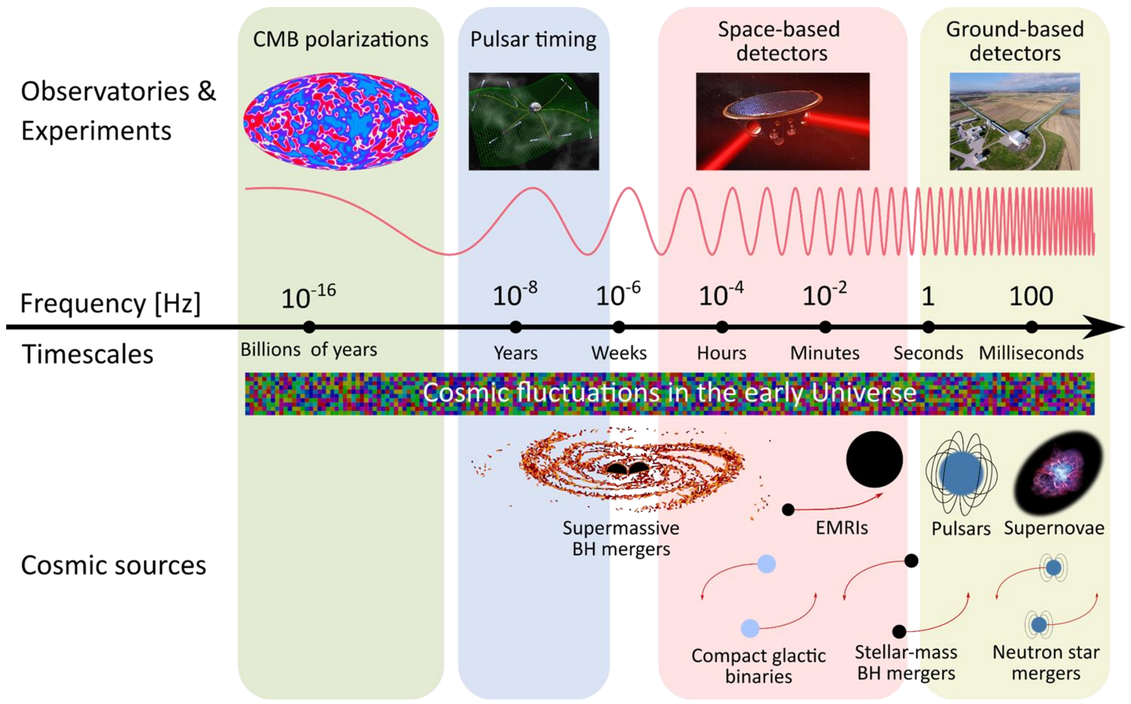
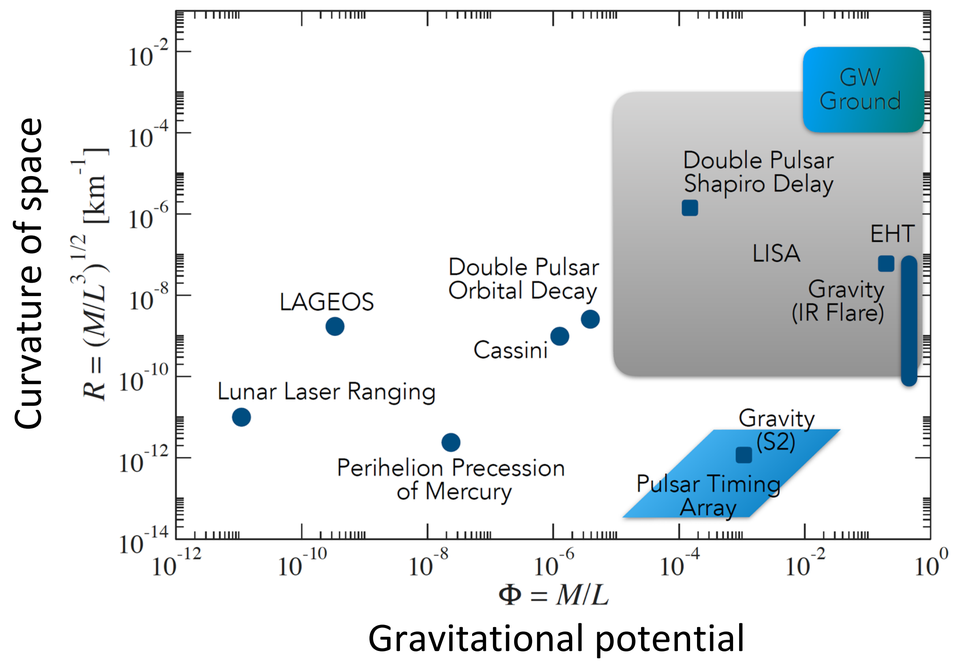
Gravitational Wave Observations and Fundamental Physics

Virgo, LISA, Einstein Telescope, TEONGRAV

The Gravitational Wave Spectrum



Unveiling the Universe and the nature of space and time in extreme conditions of curvature and gravity at different scales



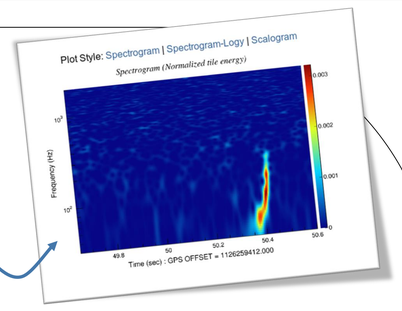
Gravitational Wave Astronomy @ Trento

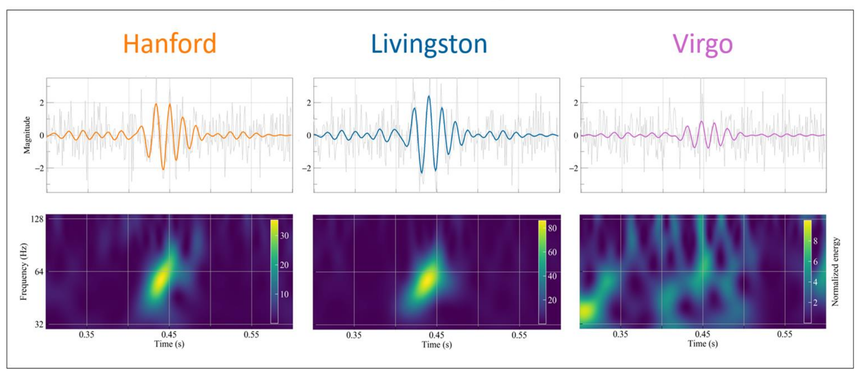
Data analysis methods developed at Trento are focused on searching and reconstructing GW transients without relying on morphological models.

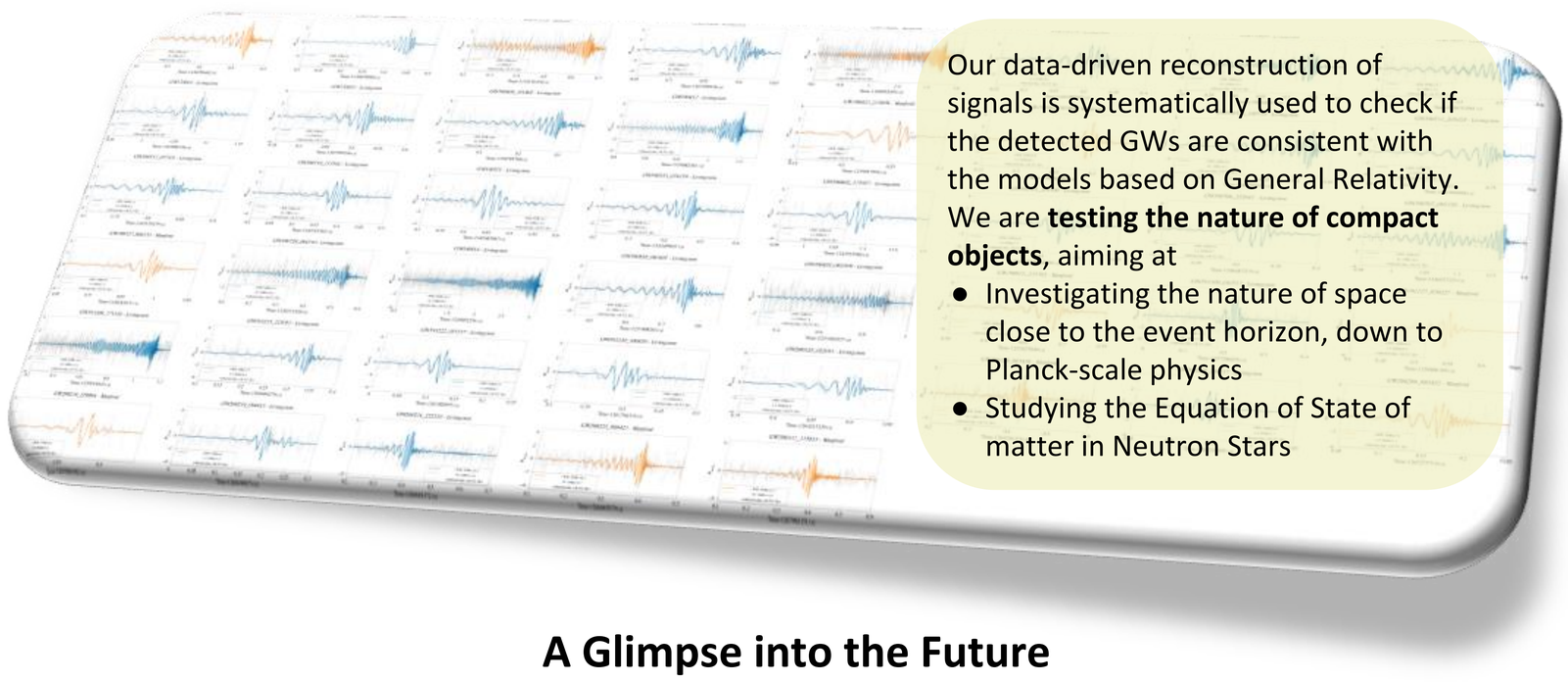
The ears-wide-open searches are discovery tools that achieved relevant successes as the earliest identification of

- GW150914, the first direct observation of a GW
- GW190521, the first direct observation of a black hole in the intermediate mass range (between stellar mass and supermassive)

Historic signal of the first GW event







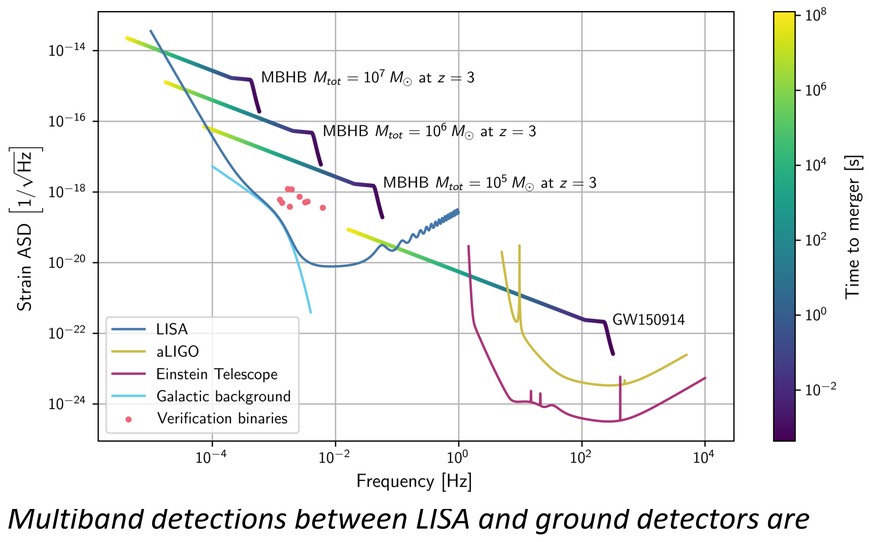
Our data-driven reconstruction of signals is systematically used to check if the detected GWs are consistent with the models based on General Relativity. We are **testing the nature of compact objects**, aiming at

- Investigating the nature of space close to the event horizon, down to Planck-scale physics
- Studying the Equation of State of matter in Neutron Stars

A Glimpse into the Future

Fundamental questions that **LISA** and next-generation detectors (**AdV+** & **ET**) could answer:

- Gravitation
  - Is General Relativity the correct theory of Gravitation?
  - What is the true nature of black holes?
- Nuclear physics & quark-gluon plasma
  - What is the equation of state of neutron stars?
  - What is the explosion mechanism of supernovae?
- Cosmology and particle physics
  - What is dark matter?
  - What is dark energy?
  - How did supermassive BHs form?
  - Can we probe the Big Bang through the stochastic gravitational background?

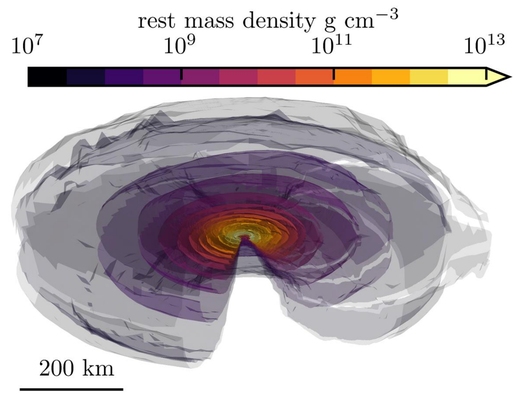


*Multiband detections between LISA and ground detectors are possible. Ground and space observatories are at the same time **complementary** and **synergic** (they see the same sources at different inspiral phases).*

Understanding Neutron Stars Mergers

Interpretation of present and future GW detections requires sophisticated source models, including:

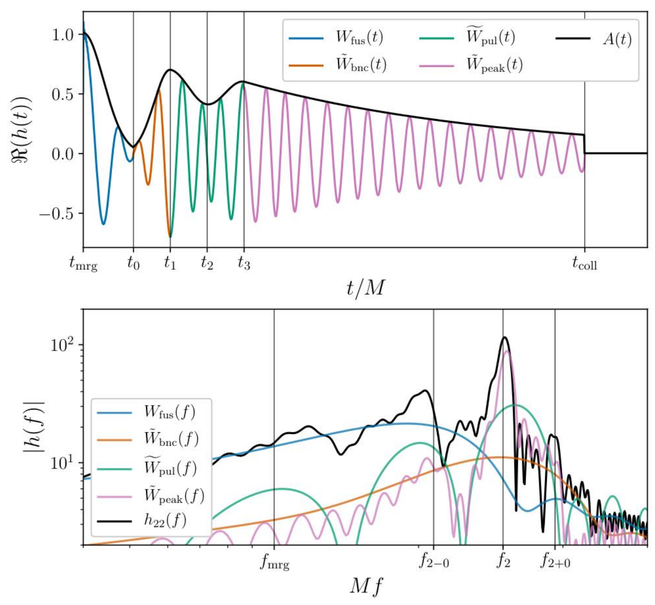
- Dynamical spacetimes
- Relativistic radiation hydrodynamics;
- Detailed microphysics, with nuclear EoS and neutrinos.



Disk remnant profile from a BNS merger, from Camilletti et al, PRD accepted (2024)

Some of our goals from neutron star merger modeling:

- Remnant fate and dependence on the microphysics;
- NR-informed GW waveforms for inspiral and high-frequency post-merger emission



Post-merger GW signal of a BNS merger, from Breschi et al, 2205.09112