BOOK REVIEWS

Pulsar Processes

Physics of the Pulsar Magnetosphere. V. S. BESKIN, A. V. GUREVICH, and YA. N. ISTOMIN. Cambridge University Press, New York, 1993. xxiv, 408 pp., illus. $125 or £75. Translated from the Russian by M. V. Tsaplina.

Within a few months of their discovery in 1967, pulsars had been identified as rotating, strongly magnetized neutron stars. Within a few years, the essential ingredients in our current understanding of the electrodynamics of the pulsar magnetosphere had been identified. The magnetosphere is the region around the pulsar where the dynamics of particles are dominated by the magnetic field of the star. Initially it was thought that this region could be treated as a vacuum. However, this leads to a contradiction: The combination of strong magnetic field ($\gtrsim 10^8$ T) and rapid rotation (period $\lesssim 1$ s) implies a component of electric field parallel to the magnetic field; this electric field rips particles from the surface of the star and accelerates them to very high energies (10^{13} to 10^{15} eV); such primary particles produce gamma rays, which decay into secondary electron-positron pairs; the magnetosphere is thereby populated by a plasma consisting of relativistic pairs. This plasma tends to screen out the parallel electric field, quenching the pair-generation process. The presence of the plasma also tends to cause a perpendicular electric field to be set up such that the magnetosphere corotates with the angular velocity of the star. This corotation electric field has a nonzero divergence, implying a net charge density, referred to as the Goldreich-Julian density.

The essential problem of the pulsar magnetosphere is to formulate a self-consistent model that takes into account the generation of the relativistic pair plasma and its outflow from the polar caps. The generation of the pair plasma requires regions, called vacuum gaps, where the parallel electric field is unscreened. There are also regions of closed magnetic field lines where the magnetosphere corotates. However, the entire magnetosphere cannot corotate because field lines emanating from the polar caps extend beyond the light cylinder, defined by the distance at which the corotation speed would equal the speed of light. The plasma in the polar caps can escape freely and is thought to drive a pulsar wind consisting of relativistic pairs. A self-consistent model must provide satisfactory answers to numerous questions. Where are the gaps located? The net charge density coupled with the plasma outflow implies a net current flow from the polar cap regions; where does the return current flow? How is the observed radio emission generated? And so on.

In *Physics of the Pulsar Magnetosphere* Beskin, Gurevich, and Istomin present their version of a self-consistent picture of the electrodynamic processes in the pulsar magnetosphere. The book begins with a concise and relatively thorough review of the observational characteristics of pulsars. Along with two extensive tables in an appendix, it constitutes a good summary of pulsar data for the nonexpert. The review will be less useful for the expert, for it is uncritical and parts of it seem out of date. For example, the data on distances are accompanied by little critical discussion of the possible importance of selection effects that can mimic the underlying distributions. Some of the data presented on braking indices are now thought to represent timing noise. Where model-dependent descriptions are introduced—for example, Rankin's classification scheme—alternatives are not discussed critically.

Also reviewed are the physics of neutron stars and the basic electrodynamic processes in the pulsar magnetosphere. Although these discussions are neither as thorough nor as well referenced as the review of observational characteristics, they are interesting and informative and the theories are clearly presented.

The bulk of the book presents, in great mathematical detail, the model that the authors developed in a series of papers in the 1980s. In a description of their theory of processes in a pulsar magnetosphere they concentrate on what they call a "boundary layer" near the light cylinder. This layer, which contains a shock wave, is one of the major distinguishing features of their model. They go on to discuss the generation of electron-positron pairs, which is assumed to occur in a "double layer" near the stellar surface where the parallel electric field is unscreened. They also describe the processes leading to multiplication of pairs, and deduce an "ignition criterion" that needs to be satisfied for pair generation. In a chapter presenting their theory of the generation of the radio emission, which is attributed to a multistage process, they discuss the properties of the wave modes in the magnetosphere using the dielectric permittivity for a relativistic pair plasma in a curved magnetic field. The particles feed energy into waves in one wave mode, and nonlinear processes convert this energy into waves in other modes that can escape to produce the observed emission.

Finally, a detailed comparison is made between these theories and the observational data. In addition to enhancing the appeal of the book for experimentalists, this chapter serves to challenge those who favor alternative theories to suggest their own observational tests.

Have the authors succeeded in formulating a self-consistent model of the pulsar magnetosphere? Theirs is the most comprehensive attempt to date, but several aspects of their theory are controversial. Two features central to the model that concern this reviewer are the shock structure near the light cylinder, which would appear to be intrinsically unstable to perturbations in its location, and the specific dielectric permittivity tensor and the implied feeding of energy into growing waves, which have been criticized on basic grounds. The authors themselves, after some provisos, conclude, "The physical picture of the basic processes in the pulsar magnetosphere seems on the whole to be clear." Others in the field would add considerably more provisos. It is generally believed that a truly self-consistent model of the pulsar magnetosphere has yet to be formulated.

A general weakness of the book is that the authors do not compare and contrast their model with alternative theories. An addendum to the book does refer the reader to some of the other literature and provide brief comments on its significance. However, this will be of only minor assistance to the nonexpert reader who wishes to know which aspects of the model presented are widely accepted theory, which are the authors' preferred interpretation among several alternatives, and which are regarded by others in the field as speculative.

In sum, this book is an important contribution to the literature and will be an essential addition to the libraries of all those active in either observations or modeling of pulsars. Those with only a general interest in astrophysics may enjoy the three introductory chapters, but the rest of the book is likely to be appreciated only by specialists.

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