High-Field Magnets in the Universe: Prediction of the Crab Pulsar’s Emission Over 16 Orders of Magnitude in Frequency

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Summary

Very soon after the discovery of pulsars, it was realized that the very stable periodicity of the mean profiles of their pulses could only result from a source that rotates, and which therefore possesses a rigidly rotating radiation distribution. We have shown that this source rotation is not only responsible for the periodicity of the pulses, but also determines the detailed frequency dependence of the emitted radiation [1]. By inferring the values of just two adjustable parameters from observational data (values that are consistent with those of plasma frequency and electron cyclotron frequency in a conventional pulsar magnetosphere), and by mildly restricting certain local properties of the source, we are able to account quantitatively for the emission spectrum of the Crab pulsar over 16 orders of magnitude of frequency (see Figure 1) [1].

Fig 1. The predicted spectral distribution for a rotating superluminal source (red curves) compared with observational data (where available) of the spectrum of the Crab pulsar. In the model, the recovery of intensity at the ultraviolet peak is probably caused by resonant enhancement due to cyclotron resonance of free electrons in a magnetic field ~100 T.

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The “engine” that drives the emission is the pulsar’s huge magnetic field, which rotates rigidly with it. Unless the plasma atmosphere surrounding the pulsar is restricted to an unrealistically small volume, it is therefore inevitable that the macroscopic distribution of induced electric current in the magnetosphere has a rigidly rotating pattern whose linear speed exceeds the speed of light in vacuum $c$ for $r > c/\omega$, where $\omega$ is the pulsar’s angular velocity and $r$ is the radial distance from the axis of rotation. Although Special Relativity does not allow a charged particle with a non-zero inertial mass to move faster than $c$, there is no such restriction on a polarization current. Using a model of a superluminal, rotating polarization currents, we are able to predict all of the observed features of the Crab’s spectrum [1].

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References