Gravitational wave astrophysics and cosmology

Elective course – second year (first semester)
Master in astrophysics and cosmology
University of Bologna

Teachers:
Carlo Nipoti (module 1)
Michele Moresco (module 2)

Bologna, September 2023

History of gravitational waves (GWs) in a nutshell

- Einstein (1916): general relativity predicts existence of GWs
- Taylor et al. (1979): indirect evidence of emission of GWs (Hulse-Taylor binary pulsar)
- LIGO collaboration (2015): first detection of GWs (binary black hole GW150914)
- From 2015 onward: era of GW astronomy

GW astrophysics and cosmology: structure of the course

First part: Theory of GWs

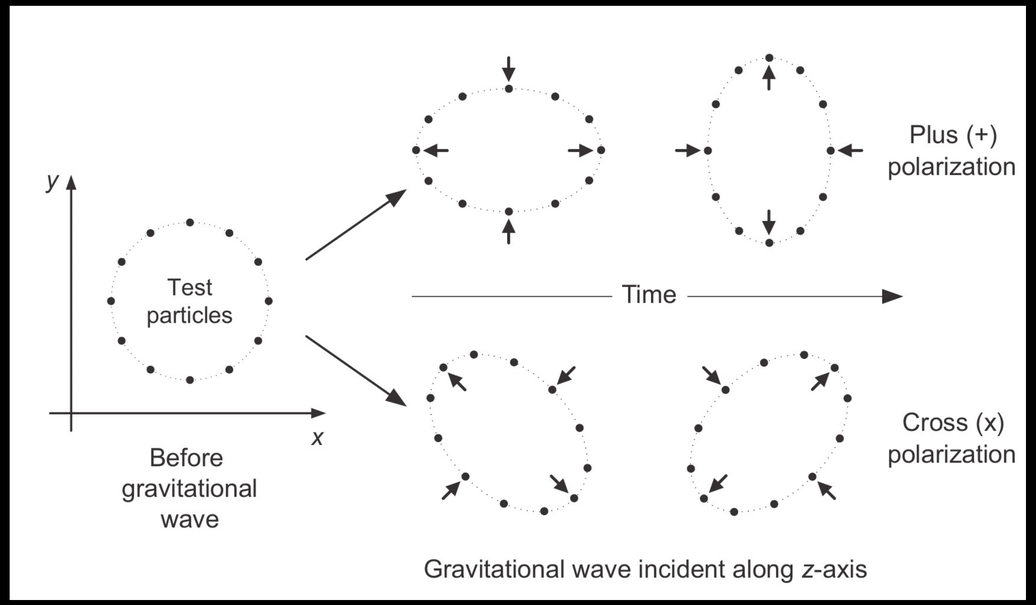
- Teacher: Carlo Nipoti
- 24 hours (module 1)

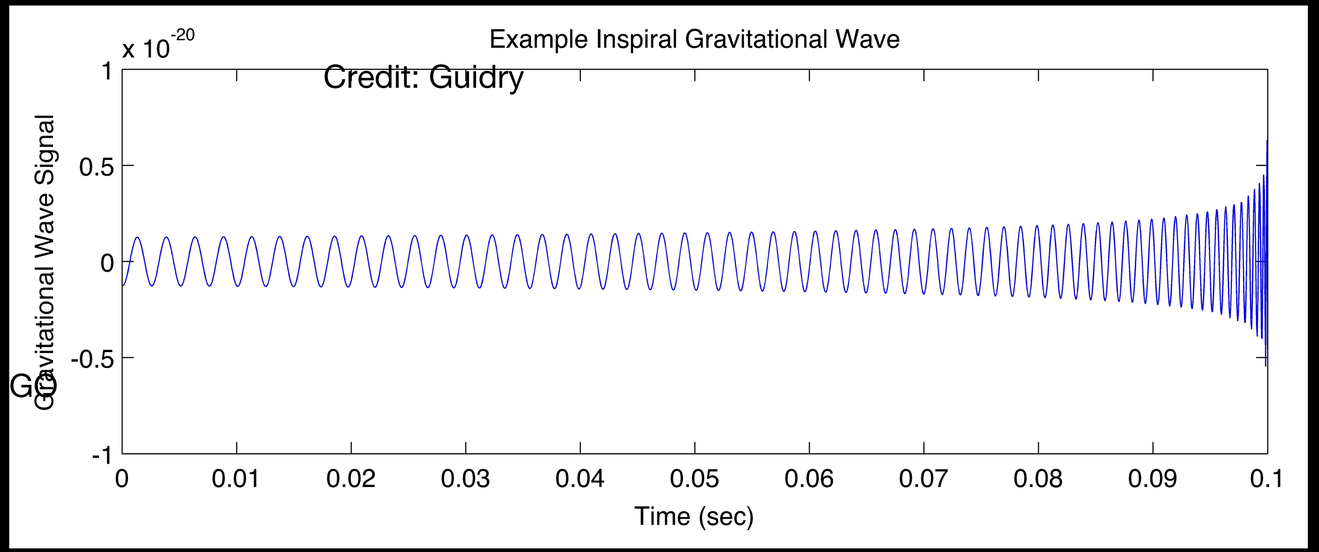
Second part: Detection of GWs and cosmological analysis

- Teacher: Michele Moresco
- 24 hours (module 2)

First part: Theory of GWs

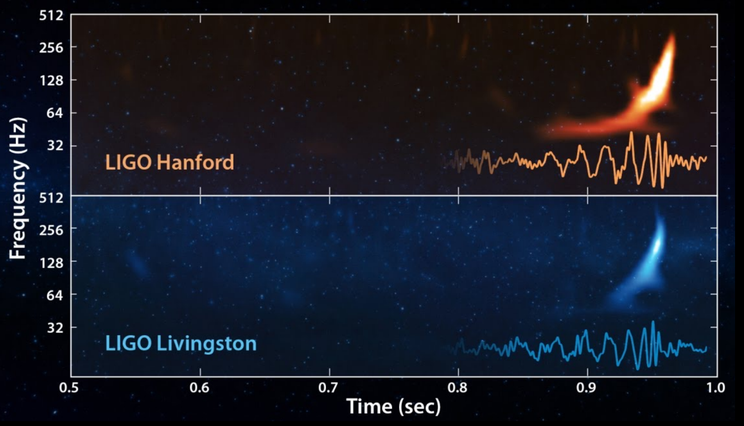
- Fundamentals of general relativity
- Excursus on electromagnetic waves
- Linearized general relativity
- GWs as solution of linearized Einstein equations
- Effect of GWs on test masses
- Energy of GWs
- Generation of GWs
- Emission of GWs and inspiral of binaries

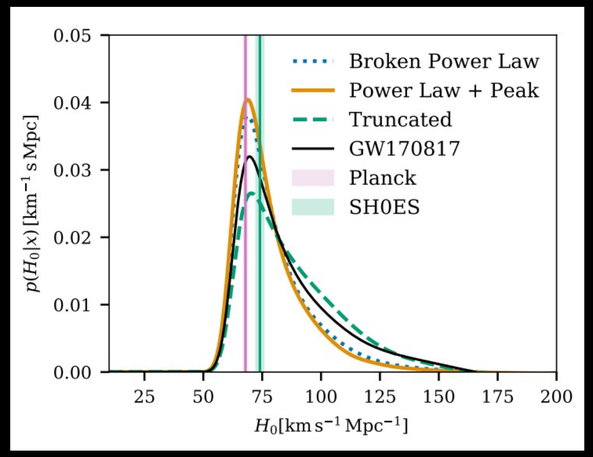




Second part: Detection of GWs and cosmological analysis

- Astrophysical sources of GW
  - Brief overview
  - Compact Binary Coalescence
- GW detection
  - Basics of interferometry
  - The GW signal





- Current and future GW observatories
  - GW analysis
  - The Bayesian framework
- Parameter estimation from GW signal
  - Cosmology with GW
  - Standard sirens (bright sirens, dark sirens, and more)
  - Astrophysical and cosmological signal

Nota bene

- The course “GW astrophysics and cosmology” is organized to be as self-contained as possible
- But it is NOT a course of general relativity
- The course of “Relativity” (Prof. Bastianelli) is highly recommended, but is not a prerequisite

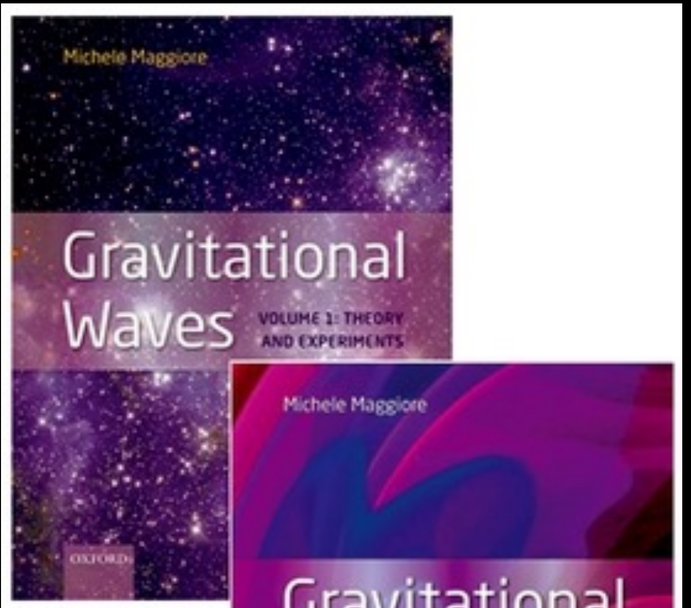
Textbooks

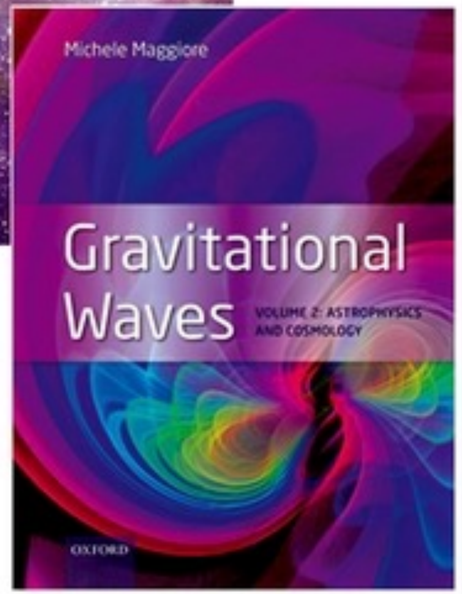
REFERENCE TEXTBOOK:

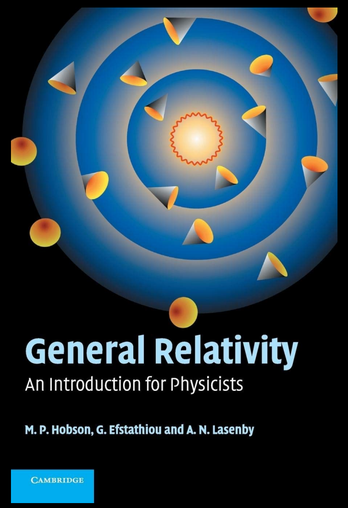
- Maggiore (2008, 2018) "Gravitational Waves" (2 volumes)

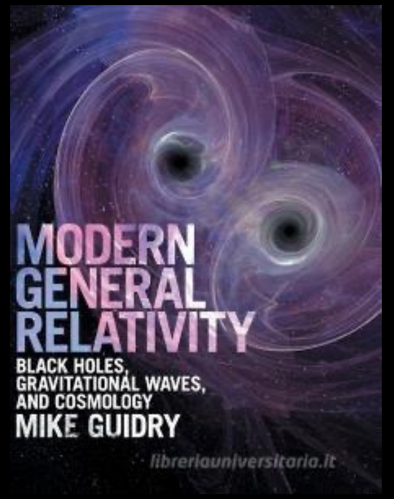
OTHER USEFUL TEXTBOOKS:

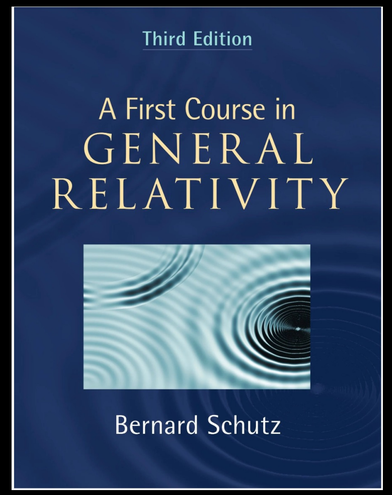
- Hobson et al. (2006) "General relativity"
- Schutz (2022) "A first course in general relativity"
- Guidry (2019) "Modern general relativity"











GW astrophysics and cosmology

- Teachers: Michele Moresco and Carlo Nipoti (michele.moresco@unibo.it; carlo.nipoti@unibo.it)
- 48 hours (6 credits). Oral exam.
- Teaching material: suggested textbooks + articles + slides
- Online resources: course web page and virtuale page