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Extreme Astrophysical Emissions: Synchrotron, Curvature, and Jet Radiation in Pulsars, Magnetars, and Black Holes

Pulsars, magnetars, and black holes, being high-energy astrophysical objects, function as natural experimental settings to explore high-energy radiation. Presenting a comparative analysis of their dominant emission processes, focusing on curvature radiation, synchrotron radiation, inverse Compton scattering, and magnetic reconnection effects, the paper also investigates high-energy radiation in pulsars and magnetars. Pulsars, powered by the loss of rotational energy, produce strong curvature and synchrotron radiation in their magnetospheres. In comparison, magnetars, with their incredibly strong magnetic fields, generate intense X-ray and gamma-ray bursts through magnetic reconnection and quantum electrodynamics (QED) effects. Black holes mostly release energy via the thermal radiation of their accretion discs and relativistic jets, involving mechanisms such as synchrotron radiation and inverse Compton scattering.

Using observational data from key sources: Crab Pulsar (PSR B0531+21), SGR 1806–20, and M87*, the study explores how these mechanisms operate across different astrophysical environments. The comparison framework highlights the differences in energy sources, magnetic field intensities, significant radiation types, and emission signatures. Furthermore, the study examines the significance of multi-messenger findings, involving neutrinos and gravitational waves, in constraining theoretical models.

The study emphasizes the importance of upcoming space missions, like XRISM, Athena, LISA, and CTA, in enhancing the knowledge of these processes. This study integrates theoretical ideas with observational data to enhance understanding of the radiation physics of compact astrophysical objects and their broader implications for high-energy astrophysics.

Collaboration(s)

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