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Disentangling Comptonization processes and mapping emission regions in accreting neutron stars

Understanding the dominant mechanisms behind radiation production and energisation, as well as the spatial distribution of emission sources near an accreting compact object, remains one of the fundamental problems in high-energy astrophysics. While it is generally agreed that multi-temperature plasma with emitting and Comptonizing components is involved, the exact mechanisms of photon production and reprocessing remain debated across various accreting systems. A similar uncertainty applies to the geometry and spatial distribution of emission regions and their interplay —specifically, which region acts primarily as a source and which serves predominantly as a site of reprocessing. While this class of problems is well known for X-ray binaries in general, high-mass X-ray binaries with neutron stars introduce additional complexity and unique diagnostic potential due to the presence of strong magnetic fields. At high and intermediate mass-accretion rates, a major challenge lies in disentangling the emission from the accretion column and its reprocessing by the neutron star atmosphere, as well as identifying the respective roles of bulk and thermal Comptonization in shaping the observed spectrum. The magnetic field induces strong anisotropy and introduces resonances into radiative processes —most notably, in Compton scattering. Using radiative transfer in a highly magnetised plasma combined with relativistic ray tracing near the neutron star, we show that observational signatures from resonant Compton scattering vary for different scenarios in the accretion channel. This enables the development of diagnostic tests to distinguish between competing models. We discuss the limitations of this approach and its relevance for interpreting observational data.

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