IDENTIFICATION OF INDIVIDUAL COMETARY IDP'S BY THERMALLY STEPPED HE RELEASE

D.E. Brownlee, D.J. Joswiak, Dept. of Astronomy, Univ. of Washington, Seattle, WA 98195, D.J. Schlutter, R.O. Pepin, Dept. of Physics, Univ. of Minnesota, Minneapolis, MN, 55455, J.P. Bradley, MVA Inc., 5500 Oakbrook Parkway, Atlanta, GA 30093, and S.G. Love, HIGP, Univ. of Hawaii, Honolulu, HI 96822

Interplanetary dust particles (IDPs) collected in the stratosphere provide a moderately representative sampling of the main belt asteroids and the short period comets that are the major dust producers in the solar system. Distinction between typical IDPs from these two sources is of key interest because the samples should contain materials and records of processes that existed both in the inner region of the solar nebula where the asteroids formed as well as the Kuiper belt region beyond 50 AU where most of the SP comets formed. One approach to distinguish between asteroidal and cometary IDPs is to use systematic differences of heating that these particles experience during hypervelocity entry into the atmosphere [1]. Unlike conventional meteorites, asteroidal dust particles reach the Earth by Poynting-Robertson drag and approach the Earth on asteroid-like orbits with low eccentricity and inclination. They typically enter at velocities near 12 km/s while comet particles, with their higher eccentricity and inclination, typically enter at speeds >14 km/s[2]. Entry calculations indicate typical peak temperature differences of 300 °C for comet and asteroid particles of the same size and density[3]. The systematically stronger heating of comet dust can in principle be detected by various temperature dependent properties such as track erasure, magnetite rim formation, volatile depletion, mineralogical changes and He depletion. We utilize several of these indicators but rely primarily on the thermally stepped He release method developed by Nier and Schlutter[4]. He trapped in unheated IDPs is released over a range of temperatures because it is sited in different phases, at various depths in grains, in defects and as interstitial atoms or as bubbles. The Nier-Schlutter technique determines the temperature release profile of particles. Low velocity (weakly heated) IDPs contain He that is released at low and high temperature while high velocity (strongly heated) IDPs retain only He released at high temperature. With this technique individual IDPs in the 5μm to 20μm size range are subjected to a series of 5 second pulses of increasing temperature and liberated $^3$He and $^4$He is measured after each pulse. The duration and shape of each pulse is similar to the typical heat pulse encountered by micrometeorites entering the atmosphere. The result for a single particle is an S-shaped curve of the fraction of total He released as a function of temperature. The 50% release temperature is usually the inflection point of the release curve and this best defined point of the curve is used as a quantitative indicator of the maximum temperature experienced by a particle during atmospheric entry. This, along with accurate measurement of the particles mass, size and density[5] can be used to calculate the most probable entry velocity. We are using these techniques along with a series of TEM, SEM and reflectance studies to determine the properties of typical cometary samples.

Identification of the cometary component has been a major preoccupation of IDP research over the past decade and the Nier-Schlutter stepped He release method appears to be a elegant solution to this problem. Because of the importance of identifying cometary materials it is critical to understand how well the He data can really distinguish cometary and asteroidal particles in light of potential complexities and unknowns. Is it possible to identify individual comet dust with a high degree of confidence or can the technique only be used in a statistical way
to distinguish groups of probable comet particles from probable asteroid dust? Laboratory heating tests on actual IDPs show that particles that were previously heated in testing retain only He that is released at high temperature while less strongly heated IDPs retain He released both at low and high temperature. The experiments indicate that the temperature where 50% of the total gas has been released provides a good determination of the maximum temperature reached during atmospheric entry over the 500-1000 °C range with a likely error on the order of 100 °C. It is not realistic, however, to expect that the measured 50% release point can be precisely related to the peak temperature of atmospheric entry of particles with varying mineralogical composition and porosity but it appears that the range of uncertainty is small enough that the high velocity fraction of cometary particles can clearly be determined. The data on particles of similar size and density show a wide range of 50% release points and even with the most conservative interpretation, the data clearly show that high velocity IDPs are being distinguished from low velocity particles. Assuming 45° entry angles, entry velocities computed from the data range from less than 11 km/s to 20 km/s. The Zook and Jackson [2] analysis of IDP sources indicate that 14 km/s speed is a reasonable discriminator between the two sources but considering all possible uncertainties this is not a sufficiently conservative division for individual particles in this study. Typical combined errors of mass, density and unknown entry angle produce velocity estimate errors of a few km/s. Fortunately most of the uncertainties involved affect asteroid identification but not the reliability of comet identification. Erroneous indication of low temperature/velocity entry (asteroidal origin) can result from low angle entry or from sublimation of a volatile component but only high velocity entry can produce strong heating indicative of cometary origin. Essentially all particles with computed entry speeds above 18 km/s should be cometary. In our program of particle analysis we have a set of IDPs with computed entry velocities of 20 km/s. In light of known uncertainties we consider a cometary origin for these samples to be well established even though there is a small probability that they could be derived from rare high inclination asteroids. The cometary particles are all porous chondritic IDPs that are dominated by GEMS [6], unique glass/metal submicron components. They are mainly anhydrous although one particle contains a 1x2μm grain of what appears to be degraded phyllosilicate. The comet particles are less than 10μm in size and were all heated to 900 °C during entry. The "window" where cometary particles can be well identified by the He release method but not heated above 1000 °C is basically limited to the 4μm to 10μm range for common IDP densities of 1.5 to 2.5 g/cc. They are briefly heated above 600 °C but retain a wealth of information on silicate and carbonaceous components that can be studied in minute detail by current laboratory techniques..


We are forever indebted to our friend the late A.O. Nier who began this project and developed the fantastic capabilities to measure the concentration, isotopic composition and thermally stepped release profile of He from individual interplanetary dust particles that are smaller than 10% the diameter of a human hair.