

Quantum nature of cyclotron harmonics in thermal spectra of neutron stars

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Abstract

Some isolated neutron stars (NSs) show harmonically spaced absorption features in their thermal soft X-ray spectra. The interpretation of the features as a cyclotron line and its harmonics has been suggested, but the usual explanation of the harmonics as caused by relativistic effects fails because the relativistic corrections are extremely small in this case. We suggest that the features, known as quantum oscillations, correspond to the peaks in the energy dependence of the free-free opacity in a quantizing magnetic field. The peaks arise when the transitions to new Landau levels become allowed with increasing the photon energy; they are strongly enhanced by the square-root singularities in the phase-space density of quantum states in the case when the free (non-quantized) motion is effectively one dimensional. To explore observable properties of these quantum oscillations, we calculate models of hydrogen NS atmospheres with B 1010-1011G (i.e., electron cyclotron energy $E_{c,e}$ 0.1-1keV) and $T_{\text{eff}} = 1$ -3 MK. Such conditions are thought to be typical for the so-called central compact objects in supernova remnants, such as 1E1207.4-5209 in PKS 1209-51/52. We show that observable features at the electron cyclotron harmonics form at moderately large values of the quantization parameter, $b_{\text{eff}} \equiv E_{c,e}/kT_{\text{eff}} \approx 0.5$ -20. The equivalent widths of the features can reach 100-200 eV; they grow with increasing b_{eff} and are lower for higher harmonics. © 2010. The American Astronomical Society. All rights reserved.

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Keywords

Radiative transfer, Stars: magnetic field, Stars: neutron