UPDATED ANALYSIS OF THE DYNAMICAL EVOLUTION FOR PARENT BODY OF THE QUADRANTIDS CORE.

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The Quadrantids is one of the strongest meteor showers. The core of the Quadrantids is only 200-300 years old and is associated with asteroid (196256) 2003 EH1 [1] while wide part of stream is connected with comet 96P/Machholz [2]. The asteroid 2003 EH1 is expected as a dormant or recently extinct comet in many works [3–5]. This work is devoted to the dynamics of asteroid (196256) 2003 EH1 and the study of its chaotic motion. We suppose that the reasons of chaos are the frequent close approaches of the asteroid with Jupiter and the overlap of resonances. The mean motion resonances and secular resonances play an important role for small bodies dynamics. Theories [6] allow us to model the basic features of orbital evolution and the secular resonances. We considered the apsidal-nodal and mean motion resonances with planets from Mercury to Saturn. It is well known that the overlap of stable and unstable resonances can lead to chaotic motion of small bodies in Solar System.

This work is update analysis of the study of the asteroid 2003 EH1 [6]. We studied the motion of (196256) 2003 EH1 and its clones on interval from 1000 to 4000 year. The asteroid has small variations of the initial orbital elements but multiple close approaches with planets lead to large deviations of trajectories of clones from the nominal orbit. We estimated the mean exponential growth factor of nearby orbits (MEGNO) and found that MEGNO < 2 only in the interval from 1700 year to 2300 year. It shows that the orbit may be considered as regular on the time interval of ± 300 years from now, and as chaotic outside this interval.

The semi-major axis remains at a value close to 3.1 au. This suggests that the orbital energy remains constant throughout the interval despite a number of close encounters with planets. The behavior of 2003 EH1 is characterized by large variations in the eccentricity and the inclination. It is very interesting note that, the semi-major axis of the orbit approximately conserves while the orbital eccentricity and inclination oscillate out of phase. The eccentricity was bigger in the past, being 0.95 in AD 500 and monotonically decreasing to its curent value of just under 0.62. Back in AD 500 its value was around 0.95 compared to its current value of 0.62. The inclination was monotonically increasing to its current value of just under 79 from smaller in the past, being 39 in AD 500. The perihelion distance *q* shows fairly smooth monotonic change on all time interval. It was significantly smaller in the past having the value of 0.15 in AD 500. The lack of cometary activity on 2003 EH1 can be explained such small perihelion distances in the past that led to complete degassing of the comet.

The orbital evolution of the asteroid (196256) 2003 EH1 exhibits another important feature – when the eccentricity has its highest value the inclination is at its lowest one and the argument of perihelion is close to 180◦(on interval 2250 – 3750 yy). This information hints at the Lidov-Kozai scenario which driven by the fact that the value of the aphelion of this asteroid oscillates around of orbit of Jupiter that controls its dynamical state. And this shows that the influence of Jupiter has significant actions on motion of the asteroid.

The investigated asteroid (196256) 2003 EH1 moves in neighbourhoods of the following mean motions resonance: 2:1 with Jupiter, 1:3 with Mars and 1:9 with Venus. Asteroid moves in a rather large neighbourhood of resonance with Venus $(-90\,''/\text{days} < \dot{\psi} < 230\,''/\text{days})$. The critical argument sometimes circulates, sometimes liberates (1500-1700 yr.) with large amplitude. So we can say that the asteroid is in neighbourhoods of the resonances but is not captured in they. All mean motion resonances are unstable and may be reason of chaotic motion.

The secular resonances demonstrate another behavior. We studied all apsidal-nodal resonsnces up to 2 order and found that the resonant arguments have libration motions (in some cases with a limiting amplitude) in the time interval under consideration for all 20 resonances. The resonance relationships osculate near zero with non significant amplitudes. The behavior is similar for all planets. The overlap of stable apsidal-nodal resonances and unstable mean motions resonances leads to chaotic motion of asteroid (196256) 2003 EH1.

References:

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