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DYNAMICAL STUDY OF THE GALACTIC INFLUENCE ON THE A(ORIG) DISTRIBUTION OF THE LONG PERIOD COMETS

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RESUMEN. Analizamos el efecto de la Galaxia como un todo, en la frontera exterior de la nube de Oort de cometas, así como la influencia de las estrellas vecinas en la distribución observada de semi ejes mayores originales de los cometas de largo período.

ABSTRACT. By means of a very simple formulation, in a Sun-centered reference frame, we analyze the effect of the Galaxy as a whole, on the exterior bound of the Oort cloud of comets, as well as the influence of the neighbour stars in the observed distribution of original semimajor axis of long period comets.

Key words: COMETS

INTRODUCTION

Actually, the gravitational influence of the Galaxy seem to be negligible inside on the observable limits of the Solar System. Nevertheles, a part of the System extends to the limits of the Sun's influence. Our present understanding of this region is limited to the study of long period comets that consistently appear from it.

According to Oort's view, in your classical paper (Oort, 1950) those long period comets wich enter in the neighbourhod of the Sun seems to come from a Sun-centered extensive halo, having a mean distance to the Sun near 5×10^4 AU. Actually, the presence of this cometary reservoir is well stablished (Weissman, 1985). Also, have been stablished the more suitable mechanisms wich deplete the Oort's cloud of comets to the observable Solar System. These mechanisms seems to be perturbations by random passing stars, or more recently invoqued, perturbations by interestelar molecular clouds (Clube and Napier, 1984) Also, galactic tides seems to play an important role in this question (Delseme, 1987).

Another important fact to explain is the observed distribution of the original semimajor axis of comet orbits (A_{orig}), because could be well indicators about the place where the comets come from. Marsden et al (1978) published a list of 200 long period comets with well stablished A_{orig}, understanding as A_{orig} the one comet has before entering in the planetary region. The A_{orig} distribution have an important predominance within the range 20000 AU $<A_{orig}<$ 30000 AU. and notably decreases for 6×10^4 AU. More recently, have been suggested the presence of another component: the inner Oort cloud, with orbit semimajor axis distributed between 40 AU and 10000 AU (Clube and Napier, 1982).

Several dynamical studies indicate that the inner Oort cloud could resupply the comets loss in the outher Oort cloud by dynamical loss process such as planetary perturbations (Fernandez 1980 and 1984).

However, the A_{orig} distribution have been calculated through backward numerical integrations, taking into account perturbations by all the planets of the Solar System and the effects of non gravitational forces in those comets with $q<3$. In order to obtain the original aphelion distances, numerical integration process was followed in time until comets were at 60 AU from the Sun (Marsden et al, 1978) where planetary perturbations are negligibles.

Keplerian elements computed at 60 AU.(or more) to the Sun could not be representatives to the region ocupied for the comet cloud. At these aphelion distances, the gravitational perturbation of the Galaxy is in fact significant, and because in the work by Marsden et al The Galaxy component was not included in the force model , the A_{orig} distribution founded by them, could be too different that the real one. An important part of the present paper is devoted to study the role that the gravitation of the Galaxy play in our understanding about the region ocupied by the comet reservoir. We arrives at a very symple formulation of the dynamical problem that permite us to found interesting quantitatives conclussions about some questions such as the stability of motion in the superposed potentials of the Sun and the Galaxy, with regard to perturbations.

It is important to note that the results wich we arrives in this work are a first approach to a more complex problem. We are meanly limited by our unknown of the internal constitution of the Oort cloud, so as the unsertainties in the density distribution of our Galaxy.

DYNAMICAL INFLUENCE OF THE GALAXY

Let us considere the problem of a comet of mass m orbiting arround the Sun, and perturbed by a third body of mass M. It is known that in a Sun-centered reference frame, we have

$$\frac{d^2\mathbf{r}}{dt^2}=-G(M_\odot+m)\mathbf{r}/r^3+GM\left\{\frac{\mathbf{r}_s-\mathbf{r}}{\rho_s^3}-\frac{\mathbf{r}_s}{r_s^3}\right\} \quad (1)$$

Where ρ_s is the mutual distance between m and M. Now we suppose that $r_s \gg r$. With this assumption we may write, by means of a Taylor's expantion

$$\frac{d^2\mathbf{r}}{dt^2}= -G(M_\odot+m)\mathbf{r}/r^3-GM/(\mathbf{r}/r_s^3+3(\mathbf{r}.\mathbf{r}_s)/r_s^5\ )+O(r/rs\ )^2 \quad (2)$$

Also, it is possible to extend this formulation to the perturbation by a continuous mass distribution enclosed in a volume V, with a density distribution δ_s with cilindrical symmetry , as

$$\frac{d^2\mathbf{r}}{dt^2}=-G(M_\odot+m)\mathbf{r}/r^3-G\mathbb{A}\mathbf{r}\ ;\quad \mathbb{A}\in\mathbb{R}^3;\quad a_{ij}=\int_{V-D_s}\delta_s(1-3(x_i x_j/r_s^2))/r_s^3 dV \quad (3)$$

Where Ds is a sphere whose radius is such our hypothesis is fullfiled In what follows, we shall consider the particular case of the perturbation of comets by the Galaxy. The density distribution can be nsidered almost stationary in a sufficiently long period of time, such as one rotation of long period comets arround the Sun. In this way, $\mathbb{A}$ can be computed from the density model of Bahcall & Soneira (1980 and 1984). For the evaluation of the integral we have used the Monte Carlo method (Björck & Dahlqüist, 1974).Finally, we have computed the values: $a_{11}=-a_{33}=2.5\times10^{-16}(M_\odot/AU^3)$, and all the other componentes of the matrix, are at least three times small.

A_{orig} DISTRIBUTION

The effect of the Galaxy on the orbital elements of long period comets have been studied trough numerical simulations by Byl(1983) and Torbett(1986). The angular distribution of the aphelias, studied in detail by R. Lüst (1984) is in good agreement with our potential.
But the most important consecuence of this force model is refered to the exterior bound of the Oort Cloud. We found that the limit of stability of the solar system is abouth 120 000 Au. This value is in accordance with the observational evidence, provided the greather semiaxes of comets are of the order of 60000 AU. In fact, because the orbits are near parabolic, the aphelion distances are $2a$. In this way, the limit of the observed A_{orig} distribution is effectively imposed by The Galaxy, and the consideration of another perturbation (GMC or random passing stars) for to impose such a limit
is innesessary.

STABILITY WITHIN THE OORT CLOUD

As a consecuence of comet revolution arround the Sun, and the motion of the Solar System among the stars, let us considere the effect of a comet approach to a neighbour star, that we can consider at rest. With the customary approximations (Binney and Tremaine, 1987) the change in the velocity of the comet is given by the well kwnown result

(5) $$\Delta V=2GM\left|1/P_c V_c - 1/P_\odot V_\odot\right|$$

Where $V_\odot$ is the peculiar velocity of the Sun among the stars of the galactic vecinity (tipically 20Km/sec) In this way the direction of the comet velocity is approximately changedin:

(6) $$\phi=\Delta V/V$$

If we assume circular velocity for comets in the Oort cloud, (This last condition, must be only an aproximation in the sense of average over a great numbers of comets).From eq.(4), (5) and (6), we have that the maximun deviation in the trajectory of comets is produced at

$$r=43000 \text{ AU}.$$

This distance is approximately, that correspond to the minimal circular velocity in the Oort cloud, and this is, in fact, just the distance corresponding to the peack in the observed aphelion distribution. This fact, strongly suggest that this peack can be due to an observational selection, rather than to a density increasing in the Oort cometary reservoir.

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