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Polarization of Thermal Radiation from Neutron Stars

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Abstract. The degree of polarization of thermal radiation from a neutron star depends on photon energy, surface temperature and magnetic field, and it oscillates with the star rotation period. Observations of this polarization provide a new tool for investigating properties of these objects.

1. Introduction

X-ray data collected with the *ROSAT* and *ASCA* missions from thermally radiating isolated neutron stars (NSs) have shown that some of these objects are sufficiently bright for polarimetric observations. For a NS with a strong magnetic field, one should expect that the NS radiation acquires strong linear polarization at energies much lower than the electron cyclotron energy (Gnedin & Pavlov 1974; Pavlov & Shibanov 1978). We show that the polarimetric observations would provide new important information on NSs.

2. Model description and results

We consider a NS with an effective temperature of 1×10^6 K, uniformly distributed over the NS surface, and a dipole magnetic field, $B_{\rm p} = 1 \times 10^{12}$ G at the pole. We assume that the NS is covered with a fully ionized hydrogen atmosphere. The GR effects on photon trajectories, orientation of the polarization vector and configuration of the magnetic field are considered for the Schwarzschild metric.

The ratio $P_L = -F_Q/F_I$, where F_I is the observed radiative flux and F_Q the Stokes parameter, gives the observed degree of linear polarization. To find F_I and F_Q, one should sum contributions from all the elements of the visible NS surface (see Pavlov & Zavlin 2000, for details).

The results are presented for a NS radius $R = 10$ km and for two masses, $M/M_\odot = 0.66$ and 1.92, chosen from a M-R domain allowed by plausible equations of state of the NS superdense matter. Figure 1 shows that, in the soft X-ray range, P_L is positive, i.e., the polarization direction is perpendicular to

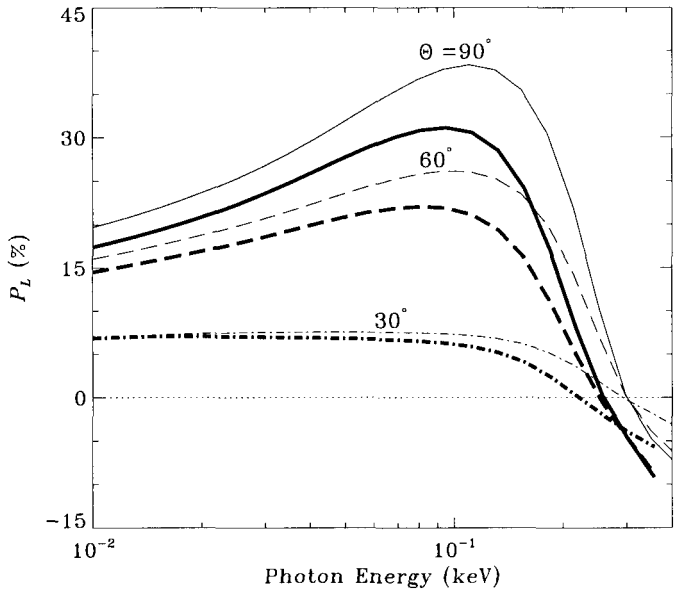

Figure 1. Degree of linear polarization *vs.* photon energy. The thin and thick lines correspond to the low and high NS masses, respectively.

the projection of the NS magnetic axis onto the image plane. The degree of polarization decreases with increasing M/R and grows with increasing angle Θ between the magnetic axis and the line of sight, reaching a maximum value at $\Theta = 90°$. Since P_L depends on Θ, the polarization pulsates with the NS rotation period.

3. Conclusions

The degree of linear polarization of thermal NS radiation is high enough to be measured with soft-X-ray polarimeters. Measuring the degree and the phase dependence of the polarization will be most useful to determine the strength of the magnetic field and the directions of the rotation and magnetic axes of NSs. The polarimetric observations can also constrain the NS mass-to-radius ratio and thus the equation of state of the superdense matter in the NS interiors.

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References

Gnedin, Yu. N., & Pavlov, G. G. 1974, Sov. Phys. JETP, 38, 903
Pavlov, G. G., & Shibanov, Yu. A. 1978, Sov. Astron., 22, 214
Pavlov, G. G., & Zavlin, V. E. 2000, ApJ, in press