Usage Report for Fiscal Year 2017

Project Title:

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

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1. Background and purpose of the project

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? And what physics mechanism was responsible for launching the jet that might end up in a cocoon? In order to address these questions, in our project we aim to perform hydrodynamical simulations 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. We plan to investigate, how the jet travels through the environment, the properties of the cocoon formed by the jet and the dependence on the jet energy, torus mass, jet injection timescale and other global parameters. Moreover, we aim to use the results of these simulations for radiative transfer calculations (outside of this project). The motivation is to find systematic effects that allow to constrain the properties of the observed GW170817 event and of future events.

2. Specific usage status and calculation method

We use the ALCAR code recently developed by the project leader and collaborators to perform neutrino-hydrodynamics simulations of the black-hole torus system (see Just, Obergaulinger, Janka 2015, MNRAS 453, 3386 for a detailed code description). This code solves the equations of viscous hydrodynamics together with those for radiation (i.e. neutrino) transport in the so-called M1 approximation, which is much less expensive than solving the original radiative transfer equation. The evolution is done using finite-volume discretization and a high-order Godunov-type scheme. We use a spherical polar coordinate system and assume axisymmetry.

The black-hole torus system and its environment is evolved on a grid of about 500 radial times 200 angular zones covering about a domain of 10^9 cm . After the jet has been launched and is detached from the center, we cut out the radially innermost part and extend the grid to larger radii to follow the long-term evolution of the jet.

The code makes use of shared-memory (openMP) as well as distributed memory (MPI) parallelization and can be run efficiently on up to ~500 cores for the given setup.

6. Reason why no job was executed.

So far we only executed small-scale test runs but we were unable to start our main production runs by now. This is mainly because during the time since the start of this project (August 2017) we have been dealing with numerical problems regarding the long-term evolution of the jet and on the development of suitable initial models. Moreover, we had other urgent commitments that were partially unforeseen because of the observation of the GW170817 event in October 2017. We sincerely apologize for leaving the allocated computing time unused so far, we hope to be able to go into production very soon.