NEAR EARTH COMETS ORIGIN

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Introduction: Careful orbital calculations done in 1950 by J.H. Oort [1] indicate that a hypothetical "Oort's Cloud" of perhaps at trillions comets orbit the Sun from about 30,000 AU to a light year. Here, the process of transforming of Oort's Cloud circle comet's orbits into the near parabolic orbits of the comets that encounter with the Sun (and the Earth) under perturbed acting of the Galaxy gravitational field and flattening of the Sun is considered.

A Model of the Comets Migration : We shall try to determine time T of migration of a comet from Oort's Cloud to the Sun. As a first approximation the secular evolution of the orbit of a comet is described by elements with mean of the perturbed function with respect to short-period variables e.g. mean anomalies of the comet and the perturbed point, barring commensurabilities of the lowest order between periods. Such averaging is performed independently and (in Hills' approximation - $a/a_1 << 1$) gives the expression for secular part of perturbed function [2], [3]. If the equatorial plane of the Sun and the orbital plane of the nucleus of the Galaxy coincides (inclination $i_1=0$) then [3]

$$de/d\tau=10e(1-e^2)^{1/2}(\sin(i))^2\sin(2\omega). \quad (1)$$

Here i is inclination, ω is the argument of the periapsis. These elements of the osculating cometary's orbit refer to the plane of perturbed body orbit (and First Point of Aries), e is the eccentricity of the cometary's orbit. For the considered celestial mechanical problem c1, c2 and a are constants with respect to time (the integrals of the system of the corresponding differential equations [4]). *a* is the semi major axis of the cometary's orbit. It should be noted [3]

$$c_1=(1-e^2)(\cos(i))^2 , \quad (2)$$

$$c_2=\frac{2\gamma}{\left(1-e^2\right)^{3/2}}\left(\frac{1}{3}+\cos(2i)\right)+2\left(e^2-(\sin(i))^2\right)+e^2(\sin(i))^2(5\cos(2\omega)-3), \quad (3)$$

$$\gamma=\frac{1}{2}\frac{\alpha}{\beta},\ \alpha=-\frac{3}{8}c_{20}\left(\frac{a_0}{a}\right)^2,\ \beta=\frac{3}{16}\frac{\mu_1}{\mu}\left(\frac{a}{a_1}\right)^3,\ \tau=\beta(t-t_0)\sqrt{\frac{\mu}{a^3}}.$$

Here μ and μ_1 are the products of the gravitational constant by the masses of the Sun and the nucleus of the Galaxy respectively; c_{20} is the coefficient of the second zonal harmonic of the gravitational field of the Sun [3]; a_0 is the mean equatorial radius of the Sun; *t* is Newtonian uniform time; a_1 is the semi major axis of the circular orbit of the Galaxy nucleus.

From the equations (1), (2), (3) we may find time P of close approaching of the comet and the Sun and (or) time of going out the sphere of action of the Sun of the comet.

$$P=\frac{1}{2}\int_{w_{min}}^{w_{max}}\frac{dw}{\sqrt{\theta(w)}}, \quad (4)$$

$$\theta(w)=[4\gamma c_1w^7-4/3\gamma w^5+w^2(-c_2+2+2c_1)-4]\cdot[-4\gamma c_1w^7+4/3\gamma w^5-10c_1w^4+w^2(8+8c_1+c_2)-6]. \quad (5)$$

In the equations (4) and (5) we denote: $w=1/(1-e^2)^{1/2}$, w_{min} and w_{max} are positive roots of eqution (6)

$$\theta(w)=0. \quad (6)$$

$w_{max}>w_{min}$, w_{max} is the nearest root of equation of (6) to w_{min} . The integral (4) may be used for circulation as well as for libration motion of periapsis.

Example: Let the initial value of the argument of periapsis of the cometary's nucleus orbit equals $\omega_{in}=0$ and the final one equals $\omega_{fin}=\pi/2$. In initial moment of time the comets move along quasi-circular orbits, radii of which are equal 50,000 AU. For the system the Sun-the Galaxy nucleus-the cometary's nucleus we put $\mu=Gm_S$, $m_S=2\cdot10^{30}$ kg, $a_1=8.5$ kpc, $\mu_1=Gm_G$, $m_G=2\cdot10^{11}m_S$, $a_0=696{,}600$ km, $c_{20}=-10^{-5}$. We denote $e_{in}=e_{min}$, $i_{in}=i_{max}$, as initial values of eccentricity and inclination of the orbit of the comet and $e_{fin}=e_{max}$, $i_{fin}=i_{min}$ are final values; P is time of migration of the comet. So, we have from (4) for $e_{in}=0.1$ and $i_{in}=89.98068554°$, $e_{fin}=0.99999990687$, $i_{fin}=0.68063329$ rad$=38.997415^0$, $r_{min}=0.004656$ AU$\approx a_0$. $P=7.15411\cdot10^8$ tropical years. ($c_1=-1.125006152\cdot10\text{-}7$, $c_2=1.9599997750$).

Conclusion: In this paper we have discussed the problem of cometary's orbits evolution and migration of comets from Oort's Cloud, as the possible cometary's reservoir, using the effect of Kozai-Lidov [2], [3] to the Sun (and the Earth). For the case of coincidence of an equatorial plane of the Sun and an orbital plane of the Galaxy's nucleus, determination of period (P) of varying of argument of pericenter of the cometary's orbit is reduced to a simple quadrature (4) in the evident form *at the first time*.

References: [1] Oort J.H. (1950) *Bull. Astron Int, Neth.* 11: 91-110. [2] Lidov M.L. and Yarskaya M.V. (1974) *Kosmicheskie issledovaniya* 12: 155-170 (in Russian). [3] Washkov'jak M.A. (1996) *Letters Astronomical Journal* 22: 231-240.