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X-ray emissions from magnetic polar regions of neutron stars

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Structures of X-ray emitting magnetic polar regions on neutron stars in X-ray pulsars are studied. It is shown that a thin, optically thick, radiation energy dominated, X-ray emitting polar cone appears in each of the polar regions. The height of the polar cone from the neutron star surface to a standing shock at the top has a large dependence on the accretion rate. When $\dot{M} \simeq 10^{16}$ g s^{-1}, the height is a tenth as low as the neutron star radius. When $\dot{M} \simeq 10^{18}$ g s^{-1}, the height is, however, about 10 times as large as the neutron star radius. Histories of the radiation energy carried with the matter flowing in the polar cone also largely varies with the accretion rate. When $\dot{M}$ is as low as 10^{16} g s^{-1}, the energy is mostly radiated away behind the shock. However, when $\dot{M}$ is as large as 10^{18} g s^{-1} or larger, the energy gain due to the gravity of the neutron star exceeds the energy loss due to photon diffusion in the azimuthal direction of the cone, and a significant amount of energy is advected to the neutron star surface. Then, the radiation energy carried with the flow should accumulate there, and the radiation pressure should overcome the magnetic pressure which has been holding the flow within the cone. As a result, the matter should expand in the tangential direction along the neutron star surface, dragging the magnetic lines of force, and form a mound-like structure. The advected energy to the bottom of the cone should finally be radiated from the surface of the polar mound and the matter should be settled on the stellar surface there. From such configurations, we can expect an X-ray spectrum composed of a multi-color black-body spectrum from the polar cone region and a quasi-single black-body spectrum from the polar mound region. This spectral property agrees with observations. A fairly sharp pencil beam is expected together with a broad fan beam from the polar cone region, while a broad pencil beam from the polar mound region. With these X-ray beam properties, basic patterns in X-ray pulse profiles of X-ray pulsars can be explained too.

Topic

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