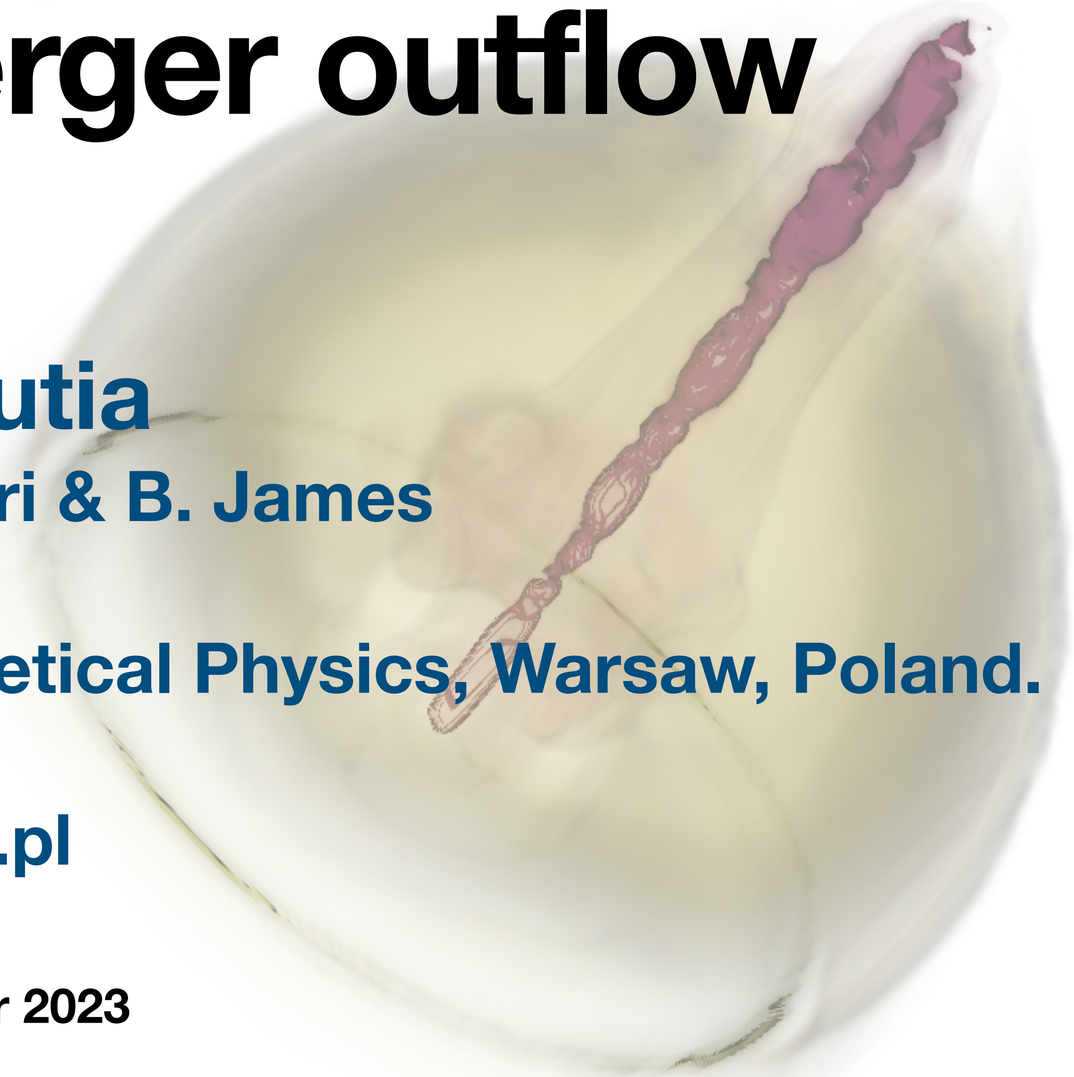
Following the jet interaction with a post-merger outflow



Gerardo Urrutia

A. Janiuk, F. Nouri & B. James

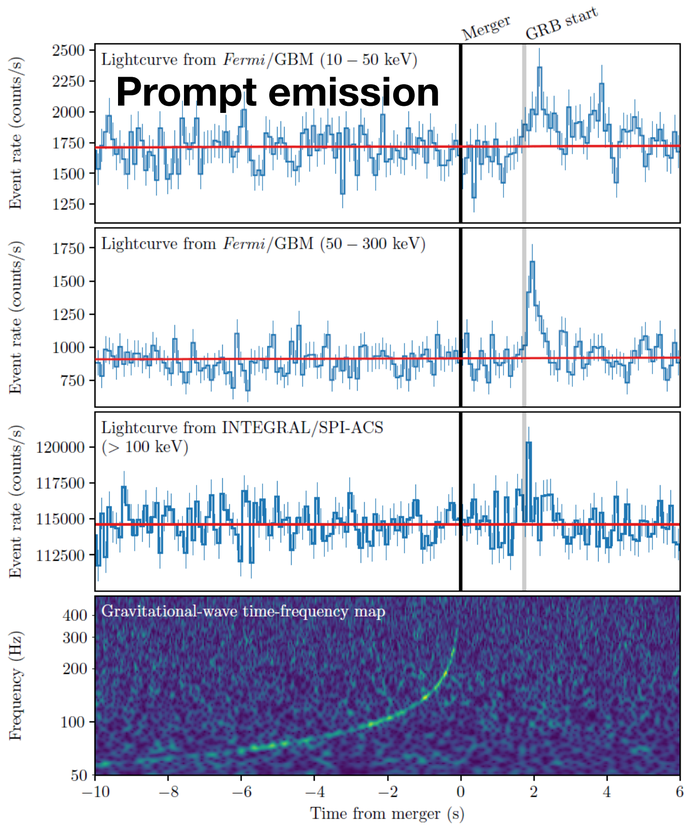
Center for Theoretical Physics, Warsaw, Poland.

gurrutia@cft.edu.pl

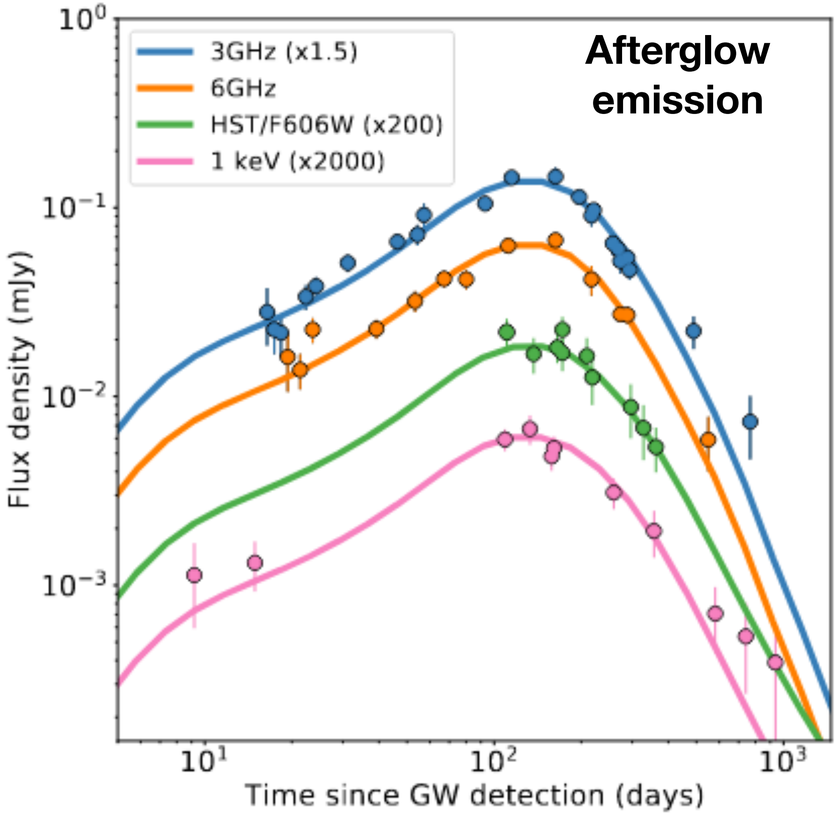
PTA meeting, September 2023

Short Gamma Ray Bursts

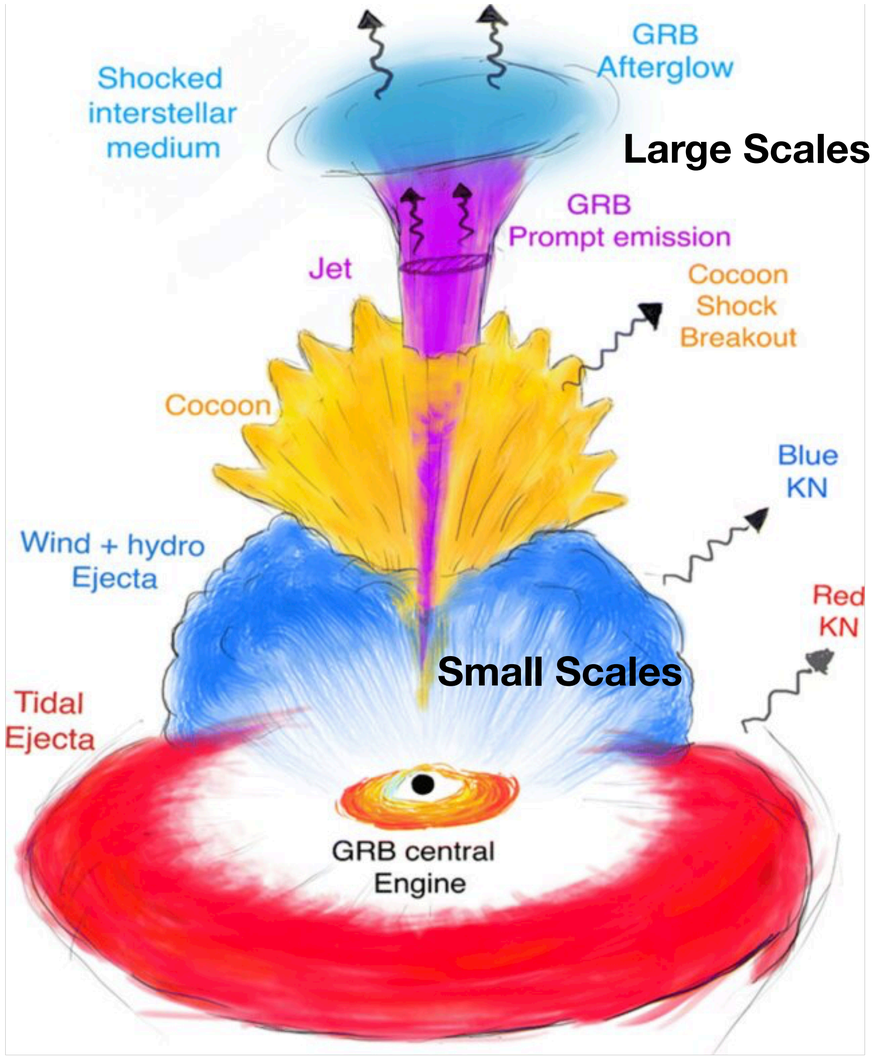
Example: GRB 170817A



Abbot., et al 2017



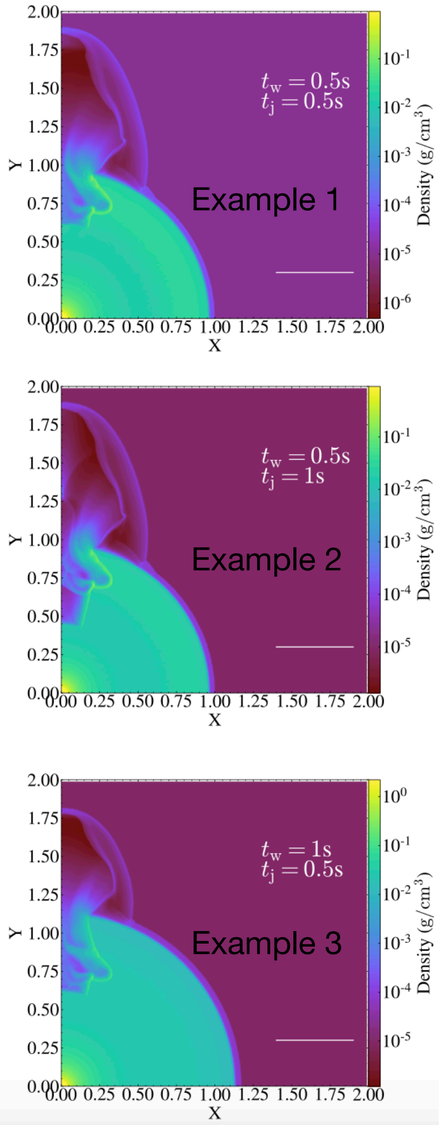
Makhatini et al., 2022



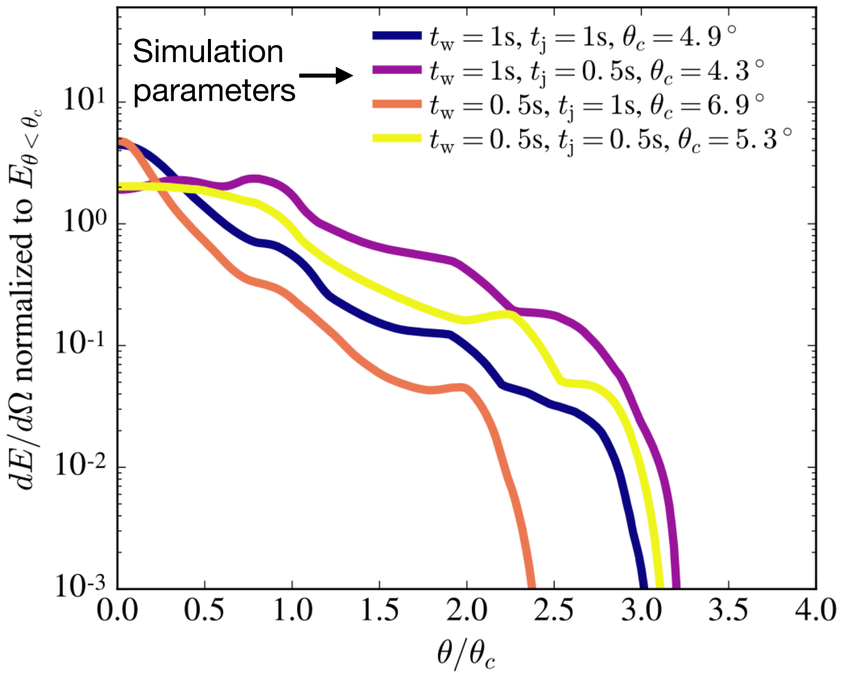
Cartoon of GRB evolution (Stefano Ascenzi)

Motivation: Jet-wind interaction modifies the dynamics at large scales

Density maps

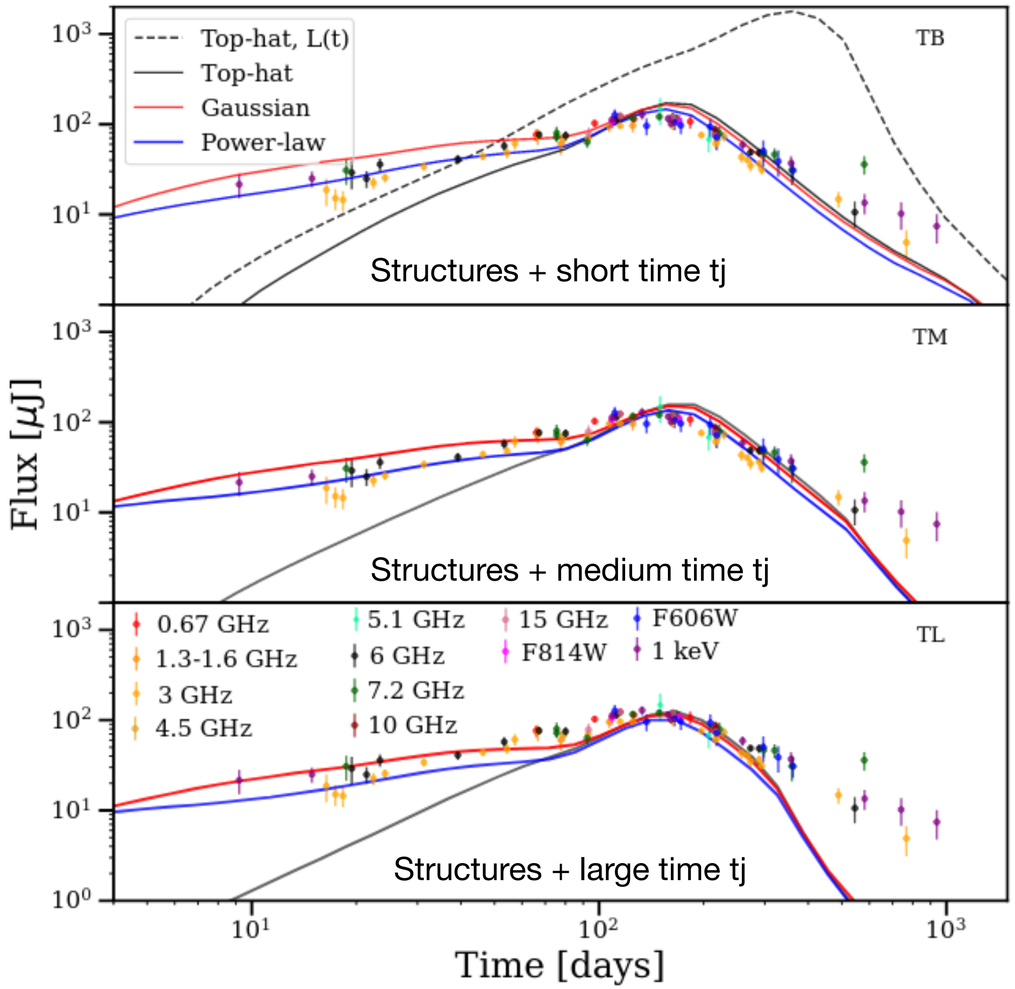


Energy distribution (jet structure)



Murguia-Berthier et al. 2021

Light Curves from simulations (Data: GRB 170817A)



Urrutia et al., 2021

Objetive: We follow the SGRB jet interaction with a realistic post-merger outflow

Small scales $r < 3 \times 10^{10}\,\mathrm{cm}$

General Relativistic MHD simulation

$$(\rho u_\mu)_{;\nu} = 0$$

$$T^{\mu}_{\nu;\mu} = 0$$

$$T^{\mu\nu} = T^{\mu\nu}_{\mathrm{m}} + T^{\mu\nu}_{\mathrm{em}}$$

-HARM CODE (Gammie 2003)
-HLL solver
-Kerr-schild metric

Neutrino treatment (Janiuk et al. 2013)
The neutrino optical depth

$$\tau_{\mathrm{a},\nu_\mathrm{i}} = \frac{H}{4\frac{7}{8}\sigma T^4} q_{\mathrm{a},\nu_\mathrm{i}},$$

Species:

$$p + e^- \rightarrow n + \nu_e$$
$$n + e^+ \rightarrow p + \bar{\nu}_e$$
$$e^+ + e^- \rightarrow \nu_i \bar{\nu}_i$$

Importing data

Methods:

- **The disc wind outflow was performed by Nouri et al. 2023 by GRMHD simulation.**
- **We import outflow data as an initial condition for a large-scale simulation.**
- **We constrain the jet parameters from GRMHD simulation.**

Large scales $10^8\,\mathrm{cm} < \mathrm{r} < 10^{10}\,\mathrm{cm}$

Special Relativistic HD simulation

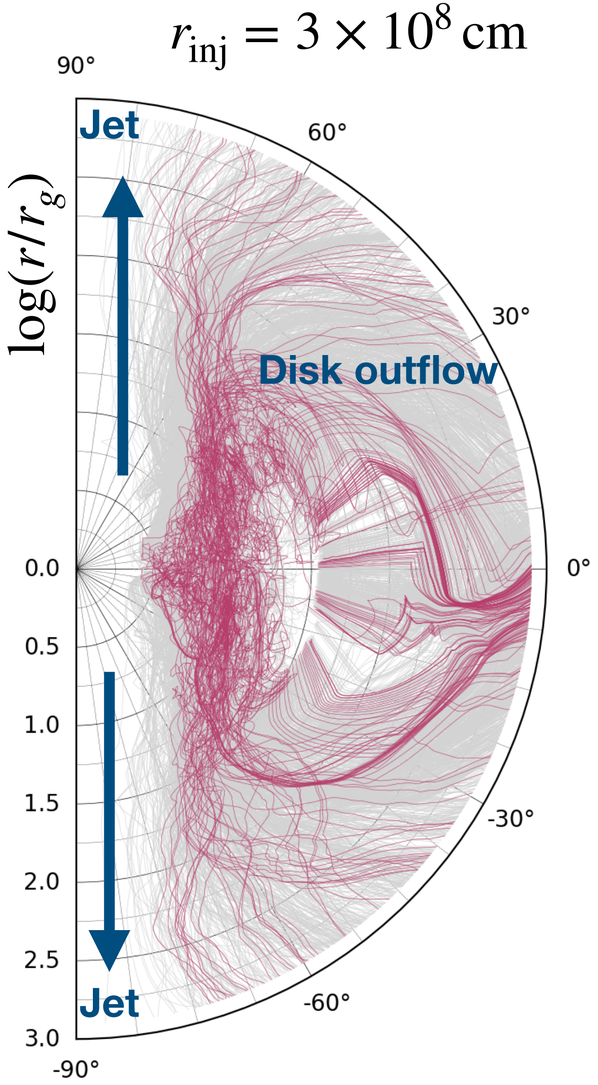
$$(\rho u_\mu)_{;\nu} = 0$$

$$T^{\mu}_{\nu;\mu} = 0$$

$$T^{\mu\nu} = T^{\mu\nu}_{\mathrm{m}}$$

- Mezcal Code (De Colle 2012)
- Adaptive Mesh Refinement
- HLLC solver
- GR effects not considered

Initial conditions: main parameters



General Relativistic MHD simulation

Disk outflow (Nouri et al. 2023)

$\beta = 50$

$a = 0.9$

$M_{\rm BH} = 2.65 M_\odot$

$M_{\rm disc} = 0.10276\, M_\odot$

$\dot{M}_{\rm out} = 3.27 \times 10^{-2}\, M_\odot\ {\rm s}^{-1}$

Special Relativistic HD simulation

Jet

$t_{\rm j} \propto M_{\rm disk}/\dot{M} \sim 1\ {\rm s}$

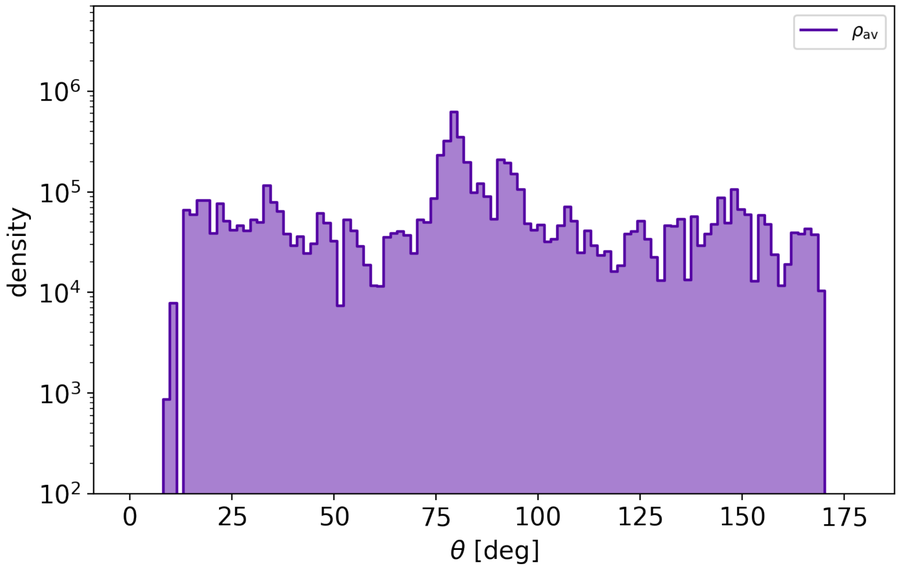
$\theta_j = 15^\circ$

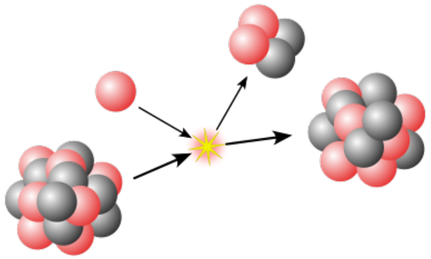
$L_j = \int_0^{\theta_j} e_j v_r\, dS \approx 1.7 \times 10^{50}\,{\rm erg/s}$

$\Gamma_j = 7.2$

$\Gamma_\infty = 100$

Wind distributions at r_{inj}

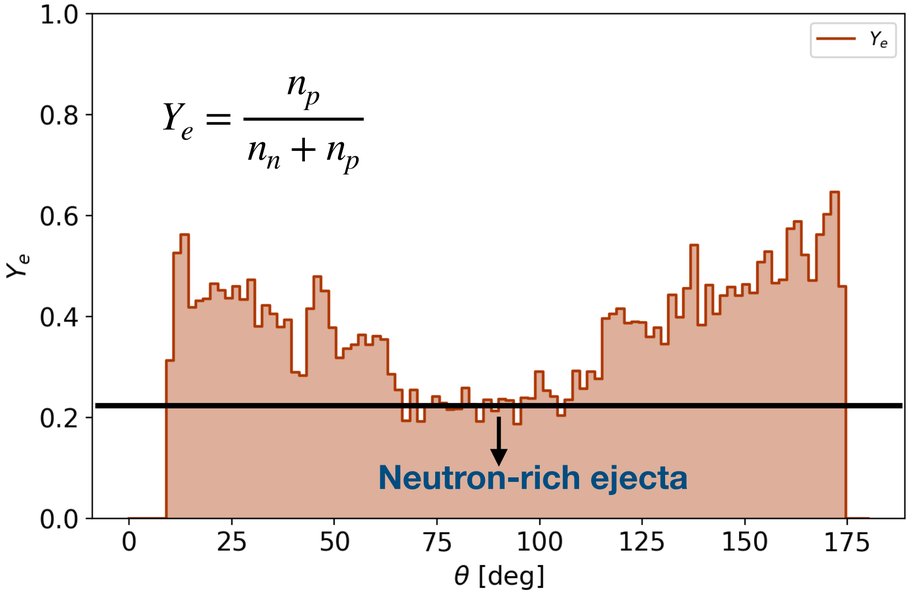


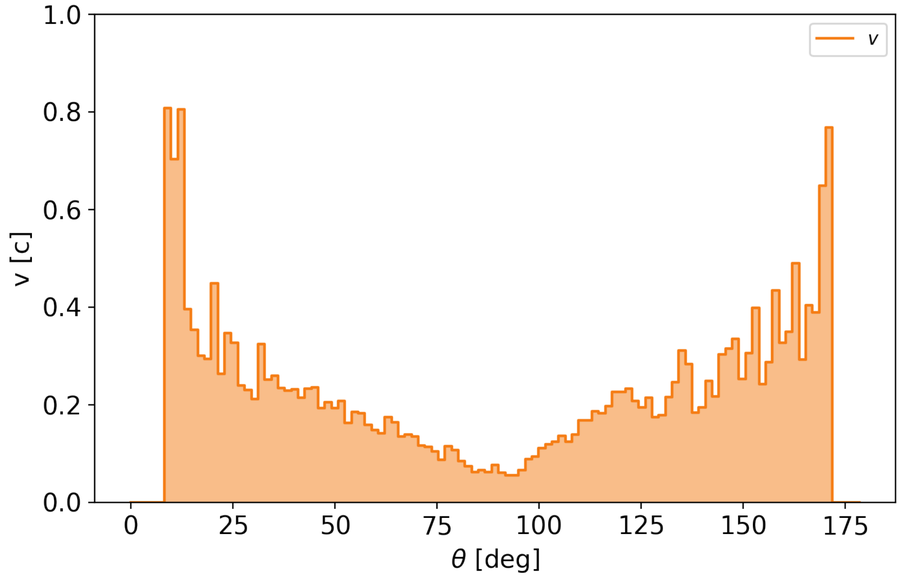


Rapid neutron-capture process

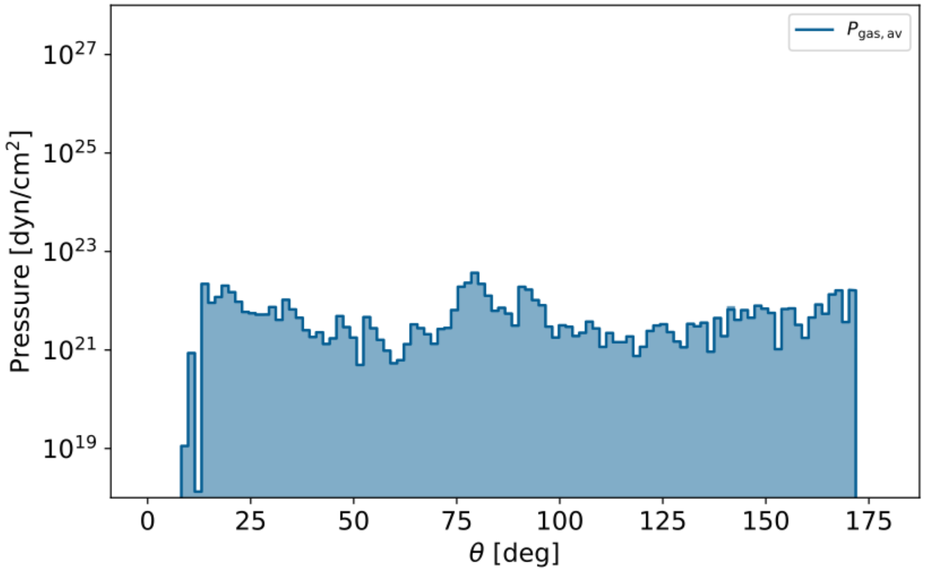
Processing

SkyNet nuclear reaction network
(Lippuner & Roberts 2017)

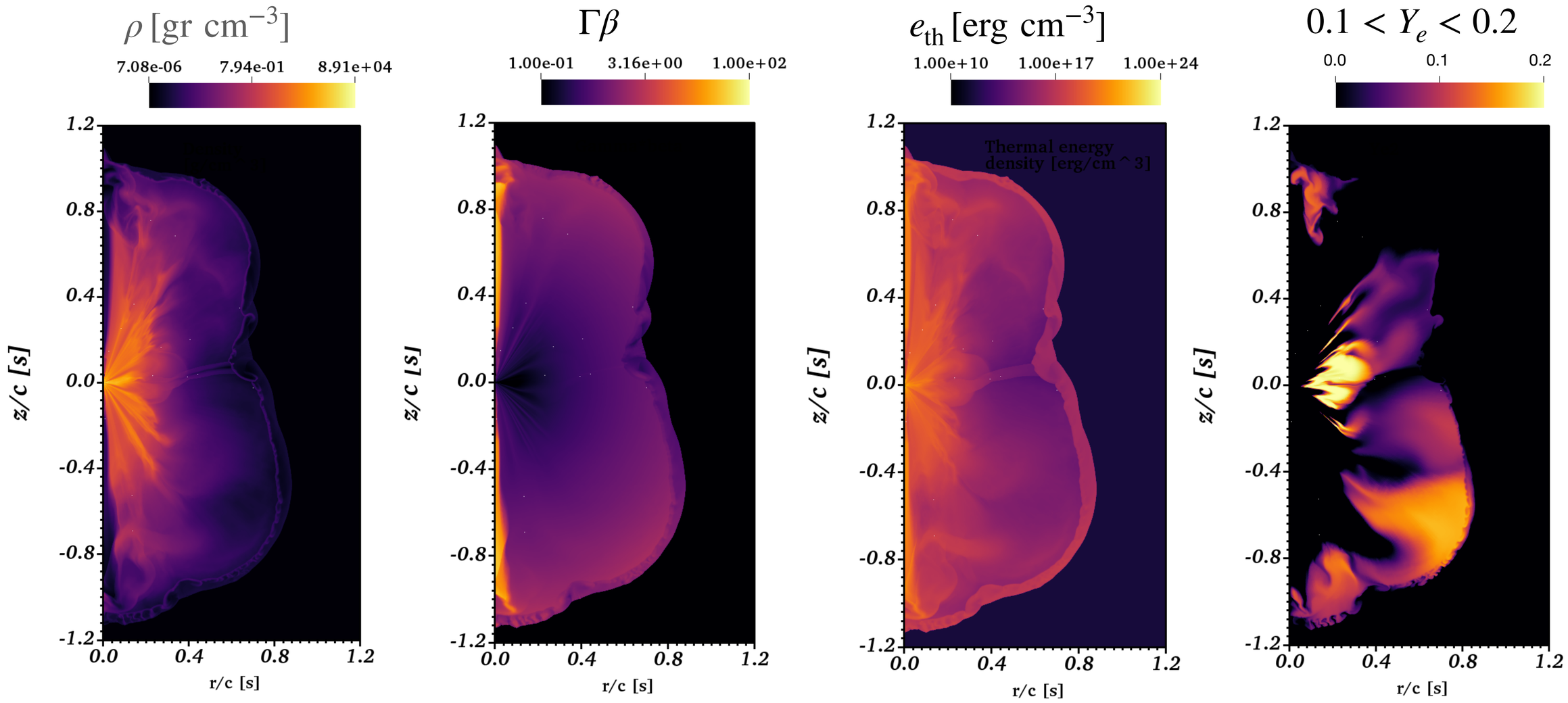




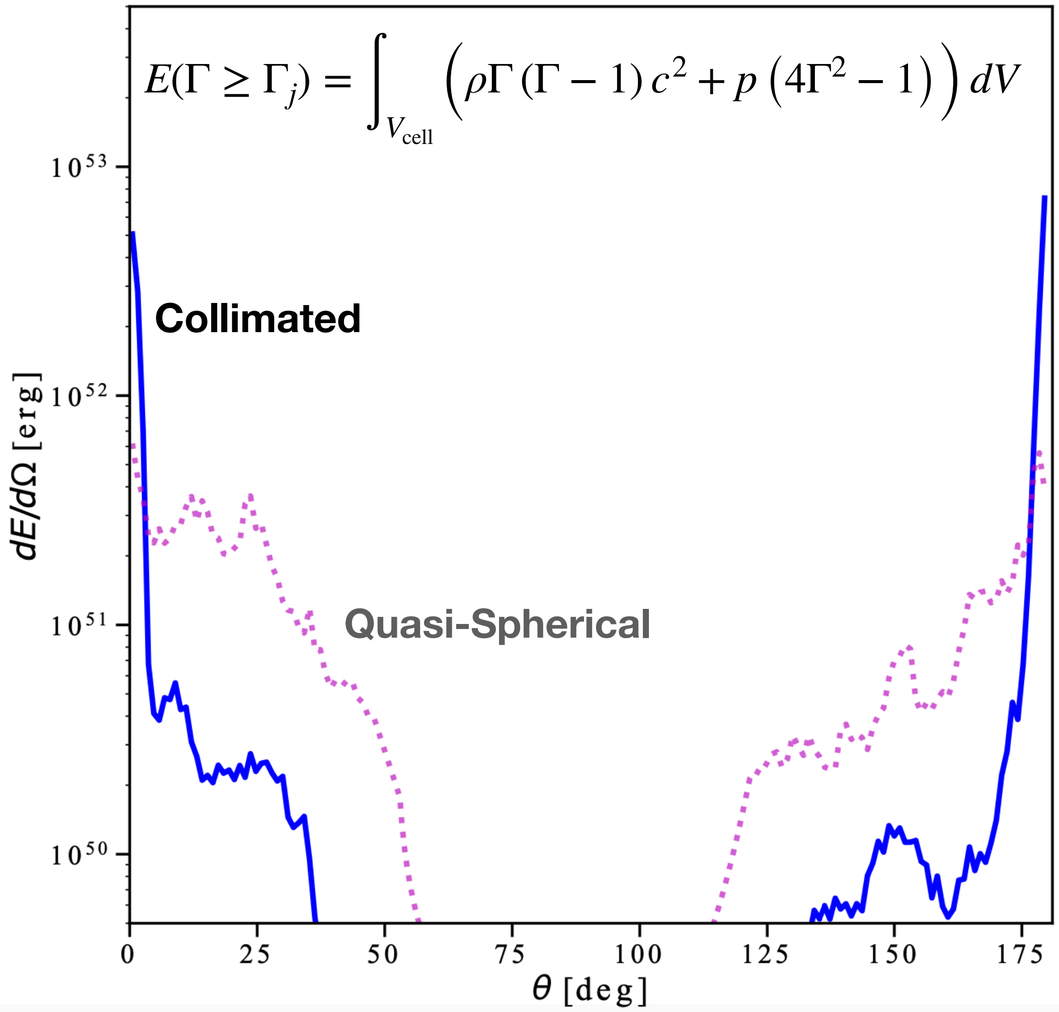
Note: Abundances are discussed by
Nouri et al., 2023

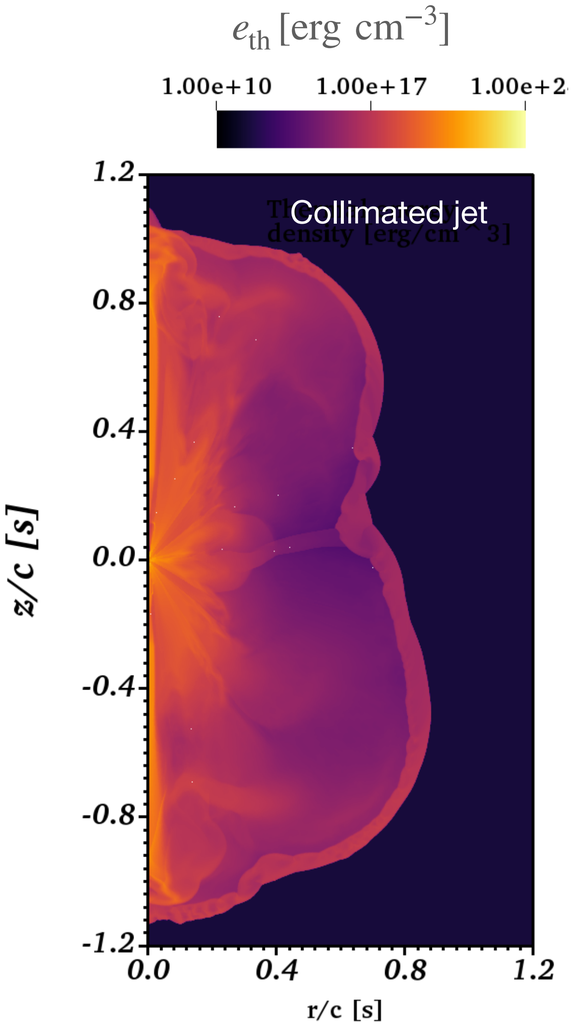


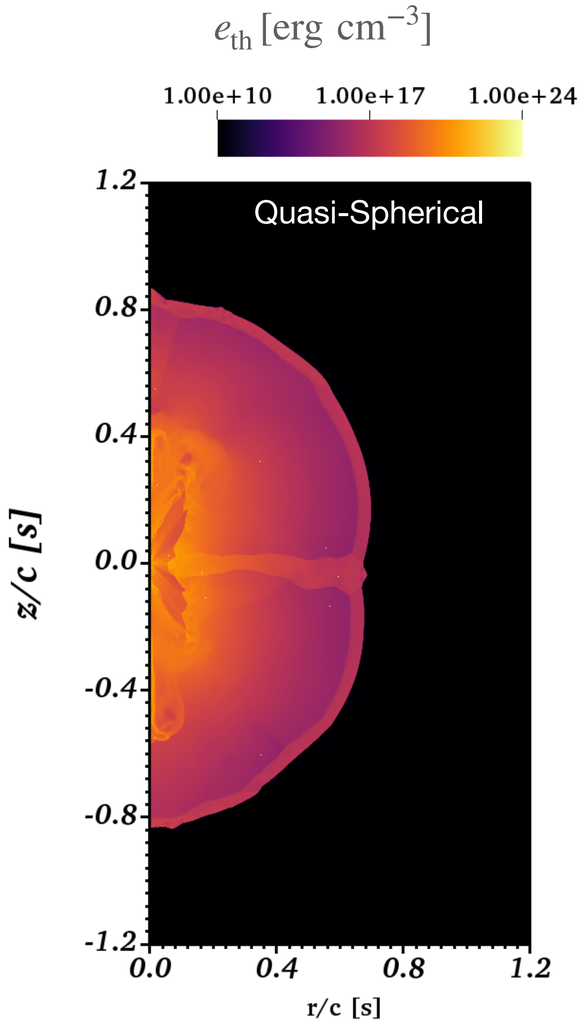
Jet-wind dynamics at $t = 1.2\,\mathrm{s}$



Comparison with the quasi-spherical model







Summary and Conclusions

- We study the interaction between a jet and a post-merger wind outflow.
- We import data representing a disc wind that was previously generated trough GRMHD simulations.
- The nuclear heating effects was considered to recover the gas pressure of the wind.
- We found that the wind produces a jet collimation (pressure effect).
- The interaction of the jet with a spherical atmosphere results in a spread distribution of material and energy.
- The disc outflow modifies substantially the dynamics of the jet, making it an essential component in Short GRB dynamics.

Thank you for your attention !