



Contribution ID: 38

Type: **Paralela**

Ultrarelativistic Double shock waves

Thursday 4 December 2025 15:00 (20 minutes)

We know that the only solution of the hydrodynamic equations that propagates in wave form, except for small perturbations, is shock waves. However, shock waves haven't been thoroughly studied in the ultrarelativistic limit. In the relativistic formulation of hydrodynamics, causality must be intrinsically preserved, which, as a consequence, limits the maximum group velocity of the theory [1]. This naturally affects the propagation of ultra-relativistic shock waves, whose velocity can often exceed this maximum group velocity of the theory. In this work, numerical simulations of ultra-relativistic shock waves will be conducted to investigate what happens to shock waves when they exceed this maximum propagation velocity. The numerical method chosen was Smoothed Particle Hydrodynamics (SPH) [2]. So, I performed a large number of simulations, varying the physical parameters, to investigate the ultrarelativistic limit for shock waves [3]. There were two methods to investigate this limit, the first involved simulating different shocks with different velocities in the same fluid, and the second involved simulating the same shock in different fluids, each with different maximum propagation velocities. After the numerical simulations, we found that as the shock velocity exceeded the maximum group velocity, a second shock formed at the trailing edge of the first one due to a buildup of matter. However, there is no proof whether the second shock is a physical phenomenon or not.

[1] G.S. Denicol, T. Kodama, T. Koide e Ph. Mota. Shock propagation and stability in causal dissipative hydrodynamics. arXiv:0805.1719v1 12 Maio 2008.

[2] J. J. Monaghan. Smoothed Particle Hydrodynamics. Annual Reviews 1992.

[3] D.D. Oliveira, G.S. Denicol. Simulações Numéricas de Ondas de Choque Ultrarrelativísticas. Universidade Federal Fluminense, 2022

Altas energias

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Session Classification: Altas Energias