Analysis and visualization of simulations in Gamma Ray Bursts jets and central engine

Summer Internship 2023 of Jakub Trzaska, supervised by Gerardo Urrutia

Objective: Enhance the style and functionality of existing plots.

Introduction: Data visualization is essential for effectively communication of scientific results, whether constrained by limited space in journals or brief presentation time at conferences. This project aims to improve current data visualization techniques and tools, focusing on the refinement of existing plots. The student worked on templates and color palettes to elevate the visual appeal and clarity of plots created in Python. The physical scenario considered in this project involves the study of a short gamma-ray burst (GRB) jet, from its launch at the central engine to its propagation until large scales.

Methodology: The student was introduced to basic notions in Relativistic Hydrodynamics through simulations performed with HARM and Mezcal codes. The student explored the structure of output data generated by HARM, focusing on the tracer particles that describe the evolution of fluid parcels generated by strong winds originating from accretion discs. The student analyzed the trajectories and arrival times of these tracer particles at different boundary points. He extract information about geometrical distributions of mass, mass loss rate, pressure, and chemical composition.

Additionally, the student improved visualization techniques by enhancing plot designs in Python. They identified and implemented appropriate templates and color schemes to achieve clearer, more nice representations of the data. The student also worked with the vtk outputs produced by the Mezcal code, which contains information from jet dynamics on a large scale. For this analysis, the student utilized the VisIt software, which is Python-based but requires non-trivial integration of external Python scripts. The student’s work involved coupling Bash and Python scripts to improve the post-processing tasks within VisIt, thereby facilitating a more efficient workflow. The results from this scripts were applied in the work (Urrutia, Janiuk, et al. 2024 submitted to MNRAS).

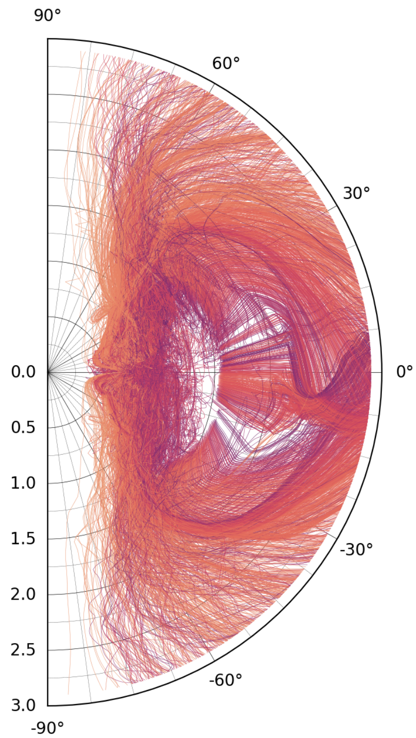


Figure Tracer trajectories: This figure shows the trajectories of fluid parcels within strong winds arising from an accretion disk. The color gradient, ranging from darker to lighter shades, indicates particle velocity, with lighter shades representing faster-moving particles. In this scenario, the faster particles are concentrated near the polar regions.

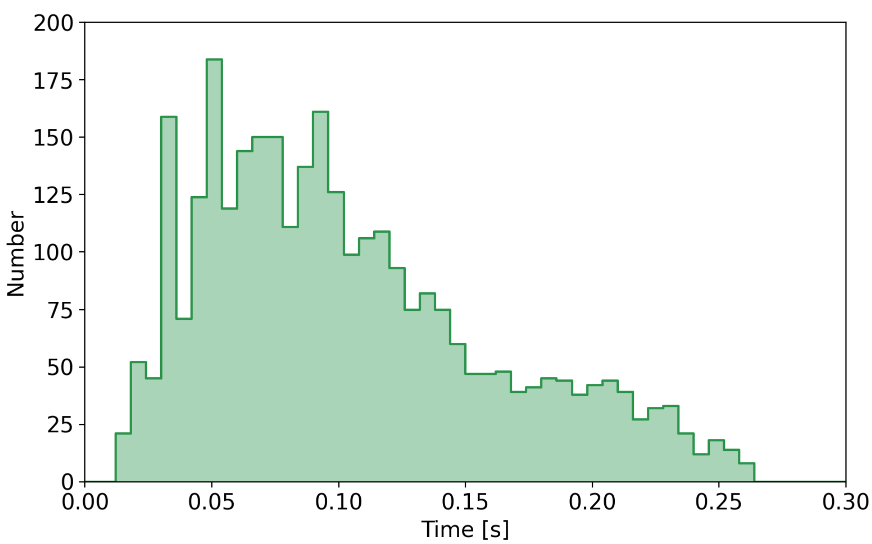


Figure rate of arriving particles:
This figure shows the rate at which particles escape from the computational box over small time intervals. It illustrates the frequency of particle arrivals per unit time.

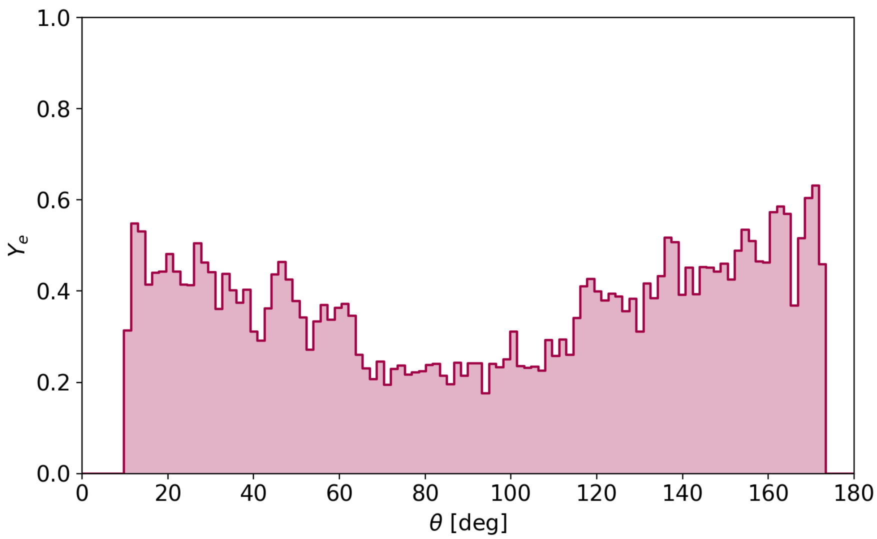


Figure of geometrical distribution of electron fraction: This figure was generated by selection of electron fraction. It provides information about the chemical composition of post-merger disk winds.

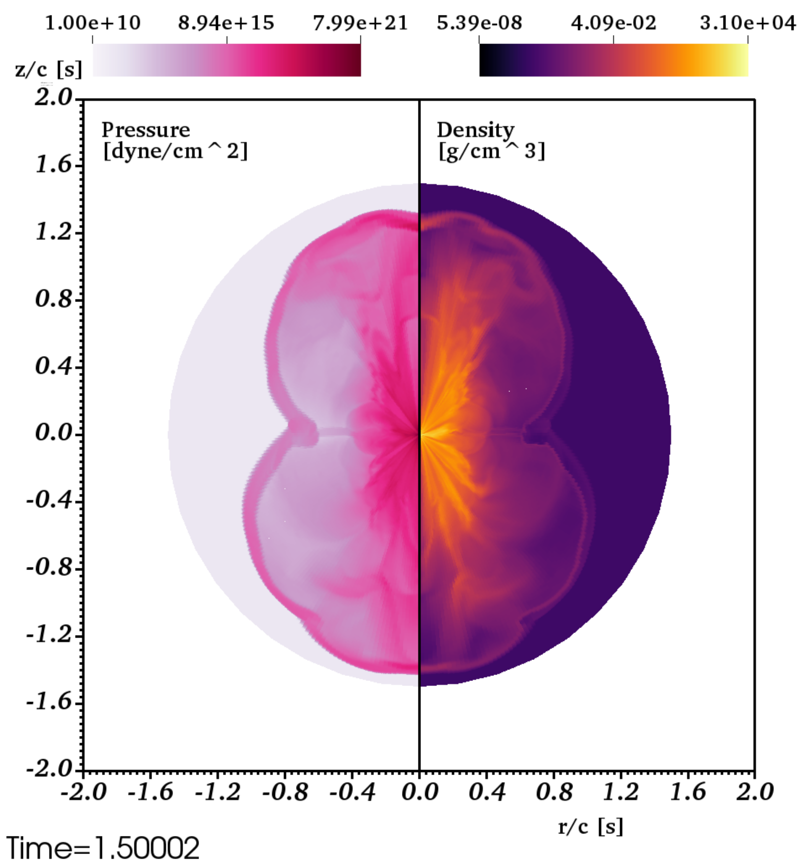
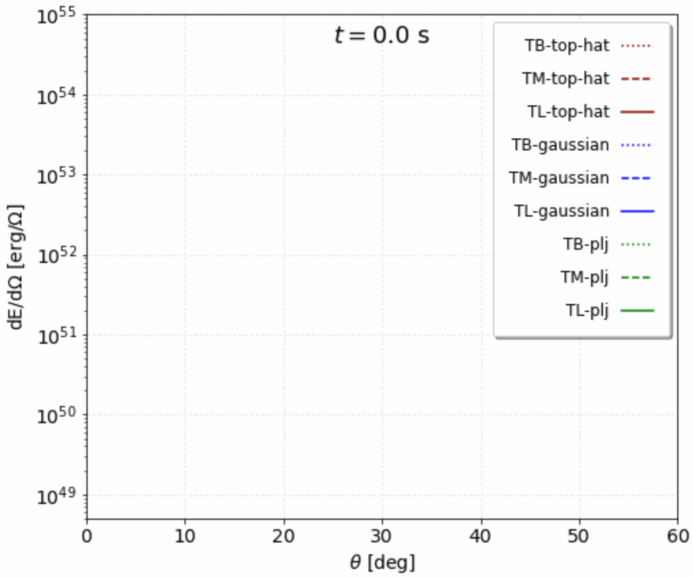


Figure of Pressure and density maps: The left panel shows a pressure map with a customized (manual control of shifting) color gradient to highlight high-pressure regions, while the right panel presents the corresponding density map. This plot style, unavailable in VisIt, was created by integrating Bash and Python scripts for enhanced visualization.



Gift of he evolution of the energy structure of the jet: This figure illustrates the evolution of the jet's energy structure, based on data from **Urrutia, De Colle et al. 2022**. Actually, it is an update of Figure 4 contained in the publication. This new version enhances readability, making it more suitable for presentations while preserving the key findings.