SOME REMARKS ABOUT THE APHELION DISTRIBUTION OF LONG PERIOD COMETS ON THE SKY

Rhea Lüst
Max-Planck-Institut für Physik und Astrophysik
Institut für Astrophysik
Karl-Schwarzschild-Str. 1
D-8046 Garching b. München, FRG

ABSTRACT. The possibility of an observational biasing in the distribution of cometary aphelia is confirmed by statistics. Furthermore, the tendency of aphelia to form clusters and their distribution with respect to different coordinate systems is investigated.

1. INTRODUCTION

The evolution of Oort's cloud has repeatedly been discussed in the past by several authors (e.g. Hasegawa 1976, Oja 1975, Tyror 1957). The dynamical influence of stellar passages or dense interstellar clouds may also provide clues for the origin of the comets (Biermann, 1978). The obvious fact that the aphelion distribution of distant comets on the sky is not really isotropic, but shows a tendency to form clusters, raised the question whether such clusters might still reflect dynamical perturbations in the past.

Arguments that one of these dense clusters might result from a stellar passage some million years ago have recently been given by Biermann, Huebner and myself (1983). The present contribution shall present the statistical basis for the former investigation. Moreover, some interesting results came out which shall be outlined here.

2. CATALOGUES

For this kind of investigation it is necessary to separate those comets coming from Oort's cloud for the first time into the inner planetary system from the rest. It was possible to do this by using a catalogue of 200 long period comets compiled from high precision orbital elements by Marsden, Sekanina and Everhart in 1978. This catalogue contains the original reciprocal semimajor axes (corrected for the perturbations of all planets), together with their osculating and future values. With the data of this catalogue it became for the first time possible to classify the long period comets reliably according to their "age", which means according to the number of their passages through the inner solar system. There

A. Carusi and G. B. Valsecchi (eds.), Dynamics of Comets: Their Origin and Evolution, 105–111.

https://doi.org/10.1017/S0252921100083834 Published online by Cambridge University Press

exist earlier calculations by various authors (e.g. Hasegawa 1976, Oja 1975, Tyror 1957) similar to this one. However, a reliable classification was not yet possible at that time. Therefore the results of the different investigations do not agree in their details with ours or with each other, though some general trends are common.

The Marsden-Sekanina-Everhart catalogue has last year been extended by adding 25 further comets (Everhart and Marsden 1983). Since we have counted three comets of the Kreutz group - which belong to the "old" comets - as one, our sample comprises 223 comets, which we divided into 3 subgroups according to their reciprocal original semimajor axes, Tab. I).

TABLE I

	N	a[a.u.]	1/a[10^6a.u.$^{-1}$]	P[y]	N_P
New comets	89	$>10^4$	<100	10^6-10^7	1
Interm. c.	69	$10^4>a>400$	100<1/a< 2500	8000-10^6	$\lesssim$ 20
Old comets	65	400>a>40	2500<1/a<25000	250-8000	multiple

The criteria for a comet to be regarded as "new", "intermediate" or "old" are stated in the Marsden-Sekanina-Everhart catalogue. They depend somewhat on the perihelion distances. The periods of the "intermediate" comets range between about a few thousand and one million years, while the periods of the "new" comets are in the range of a few million years. This is also the time scale for stellar passages.

For these three groups the aphelion directions in the galactic, the equitorial and the solar apex coordinate systems were calculated by using the orbital elements given in Marsden, 1982. By this we wished to find out whether the distributions might show symmetries with respect to one of these reference systems. The computerized equal area plots give a first impression for this, though carful statistical work is necessary for a meaningful interpretation (Fig. 1).

All former investigators have stated a larger number of aphelia on the southern celestial hemisphere in all three coordinate systems, and it has been proposed that this might at least partly be caused by an observational biasing due to better observing facilities on the northern hemisphere of our globe. Since conclusions about the dynamics of Oort's cloud should of course rest on an unbiased sample, the question of an observational influence was one aim of this work. Secondly we tried to verify the tendency for clustering. Furthermore, the distribution in the galactic system which shows pronounced symmetries towards the galactic plane was discussed. In the following, these questions are discussed in more detail.

3. EQUATORIAL COORDINATES, OBSERVATIONAL BIASING

The equatorial system is appropriate for discovering a north-south biasing. The declination of the aphelion or - which is equivalent - the heliocentric perihelion influences among other orbital parameters the

https://doi.org/10.1017/S0252921100083834 Published online by Cambridge University Press

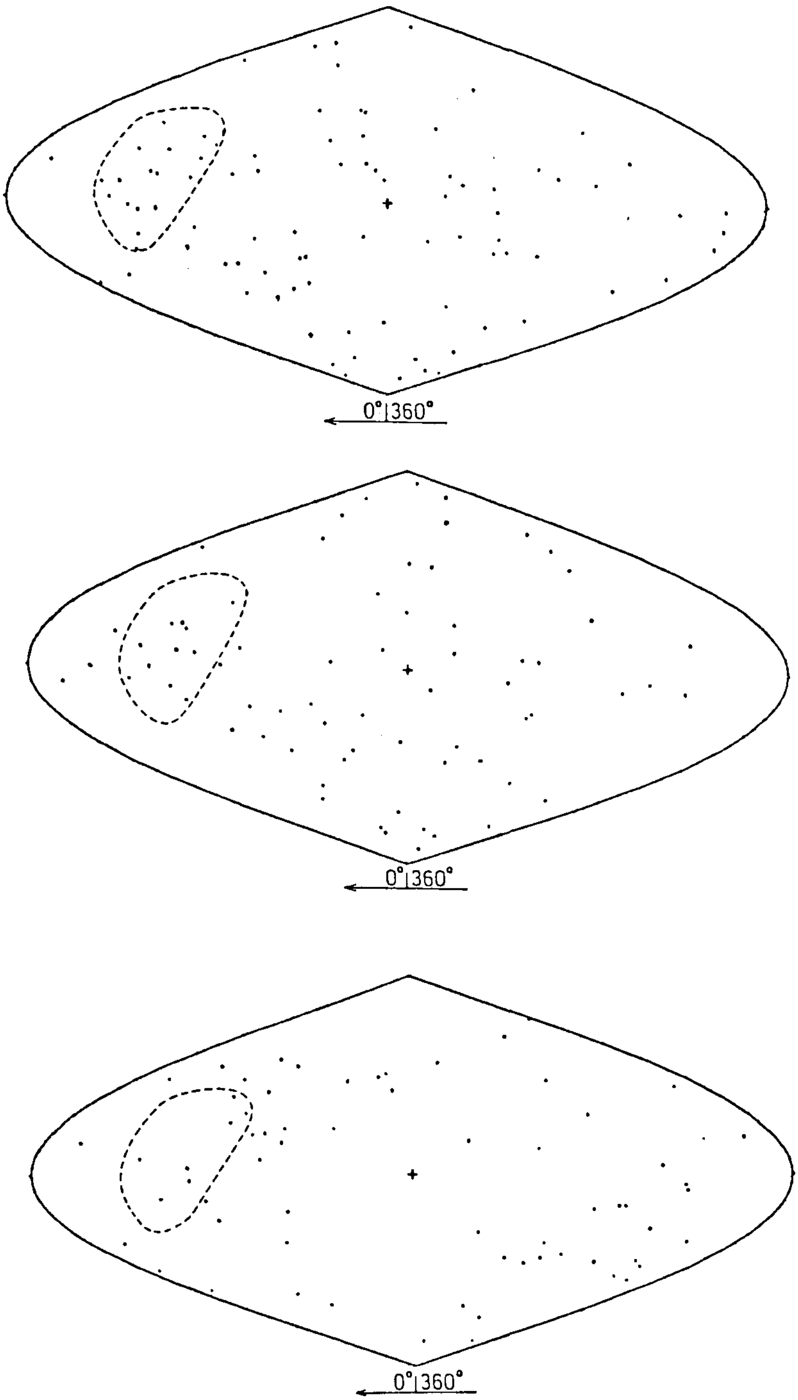

Fig. 1. Distribution of 89 "new", 69 "intermediate" and 65 "old" comets in galactic coordinates.

https://doi.org/10.1017/S0252921100083834 Published online by Cambridge University Press

detectability of a comet. The relation is, however, rather complex. So the intrinsic brightness determines together with the perihelion distance the time, or more specifically the numerical anomaly at detection. Furthermore, the position of the earth in its orbit is of major importance (see e.g. Everhart, 1967). But on the average, the best period of observation will roughly be around the date of the perihelion passage, and therefore the declination of the perihelion is an important parameter. However, the geocentric and heliocentric perihelia can differ widely from each other, while the aphelia are identical. For the visibility the geocentric positions are relevant. The maximum angle between the geocentric and the heliocentric perihelion is 90° for $q = 1$ a.u. and decreases rapidly with increasing perihelion distances. It is already less than 20° for $q > 3$ a.u.. For comets inside the earth's orbit, the two positions are practically not correlated. This weakens the correlation between the aphelion direction and detectability, especially for comets which come close to the sun. On the other hand, this fact offers a possibility to detect an observational biasing by separating the comets according to their perihelion distances.

TABLE II

Declin.	$\delta<-60^{\circ}$	$-60^{\circ}<\delta<0^{\circ}$	$0^{\circ}<\delta<60^{\circ}$	$\delta>60^{\circ}$	
Sky area %	6.7	43.3	43.3	6.7	100
Total	24	94	93	12	223
$q < 1$	8	32	40	8	88
$q > 1$	16	62	53	4	135
New	10	37	37	5	89
Intermed.	9	29	26	5	69
Old	5	28	30	2	65

TABLE III

Declin.	$\delta>40^{\circ}$	$40^{\circ}>\delta>0^{\circ}$	$0^{\circ}>\delta>-40^{\circ}$	$\delta<-40^{\circ}$
Sky area %	18	32	32	18
Observed	16	31	38	4
Isotropic distrib.	16	28,5	28,5	16

Tab. II contains comet numbers with aphelia in the two polar caps $|\delta|>60^{\circ}$ and in the northern and southern hemispheres for the two groups with small and large perihelion distances. We found 4 times as many aphelia around the south pole than around the north pole among the comets with perihelia outside the earth's orbit, and the equal numbers for the $q < 1$ group. The same trend is demonstrated by the numbers in the remaining two regions south and north of the equator. For the complete sample we got equal numbers (94:93) in these two regions. With other words: The asymmetry is exclusively caused by the

https://doi.org/10.1017/S0252921100083834 Published online by Cambridge University Press

regions around the poles. The same behavior is qualitatively found in the separated groups of the new, the intermediate and the old comets. As a further test we have calculated the geocentric perihelia for the 89 new comets, Tab. III. As was expected, the biasing is even more pronounced here. These results point very strongly to a north-south observational biasing.

4. GALACTIC COORDINATES, CLUSTERING

In galactic coordinates, the distribution of the aphelia indicates some interesting trends depending on the "age" of the comets. The trends are most pronounced among the primordial comets, they are still there among the "intermediate" comets, while the "old" comets show a different distribution.

The histograms of Fig. 2 demonstrate these findings in more detail.
a) A belt around the galactic equator 20° wide is very poorly populated (see also Fig. 1, dotted lines). This is even more evident if we omit the hatched areas which belong to a dense cluster of comets in a limited longitude space between 180° and 230°. There are only 4 aphelia out of 158 "new" and "intermediate" comets in a belt with an area of 1/7 of the total sky area. Statistical calculations give a binomial probability frequency for this to happen of about $3\ 10^{-6}$ and a deviation from the mean which is about 4 times the standard deviation. These numbers are definitely meaningful. They are also in line with a recent investigation of Byl (1983) on the influence of the galactic gravity field. The sample of the "old" comets does not show any deviation from a random distribution.
b) On the other hand, the apparent deficiency around the two poles has not been proven meaningful by statistics. The total number of aphelia in both polar caps is about 1/2 of the statistical mean. Furthermore, in this case the "old" comets do not differ generally in their behavior from the more primordial ones.
c) This higher population in the mid-latitudes among the "new" comets, especially in the south, is mainly caused by the distribution of several clusters. Though a classification into clusters is somewhat arbitrary, one can locate about 5 denser regions, four of which happen to lie on the southern galactic hemisphere. The densest cluster which has recently been discussed in detail by Biermann et al. (1983) is encircled by a dashed line in Fig. 1 and lies north of the galactic plane.

5. APEX COORDINATES

The distribution in the apex system shows an accumulation in the hemisphere of the antapex. This is mainly the result of the afore-mentioned dense cluster which is located between -60° and -20° latitude. The antapex region shows only a slight increase of aphelia which is, however, statistically not significant.

https://doi.org/10.1017/S0252921100083834 Published online by Cambridge University Press

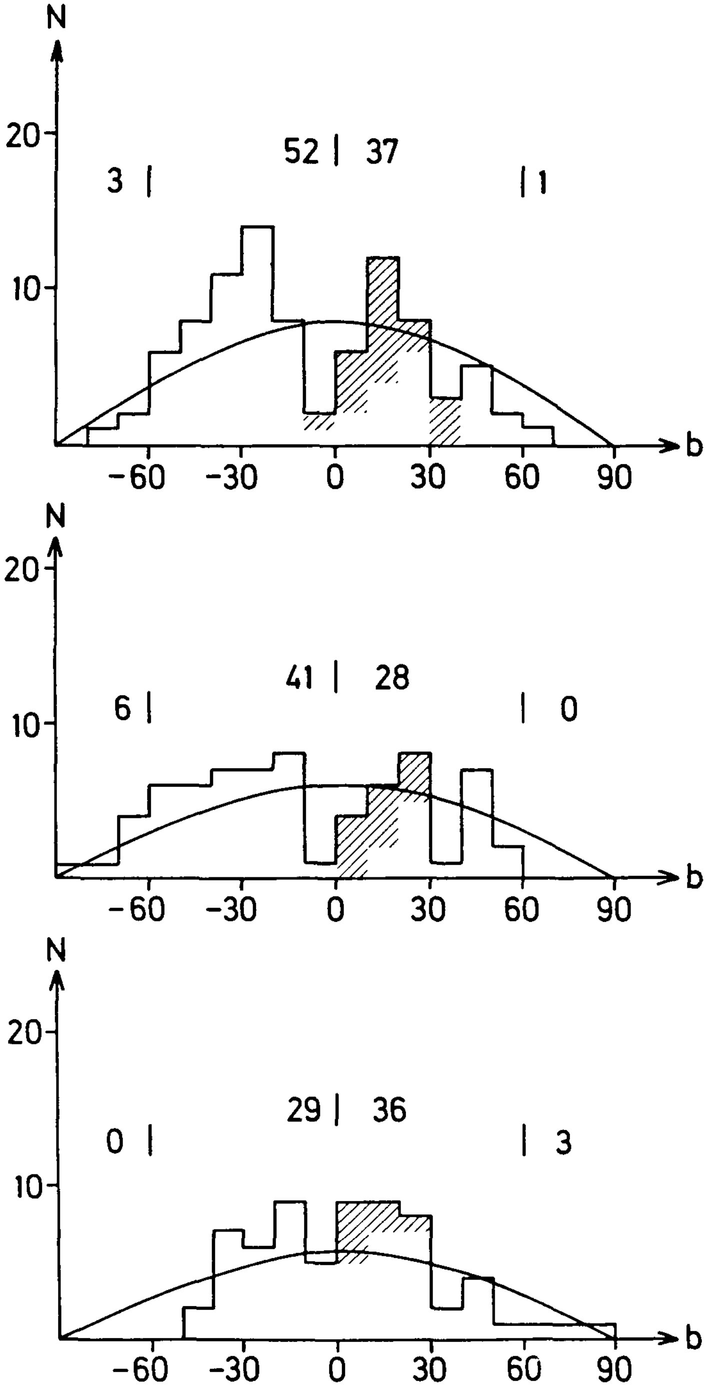

Fig. 2. Aphelion numbers of 89 "new", 69 "intermediate" and 65 "old" comets versus galactic latitude.

https://doi.org/10.1017/S0252921100083834 Published online by Cambridge University Press

6. SUMMARY

The investigation has shown that the possibility of observational biasing has to be taken into account in any conclusion about an anisotropy in the distribution of long period comet aphelia. The numbers point very strongly to the fact that comets with aphelia in high southern declinations are more easily detected that those coming from the region near the north pole. Such an effect should gradually decrease in the future with the better observing facilities on the southern hemisphere of the earth. Therefore, future investigations of this problem are desirable to verify the reality of such a bias.

Furthermore the statistics confirm the tendency of the aphelia to form clusters. The clustering is especially pronounced among the "new" comets coming from the outer regions of Oort's cloud. This is compatible with the conception that these comets have been injected into the inner solar system by the influence of stars which have encountered the solar system some million years ago. Moreover the aphelia seem to avoid a narrow zone around the galactic equator. Though the numbers point to a real effect, it is not yet clear which mechanism might be responsible for it.

REFERENCES

Biermann, L., 1978 in Astronomical Papers dedicated to Bengt Strömgren, ed. A. Reiz and T. Andersen, Copenhagen Univ. Obs., p.327.

Biermann, L., Huebner, W.F., Lüst, Rh., 1983, Proc. Natl. Acad. Sci. USA **80**, 5151.

Byl, J., 1983, The Moon and the Planets **29**, 121.

Everhart, E., 1967, Astron. J. **72**, 716.

Everhart, E. and Marsden, B.G., 1983, Astron. J. **88**, 135.

Hasegawa, I., 1976, Publ. Astr. Soc. Japan **28**, 259.

Marsden, B.G., Sekanina, Z., Everhart, E., 1978, Astron. J. **83**, 64.

Marsden, B.G., 1982, Cat. of Com. Orbits, 4th Ed., Smiths. Astroph. Obs. Cambridge, Mass.

Oja, H., 1975, Astron. Astrophys. **43**, 317.

Tyror, J.G., 1957, Mon. Not. Roy. Astr. Soc. **117**, 370.

DISCUSSION

Weissman: Do you still believe that these concentrations of aphelia are caused by recent passages of stars through the Oort cloud in that direction, as stated in your paper?

Lüst: Yes, I think that good evidence has been given in various papers for this possibility, (e.g. Biermann et al., 1983).