ALTERNATIVE EXPLANATION FOR THE CLUSTERING OF LONG-PERIOD COMET APHELION DISTANCES. J.B.Murray, Centre for Earth, Planetary, Space and Astronomical Research, The Open University, Milton Keynes MK7 6AA, U.K. *Email* j.b.murray@open.ac.uk.

Introduction: Comets are considered to be the earliest and most primitive members of the solar system, most of them orbiting in its distant reaches where they form the Oort cloud of comets. Though unobserved, this cloud has been inferred from the fact that the aphelion distances of observed long-period (LP) comets cluster between 30k and 60k A.U. distant from the sun, with a peak at around 50k A.U. (fig.1). It has been postulated that the LP comets we observe have been gravitationally diverted from the Oort cloud into the inner solar system by stellar [1] and galactic [2] perturbations. Although modifications and problems with the original idea have been voiced from time to time [3], [4], [5], [6], no other explanation has been proposed. Here it is shown that the 50k A.U. aphelion distance clustering is more simply explained as a predictable artefact of the limitation that known LP comets are restricted to those with perihelion passage within the past few hundred years. The direct tracing back of LP cometary orbits that make up the Oort spike leads to the conclusion that these comets were ejected from the solar system over a limited time period in the comparatively recent past, and are now observed at their first return back into the inner solar system. This alternative interpretation ties in well with the results of investigations that have found problems with the Oort cloud model.

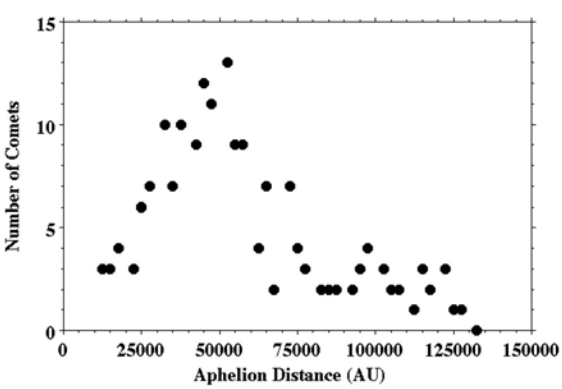

Fig.1. Histogram (3-point moving means) of original aphelion distances of long-period comets. Only 1A comets from Marsden & Williams [7], i.e. those whose orbits have been most accurately determined, have been used in this presentation. There is an uncertainty in $1/a$ (where a is the semi-major axis of the LP comet orbit in A.U.) of up to about 0.00002 even for 1A comets [8], but the pronounced peak at around 50K A.U. can be clearly seen.

Dynamical arguments for an alternative hypothesis: A histogram of aphelion distance of LP comets is shown in figure 1, in which it can be seen that they cluster at about 50K A.U. This observation has two possible interpretations: either that all LP comet aphelia really do preferentially occur at about 50k AU, which is generally assumed to be the case, or else that these comets were ejected from the inner solar system at about the same time, a possibility that does not seem to have been previously considered. The existence of the Oort cloud, in which a huge number of comets orbit the sun in approximately circular orbits around 50k AU, depends upon the postulation that stellar gravitational encounters or galactic perturbations from time to time cause some of them to be diverted into highly elliptical orbits that bring them close to the sun where they can be observed.

The second interpretation requires no such postulation, but is a simple tracing back of observed cometary orbits in time. If these comets were all ejected together from the inner solar system, then

$$T \approx Pn \qquad (1)$$

where T is the time in years since ejection, P is the orbital period in years, and n the nth return of the comet since ejection. At any one epoch therefore, there would appear to be an excess of comets with $P \approx T$, because comets can only be observed near the sun where n is close to an integer. Since

$$P^2 = a^3 \qquad (2)$$

where a is the semi-major axis of the orbit in A.U., an unavoidable consequence of this would be that all observable first-return comets that were ejected at the same time, and where the eccentricity e approaches unity, would have a similar aphelion distance D (in A.U.) of

$$D \approx 2(\sqrt[3]{P^2}) \qquad (3)$$

As well as first-return comets, the observed distribution should include comets of $T=P/n$; $n>1$. Ignoring perturbations, there should be apparent aphelion clusters at

$$D \approx 2(P/n)^{2/3}); \; n = 1, 2, 3, 4\ldots..$$

i.e. at around 31K, 24K, 20K etc., but in reality, near perihelion the LP comets are subject to planetary perturbations and non-gravitational effects that are capable of greatly shortening a after only one perihelion passage, or ejecting the comet from the solar system altogether, a fate that has befallen 24% of LP comets whose future orbits are listed in Marsden & Williams [7]. Therefore these other peaks are expected to be dispersed through too wide a range of a to

render them visible in fig. 1, and the above relation (1) is expected to effectively hold only when $n = 1$. Another consequence of equations (1) and (3) is that the apparent aphelion distance cluster would move away from the sun with time, so that for example 1, 2 and 3 million years after ejection, the apparent "Oort Cloud" would have had a peak distance of about 20K, 32K and 42K A.U. respectively, and in 1 million years' time will be at 58K A.U.

Ages of LP comets: From equations (1) & (2), if $n = 1$, we get

$$T \approx \sqrt{a^3}$$

which allows us to date the event that ejected comets at about 4 Ma B.P. There is considerable uncertainty in this value since there is significant uncertainty in each catalogued aphelion distance [8], but most methods indicate a greatest frequency of a values between 43K and 55K A.U., giving a date between 3.2 and 4.6 Ma B.P., i.e. early to mid- Pliocene.

Possible origins of LP comets: On this new interpretation, all LP comets should have highly elliptical orbits with perihelia in the inner solar system, and the Oort cloud as a massive reservoir of comets moving in more or less circular orbits at tens of thousands of AU from the Sun would not exist. The true number of comets presently in the outer solar system should therefore be very much less than that implicit from the Oort cloud hypothesis, and will depend on the nature and long-term frequency of the comet-forming events implicit from the present hypothesis.

Although the nature of comet-forming events must for the moment remain speculative, the Edgeworth-Kuiper belt is a likely source for LP comets. Collisions are frequent [9], and fragments from such collisions going into highly elliptical orbits is a possible explanation for the 4 Ma B.P. event.

Dynamical work on large EKBOs suggests that icy bodies up to 10^4 the mass of Halley's comet are in chaotic or frequently-changing orbits with lifetimes of the order of 1 Ma, and that the mean interval between the injection of nucleus diameter >100km icy bodies into short-period orbits is of the order of 10^5y [10]. Random splitting, heating and tidal disruption near the sun is liable to break these up into smaller objects, some of which could still be orders of magnitude greater than the largest known comets. Numerical integration has shown that the end result of many such bodies would be collision with the sun or close encounters with planets and ejection into long period or hyperbolic orbits [11].

A combination of these two ideas is also possible: a collision, as well as ejecting some fragments on near-parabolic orbits, would inevitably perturb much material into the inner solar system, where fragments would undergo the same kind of disruption and orbit changes described in [11]. The uncertainty in $1/a$ values means that comet-forming "events" could be very protracted, and last considerably longer than 1 Ma.

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