NEWS Project

CALIFORNIA INSTITUTE OF TECHNOLOGY

TAPIR at Caltech

Theoretical AstroPhysics Including Relativity and Cosmology

- **Research group**: TAPIR at Caltech [tapir.caltech.edu]

- **Research project**: search for an accurate method to measure the orbital eccentricity in Numerical Relativity (NR) waveform models from binary black hole (BBH) simulations

- **Planned duration**: 3-6 months (on-site from Jan-Feb ’20)

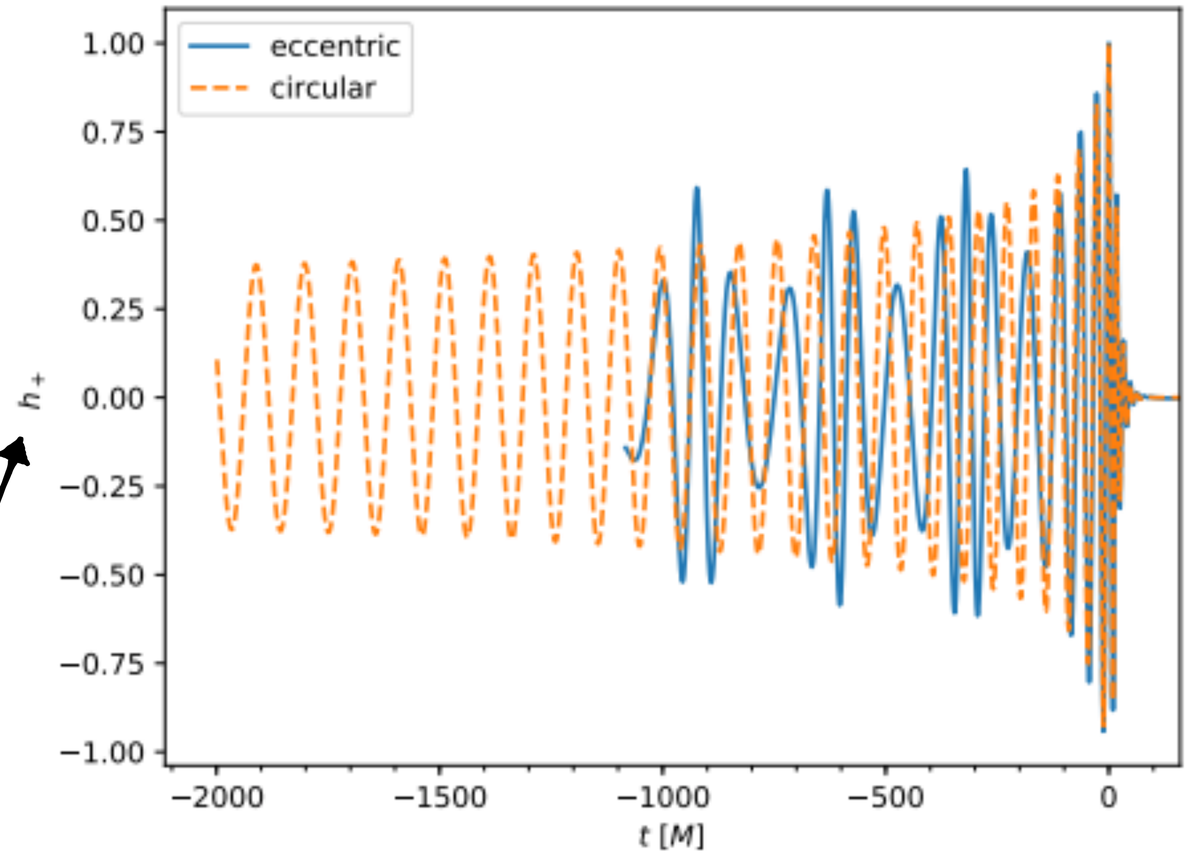
Motivations (I)

• How does an eccentric BBH waveform look like?

• Example:

$$q = \frac{m_1}{m_2} = 10$$

Real part of the $l = |m| = 2$ mode extracted at future null infinity



[Source: Huerta et al., arXiv:1901.07038]

Motivations (II)

[https://www.black-holes.org/code/SpEC.html]

- Spectral Einstein Code (SpEC) measures and reduces the orbital eccentricity in NR BBH simulations adopting the procedure presented in [Buonanno et al., PRD **83**, 104034 (2011)]

- This method relies on the use of the BH trajectories from the simulations

- However, there are some problems with that:
  - The measure is gauge dependent, so its interpretation is not fully unambiguous
  - The method is not very stable, as its result depends on the time of measurement

Project objective

[https://www.black-holes.org/code/SpEC.html]

- Find a more reliable way to measure the eccentricity in the NR waveforms produced with SpEC

- A way to pursue that is to match an NR waveform with a Post-Newtonian (PN) waveform whose eccentricity parameters are let to vary in such a way that the mismatch between the NR and PN waveforms is minimized

- Tests covering a sufficiently large q-parameter space could be needed

Possible outcomes

- To allow a better theoretical comprehension of high-q systems, where eccentricity is expected to play a fundamental role. Such systems can be detected in particular by a future space-based detector like LISA

- To implement eccentricity in surrogate waveform models, which promise to generate BBH waveforms of accuracy comparable to NR in much less time, thus improving gravitational wave data analysis

- To enrich the catalog of available NR waveforms with simulations of non-negligible eccentric BBH systems, which nowadays is still challenging