Physics, Chemistry, and Dynamics of Interplanetary Dust
ASP Conference Series, Vol. 104, 1996
Bo A. S. Gustafson and Martha S. Hanner (eds.)

When Might 2P/Encke Have Produced Meteor Storms?

D.I. Steel
The University of Adelaide, Adelaide, SA 5005, Australia

D.J. Asher
National Astronomical Observatory, Mitaka, Tokyo 181, Japan

Abstract. 2P/Encke is the only Earth-crossing short-period comet to have a meteoroid/dust trail identified in the data collected by IRAS. Such trails have been suggested by Kresák to be the cause of meteor storms, these occurring when the comet/trail node is near 1 AU and the Earth happens to pass through the trail. Here we present the results of integrations of variational orbits of 2P/Encke (the differences in the assumed initial semi-major axes representing the order of changes that could occur due to non-gravitational effects) from which we derive indications of when this comet may have produced meteor storms in the past. Pairs of sets of storms are expected about 300 yr apart, but the effects of chaotic dynamical evolution (and our ignorance of 2P/Encke's non-gravitational forces for any but the last two centuries) mean that we cannot define the epochs in which these may have occurred to better than 200 BC to AD 500 for the last pair, and 3600 to 1800 BC for the previous pair. Looking forwards in time, no meteor storm due to 2P/Encke will occur for at least 600 yr.

1. Introduction

Kresák (1993) began his paper by writing that "Meteor storms are perhaps the most impressive phenomena in the night sky." In the past two centuries, meteor storms have been observed once a decade or so, the Leonids, Draconids/Giacobinids and Andromedids/Bielids being the examples which spring to mind. Because these are very spectacular (for some eyewitness accounts see Hughes 1982, and Yeomans 1981 and Babadzhanov et al. 1991 for other studies), the question arises of whether meteor storms are recorded in the historical (or other) materials to come down to us from distant generations.

In the paper referred to above, Kresák argued that meteor storms are likely to be the result of the passage of the Earth through structures like the meteoroid/dust trails discovered in 1983 using IRAS (Sykes 1988). Eight short-period comets were found to have associated trails, but only one of those — 2P/Encke — is an Earth-crosser (Sykes and Walker 1992). It is therefore of interest to study the orbital evolution of 2P/Encke — which is relatively well-behaved, dynamically-speaking, due to its sub-jovian orbit — to see when the Earth might have intersected its trail in recent millennia. The physical behavior of this comet is an outstanding problem, because it was first recorded in 1786 and yet would have been a naked-eye object previously if it had been active (Sekanina 1991).

The intervening period of two centuries is sufficient for the formation of the observed IRAS trail (Sykes 1988), but the comet must have been active at other times in the last $\sim 10^4$ yr as evidenced by its well-developed set of meteor showers (Babadzhanov et al. 1990; Steel et al. 1991). Searches for the comet in ancient oriental records have not resulted in any plausible identifications (Whipple and Hamid 1972; Hasegawa 1979). The aim of the present study is to see whether it might be possible to identify epochs in which meteor storms due to 2P/Encke could have been observed and recorded.

2. Method

We have performed backwards integrations of the orbit of 2P/Encke using an initial orbit for epoch 1997 June 01 due to Nakano (1994). We did not integrate the planetary orbits, but used values for those orbits supplied to us by T. Quinn (see Quinn et al. 1991); the effects of random close approaches to the terrestrial planets mean that the veracity of our results is not affected by this simplification, but the required computer time is reduced by about an order of magnitude. It is well-known that 2P/Encke is subject to substantial non-gravitational forces, these causing its semi-major axis (a) to change by $\sim$0.004 AU/century in recent times (Marsden and Sekanina 1974; Sitarski 1988). With that in mind we have also back-integrated two orbits with initial values of a differing by ± 0.02 AU from the nominal value, all other start elements being maintained. For each of these three integrations we have calculated how the heliocentric distance to each of the nodes (R) has varied with time.

3. Results

In Fig. 1 we show how R has changed over the past 7 000 yr for the three start orbits mentioned above. Meteor storms may occur (depending upon whether the comet has recently spawned a trail) when a node occurs near 1 AU. At such times *sets* of storms would be expected in regular cycles, similar to the periodicity of the other storms observed in the past 200 yr (see Yeomans 1981 and Kresák 1993). For 2P/Encke one might expect storms every 10 yr (since that is close to three times the orbital period of the comet), persisting for maybe a century until the node has moved away from our orbit. A pair of such sets (one from the ascending node intersection, one from the descending) would be expected to be separated by 250–350 yr, according to Fig. 1. The last pair would have occurred between 200 BC and AD 500, the pair before that at some time between 3600 and 1800 BC: the effects of chaotic dynamical evolution, coupled with our uncertainty in the history of 2P/Encke's non-gravitational effects, mean that it is not possible to identify the years, or even the centuries, when storms may have been witnessed.

A correlated question is when meteor storms from 2P/Encke might be anticipated in the future. The answer, which can be divined from an extrapolation of the patterns in Fig. 1, is that such storms would not be expected for at least another 600 yr, and their eventuality would require the persistence of the structure (the IRAS meteoroid/dust trail) responsible for their production.

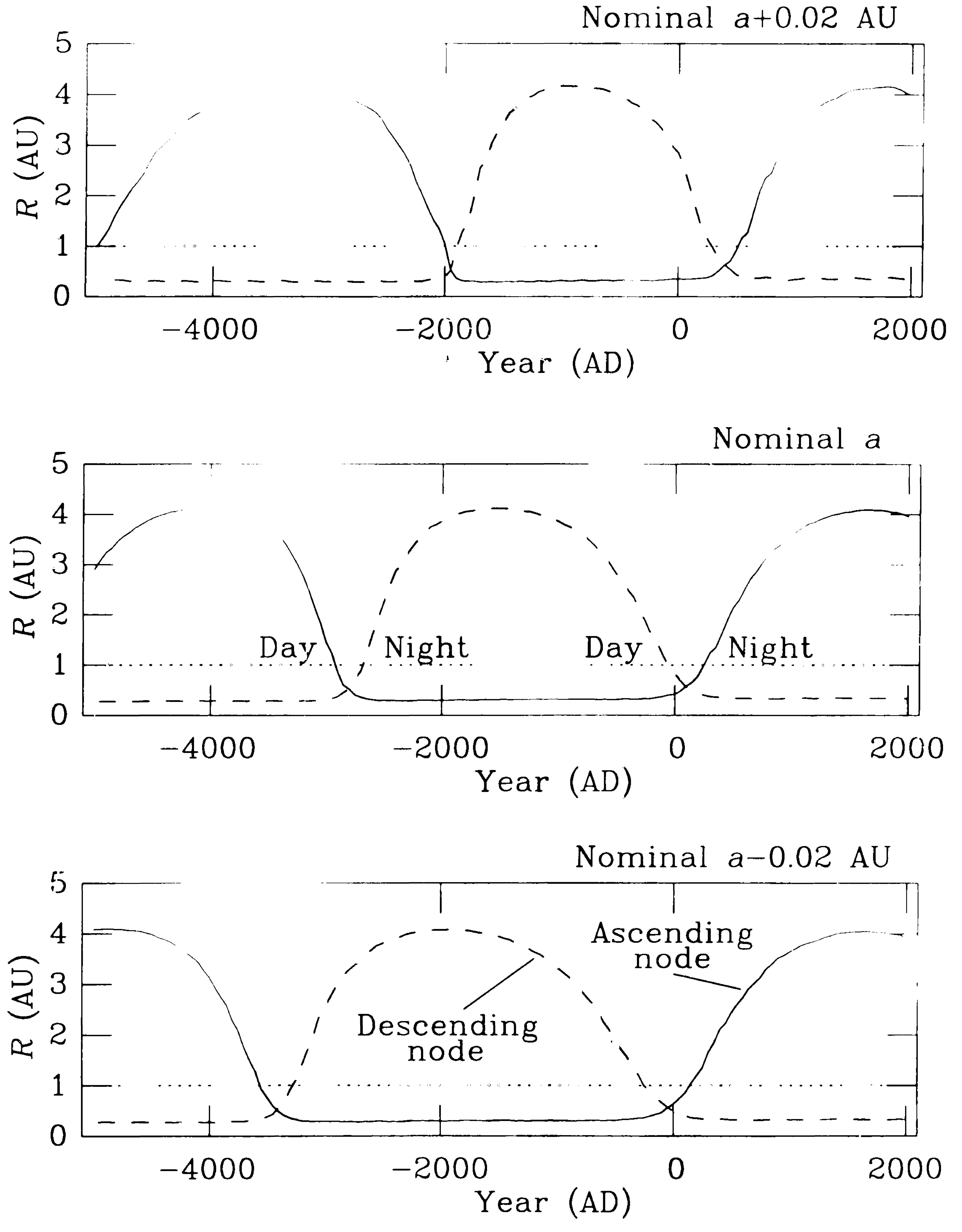

Figure 1. The variation of the heliocentric distance to the node (R) for the three orbits integrated in this work: the center panel used the nominal orbital elements of 2P/Encke for 1997 June 01 as start parameters, whilst the upper and lower panels used the same parameters except for the semi-major axis being incremented or decremented by 0.02 AU, respectively. The solid curve shows the values of R for the ascending node, the dashed curve representing the descending node. The horizontal (dotted) line at $R=1$ AU shows the location of the Earth. Meteor storms may occur in the epochs when either of the curves intersects that dotted line. Such intersections may occur on the pre-perihelion leg of the orbit, producing a nighttime storm (as indicated), or on the post-perihelion leg, producing a daytime storm (again, as indicated).

4. Conclusions

We have shown that if 2P/Encke has, over the past seven millennia, had an associated meteoroid/dust trail like that observed in the present epoch, then the meteor storms thereby produced when the comet/trail has had a node near 1 AU would have occurred in pairs of sets separated in time by ~300 yr: a 'set' of storms is a series of such events which recur every so many years (likely 10 yr for 2P/Encke, with the occasional miss due to the orbital period not being a simple divisor of an integer number of years) for so long as the node remains close enough to the terrestrial orbit for trail intersections to occur. It is not possible to say with any exactitude when the storms might have eventuated: the last pair were likely around 1 900 yr ago, with an uncertainty of several centuries, while the previous pair would have been about 4 700 yr ago with an uncertainty of almost a millennium. Each pair consists of one nighttime (pre-perihelion) and one daytime (post-perihelion) storm/shower, as shown in Fig. 1.

Backwards and forwards integrations of 2P/Encke variational orbits, and their consequences for meteor storm occurrence, are discussed in more detail by Steel and Asher (1996).

Acknowledgments. This work was supported by the Australian Research Council and the Department of Education, Employment and Training.

References

Babadzhanov, P.B., Wu, Z., Williams, I.P. and Hughes, D.W 1991, *MNRAS*, **253**, 69

Babadzhanov, P.B., Obrubov, Yu.V. and Makhmudov, N. 1990, *Solar Syst. Res.*, **24**, 12

Hasegawa, I. 1979, *Publ. Astron. Soc. Japan*, **31**, 257

Hughes, D.W. 1982, *Vistas Astron.*, **26**, 325

Kresák, Ľ. 1993, in *Meteoroids and their Parent Bodies*, J. Štohl and I.P. Williams, Bratislava: Astron. Inst., Slovak Acad. Sci., 147

Marsden, B.G. and Sekanina, Z. 1974, *A.J.*, **79**, 413

Nakano, S. 1994, *Minor Planet Circular* 23483

Quinn, T.R., Tremaine, S. and Duncan, M. 1991, *A.J.*, **101**, 2287

Sekanina, Z. 1991, *JRAS Canada*, **85**, 324

Sitarski, G. 1988, *Acta Astronomica*, **38**, 269

Steel, D.I. and Asher, D.J. 1996, *MNRAS*, in press

Steel, D.I., Asher, D.J. and Clube, S.V.M. 1991, *MNRAS*, **251**, 632

Sykes, M.V. 1988, *Ap. J.*, **334**, L55

Sykes, M.V. and Walker, R.G. 1992, *Icarus*, **95**, 180

Whipple, F.L. and Hamid, S.E. 1972, in *The motion, evolution of orbits, and origin of comets*, *IAU Symp. 45*, G.A. Chebotarev, E.I. Kazimirchak-Polonskaya and B.G. Marsden, Dordrecht: Reidel, 152

Yeomans, D.K. 1981, *Icarus*, **47**, 492