Usage Report for Fiscal Year 2018

Project Title:

Radiation-hydrodynamics simulations of central engines of short gamma-ray bursts

Name: Oliver Just
Astrophysical Big Bang Laboratory, RIKEN Cluster for Pioneering Research

1. Background and purpose of the project, relationship of the project with other projects

Neutron-star mergers have long been hypothesized as the sources of the mysterious short gamma-ray bursts that are regularly observed by telescopes. This suspicion might have been confirmed by the recent spectacular observation of the first neutron-star merger (event name GW170817), which was seen in gravitational waves and light in many wavelengths and that was accompanied by a dim, short flash of gamma radiation.

However, the origin of this flash of gamma radiation is not well understood and it is not clear if this flash is representative for other observed short gamma-ray bursts. Does it stem from a very fast conical outflow, i.e. a jet, or from more dense and slower expanding outflow, a so-called cocoon? Moreover, in what way did the jet or cocoon interact with other outflow components? And did the jet have an impact on the nucleosynthesis yields and therefore on the optically observable ("Kilonova") emission?

In order to address these questions, in this Quick Use project we aimed at developing new hydrodynamical models of the remnant of a neutron-star merger, namely a black-hole torus system, including sophisticated neutrino transport and a model for the large scale environment surrounding the torus. These models are required to cover a huge range of spatial and temporal scales, from kilometers and millisecond timescales up to 10^9 kilometers and timescales of hours. One major step was the construction of suitable initial conditions for the merger remnant consisting of a black-hole torus system that is surrounded by different components of outflows ejected before the formation of the black hole. Another major requirement for the new models was that the temperature must be evolved as accurately as possible, in order to allow the computation of the observable gamma-ray signal and the nucleosynthesis yields.

This Quick Use project Q18380 is directly connected to the General Use project G18035. Q18380 ran from April 2018 until October 2018, while the project G18035 started in October 2018 and will end in March 2019. During Q18380 we mainly developed and tested the jet models, which are now (i.e. within G18035) being investigated in larger sets and higher resolution.

2. Specific usage status of the system and calculation method

For the hydrodynamical simulations we employ the code AENUS-ALCAR, which solves the special relativistic hydrodynamics equations together with the M1 approximation of neutrino transport on a fixed, Eulerian mesh using Riemann-solver based finite-volume methods. The code (of which O. Just is a main co-developer) was extensively tested and applied in a number of published studies.

More information about the setup of the simulations is provided in the usage report of the related General Use project G18035.

３． Result

The main purpose of this half-year Quick Use project was successfully achieved, i.e. we were able to develop suitable initial models and a robust evolution scheme to accurately track the temperature. This last feature was made possible by evolving the entropy density additionally to the total energy density. This allows for a hybrid evolution scheme: In the vicinity of shocks we evolve the total energy density, and everywhere else we evolve the entropy density. In that way, we avoid that the evolution of the thermal energy (and temperature) is flawed by huge truncation errors that would otherwise result if we would evolve only the total energy density.

4. Conclusions and prospects for the future

For snapshots and more information about the developed disk-jet models as well as conclusions and prospects for the future, we refer to the usage report of the G18035 project.

While the disk-jet models still need to be analyzed and described in upcoming publications, the improvement of the code during this Quick Use project was beneficial for a project about core-collapse supernovae, from which a peer-reviewed paper already emerged (see next page).

Usage Report for Fiscal Year 2018

Fiscal Year 2018 List of Publications Resulting from the Use of the supercomputer

[Paper accepted by a journal]

O. Just, R. Bollig, H.- Th. Janka, M. Obergaulinger, R. Glas, S. Nagataki: “Core-collapse supernova simulations in one and two dimensions: comparison of codes and approximations”, MNRAS 481, 4786 (2018)

[Oral presentation]

O. Just: “Neutrino-Transport Effects in Neutron-Star Mergers and Core- Collapse Supernovae”, Theoretical Astrophysics Workshop, ASIAA, Taipei (Taiwan), 09/2018

O. Just: “Nucleosynthesis, Jets, and EOS constraints From Neutron-Star Mergers”, The Exploding Universe, Tsun-Dao Lee Institute, Shanghai (China), 05/2018

O. Just: “Modeling Core-Collapse Supernovae and Remnants of Neutron-Star Mergers”, Physics of Core-Collapse Supernovae and Compact Star Formations Workshop, Waseda University Tokyo (Japan), 03/2018