Comet and Meteor Associations: Some Observations Using the Meteor Orbits' Databases of the DMS

John Greaves [1]

1. 15 Borrowdale Walk, Northampton, NN3 6PW, United Kingdom

The photographic and video meteor orbit databases of the Dutch Meteor Society have been cross checked against a list of cometary orbits. Several previously unknown or little known associations are found, some possible associations are suggested, and some well known and lesser known associations are confirmed.

Introduction

The Dutch Meteor Society conducts multi-station photographic and video observations of meteors, and has done so now for over two decades. The databases for both the photographic and video programmes can be downloaded via anonymous ftp at the DMS website: `www.dmsweb.org.`
The author has downloaded these databases and cross correlated them against cometary orbits* using a relational database management program. Basically, each and every meteor orbit was compared against each and every comet orbit such that the former had to be within ± 10 degrees of the latter in all three each of inclination, ascending node and argument of perihelion, before being considered as even possibly associated. A visual comparison of the orbits was then made.
Although this sort of procedure is in no way statistical in nature, it is felt to be reasonably secure for the following reasons. Firstly, the positional indicators of a meteor orbit are relatively independently derived, with the ascending node Ω, determined by the time of the meteor, the argument of perihelion, ω being determined by the radiant's right ascension α, and the inclination, i, being determined by the geocentric velocity of the meteor (although right ascension and declination are also involved for this latter). As explained in Jenniskens *et al* 1997, i and Ω at least are completely independent parameters, whereas ω correlates with the perihelion distance, q, and eccentricity, e, correlates with the semimajor axis, a. q and e were not cross checked directly, as they define the *shape* of the orbit, which was to be inspected visually: indeed, e is not always usable, in any context, as many comets have parabolic rather than elliptical orbits, similarly a is rarely if ever quoted for comets.

Secondly, this method of investigation gave many confirmations thanks to the close agreement between meteor orbits for meteors identified with a particular stream, and the close agreement between the orbits for streams *already* well known to have cometary associations and the orbit of that particular comet. In more than one instance the method almost uniquely gave the *correct* cometary association for any particular meteor stream. Other comets were occasionally included in the cross correlation lists for these streams, but in cases such as the Leonids, Orionids and Perseids, the instances of correct cometary association far outweighed the incorrect ones. This even held true for minor streams of less well known association, such as the Monocerotids.

One very useful aspect of the DMS data is that each individual orbit is of high quality, with relatively small quoted errors. This allows results from an analysis to be more or less taken at face value, without the author having to continually take into consideration whether or not the data is accurately identified or reduced.

Table 1 lists the orbital details for the more interesting meteor and comet orbit associations, as detailed below.

Discoveries

1. Leo Minorids

As can be seen in table one, the meteors identified as *Leo Minorids* in the DMS databases have very similar orbital elements to both each other and the Comet of 1739. At first it seemed highly likely that this was an original discovery: the Leo Minorids are not a well known shower, and do not appear prominently in the literature.

However, a search conducted using the Articles and Abstracts service of the NASA Astrophysics Data System via adsabs.harvard.edu brought to light an article by McCrosky and Posen in 1959, which not only turned out to be the *discovery* article for the Leo Minorids, but also mentioned the likely association of Comet 1739 with this shower! They discovered the Leo Minorids during a study of meteor photographs taken with Baker Super-Schmidt cameras, and noted the similarity of their orbits with C/1739 at the same time, with details being given in their table II.

Little if any other details could be found from a literature search of the more mainstream journals, and officials at the DMS could not recollect having heard anything about any known cometary association for the Leo Minorids.

Consequently, it can be said that the DMS orbital data for the Leo Minorids has been instrumental in the confirmation cum rediscovery of a meteor shower-comet association that has lain mostly forgotten for forty years! (McCroskey and Posen do note that Denning (1925) had commented on a *possible* association between this comet and a *possible* shower radiant near to what are now known as the Leo Minorids: this comet-shower association has been a long time in coming of age!).

2. kappa Cygnids

This shower has been part of a successful campaign by the DMS aimed at characterising it better.

Although most of the elements in table 1 are not in too strict an agreement with the Comet of 1345, they are all reasonably quite close, and the element of possible coincidence is further reduced by that fact that no other comet comes close to fulfilling the criteria. Figure 2 shows the situation for the video orbits with respect to C/1345 O1, as viewed from the North Ecliptic Pole. A view from the ecliptic plane would show that the greatest difficulty is with the inclination. It should be noted, however, that this comet only has an approximate orbit, and indeed was not observed until a month before perihelion, when it was already nearly at perigee and lay in the Draco-Ursa Minor-Camelopardalis area of the sky.

This comet's apparition is quite an interesting one, considering its possible association with the kappa Cygnids, and the following description is based

Meteor/Comet	q (AU)	e	i	Ω °	ω °
Leo Minorids					
P92021	0,647	0,999	124,49	208,93	107,39
P95103	0,641	1,028	125,34	208,3592	107,34
V95414	0,6214	1,0017	125,6632	208,2784	104,43
V95465	0,5855	0,9973	126,1114	208,359	100,1
V95476	0,6136	0,9694	125,9707	208,3694	102,76
C/1739	0,6736	1	124,26	211,044	104,752
Kappa Cygnids					
P75001	0,998	0,661	29,72	130,4	196,69
P83002	0,974	0,646	26,03	137,0343	205,76
P85007	0,974	0,78	33,8	138,4235	204,28
P85029	0,955	0,705	41,51	139,3494	210,49
P85030	0,998	0,452	36,76	140,3861	197,92
P89021	1,003	0,685	34	140,3593	192,76
P93104	0,975	0,802	35,43	138,3478	203,95
P93117	0,982	0,833	37,85	139,3246	201,33
P93153	0,985	0,677	35,32	139,4163	201,55
P93293	0,985	0,815	36,37	140,2085	200,29
P93296	0,971	0,738	34	140,2249	205,45
P93308	0,963	0,765	37,09	140,3519	207,53
P93311	0,967	0,784	34,73	140,4056	206,21
P93325	0,98	0,541	29,78	141,2304	204,96
P93326	0,967	0,715	34,13	141,287	206,87
P93327	0,97	0,799	36,08	141,289	205,28
P94003	0,987	0,803	24,17	131,5175	200,19
P94006	0,896	0,873	25,51	134,4131	221,46
V93115	0,9806	0,6443	32,9606	143,1616	203,17
V93121	0,9764	0,7113	34,5389	143,204	203,93
V93135	0,9812	0,7104	36,3307	143,2538	202,29
V93143	0,9729	0,7239	33,7458	144,0795	204,9
V93145	0,9679	0,7126	36,514	144,0927	206,58
C/1345 O1	0,89	1	23	150	210
Northern Piscids					
P95100	0,39	0,918	5,5	208,3	285,7
V93204	0,429	0,797	9,5	205,7	286,5
V93215	0,433	0,716	2	205,7	290,7
V93230	0,432	0,784	6,3	205,8	286,8
V93247	0,359	0,793	2,9	205,8	296,5
V95411	0,503	0,853	5,7	208,3	274,2
MSSI41	0,338	0,763	4,9	198,4	301,9
MSSI46	0,298	0,833	5,3	198,4	303
MSSI49	0,355	0,719	2	198,4	302,8
MSSI4F	0,395	0,81	3,8	198,5	290,5
MSSI4R	0,35	0,803	5,4	198,5	297,4
MSSI4U	0,346	0,821	8,9	198,5	296,7
MSSIA2	0,369	0,709	9,7	201,1	301,3
MSSIR9	0,57	0,676	3,2	208,6	273,5
Lindblad31	0,399	0,797	3,4	199,1	290,8
C/1702 H1	0,647	1	4,4	193,3	309,6

Table 1: *Orbital Elements for Meteors and Comets.*
P=Photographic, V=Video database.

in part on dates given in Yeomans 1991, the calendar used being the Julian one (ie **not** Julian Date, but Julian Calendar), with other events being deduced from the comet's orbit.

Closest approach to the earth was on 31st July 1345, when the comet was only 0.05 AU distant, the ascending node was crossed around 3rd August with the comet only 0.06 AU from earth, and perihelion followed on 23rd August when the comet was 0.89 AU distant from the sun. The earth was therefore "downtail" of this bright naked eye comet (positively identified as a "broom star" with a roughly 6 degree tail by the Japanese on 2nd August) for a couple of weeks at least.

This is interesting in light of the fact that Jenniskens (1994) quotes the kappa Cygnids as being one of three meteor showers that are exceptionally broad in view of their high inclinations. His activity profile for this shower, given in the same paper, is also highly asymmetric on the pre-maximum side of the plot, although this could merely be due to observer bias, with pre-maximum kappa Cygnids liable to being observed serendipitously during observations of post-maximum Perseids.

Another intriguing, but no doubt circumstantial, aspect of the apparition is that the path of this comet took it within five degrees of the (suitably precessed) centroid of the DMS kappa Cygnid meteors' radiants. Remembering that the orbit for this comet is an approximate one and that it was already *past* Cygnus and Cepheus on the sky when first observed (thus allowing some leeway in its actual path when it was near the kappa Cygnid radiant), the author notes the following:

C/1345 O1 passed nearest the kappa Cygnid radiant 18 days prior to the current date of maximum (when the latter is expressed in the Julian Calendar), 8 days prior to a perigee in the Dra-UMi-Cam border area, 11 days prior to crossing the ascending node when it lay near Castor in the sky and 31 days prior to a perihelion in the direction of Leo. In other words, several significant events in this comet's orbit in relation to the Earth occurred very close to present day maximum. Although position on the sky is likely to be no more than coincidence, it should be noted that the path of this comet was long, fast and relatively "straight", and it only traversed particular areas of the sky. This is something that needs looking into by celestial mechanics of far greater competence than the author!

It would also be interesting to know if the kappa Cygnid meteor shower is prone to variability from year to year.

DMS	RA geo	DEC geo	V geo	Mv	DMS_ID
P95100	35,48	9,17	30,3	-1	Spo
V93204	35,6	4,12	26,1	5	S-Tau
V93215	34,55	11,43	23	4	S-Tau
V93230	34,41	6,92	25,4	4	S-Tau
V93247	35,48	16,89	26,5	5	N-Tau
V95411	30,98	5,82	25,9	5	S-Tau
IMO	26	14	29		

Table 2: *Possible Northern Piscids in the DMS Databases*

3. Northern Piscids

The first problem here lies in the actual identification of these objects! As can be seen in table 2, the original DMS identifications of these objects are predominantly as Southern Taurids, with one possible Northern Taurid and one sporadic meteor. The IMO details for the Northern Piscids allow possible identification of these meteors with this shower, although other interpretations are still possible. Both the North Taurids and the South Taurids have similar geocentric velocities to the Northern Piscids, 29.2, 27.0 and 29.0 kms^{-1} respectively, and all the showers are ecliptic ones with long, overlapping, periods of activity. The meteor dates are sufficiently distant from the shower maxima for drift to resolve any radiant problems, with right ascensions favouring the Northern Piscids, but declinations favouring the Taurid streams.

Accordingly, table 1 includes details of eight meteor orbits from the Japanese Meteor Society Section Working Group's database (available via www.imo.net) which the author has also identified as being possible Northern Piscids.
Interestingly, most were also observed in 1993, with those marked MSSI4*x* occurring on 11/10/1993.
Equally, all the orbits are very similar, but here lies another problem. Except for DMS V93247 and MSSIA2 the ascending nodes of these meteors are actually catalogued at 180 degrees *less* than stated here. Now, apparently, the disposition of the ascending node is dependent upon whether or not a meteor's vector crosses the ecliptic from south to north, or north to south, once the Earth's vector has been removed (de Lignie, M, *pers. comm.*). Identification of the relative situation can be problematic for ecliptic constellations, and the author prefers the view that these meteors should indeed have nodes equivalent to their solar longitude, which consequently also effects the argument of perihelion (which is defined as the distance of the longitude of perihelion from the ascending node).

This decision has not been made on a purely arbitrary basis. Gary Kronk's descriptive catalogue of meteor orbits is now, unfortunately, out of print;

fortunately, however, he maintains it as a web resource based at www.amsmeteors.org, and reference to the data on the Piscids reveals the following. The Piscids are split into two branches, the Northern and Southern. Kronk gives good evidence that the latter, with maximum in mid August, may not actually exist to any great extent, with most previously identified members actually belonging to other streams.

He then notes that the lesser known Northern branch has had increasing evidence of its existence, with Lindblad describing a stream 31 in 1971 that had an orbit as shown in table 1. The similarity between this orbit and the "180 degree position rotated" orbits of the meteors in table 1 is evident, and therefore the author presents these orbits as a valid interpretation. Interestingly, Kronk also gives a radiant declination more in line with these presumed Northern Piscids than the IMO value is.

The "bonus" to this interpretation is that it is now possible to associate a comet, and only one comet, with the *Northern Piscid* stream. This comet is C/1702 H1 = C/1702II and its elements are given in table 1. It can be seen that the elements are all in fair agreement, and although in relative terms the perihelion distance is nearly twice that of the perihelia for the meteors, in absolute terms the difference is not at all great.

More intriguing aspects of the Northern Piscids and C/1702 H1 situation are the parallels with the case of the kappa Cygnids and C/1345 O1!

C/1702 H1 also approached the Earth to within 0.05 AU, but in this instance the event was a post-perihelion one. Perihelion was on 17th March 1702, the node was traversed around 4th April, and perigee was on 20th April 1702. The author notes that the nodal crossing of 4th April is very nearly six months prior/posterior to the current shower maximum of 12th October, and suggests this may explain the values for the ascending nodes in the databases, as mentioned above. The motion was also south to north at that time. With perigee being post-perihelion in this instance, and the low inclination placing the orbit near the plane of the ecliptic, the earth on this occasion would have spent some time *uptail* of the comet: probably for about a week to a fortnight from the look of the orbit.

Another curious situation also applies. C/1702 H1 showed considerable motion along a set path upon the sky for the six to eight weeks prior to closest approach, and six weeks prior to perigee passed a point more or less central to the radiant positions of the objects identified as possible Northern Piscids by the author! C/1702 H1 has an orbit that is far better determined than C/1345 O1, and the author would be very interested to learn whether there is any meaning to such relationships.

Finally, it should be noted that the Northern Piscids, if mentioned at all, are usually noted as being associated with an "Encke ecliptic complex", along with various Taurid streams. The author notes that there is a tendency to "lump" all showers near in radiant position and activity date to an "Encke ecliptic complex", in a similar manner to other Winter showers near the Orionids' radiant being associated with Halley. An association of comet 2P/Encke with the Northern Piscids would obviously affect the above conclusions, but the validity of "ecliptic complexes" both in general and in specific instances are matters both currently beyond the author's capabilities and the remit of this article.

Ecliptic showers

1. alpha Capricornids

The alpha Capricornids are well characterised by the following orbit for DMS P92009: q = 0.61 AU, e = 0.84, i = 8.3°, Ω = 131° and ω = 263°, whereas the periodic comet 101P/Chernykh's 1978 orbit was: q = 2.57 AU, e = 0.59, i = 5.7°, Ω = 135° and ω = 266°. The similarity is not great, especially with respect to perihelion distance, but the alpha Capricornids are a very broad stream of near Ecliptic inclination. Consequently any putative parent comet that is also of low inclination need not necessarily be of a common perihelion distance for the earth to spend a long time in its orbital stream, so long as that perihelion distance is greater than that of the meteor shower in question, and probably also that the orbit is not parabolic. Such a situation could lead to a pre-maximum biased asymmetry in the activity profile of the shower if the eccentricity of the comet orbit was greater than that of the Earth's (usually the case).

However, the main reason for including the alpha Capricornids is that in the cross correlation of meteor orbits against comet orbits, nearly every meteor orbit tallied with each of the 1978 and 1992 101P/Chernykh orbits. Despite similar results for all new comet-meteor associations mentioned in this article, none were as impressive as in this case. It could be thought that this was a consequence of the orbit lying near the ecliptic, in which case it has to be mentioned that despite many comets having orbits in the plane of the ecliptic, 101P/Chernykh was virtually the only one that fulfilled the three way criteria of ascending node, argument of perihelion and inclination, and for every identified alpha Capricornid! Further, lessening of the criteria restrictions (by increasing the inclusive ranges of the parameter) failed to increase the number of comet candidates.

Finally, however, on the alpha Capricornids, figure 5 has to be included. It shows the DMS photographic alpha Capricornids with orbits having aphelia within Jupiter's orbit and the orbit of the Near Earth Object 4179 Toutatis as viewed from the North Ecliptic Pole. Whilst immediately pointing out that although the orbit of 4179 Toutatis has an inappropriate orbital inclination of barely half a degree, it is interesting to think of this asteroid being the biggest meteoroid anyone has ever seen!

2. Northern iota Aquarids

Only two Northern iota Aquarids are listed in the DMS database, the following being the orbital elements for DMS V93165: q = 0.38, e = 0.75, i = 8.1°, Ω = 145° and ω = 297°, whilst Comet Daniel 1907 IV had the orbital elements q = 0.51, e = 0.999, i = 9.0°, Ω = 144°, and ω = 294°. Although the shower pre-dates the comet, with the Northern iota Aquarids being known from before 1907! However, the orbit of Comet Daniel 1907 IV is just barely elliptical, and suggests a periodic comet of nearly 9000 years period, which could be even less given the uncertainties when the eccentricity approaches 1.0.

Interestingly the comet notes in a 1908 copy of the Journal of the British Astronomical Association (JBAA 18, 1, 1908) quotes one Herr Kritzinger as suggesting that a meteor shower could occur on 12th September 1907 when the orbit of Comet Daniel 1907 IV passed near Earth. No such shower was seen. The notes go on to mention a known September shower with a radiant in agreement with this comet's orbit, but strangely fails to name the shower! The North iota Aquarids are currently characterised by a maximum in late August, not September, which does not clarify matters. Comet Daniel 1907 IV had a path that traversed the positions of the DMS North iota Aquarid meteors in April 1907 and it is slowly dawning on the author that the fact that meteor orbital elements such as i and q are dependent on radiant position, such relations between meteor orbits and associated comets are bound to arise!

Confirmation of known comet-meteor associations.

Of course, the meteor orbits' databases of the DMS contain many orbits which amply confirm the situation with respect to already known associations of comets and meteor showers, whether major or minor showers, as exemplified by the following list:

Comet	**Shower(s)**
1P/Halley	*Orionids, ε Geminids*
8P/Tuttle	*Ursids*
55P/Tempel-Tuttle	*Leonids*
109P/Swift-Tuttle	*Perseids*
P/Thatcher (1861I)	*Lyrids*
P/1917 F1 Mellish	*Monocerotids*
C/1491 Y1 = C/1491I	*Quadrantids*

The final association on the list, that of the Quadrantids (more appropriately known as the Boötids on the Continent), is noted as dubious in Jenniskens *et al* (1997), but it is interesting to note that it resulted from the same procedure used to confirm the other more accepted associations. Further, many of the Quadrantid-Boötid orbits in the DMS database each individually fitted well with the orbit of C/1491 Y1. However, it is equally interesting to note that another comet that was matched by many of these meteor orbits is C/1939I Kozik-Peltier, a comet not mentioned in association with the Quadrantids in Jenniskens *et al* (1997).

A cross correlation was also undertaken between meteor shower orbits in the DMS databases and asteroids with perihelion distances within 0.5 AU of the Earth's. The only certain and readily evident association was, of course, the Geminid meteor shower and *3200 Phæthon*, which again could be considered a confirmation by the DMS dataset.
There are some comet-meteor associations which are conspicuous by their absence from the above list. The best example of these would be 2P/Encke and the Taurid complex. There is a very good reason for this: the current meteor orbits of such showers are thought to have either evolved from their original orbits to the current ones, due mainly to their low inclinations making them ecliptical objects, or conversely, the meteor orbits have remained more or less the same whilst the parent comet's orbit has undergone evolution.
Thus, when using any method based on close similarity of current orbits, associations of a nature akin to that between the Taurid stream and 2P/Encke are unlikely to be found. They are simply not within the context of such methods.

Esoterica

1. beta Cygnids

In an alert from the IAU C-22 Pro-Am working group P. Jenniskens made notification of a possible beta Cygnid shower around the 1997 apparition of 103P/Hartley 2, suggesting that observation of any possible shower from this comet would assist in determining how meteoroid orbits vary in relation to the varying orbits of their parent comets, as 103P/Hartley 2 had an orbit change between its 1991 and 1997 apparitions.

A search through the entirety of both the photographic and video orbit databases of the Dutch Meteor Society revealed only one possible candidate beta Cygnid, thus **DMS P88035**:
RA 299.16°, Dec +41.05°,
V_{geo} 11.9 kms^{-1}, Date 3.8 Nov (1988)
which compares well with the following details given in the alert, attributed to Yeomans:
RA 295.6°, Dec +31.3°,
V_{geo} 17 kms^{-1}, Date 3.4 Nov

Object	T	q	e	i	Ω °	ω °
103P	5,2 6 1985	0,951	0,720	9,252	226,836	174,836
103P	22,0 12 1997	1,032	0,700	13,619	219,954	180,721
P88035		0,992	0,587	15,630	221,748	179,670

Table 3 : *1995 and 1997 orbit of 103P/Hartley2 and DMS P88035*

The resultant orbit as viewed from the North Ecliptic Pole, shown relative to the 1985 orbit of 103P/Hartley 2, is shown in figure 6. The data in table 3 represent the 1985 and 1997 orbits of 103P/Hartley 2 (the 1991 orbit is little different from that of 1985), plus that of P88035.

As can be seen, the meteoroids orbit has more in common with that of the *latest* orbital elements for 103P/Hartley 2, despite in fact occurring at a time more contemporaneous with the *1985/91* elements. The meteoroid had a near bolide absolute magnitude of -5, which is more suggestive of fresh cometary material than of an object that has been present in a meteoroid stream for quite some time, and thus subject to a collisional history. However, this could just be a sparse stream with little interaction between constituent members, something possibly reflected in the rarity of these meteors! Another point of interest is that the meteor occurred whilst the comet was near *aphelion*.

Conclusions

Using a relational database management package to cross correlate comet and meteor orbits based on parameter ranges for the criteria of orbital inclination, ascending node and argument of perihelion, has proven to be a successful method of categorising comets associated with meteor streams. Several well known, and some not so well known, associations have been confirmed by this method, including that of the little known Leo Minorid shower and C/1739. Evidence of consistency for the method was provided by the fact that such associations were either unique in terms of the comet actually identified, or said comet was the predominant object in the list.

In certain instances the situation was not clear, and in those cases a visual inspection of the comet orbit relative to the meteor orbit(s) is useful. If the perihelion distance is also very similar between comet and shower meteors then the association is almost beyond doubt, yet agreement between them for this parameter is not necessarily as evident as for the above mentioned factors. In some very few instances a small number of meteoroid orbits in tandem with either more than one candidate comet or a comet whose orbit is only approximately known, caused the method to be inadequate, and a more statistical approach is probably in order. Of course, another solution would be to obtain more data for that particular shower, or the inclusion of data from other databases.

The author recommends the Northern Piscids as a shower whose nature and cometary association are on the edge of being characterised with the currently extant data, and could be well defined with only a little more work in regard of more observations about its maximum on 12th October. This time of year lies a little prior to the peak activity of more traditionally observed showers, and the contemporaneous Giacobinids are almost opposite on the sky, so it could simply be an overlooked shower, as well as its members possibly being confused with early Taurids of various sorts.

Finally, the DMS databases prove themselves to be highly useful and interesting datasets of high internal quality, and the members of that organisation should be justly proud of their efforts. The author greatly appreciates the fact that this organisation sees fit to make its data readily available to others for analysis.

Acknowledgements

* The comet data in this article is from an electronic dataset contained on the well known planetarium software Guide 7.0 CDROM by Project Pluto, which has a webpage at www.projectpluto.com.

Hans Betlem, Marc de Lignie and Marco Langbroek of the Dutch Meteor Society for advice and information on matters meteoric and Steven Gregory for access to web and email facilities, without which large gobbets of data would not have been accessible to me.

References

[1] Denning, R. M., “*Hutchinson’s Splendours of the Universe*”, New York, 1925, p431.

[2] Jenniskens, P., *Astron. Astrophys.*, **287**, 990 (1994)

[3] Jenniskens, P., Betlem, H., de Lignie, M., Langbroek, M., van Vliet, M., *Astron. Astrophys.*, **327**, 1242 (1997)

[4] McCroskey, R. E., and Posen, A., *Astronomical Journal*, **64**, 25 (1959)

[5] Yeomans, D. K., “*Comets: A Chronological History of Observation, Science, Myth and Folklore*”, John Wiley & Sons, New York, 1991: p 402

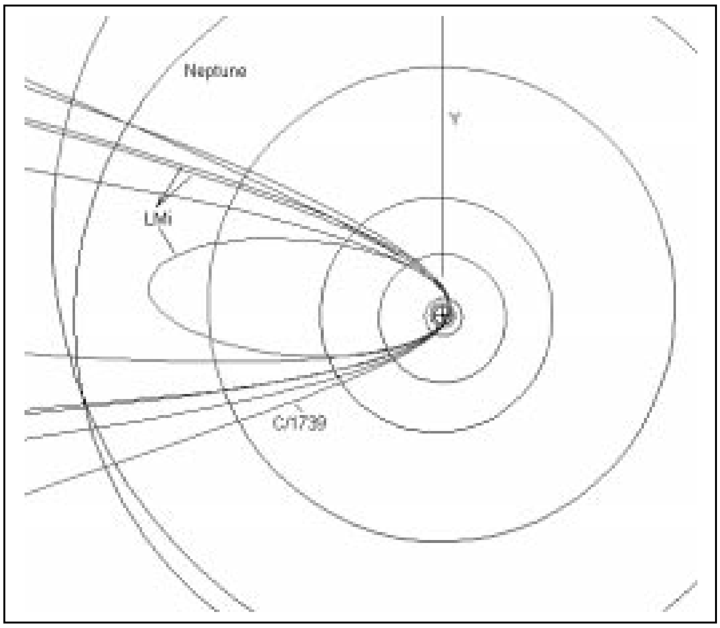

Figure 1: *The orbits of DMS Leo Minorids and C/1739 as viewed from the North Ecliptic Pole, with the orbits of the planets also shown and the direction of the First Point of Aries marked.*

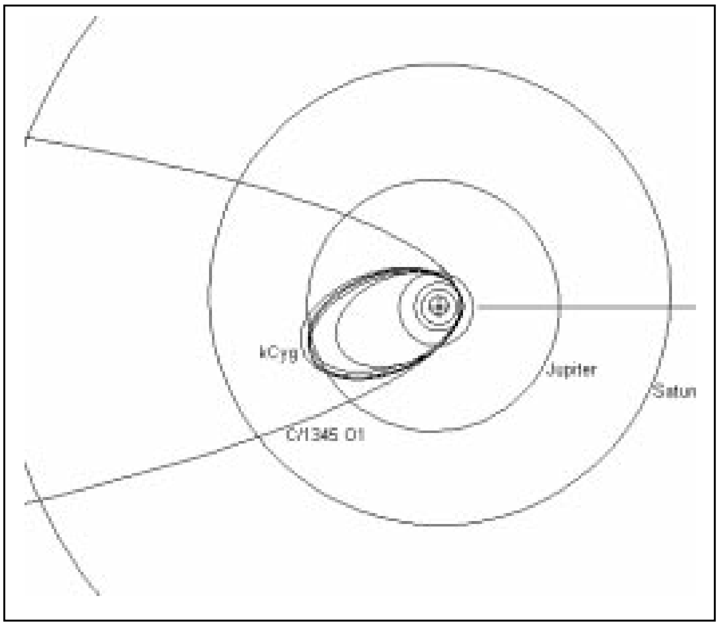

Figure 2: *The orbits of DMS kappa Cygnids and C/1345 O1 as viewed from the North Ecliptic Pole, with the orbits of the planets also shown and the direction of the First Point of Aries marked. Note how the meteor orbits are truncated at the orbit of Jupiter,*

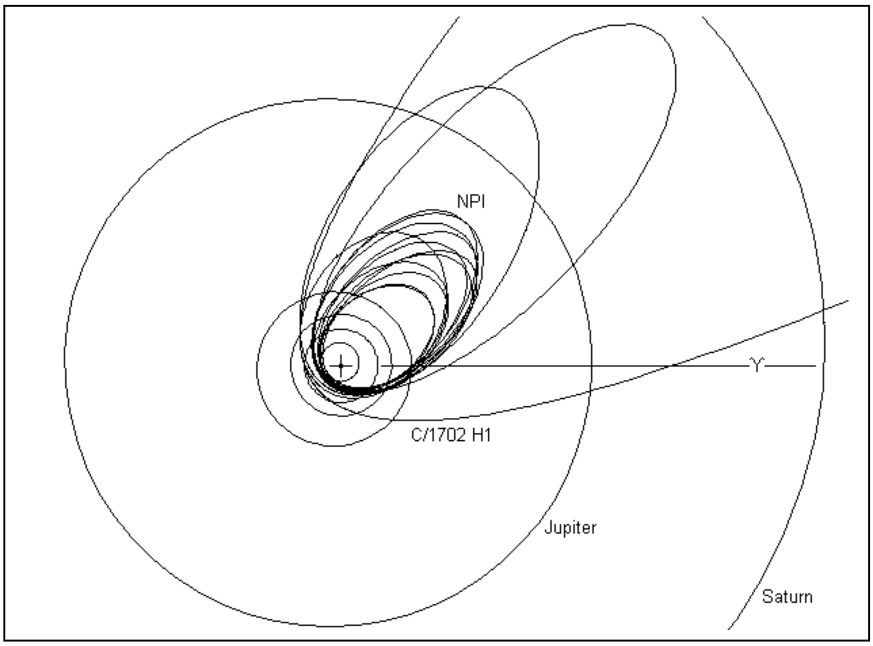

Figure 3: *The orbits of Northern Piscids and C/1702 H1 as viewed from the North Ecliptic Pole, with the orbits of the planets also shown and the direction of the First Point of Aries marked),*

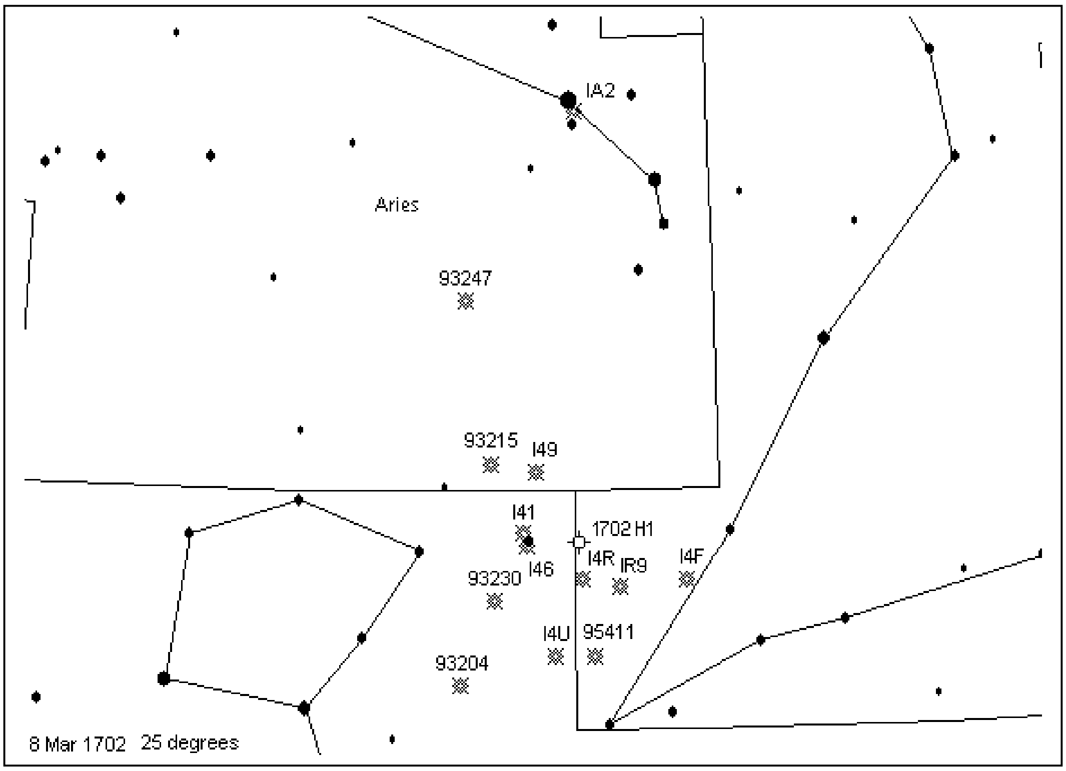

Figure 4 (above) : *The radiant positions of the presumed Northern Piscid meteors and the position of C/1702 H1 on 8th March 1702,*

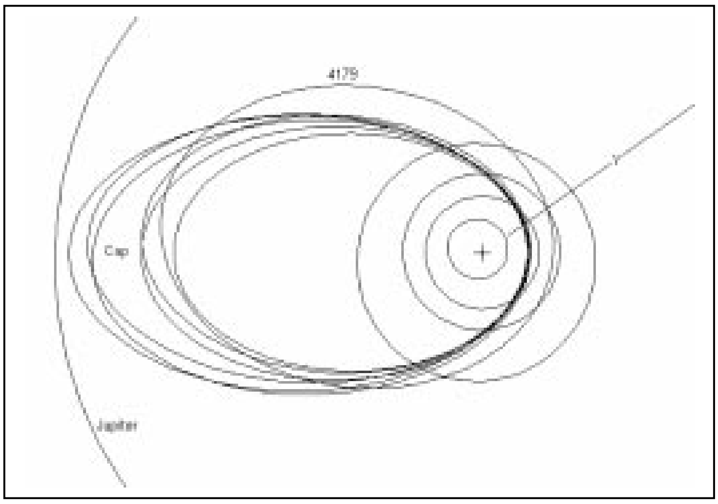

Figure 5: *The orbits of DMS photographic alpha Capricornids and 4179 Toutatis as viewed from the North Ecliptic Pole with the orbits of the planets also shown and the direction of the First Point of Aries marked. It should be noted that the alpha Capricornids are inclined by about 10°, whilst 4179 Toutatis lies almost in the plane of the Ecliptic, Note also how the meteor orbits are truncated at the orbit of Jupiter.*

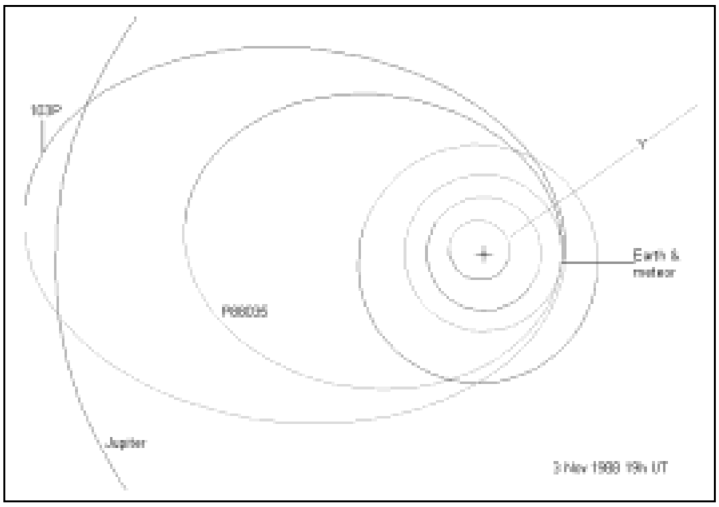

Figure 6: *The orbits of DMS photographic meteor 88035 and the short period comet 103P/Hartley 2 as viewed from the North Ecliptic Pole, with the orbits of the planets also shown and the direction of the First Point of Aries marked. The positions pointed to by lines mark the actual positions of the Earth, comet and meteor at the time the latter was seen.*