FORMATION AND GROWTH OF BODIES IN THE EARLY SOLAR SYSTEM: FROM TURBULENCE MOTION TO REVOLVING MOTION OF THE PARTICLES AND SMALL BODIES. T. R. Abdulmyanov, Kazan State Power Engineering University, Kazan, Russia (abdulmyanov.tagir@yandex.ru).

Introduction: Dynamic structure of the ring of asteroids was well studied in the past a few decades and can give a good overview of the evolution of the orbits of small bodies of the Solar System. At present day the asteroid belt is a nearest laboratory for the simulation of the formation of the Solar System bodies in the early stages of its evolution. Classification of asteroids in their chemical composition shows that in the central part of the asteroid belt (about 2.7 AU) located mainly asteroids class M, metallic asteroids. In the outer part of the belt (about 3.2 AU) carbonaceous asteroids are located. In the inner part of the belt (about 2.5 AU) - silicate asteroids [3]. According to this classification, the asteroid belt has a special distribution of bodies. According to the distribution of bodies the denser bodies are located in the central part of the ring. If the mechanism of formation of the planets was the same, we can assume that this distribution was also same of other proto-planetary rings of the proto-planetary disk. What is a reason for such a special distribution of bodies?

The study of the formation of planetary systems intensified in the last decade due to the discovery of new planetary systems. In 2008 a group of German astronomers from the Max Planck Institute of Astronomy have discovered a planet on the star TW Hydra. TW Hydra refers to a type of T Tauri. At the moment it is important to answer the following two questions. Firstly, what is the way in which the first dense bodies formed? Secondly, what is the reason for which in the asteroid belt small bodies could not come together and form one large planet? According to a survey [4] the destruction and fragmentation of proto-planetary disks occurs under the disk photoevaporation by the central star. Formation of the first dense bodies could occur in the centers of the turbulent motion of gas and dust particles [4].

Compression of a proto-stellar clouds and the formation of the proto-planetary disk and rings: Compression of a proto-stellar clouds and the formation of the proto-planetary disk is accompanied by the movement of light gases from the central part of the disk to its periphery (Fig. 1). The main forces that support the proto-planetary disk in equilibrium are the force of gravitational attraction $\delta F_g = 4\pi G\rho_0 u$ and gas pressure δF_P, occurs when a change in the density $\rho = \rho_0 + \delta\rho$ on the value of $\delta\rho$, where u - the value of the isothermal displacement of gas and dust particles [5]. Equating these forces, we obtain the condition: $\delta F_P = -4\pi G\rho_0 u$, under which gas and dust particles in the proto-planetary disk will generally be in a state of equilibrium. Gravitational instability would arise in the case if will satisfied the inequality $\delta F_g > -\delta F_P$. In this case, the density of gas and dust particles will increase. If $\delta F_g < -\delta F_P$, gas and dust particles will be scattered.

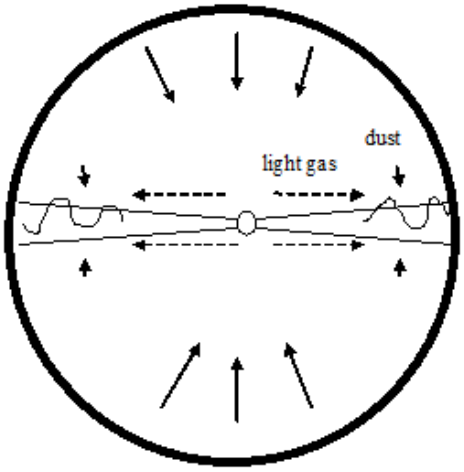

Fig.1: Schematic overview of a stage in the formation of a stars.

The motion of light gases (Fig. 1), at non-zero angles of inclination of the surface of the proto-planetary disk, will generate wave disturbances in the motions of gas and dust particles: the gas and dust particles will move vertically to the plane of the proto-planetary disk whith the acceleration $\partial^2 u/\partial^2 t$. Therefore, the dynamics of the process of change u will be considered using the wave equation. The equation of the particles motion in the polar coordinate system will has the following form:

$$\frac{\partial^2 u}{\partial t^2} = c_s^2\left(\frac{\partial^2 u}{\partial r^2} + \frac{1}{r}\frac{\partial u}{\partial r} + \frac{1}{r^2}\frac{\partial^2 u}{\partial \varphi^2}\right) + 4\pi G\rho_0 u. \quad (1)$$

The solution $u(r, \varphi, t)$ of equation (1) can be given by the following double series:

$$u(r,\varphi,t) = \sum_{\nu=0}^{\infty}\Phi_\nu(\varphi)\sum_{k=0}^{\infty}T_{k\nu}(t)R_{k\nu}(r),$$

where $\Phi_\nu(\varphi) = \cos(\nu\varphi + \varphi_0)$, $R_{k\nu}(r) = J_\nu(\lambda_{k\nu} r/R_0)$, J_ν - Bessel function of ν, $\lambda_{k\nu}$ - the zeros of the Bessel function J_ν; R_0 - constant (the radius of the proto-planetary disk), φ_0 - an arbitrary constant.

Circular waves action: Circular waves can occur as a consequence of active star formation processes in the early stages of the proto-planetary disk. According to solution $u(r, \varphi, t)$ of equation (1) the circular waves will librate around some centers of libration (Fig. 2). As a result of this wave motions the denser particles will concentrate near the libration centers. the central part of the ring (Fig. 2). It follows that the waves action in the early stages of the evolution of protoplanetary rings could be a reason for a special distribution of asteroids.

Circular waves are observed only in supernova stars. However, we can see such waves around other stars**.** In 2008, a group of German astronomers from the Max Planck Institute of Astronomy have discovered a planet on the star TW Hydra. By weight is a little more of our Jupiter. In 2013 at the 80 AU from the parent star was discovered planet-forming mass from 6 to 28 Earth masses (Hubble Space Telescope). These observations indicate that the formation of the planets preceded the fragmentation of the proto-planetary disk to proto-planetary rings. Wave fragmentation of the proto-planetary disk of the solar system, in the early stages of its formation, is confirmed also in the regular arrangement of the orbits of the major planets of the Solar System. Nearest proto-planetary rings at a late stage in the evolution are the main asteroids belt and the Kuiper belt. Studies of the dynamics of asteroids of the main ring and the Kuiper belt can play a key role in solving the problem of formation of planetary systems.

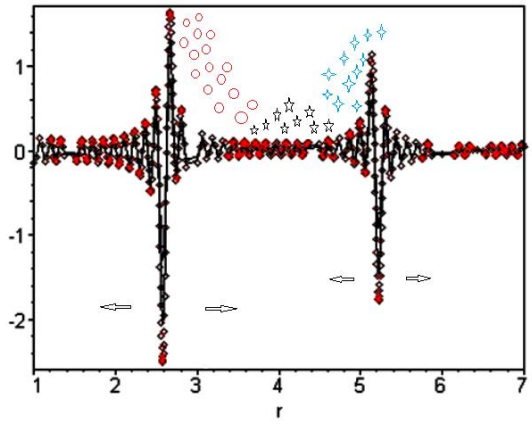

Fig.2: The form waves $u(r, \varphi, t)$ for the initial time t = 0 and the angle φ = 0, R_0 = 1.3 AU, ($H = H(1, 0)$ = 0.1081; $H = H(1, 1)$ = 0.0678; $H = H(2, 0)$ = 0.024); where ☆ - are the denser particles which are located in the central part of the ring.

Distribution of gas and dust particles in the Gauss rings and the formation of bodies: The numerical integration of the equations of gas dynamics in [2] shows that the initial formation of small bodies could occur as a result of turbulent motions of gas and dust particles in the initial stages of the evolution of the proto-stellar clouds. The rapid growth of the mass of bodies could be as a result of the secular motions of the particles or as a result of the revolving motion of the particles. Accoring to the theory of secular motion of small bodies, the secular motion will arrised when the density distribution of dust particles will close or equal to the density distribution in the ring of Gaussian:

$$\rho(\theta) = \frac{mr^2}{2\pi ab} / \sqrt{r^2 + \left(\frac{dr}{d\theta}\right)^2}.$$

The secular motion of the particles leads to a rapid growth of bodies and leads to dust accumulation inside the ring Δ having a width $[r_p - r_0, r_a + r_0]$, where $r_p = a(1 - e)$, $r_a = a(1 + e)$, $r_0 = \sqrt[5]{m}$, m - mass of the planet, a, e - semi-major axis and eccentricity the planet's orbit [1]. For the rapid formation of bodies needs a large influx of gas and dust particles from the outer zones of the resonances in the resonance zone. External mechanism to ensure the rapid influx of dust particles in the ring Δ could be a wave mechanism (1) of surface perturbations of the proto-planetary disk. In the denser rings with a sufficiently large influx of gas and dust particles will be formed only planetesimal of planet. Otherwise in the proto-planetary ring are formed some of bodies of small dimensions and mass. As a result, was formed the asteroid belt.

Conclusions: The transition from turbulent motion phase of particles to regular secular motions of the particles, and hence to the stage of rapid growth is only possible with rapid influx of dust in the area of the ring Δ. Such an influx of dust in Δ-ring can provide by non-stationary mechanisms of evolution, for example, the mechanism of wave disturbances of the protoplanetary disk (1).

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