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COMPREHENSIVE STUDY OF HYDRATED IDPs: X-RAY DIFFRACTION, IR SPECTROSCOPY AND ELECTRON MICROSCOPIC ANALYSIS.

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Introduction: Chondritic hydrated interplanetary dust particles (IDPs) comprise up to 50% of all IDPs collected in the stratosphere[1]. Although much is known about the mineralogy, chemistry and carbon abundance of hydrated IDPs [2-4] controversies still exist regarding their formation, history, and relationship to other primitive solar system materials. Hydrated IDPs are generally believed to be derived from asteroidal sources that have undergone some degree of aqueous alteration. However, the high C contents of hydrated IDPs (by 2 to 6X CI levels [3,4]) indicate that they are probably not derived from the same parent bodies sampled by the known chondritic meteorites.

Methods: We report the comprehensive study of individual hydrated IDPs. The strong depletion in Ca [1] has been used as a diagnostic feature of hydrated IDPs. The particles are embedded in elemental sulfur or low-viscosity epoxy and ultramicrotomed thin sections are observed using a transmission electron microscope (TEM) equipped with an energy-dispersive X-ray detector (EDX) followed by other measurements including: 1) FTIR microspectroscopy to understand the significant constraints on the organic functionality and the nature of the C-bearing phases and 2) powder X-ray diffraction using a synchrotron X-ray source to understand the bulk mineralogy of the particles.

Bulk Composition and Mineralogy: Hydrated IDPs are composed predominantly of smectite and/or serpentine phyllosilicates and usually contain minor anhydrous grains as shown in Figure 1 from IDP L2036E23. L2036E23 exhibits distinctive intergrowth of smectite and serpentine that has been reported from the Orgueil CI chondrite [5], the Tagish Lake CI2 [6] and a hydrated IDP [7]. Mg-Fe carbonates common in CI chondrites [8], Tagish Lake [9] and other hydrated IDPs [8,9] are also abundant in L2036E23. Magnetite is the major Fe-bearing phases in CI chondrites, whereas magnetite in L2036E23 is observed as a prominent rim in response to atmospheric entry heating. Tochilinite which is commonly intergrown with serpentine in CM matrices is observed in IDP L2006A5. Although the majority of hydrated IDPs have chemical compositions that resemble to CI and CM chondrites [1,2,5], there are mineralogical similarities to the fine-grained material in certain altered type-3 carbonaceous and ordinary chondrites [10,11].

Possible Parent Bodies: Reflectance spectra (380-850 nm) of most IDPs are similar to those of P- and D-class outer belt asteroids [12] as well as the Tagish Lake meteorite [13]. Extraterrestrial materials resembling Tagish Lake are rare as meteorites, but appear to be much more common as stratospheric IDPs[14] and micrometeorites [15]. Recent shock experiment results indicate that hydrated asteroids produce dust particles by mutual collisions at much higher rate than anhydrous asteroids[16]. TEM observations of samples recovered from the Murchison CM chondrite shocked at 30 GPa shows marked similarities to the hydrated IDPs[16].

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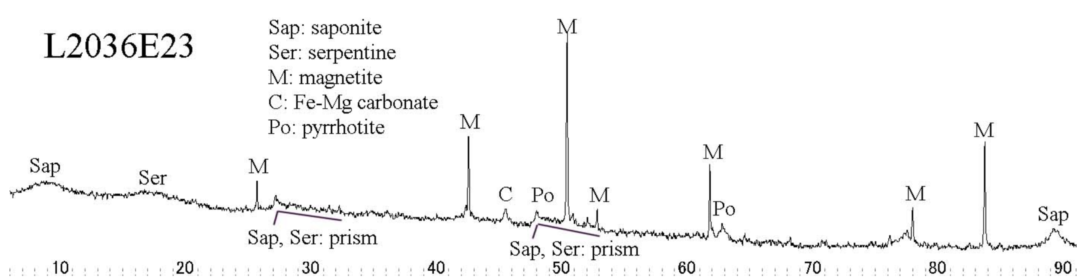

Fig. 1: X-ray diffraction patterns in a range of diffraction angle from 12 to 52° (2θ) of a hydrated IDP L2036E23.

ANALYSIS OF SUBMICRON PRESOLAR OXIDE GRAINS BY SINGLE GRAIN ANALYSIS AND MULTI-DETECTION RASTER IMAGING.

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Introduction: Oxygen isotopic measurements of grains from the spinel-rich Murray residues CF and CG, having average sizes of 0.15µm and 0.45µm, respectively, have been performed with the NanoSIMS. Zinner et al. [1] analyzed individual grains that were well dispersed from one another on a gold foil and found that the smaller grain size fraction CF had a higher abundance of presolar spinel than the fraction CG (15/628 vs. 9/753). For these analyses, the primary ion beam was deflected successively onto single grains. Subsequently we determined the oxygen isotopic compositions of grains from the same residues using multi-detection raster ion imaging of densely packed areas on the grain dispersion mount. Using this technique, we identified 81 presolar spinel and 3 presolar corundum grains out of ~51,700 analyzed CF grains. In addition, we identified 171 presolar spinel and 29 presolar corundum grains among ~21,500 CG grains. While both methods prove to be effective in analyzing very small grains, raster ion imaging is more efficient for locating anomalous grains among many isotopically normal grains.

Experimental: Analyses were made on the NanoSIMS ion microprobe. The same CF and CG grain mounts were used for both single grain analysis and for ion imaging. These sample mounts were prepared by depositing grains from liquid suspensions onto gold foils. In most areas on the mounts, the grains were well dispersed. On the other hand, areas containing tightly packed grains were well suited for ion imaging. For imaging, a Cs^+ primary ion beam of ~100nm diameter was rastered over 15x15 or 20x20µm^2 areas on the sample mount. Negative secondary ions of the three O isotopes, as well as ^{24}MgO and ^{27}AlO ions were counted concurrently in five small electron multipliers. MgO and AlO were measured to distinguish between spinel and corundum grains. Isotopically anomalous grains were identified from oxygen isotopic ratio images (Fig. 1).

Results and Discussion: The analysis of oxide grains larger than 1µm led to the conclusion that presolar spinel grains were much rarer than presolar corundum grains [2]. However, with the NanoSIMS ion microprobe, we now have the capability of measuring submicron grains. Single grain analysis of small spinel grains from the Murray CF and CG residues indicated that the abundance of presolar spinel grains is actually quite large relative to presolar corundum grains, and that the abundance of presolar grains increases with decreasing size (Table 1) [1]. Whereas 26 presolar spinel and 3 presolar corundum grains were identified through single grain analysis, 252 presolar spinel and 32 corundum grains were identified by raster ion imaging in a shorter amount of time. It is apparent that we have two successful NanoSIMS techniques that can be applied to the elemental and isotopic analysis of small grains down to ~0.2µm. Ion imaging is particularly effective in searches for rare presolar grain types, as we can analyze many more grains within a certain amount of time. This method has led to the discovery of presolar silicates in IDPs [3], and can be applied to the search for presolar silicates in meteorites and to the analysis of cometary dust returned from Stardust.

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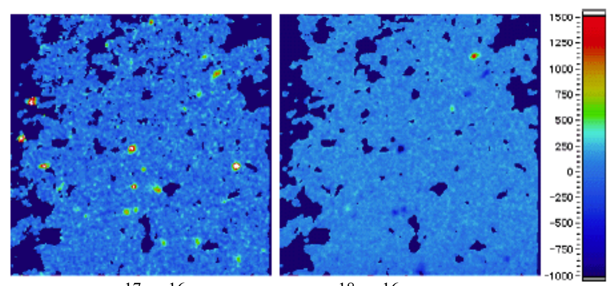

Figure 1. ^{17}O/^{16}O (left) and ^{18}O/^{16}O (right) isotopic ratio images of a 20x20µm^2 area partly covered with Murray CG grains. Ratios are given as deviations from normal isotopic ratios in permil (‰). Presolar grains can clearly be identified as having large isotopic anomalies.

Meteorite/ Residue	Analysis Technique	Presolar Spinel/ Total	Presolar Corundum/ Total	Abundance Spinel	Abundance Corundum
Murray CF	Ion Imaging	81/51,700	3/51,700	0.2%	0.01%
(0.15µm)	Single Grain*	15/628	3/628	2.4%	0.9%
Murray CG	Ion Imaging	171/21,500	29/21,500	0.8%	0.1%
(0.45µm)	Single Grain*	9/753	0/753	1.2%	<0.2%

*Zinner *et al.* (2003)

FUTURE MISSION PROPOSAL OPPORTUNITIES: DISCOVERY, NEW FRONTIERS, AND PROJECT PROMETHEUS. S. M. Niebur[1], T. H. Morgan[1], and C. S. Niebur[1], [1]Solar System Exploration Division, NASA Headquarters (300 E Street SW, Washington, D.C. 20546-0001, Susan.M.Niebur@nasa.gov).

Introduction: The NASA Office of Space Science is expanding opportunities to propose missions to comets, asteroids, and other solar system targets. The Discovery Program continues to be popular, with two sample return missions, Stardust and Genesis, currently in operation. The New Frontiers Program, a new proposal opportunity modeled on the successful Discovery Program, begins this year with the release of its first Announcement of Opportunity. Project Prometheus, a program to develop nuclear electric power and propulsion technology intended to enable a new class of high-power, high-capability investigations, is a third opportunity to propose solar system exploration. All three classes of mission include a commitment to provide data to the Planetary Data System, any samples to the NASA Curatorial Facility at Johnson Space Center, and programs for education and public outreach.

Discovery: NASA's Discovery Program provides regular opportunities to conduct planetary system(s) science investigations that require free-flying missions launched on the space shuttle or expendable launch vehicles. These are complete missions, directed by a single Principal Investigator (PI), with participation from a number of scientific Co-Investigators, Participating Scientists, and Collaborators, as well as the engineering project team and industry partners. Post-mission scientific value is enhanced by the availability of mission data in the Planetary Data System, samples at the Curatorial Facility, and funding available from the Discovery Data Analysis Program, Sample Return Laboratory Instruments and Data Analysis Program, and a number of other programs available through the annual NASA Research Announcement entitled Research Opportunities in Space Science (ROSS NRA). There have been six Discovery missions launched to date: NEAR, Lunar Prospector, Pathfinder, Stardust, Genesis, and Contour. The next opportunity to propose a Discovery mission is planned to occur late in 2003. Discovery missions are cost-capped missions, with a current total NASA Office of Space Science (OSS) cost of up to $350 M. Missions typically launch three years after confirmation.

New Frontiers: The New Frontiers Program has recently been introduced in order to further enable PI-led missions to explore the solar system and/or return samples for study. The National Academy Decadal Survey (*New Frontiers in the Solar System*, National Research Council, 2002) has recommended five medium-class mission investigations as an initial target set: Comet Surface Sample Return, South Pole Aitken Basin Sample Return, Venus In Situ Explorer, Jupiter Polar Orbiter with Probes, and a Kuiper Belt/Pluto mission. The first New Frontiers mission will be New Horizons, a mission to Pluto and the Kuiper Belt. The other four investigations will comprise the possible target set for mission proposals in 2003. The NASA OSS cost for these missions can be up to $650 M. These missions may therefore employ radioactive power sources and Evolved Expendable Launch Vehicles, such as the Atlas V or Delta IV, enabling an expanded opportunity to explore the solar system, including the return of samples. Missions should launch within four years of confirmation.

Project Prometheus: The newly created Project Prometheus Program will develop nuclear electric power and propulsion technology to allow a new era of scientific investigation with capabilities far beyond those available today. These missions will utilize onboard nuclear fission reactors and high power ion engines to provide revolutionary capabilities such as high power levels for instruments (10 – 45 kW), high data rates for acquisition and telecom (10 Mbps), large payload mass, multi-target rendezvous and orbits, and extended observation time. The first Project Prometheus mission is the Jupiter Icy Moons Orbiter, which has recently begun formulation. Since Project Prometheus is planned as a recurring mission line, NASA will soon release a request for studies of future high capability missions. A list of possible future missions includes, but is not limited to, Titan explorer, comet chaser, interstellar probe, and Neptune/Triton missions.

Conclusion: The Discovery, New Frontiers, and Project Prometheus mission lines provide opportunities for small, medium, and high-powered missions to explore the Solar System and return valuable data and extraterrestrial samples. The Office of Space Science welcomes your ideas, proposals, and participation in these three exciting mission lines.

CIRCUMSTELLAR GRAINS IN METEORITES AND IDPS: ISOTOPIC CONNECTIONS BETWEEN STELLAR GENERATIONS. L. R. Nittler, Dept. of Terrestrial Magnetism, Carnegie Instituion of Washington, 5241 Broad Branch Rd NW, Washington DC, 20015, lrn@dtm.ciw.edu

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Primitive meteorites and interplanetary dust particles (IDPs) contain tiny dust grains that condensed in outflows and explosions of ancient stars prior to the birth of our solar system [1-3]. These *presolar* or *circumstellar* grains are solid samples of stellar matter that trace a diversity of processes including stellar evolution and nucleosynthesis, stellar dust formation, dust processing in the interstellar medium (ISM) and early solar system processes. They are recognized by their highly unusual variations in isotopic compositions, caused in many case by the nuclear reactions which occur at high temperatures in stellar interiors.

This talk will review how isotopic signatures of presolar grains are used to infer their stellar sources and probe the nucleosynthetic and evolutionary processes which led to their compositions. Of particular interest are connections between different types of circumstellar grains and connections between grains found in meteorites and those found in IDPs. Cometary and interstellar samples returned by the STARDUST mission could provide crucial information on these connections.

I will focus on three types of circumstellar grains: SiC, refractory oxides (primarily Al_2O_3 and $MgAl_2O_4$) and silicates (e.g., $MgSiO_3$). The majority of these grain types are all believed to have originated in similar types of stars: low-mass ($<3M_{\odot}$) red giant branch (RGB) and asymptotic giant branch (AGB) stars. Some tens to hundreds of individual stars probably contributed SiC and/or oxide stardust to the Sun's parent cloud [4, 5]. SiC production is confined to late-stage AGB stars in which convective mixing of freshly synthesized ^{12}C increases the surface C/O ratio greater than unity. In contrast, oxides and silicates can be produced throughout the RGB and early AGB stages and thus can form in the same stars which later condense SiC.

Many isotopic ratios measured in presolar grains are dominated by the effects of nuclear processing within the parent stars themselves. These include C, N, Mg and heavy elements in SiC grains and $^{17}O/^{16}O$ ratios in most oxide grains. These signatures provide constraints on nucleosynthesis and mixing processes in stars. Other isotopic ratios, including Si and Ti isotopes in SiC and $^{18}O/^{16}O$ ratios in O-rich grains, apparently reflect the initial compositions of the parent stars, with little further modification by stellar processing. The initial compositions of stars are determined by the nuclear history of the material from which they form. The theory of Galactic Chemical Evolution (GCE) describes how the composition of the ISM changes with time and location as succeeding generations of stars inject newly-synthesized material [6-7]. Presolar grain data provide new constraints on the GCE of isotope ratios. Comparison of the O-isotope distribution of oxide grains and the Si distribution in SiC indicates that the oxides originated in stars with a wider range of compositions than did the SiC, despite the expectation that they come from similar types of stars.

Although the number of circumstellar silicate grains identified in IDPs is still limited [3], there is a hint that the O-isotopic distribution differs from that observed in the meteoritic oxide grains. This could reflect sampling biases; perhaps different types of stars preferentially produce silicates relative to oxides, though there is little evidence for this from astrophysical considerations. Alternatively, if the IDPs with presolar grains are cometary, this might indicate heterogeneity in the distribution of different presolar grain types in the solar nebula. Clearly STARDUST samples should help shed light on this issue.

It is unknown how large a fraction of present day interstellar dust is comprised of pristine circumstellar grains, but the interstellar dust returned by STARDUST should be extremely useful for presolar grain science. First, direct isotopic measurement of the average isotope composition of present-day interstellar dust will help constrain GCE trends and provide tests of GCE interpretations of the grain data. Second, if circumstellar grains are found, these will have formed much more recently than the presolar grains and thus provide information in how the stardust population has changed in the solar neighborhood in the last 4-5 billion years.

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AN OBSERVATIONAL TEST FOR SHOCK-INDUCED CRYSTALLIZATION OF COMETARY SILICATES.
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Introduction: Crystalline silicates have been observed in comets and in protostellar nebulae[1,2], and there are currently at least two explanations for their formation: thermal annealing in the inner nebula, followed by transport to the regions of cometary formation and in-situ shock processing of amorphous grains at 5 – 10 AU in the Solar Nebula [3,4]. The tests suggested to date to validate these models have not yet been carried out: some of these tests require a long-term commitment to observe both the dust and gas compositions in a large number of comets. Here we suggest a simpler test.

Shock Processing: Harker and Desch [4] presented a fairly comprehensive model of the shock processing of grains in the solar nebula and demonstrated that grain temperatures for moderate-sized dust particles could easily reach the temperatures required for crystallization [5] and maintain these temperatures for a sufficient time to crystallize magnesium silicate grains. We have re-examined the calculations presented in their paper in more detail and present below a simple extrapolation of their results. The ultimate temperatures of the grains heated via single shock events is highly dependent on the individual particle size. It has also been previously demonstrated that magnesium silicate grains anneal to crystallinity within a few seconds at temperatures near 1100K [6] whereas we might expect that iron silicate grains would require temperatures exceeding 1400K to crystallize in this same time scale [7]. If a 'large' silicate grain is heated to near 1100K, a smaller grain can be heated to 1400K. Therefore, if shocks produce large crystalline magnesium silicate minerals, they should also produce a population of smaller crystalline iron silicates. Because smaller grains in a population illuminated by the same source (e.g. the sun) should equilibrate at a higher temperature than larger grains, these small iron silicate grains within the cometary dust population should shine brightly. Detection of a smaller population of crystalline iron silicate grains in cometary comae could therefore demonstrate the viability of the shock processing model for the origin of crystalline silicates in protostellar sources.

Thermal Annealing: It has been proposed that crystalline silicates seen in cometary comae are the product of thermal annealing in the innermost regions of the Solar Nebula followed by transport of some fraction of the processed grains outward to the regions of comet formation [8,9]. No estimate of the residence times for grains at any particular radial distance from the sun is available in the literature. However, timescales of from months to many hours are required to form crystalline silicates at temperatures between 1025K to 1050K [5]. It seems logical to conclude that a grain may spend a minimum of several orbital periods at the temperature (radius) required for crystallization. By this logic, since crystallization of iron silicates could occur within a month or so at temperatures near 1350K, it should also be possible to produce crystalline iron silicates closer to the sun. Should we therefore also see such grains in comets and protostars? No!

The difference between shock processing and straight thermal annealing is one of timescale. Whereas shock processing is complete in from minutes to seconds, thermal annealing in hotter regions of the Solar Nebula may require months to work. On that timescale at 1400K, the grains will evaporate.

CHEMICAL ANALYSIS OF PRIMITIVE OBJECTS USING A SLITLESS ULTRAVIOLET METEOR SPECTROMETER (CAPO-SUMS). J. A. Nuth[1], T. Wdowiak[2], J. Lowrance[3], G. Carruthers[4], P. Jenniskens[5] and P. Gerakines[2], [1]Code 691, NASA-Goddard Space Flight Center, Greenbelt MD 20771 (nuth@gsfc.nasa.gov), [2]Physics Department, University of Alabama, Birmingham, AL, [3]Princeton Scientific Instruments, Fort Monmoth NJ, [4]Naval Research Laboratory, Washington DC, [5]SETI Institute, 2035 Landings Dr., Mountain View, CA 94043.

SUMS Science Objectives: ***Primary Objective:*** Measure the elemental composition in both random meteors and in the bolides forming specific meteor streams (these are traceable to specific small bodies in the solar system). These will yield the average chemical composition and degree of chemical variability in a statistically significant number of planetesimals. CAPO-SUMS is functionally equivalent to a series of multiple, small-body sample analysis missions, but provides much more analytical capability than is possible on any orbital or flyby mission due to the vaporization, ionization and ultraviolet emission from the ablating bolide as it enters the atmosphere. CAPO-SUMS will provide a chemical context from which the detailed analytical studies provided by a cometary or asteroidal lander mission can be interpreted.

Secondary Objectives: 1. Measure the relative abundances of the Biogenic Elements in these same bolides. These measurements will yield the average abundance and degree of variability of the Biogenic Elements in a statistically significant number of planetesimals.

Secondary Objectives: 2. Measure the chemical stratification of primitive bodies by obtaining measurements of the average elemental abundance in their shower meteors over multiple apparitions, thus analyzing materials emitted from the body at different times. These measurements will be used to infer the structural homogeneity of the individual body, thus separating differentiated objects from rubble piles and yielding a better understanding of the formation and evolution of each individual small body.

Secondary Objectives: 3. Compare the atmospheric entry characteristics (deceleration, fragmentation, catastrophic vaporization, etc.) of meteors with their chemistry to search for compositional types that may be under-represented or absent from modern meteorite collections due to atmospheric destruction

SUMS Mission Characteristics: A hyperspectral imager using seven fast (f/1.5) cameras, each with a 10 degree field of view, looks down into the terrestrial atmosphere. The dispersed spectral images are recorded at 400 frames per second for later transmission to ground control. Each camera contains event-detection software: data is only recorded if a meteor is in the field of view. The payload will be delivered by the Space Shuttle to the International Space Station and accommodated on a truss mounted carrier system to be developed by GSFC's Shuttle Small Payloads Project Office.

Mission Management: The high-frame-rate ultraviolet cameras will be built by Princeton Scientific Instruments as a Phase III Small Business Innovative Research Program Contract. The original instrument concept and demonstration system were constructed using SBIR Phase I and Phase II funding in order to develop and test this innovative camera. Each camera will be integrated into a telescope design that has flown on several successful sounding rocket missions by the Naval Research Laboratory. The cameras will be integrated into the telescopes constructed by NRL, then tested and calibrated at NRL before delivery to GSFC's SSPPO for integration with the truss-mounted carrier system. The SSPPO will manage all interfaces with both the Space Shuttle and the International Space Station (ISS) Offices in order to assure that the payload is fully compliant with all relevant safety standards and to ensure that these offices receive all necessary payload information in a timely manner. The SSPO will manage the launch of the CAPO-SUMS payload to the ISS, the deployment to the attach point and the initial on-orbit testing of the instruments. Ground systems at the University of Alabama, Birmingham and at NASA's Goddard Space Flight Center will operate the CAPO-SUMS Instruments for the next three years through the Marshall Space Flight Center's Payload Operations Center. During this time CAPO-SUMS will acquire the spectra of more than 1000 sporadic meteors as well as the spectra of tens of thousands of meteors originating in specific meteor showers traceable to individual sources such as Comets Halley, Swift-Tuttle, Giacobini-Zinner and Metcalf. This data set will be analyzed to yield measures of the chemical composition and homogeneity of the parent body. A secondary goal will be to extract a measure of the survival probability of incoming meteors as a function of their chemical composition.

Schedule and Cost: The CAPO-SUMS instruments will be constructed and integrated with the truss carrier before January 2008 for launch in July 2009. On orbit operation will extend through July 2012 with return of the CAPO-SUMS payload to GSFC by December 2012. To design, build, test and calibrate the CAPO-SUMS instruments will cost $42M. To acquire and analyze the data will require $30M. Development of the truss carrier, integration and testing of the instruments and carrier system, management of the deployment of the CAPO-SUMS payload to the ISS and its subsequent retrieval will cost $38M. Adding a generous reserve to account for problems caused by changes in the ISS or space shuttle policies or costs of $75M brings the total cost of the mission to $185M.

ASSESSMENT OF ANALOG PARTICLE CAPTURING BY AEROGEL AT THE FLYBY SPEED OF STARDUST. K. Okudaira[1], T. Noguchi[2], T. Nakamura[3], M.J. Burchell[4], M. Cole[4], and H. Yano[1], [1] Institute of Space and Astronautical Science (ISAS) (3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, JAPAN, okudaira@planeta.sci.isas.ac.jp), [2] Ibaraki University (2-1-1 Bunkyo, Mito, Ibaraki 310-8512, JAPAN, tngc@mx.ibaraki.ac.jp), [3] Kyushu University (6-10-1 Hakozaki, Fukuoka 812-8581, JAPAN), [4] University of Kent (Canterbury, Kent, CT2 7NZ, UK).

Introduction: In 2006 the STARDUST spacecraft will return to the Earth with cometary dust and hopefully interstellar dust grains. They are to be collected by silica aerogel, amorphous SiO_2 with extremely low bulk density (0.02 g/cm^3 for STARDUST [1]). Several investigations suggested that aerogel is suitable for hypervelocity particle capturing. But aerogel is an excellent thermal insulator, the heat converted from the kinetic energy of particles would affect the particles themselves. In these few years the authors have evaluated physical alterations of micrometeoroid analog particles captured by aerogel [2]. Here we report on the results of impacts at around 6 km/s, which is the flyby speed of the STARDUST [1].

Hypervelocity Impact Experiment: Hypervelocity impact (HVI) experiments are conducted in order to simulate hypervelocity particle capture. Two-stage light gas guns were used. We conducted the HVI experiments at 2-4 km/s (ISAS) [2] and at 6 km/s (University of Kent) [3].

In this study aerogel with 0.03 g/cm^3 density was used as targets. They were manufactured by the Institute of the High Energy Accelerator Research Organization (KEK), Tsukuba, Japan and they have been proven capable of capture up to 6 km/s [4].

Sample selection and preparation. Serpentine and cronstedtite were selected as projectiles. These phyllosilicate minerals are analog materials of micrometeoroid since they are common in CM/CI and CM chondrites, respectively. As these hydrated minerals are broken down to anhydrous at relatively low temperatures, it is suitable for the evaluation of thermal alteration during the capture process. The powdered samples were packed into a plastic sabot and shot into aerogel separately. The original particle size range was 125 to 167 µm. To verify whether fragmentation occurs at the moment of launch, thin Al film (2 µm) was placed in front of the target in some shots.

Analytical Methods: Both mineralogical and image analyses were applied to the samples.

Image analysis. Before extraction from each aerogel block, several physical parameters such as sizes of the captured particles and diameters of their entrance holes, length and volume of the penetration tracks were measured by an images analysis.

Mineralogical analyses. Some portions of the samples were then extracted for mineralogical analyses, such as SEM/EDS and Synchrotron Radiation-XRD analysis [5].

Results and Discussions: Although there was fragmentation of particles at the moment of launch, we found an apparent mass reduction of each particle in volume during penetration into the aerogel (down to only 1 to 5 % of their original volumes, without Al foil). In the previous study, the same minerals shot at about 4 km/s reduced their volumes down to 10 % [2]. The SR-XRD analysis revealed that a cronstedtite grain shot into aerogel at 6.06 km/s began to break down into maghemite at the surface. The decomposition temperature of cronstedtite is about 470 °C [6] so it can be said that outermost layer of the remained grain has experienced that temperature. On the other hand, a serpentine grain which decomposes at about 600 – 660 °C [7] was unchanged.

Conclusions: Even shot at 6 km/s into 0.03 g/cm^3 aerogel, a serpentine grain and the bulk of the cronstedtite grain remained mineralogically unchanged. Therefore, for the samples of STARDUST, we will be able to see the pristine states of minerals inside each recovered grain, although these grains lose their volumes and the original surface morphologies.

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MID-INFRARED SPECTRUM OF THE ZODIACAL EMISSION: DETECTION OF CRYSTALLINE SILICATES IN INTERPLANETARY DUST. T. Ootsubo[1], T. Onaka[2], I. Yamamura[3], D. Ishihara[4], T. Tanabe[5] and T. L. Roellig[6], [1]National Astronomical Observatory of Japan, Tokyo 181-8588, Japan (ootsbotk@cc.nao.ac.jp), [2]Department of Astronomy, Graduate School of Science, The University of Tokyo, Tokyo 113-0033, Japan, [3]Institute of Space and Astronautical Science, Kanagawa 229-8510, Japan, [4]Department of Astronomy, Graduate School of Science, The University of Tokyo, Tokyo 113-0033, Japan, [5]Institute of Astronomy, Faculty of Science, University of Tokyo, Tokyo 181-8588, Japan, [6]NASA Ames Research Center, Moffet Field, CA 940035-1000, U.S.A.

Introduction: Within a few astronomical units of the Sun the solar system is filled with interplanetary dust, which is believed to be dust of cometary and asteroidal origin. Spectroscopic observations of the zodiacal emission with moderate resolution provide key information on the composition and size distribution of the dust in the interplanetary space. They can be compared directly to laboratory measurements of candidate materials, meteorites, and dust particles collected in the stratosphere. Recently mid-infrared spectroscopic observations of the zodiacal emission have been made by two instruments on board the Infrared Space Observatory; the camera (ISOCAM) and the spectrophotometer (ISOPHOT-S). A broad excess emission feature in the 9-11 μm range is reported in the ISOCAM spectrum [1], whereas the ISOPHOT-S spectra in 6-12 μm can be well fitted by a blackbody radiation without spectral features [2].

Observation: The spectrum of the zodiacal emission from the dust in the interplanetary space was observed at wavelengths from 4.5 to 11.7 μm with the Mid-Infrared Spectrometer (MIRS) on board the Infrared Telescope in Space (IRTS) [3,4]. The MIRS was one of the four focal plane instruments on board the IRTS and surveyed about 7% of the entire sky. The observations of the IRTS were made from 1995 March 29 to April 24. The mid-infrared spectrum of the zodiacal emission on the ecliptic plane (solar elongation ~ 97 degrees) was used for the analysis.

Results: The MIRS spectrum of the zodiacal emission at the ecliptic plane is compatible with the ISOCAM and the ISOPHOT-S results at a 20% level and the spectral shapes are all quite similar. The MIRS spectrum is well fitted by the three-dimensional DIRBE (Diffuse Infrared Background Experiment) zodiacal dust cloud model spectrum [5] with a possible excess emission feature in 9-11 μm. The excess feature has a broad 10-μm peak and a small peak at 11.2 μm. We found a combination of 75% amorphous and 25% crystalline silicate particles in weight accounts for the "double-peaked" 9-11 μm feature in the MIRS spectrum.

Discussion and Conclusions: Crystalline silicates have been detected in several comets and interplanetary dust particles (IDPs) collected in the stratosphere. The fraction of the crystalline silicate in case of the MIRS spectrum is similar to that of comet Hale-Bopp (~30-38% in weight) [6]. The particles producing the zodiacal emission in the mid-infrared region are composed of silicates similar to those found in the comae of comets and collected IDPs. The MIRS spectrum suggests that the dust particles in the interplanetary space contain crystalline silicates, particularly Mg-rich olivine comes from comets for the first time [7].

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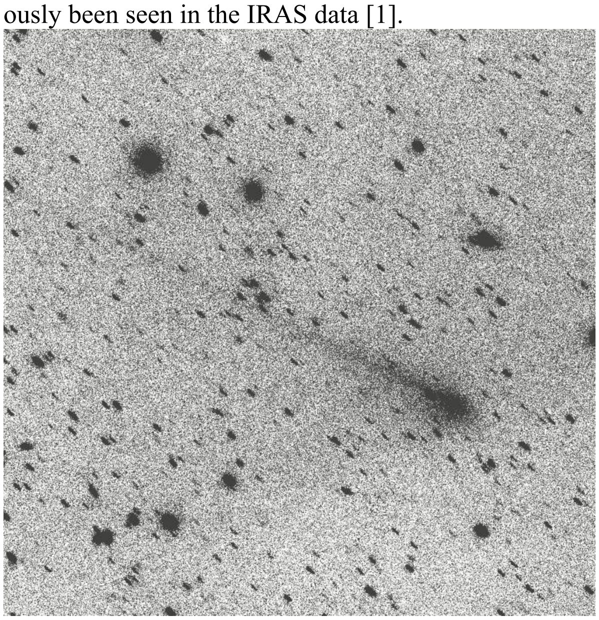
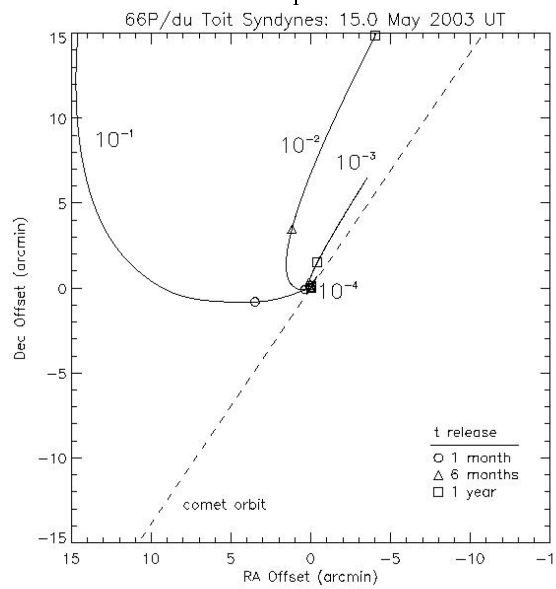
LARGE PARTICLES FROM SHORT-PERIOD COMETS. W. T. Reach[1], M.V. Sykes[2], M. S. Kelley[3]. [1]SIRTF Science Center, Caltech, MS 220-6, Pasadena, CA 91125 (reach@ipac.caltech.edu). [2]Steward Observatory, Univ. of Arizona, Tucson, AZ [3]Dept. of Astronomy, Univ. of Minnesota, Minneapolis, MN

Introduction: Deep optical and mid-infrared images reveal that short-period comets are trailed by large (>mm sized) particles. These particles are the same as those that produce meteor storms in the rare case when a comet's orbit nearly intersects the Earth's. We have begun a campaign of deep observations to determine whether all short-period comets produce large meteoroids. Cometary debris trails were first discovered (serendipitously) by the *Infrared Astronomical Satellite* [1], and they have only recently been detected in visible light [2]. While we ultimately expect to observe nearly all short-period comets, we will initially concentrate on those with favorable apparitions and those that are targets of upcoming spacecraft missions.

Optical Observations: We are using the Palomar Observatory 60-inch and 200-inch telescopes to search for sunlight scattered by large particles with orbits similar to the parent comets. These observations have just begun; so far (May 2003) we have moderately deep observations of Wild 4, duToit, Wirtanen, Tempel 2, Wild 2, Russell 4, Reinmuth 1, Gunn, duToit-Hartley, Churyumov-Gerasimenko, and 2001 RX14. Deep observations of Encke were recently reported [3]. Figure 1 shows a moderately deep observation of Churyumov-Gerasimenko, a potential target for the ESA *ROSETTA* mission, revealing the first optical detection of its dust trail; infrared emission had previously been seen in the IRAS data [1].



Infrared Observations: We used the *Infrared Space Observatory* to observe comets Kopff [4] and Encke[5]. New observations are scheduled for the Space Infrared Telescope Facility (SIRTF). The target list for the SIRTF observations is evolving as the launch is delayed; for an August 2003 launch the target list includes (in time order, from November 2003 to April 2005) Encke, Grigg-Skjellerup, Whipple, Tempel 1, Russell 4, Churyumov-Gerasimenko, Wild 2, Tempel 2, Wilson-Harrington, Neujmin 2, van Biesbroeck, Gunn, Howell, Oljato, Tsuchinsan 2, Hartley-IRAS, Tsuchinsan 1, Elst-Pizarro. For all comets, a 24 micron image will be obtained, and for most comets a 5-40 micron spectrum will be obtained.



Dynamical Modeling: To determine whether large particles are present around the target comets, we predict the trajectories of particles of various size (parameterized by the ratio of radiation pressure to gravity, β, emitted over the current and previous orbit of the comet. Figure 2 shows the syndynes for comet duToit in May 2003. Small particles ($\beta > 10^{-2}$) travel on orbits sufficiently different from the nucleus that they are quickly lost from the nuclear environment and can only be seen if they were produced within months of the observation. Large particles have orbits so similar to the nucleus that they remain close by and only spread gradually, along a trail defining the nucleus' orbit, over years.

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