Usage Report for Fiscal Year 2019

Project Title:

Improved hydrodynamical simulations of gamma ray burst central engines

Name: ○Yuki Takei (1, 2, 3), Oliver Just (1)
(1) Astrophysical Big Bang Laboratory
(2) Research Center for the Early Universe, Graduate School of Science, The University of Tokyo
(3) Department of Astronomy, Graduate School of Science, The University of Tokyo
Laboratory at RIKEN: Astrophysical Big Bang Laboratory

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

As a result of an explosion of a massive star (more than about 8 solar masses), a neutron star is formed. If two neutron stars are in a binary system, they continue to emit gravitational waves (GWs) and GWs take away their angular momentum. As a result, they merge together, possibly accompanying a jet, and forming a single compact object. On 17th August 2017, GWs have first been detected by LIGO and Virgo (identified as GW170817), followed by a short gamma-ray burst (sGRB) (GRB 170817A). At the same time, many observatories detected electromagnetic signals in multiple wavelengths from the same direction. This event represents the first direct evidence that neutron-star mergers are the progenitors of sGRBs.

Despite these amazing discoveries, many aspects and questions still remain open. The purpose of this Quick Use project Q19466 was to investigate the properties of the cocoon that is formed when the incipient jet travels and breaks out through the surrounding cloud of merger ejecta.

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.

In this Quick Use project, we investigate the change of cocoon properties under variation of several parameters characterizing the initial jet beam, namely the specific enthalpy h (varied from its original value of h=100 down to h=20), and the energy-injection rate (which was varied from 1E50 erg/s to 5E49 erg/s and 2E49 erg/s). Moreover, we aimed at testing the impact of a newly developed scheme that evolves the entropy instead of the total energy.

3. Result

In Fig. 1, the cocoon masses are plotted as functions of time. As a reference model, we adopt an existing model computed in the course of General Use project G19024. As can be seen from Figure 1, the cocoon masses of models do not significantly depend on the initial specific enthalpy or on the use of the entropy solver. At t~0.12s the jets break out of the dynamical ejecta, which is causes slope to become shallower. In contrast, the cocoon properties depend sensitively on the injected jet energy.

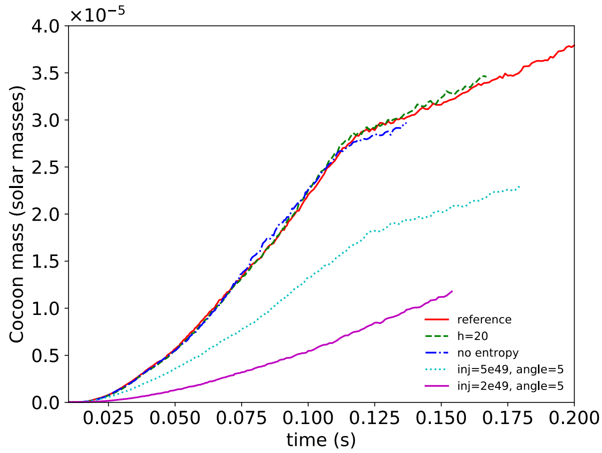

Figure 1. Plots of cocoon masses as functions of time.

4. Conclusion

Our results are encouraging regarding our future goal to connect sGRB signals with jet properties based on our hydrodynamics simulations.

5. Schedule and prospect for the future

Our small study lays the basis for an upcoming more extended study, in which we want to investigate the possibility to constrain the initial jet properties (and therefore the Blandford-Znajek mechanism powering the jet) by observational features of the sGRB. In this project, we will evolve the jets for much longer times of 1000's of seconds in order to be able to compute the sGRB lightcurve.