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Astrophysical applications of gravitational waves observations.

Gravitational waves are perturbations of space-time. Existence of such objects was predicted by Einsteins General Relativity. So far, they are purely theoretical, because no direct detection was made. Despite that, scientist from all over the world are working to make the first detection possible. Gravitational radiation is completely different from the electromagnetic one. It will be a complementary source of information about various astrophysical events. We are convinced that gravitational waves will open a whole new window to the Universe. The first detection of gravitational wave will be one of the most important events in modern science.

In this work, we are analyzing what astrophysical information we can obtain from gravitational wave observations. Among many different sources of gravitational waves, the most powerful and probably the most common in the Universe, are compact binaries (by compact binaries, we mean binaries containing neutron stars or black holes). In 1974 Hulse and Taylor discovered the PSR B1913+16 binary pulsar. It consists of two neutron stars. Their orbital period is decaying. The rate of those changes very well matches to the theoretical function which assumes that gravitational waves are responsible for that decay. It was indirect evidence that gravitational waves can be produced in compact binaries.

In the first part of that work we considered the effect of eccentricity of the orbit. When the orbit is circular, signal from binary has one specific frequency (twice the orbital frequency). If we have eccentric orbit, the velocity is not constant, so the signal will contain different frequencies. This effect is negligible when the signal is the strongest (just before the merger), but can be quite important when we observe binary far from coalescence. We analyze how many compact binaries can have significant eccentricity. We created synthetic population of compact binaries using `StarTrack` code. All of our binaries evolved due to gravitational emission (including effect of eccentricity) up to the frequency at which they will be observed by future detectors. We have considered three different frequencies: 30 Hz (AdvLIGO/AdvVIRGO), 3 Hz (ET) and 0.3 Hz (DECIGO). At each of those frequencies we created distribution of eccentricity. Results have shown that for II generation of detectors (AdvLIGO/AdvVIRGO) we can assume circular orbit without any negative effect on data analysis. However, during data analysis from III generation detectors (ET) and cosmic detectors (DECIGO) eccentricity should be taken into account.

The Second part was focused on the metallicity in which stars were born. It was shown that in lower metallicity stars are forming with higher mass and they preserved almost all of it. Therefore, more massive compact objects are created in low metallicity environment. We have considered three stellar populations. Population III stars are the first stars in the Universe. They were very massive, because of lack of heavy elements in their chemical composition. We also calculated gravitational waves background from population II stars (old stars, low metallicity) and population I stars (Sun - like stars). In each case we included effect of eccentricity during our calculations.

The third part of this work concerns recovering important astrophysical information from gravitational waves observations. So far no detection was made, so we created fake set of observations to test our methods. We assumed 2 sets of parameters: Star Formation Rate (SFR) and cosmology (Ω_M, H_0). Then, we recovered one of them, assuming that we know the other one. For each set of parameters we created a grid of models in considered parameter space. Then, using maximum likelihood method, we determined which model was the best one. As a result, we presented 68% confidence limits on considered parameters. This method can be used to estimate accurately various parameters of stellar populations as well as investigating the model of cosmology.