# Quasinormal Modes of Dirac and Gravitational Fields in Generalized Nariai Spacetimes

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***Abstract*** - Quasinormal modes (QNMs) are eigenmodes of dissipative systems. For instance, if a spacetime with an event or cosmological horizon is perturbed from its equilibrium state, QNMs arise as damped oscillations with a spectrum of complex frequencies that does not depend on the details of the excitation [1]. From the mathematical point of view, this discrete spectrum of QNMs stems from the fact that certain boundary conditions must be imposed to the physical fields propagating in such background [2]. QNMs have been studied for a long time and its interest has been renewed by the recent detection of gravitational waves, inasmuch as the modes whose frequencies have small imaginary parts are the ones that survive for a longer time when a background is perturbed, so that these comprise the signals that are generally measured by experiments [3]. In the present work, we consider a higher-dimensional generalization of the charged Nariai spacetime [4], namely $dS_2 \times S^2 \times \ldots \times S^2$, and investigate the dynamics of perturbations of the electrically charged Dirac field (spin 1/2) as well as the perturbations of the gravitational field (massless spin 2) [5]. In this geometry, the spinorial formalism is used to show that the Dirac equation is separable [6] and can be reduced to a Schrödinger-like equation whose potential is contained in the Rosen-Morse class of integrable potentials, which has the so-called Pöschl-Teller potential as a particular case [7]. This latter being the same potential that shows up in the massless spin 2 case, although the spectrum of the two fields are different from each other, which should be expected from the fact that the Dirac field has mass and electric charge. We also investigate the boundary conditions that lead to QNMs.

**Keywords:** Quasinormal modes. Generalized Nariai spacetime. Gravitational Perturbation. Dirac Fields. Boundary conditions. Integrability.

## References

[1] C. V. Vishveshwara, Scattering of Gravitational Radiation by a Schwarzschild Black-hole, Nature **227**, 936 (1970).

[2] H. P. Nollert, *Quasinormal modes: the characteristic 'sound' of black holes and neutron stars*, Classical and Quantum Gravity **16**, 159 (1999).

[3] B. P. Abbott et al. (LIGO Scientific and Virgo Collaborations), *Observation of gravitational waves from a binary black hole merger*, Physical Review Letters **116**, 061102 (2016).

[4] C. Batista, *Generalized charged Nariai solutions in arbitrary even dimensions with multiple magnetic charges*, General Relativity and Gravitation **48**, 160 (2016).

[5] T. Regge and J. A. Wheeler, *Stability of a Schwarzschild Singularity*, Physical Review D **108**, 1063 (1957).

[6] J. Venâncio and C. Batista, *Separability of the Dirac equation on backgrounds that are the direct product of bidimensional spaces*, Physical Review D **95**, 084022 (2017).

[7] J. Venâncio and C. Batista, *Quasinormal Modes in Generalized Nariai Spacetimes*, Physical Review D **97**, 105025 (2018).

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