Gamma-ray bursts (GRBs) are short flashes of high energy photons (~MeV) that make their journey to Earth from the edge of the Universe, heralding the death of a stellar system and most likely the birth of a stellar mass black hole. GRBs are natural laboratories enabling us to study processes that take place in high energy densities and in ultra-relativistic plasma. Additionally they are very useful as tools to explore other related astrophysical phenomena as well as the Universe at high redshift. For these reasons, GRB research is among the fastest developing areas in astrophysical research today, fuelled by a continuous flow of new and surprising observations.

The main goal of the project is to gain a better understanding of the theory of GRBs and related astrophysical high-energy phenomena. The reintegration project was very successful. As part of the project I carried out several studies that were summarized in 13 scientific publications in peer-reviewed journals. Below I give a brief description of selected achievements from the project.

*Electromagnetic counterparts of Compact Binary Mergers*:

Neutron star mergers are the prime candidates for gravitational wave sources for the next generation ground based gravitational wave observatories. Thus, their electromagnetic counterparts are of great interest. One of the results of the merger process is the ejection of sub-relativistic and possibly relativistic outflows. We were the first to suggest that these outflows interaction with the surrounding medium will produce a detectable long lasting radio signal. We first carry out a suit of numerical simulations to constrain the outflow from various merger scenarios and then calculate the expected radio signal. We also use our results to calculate the optical emission expected on time scales of days. This emission is powered by the radioactive decay of freshly synthesized r-process elements. These studies are summarized in Nakar & Piran 2011 Nature, 478, 82; Piran, Nakar & Rosswog, 2013, MNRAS, 771 and Rosswog, Piran & Nakar 2013 MNRAS 795

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*The Propagation of Relativistic Jets in External Media:*

Relativistic jets are ubiquitous in astrophysical systems that contain compact objects. They transport large amounts of energy to large distances from the source and their interaction with the ambient medium has a crucial effect on the evolution of the system. The propagation of the jet is characterized by the formation of a shocked "head" at the front of the jet which dissipates the jet's energy and a cocoon that surrounds the jet and potentially collimates it. We developed a self-consistent, analytic model that follows the evolution of the jet and its cocoon, and describes their interaction. This model agree with detailed numerical simulations and it enables to estimate the outvome of jet-medium interaction in various environment such as GRBs and active galactic nuclei (AGNs). This study was published in Bromberg, Nakar, Piran & Sari 2011 ApJ 740 100.

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*Low-luminosity Gamma-Ray Bursts and Relativistic Jets:*

Low-luminosity gamma-ray bursts (ll-GRBs) constitute a subclass of GRBs that play a central role in the GRB-supernova connection. While ll-GRBs differ from typical long GRBs (LGRBs) in many aspects, they also share some common features. Therefore, the question whether the gamma-ray emission of ll-GRBs and LGRBs has a common origin is of great interest. We study the propagation of jets within the progenitor stars of low ll-GRBs and find that, unlike LGRBs, these jets are unlikely to breakout of the stellar envelope. The conclusion is that the processes that dominate the gamma-ray emission of ll-GRBs and of LGRBs are most likely fundamentally different. This study was published in Bromberg, Nakar & Piran, 2011 ApJ 739 L55.

*LAT-Fermi Limits on the GeV emission from gamma-ray bursts:*

The Large Area Telescope (LAT) on-board the Fermi satellite detected emission above 20 MeV only in a small fraction of the long gamma-ray bursts (GRBs) detected by the Fermi Gamma-ray Burst Monitor (GBM) at 8 keV-40 MeV. Those bursts that were detected by the LAT were among the brightest GBM bursts. We examine a sample of the most luminous GBM bursts with no LAT detection and obtain upper limits on their high energy fluence and find that GeV emission dfrom most bursts are significantly fainter than the MeV emission.

Our results strongly constrain various emission models and in particular they rule out synchrotron self-Compton models for the prompt emission. We also find that in about a third of both LAT-detected and LAT-non-detected bursts, the extrapolation of the MeV range spectrum to the GeV range is larger than the observed GeV fluence (or its upper limit). His implies a decline in the high-energy spectral slope in at least some of these bursts, possibly an evidence for the long sought-after pair creation limit. This study was published in Beniamini, Guetta, Nakar, & Piran, T. 2011 MNRAS 416 3089.