A MODEL OF DUST MATTER DISTRIBUTION IN THE SYSTEM OF "A STAR AND A PLANET". N. I. Perov, Cultural and Educational Centre named after Valentina Tereshkova, ul. Chaikovskogo, 3, Yaroslavl, 150000, Russian Federation. E-mail: perov@yarplaneta.ru.

Introduction: Knowledge of dust matter distribution in the planetary systems play an important role for security of space flights, successful searching for hazardous small bodies, solving of exoplanets origin problem [1]. So, models of localization of dust matter in the gravitational systems are of great scientific and practical interest.

Below, we consider the region of stable motion of a particle with negligible small mass m_3 in the frame of the planar circular restricted photo gravitational three body problem [2], [3], [4]. Let us, m_1 and m_2 are mass of main bodies, r_{12} is a distance between these bodies, q_1 is the "solar" constant, R is the radius of the particle, ρ is its density, c is the velocity of light, G is the gravitational constant, r_{SE} is the mean distance between the Earth and the Sun.

We find the positions of the libration points, - distance r_3 in respect of the system center mass, – state the stability of these libration points, based on Lyapunov's method for the first approximation and numerically investigate the region of motion the particle stability, using method of Runge-Kutt integrating, where N is a number of points in the picture. (The regions of stable motion of the particles, in the given model, will be considered as the regions of concentration of dust matter in the system).

Fundamental Equation: In accordance with works [2] and [3] we have the vectorial differential equation (1) of the particle m_3 motion near the point of libration (some analogue of the Lagrangian point libration "L_2") in the uniformly rotating system.

$$d^2\mathbf{R_3}/dt^2+Gm_1(1-\beta)(\mathbf{r}_3-\mathbf{r}_1+\mathbf{R}_3)/(|\mathbf{r}_3-\mathbf{r}_1+\mathbf{R}_3|)^3 + Gm_2(\mathbf{r}_3-\mathbf{r}_2+\mathbf{R}_3)/(|\mathbf{r}_3-\mathbf{r}_2+\mathbf{R}_3|)^3)-2[d\mathbf{R}_3/dt,\quad \mathbf{\Omega}]-\Omega^2(\mathbf{R_3}+\mathbf{r}_3) \qquad (1)$$

Here, $\mathbf{r}_3$ is the radius-vector determined the position of libration point in respect of the center mass of the system (unperturbed motion) and $\mathbf{R}_3$ is a radius - vector determined the position of m_3 in respect of the libration point (perturbed motion). $\mathbf{r}_1$ and $\mathbf{r}_2$ are radii – vectors in respect of the center mass of the system determined the positions of major bodies with mass m_1 and m_2 correspondingly. Ω is the angular velocity of uniformly rotation of major bodies. β is depended upon properties of the spherical particles

$$\beta=\beta_0 b,\ \beta_0=\frac{3r_{SE}^2 q_1}{4G\rho Rcm_1},0\le b<\frac{1}{\beta_0}. \qquad (2)$$

$$\mathbf{r}_1=-m_2/(m_1+m_2)\,\mathbf{r}_{12},\ \mathbf{r}_2=m_1/(m_1+m_2)\,\mathbf{r}_{12}, \qquad (3)$$

$$\Omega=\sqrt{\frac{G(m_1+m_2)}{r_{12}^3}}\ . \qquad (4)$$

Examples: For the numerical experiments we put $R=10^{-4}$m, $\rho=1000$kg/m^3, $c=3\cdot10^8$m/sec, $G=6.672\cdot10^{-11}$ m^3/(sec$^2\cdot$kg), $m_1=2\cdot10^{30}$kg, $m_2=0.001m_1$, $r_{SE}=149.6\cdot10^9$ m, $q_1=1360$Wt/m^2. b varies between the limits from 0 to 175.35. In the process of the equation (1) solving we use the following units: m_1 is the unit of mass, r_{12} is the unit of length, the unit of time t is corresponded for the case G=1. In Fig.1. the dependence $r_3=r_3(b)$ is presented. In Fig.2. the dependence θ=θ(b) is presented, where θ is the angle between vectors $\mathbf{r}_{23}$ and $\mathbf{r}_{13}$ with the vertex placed in the investigated point of libration. Fig.3. and Fig.4 illustrate the stable motion of the particles near the points of libration. Fig.5. and Fig.6. show "unstable" motion of the particles with mass m_3 near the points of libration at finite interval of time. *Note*, if $m_1=1$, then the stable motion (near L_2) is observed for $m_2/m_1< 25/2-3\cdot69^{1/2}/2 = 0.0400642056228877211236$0; if $m_1+m_2=1$, then the stable motion is observed for $m_2/m_1<½-69^{1/2}/18=0.0385208965045513970786$52.

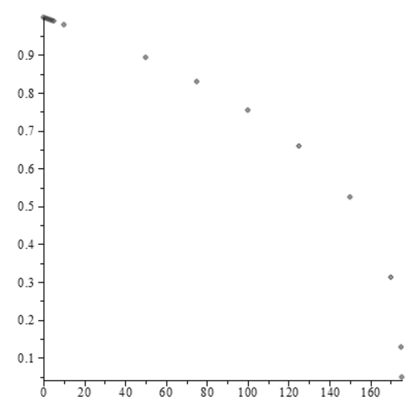

Fig.1. The distance r_3, determined the positions of the points of libration (analogue of L_2), in respect of the center mass of the system (m_1 and m_2), depended on b. Units of length equals r_{12}.

Conclusions: a) In the considered celestial mechanical model in the case of equilibrium the light small-sized particles are placed near the star and heavy large-sized particles are placed near the classical Lagrangian point "L_2" (Fig.1). b) The angle θ varies between the limits from 60 degrees (the Lagrangian point of libration L_2) for b=0 to almost 90 degrees for b tends to 175.370357169036216809331 (Fig.2.). c) For the small values of initial velocities $V_{0x}=V_{0y}$ of the body with mass m_3 this body moves in the restricted region (Fig.3) and (Fig. 4). d) For the large values of initial velocities $V_{0x}=V_{0y}$ of the body with mass m_3 this body may escape the system (Fig.5.) and (Fig.6). In the next work we checked up this results applied them to real clouds of dust matter in the solar (and exosolar) systems.

References: [1] Ipatov S. I. and Mather J. C. (2005) Proc. of the 197th Coll. IAU *Dynamics of Populations of Planetary Systems*, P 399–404. [2] Radzievskii V. V. (2003) *Photogravitational Celestial Mechanics*. Nijniy Novgorod. Eds. Yu.A. Nickolaev, 196 pp. [3] Szebehely V. (1967) *Theory of Orbits. The Restricted Problem of Three Bodies.* Yale University. New Haven Connecticut. Academic Press New York and London. [4] Perov N. I. et. al. (2011) *Theoretical Methods of Localization in the Space–Time of Unknown Celestial Bodies*, Yaroslavl, YSPU, 208 pp.

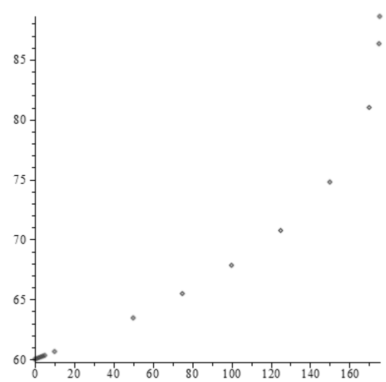

Fig. 2. The angle θ between vectors $\mathbf{r}_{23}$ and $\mathbf{r}_{13}$ (the vertex placed in the point of libration) depended on b.

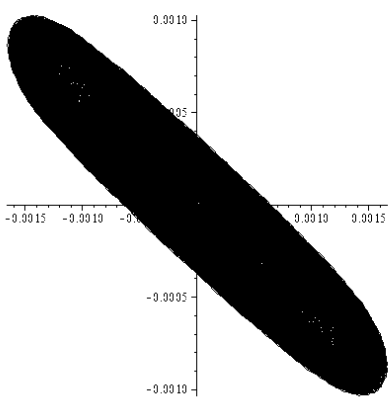

Fig. 3. Region of stable motion of m_3 (b=0, $V_{x0}=V_{y0}$=0.0001, 0<t<10000; N=20000) near the point of libration "L_2"

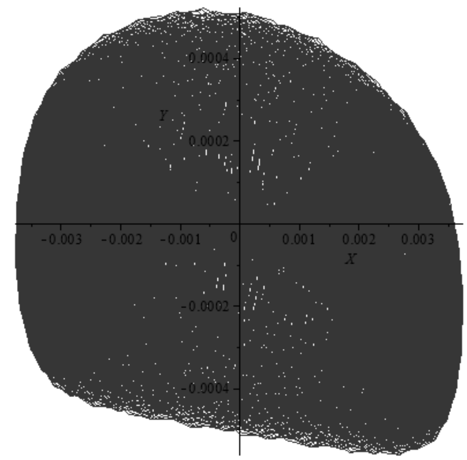

Fig.4. Region of stable motion of m_3 (b=175.35, $V_{x0}=V_{y0}$=0.0001, 0<t<10000; N=25000) near the star.

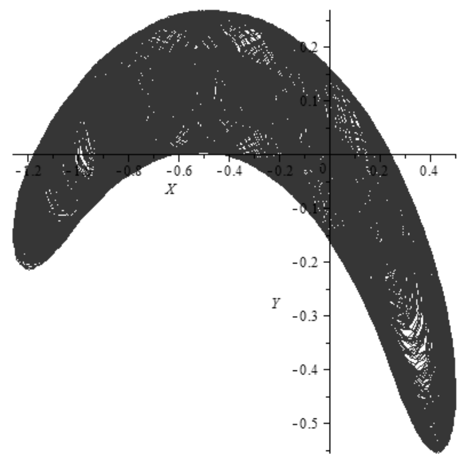

Fig.5. Region of unstable motion of m_3 (b=0, $V_{x0}=V_{y0}$=0.065, 0<t<10000; N=20000).

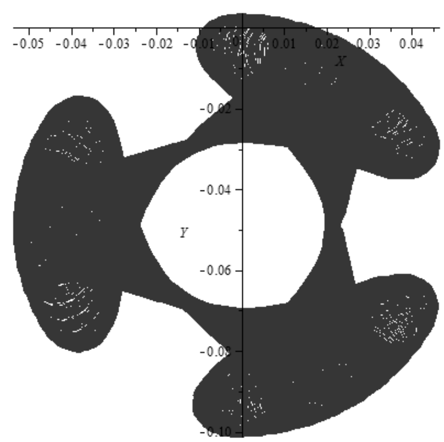

Fig.6. Region of unstable motion of m_3 (b=175.35, $V_{x0}=V_{y0}$=0.01, 0<t<8602; N=25000). r_{12} is unit of length.