EVOLUTION OF THE ORBITS OF BODIES FORMED WITHIN THE PROTO-PLANETARY RINGS. T. R. Abdulmyanov, Kazan State Power Engineering University, Kazan, Russia (abdulmyanov.tagir@yandex.ru).

Introduction: Formation of the solar system, according to recent research [4], could start with the fragmentation of the proto-planetary disk and the formation of proto-planetary rings. The rings with a critical density, by gravitational instability will collapse [2]. The compression will not be local, if and only if the critical density will support by influx of particles from the outer regions of the ring. If the collapse is not local, then in the ring will be formed single planetesimal. Accumulation of dust particles in the protoplanetary rings and determination of the orbital elements of formed bodies are considered in this work.

Accumulation of dust particles in the proto-planetary rings: When the gravitational instability condition is satisfied, dust particles will combine to form the body of various mass and sizes. We assume that the dust particles of mass m_i are moved by the Kepler orbits around the central body of mass M ($M >> m_i$). Elliptical orbits of the particles in the polar coordinate system can be expressed as the following: $s = 1 / r = [1 + e\cdot\cos(v)]/p + G(M + m_i)/h^2$, where $p = a(1 - e^2)$, a, e, v - semi-major axis, eccentricity and the true anomaly of the particle orbits, h - the arbitrary constant. With the accumulation of dust particles orbit of new particles with mass $m = m_1 + +m_2 + ... + m_i$, will be changed. The equations of motion for new particles can be presented in the following form [3]: $ds_i /dv_i + + k_i^2 s_i = G(M + m_1 + ... + m_i)/h^2$, $dv_i/dv = k_i$, (1)

$i = 1, 2, ..., n$. The solutions of these equations are as follows: $s_i = (e/p)\cdot\cos(k_i v) + G(M + m_1 + ... + m_i)/(h^2 k_i^2)$. New particles will have the following orbital elements: $p_i = h^2 k_i^2 /[G(M + m_1 + m_2 + ... + m_i)]$, $e_i=e\cdot p_i /p$. Since the mass of the dust particles and the newly formed particles is small compared with the central body, the changes in the orbital elements will also be small ($e_i \approx e$, $p_i \approx p$). However, the accumulation of orbital bodies will have a revolving of apsidal line [1]. As a result, the process of accumulation will occur in a short period of time, which is comparable with the period of rotation of the apsidal line.

Determination of the orbital elements of formed bodies: Suppose that at time t rectangular coordinates of the celestial body m are equal x, y, z, and coordinates of velocity are equal: x', y', z'. Initial speed φ' of the angle of perihelion φ also will be considered known. Using formulas: $c_1 = xz' - zx'$, $c_2 = yz' - zy'$, $c_3 = yx' - xy'$ the coordinates of the vector $\vec{r} \times \vec{V}$, orthogonal to the plane of the orbit are defined. Hence find the constants: $h_2^2 = c_1^2 + c_2^2 + c_3^2$, $h_1 = h_2 - r^2\varphi'$, $k = h_2 / h_1$ and $p = h_2^2 / \alpha^2$, where $r^2 = x^2 + y^2 + z^2$, $h_1 = r^2 dv/dt$, $h_2 = r^2 d(v + \varphi)/dt$. Then the eccentricity of the orbit can be determined by the formula: $r' = (V^2 - h_2^2 / r^2)^{1/2}$, $e^2 = (p/r - 1)^2 + (r' p / h_2)^2$. Define the inclination of the orbit and the longitude: $\cos i = c_3 / h_2$, $tg\Omega = -c_1 / c_2$. The angle $v + \varphi + \omega$ can be defined from the equations of the elliptic motion:

$$\sin(v + \varphi + \omega) = z / (r \sin i),$$

$$\cos(v + \varphi + \omega) = (x \cos\Omega + y \sin\Omega) / r .$$

To determine the true anomaly can be used the formulas: $\sin kv = r' p / (e h_2)$, $\cos kv = (p / r - 1) / e$. From the two laws (4) it follows what the partial $d\varphi / dv$ of differentials is a constant equal to k -1. Hence find the angle of perihelion, because the true anomaly is already known. As for as the angles $v + \varphi + \omega, v, \varphi$ are known can be find also the argument of perihelion - ω. Then the time of perihelion will define the known formula:

$$tg(E/2) = tg(v/2)\sqrt{(1-e)/(1+e)},\ t - \tau = M / n,$$

$$M = E - e \sin E,\ n = \alpha / a^{3/2},\ \alpha^2 = G(M + m).$$

Thus, orbital elements can be defined from the initial conditions of motion for the case rotation of the perihelion. According to the solution of the equations (1) the coefficient k indicated the absence or presence of spin-orbit perihelion. When k is equal to 1 the rotation will be absent, in other cases, the perihelion would rotate. It is known what the anomalies of the rotation of perihelion by Mercury, Venus, Earth and Mars are respectively 43,03''; 8,62''; 3,83''; 1,35''. Then the constant values k - 1 for these orbits of the planets will be respectively $3{,}3202\cdot10^{-5}$; $6{,}6512\cdot10^{-6}$; $2{,}9552\cdot10^{-6}$; $1{,}0416\cdot10^{-6}$.

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