43. COMMISSION DE LA MAGNETO-HYDRODYNAMIQUE ET DE LA PHYSIQUE DES GAZ IONISES

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The 1961 Report was made very comprehensive because it was the first one after Commission 43 was constituted. The present report concentrates on the progress that has been made since then in the major fields of research covered by the Commission.

The report is divided into three parts:

1. Solar and Stellar Magnetic Fields
2. Interstellar and Interplanetary Magnetic Fields and Plasmas
3. Origin and Propagation of Cosmic Rays

The subject of Solar and Stellar Magnetic Fields was covered by an IAU Symposium (**1**) in the autumn of 1963, the Proceedings of which will be available in print. It has been found adequate to let Part 1 of the Report consist simply of a reference to those Proceedings.

Part 2 is written by L. Davis and Part 3 by S. B. Pikelner.

It is a pleasure for me to express my great appreciation of the contributions of Dr Davis and Dr Pikelner. My best thanks are also due to Dr C-G. Fälthammar for kind help.

H. ALFVÉN
President of the Commission

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INTERPLANETARY AND INTERSTELLAR MAGNETIC FIELDS AND PLASMAS

(prepared by L. Davis, Jr.)

Interplanetary Fields and Plasmas

The probable existence and plausible properties of the interplanetary plasma and magnetic fields may be deduced indirectly from many observations such as, for example, those of geomagnetic fluctuations, comet tails, comic ray modulations, zodiacal light, scattered solar Lyman-α radiation, etc. Much may also be done by extrapolating outward from conditions observed in the solar corona and photosphere, Parker's (**1**) model being the most successful. Within the last few years, direct observations from space craft have provided much more direct and certain information although only a small part of the solar cycle has been covered and some of the analysis of observations is still incomplete.

The exploratory observations made by the earlier probes, (**2, 3**) and those reported at the 11th General Assembly, were generally confirmed, but were greatly extended and made more

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precise by the observations received from Mariner II between 1962 August 29, and 1963 January 3. During this entire period, plasma flowed (4) outward (apparently very nearly radially) from the Sun with velocities that were almost always between 350 and 750 km/sec, with densities of a few per cm^3 (perhaps ranging from less than 1 to as much as 30), and with temperatures (or equivalent velocity dispersion due to high frequency waves) of the order of 2×10^5 °K. The plasma velocity showed a series of peaks, each lasting from two to four or five days, which had a strong tendency to recur at approximately 27-day intervals (5). A magnetic field of the general order of 5 gamma in quiet times and 20 gamma or more in disturbed periods was observed (6). Averaged over long periods, the field showed a tendency to lie nearly in the plane of the ecliptic, perhaps forming roughly the expected spiral, but with many fairly large, short term fluctuations (7). Observations made from space craft just outside the geomagnetic field (8, 9) are very difficult to compare with observations at a great distance because the behavior of the solar wind is affected to a considerable distance from the magneto-pause.

A number of recent conferences have dealt both with the observations on interplanetary fields and plasmas and with the relevant magneto-hydrodynamic theory. Their proceedings (10-12) give further information and references.

Interstellar Fields and Plasmas

Information on the line of sight component of the galactic magnetic field can be obtained by radio astronomical observations of the Zeeman splitting of the hydrogen line and by the Faraday rotation of polarized radiation. No clear picture of the structure of the galactic field has yet emerged from this work, but the rapid development of instrumentation gives much promise in the immediate future. The field strengths given by these methods (13-15) are usually low, of the order of 2 to 5×10^{-6} gauss. A variety of other arguments, reviewed by Wentzel (16), give field strengths that range up to 3×10^{-5} gauss. For a review of the conclusions to be derived from the polarization of starlight, see Hall and Serkowski (17). Symposia at Princeton (18) in 1961 and in Australia (19) in 1963 dealt with the Galaxy and its interstellar fields and plasma.

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ORIGIN AND PROPAGATION OF COSMIC RAYS

(Prepared by S. B. Pikelner)

Three concepts of the origin of cosmic rays have been developed during these years—the metagalactic, the galactic, and the local generation.

(1) According to the metagalactic concept, cosmic rays come into the Galaxy from metagalactic space, in which they are distributed uniformly with a density similar to the density near the Earth (**2**). There are here difficulties with energy (**1**) and also other difficulties (**3**). Now some modifications of this hypothesis have been developed, which connect the cosmic rays with the local group of galaxies (**4**) and with the local supergalaxy (**5**). In both cases, the systems are considered as ideal traps completely confining the cosmic rays.

In (**4**), it is suggested that cosmic rays conserve the adiabatic invariant during the whole life of the system. In that case the density of the particles changes as $\sqrt{B}$. The chemical composition of cosmic rays puts definite restrictions to the density of gas in the system.

Critical discussion of the fundamental assumptions of these papers is given in (**1**). Besides there are difficulties with respect to energy. The idea that cosmic rays are kept rigorously in the systems is interesting in connection with magnetic configuration and magneto-hydrodynamics in general. The question arises if the trap might be closed when galaxies, gas and a system as a whole move. Moreover, the constancy of the adiabatic invariant causes a strong anisotropy of cosmic-ray pressure in the regions of weak magnetic field. This anisotropy may lead to instability.

The balance of kinetic, magnetic and cosmic-ray energy is interesting from the magneto-hydrodynamic point of view. Usually it is accepted that these three kinds of energy are equal. If this applies to the metagalactic medium, and if $\rho \cong 10^{-29}$ g/cm^3, $V \cong 1$ to $5\ 10^7$ cm/sec, then the density of cosmic-ray energy is about 10^{-14} erg/cm^3 (**1**). This is considerably less than that in our Galaxy. The possibility of considerable deviations from the equipartition is not clear yet.

An electron component of cosmic rays and cosmic γ and X-rays attract great attention now.

Besides radioastronomical data, direct measurement (**6, 7**) proved the presence of 1 to 3% electrons in cosmic rays. Calculations show (**8**) that electrons which appear in the encounters of cosmic rays with nuclei of atoms of interstellar gas and in the following desintegration of $\pi\pm$ mesons are not enough to explain the observation. Consequently electrons should be original and in the frame of metagalactic theory they should be present in the Metagalaxy with the same density. In this case the radio emission of the Metagalaxy should be much stronger than the observed upper limit of it.

Encounters of relativistic electrons with photons of stellar light should create γ-quanta in metagalactic space (**9**). As calculations show (**8**), this process is principal. To explain the observed upper limit of intensity of γ rays (**10**), it is necessary that the density of relativistic electrons be less than 3% of their galactic density.

(2) According to the concept of galactic origin the cosmic rays are associated with processes

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taking place inside galaxies, including ours. Cosmic rays come into metagalactic space from galaxies. The density of cosmic rays in the Metagalaxy should be three orders of magnitude less than that in the galaxy.

Supernovae explosions are considered as the origin of cosmic rays in galaxies. They inject cosmic rays into the Galaxy in a quasi-stationary way. The observed frequency of supernovae explosions is enough to maintain the density of cosmic rays taking into account their diffusion out of the Galaxy. This hypothesis is developed now more completely than others (see (**1**) and a bibliography there). This allows co-ordination of all data of observations except in the very high energy region. The origin of the highest-energy particles should be connected with other more extended sources of radiogalaxy type.

In opposition to such a stationary model there was suggested recently a non-stationary model supposing that enormous explosions took place in the nuclear regions of galaxies (**11**). In our Galaxy such explosion might have taken place $5 \cdot 10^7$ years, or more, ago. The origin of the galactic halo is connected with this explosion (**12**). Similar explosions are really observed in other galaxies (M82 and especially some distant radiogalaxies). In our Galaxy we may observe several indirect results of such explosions, for instance, a movement of inner spiral arm ($R = 3$ kpc).

It can be shown (**8**) that such explosions hardly can give cosmic rays with the observed concentration, as the energy of cosmic rays decreases when the gas expands. However, such explosions can be important for the theory of origin of cosmic rays as they change considerably the conditions of diffusion of particles and the model gets non-stationary.

Concerning the question about the diffusion of cosmic rays in galactic magnetic fields it is important to clear up if particles move strictly along magnetic lines conserving the adiabatic invariant or if there are some processes facilitating the guiding of cosmic rays inside the Galaxy. The second possibility seems more realistic both according to the observational data (isotropy of cosmic rays) and according to some theoretical suggestions connected with the inverse influence of relativistic gas upon the magnetic field. This influence is connected with the possible instability when the distribution is non-uniform and velocities are not isotropic (**1**). This very important and interesting question requires more complete theoretical analysis.

(3) Local generation. Varying magnetic fields in space are likely to produce acceleration of particles under very general conditions. Besides the acceleration due to variations in metagalactic fields and galactic fields we should also consider variations in fields in our close environment as possible sources of cosmic rays. We know that the interplanetary magnetic field is varying, and we may infer that the ejection of plasma beams into interstellar space around us is likely to drive acceleration mechanisms also in the local environment of the solar system. A local generation of cosmic radiation would be an analogy to the generation of the van Allen radiation close to the Earth (**13**, **14**).

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