THE PAST AND FUTURE OF 1983 TB AND ITS RELATIONSHIP TO THE GEMINID METEOR STREAM.

Ken Fox, Iwan P. Williams and J. Hunt,
Theoretical Astronomy Unit,
School of Mathematical Sciences,
Queen Mary College, Mile End Road,
London. E1 4NS, U.K.

ABSTRACT. It is now well known that object 1983 TB, discovered by IRAS, has an orbit very similar to that of the Geminid meteor stream. Calculations show that this orbit crossed over the orbit of Venus about 500 years ago. We will describe calculations tracing the history of both the object and the stream through this interaction with Venus and the present interaction with the Earth.

1. INTRODUCTION

Mathematical models of the formation of meteor streams, simply by the ejection of material away from a cometary nucleus, are never able to produce a stream wide enough to match the length of the shower which is actually observed. This implies either that during formation the parent comet spiralled away from its Keplerian orbit under the influence of non-gravitational forces, as proposed by Weissman (1979) or that after formation the stream was dispersed by gravitational perturbations, radiation effects or some other unknown mechanism. This paper investigates the effects of gravitational perturbations on the evolution of the Geminid meteor stream cross-section.

Table I

Orbital element	Geminid Stream	1983 TB
Argument of perihelion	324.8°	321.6839°
Ascending node	260.3°	265.0332° 1950
Inclination	23.6°	22.0339°
Eccentricity	0.896	0.8902365
Perihelion distance	0.140 AU	0.1395603 AU
Period	1.57 years	1.434 years
Aphelion distance	2.56 AU	2.4033679 AU

A. Carusi and G. B. Valsecchi (eds.), Dynamics of Comets: Their Origin and Evolution, 143–148.

The mean orbital elements of the Geminid meteor stream and asteroid 1983 TB (MPC 8678) are listed in Table I. As can be seen, they follow virtually identical orbits. Fox et. al. (1984) have concluded that 1983 TB is not just an Apollo asteroid but is the degassed remains of the parent comet of the Geminid meteor stream. Fox et. al. (1982,1983) described a mechanism for the formation of the Geminid meteor stream by the ejection of particles away from the nucleus of a hypothetical comet, travelling on the present day Geminid orbit. This model was able to explain many of the observed features of the Geminid shower, in particular its skew rate profile. However, the model was not entirely realistic as it would have produced a shower of less than two days duration compared to that observed (Spalding (1984)) of about eight days.

Babadzhanov and Obrubov (1980) have studied the long term behaviour of the Geminid meteor stream using a secular perturbation technique. They have shown that the stream is undergoing rapid orbital evolution, in the past 4000 years alone it has crossed over the orbits of Earth, Venus and Mercury twice at either its descending or ascending node. Such crossings must disrupt the stream causing it to spread, but whether this disruption is significant is not easy to estimate. Secular perturbation methods are only able to describe the average behaviour of an orbit's evolution. In particular they cannot describe the disruption of a stream as its orbit crosses over the orbit of any perturbing planet, as a singularity occurs in the equations when the orbits intersect. Therefore the only way to accurately study this disruption is to use the direct approach and integrate the full equations of motion.

2. THE FORMATION MODEL

The same procedure is used here as that used by Fox et. al. (1982), except that this time the orbit used for the parent comet is that of asteroid 1983 TB. The orbit of 1983 TB was integrated backwards 500 years so that it was now interior to the orbit of Venus. Twenty particles were then ejected from equally spaced points around this orbit with speeds v, given by Whipple's formula , below, taking typical values of s=0.1 cm and ρ=0.8 g/cm^3 for the particles' radius and density respectively and a cometary radius R_C of 5 km, a value which is slightly larger than the observed radius of 1983 TB.

$$v = \left[\frac{1}{s\,\rho\,r^{9/4}} - 0.013\,R_c \right]^{1/2} R_c^{1/2} \times 656 \text{ cms}^{-1}.$$

The equations of motion of these twenty particles were then integrated forwards in time one thousand years, at which stage virtually all their orbits had crossed over the orbits of Venus and the Earth. Perturbations by Venus, Earth and Jupiter were included in the calculations. The equations were integrated by a Runge-Kutta-Nystrom method of Dormand and Prince (1978) as Fox (1984) has shown this to be one of the best methods available for systems like this.

3. THE EVOLUTION OF THE THEORETICAL STREAM

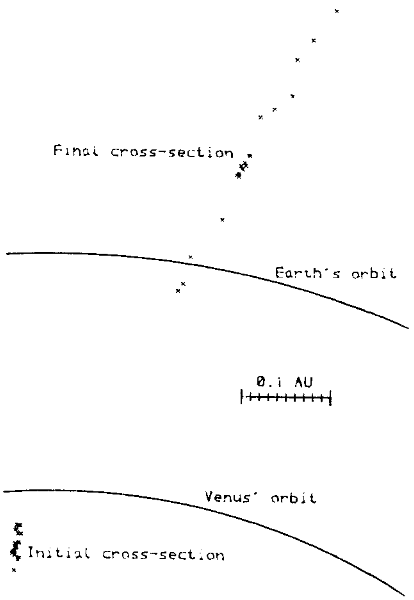

Figure 1. In the plane of the ecliptic, the initial and final positions of the descending nodes of the particles in the theoretical stream.

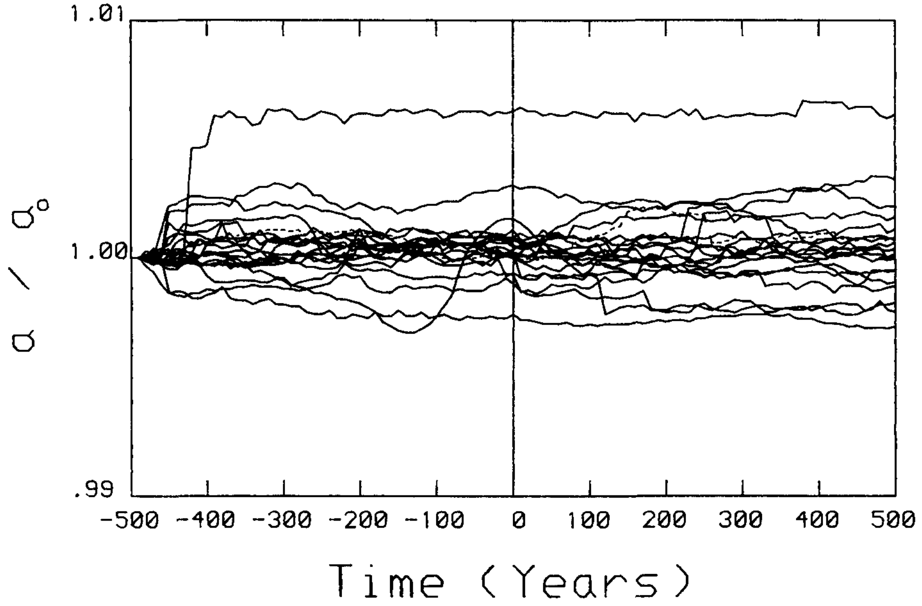

Figure 2. The variation of the normalised semi-major axes of the twenty particles as a function of time. The variation of the semi-major axis of 1983 TB is also shown as a dashed line. Time = 0 is September 23rd 1983.

Figure 1 shows the initial state of the theoretical stream cross-section 500 years ago, interior to the orbit of Venus, and how over the one thousand year period the cross-section has evolved across both the orbits of Earth and Venus. This movement is virtually entirely due to perturbations by Jupiter. One of the best ways of seeing how the stream has been disrupted is to look at the changes in the semi-major axes of the particles in the stream as a function of time. Normalising the semi-major axes by dividing by their initial value enables relative changes to be seen more clearly. Figure 2 is a plot of these normalised semi-major axes over the one thousand year period. It is evident that many of the particles are affected by crossing over Venus' orbit during the first one hundred years of the integration by the large relative changes in their semi-major axis. The disruption caused by the Earth is not so obvious, because the stream soon spreads out and the crossing point occurs at different times for each particle. However, further spreading can be seen during the last five hundred years due to this cause.

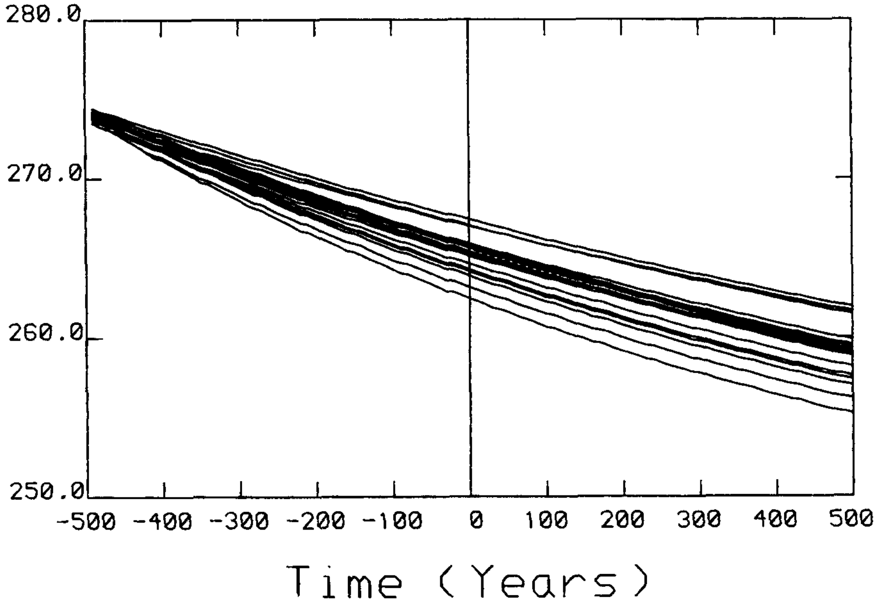

Figure 3. The variation of the longitudes of the ascending node of the twenty particles as a function of time. Time = 0 is September 23rd 1983.

Of more relevence to the observed shower duration is the variation in the change of the longitude of the ascending node of each of the particles. Figure 3 shows the change in this angle as a function of time. It is clear that all the particles are evolving at different rates causing the stream to slowly spread. This is mainly due to the fact that the particles started out on slightly different orbits and thus Jovian perturbations are different for each orbit. There is virtually no sign of any major disruption caused by the Earth and Venus in the evolution of this angle.

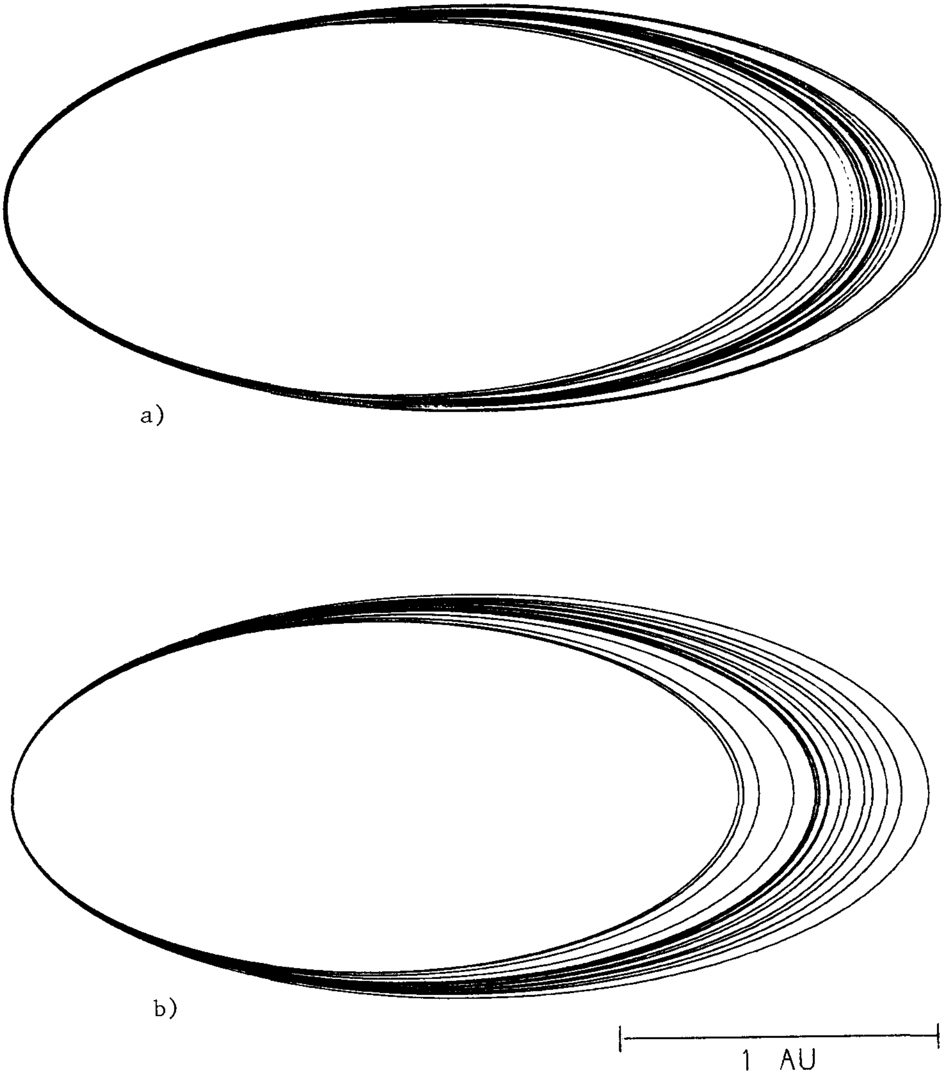

Figure 4. A comparison of a) the orbits of actual observed Geminid meteors with b) those produced by the theoretical model.

Finally a comparison should be made of the actual shapes of the theoretical orbits compared to those observed. Jacchia and Whipple (1961) obtained twenty high precision orbits of photographic Geminid meteors. These ellipses, with pericentres alligned are shown in Figure 4, alongside the elliptical orbits produced by the theoretical model at time = 0. As can be seen the orbits are very similar.

4. CONCLUSIONS

Due to secular perturbations by Jupiter and to a lesser extent, disruption by crossing over the orbits of the inner planets, the Geminid meteor stream is slowly spreading out. The lack of any close approaches to or resonances with Jupiter means that the spreading is slow. From calculations presented here it would seem that thousands of years are necessary for gravitational perturbations to spread out the stream enough to match the present day observations of the shower.

The formation mechanism used here produces an asymmetric distribution of semi-major axes in the ejected particles' orbits about that of the parent body. However, with realistic values for the comet's radius and the particles' radius and density the asymmetry is not so great as to immediately explain the non-central position of asteroid 1983 TB relative to the Geminid meteor stream. The crossing of the orbit's of the inner planets causes small jumps in the orbital elements of any individual particle within the stream. This mechanism is probably sufficient to explain this non-central position.

REFERENCES

Babadzhanov, P. B. and Obrubov, Y. V.: 1980, in 'Solid Particles in the Solar System', p. 157, ed. Halliday, I. and McIntosh, B. A., D. Reidel.

Dormand, J. R. and Prince, P. J.: 1978, Celest. Mech., 18, 223.

Fox, K.: 1984, Celest. Mech., 33, 127.

Fox, K., Williams, I. P. and Hughes, D. W.: 1982, Mon. Not. R. astr. Soc., 200, 313.

Fox, K., Williams, I. P. and Hughes, D. W.: 1983, Mon. Not. R. astr. Soc., 205, 1155.

Fox, K., Williams, I. P. and Hughes, D. W.: 1984, Mon. Not. R. astr. Soc., 208, Short Communication, 11P.

Jacchia, L. G. and Whipple, F. L.: 1961, Smithson. Contrib. Astrophys., 4, 97.

Spalding, G. H.: 1984, J. Brit. astron. Assoc., 94, 3.

Weissman, P. R.: 1979, Astr. J., 84, 580.