

Dynamics and gravitational waves' emission of spinning and eccentric compact binary systems in general relativity

Tom Colin

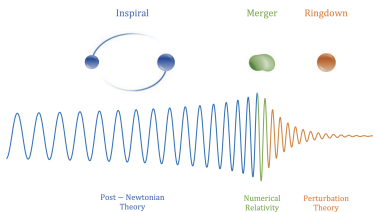
Second-year PhD Student

Supervised by Laura Bernard

LUX Day
June 16, 2026

Gravitational Waves: A New Window onto the Universe

Ground-Based: LVK [$10-10^4$ Hz]

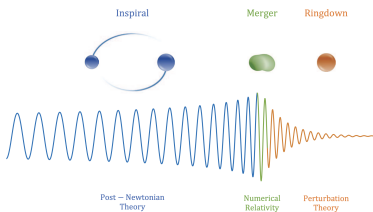


[Antelis & Moreno, 2016]

- Late inspiral & merger of stellar-mass CBs
- Orbits circularize before entering the detector frequency band
- Numerical Relativity is too expensive to generate the inspiral phase for the $\sim 10^6$ templates needed for matched filtering

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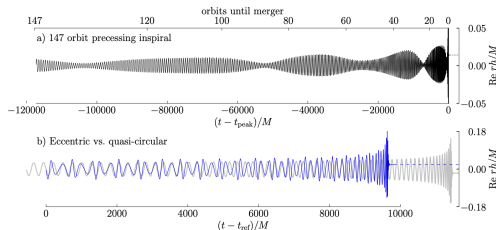
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Space-Based: LISA [10^{-4} – 10^{-1} Hz]

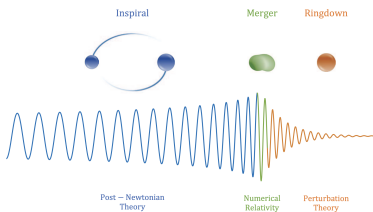


[SXS Collaboration, 2505.13378]

- Early inspiral of BBHs, EMRIs, galactic binaries
 - Orbits can be **highly eccentric** and spins cause the orbital plane to **precess**
- ⇒ Current models **will bias** LISA parameter estimation

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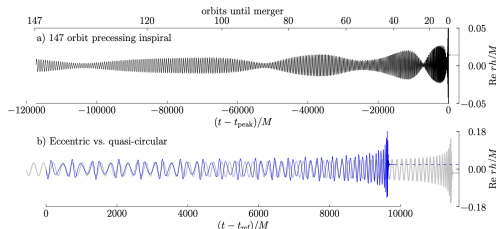
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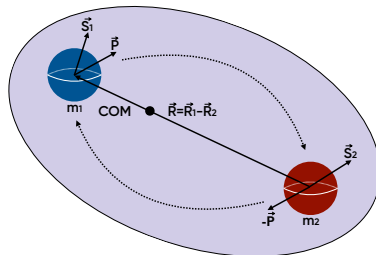
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Aim: Compute analytical solutions for the dynamics of **spinning, eccentric inspiralling BBHs**

The physical system

- Two black holes, each carrying a **spin**, on an **eccentric** orbit

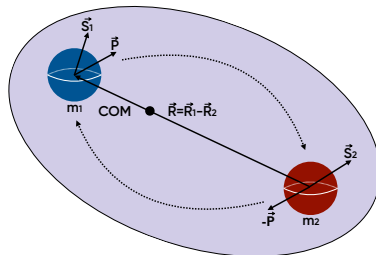
Goal : $\{\mathbf{R}(t), \mathbf{P}(t), \mathbf{S}_1(t), \mathbf{S}_2(t)\}$



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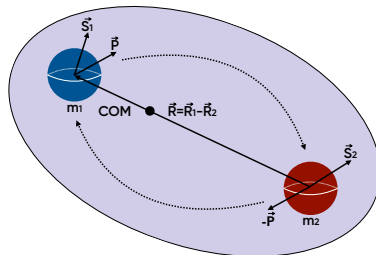
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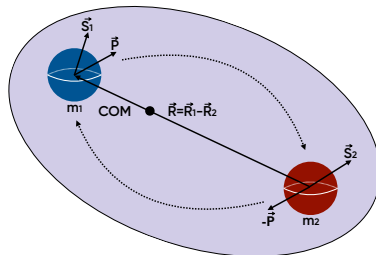
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- At **2PN order**, the system is conservative:
$$H = H_N + \frac{1}{c^2} H_{1PN} + \frac{1}{c^3} H_{SO} + \frac{1}{c^4} H_{2PN} + \frac{1}{c^4} H_{SS}$$

State of the art

- ✓ $H_N + H_{1PN} + H_{2PN}$ solved [Damour, Wex & Schäfer, 1988]
- ✓ $H_N + H_{1PN} + H_{SO}$ solved [Cho & Lee, 2019]
- ✗ H_{SS} not yet included

Goal : $\{\mathbf{R}(t), \mathbf{P}(t), \mathbf{S}_1(t), \mathbf{S}_2(t)\}$



Recent work: 2PN analytical dynamics of spinning, eccentric BBHs [arxiv:2603:20031]

- ✓ Full analytical solution for $\mathbf{R}(t)$, $\mathbf{P}(t)$, $\mathbf{S}_1(t)$, $\mathbf{S}_2(t)$.
- ✓ Verified against all known limits: spin-aligned, quasi-circular, non-spinning

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Next steps

- **2.5PN conservative:** next-to-leading order spin-orbit coupling
- **2.5PN dissipative:** leading-order radiation reaction driving the inspiral
- Build more accurate **GW templates** for LISA data analysis

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2PN Analytical dynamics → 2.5PN extensions → **LISA waveform templates**

Thank you!