Scientific session of the Division of General Physics and Astronomy, Academy of Sciences of the USSR (27–28 September 1978)

Usp. Fiz. Nauk 127, 533–536 (March 1979)

A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR was held on September 27 and 28 in the conference hall of the P. N. Lebedev Physics Institute. The following papers were delivered:

1. *S. N. Vernov*, The earth's radiation belts (new data).

2. *K. I. Gringauz*, The low-energy magnetospheric plasma: its origin and its role in large-scale magnetospheric processes.

3. *B. A. Tverskoĭ*, The magnetosphere-ionosphere interaction and mechanisms of charged-particle acceleration in near-earth space.

4. *R. Z. Sagdeev*, How well do we understand the magnetosphere today?

5. *V. Yu. Trakhtengerts*, The magnetosphere as an Alfven maser

6. *A. A. Galeev*, The mechanism of magnetospheric substorms. We publish below brief contents of two of the papers.

V. Yu. Trakhtengerts. *The magnetosphere as an Alfven maser.* Studies of recent years have shown that the dynamics of the Earth's radiation belts (RB) is determined in many respects by low-frequency electromagnetic radiation in the range from 10^5 to fractions of a hertz. This emission owes its origin to a maser mechanism that arises in the Earth's radiation belts. It consists essentially of the following. The magnetosphere as an electrodynamic system is an enormous plasma-filled cavity resonator whose shape is controlled by the geometry of the magnetic field. The natural oscillations of this cavity are Alfven waves and whistlers. The amplifying material in the magnetosphere is composed of energetic RB electrons and protons, whose source is the various accelerating mechanisms that operate in the Earth's magnetosphere. Over population of levels in the Alfven maser (AM) is brought about by the presence of a loss cone formed when particles with high longitudinal (along the magnetic field) velocities reach the dence layers of the atmosphere and are absorbed there. This gives rise to transverse anisotropy, which in turn, causes cyclotron instability (CI) of the RB. As CI develops, Alfven waves (in the case of RB protons) and whistlers (in the case of the electron component) are generated and cause pitch-angle diffusion of the RB particles and preciptation of these particles into dense layers of the atmosphere. Alfven waves have a remarkable property in that they are rigidly "tied" to the lines of force on which the source is situated. As a result, the cyclotron waves may be multiply amplified in the RB with reflection from the ends of the geomagnetic trap. Whistlers have the same property, though to a lesser degree. Another essential fact is that if CI arises at the center of an RB, it also obtains over the entire length of the trap. All this makes CI rather universal and often the most dangerous instability under space conditions.

Even this cursory description of the magnetosphere brings out its close resemblance to maser systems. According to recent studies,[1] this similarity also has a profound physical basis. A wide variety of regimes have been detected in the dynamics of CI: stationary, periodic, stochastic, and peaking, i.e., practically all the regimes characteristic of lasers.

The foundations for understanding the operation of an AM were laid already in 1960–1961 in the first papers on the linear and quasilinear theory of the CI of an anisotropic collisionless plasma.[2,3] For application to the RB, it was found necessary to supplement the quasilinear CI equations with a number of essential factors, including allowance for the effects of the cold plasma component and magnetic-field nouniformity, and to introduce particle and wave sources and sinks.[4-9]

The theory of cyclotron instability of the Earth's radiation belts (RBCI) has now been reliably confirmed by experiment and is generally accepted.

Analysis of RBCI under the action of a strong external particle source brought out an interesting effect in which particles are "locked" in the magnetic trap by their own turbulence.[10] When the characteristic pitch-angle diffusion time of the particles in cyclotron waves become smaller than the time of oscillation of the particles between magnetic mirrors, a kind of anomalous viscosity arose in the hot plasma and retarded its escape through the magnetic mirrors. In the magnetosphere, this effect may prove significant in strongly turbulent regions at the boundary with the solar wind and during the explosive of a magnetic substorm.

Active experiments play an important role in better

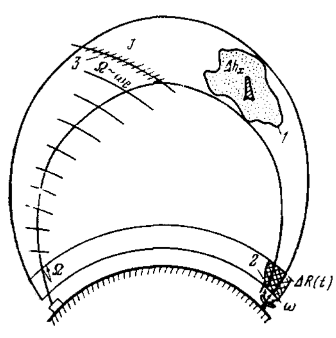

FIG. 1. Active experiments: variation of n_{xL} (1), modulation of R by periodic heating of the ionosphere (2), and cyclotron heating of the RB (3).

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understanding of the RB processes (some of them are represented in Fig. 1). The first experiment, which was proposed by Brice in 1970,[9] was based on the dependence of CI on cold-plasma density. By releasing cold plasma into the magnetosphere from an artificial satellite, it is possible to initiate CI beyond the limits of the plasmosphere, where instability is not generally excited under natural conditions. Q-switching of the Alfven cavity by periodic heating of the ionosphere is the content of the second experiment. Here we may expect the excitation of periodic CI regimes. The third experiment is based on cyclotron heating of RB electrons with ULW transmitters, an effect that can be regarded as an artificial particle source in the RB. The various regimes of this heating open the way to the most comprehensive study of Alfven-maser dynamics.

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