LUNAR MICROCRATER RECORDS: WHERE IS THE COMETARY EFFLUX?
J.A.M. McDonnell and R.J. Allison, Space Sciences Laboratory, University of Kent at Canterbury, U.K.

With more than 10 years of observation of lunar rocks and spherules, it is now generally accepted that we know the relative size distribution of the accumulated hypervelocity impact features on an exposed lunar surface to within a factor of approximately ±2. The work of Morrison and Clanton (1) summarises excellent observations of this distribution, and is taken as the best available data on recent lunar exposure conditions (< 10^6 yrs). With some 20 years of space observations we have now reached the stage where the flux rate is known from .3 AU (Helios 1 and 2) to 5 AU (Pioneers 10 and 11). Pioneers 8 and 9 (2) added a new dimension to interplanetary dust studies by the discovery that the smaller particles were emanating from solar directions and had velocities commensurate with hyperbolic orbits.

With the advent of a new era of interplanetary dust studies, namely the interception of Comet Halley near perihelion with ESA's GIOTTO MISSION, it is vital to examine and correlate these sets of data to ask just how much of the cometary efflux has been detected. Selection of a Dust Impact Detection System (DIDSY) to instrument the Giotto Meteoroid Bumper Shield will give the first opportunity to measure directly a cometary dust emission, and will extend over the mass range 10^{-3}g to 10^{-18}g. We identify outstanding questions in the interpretation of lunar and in-situ space data, and what knowledge may be deduced about the probable cometary efflux.

Lunar data exists as an accumulated areal density and the "clock" required to evaluate a flux rate has been discussed at length, e.g. (3). We see no substantial error in recent exposure age determinations e.g. $1.75.10^5$ yrs for Apollo 12054 (4).

Other factors affecting lunar data are the obscuration by dust accumulation and the effects of secondary cratering. The data here accepted is expected to be free from the first effect. We have continued the study of secondary cratering and have calculated for both lunar data and space data (Figure 1) the number of secondary craters expected as a function of the angle of the crater host surface to the lunar surface, ϕ. For the space data, only 90° is illustrated. We have used secondary cratering data of Flavill, McDonnell, Carey (5) relevant to micron scale impacts and of Schneider (6) for millimetre scale impacts. Effects can be seen to be quite appreciable. Of greatest significance is that the effects are very strongly dependent on the primary incident flux model assumed. For lunar data the effect is concentrated over micron crater dimensions. For space data the effect increases for all sizes below .3μm as a result of the different impact model.

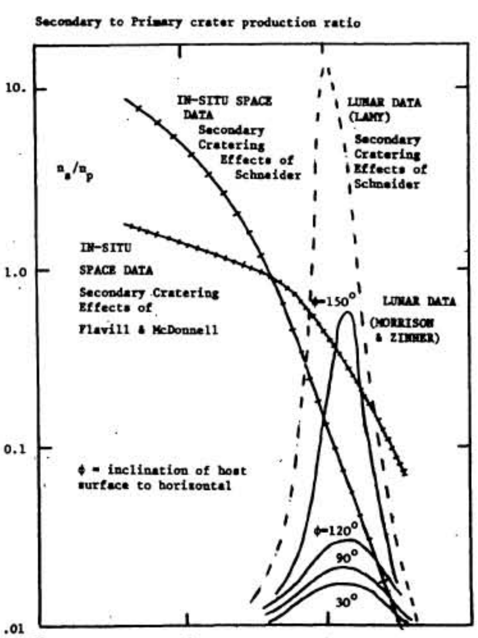

Figure 1. Secondary crater production ratios calculated from in-situ space data and deconvolved (primary component) of lunar data.

LUNAR MICROCRATER RECORDS

McDonnell, J.A.M., Allison, R.J.

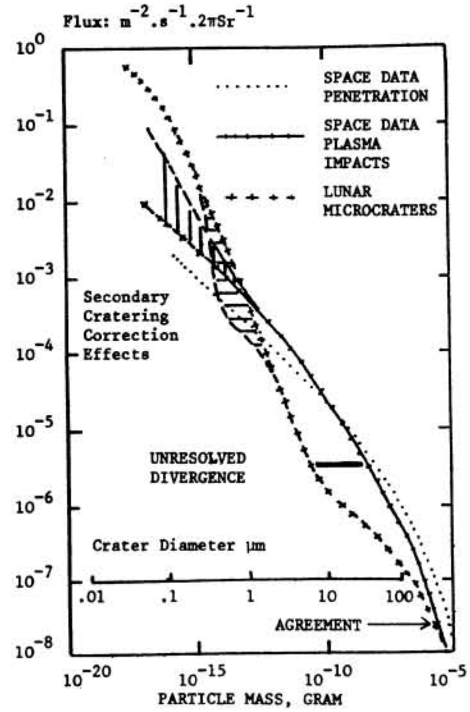

Figure 2

The effects on observed flux rates and distributions are shown in Figure 2. We note that they lead to some convergence between the two data sets, but that such agreement has to be "stretched" a little. We see little divergence at larger masses in the meteor range and above ($> 10^{-6}$g) though calibration uncertainties are here perhaps a factor of ±3 in mass. Of outstanding disagreement is the point of inflexion at ∿ 10μm crater diameter observed in lunar data; interpreted as a bimodal particle distribution (7). We must note that it is *not* observed in the space data by plasma sensors, but is observed in penetration data obtained in space (e.g. Apollo windows (8)).
Introduction of the effects of collisions of dispersed cometary streams by Zook and Berg (9) and by Dohnanyi(10) shows that in their inward spiral to the sun, collisions within solar regions can fully account for the observed particle fluxes below 10^{-11}g. Firstly we have the α particles (the apex distribution) corresponding to bound but eccentric comminution products and at lower masses the hyperbolic β particles. Regretfully we must say of the lunar data, therefore, that all craters less than 1μm have the most probable source as <u>indirect</u> cometary products. The nature of the impact process totally excludes the possibility of distinguishing between α and β particles and pristine cometary products by examination of crater profiles or residues; both classes of particle are chemically similar and could be distinguished only by their topology. Both α and β meteoroids should show evidence of a hypervelocity impact or collision, since collision velocities near the sun are well above the impact melting region (9). The smaller of the Brownlee particles (∿ 1μm) represent generally fragile agglomerates and hence in looking for a source of such particles we are in a dilemma. At this mass the lunar crater distribution cannot be shown to be caused by particles emitted directly from comets, and hence we should ask if the smaller of Brownlee particles represent either 1) only a small fraction of the lunar flux and yet *are* the direct cometary expulsion fraction or 2) are only parts of the larger (∿ 100μm) direct cometary expulsion products which are subsequently fragmented in the atmosphere. This mass range carries the maximum of that incident on the Earth (11) and is the most plausible of expectations.
Lunar data thus provide clear evidence of directly emitted cometary particles only for masses $\gg 10^{-11}$g, and it is here that a divergence by more than a magnitude in flux occurs by comparison with the space data (11). Only by the determination of orbital elements for individual particles can we clearly distinguish between direct or indirect cometary products. The perihelion so determined may be taken to be the most probable source region, and space data to date (2, 11) does show a solar origin for masses $\lesssim 10^{-11}$g. At masses $< 10^{-11}$g, thus, even from the space measurements we can only indirectly deduce cometary effluxes, since their small cross section is masked by the larger particles in cometary dust tails.

Figure 2 (above). Effects of secondary cratering (shaded areas).

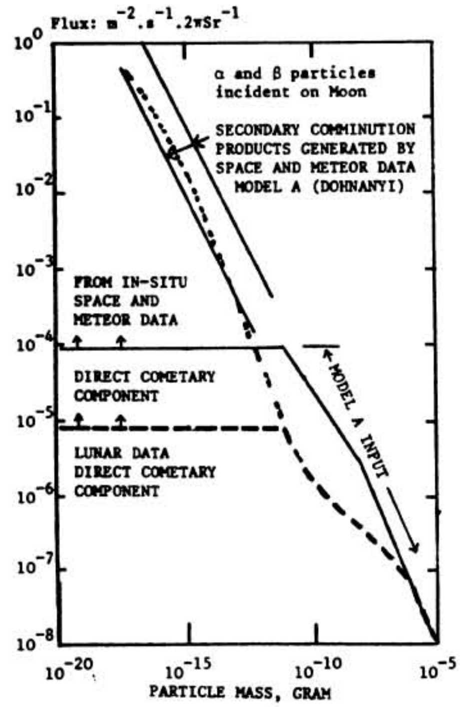

Figure 3. Extent to which Lunar and space derived particle distributions relate to primary cometary expulsion products.

REFERENCES

(1) Morrison, D.A. and Clanton, U.S. (1979) Proc. Lunar Planet. Sci. Conf. 10th, p. 1649-1643.

(2) Berg, O.E. and Grün, E. (1973), Space Research XIII, p. 1046-1055.

(3) Hartung, J.B. (1975) Lecture Notes in Physics, 48, p. 209-226, Springer Verlag.

(4) Morrison, D.A. and Zinner, E, (1977) Proc. Lunar Sci. Conf. 8th, p. 841-845

(5) McDonnell, J.A.M. and Flavill, R.P. and Carey, W.C. (1976) Proc. Lunar Sci. Conf. 7th p. 1055-1072.

(6) Schneider, E. (1975) The Moon, 13, p. 173-184, D. Reidel.

(7) Le Sergeant d'Hendecourt, L.B. and Lamy, Ph.L. (1980) Icarus (In Press).

(8) Cours Palais, B.G. (1979) Proc. Lunar Planet. Sci. Conf. 10th, p.1665-1672.

(9) Dohnyani, J.H. (1975) Lecture Notes in Physics, 48, p. 170-180, Springer-Verlag

(10) Zook, H.A. and Berg, O.E. (1975), Planet. Space Science, 23, p. 183-203.

(11) McDonnell, J.A.M., Cosmic Dust, Chapter 6, p. 337-426.

ACKNOWLEDGEMENTS

The Science Research Council (U.K.) supports the Lunar Sample Investigation Programme. I thank Alison Rook for manuscript preparation.