INSTITUT HENRI POINCARÉ: WORKSHOP ON GRAVITATIONAL WAVE DATA ANALYSIS

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The workshop is devoted to

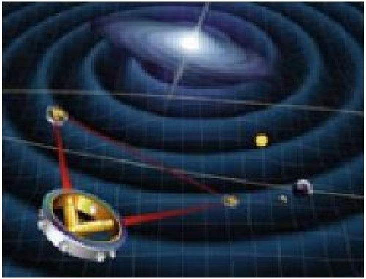
1. The theoretical aspects of gravitational radiation which are directly used in the data analysis of detectors LIGO/VIRGO/LISA (*i.e.* construction of template waveforms)
2. The specific data analysis techniques that are currently implemented in these detectors (depending on the type of sources)
3. The relevant astrophysical models of some particularly promising gravitational-wave sources

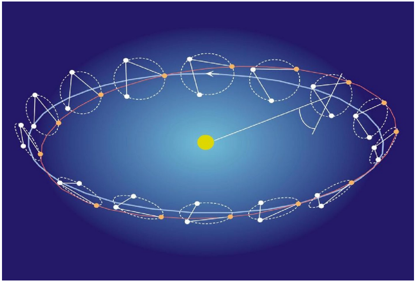
Ground-based laser interferometric detectors

LIGO

VIRGO

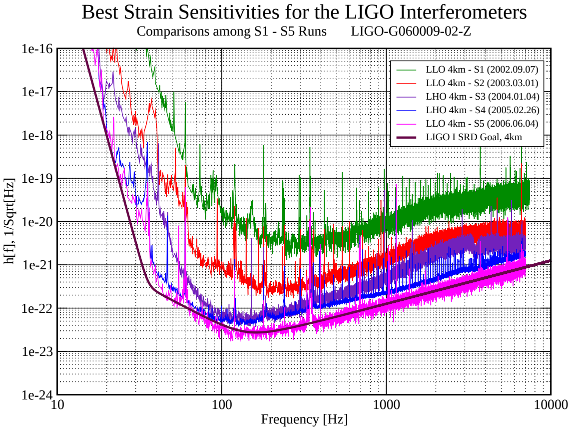
Space-based laser interferometric detector



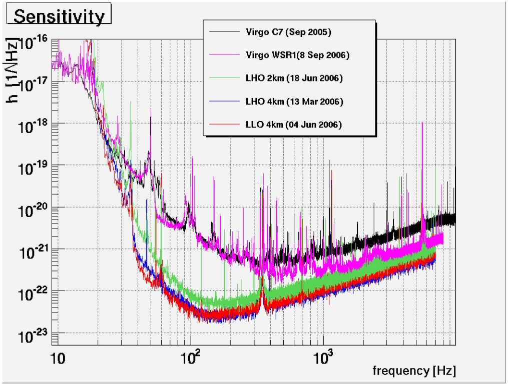


LISA

The LIGO noise curve

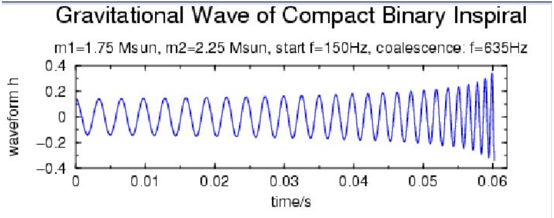


The current VIRGO noise curve



VIRGO should reach a very good sensitivity at low frequency $\sim$ 10Hz thanks to its specific seismic isolation system

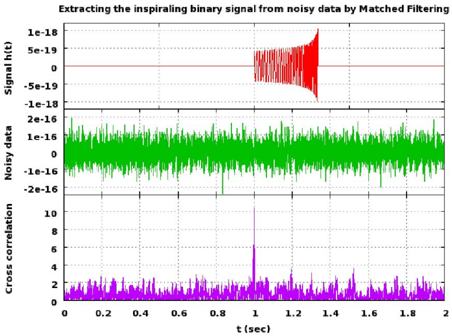
The compact binary (chirp) signal



$$\left.\begin{aligned} h_+ &= \frac{2G\mu}{c^2 D}\left(\frac{GM\omega}{c^3}\right)^{2/3}(1+\cos^2 i)\cos(2\phi) \\ h_\times &= \frac{2G\mu}{c^2 D}\left(\frac{GM\omega}{c^3}\right)^{2/3}(2\cos i)\sin(2\phi) \end{aligned}\right\} + \text{high PN corrections}$$

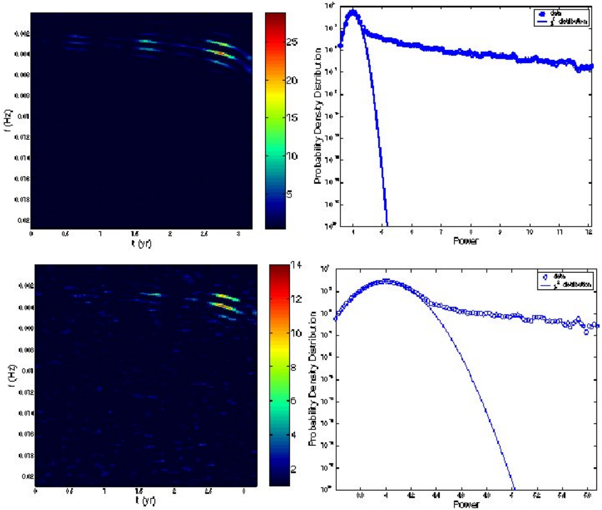
Matched filtering of the chirp signal

In the matched filtering technique, one cross correlates the noisy output of a detector with theoretically computed waveforms or templates



Templates must remain in phase with the exact waveform as long as possible. If the signal and template lose phase with each other their cross-correlation will be significantly reduced and one may lose the event altogether

Time-frequency technique for detecting EMRIs



[Wen & Gair 2005]

Strategy to detect a stochastic GW background

Suppose we have two interferometric detectors with statistically independent noises n_1 and n_2 (like VIRGO and LIGO)

- In the case where the detectors are located at the same point and have the same response to the gravitational wave

$$\begin{aligned} s_1(t) &= h(t) + n_1(t) \\ s_2(t) &= h(t) + n_2(t) \end{aligned}$$

- One constructs the correlation signal (with $T =$ the integration time)

$$S = \langle s_1, s_2 \rangle = \int_{-\frac{T}{2}}^{\frac{T}{2}} s_1(t)\, s_2(t)\, dt$$

- One can detect the signal $|h| \ll |n|$ by integrating a long enough time

$$S \approx \underbrace{\langle h, h \rangle}_{\propto T} + \underbrace{\langle n_1, n_2 \rangle}_{\propto \sqrt{T}}$$

GW source modelling

1. Analytical methods
   - Post-Newtonian approximation
     - definition for general isolated systems
     - PN equations of motion and radiation field
     - problem of self-field regularization
   - Black-hole perturbations
     - problem of the back reaction
     - close-limit approximation for binary black-holes
   - Self-force approach
     - problem of the radiative Green's function
     - evolution of Carter's constant for EMRIs
2. Numerical methods
   - Binary black-hole grand challenge
     - formulations of the vacuum Einstein field equations
     - problem of physical initial conditions
     - link with the post-Newtonian inspiral
   - Neutron star binaries
     - relativistic hydrodynamics
     - problem of equation of state of dense matter
   - Oscillations and instabilities of compact stars
     - damping and saturation of r-modes