Title:

Internal hydrodynamical shocks as a mechanism for GRB prompt emission

Abstract:

Among the models used to explain the prompt emission of gamma-ray bursts (GRBs), internal shocks is a leading one. Its most basic ingredient is a collision between two cold shells of different Lorentz factors in an ultra-relativistic outflow, which forms a pair of shock fronts that accelerate electrons in their wake.

We investigate the internal shocks model as mechanism for prompt emission based on a full hydrodynamical analytic derivation in planar geometry, extending this approach to spherical geometry using hydrodynamic simulations. Using a moving-mesh relativistic hydrocode, we highlight spherical effects on quantities such as shock strength that were not predicted by simple propagation models. We derive the corresponding emission considering an infinitely thin radiating shell downstream of each front, assuming the accelerated electrons are deep in the fast cooling regime. Our model naturally obtains key features of GRB prompt emission such as the doubly-broken power-law spectral shape, where the subdominant spectral component results from the contribution of the weaker forward shock.

Spherical effects on the hydrodynamics modify the corresponding emission. In particular, the observed peak frequency decreases faster than expected by other models in the rising part of the pulse, and the peak flux saturates even for moderately short pulses. This brings the predicted hardness - intensity diagram closer to GRB observations. Our model also predicts the link between the peak frequencies of the two spectral components, their ratio staying within the range observed in bursts. This prediction happens over a wider range of parameters than expected from analytical estimates, without fine-tuning of the initial hydrodynamical conditions. We then introduce expected effects from cooling regimes and non-infinitely thin emission regions, bringing low-energy spectral slopes closer to current observations.