11th meeting of the BRICS Astronomy Working Group

13 to 17 October 2025

Instituto Nacional de Pesquisas Espaciais (INPE)
São José dos Campos, São Paulo, Brasil

# The Impact of β-Dependent Tearing Instability Suppression on Cos- mic Ray Acceleration and Multi-Messenger Transients

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## Abstract

Magnetic reconnection is a primary mechanism for powering energetic, transient astrophysical phenomena, with profound implications for multi-messenger astronomy. Theoretical estimates for reconnection rates rely on the presence/absence of instabilities, such as the Tearing Instability, whose growth rate in classical magnetohydrodynamic (MHD) theory is independent of the plasma-β (the ratio of thermal to magnetic pressure). However, many astrophysical environments are filled with a weakly collisional plasma and are characterized by high-β conditions, where the validity of classical MHD is limited. This work investigates the theory of Tearing Instability under these more realistic conditions using a non-ideal gyrotropic-MHD framework. Our analysis revealed a novel and previously unknown scaling relation for the instability's maximum growth rate in high-β regimes, which scales as $\gamma_{max} \propto \beta^{-1/4}$. This suppression arises from dynamically generated pressure anisotropy that introduces a stabilizing restoring force, absent in standard MHD. Our results suggest that the onset of plasmoid-mediated fast reconnection and subsequent particle acceleration by first order Fermi process may be significantly inhibited or delayed in high-β regions of astrophysical sources. For multi-messenger astronomy, this β-dependent suppression introduces a crucial physical constraint on the production of UHECRs, VHE gamma-rays, and high-energy neutrinos.This challenges the universal applicability of reconnection models that neglect pressure anisotropy and suggests that plasma-β could be a key modulating factor in the multi-messenger output of the most energetic cosmic accelerators.