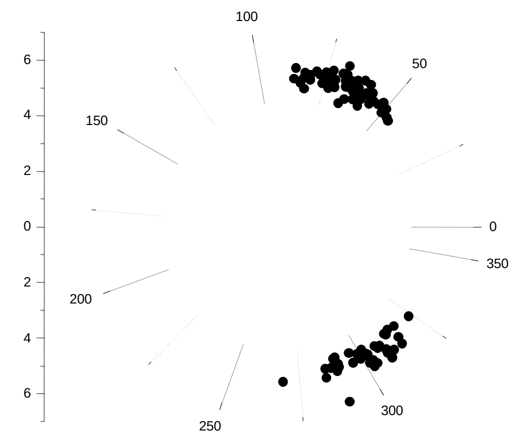
FORMATION AND GROWTH OF THE SOLAR SYSTEM BODIES IN THE EARLY STAGES OF ITS EVOLUTION.

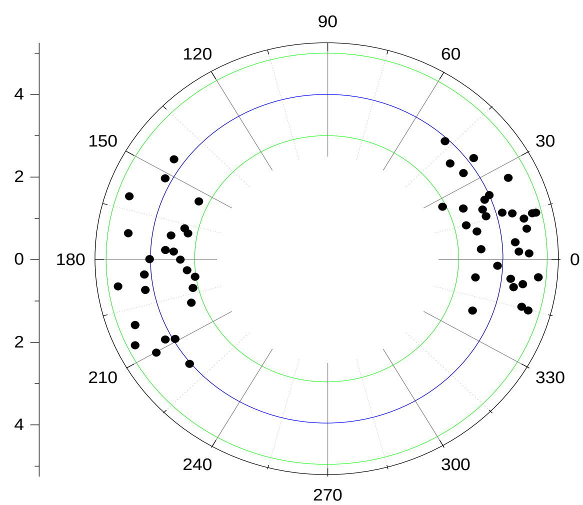
T. R. Abdulmyanov, Kazan State Power Engineering University, Kazan, Russia (abdulmyanov.tagir@yandex.ru).

Introduction: Dynamic structure of the asteroid belt, which is well studied in the past decade, provides a good overview of the evolution of the orbits of small bodies of the solar system and the asteroidal dangerous. On the other hand, the asteroid belt - is a good laboratory for the simulation of the formation of the solar system bodies in the early stages of its evolution. Study of the dynamic structure of the asteroid belt and the classification of the chemical composition of asteroids so far have created a sufficiently reliable basis to attempt to build a more detailed model of the formation of the solar system bodies. The results of these studies show that in the evolution of the asteroid belt could play a significant role catastrophic mutual collisions formed bodies. Mechanism of mutual collisions of bodies could act in other proto-planetary rings. However, this mechanism is likely not the primary mechanism for the formation and growth of the body in the early stages of the evolution of the proto-planetary disk. The mechanism of formation and growth of small bodies $10^2 – 10^5$ cm, in the early stages of the evolution of the solar system, so far not been elucidated [4]. For the simulation of the formation and growth of small bodies in proto-planetary rings, in this paper we use the results of research libration motions of asteroids [6, 1]. It is shown that the libration centers could appear before the formation of large bodies and planetesimals in proto-planetary rings when there was a redistribution of gas and dust particles. The density of gas and dust particles, at a certain stage of evolution of the proto-planetary disk, could be close or equal to the density of the ring of Gauss. Then, the initial formation of bodies, will occur in the centers of libration.

Long-period libration of small bodies in the model of an ideal resonance: The results of modern observations show rapid growth in the number of newly discovered asteroids Trojan group. According to these observations, near the Lagrange points L_4 and L_5, there is a huge number of small bodies and dust particles. From these observations, we can conclude that in stable libration point occurs accumulation of dust particles and small bodies. However, a deeper study of this problem shows that there is no reason to assume that these two groups of asteroids are accumulated in two new minor planets. If the accumulation of dust particles occurs near stable libration points L_4 and L_5, when and for what reason accumulation process stops? In some cases, gravitational perturbations will not contribute to the accumulation and growth of small bodies? Before try to find answers to these questions, consider the libration of small bodies near the mean motions commensurabilities of 1/1 and 3/2.



a)



b)

Fig.1: Distribution of polar coordinates: a) of asteroids of the resonance 1/1 (G, λ'); b) of the Hilda group asteroids (G, $\lambda^* + qg/p$), $\lambda' = \lambda – \lambda_1$, $\lambda^* = \lambda' - q\lambda_1/p$.

Fig. 1 shows the distribution of asteroids of the orbital resonances 1/1 and 3/2. Comparison of the distributions of the Trojan asteroids (Fig. 1a) and asteroids of the Hilda group (Fig. 1b) shows that Trojans form subgroups closer than asteroids of the

Hilda group. The comparison shows that the resonance groups having relatively larger order resonance will be subjected to more scattering and disintegration. Consequently, more favorable conditions for the accumulation of particles is the conditions near resonance 1/1.

Distribution of gas and dust particles in the Gauss rings and the formation of bodies: The results of the study of libration motions of small bodies show that libration centers appear in gravitational systems like the Sun - asteroid - the planet. However, in the early stages of evolution was not planets and planetesimals. Nevertheless, the libration centers could appear before the planets and planetesimals. In order to understand how this is possible, it is necessary to consider the details of the method for determining the long-period librations of asteroids. To determine the secular perturbations of asteroids Gauss [6] applied the method of averaging. Application of this method is equivalent to the mass distribution of the planet along its elliptical orbit (Gauss ring) with some non-uniform distribution. Suppose now that the gas and dust particles of proto-planetary rings, as a result of evolution, have been redistributed so that the density of this ring was equal or close to that of the ring of Gauss:

$$\rho = \frac{dm}{dS} = \frac{mr^2}{4\pi a^4 e\sqrt{1-e^2}},$$

where $r = p/(1\text{-}e\cdot\cos v)$. In the proto-planetary ring with such a distribution will act the mechanism of long-period librations. That is, in the proto-planetary ring will appear libration centers, which will accumulate the dust particles. These centers will occur long before the formation of planetesimals. The rapid influx of a large amount of dust particles in the libration centers could be when the gas and dust particles were the main part of the proto-planetary disk. That is, at the initial stage of formation of the proto-planetary disk. Therefore, the most rapid growth of bodies could occur exactly at the initial stage of the evolution of the proto-planetary disk.

The width of the proto-planetary rings: Together with the formation and growth of bodies in the libration centers will be running out of gas and dust particles from the resonance zone. That is, the growth of bodies, without an influx of new dust particles from outside the resonance zone is limited. The rapid growth of body size to kilometer or more, could not occur without an effective mechanism for providing the necessary flow of gas and dust particles in the resonance zones of the outer zones of the resonances. Such a mechanism could be the mechanism of surface perturbations of the protoplanetary disk [2, 3]. If the ring is presented as material Gauss elliptic curve, the linear density of such a curve should be much larger than the average density of the proto-planetary disk. For this reason, we consider a flat or a cylindrical ring with their respective densities distributions. We define the width of the solar system protoplanetary rings as an interval $[r_p - r_0, r_a + r_0]$, where $r_p = a(1\text{-}e)$, $r_a = a(1\text{+}e)$, $r_0 = m^{1/5}$, m - mass of the planet, a, e - semi-major axis and eccentricity of the orbit of the planet. The average height of the protoplanetary disk is 0.088 AU (for β = 0.026) [7].

Conclusions: In this paper we consider the accumulation of gas and dust particles in the centers of libration. It is shown that 1) the libration centers have existed long before the formation of planetesimals. The emergence of centers of libration is possible immediately after the appearance of irregularities in the distribution of gas and dust particles in protoplanetary rings still in the early stages of the evolution of protoplanetary rings. 2) In the libration centers could be the accumulation of gas and dust formations: the beginning of the formation of dense bodies and the growth of small-sized bodies. Large motion velocity will not prevent their accumulation and growth, as the relative velocity of small bodies and dust particles in the centers of libration are practically zero. 3) The rapid growth of body size to kilometer or more, could not occur without an effective mechanism for providing required for the growth of the inflow of gas and dust particles of bodies in the resonance zones of the outer zones of the resonances. Such a mechanism could be the mechanism of surface perturbations of the proto-planetary disk [2, 3].

References: [1] Abdulmyanov T.R. (2001). Determination of Libration Characteristics of Asteroids near Mean Motion Commensurabilities 1/1, 4/3, 3/2, 2/1, 7/3, 5/2 and 3/1. //*Solar System Research*. – V. 35. № 5. P. 408 – 414. [2] Abdulmyanov T.R. (2013a). Origin of proto-planetary rings in the Solar // *European Planetary Science Congress*. 8 – 13 September. Londod. UK. Abstracts. – V. 8. EPSC2013 – 720.
[3] Abdulmyanov T.R. (2013). Evolution of proto-planetary rings in the Solar system // *European Planetary Science Congress.* 8 – 13 September. London. UK. Abstracts. – V. 8. EPSC2013 – 722.
[4] Armitage P.J. Lecture notes on the formation and early evolution of planetary systems. In: *Astrophysics of Planet Formation*. Cambridge University Press. 2010. 63 p.
[5] Garfinkel B. (1977). Theory of the Trojan asteroids. Part 1.//*Astron. J*. – V. 82, P. 368 – 379.
[6] Gauss K. F. (1866). Werke. Bd. III. P. 333 – 355.
[7] Safronov, V.S. (1986). Evolution of the proto-planetary cloud and formation of the Earth and planets. Moscow: Nauka, 244 p.