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Gravitational waves are an exciting potential new messenger for the knowledge of the universe, complementary to electro-magnetic waves and to particles. Intense instrumentation efforts in the last three decades will open soon a new window on astrophysical phenomenons. Conversely, the predictions on sources have considerably improved, both on waveform predictions and on event rates.
Gravitational waves are predicted by the General Relativity theory (cf. glossary), established by A. Einstein in 1915. They convey the perturbations of the gravitational field. Far from the sources, they are defined by a perturbation to theEuclidian metric. An infinitesimal element of space time is then, for a plane wave propagating along the z axis:

$$ds^2 = c^2dt^2 - (1+hp(t))\, dx^2 - (1-hp(t))\, dy^2 - dz^2 + 2\, hc(t)\, dx\, dy$$

where c is the speed of light, hp(t) and hc (t) the amplitude of the two polarizations. The gravitational wave amplitudes are dimensionless. It can be shown that at first order the amplitude is proportional to the source mass, to the source acceleration, and inversely proportional to the source distance. Numerical data show that massive astrophysical sources, at speed close to the speed of light, for example a binary neutron star in the Virgo cluster, in the last orbits before coalescence, can emit waves of an order of 1e-21, while an earth based emitter would be at minimum 20 orders of magnitude below that.
The sources range from continuous ones, asymmetrically rotating pulsars, to impulse ones, such as imploding supernovae, binary neutron stars (cf. glossary), rotating stars and dust around black holes, and to stochastic background emitted in the big-bang era. Otherwise invisible sources could be detected, for example kicks on "cosmic strings", i.e. line-like singularities of space-time. The pulsar 1913+16 was discovered in 1974 by R.A. Hulse and J.H. Taylor; monitoring the arrival times of the radio pulses allowed to assert that the system is actually a couple of neutron stars, and that the orbital period is decreasing. Calculations by T. Damour and N. Deruelle have shown that the amount of energy lost by the system actually corresponds to the predicted emission of gravitational waves.
The first detection efforts were led by J. Weber, with initially a 2 m length and 1 meter diameter cylinder of aluminium 1968: the bar would ring like a bell when a gravitational wave passes through. The system has been duplicated around the world, eventually with cryogenic systems. Only the energy of the wave with frequencies very close to the cylinder can be transduced to a signal. In comparison, the interferometric gravitational wave detectors, first introduced by R. Weiss, are large bandwidth detectors. In these detectors, the test-masses that proof the space time are suspended mirrors; the gravitational wave induces a dephasing of a resonating laser in the optical cavity. Significant improvements of the optical setup by R. Drever made it a possible receiver, with a reasonable bandwidth of 50 Hz - 5 kHz similar to the frequency range where binary neutron stars have the maximum of emission. In the 80's, several interferometers have been designed, 2 in the United States (LIGO), 2 in Europe (Virgo between France and Italy and GEO between Germany and United Kingdom), 1 in Japan (TAMA) and one in Australia. In 2011 second generation detectors are designed and construced, two in U.S. (Advanced LIGO), one in Europe (Advanced Virgo) and one in Japan (LCGT). Two space detectors LISA (NASA/ESA) and DECIGO (Japan), have also been designed; they would be sensitive to longer wavelengths and sensitive to sources like the numerous white dwarfs coalescences.
The instrumental challenges, both for bar and interferometric detectors, have led to significant improvements in technology: control of mirror surfaces at the angstrom level on 35 cm diameter, large volumes (about 40 kg) of silica for the mirrors with ultra-low absorption less than 0.1 ppm/cm, lasers with line widths much below 1 Hz, microwave generators with ultra-low phase noise, seismic isolation systems than can reduce the seismic noise by 15 orders of magnitude. These topics benefit to larger communities, in the academic and industrial worlds. The resolution of the earth-based detectors is fundamentally limited by two factors, the thermal agitation of the mirrors, and the quantum noise of light. The first requires to reduce to a minimum level the dissipation of acoustic waves in the bulk and in the thin layer coatings of the mirrors; the second induces to have a laser power of about 100 W, and a fraction of a MW inside the main optical resonators. Many spurious noise sources need to be controlled to not limit the signal to noise ratio.

The data analysis strategies depend on the predictability of the waveform. For the sources were the waveform is predictable, the "matched filtering" is the optimal detection: the signal buried in the noise can be recognised by looking to a specific pattern. Technical alternatives are developed for other sources. The second generation detectors are expected to be on line after 2015. They should be sensitive to a few binary neutron star coalescences events per year. Co-detection of several detectors improves the signal to noise, the false alarm rate and allow a reconstruction of the source direction on the sky. Detection with other astrophysical detectors, for example gamma ray bursts detectors, will improve the confidence for impulse signals.

In conclusion, the intense instrumental efforts, together with careful analysis of the rate event and waveforms of sources, and optimized data analysis should open in this decade a new window on the universe. We hope many exciting surprises.