Gravitational wave @ IUCAA

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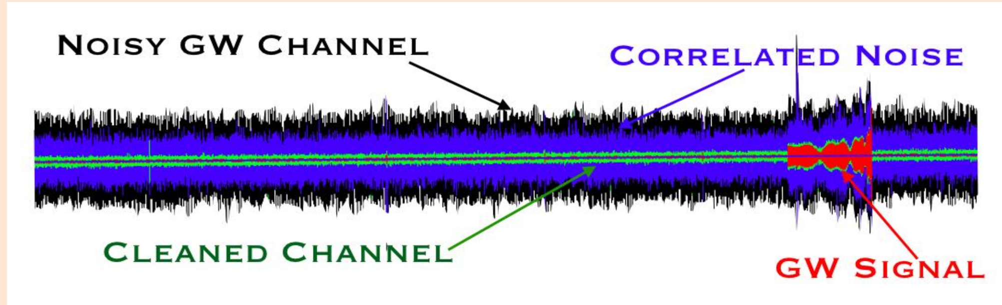
Detector characterisation

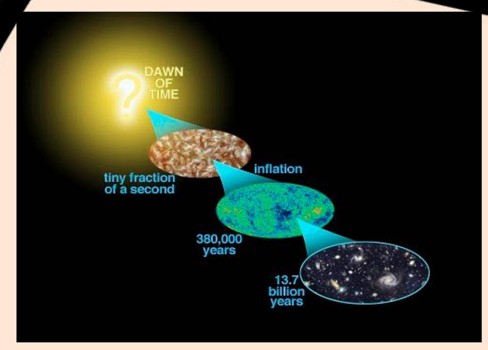
The detector-characterization group is primarily interested in the characterization and reduction of noise in GW detectors, in particular, the Newtonian gravity gradient noise which affects low frequency sensitivity of Advanced LIGO-like detectors. Currently, the focus is on developing realistic estimates of this noise using the measured seismic spectra. Another area of interest is the application of machine learning and neural networks for noise detection, classification and their subsequent removal from various LIGO channels.



Effect of adaptive noise cancellation on simulated gravitational wave strain channel where noise in the channel is reduced by using information from a correlated auxiliary channel

Cosmology

In 1986 B. Shutz proposed that kilometer-sized GW interferometers can be used to constrain cosmological parameters like the Hubble constant to an accuracy of 3 % using observations of coalescing double neutron star binaries.



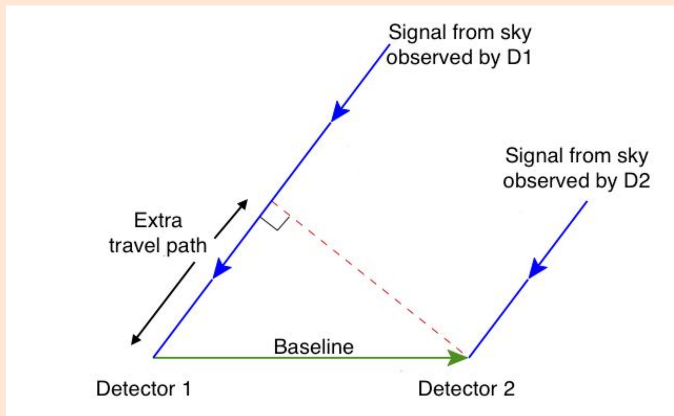
Studying the cosmic evolution

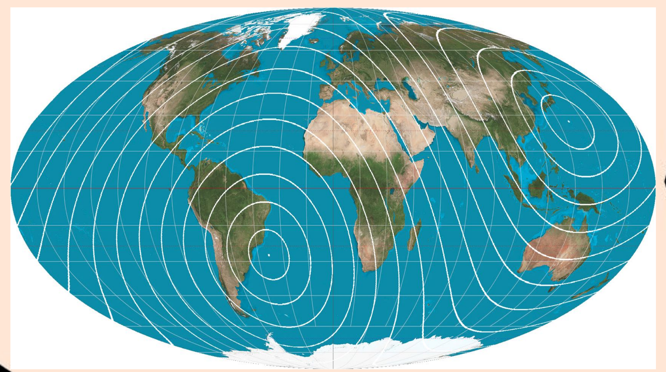
The major handicap in using GW measurements for doing cosmology is the absence of redshift information. To get around this problem our group is exploring how to combine information from galaxy clustering with compact binary coalescence signals to estimate the Hubble constant.

Gravitational wave radiometry

The basic idea of GW radiometry is that signals from different directions of the sky reach different detectors at different times. If the relative locations of the detectors is known accurately, one can use this information to identify the direction of the source. But this information is incomplete because one baseline signal from multiple directions can have the same time delay. This ambiguity can be settled because as the Earth rotates the baseline and thus the contours of equal time delay changes, and a full day worth of data becomes enough to map the entire sky.

Basic Principle of Radiometry

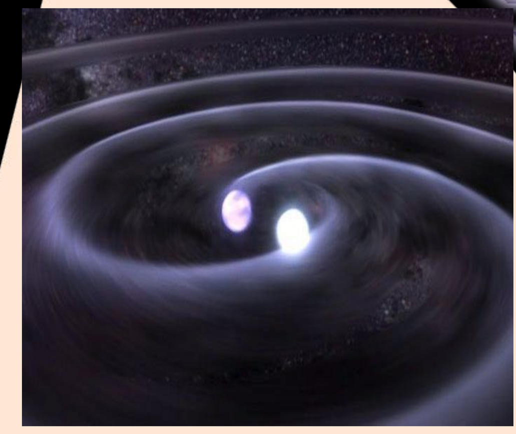




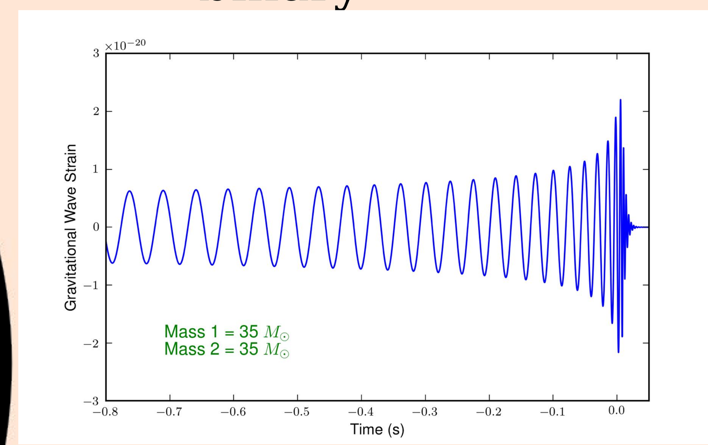
Projected Contours of Equal Time delay

Compact binary coalescence

Inspiralling binaries of compact objects like black holes and neutron stars are ideal sources for doing GW astronomy with ground based detectors like LIGO. The method of choice to detect signals from such systems, is matched filtering, where the expected GW signal is modelled using template waveforms. The noisy data is searched through to see if a signal similar to the template is buried in it. This is similar to being in a very loud and crowded party but being able to hear someone calling out our name. Our name thus works as a modelled signal for our brain. **This method was proposed and developed over a decade (1991 - 2002) here at IUCAA.**

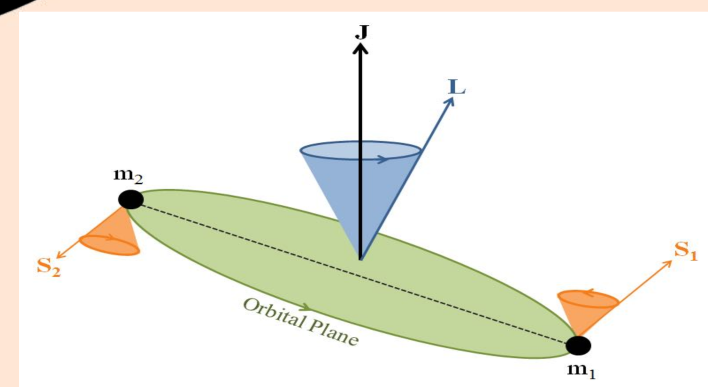


Artist's rendition of a coalescing binary



Chirp signal: an example template for the GW signal from an inspiralling binary

Currently, the focus is to improve the method, reduce its computation cost and, find other strategies to make LIGO data analysis cheaper. One way to speed-up the search for inspiraling binaries is to perform the matched filtering search in multiple stages since the combined computational cost, in that case, is less than the one stage search. **Earlier studies in the direction of hierarchical search, carried out by members of the group, showed a speed-up by a factor of ~7.** Now a more generalised development and implementation of the hierarchical method is being carried out for advanced LIGO-like detectors. The group is also involved in modelling two important classes of noise transients: sine-Gaussian and chirping sine-Gaussian glitches, that adversely affect the detector sensitivity to the inspiral signals.



Compact objects in a binary having precessing spins. The orbital angular momentum L and the total angular momentum J are also shown

Another focus of the group is accurate & efficient modeling of GWs from spinning compact binaries. The group is interested in incorporating tidal effects accurately while modelling the binary system. Existing wave-forms are compared with accurate hybrid waveforms which are generated by the group, by stitching inspiral waveforms with new and accurate numerical relativity waveforms. These can be employed for parameter estimation of GW sources. This is interesting because the extended nature of the neutron star in the system leads to tidally induced modulations in GWs & if detected this can unravel the equation of state of the neutron star.