

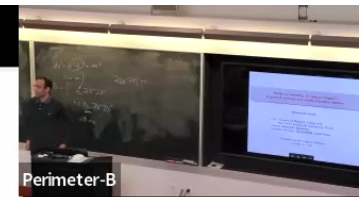
Title: Session 2 - Mohammed Khalil

Speakers: Mohammed Khalil

Collection: POSTDOC WELCOME 2022

Date: October 24, 2022 - 12:40 PM

URL: <https://pirsa.org/22100116>



Analytical modeling of compact binaries in general relativity and modified gravity theories

Mohammed Khalil

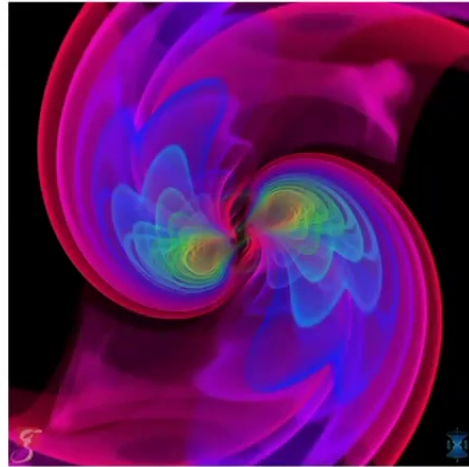
PhD: University of Maryland, College Park
Max Planck Institute for Gravitational Physics
Advisor: **Alessandra Buonanno**
Secondary Advisors: **Jan Steinhoff, Justin Vines**

Perimeter Institute Postdoc Welcome
October 24, 2022

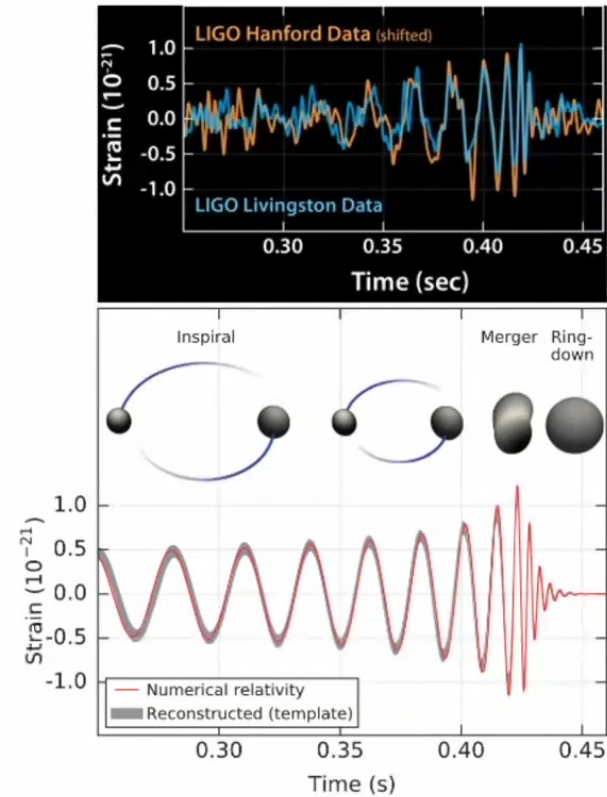


Gravitational waves (GWs) from compact binaries

- Almost 100 GW signals have been detected since 2015.
- Accurate waveform models are crucial in searching for GW signals and inferring their parameters.



[Ossokine, Buonanno, SXS]

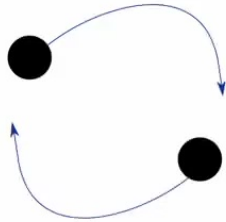


[LIGO Scientific Collaboration 2016]

Analytical approximation methods for binary dynamics

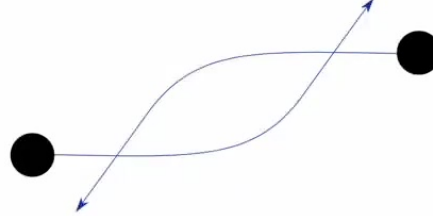
Post-Newtonian (PN)

$$\frac{v^2}{c^2} \sim \frac{GM}{c^2 r} \ll 1$$



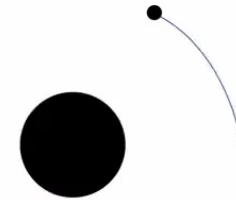
Post-Minkowskian (PM)

$$\frac{GM}{c^2 r} \ll 1$$



self-force (SF)

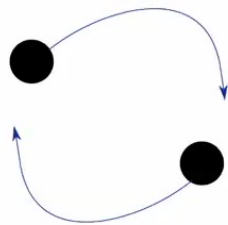
$$\frac{m_1}{m_2} \ll 1$$



Analytical approximation methods for binary dynamics

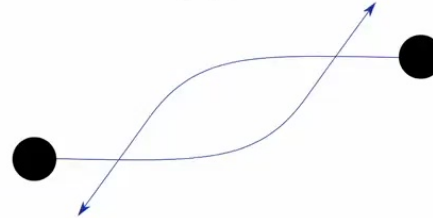
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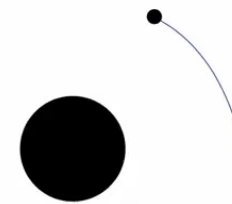
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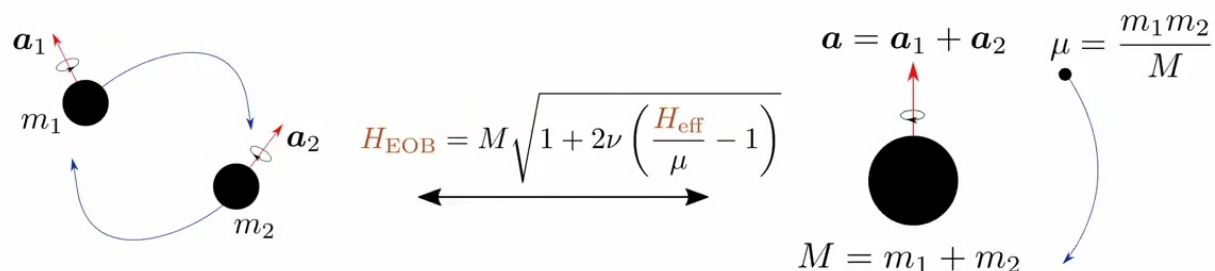
- Derived PN results for the **4.5PN** and **5.5PN** spin-orbit, and **5PN** aligned spin-spin dynamics, by combining PN, PM, and SF approaches.

[Antonelli, Kavanagh, MK, Steinhoff, Vines 2003.11391, 2010.02018], [MK 2110.12813]

- Derived the spin contributions to the waveform, for **eccentric (2PN)** and **circular orbits (3.5PN)**.

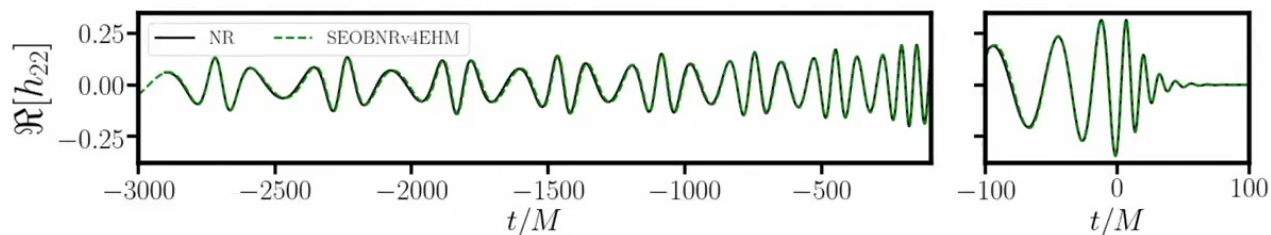
[MK, Buonanno, Steinhoff, Vines 2104.11705], [Henry, Marsat, MK 2209.00374]

Effective-one-body (EOB) waveform models



- Binary motion is mapped to that of a test body in a deformed Schwarzschild or Kerr background. [Buonanno, Damour 9811091, 0001013]
- EOB combines **PN**, **SF**, and **NR** results to produce accurate waveforms.
- Included **spin-precession** effects up to 4PN, incorporated **PM information** in EOB Hamiltonians, and developed a waveform model for **eccentric orbits**.

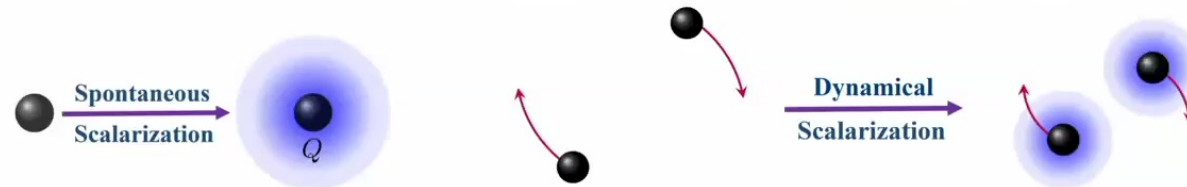
[MK, Buonanno, Steinhoff, Vines 2003.04469, 2204.05047], [Ramos-Buades, Buonanno, MK, Ossokine 2112.06952]



Signatures of modified gravity theories on GWs

- GW observations offer unprecedented opportunities to test gravity in the highly dynamical, strong-field regime.
- Several theories predict **spontaneous and dynamical scalarization**: phase transitions in the strong field due to a symmetry breaking of the scalar field.

[Damour, Esposito-Farèse '93], [Barausse, Palenzuela, Ponce, Lehner 1212.5053]



- Developed a **theory-agnostic effective-action approach** to model scalarization.

[MK, Sennett, Steinhoff, Buonanno 1906.08161], [MK, Mendes, Ortiz, Steinhoff 2206.13233]

- Derived the 1PN conservative and dissipative dynamics in **Einstein-Maxwell-dilaton** theory.

[MK, Sennett, Steinhoff, Vines, Buonanno 1809.03109]