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Simulating the recollimation shocks, instabilities and particle acceleration in relativistic jets

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AGN jets are the most powerful persistent emitters in the Universe, but the mechanisms through which they dissipate part of their energy flux and convey it to relativistic particles are still elusive. Despite advances on the numerical and theoretical side, the identification of the processes at work is made difficult by the huge range of spatial and temporal scales involved and by the strong interplay between kinetic-scale processes and large-scale dynamics, with the important role of instabilities. Numerical simulations are therefore the natural tool for exploring the vast range of jet phenomenology.
In this framework, 3D MHD simulations of relativistic jets surprisingly reveal that the (intensively studied in 2D) recollimation caused by pressure unbalance with the external medium triggers a rapidly growing instability that leads to the development of strong turbulence, eventually resulting in the complete disruption of the flow (Komissarov et al. 2019). Existing simulations are inadequate to fully characterize the instability and the level of turbulence injected in the plasma, therefore in order to understand the impact of this newly discovered instability, we are pursuing a vigorous program of relativistic MHD simulations. Preparatory 2D and complete 3D simulations are carried out with the state-of-the-art PLUTO code, and the treatment of particle acceleration and transport is included via a hybrid approach. In particular the setup we are considering is designed to be applied to the most extreme and still enigmatic blazars, the EHBL. Their observational properties are different from the bulk of the blazar population, challenging the standard emission scenarios, and the multiple-shock model proposed by Zech &Lemoine, justified by 2D simulations, is instead questioned by the results of these 3D simulations. In addition, the presence of strong turbulence downstream of the recollimation shock is an interesting feature for building a new model for the VHE-emission of the EHBL.

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