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Sources of Gravitational Waves

Gravitational Waves (GW), predicted by Einstein's theory of General Relativity, are small perturbations of space-time curvature created by asymmetric acceleration of masses or non-stationary field, and propagating at the speed of light without being stopped or slowed down. The binary pulsar discovered by Hulse & Taylor in 1974 provides indirect evidence of their existence but no direct detection of GW has been done so far.
Gravitational Waves ground based experiments, after a decade of detector installation and commissioning, have reached or surpassed their design sensitivities, opening a new window into the Universe. Not only one expects to discover a set of new exotic sources, but also to travel back in time, toward the very early stages of the evolution of the Universe.
The first generation of LIGO and Virgo interferometers has already put interesting astrophysical constraints on the ellipticity of known fast or the gravitational wave stochastic background. Second generation detectors such as Advanced LIGO/Virgo (Ad LIGO/Virgo) expected to start collecting data in 2014 with a sensitivity of about 10 times better, should make gravitational wave detections a routine occurrence, detecting a few tens of compact binary coalescences a year, while third generation detectors such as the planned LCGT (~ 2020) or Einstein Telescope (ET) (~2025), or the space antenna LISA (2018), will bring GW astronomy to the next level, when it will be possible to detect a wide variety of sources, and address a large range of problems in astrophysics but also fundamental physics and cosmology. In particular, coalescing compact binaries that could be detected up to very large distances with advanced GW detectors and whose waveform is well modeled up to the last stable orbit are ideal standard candles (or standard sirens) that can be used to put constraints on the cosmological parameters and to shed light on the nature of dark energy (DE), one of the most compelling problem in physics [7]. The next decade will also mark the beginning of multi-messenger astronomy. GW detectors have used X and radio telescopes information to search for known pulsars since the beginning, but recently, LIGO/Virgo extended its external collaborations to optical, gamma and neutrino detectors. Several alerts have already been sent to robotic optical telescopes TAROT and QUEST, the gamma ray satellite SWIFT, or the neutrino detectors ANTARES and ICECube ; a comprehensive and sophisticated real time data analysis pipeline is currently under development. Coincident searches will improve the sensitivity as well as our detection confidence, and will put complementary constraints on the astrophysics of compact objects, e.g GRB progenitors. Ground based interferometers can detect frequencies in the range 10 Hz-10 kHz and then are sensitive to GW radiation produced by stellar mass objects such as neutron stars (NSs) and black holes (BHs), while the space antenna LISA will search for more massive objects such as supermassive black holes (SMBHs) in the band 0.1 mHz-0.1 Hz. The sources are usually classified in four categories, each of them having specific detection strategies: - Periodic sources : long-life sources whose signal varies very little during the observation time. Typical examples are rotating neutron stars (pulsars) or low mass X ray binaries whose GW emission is kept up by matter accretion. Two types of searches are performed, a targeted search for known sources and a blind all sky/all frequency search.
- Coalescing binary systems : close systems composed either of two neutron stars, a neutron star and a black hole or two black holes. We distinguish between three phases, the inspiral phase (when the two stars orbit each other and the orbital separation shrinks through the emission of GW), the plunge (when the two stars merge) and the ringdown (oscillations) of the final BH. The waveform being very well modeled up to the last stable orbit and during the ringdown, the optimal detection strategy is match filtering. The use of the other detectors (e.g. electromagnetic) can improve the sensitivity of the searches by a factor of about 3.
- Unmodelled bursts : pertain to this category sources whose GW signal is not well modeled, for example supernovae. They are searched in coincidence in a network of GW detectors, or in coincidence with electromagnetic or neutrino counterparts.
- GW stochastic backgrounds (GWSB) : the superposition of all sources of GW produces a stochastic background, which could be detected by cross-correlating two (or more) detectors. We distinguish

between two contributions, the cosmological stochastic background, a memory of the very early stages of the Universe, and a background of astrophysical origin, a memory of the evolution of the galaxies and star formation, arising from a large number of unresolved sources since the beginning of stellar activity.

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