ELECTROMAGNETIC EFFECTS AND THE STRUCTURE OF THE SATURNIAN RINGS.
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The most important result of the Voyager encounter with Saturn is probably that the importance of electromagnetic forces for the structure of the solar system has been demonstrated in a way which should convince everybody that it is impossible to neglect plasma effects (see Alfvén and Arrhenius, 1975, 1976). Recent in situ plasma measurements in the magnetospheres and heliosphere have given us a much better understanding of cosmic plasmas, which makes it possible to discuss cosmogonic phenomena with much more confidence (see Alfvén, 1981).

The present state of cosmogony was recently reviewed at the Cospar meeting in Budapest (July, 1980). The conclusions were the following:

1. Properties of interstellar clouds. Electromagnetic forces were of decisive importance. The clouds may have been formed out of diffuse interstellar matter by electromagnetic attraction ("pinch effect"). Their evolution is treated by the theory of highly inhomogeneous dusty plasma, penetrated by a network of electric currents. Contrast-enhanced pictures of interstellar clouds support this scenario.

2. Chemical differentiation. From observations of particle ejection from the sun, we know that in plasmas of comparable densities a chemical differentiation takes place, resulting in regions with He or the CNO elements or the heavy elements dominating (or strongly enhanced). Similar processes should take place in interstellar clouds and give similar results. This is basic for our understanding of chemical differences between the celestial bodies in the solar system.

3. Band structure and the critical velocity. Next phase in the evolution is the falling in of chemically differentiated gas clouds and dust towards the primeval sun. (This process is later reproduced on a smaller scale around the giant planets.) This leads to the accumulation of matter in certain bands, which explains the band structure of the solar system. Laboratory experiments and the theory of the critical velocity are now giving increased understanding of this process.

4. Discovery of the rings of Uranus and Jupiter. These fall within the bands where matter should be accumulated, thus confirming the importance of the band structure. The Uranus ring was explicitly predicted.

5. All the satellites discovered after the publication of the band structure fall within the bands.

6. Transfer of angular momentum. In situ measurements of the auroral current system and the Io-Jupiter circuit make it possible to base the theory of transfer of angular momentum on present-day phenomena, which can be extrapolated to cosmogonic conditions. The two-third fall down law at the condensation is supported.

The electromagnetic effects on the Saturnian rings are of two different kinds:

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A. Forces acting today. These forces produce structures which change with a time constant of hours or days (the spoke structure, and probably also the braided structure of the F-ring). According to Hill and Mendis (1980), they are due to a combination of three phenomena, each of which has been studied extensively in other connections:

1. The electrostatic levitation of micron-sized grains from the surfaces of larger bodies, in the rings.

2. The generation of a radial electric current due to the difference in angular velocity between the Saturnian ionosphere and the rings.

3. A spoke formation in a radial electric current in the presence of an axial magnetic field of the same kind as has been observed extensively in homopolar experiments.

4. Magneto-gravitational orbits of charged micron-sized grains in the Saturnian magnetosphere.

B. Cosmogonic effects. The more permanent ring structure can probably be explained as produced by three effects:

1. Satellite resonances. These give gaps analogous to the Kirkwood gaps in the asteroid belt. They also stabilize the ring by preventing radial diffusion.

2. Negative diffusion. As shown by Baxter and Thompson (1971, 1973), the mass diffusion is expected to be negative. This is probably what produces the large number of ringlets analogous to the jet streams which probably are an intermediate state in the formation of planets-satellites.

3. The bulk distribution of matter can be accounted for by condensation from a free-wheeling (partially corotating) plasma at cosmogonic times. The fall-down ratio 2/3 which is essential for the understanding of the asteroid distribution gives also the key to the bulk density structure of the Saturnian rings.

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