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Radiative properties of magnetic neutron stars with metallic surfaces and thin atmospheres

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Abstract

Context. Simple models fail to describe the observed spectra of X-ray-dim isolated neutron stars (XDINSs). Interpretating these spectra requires detailed studies of radiative properties in the outermost layers of neutron stars with strong magnetic fields. Previous studies have shown that the strongly magnetized plasma in the outer envelopes of a neutron star may exhibit a phase transition to a condensed form. In this case thermal radiation can emerge directly from the metallic surface without going through a gaseous atmosphere, or alternatively, it may pass through a "thin" atmosphere above the surface. The multitude of theoretical possibilities complicates modeling the spectra and makes it desirable to have analytic formulae for constructing samples of models without going through computationally expensive, detailed calculations. Aims. The goal of this work is to develop a simple analytic description of the emission properties (spectrum and polarization) of the condensed, strongly magnetized surface of neutron stars. Methods. We have improved our earlier work for calculating the spectral properties of condensed magnetized surfaces. Using the improved method, we calculated the reflectivity of an iron surface at magnetic field strengths B ~ 10 12 G-10 14 G, with various inclinations of the magnetic field lines and radiation beam with respect to the surface and each other. We constructed analytic expressions for the emissivity of this surface as functions of the photon energy, magnetic field strength, and the three angles that determine the geometry of the local problem. Using these expressions, we calculated X-ray spectra for neutron stars with condensed iron surfaces covered by thin partially ionized hydrogen atmospheres. Results. We develop simple analytic descriptions of the intensity and polarization of radiation emitted or reflected by condensed iron surfaces of neutron stars with the strong magnetic fields typical of isolated neutron stars. This description provides boundary conditions at the bottom of a thin atmosphere, which are more accurate than previously used approximations. The spectra calculated with this improvement show different absorption features from those in simplified models. Conclusions. The approach developed in this paper yields results that can facilitate modeling and interpretation of the X-ray spectra of isolated, strongly magnetized, thermally emitting neutron stars. © 2012 ESO.

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Keywords

Magnetic fields, Radiation mechanisms: thermal, Stars: atmospheres, Stars: neutron, X-rays: stars