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INTERPLANETARY TYPE III RADIOBURSTS

K. Papadopoulos

Naval Research Laboratory, Washington, D.C. 20375

Type III solar radiobursts are a form of sporadic solar radioemission originating throughout the solar corona and also in the interplanetary region, to heliocentric distances of 1AU and beyond. They are associated with fluxes of moderately energetic electrons (10-100 keV) which are accelerated either in flares or in active storm regions and which escape along magnetic field lines that penetrate the high corona. The bursts appear to have a frequency corresponding to twice the local plasma frequency ($2\omega_e$) (sometimes, the plasma frequency), their frequency drifts at a rate suggesting a source velocity of $10^{10} \frac{cm}{sec}$. At a fixed frequency the duration ranges from < at the highest frequencies, to more than 1 hr at the lowest frequencies [Smith 1974; Fainberg and Stone 1974].

The observed frequency ranges from a few kHz to several hundred MHz. A vast literature of observational studies over the last thirty years has produced a fairly detailed morphological picture of the radioemission, its scaling and decay properties. However, the interest in the phenomenon has not diminished and challenging theoretical problems have been encountered in constructing convincing models describing its behavior. It is a testimony to the increased sophistication of both the observational tools and of the theoretical computational modeling efforts that the last four years have shed light upon many of the paradoxes connected with type III radiobursts [Smith et al. 1978].

The outstanding experimental result was the first in-situ observation of electrostatic waves at the local plasma frequency ω_e, associated with the radioemission at $2\omega_e$ [Gurnett and Anderson, 1976, 1977]. The importance of these measurements cannot be overestimated, since previous in-situ observations had failed to detect any ω_e electrostatic waves, causing doubt in the hypothesis that the electromagnetic waves at $2\omega_e$ were due to conversion of electrostatic plasma waves [Kellog 1976; Gurnett and Frank 1975]. Perhaps the most important aspect of the observations was that the electrostatic waves were in the form of localized patches of turbulence, with an amplitude consistent with theory [Papadopoulos et al. 1974]. This theory had actually predicted that the electrostatic waves would be localized and had stated that lack of instrumental resolution was the reason that previous attempts had failed to observe such waves [Smith et al., 1976, 1978]. The exact size of these clumps remains a topic of active research.

Another observation of extreme importance was the simultaneous measurement of type III bursts and of the associated electrons near the earth [Lin, 1974; Fitzenreiter et al., 1976]. This measurement revealed an important scaling law connecting the radio intensity I and the electron flux J_E, namely that $I \alpha J_E$ for $J_E < 100\ \mathrm{cm}^{-2}$ and $I \alpha J_E^{2.4}$ for larger fluxes [Fitzenreiter et al., 1976]. Experimental advances have also been made in measuring the directivity, source location and size, energy loss and other characteristics of the type III bursts [Alvarez et al., 1974; Fitzenreiter et al., 1975; Baumback et al., 1976; Fitzenreiter et al., 1977; Alvarez et al., 1975; Kaiser, 1975; Gurnett et al., 1978b; Weber et al., 1977; Caroubalos and Steinberg, 1974; Caroubalos et al., 1974; Kellogg and Lin 1976]. A key feature revealed in the above observations was the predominance of second harmonic emission for the low frequencies. Other important aspects of type III bursts revealed from surveying the observations have been the dependence of the type III intensity and frequency of occurrence upon heliocentric distance [Gurnett et al., 1978a] and the correlation of the burst spectral shape and frequency with properties of the exciting beam [Weber, 1978].

The key advance in the theoretical area has been the introduction of strong turbulence theory to the study of type III solar radio bursts [Papadopoulos et al., 1974]. It should be noted that type III bursts have constituted the first application of strong turbulence theory and collapse to any beam plasma instability problem [Papadopoulos 1974, 1975]. An enormous amount of theoretical work using strong turbulence theory has followed their initial introduction, including numerical modeling of actual measurements, two dimensional theories and computations of electromagnetic $2\omega_e$ emission from localized solitons [Papadopoulos, 1975; Smith, et al., 1975; Bardwell and Goldman, 1976, Rowland, 1977, Rowland and Papadopoulos, 1977; Smith et al., 1978; Nicholson and Smith 1978; Goldstein et al, 1978a, b; Papadopoulos and Freund, 1978; Nicholson et al., 1978, Goldman and Nicholson, 1978]. The results of these calculations have shown good agreement with the data and have explained such riddles as the localized structure of the electrostatic oscillations, the predominance of the second harmonic radiation, the I vs J_E scaling, the constancy of the beam velocity and the decay of the radiation. In parallel to the above there were several efforts using the theory of weak plasma turbulence [Magelssen, 1976; Magelssen and Smith; Smith, 1977; Takakura, 1977; Takakura and Shibayashi, 1976; Smith and Riddle, 1975].

In summary we can say that the work of the past 4 years in the U.S. has produced extremely gratifying results in both the experimental and the theoretical-computational area. Contrary to previous years when it lagged behind the European and Australian efforts, the U.S. has now become the recognized leader. Future investigations should focus on the decay properties of the type III bursts and associated topics such

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as the soliton-like structure and the possible soliton size and collapse properties in the absence of the excitor beam. On the experimental side, increased spatial resolution of in-situ observations can produce more detailed measurements of the localized turbulence and its decay characteristics. Future theoretical studies may use better computational models in 2 and 3 dimensions, including the effects of a magnetic field, kinetic effects and electromagnetic radiation. Such advanced numerical codes may provide a complete understanding of the type III phenomenology as well as help with the development of strong turbulence plasma theory with important applications in the entire field of modern plasma physics.

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THE ELECTRIC FIELD AND GLOBAL ELECTRODYNAMICS OF THE MAGNETOSPHERE

Review and Quadrennial Report to the IUGG

David P. Stern
Planetary Magnetospheres Branch, Goddard Space Flight Center,
Laboratory for Extraterrestrial Physics, Greenbelt, Maryland 20771

> "..We turn to our modern theologians, the physical scientists, for words of comfort. They peer beyond the limits of time and space, wrestle with the inadequacies of language, and at last come forth with the answer: *the mystery is even bigger than we thought*."
>
> Bruce Catton

Introduction and Highlights

When the radiation belt was discovered some 20 years ago, its very existence posed a fundamental problem. The way the geomagentic field managed to trap and to hold particles was readily explained--but what processes energized them in the first place, and how were they brought into their trapped orbits?

As our knowledge about the Earth's environment increased it became evident that similar questions also applied to other plasma populations such as those of the ring current and of the plasma sheet. In most cases, it turned out, both the particles' energization and their transport were provided by a large-scale electric field $\vec{E}$, permeating the magnetosphere. The "main" part of $\vec{E}$, oriented roughly from dawn to dusk (near the equatorial plane), is the one responsible for a large-scale sunward plasma flow ("convection") found throughout most of the magnetosphere. In addition, the various sources of $\vec{E}$ accelerate charged particles in several distinct ways, maintain a global system of electric currents linking the magnetosphere with the ionosphere [Potemra, 1979] and transfer energy from the solar wind to the magnetosphere. For more complete details the reader is referred to a recent review by Stern [1977].

At the time of the previous report to IUGG, several important properties of $\vec{E}$ had been established. Its magnitude and extent had been measured directly by means of double probes aboard near-Earth polar satellites and indirectly by the motion of barium vapor clouds and by about ten other methods [Stern, 1977, sect. 8]. As for its origin, the notion (first proposed by Dungey in 1961) that $\vec{E}$ was conveyed into the magnetosphere along "open" magnetic field lines, connecting the polar ionosphere with the interplanetary magnetic field (IMF), has gained almost complete acceptance. Such an "open magnetosphere" requires a constant process of "magnetic merging" or "reconnection" which continually links interplanetary magnetic field lines, newly arrived in the solar wind, with those of the magnetosphere, and a similar process disconnecting such lines again on the downstream end of the magnetosphere. Simple models for magnetic reconnection had been proposed [see review by Vasyliunas, 1975] but some basic questions--e.g., concerning the rate at which

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