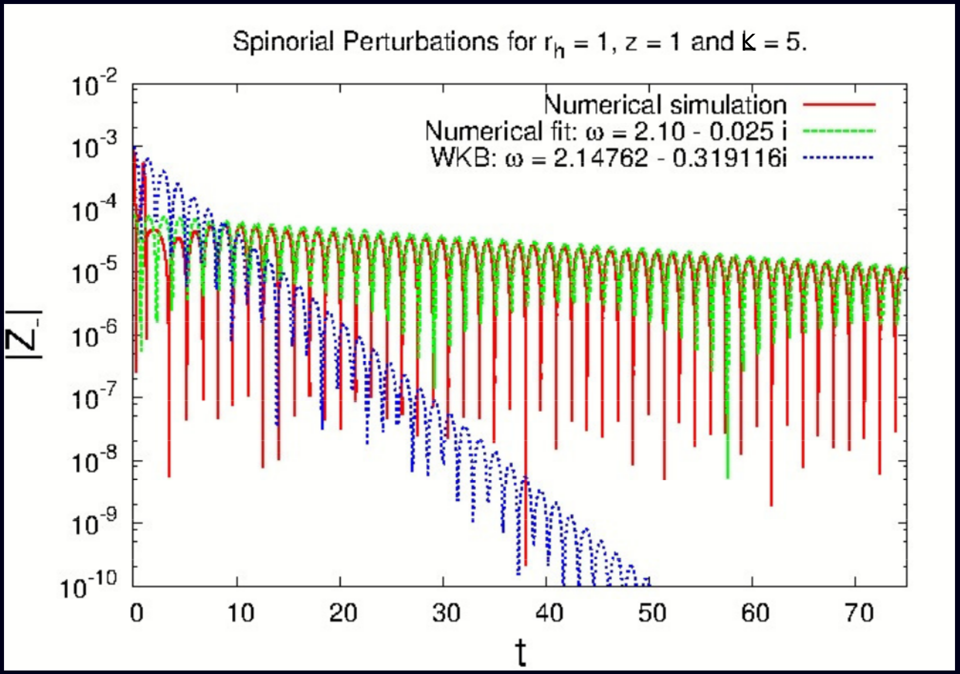


Figure 4: Perturbations evolution for a superpartner potential V_{-}.

Summary

♣ We considered fermion perturbations in the context of galileon black holes.

♣ Due to potentials shape for massless fermions WKB method can be applied. For $\bar{z} \sim r_h$ convergence is poor. However, as K increases, convergence is improved.

♣ Numerical method shows very good agreement for ω_R at big K and ω_I at small K.