THE STABILITY OF SOME ASTEROIDS

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ABSTRACT

The utilization of two different stability criteria, namely, Hill's modified stability criterium and the method of surface of section, has been employed for asteroid orbits. The idea is to compute different criteria of stability for the same asteroids in order to compare the results and see the practical interest of the computations for researches about evolutionary trends of individual asteroids, groups and families of asteroids.

1. INTRODUCTION

This paper is an application of the criteria of stability defined and employed in the papers by Szebehely *et al* (1983),and Hadjidemetriou and Ichtiaroglou (1983); it is the result of discussions among the authors previously mentioned.

It is well known there are several definitions of stability in celestial mechanics but, unfortunately, some of them are not easy to apply to practical cases. Also, it would be convenient to try to verify the conclusions of different criteria of stability when applied to the same bodies of the solar system.

As pointed out by Vicente (1979) it is advantageous to apply different criteria of stability to the asteroids because they are far more numerous than planets and natural satellites, and, therefore, there is greater likelihood to find cases of instability among the asteroids. Unfortunately, there are only about 2,700 asteroids with reliable computed orbits.

We shall consider some well known asteroids, computing the measure of stability S, introduced by Szebehely (1978) and corresponding to the criteria defined by Hill (1878). The results obtained are confirmed by the computations of Hadjidemetriou and Ichtiaroglou (1983) whenever possible.

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2. PRACTICAL APPLICATIONS

The Trojans group, east or west of Jupiter, present S slightly negative ($S < 0$); they correspond to a resonance of 1/1 with libration cycles of about 150 years. Considering this result they might escape from their present positions.

In the Hilda group some (Hilda, Ismene, Bononia) show $S < 0$ while others (Chicago, Normannia) show $S > 0$; they correspond to a resonance of 2/3 with libration cycles of 250 to 300 years. The resonance 2/3 is represented by branches B_1 and B_2 of Fig. 1 of Hadjidemetriou and Ichtiaroglou (1983).

The Hecuba group shows $S > 0$ corresponding to a resonance 1/2, and can be identified on the stable branch A_1 of Fig. 1 (Hadjidemetriou and Ichtiaroglou, 1983). The Hestia type of asteroids also present $S > 0$ and correspond to stable orbits with non-zero eccentricity at resonance 1/3.

The Hirayama families of Themis, Eos and Koronis show positive values of S and correspond to stable resonant orbits. There is therefore agreement between the two criteria of stability and we can interpret that as corresponding to stable families of asteroids.

There are different opinions not only about the existence of certain families of asteroids but also on the advantages or disadvantages of grouping asteroids into families. There is no doubt that, at least certain families, do have dynamical and evolutionary meaning, and the criteria of stability employed in the present paper corroborate the existence of such families, showing stable values.

The regions exemplified by the Hungaria and Phocaea asteroids present positive values of S, having non-zero eccentricities, and they are isolated by resonances as it was shown by Brouwer and van Woerkom (1950).

At the resonance 1/3, asteroid Alinda shows $S > 0$, having an eccentricity of 0.543 and appearing on the stable family of periodic orbits. It crosses the orbit of Mars and is a known librator.

The regions corresponding to the asteroids Maria and Flora, sometimes considered as families and other times not considered as families, present positive values of S. Following our criteria these regions are stable and, for that reason, there are numerous asteroids in those regions. Kozai (1983) has proposed better parameters, among the orbital elements of the asteroids, for characterising asteroid families, for instance the Flora and Maria families.

Among the group of Earth crossing asteroids, we mention some of the Apollo group, for instance, Icarus and Geographus showing $S < 0$. The groups represented by Amor and Betulia also show $S < 0$. The case of Betulia is an interesting one because it might be one of the candidates for a cometary origin. Eros, also approaching the Earth, and which was extensively observed for astrometric purposes, has $S < 0$ but with smaller value than the Apollo and Amor groups.

Considering the asteroids with orbits going outside Jupiter´s orbit, we mention Hidalgo and Telamon, both having $S < 0$, but Hidalgo presenting a larger negative value because its inclination is 42° while Telamon´s is only 6°. This, again, justifies the conclusions presented by Szebehely *et al* (1983) that greater inclinations correspond to greater degrees of instability. The same conclusions can be inferred for greater values of the eccentricity. Chiron is another interesting case because $a = 13.69$ and the computed value of S is negative. It has been shown that it corresponds to a chaotic orbit, and, therefore, our conclusions are in agreement.

3. CONCLUSIONS

Laplace (1798) was impressed by the regularities of the solar system, that is, small inclinations and eccentricities, and, about 200 years later, we can prove, thanks to the asteroids, that these features correspond to greater stability and, therefore, are more prominent in the solar system.

We must remember that present day theories of the motions of the asteroids are not as well developed as for other bodies of the solar system, namely, the planets. One reason for that is the comparative neglect of the systematic study of the orbits of asteroids which is unfortunate because they show far greater variability in their motions than other bodies of the solar system. As a consequence, some families of asteroids are not yet so well defined and we cannot infer many conclusions about possible evolutionary trends of the solar system.

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