

Planetary rings as relics of plasma proto-rings rotating in the magnetic field of a central body

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A possibility is discussed in accordance to hypothesis by H. Alfvén, that the rings of large planets are relics of some plasma proto-rings rotating in the magnetic fields of central bodies. A finite-dimensional mathematical model of the system is synthesized using the solution of the boundary-value problem by the Boubnov – Galerkin method.

The dipole magnetic field of the central body is assumed to have a small eccentricity, and the dipole axis - to be inclined at a small angle to the central body's axis of rotation which coincides with the ring's rotation axis. The proto-ring is supposed to be thin and narrow and having the same rotating axis as the central body. A medium forming the ring is cold rarefied plasma with high electron density, so that electric conductivity of the medium tends to infinity, as well as the magnetic Reynolds number. The original mathematical model is reduced to a system of finite-difference equations whose asymptotic analytical solution is obtained. Emphasis is placed on the problems of stability of the ring's steady state rotation and quantization of the eigenvalues of nondimensional sector velocity of the ring with respect to the central body. The solutions corresponding to magneto-gravitational and to magneto-gyroscopic waves are considered

It is demonstrated that some «elite» rings characterized by integral quantum numbers are stable and long-living, while the rings which are associated with half-integer quantum numbers («anti-rings») are unstable and short-living. As a result, an evolutionarily ripe rotating plasma ring turns out to be stratified into a large number of narrow elite rings separated by gaps whose position correspond to anti-rings. The regions of possible existence of elite rings in near-central body space are determined. The main result

of eigenvalue spectrum's analysis is as follows. *Quantum numbers determining elite eigenvalues of the sector velocity of a ring (normalized in a certain manner) coincide with the quantum numbers appearing in the solution of the Schrödinger equation for a hydrogen atom. Perturbations of the elite orbits corresponding to these numbers satisfy the de Broglie quantum-mechanical condition.*

The solution of the model boundary-value problem has been applied to planetary rings origin and evolution. The main result is a mechanism of stratification of the evolutionally mature plasma proto-ring into a large number of narrow elite rings separated by anti-rings (gaps), which were playing a role of «ancestors» for present-day planetary rings. Another result is the theoretical substantiation of the presence in the near-planetary space of a region of existence and stability of plasma rings. The data, which had been obtained in the course of the *Voyager*, *Galileo*, and *Cassini* missions were used for verification of theoretical results concerning the planetary rings and Io plasma torus. The theoretical dates turned out to be in accordance with experimental dates.

References

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