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Condensation of gas-dust particles in the dust shells of protostars and the formation of "embryos" of planets

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Abstract

The paper analyzes the basic ideas of migration of primary solids in passive and active protoplanetary disks. Comparing the "hybrid" migration models [2] with the Safronov model, it is noted that the hypothesis of fast migration of "embryos" contradicts the basic laws of celestial mechanics and Laplace's stability theorem. Using the model of wave perturbations of dust shells of protostars and the model of orbital resonance, a general model for the formation of "embryos" of planets has been constructed. The appearance of a single "embryo" in protoplanetary rings is explained by the effect of the 1/1 orbital resonance mechanism.

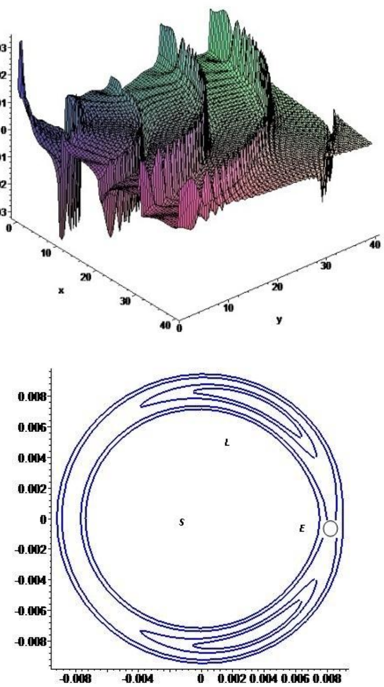
1. Introduction

According to the results of studies, the migration and growth of "embryos" of planets in passive discs can occur through the internal and external trajectories of the Lindblad resonance, as well as through the librational trajectories of orbital resonance. It is also shown that in the centers of turbulent motion of particles in active disks, initial formation and growth of the "embryos" of the planets is possible. At the same time, questions remain to "hybrid" hypotheses [2], in which a rapid migration of the "embryos" of planets from the giant planet zone to the zone of planets of the terrestrial group is expected. Such migration is contrary to the basic laws of celestial mechanics and the Laplace stability theorem. In this paper, the main arguments of "hybrid" hypotheses are analyzed and the mechanism of equilibrium of the dust shells of the protostar is considered, with the help of which an attempt is made to explain the formation and growth of "embryos" of planets without the condition of their rapid migration. Using the model of wave perturbations of the dust shells of protostars and the orbital resonance model [1], a general model for the formation of "embryos" of planets has been constructed, starting with the primary condensation of gas-dust particles in dust shells, before the formation and growth of "embryos" of planets on the equatorial plane of protostars.

2. Growth of sizes and masses of small particles

Causes that can interfere with gravitational instability can be enclosed in the general mechanism of star formation, part of which is the formation of a protoplanetary disk. Connection with gravitational compression of protostars, it is possible to change the regime of unstable equilibrium of the dust shells to a stable equilibrium. The stable equilibrium of the dust shells is established when the following condition is fulfilled: $4\pi G\rho_0 / c^2 - \lambda_k^2 / R_0^2 + \gamma^2 > 0,$ (1)

where ρ_0 is the average density of the protostar of radius R_0, $\gamma = [1/(z_1 - z_0)] \cdot ln\, (\rho(z_0)/\rho(z_1)\}$, z_0, z_1 is the initial and final radius of the protostar, λ_k are the zeros of the Bessel function $J_0(r)$, G is the gravitational constant, and c is the speed of sound for the dust shells. Fig. 1a is shown the form of the density waves corresponding to the stable equilibrium condition (1). Periodic displacements of the maxima could redistribute dust particles even in the dust shells so that the settling solid particles formed dense protoplanetary rings located at a distance d ($d = 2R_0$, $R_0 = 5$ AU, Fig. 1a) from each other. According to model of wave fragmentation, protoplanetary rings of planets more distant from the center of the protostar will be formed first, and then those that are located closer to the center. It follows there is no need to explain the reasons for the migration of "embryos" of planets from the zone of giant planets into the zone of planets of the terrestrial group. The influx of dense particles for the rapid growth of the "embryos" of the planets will be provided by the wave mechanism, the rapid settling of the solid particles of the dust shells on the equatorial plane, and the wave fragmentation of the dust shells, including in the equatorial plane where the protoplanetary disk is formed.



a) b)

Figure 1: (a) 3-*D* density profiles $\rho_1(r, \varphi, t)$ for $t = 0$. (b) Libration orbits of small celestial bodies near the orbital resonance 1/1 for resonance parameters $\alpha^2 = 0.6; 0.8; 1.7; 2.2$ and inclination of the orbits $i = 25°$, $r^* = r - 0.817$ (projections onto the plane of Jupiter's orbit).

Unlike the Safronov model [3], the accretion of small bodies into the "embryos" of planets occurs through the librational orbits of the 1/1 resonance. In such a model, the "embryos" will be formed [1] on one of the vertices of an equilateral triangle *SLE*, where *S* is the center of the protostar, *L* is one of the two triangular points of Lagrange L_4 and L_5, and *E* is the "embryo" (Fig 1b). In accordance with the barometric formula [3], in the absence of turbulence, solid particles will settle in a short time to the equatorial plane, forming a layer of increased density in it. At critical values of disk density, bodies of kilometer sizes will arise [3]. Modern ideas about the gravitational contraction of protostars are based on the model of Shakura and Syunyaev [4]. In the model of Shakura and Syunyaev, only the scenario of gravitational compression of protostars is considered and the possibility of temporary equilibrium is not considered. However, considering the complexity of the trajectories of entering the Main sequence of stars comparable in mass to the mass of the Sun, this possibility should be considered.

3. Wave model of fragmentation of dust shells

The gravitational instability of the protoplanetary disk in the zone of formation of the Earth group planets could have come due to the inflow of settling dense particles that originate in the fragmentation of the dust envelopes of young stars. In view of the fact that the model of wave fragmentation essentially and fundamentally differs from the migration growth model of the "embryos" of the terrestrial planets [2], we list all the main stages of the formation of "embryos" of planets in the wave model: 1) A gas dust cloud whose mass is equal to the mass of the Sun *Ms* will be gravitationally unstable if it has a radius of 2×10^6 *Rs*, an average density $\rho_0 = 10^{-19}$ g/cm^3, the temperature $T = 15K$ and will be compressed. 2) According to the model of wave fragmentation, under the conditions of stable equilibrium (1), the mechanism of density waves, which will form solid particles, will act in the dust shells. As they form, these particles will settle on the equatorial plane. As a result of the action of density waves, the zones of the dust envelope removed at a distance of $2R_0$ will be stripped. The same distances will be between protoplanetary rings formed as a result of the settling of solid particles. 3) In accordance with the model considered here, the protoplanetary rings of Pluto, Neptune, Uranus and Saturn began to form substantially earlier than the rings of other planets. The Neptune ring was formed at the beginning of the Hayashi stage (4.5836 billion years ago). After this, after 2.0186 million years and 2.3857 million years, the rings of Uranus and Pluto began to form.

4. Summary and Conclusions

According to the wave model of the fragmentation of the dust shells of protostars, the essential difference in the structures of the two groups of planets, giant planets and terrestrial planets can be explained by the fact that these groups of planets formed at different stages of protostar compression. These stages corresponded to essentially different parameters ($d = 2R_0$) of the wave mechanism, which acted in the dust envelope of the protostar.

References

[1] Abdulmyanov T.R. //Moscow Univ. Phys. Bull. 2014, **69**, 558.

[2] Nayakshin S. //Mon. Not. R. Astron. Soc. 2014, **441**, 1380.

[3] Safronov, V. S.: Evolution of the proto-planetary cloud and formation of the Earth and other planets, NASA TTF-677, 1972.

[4] Shakura N.I., Sunyaev R.A. // A&A, 1973, **24**, 337.