The Strong group activities

MSc day 2022

12th October

Niels Bohr International Academy

strong.
niels bohr
institute

The strong team

Black holes & gravitational-wave physics

a. Tests of gravity
b. Quantifying the existence of black holes in our universe
c. Use gravitational-wave observations to understand dark matter
d. Study black hole physics, and how to go beyond Einstein
e. Use gravitational waves to probe the universe

Extreme Mass-Ratio Inspirals (EMRIs)

(Compact object orbiting massive black hole)

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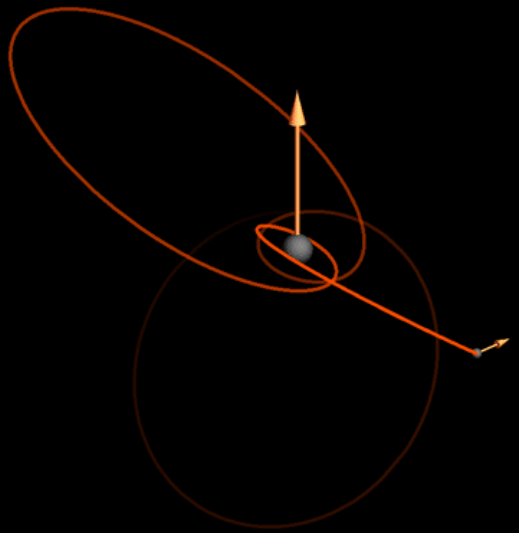
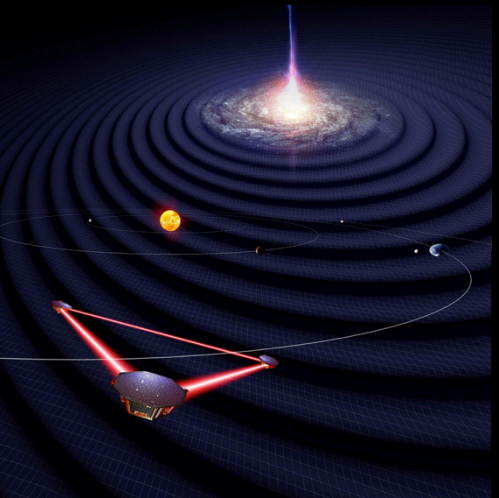
- Gravitational waves from EMRIs observable by LISA
- EMRI ultimate probe of strong field geometry





- Modelled using perturbation theory in mass-ratio (Gravitational Self-Force)

- Projects feature:
  - Analytical work (GR calculations, dynamical systems, elliptic integrals)
  - Numerical methods (e.g. spectral methods)
  - Coding (need efficient methods)

Black Holes as Particle Detectors

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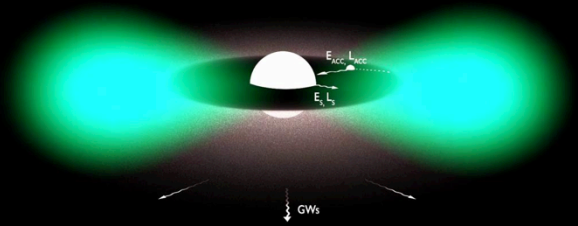
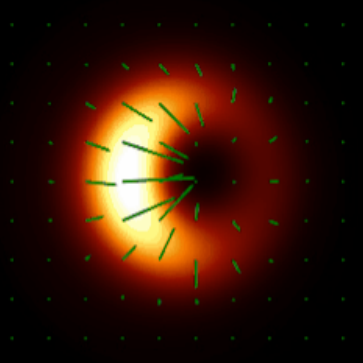
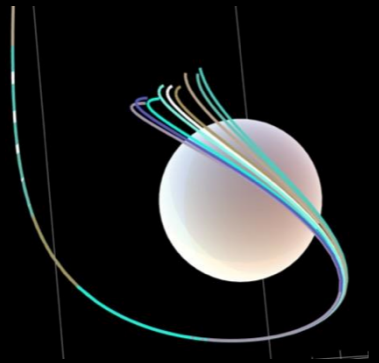
- Ultralight bosons: strong motivation in particle physics, astrophysics and string theory.
- Superradiance: boson grows exponentially outside BH by extracting rotational energy:

$$M_{BH} \sim 10^{9}\, M_{\odot} \leftrightarrow m_{b} \sim 10^{-21}\, \mathrm{eV}$$

- Imprints on BH images by Event Horizon Telescope?
- Dynamics of gravitational atom and bosonic dark matter: GW emission, transition, precession, ionization…







Black hole resonances as fundamental physics discovery tools

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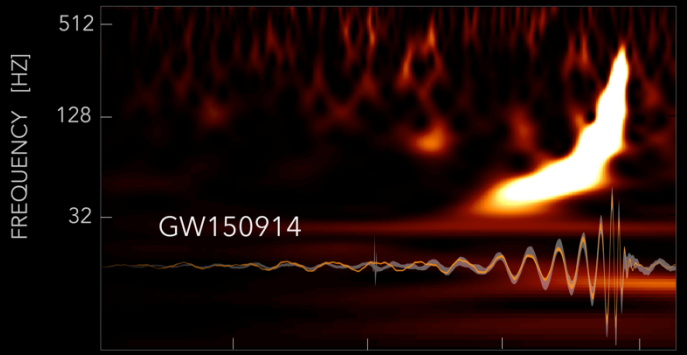
- Theory of gravity at high curvature? Black holes or mimickers? Quantum effects at the horizon? Additional charges or “hairs”?

- Frantic recent developments, serious observational challenges, immense discovery potential.

- A future “black hole spectroscoper” needs to master:
  - Highly-accurate general relativistic models
  - Advanced statistical Bayesian techniques
  - State-of-the-art beyond-Einstein predictions



Probing the Universe with Gravitational Waves

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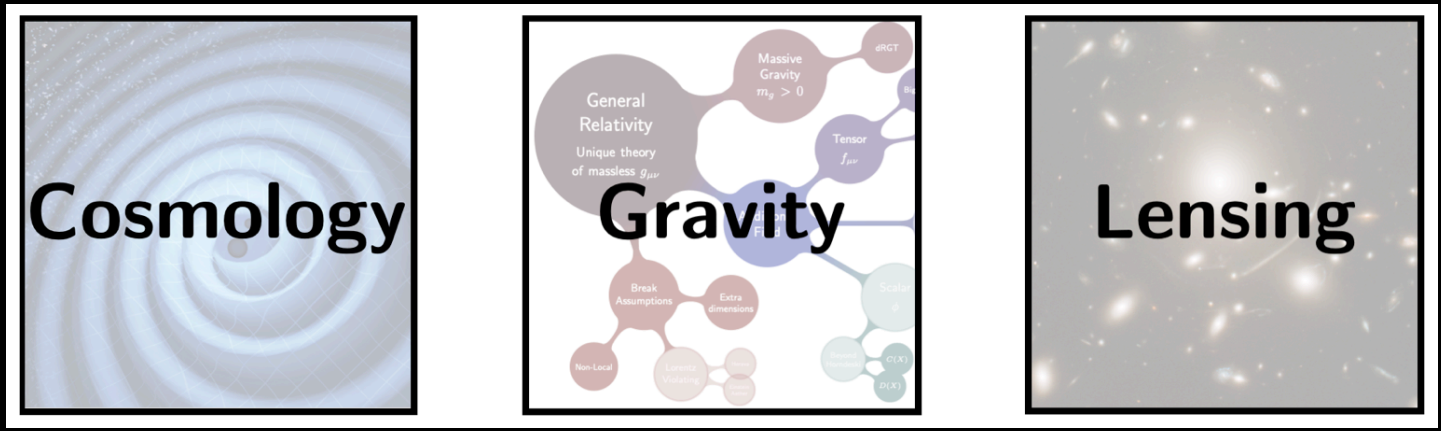
- Gravitational waves from binary black holes merging billions of years ago are ***unique*** probes of the Universe's expansion and its large scales structures, helping to unveil the nature of ***dark energy***, ***dark matter*** and ***gravity***
- Plenty of possible projects related to current data of **LIGO-Virgo** and future facilities (**Cosmic Explorer**, **Einstein Telescope**, **LISA**)



Black Holes and Gravitational Waves in GR and Beyond

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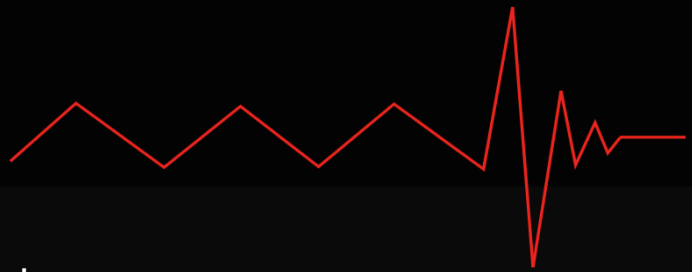
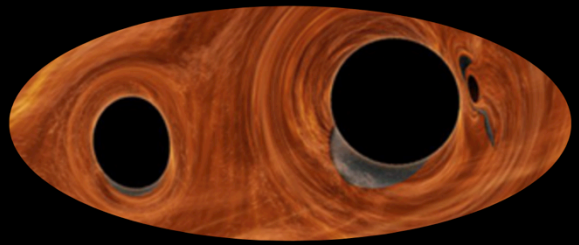
GR is GReat… but *incomplete!*

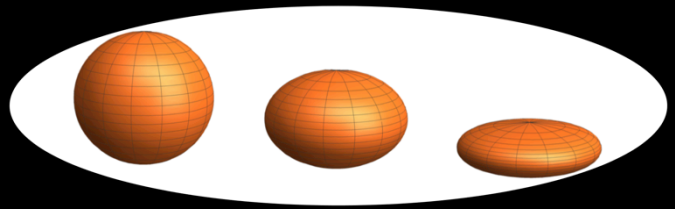


Black hole tidal deformability



Black holes and new fundamental fields

Higher-derivative corrections



Black holes and gravitational waves: sustaining theoretical pillars

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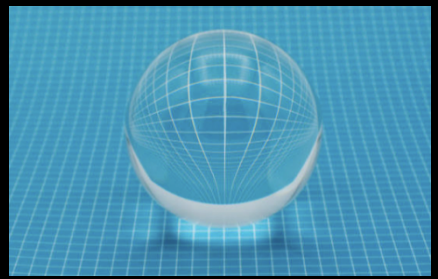
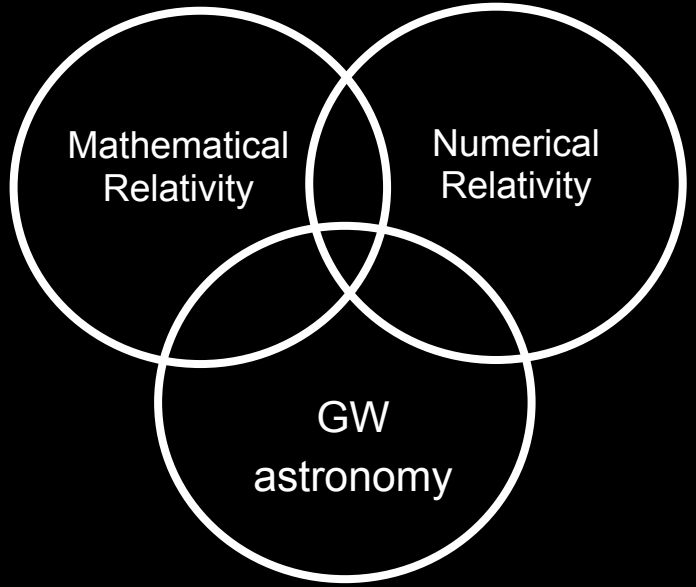
To infinity and beyond

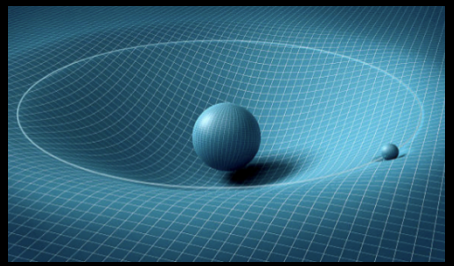
1) Gravitational waves from compact objects: the infinitely far wave zone





Infinity in a nutshell

2) The infinitely far wave zone in the computer: sensible data and high accuracy



3) Projects in black hole spectroscopy and extreme mass ratio inspirals

The Strong group activities

Contact us, we want *you* !

www.strong-gr.com

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