# INTERSTELLAR COMETS AND OORT CLOUD.

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**Introduction**: In the works [1] and [2] it is shown that the formation of the Oort cloud of comets can be associated with the region of a giant gaseous clump, that form in the outer solar nebula via gravitational instability and fragmentation of the protoplanetary disk. Below, we consider the regions of motion of the particles with negligible small mass $m_3$ in the frame of the planar circular restricted three body problem [3], [4]. Let us, $m_1$ and $m_2$ are mass of main bodies, $r_{12}$ is a distance between these bodies, *and* $G$ is the gravitational constant. We find the region of the point motion $m_3$, – distance $r_3$, ($\boldsymbol{r}_3=\boldsymbol{r}_3(x_3,y_3)=\mathbf{r}_3(X, Y)$ ) in respect of the system center mass, – and numerically investigate the migration time of the particles from the interstellar medium into the Oort cloud using method of Runge-Kutta integrating. $N$ is the number of points in the figures. The regions of the particles concentration moved near the Sun, in the given model, will be considered as the regions of Oort cloud (and as well as Hill's and other clouds). So, we shall consider *temporary* capture of interstellar comets by the Sun into the Oort cloud.

**Fundamental Equation:** In accordance with works [3] and [4] we have the vector differential equation (1) of the particle $m_3$ motion in the uniformly rotating system

$$d^2\boldsymbol{r}_3/dt^2+Gm_1(\boldsymbol{r}_3-\boldsymbol{r}_1)/(|\boldsymbol{r}_3-\boldsymbol{r}_1|)^3 + Gm_2(\boldsymbol{r}_3-\boldsymbol{r}_2)/(|\boldsymbol{r}_3-\boldsymbol{r}_2|)^3)-2[d\boldsymbol{r}_3/dt, \boldsymbol{\Omega}]-\Omega^2\boldsymbol{r}_3 = 0. \quad (1)$$

Here, $\boldsymbol{r}_3$ is the radius-vector determined the position of considered point in respect of the center mass of the system. $\boldsymbol{r}_1$ and $\boldsymbol{r}_2$ 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. $\Omega$ is the angular velocity of uniformly rotation of the major bodies.

$$\boldsymbol{r}_1=-(m_2/(m_1+m_2))\boldsymbol{r}_{12},\ \boldsymbol{r}_2=(m_1/(m_1+m_2))\boldsymbol{r}_{12}, \quad (2)$$

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

Points of libration are determined from the equation (1) and the following conditions

$d^2\mathbf{r}_3/dt^2=0.$

$d\mathbf{r}_3/dt=0.$

Near these points bodies with mass $m_3$ have been placed in the initial moment of time.

**Examples:** For the numerical experiments we put $G$=$6.672\cdot10^{-11}$ m$^3$/(sec$^2\cdot$kg), $m_1$=$400\cdot10^9\cdot2\cdot10^{30}$ kg is mass of the Galaxy inside the galactic orbit of the Sun, $m_2$=$2\cdot10^{30}$ kg is mass of the Sun. 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. Moreover, we put for all considered cases the following *initial* conditions in the synodical coordinate system: $x_{10}\neq0$, $dx_{10}/dt=0$, $y_{10}=0$, $dy_{10}/dt=0$, $x_{20}\neq0$, $dx_{20}/dt=0$, $y_{20}=0$, $dy_{20}/dt=0$, $x_{30}\neq0$, $V_{x0}=dx_{30}/dt\approx0$, $y_{30}=0$, $V_{y0}=dy_{30}/dt\approx0$. The results of the numerical experiments in intervals of time motion corresponded several revolutions of the Sun along galactically orbit are presented in Fig. 1 – 6.

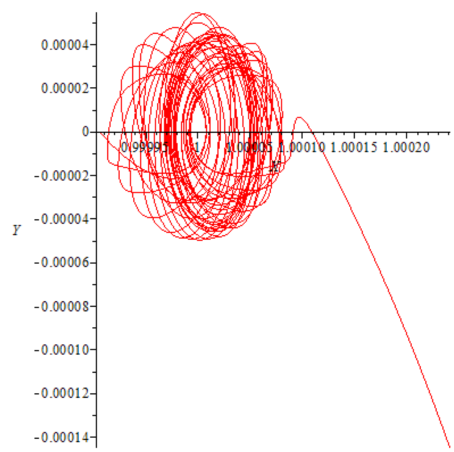


**Fig**.1. The trajectory of a comet. Y=Y(X). t=0-62.8 (~10 revolutions of the Sun along the galactically orbit). N=20000. $V_{x0}$=0.0000002. $V_{y0}$=0.0000002. $x_{30}$= 0.99990589934653387084680 7, $y_{30}$=0 (libration point $L_2$).

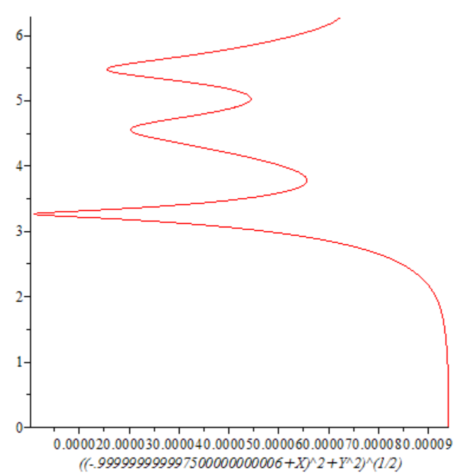


**Fig.2.** Approaching of the comet and the Sun. t=t($r_{23}$). t=0-6.28 (~1 revolution of the Sun along the galactically orbit). N=100000. $V_{x0}$=0.0. $V_{y0}$=0.0000002. $x_{30}$= 0.999905899346533870846807, $y_{30}$=0 (libration point $L_2$).

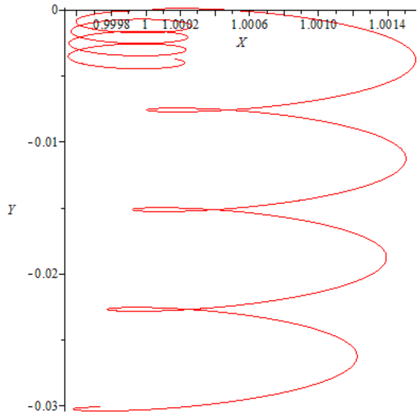


**Fig.3.** The trajectory of a comet. Y=Y(X). t=18350-18400 (~7.96 revolutions of the Sun along the galactically orbit). N=100000. $V_{x0}$= 0.0. $V_{y0}$=+0.00005701. $x_{30}$ =-$x_2$= -0.99999999999750000000006, $y_{30}$=0. $r_{23min}$≈0.00001115.

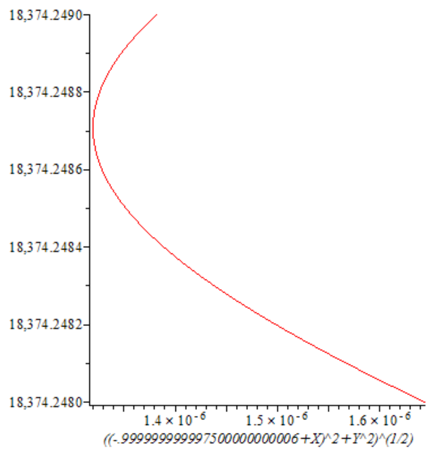


**Fig.4.** Approaching of the comet and the Sun. t=t($r_{23}$). t=18374.248-18374.249 (~0.000159 revolution of the Sun along the galactically orbit). N=1000. $V_{x0}$=0.0. $V_{y0}$= +0.000057. $x_{30}$=-$x_2$= -0.99999999999750000000006, $y_{30}$=0. $r_{23min}$≈0.000001.

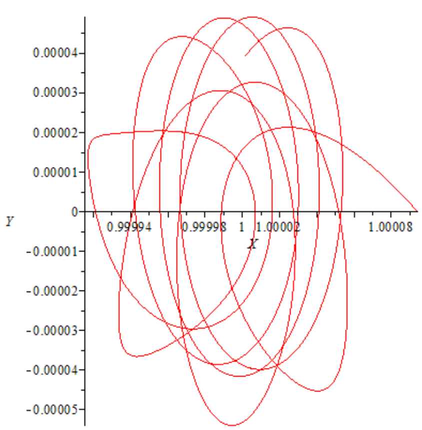


**Fig.5.** The trajectory of a comet. Y=Y(X). t=0-40 (~6.369 revolutions of the Sun along the galactically orbit). N=100000. $V_{x0}$≈0. $V_{y0}$≈0. $x_{30}$=1.0000941065521248390810З, $y_{30}$≈0 (libration point $L_3$).

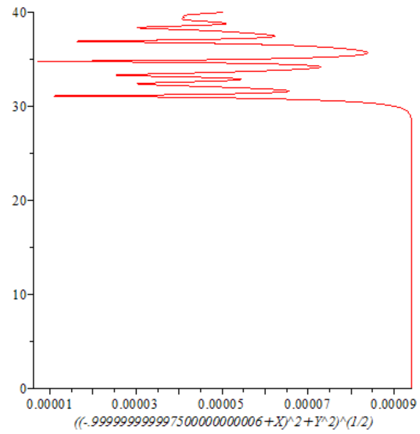


**Fig.6.** Approaching of the comet and the Sun. t=t($r_{23}$). t=0-40 (~6.369 revolutions of the Sun along the galactically orbit). N=100000. $V_{x0}$≈0. $V_{y0}$≈ 0. $x_{30}$ =1.00009410655212483908103, $y_{30}$=0. (Libration point $L_3$). $r_{23min}$≈0.00001.

**Conclusions:** Using the considered celestial-mechanical model of comets origin, we may draw some conclusions. A) It is impossible to explain the process of comets migration into the internal part of the Solar system from any unique source. B) Long-period comets may arrive from interstellar medium. C) There are sources of comets placed far out of the Sun, in particularly these are point-related librations in a circular restricted three-body problem "The Galaxy center-the Sun-a cometary nucleus". D) The initial positions and velocities of comets are within narrow limits in order for the comet to come close to the Sun. E) In the given model Oort and Hill's clouds should not be considered as stationary formations [5] (cometary nuclei come into them and after a few (or dozen) revolutions of the Sun along galactically orbit they leave).

**References:** [1] Emel'yanenko V.V. (2021) http://www.agora.guru.ru/bredikhin2020. [2] Fouchard M., Emel'yanenko V., Higuchi A. (2020) Long-period comets as a tracer of the Oort cloud structure. Celestial Mechanics and Dynamical Astronomy, Volume 132, Issue 8, article id.43. [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. [5] Murray C.D. and Dermott S.F. (2009) Solar System Dynamics. Cambridge University Press.