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Double-Adiabatic Equations of State for Relativistic Plasmas

The pressure tensor in a collisionless, magnetised plasma is anisotropic with respect to the guide magnetic field. We derive evolution equations of the perpendicular and parallel pressure components for the case of a relativistically hot plasma. When a plasma is subject to a mean perpendicular flow, these reduce to double-adiabatic laws, with adiabatic indices dependent on the temperature and pressure anisotropy. For example, in the case of an ultra-relativistic plasma close to isotropy, our theory predicts the perpendicular and parallel pressure components evolve with adiabatic indices equal to 8/5 and 4/5, respectively. This differs from the non-relativistic result, whereby these values should be 2 and 1 independently of anisotropy. Our analytic picture is numerically confirmed using two-dimensional particle-in-cell simulations of a plasma in a compressing box.

Authors: WIERZCHUCKA, Agnieszka (University of Oxford); Prof. SCHEKOCHIHIN, Alexander (University of Oxford); THOMAS, Alexander (university of michigan); Prof. UZDENSKY, Dmitri (University of Oxford); BILBAO, Pablo (University of Oxford)

Presenter: WIERZCHUCKA, Agnieszka (University of Oxford)