Popular science description

Gamma ray bursts (GRBs) are astronomical phenomena detected at highest energies. The gamma ray photons carry energies on the order of mega-electronovolts and arrive to us from the point-like sources that are uniformly distributed on the sky. A typical burst has a form of a pulse that lasts for about a minute. As the Earth's atmosphere is not transparent to the very high energy radiation, the bursts are detected by means of the telescopes onboard satellites that are placed on the orbit.

The total energetics of GRB events, which is given by the integrated energy flux by the detector unit area, implies that we are witnessing very powerful explosions, where an enormously great power is released within a short time. There is only one way to obtain such huge energies in cosmos: the disruption of a star.

Already from 1990's we know that the GRBs originate mostly in the distant galaxies, and many of them are associated with supernovae. They have to be in fact special supernova types (only 10 per cent of them meet the criteria), because the core of collapsing star needs to form a black hole, surrounded by a disk composed from the remnant matter from the stellar envelope. It is the accretion of matter onto a rotating black hole that is able to provide energy large enough to account for the observed properties of GRB phenomena.

For several decades, the observational constraints confirming the collapsar model (i.e. the final through of the collapsing massive star) were strong enough in the case of long GRBs. However, for the short events, which have duration times less than two seconds, there were no precise measurements of their astrophysical environment. These data can be obtained by observations of the so-called afterglows, which are the emission at lower energies, from X-ray through Optical, down to the radio band, which arises when the fireball of the explosion interacts with the interstellar medium.

For technical reasons, such afterglows are very difficult to detect in case of short GRBs. It appears though, that the short bursts originate in very different regions of their host galaxies, and in contrast to long GRBs, they are associated with old stellar populations. Based on these observations, and on theoretical arguments (short duration time implies rather small size and mass of the star responsible for the event), the most popular explanation for their origin is the coalescence of two compact objects: two neutron stars or a neutron star and a black hole. After such coalescence, a transient structure is being formed, often involving a hypermassive, unstable neutron star, which then collapses and forms a black hole. The surrounding remnants of dense matter that are there after disruption of the neutron star, form a disk. The process of disk accretion, mediated by magnetic fields, similarly to the case of long GRBs, provides power to extract the rotational energy of the black hole and launch a relativistic jet. This collimated outflow is expanding and drilling through the interstellar medium, and when it gets optically thin, the gamma rays are produced.

The beautiful, direct confirmation of the binary neutron star merger phenomenon was obtained only very recently, in 2017. It was possible due to the discovery of gravitational wave signal, that is produced during the inspiral and merger of two compact objects, like binary neutron stars or black holes. The waves are the propagating 'ripples' in the spacetime, that are induced by a non-spherical, quickly changing distribution of mass in a very small region. This causes the change of the spacetime curvature, according to Einstein's General Relativity theory. The event named GW-GRB 170817 confirmed the existence of a gravitational wave which form is consistent with that predicted for a binary neutron star merger. And, at 1,7 seconds after the maximum of the gravitational wave signal, the electromagnetic emission in the gamma rays was detected from the same region in space.

In our project, we shall study the origin and appearance of the gamma ray bursts, of both long and short durations. We will check if and under what conditions the long GRBs could be connected with the gravitational wave emission, and which other electromagnetic observations (i.e. messengers, like the kilonovae vs. supernovae), might bring important data about the short GRBs.

Our project will involve detailed numerical massive simulations of the GRB progenitors and their central engines, based on the modern theoretical apparatus: numerical relativity, magnetohydrodynamics, and nuclear physics.