Trans-Relativistic Afterglow Code (TRAC)

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1 Description

TRAC is a semi-analytic code for modeling GRB afterglows. TRAC can use any (axisymmetric) initial energy and mass distribution for the explosion, seen at any viewing angle, and either an ISM or wind external medium.

For an ISM medium (constant external density), the radius vs. time is calibrated to 1D spherical relativistic hydrodynamic simulations using PLUTO. The evolution is consistent with simulations and analytic models from the initial cruising phase while the shock is developing, through the relativistic and non-relativistic blastwave phases, and the transitions in between.

For a wind medium, the early evolution before the shock fully develops is not included and has not been calibrated with simulations, but the relativistic and non-relativistic blastwave phases should be working properly.

Radiation is modeled as synchrotron emission, including synchrotron self-absorption. Synchrotron Self-Compton is not included, and only forward-shock emission is calculated. Fast- and slow-cooling are modeled, but fast-cooling may not be 100% reliable. This primarily effects early time emission with a wind external medium.

A more complete description of the TRAC hydrodynamics and radiation model for this ISM case can be found in Morsony et al. 2023 (in preparation).

2 Citing TRAC

TRAC was origionally used by Morsony, B.J., Workman, J.C., & Ryan, D.M., 2016, ApJL, 825, L24. This article should be cited when referencing TRAC.

3 Running TRAC

This repository contains a number of python files needed to run TRAC, along with some example Jupyter notebooks used to make models and load the data created.

The file run_code_test_sphere_ISM.py contains all the setup parameters and code calls to run TRAC for a spherical explosion in an ISM medium. It can be executed by running the notebook run_TRAC_example_sphere_ISM.ipynb . This will create 2 data files - savefile.short.onaxis.sphere.ISM.p which save the hydrodynamics of the model, and afterglow_sych_spectrum.sphere.ISM.p which save the radiation model results. Radiation information across the 2D face of the shock is save.

To load and visualize the resulting data, the notebook TRAC_lightcurve_sphere_ISM.ipynb will load the radiation data and plot a light curve vs time, an example spectrum, and an example spectrum compared to a analytic model form Granot & Sari (2002).

An example model of the same explosion in a wind medium is provided in run_code_test_sphere_wind.py and corresponding notebooks run_TRAC_example_sphere_wind.ipynb and TRAC_lightcurve_sphere_wind.ipynb to run it and load the data.

The file run_code_test_GW170817_bestfit.py models the best-fit model to the afterglow of GW170817 from Morsony et al. 2023 (in preparation). This is a structured jet seen off-axis in an ISM external medium. The jet energy and mass distribution is provided in the data file summarized_data_lazzati_2017.dat and is taken from relativistic hydro simulations published in Lazzati et al. (2017).

The GW170817 model can be run with run_TRAC_example_GW170817_bestfit.ipynb and TRAC_lightcurve_GW170817_bestfit.ipynb will load the data and plot light curves.

The two spherical models take about 5 minutes to run. The GW170817 model takes about 2 hours. This is because for the off-axis model it is necessary to calculate several different angles around the observers line of sight. We use 54 angles in this case, which produces fluxes within $3\% - 4\%$ of the converged fluxes at higher resolution.