Ringdown of rotating black holes in higher-derivative gravity

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[2304.02663 and 2307.07431]

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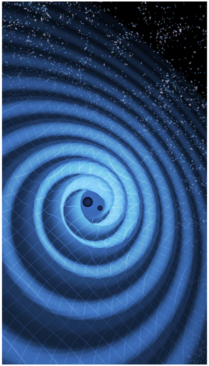


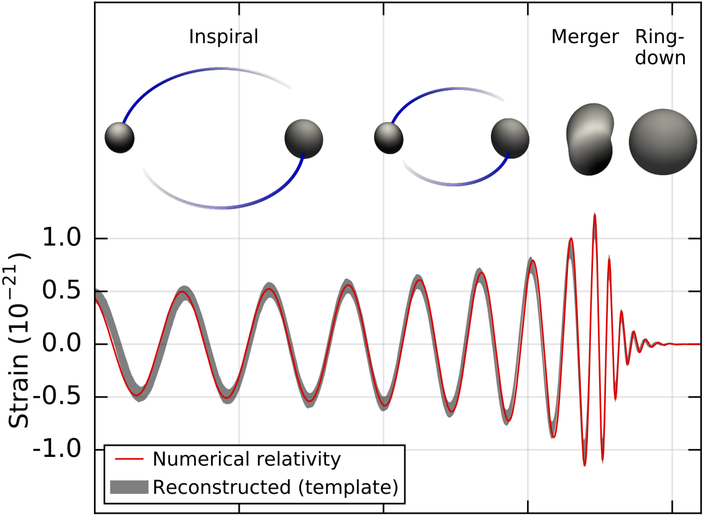
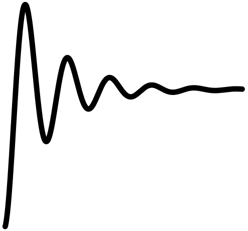


Figure: Theoretical signal and phases of a binary black hole merger [LIGO Collaboration]

Ringdown frequencies

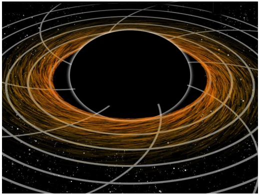
- Perturbations of black hole decay over time
- GWs come from space around the black hole
- Fluctuations of a damped harmonic oscillator
- Boundary conditions set a dissipative system
- Resonance modes have complex frequencies



$$\sum A_k \exp(i\omega_k t)$$

Rotating black holes

- Schwarzschild black hole is static and spherically symmetric
- Perturbations of these black holes decouple and separate
- Adding angular momentum yields a Kerr black hole in GR
- Finding perturbations requires solving Teukolsky equations
- A modified Teukolsky equation is needed to go beyond GR



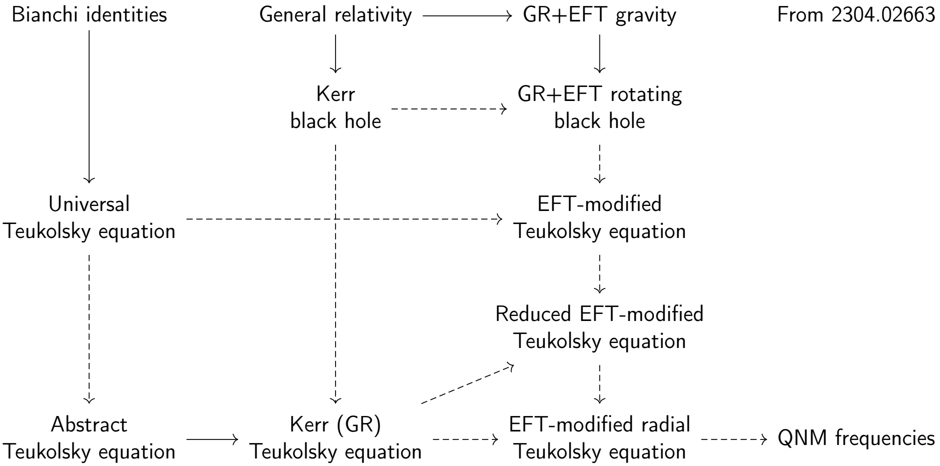
Higher derivative Gravity

- Extend GR as an effective field theory of higher derivatives
- An approximation to study phenomena at one energy scale
- The complete theory at a higher energy scale is unknown

$$S = \int \mathrm{d}^4x \, \sqrt{g} \left[R + \sum_{n=2}^{\infty} \ell^{2n-2} \mathcal{L}_{(n)} \right]$$

$$\mathcal{L}_{(3)} \ell^4 = \lambda_{\text{ev}} R_{\mu\nu}{}^{\rho\sigma} R_{\rho\sigma}{}^{\delta\gamma} R_{\delta\gamma}{}^{\mu\nu}$$

Universal Teukolsky equation near Kerr



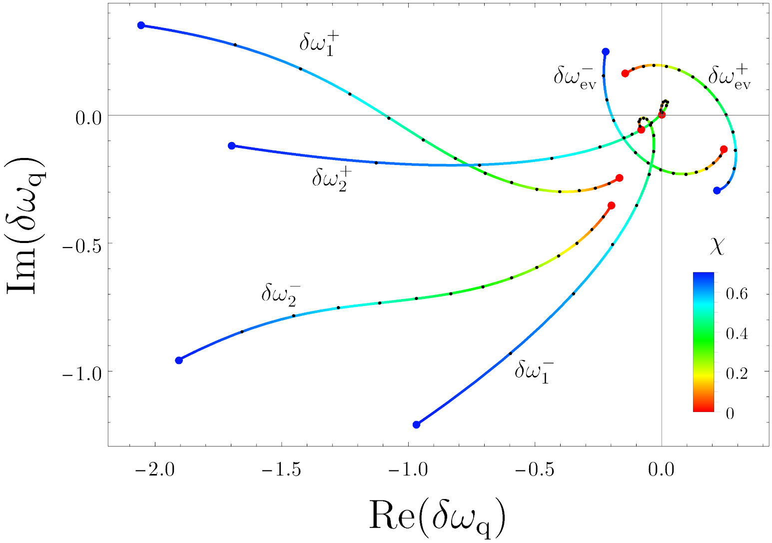
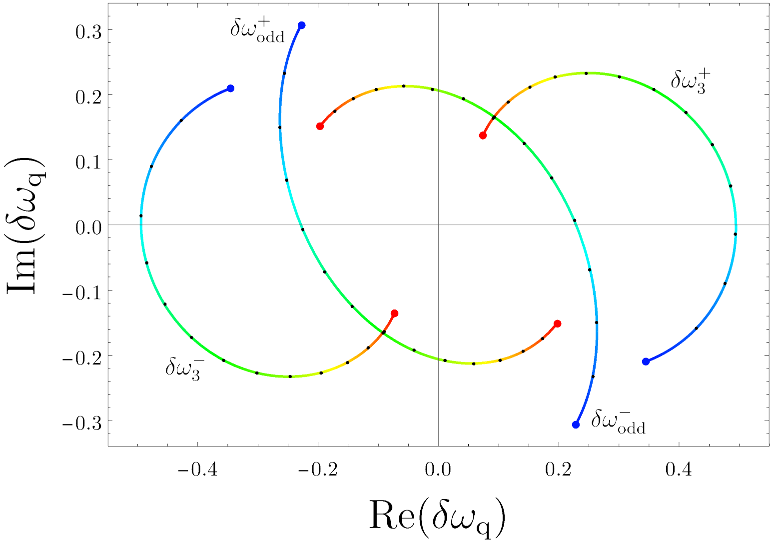


Figure: Shift in the 220 QNM frequency relative to Kerr [arXiv:2307.07431]



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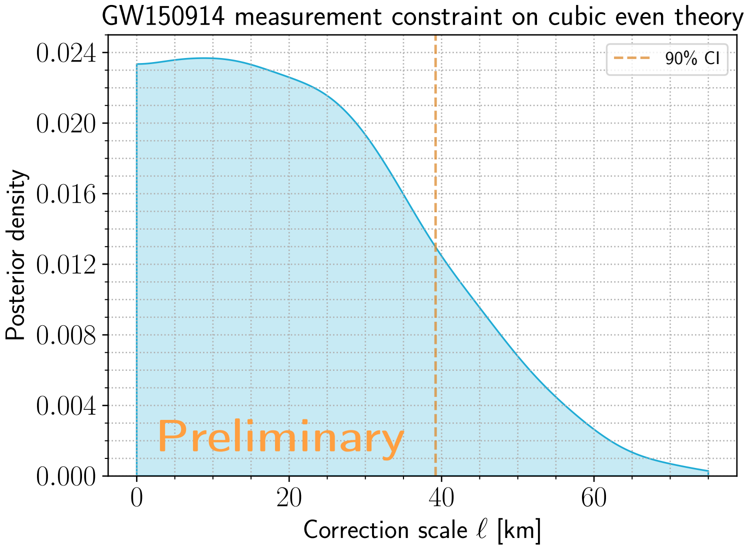
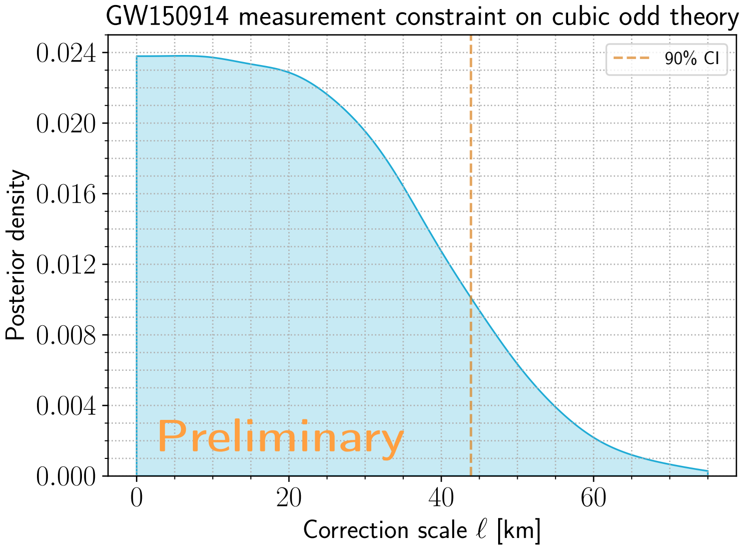


Figure: Calculated constraints on ℓ from the ringdown analysis of GW150914



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Conclusions

- QNMs of rotating BHs with the universal Teukolsky equation
- Applied to the general EFT class of higher derivative gravity
- Correction coefficients were calculated up to ~ 0.7 in spin
- Preliminary analysis shows constraints from current data
- Sensitivity of future GW detectors from further analysis

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Thank you for your attention!