NONSINGULAR BLACK HOLES IN MODIFIED GRAVITY

Mercè Guerrero Román and Diego Rubiera García

Departmento de Física Teórica and IPARCOS, Universidad Complutense de Madrid,
E-28040 Madrid, Spain

merguerr@ucm.es

Introduction

The Kerr (exterior) solution of General Relativity (GR) describes real black holes in the Universe, but its interior part unavoidably yields space-time singularities, where our ability to prediction comes to an end. This suggest the need to extend GR on its strong-field regime, while being compatible with current observational constraints. We addressed the issue with space-time singularities within metric-affine gravity theories, where metric and affine connection are independent fields.

Metric-affine gravities

A suitable family of metric-affine gravities are Ricci-based gravities (RBGs), defined by the action

$$\mathcal{S}_m = \frac{1}{2\kappa^2}\int d^4x\sqrt{-g}\mathcal{L}_G(g_{\mu\nu}, R_{\mu\nu}(\Gamma)) + \mathcal{S}_m(g_{\mu\nu}, \psi_m). \tag{1}$$

From (1) one finds a system of Einstein-like equations

$$G^{\mu}{}_{\nu}(q) = \frac{\kappa^2}{|\Omega|^{1/2}}\left[T^{\mu}{}_{\nu} - \delta^{\mu}{}_{\nu}\left(\mathcal{L}_G + T/2\right)\right], \tag{2}$$

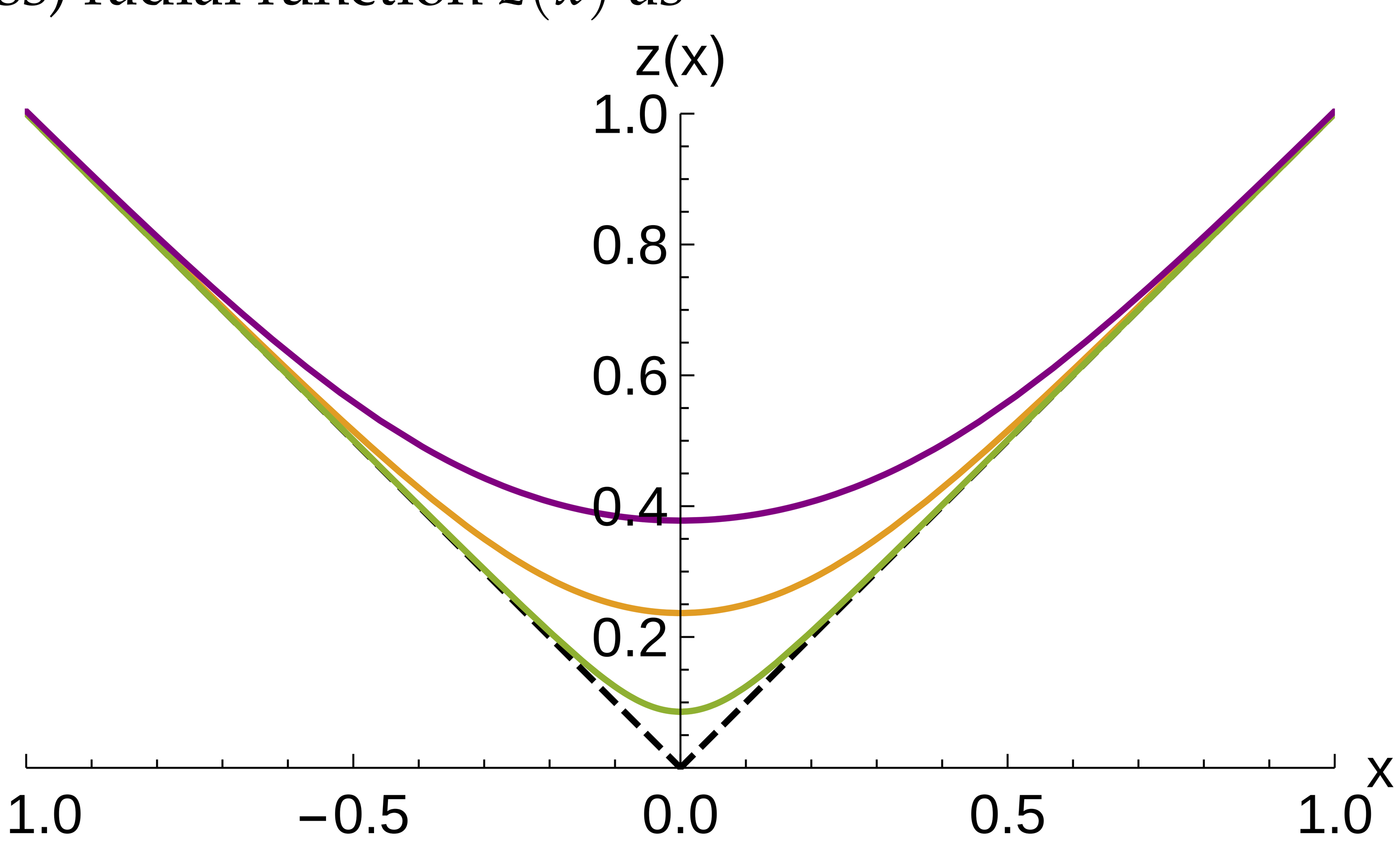
for an auxiliary metric defined as

$$q_{\mu\nu} = g_{\mu\alpha}\Omega^{\alpha}{}_{\nu}, \tag{3}$$

where $\Omega^{\alpha}{}_{\nu}$ is on-shell a function of the matter fields. For simplicity, we shall restrict our analysis to spherically symmetric solutions, where explicit solutions to (2) and (3) are found for two RBGs: quadratic $f(R)$ gravity and Born-Infeld (BI) gravity [1].

Results

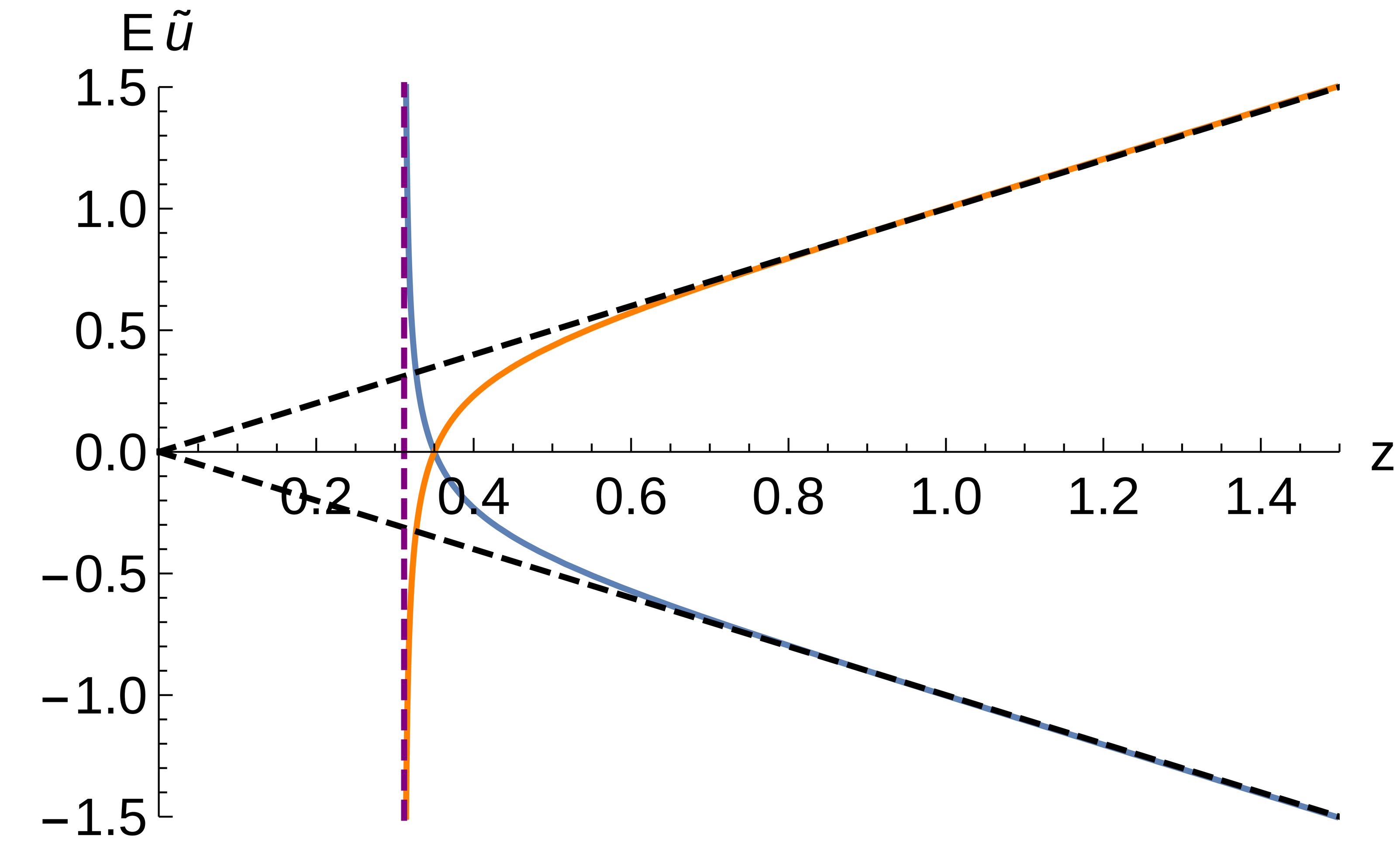
From Eq. (3) one finds the behaviour of the (dimensionless) radial function $z(x)$ as

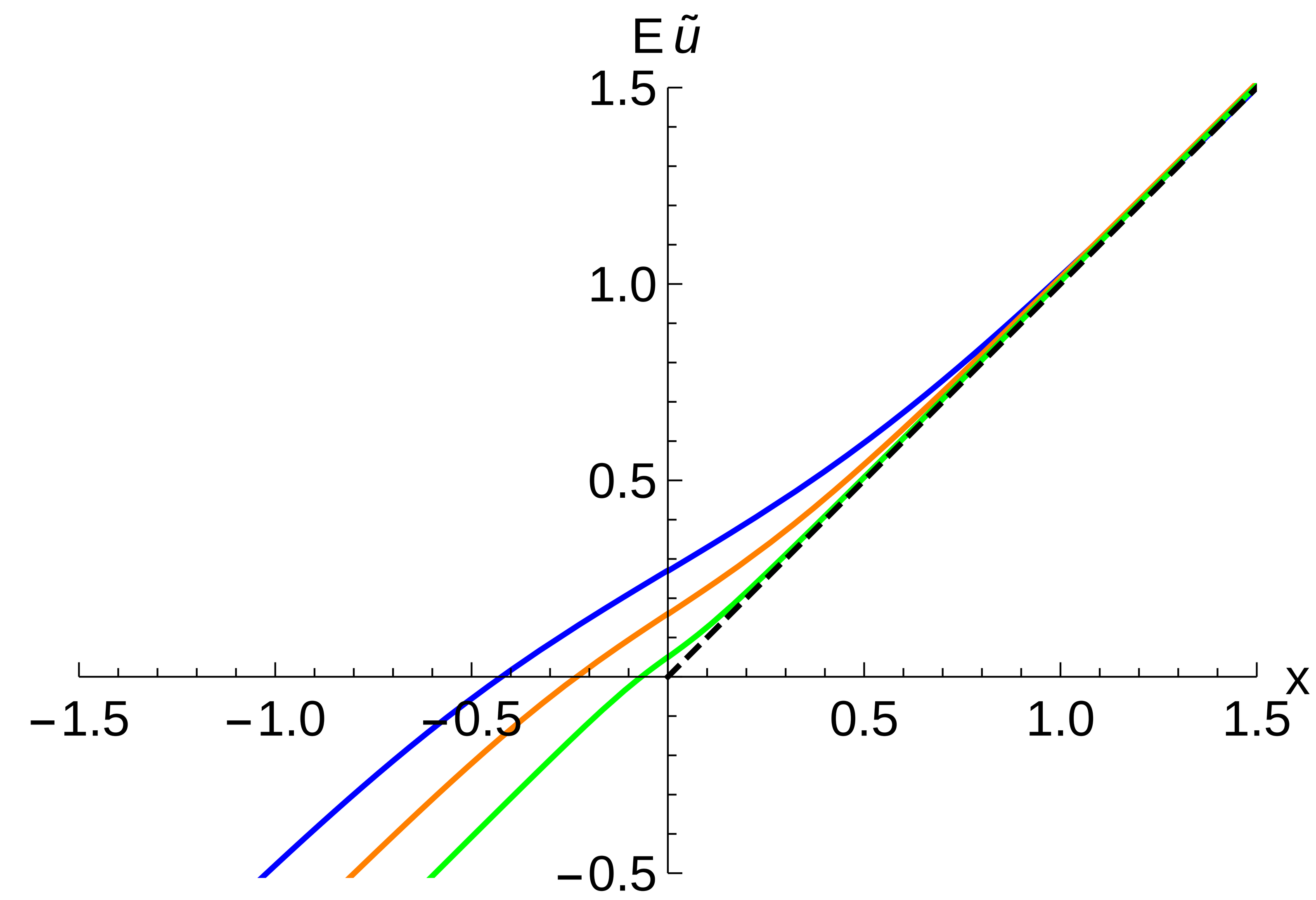


which corresponds to wormhole structure with $z = z_c$ representing its throat. Are the solutions geodesically complete?. For any spherically symmetric space-time $ds^2 = -C(x)dt^2 + B^{-1}(x)dx^2 + r^2(x)d\Omega^2$, the geodesic equation may be written as [2]

$$\frac{C}{B}\left(\frac{dx}{du}\right)^2 = E^2 - C(x)\left(-k + \frac{L^2}{r^2(x)}\right). \tag{4}$$

where $k = -1, 0$ for time-like and null geodesics. For radial $L = 0$ null geodesics, Eq.(4) is integrated as





for $f(R)$ and BI. Though in both cases these geodesics are complete (time-like geodesics are too), curvature divergences $\sim (z - z_c)^{-2}$ may be found at the wormhole throat $z = z_c$. While in the $f(R)$ case such divergences lie at the boundary of the manifold, in the BI case physical observers can reach them in finite time, raising the question on the effect of tidal forces upon them, and requiring the consideration of congruences of geodesics.

Conclusions

Spherically symmetric solutions in metric-affine gravity can be geodesically complete. Extension of this result to rotating black holes is possible [3]. Need to find observation discriminators in terms of gravitational waves and shadows (work in progress).

Acknowledgments

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References

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