CHARACTERISTICS OF SINGLE ENCOUNTERS OF LONG-PERIODIC COMETS WITH JUPITER

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Original nearly parabolic orbits of comets are known to be evolved toward short-periodic elliptic orbits as statistical results of hundreds of encounters with Jupiter. There seems to be two methods to handle the process, namely, the method by exact numerical integrations for each orbit (Everhart, 1972) and random walk approach by using probability distributions of perturbations after single encounters(Lyttleton and Hammersley, 1963; Shteins, 1972). Since both methods need a great number of input parabolic comets to have only a few tens of short-periodic ones, the second method may save time compared with the first one, which is in turn more accurate. The purpose of this paper is to clarify the characteristics of single-encounter effects, in order to develope the second method more elaborately and extensively.

The second method often has been done by adopting simple, empirical and/or assumed Gaussian forms for the distributions of perturbations of the barycentric total energy ΔE. On the other hand Everhart(1968) gives one of the most detailed distributions. His results show that forms of the distributions are very sensitive to the variation of the adopted parameters q(perihelion distance) and i(inclination). This means that if q and i change considerably in the course of the evolution, the distributions of their perturbations must be calculated as well. As is said later, when nearly parabolic orbits evolve to short periodic ones, there is some possibility that q and i change greatly, and in fact Everhart(1972) showed such an example by using the first method.

Instead of the perturbations of q and i I compute those of barycentric total amount and z-component of the angular momentum, ΔG and ΔH, besides ΔE and describe the 3-dimensional distributions. The computations are carried out by integrating the equations of motion for the restricted three body problem. The equations of motion are regularized near the Sun and Jupiter. For one set of the parameters, a(semi-major axis), q and i, more than one thousand orbits are integrated by changing Ω(node) and ω(perihelion argument) randomly. The parameters are varied in the intervals of $1/500 \geq -1/a \geq -1$, $0.1 \leq q \leq 1.2$ and $0° \leq i \leq 180°$, where the unit of length is Jupiter's orbital radius. Thanks to the existence of the Jacobian inte-

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gral, ΔE is always approximately equal to ΔH so that the distributions actually reduce to the two-dimensional ones.

The marginal distributions of ΔG is found to be almost always symmetric with respect to zero and can be well represented by a single- or double-peaked Gaussian form with extended skirts. The situation is very similar to the distributions of ΔE(Everhart, 1968). Then let us see the two-dimensional distribution of points on the ΔE- ΔG plane. One might expect such simple bi-variate Gaussian forms as the distributions of ΔE. However, every pattern is far from such simple forms. Some characteristics of the distributions are as follows:(1)Patterns are symmetric with respect to the two straight lines which are orthogonal to each other, regardless the values of the parameters. (2) The distributions generally consist of a dense core and a sparse envelope. (3) The distributions are almost insensitive to the variation of a, especially for small q. This fact seems to suggest a possibility that we might extrapolate the random-walk method to the orbits with small semi-major axis, say a $\leq$ 1.0, which, exactly speaking, should be treated by numerical integrations or the theory of secular perturbations. (4) For small q the dense core appears as a rectangle whose sides are very sharp. Those sides or its inside may correspond to some quasi-integral of motion. (5) For large q the distributions show approximately elliptical forms though they have complex structure inside. (6) For direct motions ΔE and ΔG have the same sign, while for retrograde motions the sign changes. However, for large q, ΔE and ΔG have the same sign even for a great part of retrograde orbits. (7) ΔE and ΔG usually are of the same order of magnitude.

According to the last two items there comes a possibility that q and i can change considerably when the original nearly parabolic orbits of comets evolve to short-periodic ones. So the assumption that the perihelion distances are invariable under random-walk process is not accurate although it is often assumed. Consulting with the distributions I derived I can infer local pathes of the evolution to some extent. If, as the second step, I express these all distributions by appropriate functions, I will be able to treat the random-walk process rather in details. As the concrete forms and the values of the distribution functions are somewhat arbitrary, they are not presented here.

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DISCUSSION

Yabushita: I have two comments. The assumption of constant q (perihelion distance) is good when you consider the diffusion of comet with $a=10^4$ AU to a=20 AU or so. The relation $(\Delta E)=(\Delta G)$: is that not a consequence of Jacobi integral?

Nakamura: As for the first point, I quite agree with you; however, since we want to handle uniformly the diffusion of comets to, say, $a \simeq 5$ AU, we must take into account the variation of perihelion distance and inclination. In fact, we have found that our method can treat the diffusion process to within the region of a, mentioned above. The relations $O(\Delta E)=O(\Delta H)$ and sign $(\Delta E)=$ I sign (ΔH) are not a consequence of Jacobi integral but come from another quasi-integral.

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