Coherent and Coincident Analyses of LIGO-Virgo Data from the Third Observing Run

Tesi di laurea magistrale in Fisica

SAPIENZA
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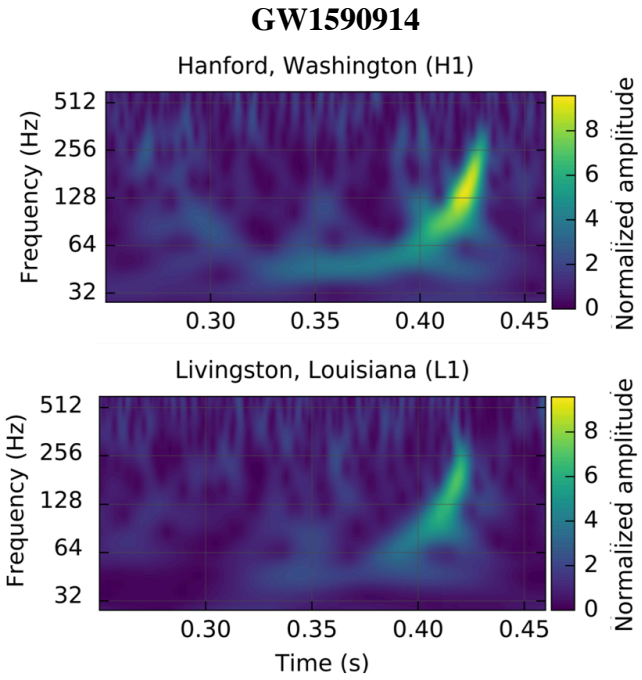
Gravity: from apples to ripples

Einstein Field Equations

$$G_{\mu\nu} = \frac{8\pi G_N}{c^4} T_{\mu\nu}$$

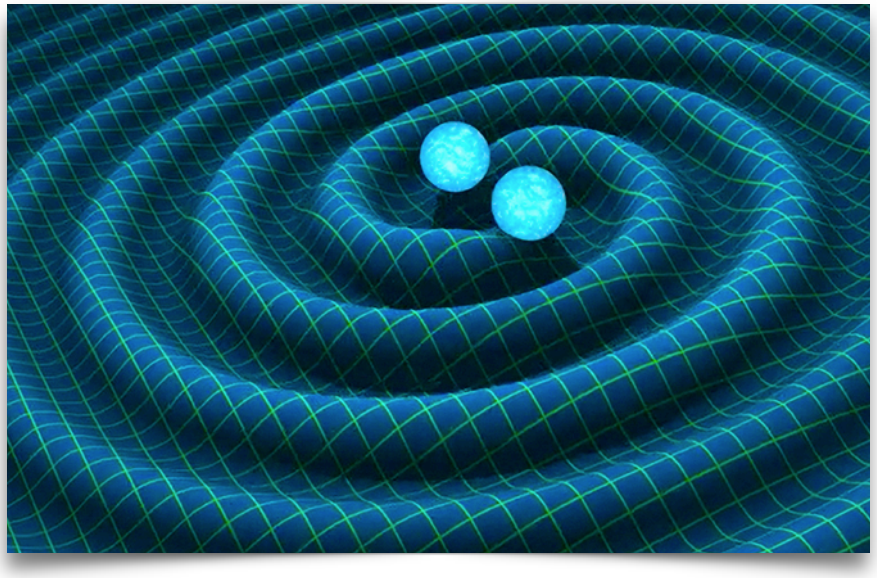
Linearised Field Equations

$$\Box \bar{h}_{\mu\nu} = 0$$



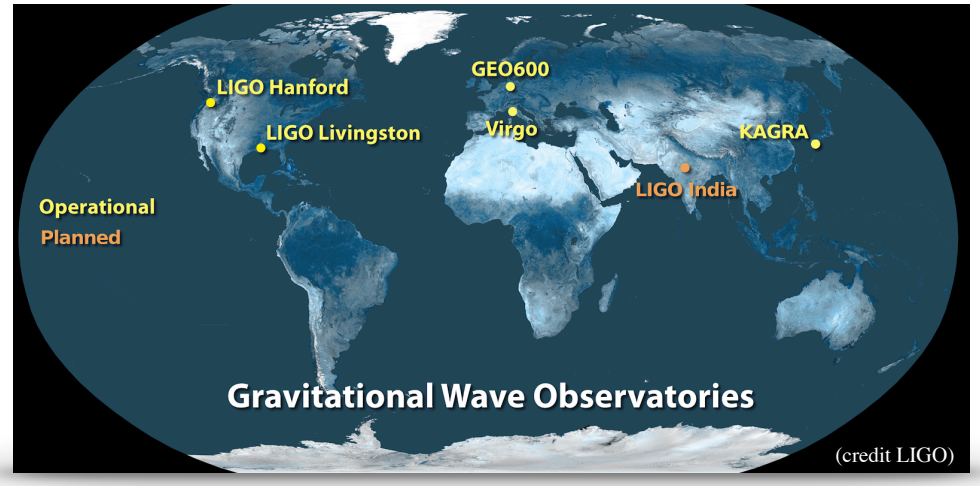
Abbott et al. (2016) Phys. Rev. Lett. 116, 061102

Gravitational Waves



Gravitational Wave Detection

Network of detector required.



- COINCIDENCE OF DETECTIONS: confidence that signal is from extraterrestrial sources, rather than from noise.

- SKY LOCALISATION: triangulation techniques based on the time delay in more than two detectors.

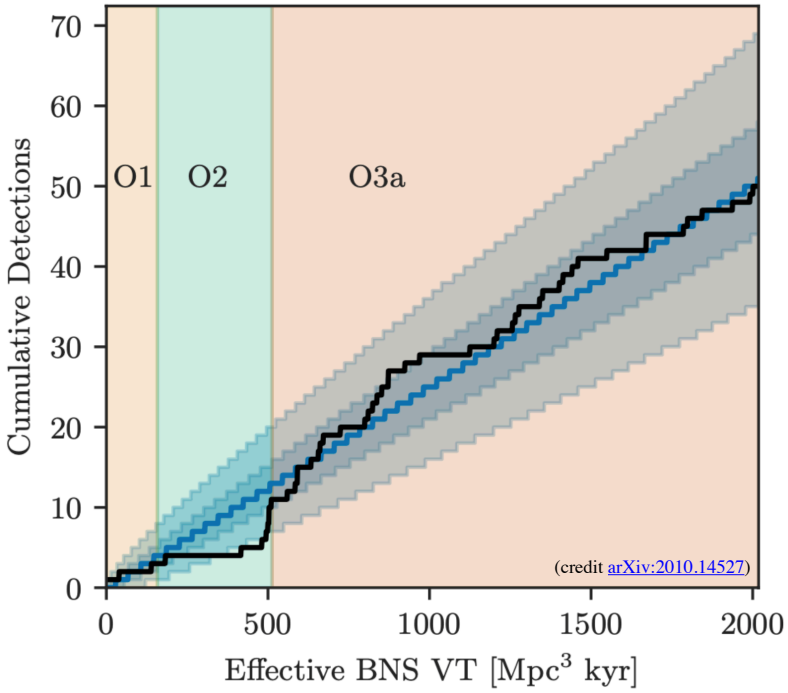
  Multi Messenger Astronomy: given an accurate sky location, a corresponding EM transient

  - identified in a list of events obtained with the all-sky telescope surveys,

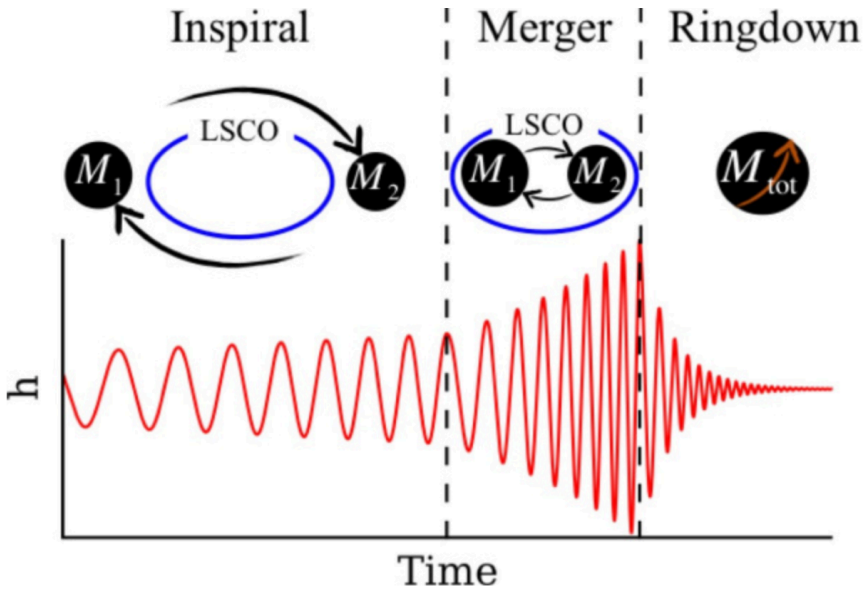
  - guide EM instruments to take images of a small area in the sky.

- Smaller sky localisation, larger signal-to-noise ratio.

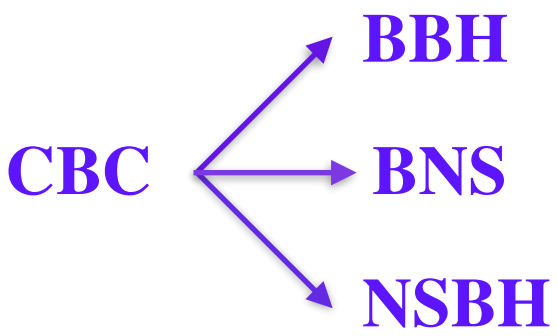
Compact Binary Coalescence (CBC)



Abbott et al. (2016) arXiv:2010.14527



O1: September 12, 2015 - January 19, 2016
O2: November 30, 2016 - August 25, 2017
O3a: April 1, 2019 - 30 September, 2019



CBC searches

- **ONLINE**: detect and report events with sub-minute latencies.
- **OFFLINE**: data calibration and data quality to produce a more sensitive search.

PyGRB

- Targeted coherent search
- Follow-up to EM transient (GRBs)
- Analysis of three GRBs in O3a data published in arXiv:2010.14550

PyCBC

- All-sky coincident search
- Targets all kind of CBC
- Background analysis of a chunk of O3b data (yet to be published by LVC)

Gamma Ray Bursts

Farthest and brightest explosions in the Universe (1 keV–10 MeV).

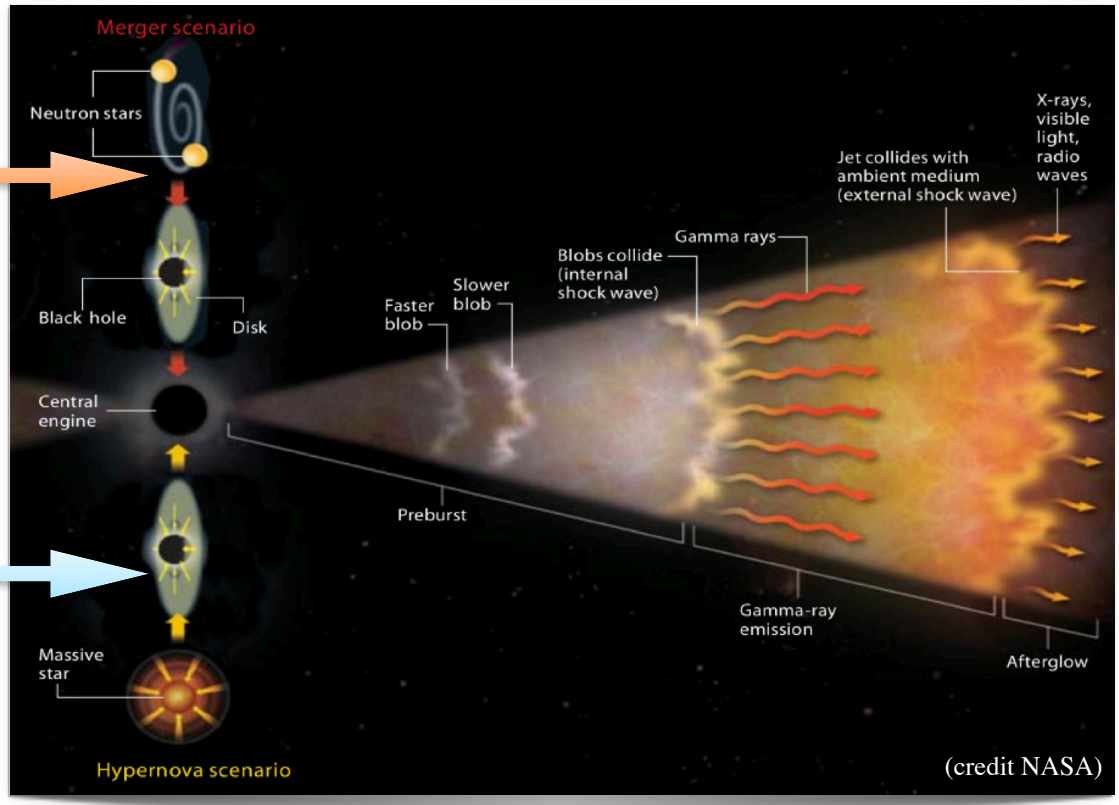
Short Gamma Ray Burst ($T_{90} < 2s$)

- More highly-energetic (hard) gamma rays
- Fainter afterglow
- Offset relative to their host galaxy center
- Baryon-poor environments
- Observation in all type of host galaxies

MERGER PROGENITOR HYPOTHESIS

Long Gamma Ray Burst ($T_{90} > 2s$)

- Observed only in star-forming galaxies
- Direct associations of LGRBs with core-collapse supernovae



Short Gamma Ray Bursts

Necessary condition for SGRB ignition: presence of NS.

PROGENITOR CANDIDATES

BNS

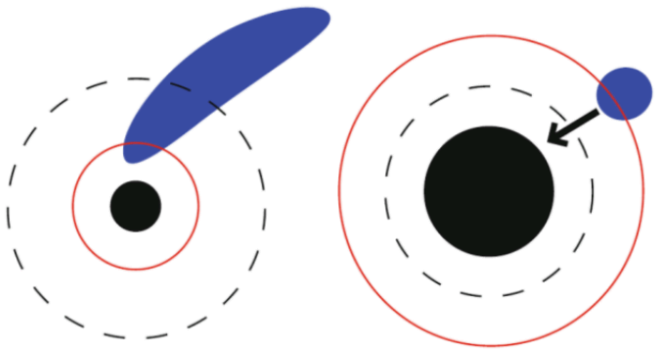
Confirmed by the joint detection of GW170817 and GRB 170817A.

[Abbott *et al* 2017 *ApJL* **848** L13]

NSBH

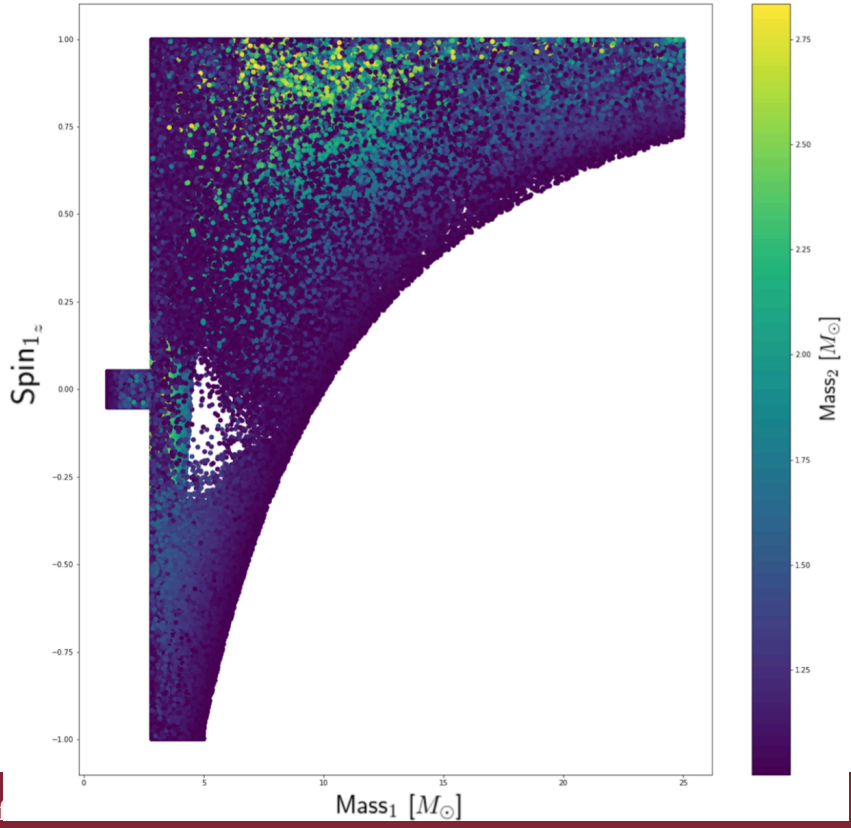
- Potential source, no observed NSBH so far
- Not all systems are "bright"

EM-BRIGHT TEMPLATE BANK



aggiornato il codice con la nuova formula (le 2 formule mettitele in back up)
e che hai generato *la* bank usata per O3a. usata per tutte le GRBs. ***
Bank che si genera accumulando proposte di template man mano che vengono accettate: il criterio è il match 0.97 che si traduce nell'accettare 10% signal loss al massimo.

La tua template bank ha XYZ templates e mostri Fig.4.2. Se ti chiedono del buco, ormai sai che le binarie lì dentro sono degeneri con altre binarie già nella template bank: dì pure che lo hai dimostrato facendo injections lì dentro e che la bank le vedeva tranquillamente. Infine parla delle 10,000 + 10,000 injections e dell'effective fitting factor di 99%.



$$\frac{M_{\rm rem}^{\rm model}}{M_{\rm NS}^{b}} = \alpha(3q)^{1/3}(1-2C_{\rm NS}) - \beta\frac{R_{\rm ISCO}}{R_{\rm NS}}$$

$$\frac{M_{\rm rem}^{\rm model}}{M_{\rm NS}^{b}} = \left[\max\left(\alpha\frac{1-2C_{\rm NS}}{\eta^{1/3}} - \beta\frac{R_{\rm ISCO}C_{\rm NS}}{\eta M_{\rm BH}} + \gamma, 0\right)\right]^{\delta}$$