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Dynamical effects of the Galaxy on the Oort's Cloud

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Abstract. The radial effects due to the Galaxy tide on some cometary nuclei of the Oort's Cloud are taken into account. We model the galactic structure by only considering the three components which are able to exert the main dynamic effects: the bulge, the disk and the dark halo. First we prove the stability role of the dark matter on a solar-type stellar orbit, either by numerical simulations or from the theoretical point of view. Then we simulate the orbital motions of some of the cometary nuclei which lie on the galactic plane at different longitude. The aim is to study the perturbations on the Keplerian orbits of these nuclei as soon as the whole galactic potential is switched. By assuming the solar distance from the Galaxy center as a parameter, a drastic reduction of the perihelions appears for some of them when the solar distance decreases. Finally the connection with the development of the Life inside the solar system is considered.

Key words. Oort cloud – Galaxy: kinematics and dynamics – Solar system: general

1. The model

A model was performed in order to give the total force and velocity field of Galaxy, by taking into account its three main gravitational components: bulge, disk and dark halo. The corresponding potentials are available in the related literature (Masi 2001). First, we tested the effect of the dark matter halo on the rosette orbit of a solar-type star around the galactic center. On the analytical basis, we expect a stabilizing effect on a proof particle, which orbits inside a spherical matter distribution, by adding a dark potential well with spherical symmetry. Actually the bound potential energy increases in spite of the contemporary increase of the centrifugal barrier. In the numerical simulation of a particle movement inside an axisymmetric potential, the stabilizing effect appears as a shrinkage of the rosette orbit by conserving the radial kinetic energy and perigalactic distance.

Then we looked for the effects due to the radial component of the Galaxy tide (usually neglected in respect to the perpendicular one; e.g. Whitman & Matese 1992; Matese et al. 1995; Matese & Whitmire 1996) on the Keplerian orbits of some Oort's cometary nuclei, which lie on the equatorial plane of the Galactic disk, as soon as the total potential of the

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Galaxy is added to that of the solar one. We took into account cometary nuclei with perihelium $q = 2000$ UA and major semi-axes a in the range $40.000 - 140.000$ UA, which plausibly are present in the the external part of the Oort's Cloud (Weissman 1985; Fernandez 1980) with orbits near to parabolic and then which are less bound to the solar system. The effects of the radial perturbation due to the switch of Galactic potential depend also on the Galactic longitude of the cometary orbits. Then we considered for each bin of the major semi-axis: $a = (40, 60, 80, 100, 120, 140) \times 10^3$ UA the following longitudes $l = (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°)$. Then the integration was done for 48 proof particles on a time of 224×10^6 years, which is about the period of a solar-like star around the Galactic center at a distance of 8 kpc. The general effect of the radial Galaxy tide is to reduce the comet perihelions. This reduction increases as the distance from the center decreases. If the solar system is at 8 kpc, the lower limit of the perihelions becomes about 80 UA. If the solar system distance decreases to 6 kpc, the cometary nuclei with the higher major axes ($a = 140 \times 10^3$ UA) reduce their perihelions until 1.5 UA. It means that a cometary swarm may enter into the solar system at a typical Sun-Earth distance and may then produce dangerous impacts with the place of the Life. At 2 kpc the *tidal stripping* on the orbits with values of a greater than about $80.000 - 100.000$ becomes catastrophic. The simulations were repeated by increasing the solar mass to 2 $M_\odot$ and by decreasing it to 0.8 $M_\odot$, in order to test the gravitational screening effect of the solar system attractor.

2. Conclusions

The numerical simulations performed suggest that the marginal position of the solar system inside the Galaxy is not be a casual one, in accordance with the Anthropic Principle (e.g. Dallaporta & Secco 1993), but that a Galactic Habitable Zone (GHZ), inside which life development is allowed, exists, as by Gonzales et al. (2001) has been already settled on the basis of the Galactic chemical gradient. The stripe they have found is limited by the distances 4.5 and 11.5 kpc. Our dynamical approach, which refers to the lowest distance from the galactic center at which the Earth in a solar system may avoid dangerous cometary bombardments, reduces to 6 kpc the inferior limit of the GHZ. The work is still in progress; a greater number of cometary nuclei orbits have to be integrated in order to complete our preliminary results.

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