THE QUADRANTID STREAM, CHAOS OR NOT?

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Abstract. The Quadrantid stream covers a region of space which contains many strong resonances and commensurabilities with the Jovian orbit. We have numerically integrated the orbital evolution of over one hundred actual meteoroids backwards to BC 5000. The evolution is quit complex, but most of the meteoroids are quite well behaved with rapid but smooth changes in the orbital elements. One meteoroid however shows sharp sudden changes in its orbital parameters and these changes are generally indicative of the presence of chaos.

1. Introduction

The Quadrantid meteor shower is one of the most regular and active of the annual meteor showers and as a consequence has a history of regular observations dating back to the beginning of the 19th century. The absence of observations before that date was explained by Murray et al (1979) as being due to the effect of planetary perturbations, in particular by Jupiter. Hughes et al (1981) have discussed the difference in the observed retrogression rate between the visible and radio meteors and attribute this to a complex orbital evolution of meteoroids with aphelia close to the orbit of Jupiter. They also pointed out that such meteoroids were close to being in a 2:1 resonance with Jupiter. In fact, this is not the only orbital resonance that lies within the region occupied by the Quadrantid stream, which has meteoroids with orbital aphelia in the range 3.2 to 6.4 AU. Table 1 shows the aphelion distance, semi-major axis and ratio of orbital periods with Jupiter of orbits lying within the relevant region. With this possibility both of having close encounters with Jupiter and having commensurabilities with Jupiter, it may be expected that parts of the Quadrantid stream could be chaotic. Indeed, the early numerical integrations of Williams et al (1979) and Froeschle and Scholl (1981) show some evidence for chaotic behaviour amongst the hypothetical meteoroids of the models. In this paper, we numerically integrate a set of real meteoroid orbits and search for abnormal or chaotic behaviour amongst these.

2. The investigation

In the IAU Meteor Data Center catalogue at Lund, there are data on nearly 70000 meteor orbits archived. We have searched through this data set to find meteoroid orbits likely to belong to the Quadrantid stream, using the Drummond D' criterion (Drummond, 1981). Further details of this search may be published later, but as a consequence of it, a set of 122 real meteor orbits were found, all probably belonging to the Quadrantid stream. The motion of each of these meteoroids was integrated back to BC 5000, using the Runge-Kutta-Nystrom integrator described by Dormand et al (1987).

The evolution in space of two very typical meteoroids are shown as Figs 1 and 2, while Figures 3 and 4 show the calculated changes in perihelion distance and eccentricity of a small, but representative sub-set of meteoroids. Most show considerable variation but nothing irregular. However, one meteoroid, number 9955,

S. Ferraz-Mello (ed.), Chaos, Resonance and Collective Dynamical Phenomena in the Solar System, 329–332.

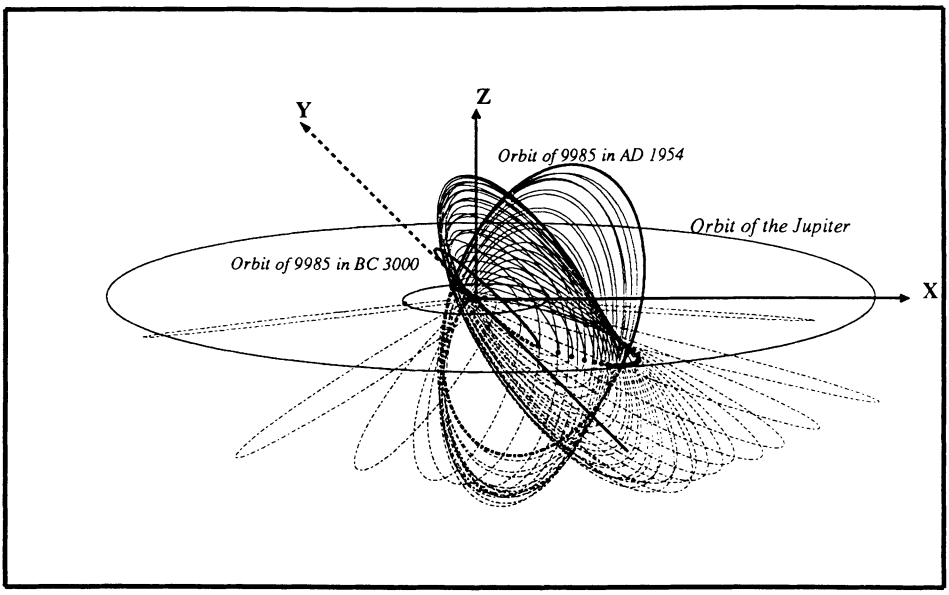

Fig. 1. Orbital motion of Quadrantid 9985 from BC 3000 to AD 1954

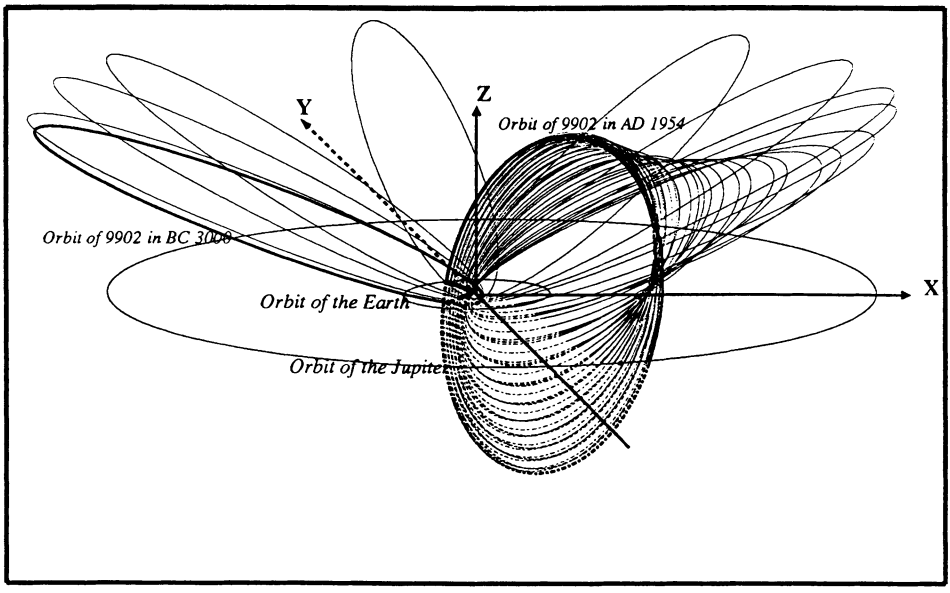

Fig. 2. Orbital motion of Quadrantid 9902 from BC 3000 to AD 1954

https://doi.org/10.1017/S0074180900091348 Published online by Cambridge University Press

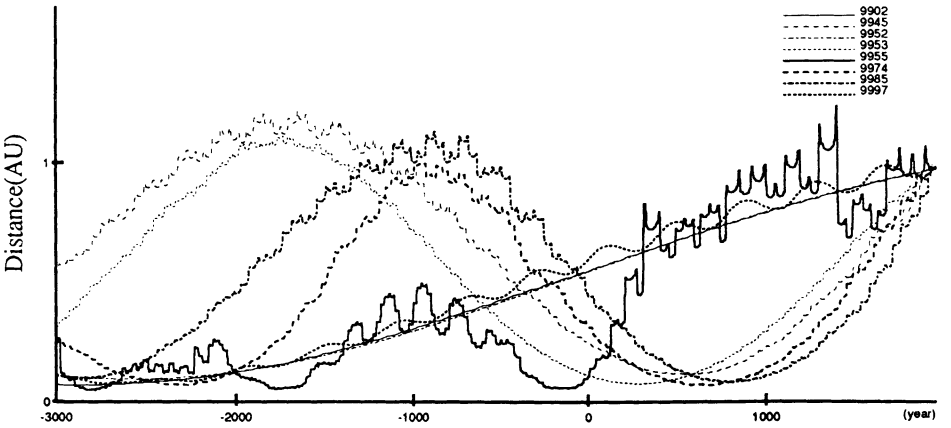

Fig. 3. Perihelion distance of the orbits of the Quadrantids

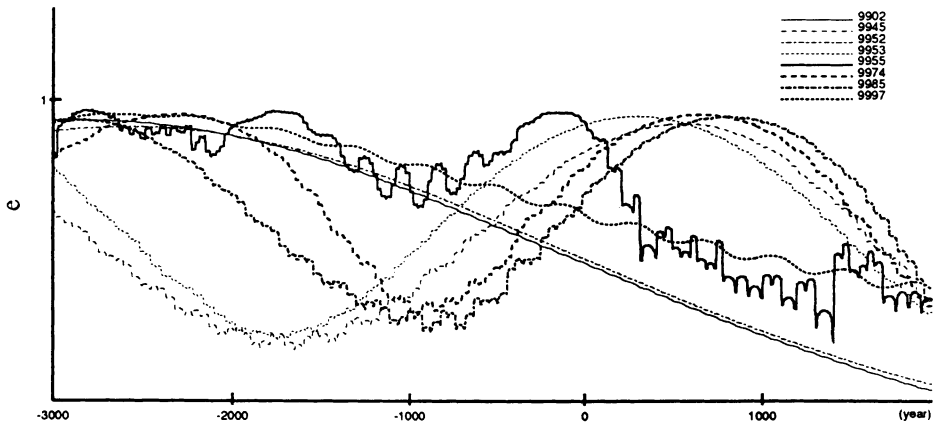

Fig. 4. Eccentricity of the orbits of the Quadrantids

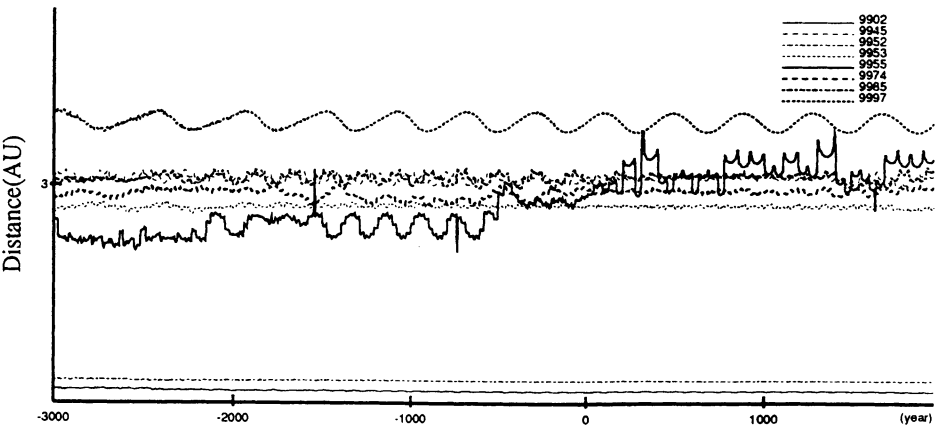

Fig. 5. Semimajor axis of the orbits of the Quadrantids

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TABLE I

Period and ratio of Jovian periods in the region of the Quadrantid stream

Aphelion AU	Semi-major axis AU	Period Years	Period Ratio
3.12	2.06	2.96	4 : 1
3.98	2.49	3.93	3 : 1
4.62	2.81	4.72	5 : 2
5.25	3.12	5.51	15 : 7
5.52	3.26	5.89	2 : 1
6.36	3.68	7.07	5 : 3

deserves further mention. Irregular jumps appear in both the perihelion distance and the eccentricity, and irregular changes also appear in the semi-major axis plot, Fig 5.

These irregular jumps are typical of the behaviour of an object in a chaotic zone and we would strongly suggest that at least one real meteoroid has behaved chaotically in the past. We should note further that meteoroid 9955 has a semi major axis of 3.119 AU and an aphelion distance of 5.254 AU, thus just outside the orbit of Jupiter and so very close approaches to Jupiter are possible. In addition, while not being far away from a 2: 1 ratio of periods with Jupiter, it is very close to a ratio of 15:7.

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