Spectral Compression of Charged Black Holes: (Q) for Kerr-Newman

How Electric Charge Modifies the Analyticity Parameter

Tamás Nagy

tnagyphd@gmail.com

Scaffold

Abstract

The quasinormal mode analyticity parameter = / 3 is universal for Kerr (uncharged) black holes [Paper I]. We extend this analysis to Kerr-Newman spacetimes, computing (a, Q) across the full parameter space. The WKB approximation predicts $\to 3$ whenever the standard light ring structure persists. We map the (a, Q) surface and identify [potential deviations / continued universality] near the extremal Kerr-Newman limit where $a^2 + Q^2 \to M^2$.

1. Introduction

1.1 Motivation

- Paper I: 3 for Kerr ($Q = 0$), universal across spins
- Natural question: what happens with charge $Q > 0$?
- Relevant for: primordial black holes, dark photon models, charged BH solutions in modified gravity

1.2 Kerr-Newman QNMs

- Teukolsky equation generalizes to KN with additional Q-dependent terms
- QNM frequencies (M, a, Q) computed by various methods
- Light ring at r_ph(a, Q) — shifts with charge

2. Method

2.1 QNM Computation

- Use Leaver's continued fraction for KN (Berti & Stergioulas tables)
- Or: direct computation via spectral methods
- Compute l=2, m=2 gravitational QNMs for grid: a/M [0, 0.99], Q/M [0, 0.99]
- Subject to extremality bound $a^2 + Q^2$ M^2

2.2 WKB Analysis

- Light ring radius r_ph(a, Q)
- Surface gravity (a, Q)
- WKB prediction: $\to$ (n + 1/2)/(n + 1/2) = 3

- Does this persist for all Q?

2.3 Surface

- Compute (a, Q) on 50×50 grid
- Identify: contour at = 3, maximum/minimum , gradients

3. Results

3.1 The (a, Q) Surface

[Heatmap: a vs Q, color =] [Prediction: 3 everywhere except possibly near extremal KN]

3.2 WKB Universality

- If 3 for all (a, Q) → "super-universality", is a topological invariant of ANY stationary BH light ring
- If (Q) deviates → charge provides a new handle

3.3 Extremal Limit

- At $a^2 + Q^2 \to M^2$: what happens to ?
- Kerr limit (Q → 0): → 3.00
- Reissner-Nordström limit (a → 0): (Q) = ?

4. Implications

4.1 Charged BH Spectroscopy

- If depends on Q: measuring constrains Q
- Combined with mass/spin from fundamental mode → three independent tests

4.2 No-Hair Theorem Test

- For Kerr (Q = 0): = 3 is a prediction
- Any deviation from = 3 in an observed ringdown → evidence for charge or beyond-GR physics

4.3 Dark Sector

- Millicharged BHs: small Q → small deviation
- Observable threshold: how much Q is needed for Δ > measurement error?

5. Conclusion

[Map of (a, Q) provides theoretical predictions. If universality persists → = 3 is a fundamental property of ALL BH light rings.]

References

[TBD — Berti et al. 2009, Kokkotas & Schutz 1999, Dias et al. for KN QNMs, Paper I]