



Reissner-Nordström Blackholes in the Marongwe Space-time

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1. Introduction

The Reissner–Nordström black hole is a fundamental solution in General Relativity that describes a static, spherically symmetric black hole possessing electric charge. It extends the Schwarzschild solution by incorporating electromagnetic interactions through the Einstein–Maxwell equations. This makes it an important model for studying the interplay between gravity and electromagnetism in curved spacetime.

In this work, we solve the Einstein-Marongwe field equations (EMFEs) for a charged static black hole in the Marongwe Nexus Paradigm, within the semi-classical limit.

2. Theoretical framework

2.1 Einstein-Marongwe Field Equations (EMFEs) The Einstein-Marongwe Field Equations (EMFEs) are [1, 2]:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = \frac{8\pi G}{c^4}T_{\mu\nu} + (n^2 - 1)\Lambda g_{\mu\nu}, \quad (1)$$

where $R_{\mu\nu}$ is the Ricci tensor, G is Newton's constant of gravitation and Λ is the cosmological constant. n is the quantum number of the state of space-time. R is the Ricci scalar while the electromagnetic energy tensor is given by

$$T_{\mu\nu} = \frac{1}{\mu_0} \left(\frac{1}{4}g_{\mu\nu}F_{\alpha\beta}F^{\alpha\beta} - g_{\nu\beta}F_{\mu\alpha}F^{\beta\alpha} \right). \quad (2)$$

with

$$F_{\mu\nu} = \begin{pmatrix} 0 & E_r/c & 0 & 0 \\ -E_r/c & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}.$$

Due to the spherical symmetry of the problem, the radial electric field is given by

$$E_r = \frac{Q}{4\pi\epsilon_0 r^2}, \quad (3)$$

where Q is the charge of the blackhole and ϵ_0 is permittivity of free space. $g_{\mu\nu}$ is the metric tensor for a charged spherical mass distribution. The solution of the EMFEs is

$$ds^2 = \left[1 - \frac{r_s}{r} + \frac{r_Q^2}{r^2} + \frac{\Lambda(n^2 - 1)r^2}{3} \right] dt^2 - \frac{dr^2}{\left[1 - \frac{r_s}{r} + \frac{r_Q^2}{r^2} + \frac{\Lambda(n^2 - 1)r^2}{3} \right]} - r^2 d\Omega^2, \quad (4)$$

where $r_s = \sqrt{\frac{2GM}{c^2}}$ is the Schwarzschild radius, $r_Q = \sqrt{\frac{GQ^2}{4\pi\epsilon_0 c^4}}$ and

$$d\Omega^2 = -d\phi^2 - \sin^2\theta d\theta^2. \quad (5)$$

The ratio of proper frequencies f_1 and f_2 measured by an observer located at r_1 and r_2 , respectively, is

$$\frac{f_2}{f_1} = \frac{\sqrt{1 - \frac{r_s}{r_1} + \frac{r_Q^2}{r_1^2} + \frac{\Lambda(n^2 - 1)r_1^2}{3}}}{\sqrt{1 - \frac{r_s}{r_2} + \frac{r_Q^2}{r_2^2} + \frac{\Lambda(n^2 - 1)r_2^2}{3}}} \quad (6)$$

3. Results

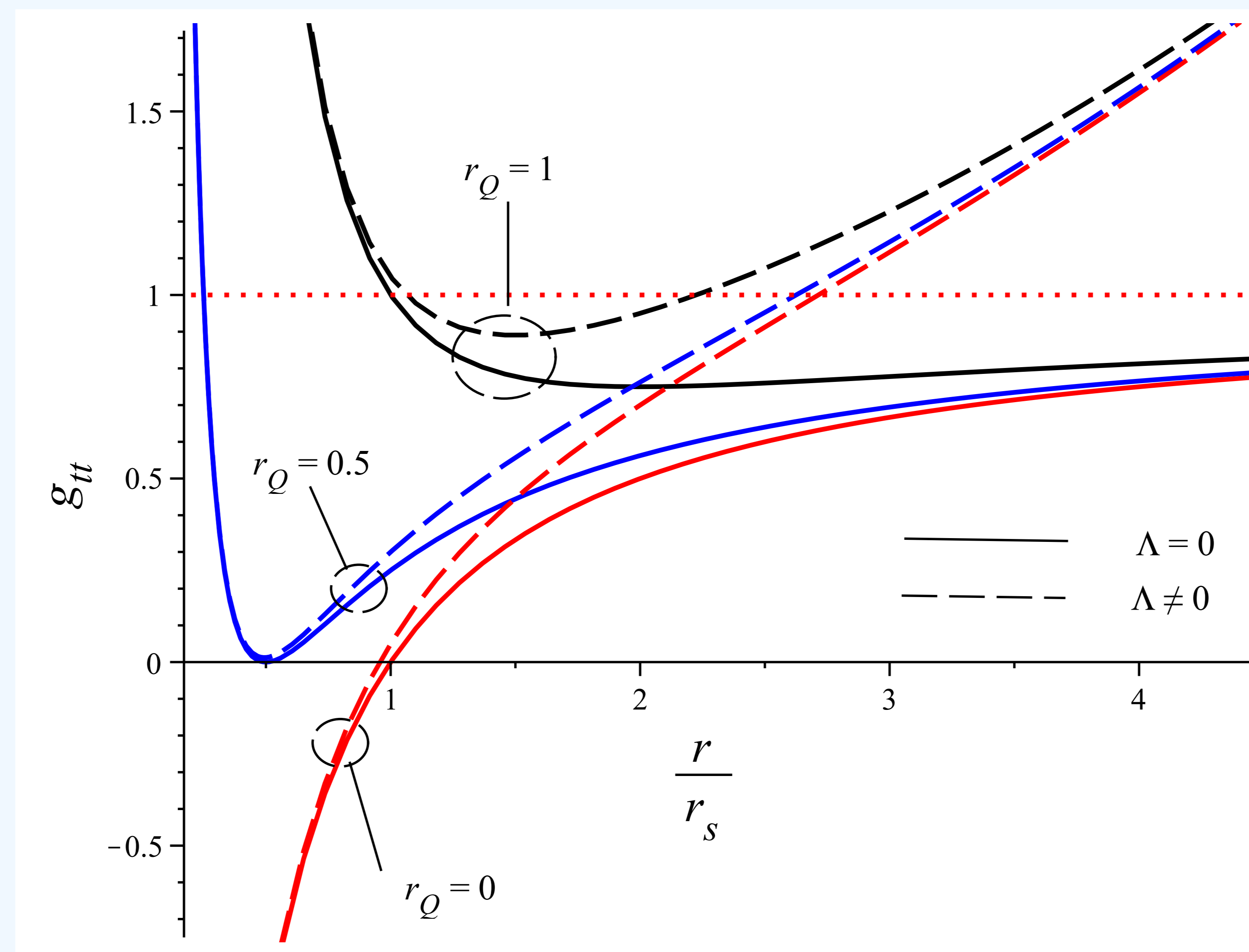


Figure: The tt component of the metric tensor as a function of radial distance from the centre of the BH for different values of the charge for $n = 2$

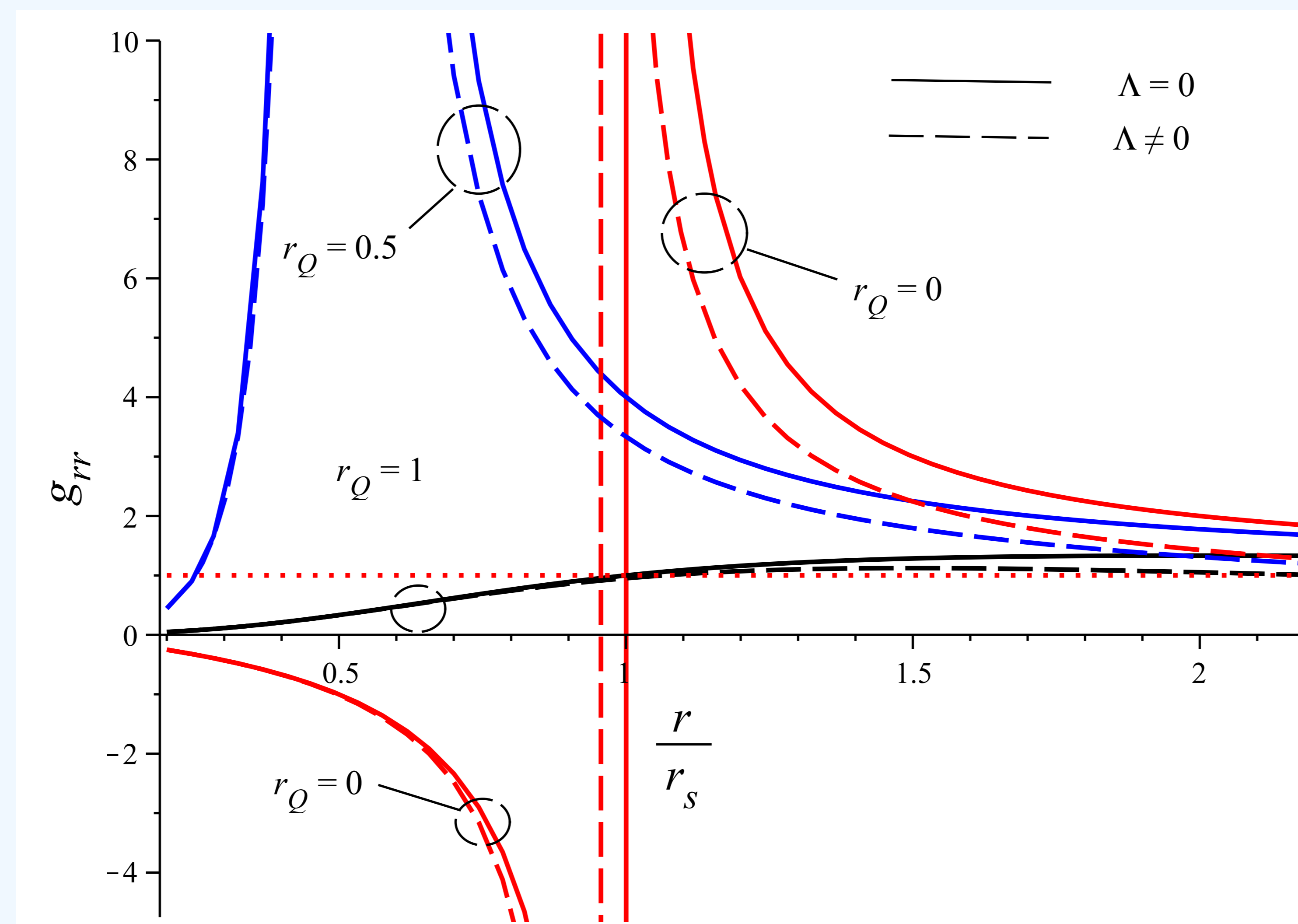


Figure: The rr component of the metric tensor as a function of radial distance from the centre of the BH for different values of the charge for $n = 2$

3. Results

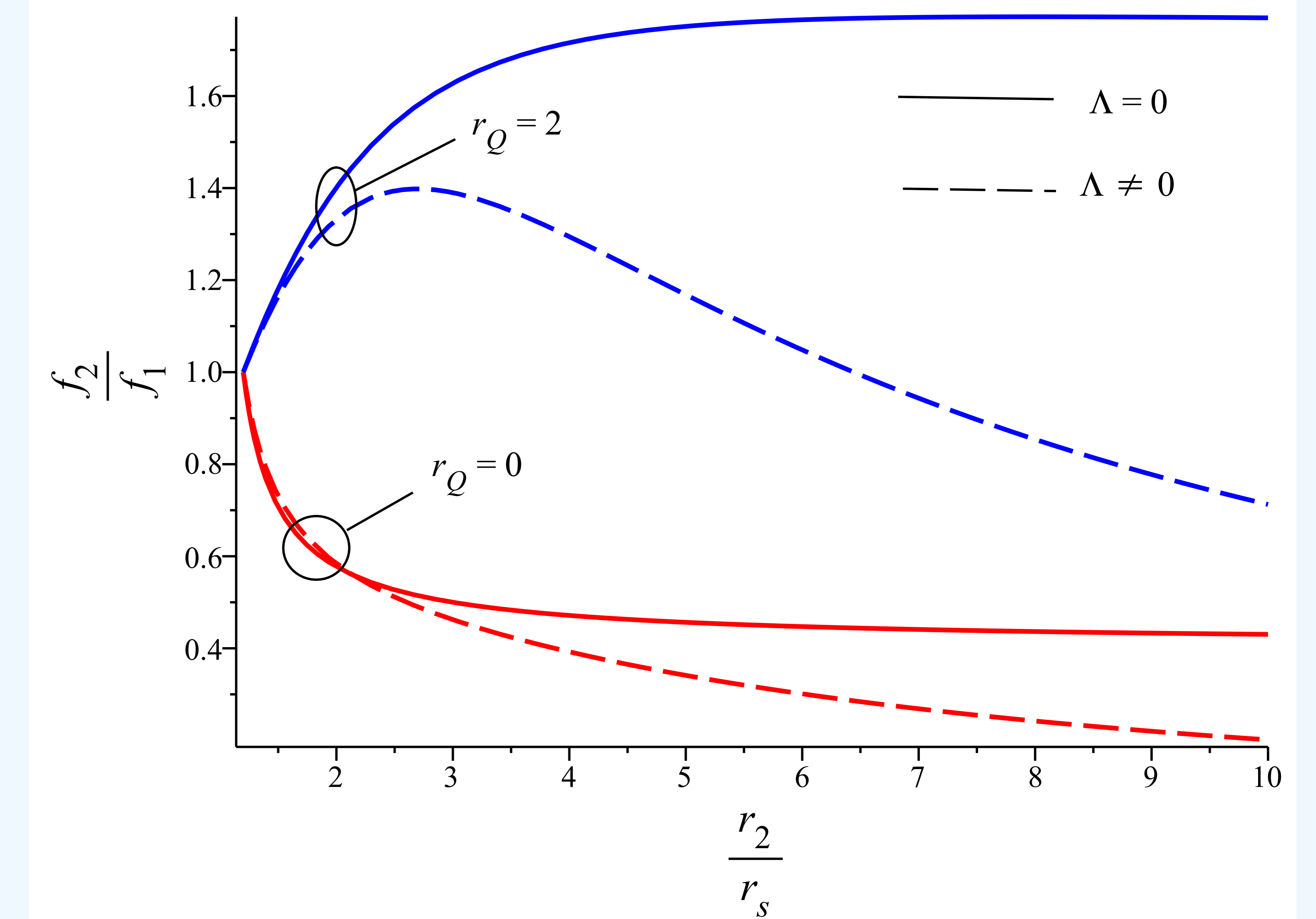


Figure: Ratio of frequency measured at r_2, f_2 , to the frequency measured at r_1, f_1 , for $n = 2$. Here, $r_1 = 1.2r_s$.

4. Conclusions

- ▶ Einstein-Marongwe field equations have been solved for charged non-rotating BH's.
- ▶ The results of the Einstein's field equations are merely the $n = 1$ state of ST in the Marongwe's Nexus Paradigm.
- ▶ The rate of flow of time increases with the radial distance away from the BH.
- ▶ The Λ term promotes redshifting of electromagnetic radiation of light emitted from the vicinity of a charged BH.
- ▶ Additionally, space shrinks at very large radial distances from the charged BH.
- ▶ The effects of the Marongwe ST are apparent only at very large scales due to the extremely small value of the cosmological constant Λ .

5. References

- S. Marongwe, "Covariant canonical quantization of general relativity," *Advances in High Energy Physics*, vol. 2018, p. 4537058, 2018.
- S. Marongwe, M. Tshipa, and C. Corda, "Bayesian analysis of the nexus paradigm predictions for supermassive black hole observations by the event horizon telescope," *Universe*, vol. 11, p. 289, 2025.