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Visible-IR and Raman spectra of three Itokawa particles

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Abstract

The present study characterizes the mineralogy and the extent of space weathering of three particles collected by the Hayabusa mission at the surface of asteroid 25143 Itokawa.

1. Introduction & methods

Hayabusa-returned samples offer a unique perspective to understand the link between asteroids and cosmomaterials available in the laboratory, and to provide insights on the early stages of surface space weathering. In this work we characterize the mineralogy and the extent of space weathering of the three Itokawa particles RA-QD02-0163, RA-QD02-0174, and RB-QD02-0213 provided by JAXA to our consortium. We report here a series of results based on non-destructive analyses through visible near-infrared reflectance and Raman spectroscopy. Results were obtained on the raw particles, both in their original containers and deposited on diamond windows.

2. Results

Particle RA-QD02-0163 consists of a heterogeneous mixture of minerals: olivine (Fo76) dominates an assemblage of Ca-rich (En50, Wo50) and Ca-poor (En85) pyroxenes. The elemental compositions of silicates are consistent with those previously reported for distinct Hayabusa particles. Particles RA-QD-0174 and RB-QD02-0213 are solely composed of olivine, whose chemical composition is similar to that observed in RA-QD02-0163. It has been previously shown that the S-type asteroid 25143 Itokawa is a breccia of poorly equilibrated LL4 and highly equilibrated LL5 and LL6 materials [1].

The three particles studied here can be related to the least metamorphosed lithology (LL4) based on the high Fo content of the olivine. Neither carbonaceous matter nor hydrated minerals were detected through Raman on the three allocated particles.

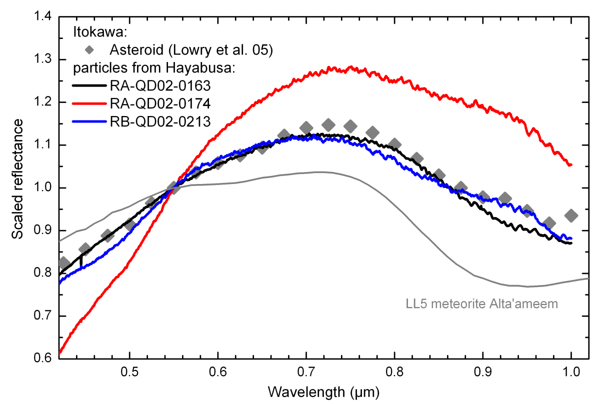

Figure 1: Comparison of the reflectance spectra of objects having experienced distinct extents of space weathering: our three Hayabusa particles [2], the laboratory spectrum of the Alta'ameem LL5 meteorite [3] and the ground-based spectra of asteroids Itokawa [4].

The NIR-VIS reflectance (incidence = 45°, light collection at e=0°) spectra of the three particles, in particular the 1-µm band, are consistent with the presence of both olivine and pyroxene detected via Raman. As shown in Figure 1, the spectra of particles RA-QD02-0163 and RB-QD02-0213 are also fully compatible with the ground-based observations of asteroid (25143) Itokawa in terms of both spectral features and slope. By contrast, particle RA-QD02-0174 has a similar 1-µm band depth but higher (redder) spectral slope than the surface of Itokawa.

This probably reveals a variable extent of space weathering among the regolith particles. RA-QD02-0174 may contain a higher amount of nanophase metallic iron and nanophase FeS. Such phases are produced by space weathering induced by solar wind, as previously detected on other Itokawa particles [5].

6. Summary and Conclusions

Identification of the minerals, characterization of their elemental compositions and measurements of their relative abundances were led through Raman spectroscopy in punctual and automatic mode. Reflectance spectra in the visible and near-IR wavelengths constrain the mineralogy of the grains and allow for direct comparison with the surface of Itokawa. The spectra reflect the extent of space weathering experienced by the three particles.

To go further in the characterization of space weathering and to better constrain the link between the spectral slope of reflectance spectra and the abundance of nanophase metallic iron, additional analytical techniques, such as STEM, need to be applied to image the Fe-rich nanoparticles.

Acknowledgements

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References

[1] Nakamura T. and 21 colleagues (2011) Itokawa dust particles: a direct link between S-type asteroids and ordinary chondrites. Science 333, 1113-1116.

[2] Bonal L., Brunetto R., Beck P., Dartois E., Dionnet Z., Djouadi Z., Duprat J., Füri E., Kakazu Y., Oudayer P., Quirico E., Engrand C., 2015. Visible-IR and Raman micro-spectroscopic investigation of three Itokawa particles collected by Hayabusa: mineralogy and degree of space weathering based on non-destructive analyses. Meteoritics & Planetary Science, submitted.

[3] Hiroi T., Abe M., Kitazato K., Abe S., Clark B.E., Sasaki S., Ishiguro M., Barnouin-Jha O.S., 2006. Developing space weathering on the asteroid 25143 Itokawa. Nature 443, 56-58.

[4] Lowry S.C., Weissman P.R., Hicks M.D., Whiteley R.J., and Larson S., 2005. Physical properties of asteroid (25143) Itokawa – Target of the Hayabusa sample return mission. Icarus 176, 408-417.

[5] Noguchi T. and 16 colleagues, 2014. Space weathered rims found on the surfaces of the Itokawa dust particles. MAPS 49(2), 188-214.

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Coherent dust cloud observed by three *Cassini* instruments

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Abstract

We revisit the evidence for a "dust cloud" observed by the *Cassini* spacecraft at Saturn in 2006. The simultaneous data of 3 instruments are compared to interpret the signatures of a coherent swarm of dust that could have remained floating near the equatorial plane.

1. Introduction

Interplanetary dust clouds are local density enhancements of particles of a specific mass type. Such clouds might usually be relicts of a dissolved comet, debris of an asteroidal collision, ejecta from planets or moons, and a few may also go back to jet streams from active bodies, or coronal mass ejections. In the vast range of patterns, the characteristics of dust will vary on all dimensions: size, density, mass, lifetime, and more (see, e.g., Grün *et al.* (2004)).

Kennedy *et al.* (2011) looked for a dust swarm in the far-off field at Saturn (>100 Saturnian radii, R_S) using *Spitzer* observations. A large-scale cloud, that could be attributed to an irregular satellite or other cosmic origin, was not found definitely. More recently, Khalisi *et al.* (2015) reported of one possible dust cloud detected as a persistent feature in the impact rates of the Cosmic Dust Analyser on the *Cassini* spacecraft. We revisit their data in a broader context and complement it with new evidence. We synchronised the data by the Cosmic Dust Analyser (CDA), the Radio/Plasma Wave Detector (RPWS), and Magnetometer (MAG) to search for patterns that may give evidence for a cloud of particles. Unfortunately, the Plasma Spectrometer (CAPS) did not provide sufficient output in the time slot considered.

2. Data Basis

The key parameters of the instruments on the *Cassini* spacecraft are stored in the MAPSview database. We employed the following parameters for our study:

- CDA: impact rate r'_{all} of all the registered dust events per 64 seconds, see [4];
- RPWS: qualitative radio signals in the frequency bands of 1 Hz, 10 Hz, 100 Hz, 1 kHz, and 10 kHz;
- MAG: strength of the magnetic field |**B**| plus its three spacial components in the kronocentric solar-magnetospheric (KSM) coordinate system.

Most parameters are provided at 1-minute intervals of time, except some very few cases when the instrument was out of nominal operation.

The CDA data depend on the current instrument pointing and reflect the density as well as other states of the dust only partially. RPWS and MAG are not reliant on the spacecraft attitude and have the advantage of a continuous measurement of their respective signals throughout the orbit. In particular, the components of the **B**-vector give important clues to alignments of the magnetic field or circular currents.

3. The dust cloud of DOY 203/2006

The *Cassini* spacecraft just changed its sequence of orbits from equatorial to inclined trajectories after a targeted flyby at Titan (T16) on DOY 203.02. It set in for four consecutive revolutions (#26–29, Fig. 1) out of the equatorial plane to traverse almost the same spot in the Saturnian space. The inclination to the ring plane was about 15° for these revolutions (not seen in that projection). The ring plane of Saturn was crossed at DOY 203.11 in a distance of 20.126 R_S. The green segments mark the region of the supposed dust cloud.

Figure 2 shows the time-depended signals of the three instrumental parameters in July 2006. The peak in the dust rate at DOY 203.40 coincides with a depression of |**B**| (black line), and, in particular, the B_x-component (blue) changes its direction. The B_y-component (orange) exhibits a decline from positive to negative values and rising back again showing a clear sign of rotation as a ring current was hit. At time T = 203.50, the previous **B**-values were restored acting as

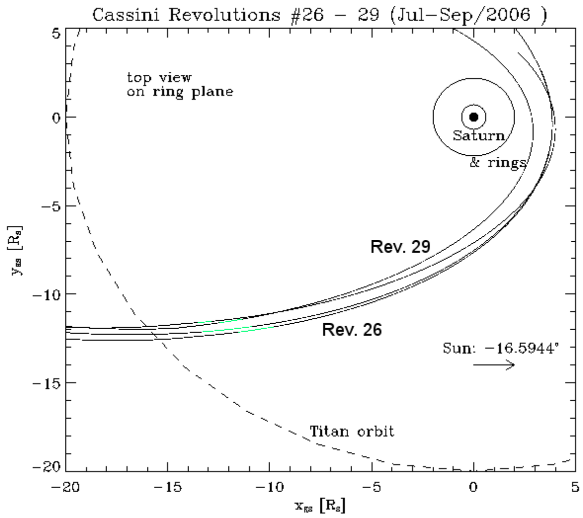

Figure 1: Trajectory of *Cassini* from outer regions heading to its perikronium. The region of the dust cloud is highlighted green.

if separated by a bulkhead. Goertz (1983) reported of similar plasma tubes from both *Voyager* flybys. He interpreted that as "plasma blobs" breaking off the magnetospheric sheet.

The RPWS data support the thought of a "magnetic bubble", for it shows a remarkable tranquility in the 100 Hz and 1000 Hz band (third and fourth curve of RPWS in the middle panel). A dozen "negative peaks" appear in the 1 Hz band (top black curve). These peaks can be considered as micron-sized dust grains impacting on the spacecraft. Similar features in the 10-kHz-band were discussed by Kurth *et al.* (2006). Moreover, the CDA registered twice as much impacts on the instrument housing than on its sensitive areas, meaning that many particles did not enter from the Kepler-RAM direction. Time stamps of the most conspicuous features are given in Table 1.

The same pattern repeated at the next two passages when the spacecraft passed almost the same spot of space. During the Revolution #27 (Fig. 3), the CDA pointed to an unsuitable direction, but the countersink of the magnetic field remained. — At the third return the signals resemble DOY 203 again (Fig. 4). In spite of some changes among minor features, important characteristics of the first passage can be identified. From the time stamps of entering and leaving, the radial extent of that "cloud" or "blob" can be estimated to ≈82,500 km or 1.36 R_S. Its z-location is found 1 R_S below the ring plane. — At the fourth passage on DOY 266/2006 (not shown), the CDA data displays even stronger deviations, and the allocation of that cloud turns out uncertain.

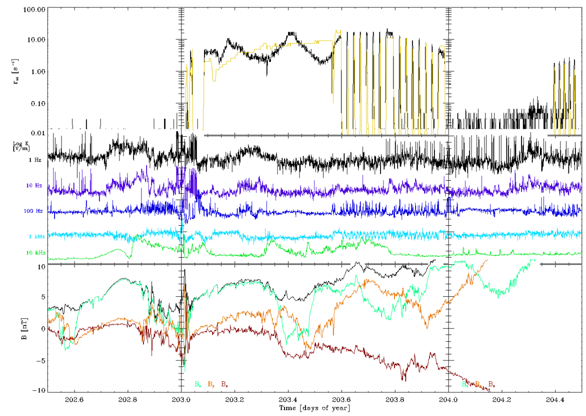

Figure 2: Data comparison of three Cassini instruments at Revolution #26 in July 2006. *Uppermost panel:* Dust impact rate r_all (black line) and the sensitive area (yellow) of the CDA exhibited to the Kepler-RAM. *Middle panel:* Five frequencies of the radio and plasma data (RPWS). *Bottom panel:* Magnetic field strength $|\mathbf{B}|$ (black) as well as the 3 B-components in the frame of kronocentric-solar-magnetospheric coordinates.

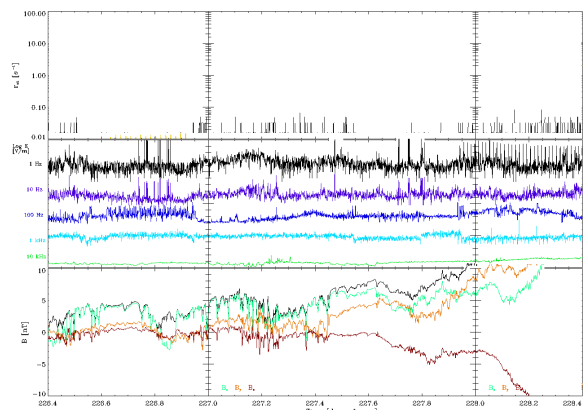

Figure 3: Data of CDA, RPWS, and MAG for Revolution #27. The main feature of the supposed dust cloud resides from T = 227.11 to 227.42.

The MAG-data suggests that the cloud has broadened by 15,000 km from Revolution #26 through #28. It could also have moved outwards from 18.5 R_S to 18.9 R_S, though this might be an effect of the spacecraft hitting the cloud at different parts. The slightly different trajectory can also be the reason for the discrepancies in the data at the second return (DOY 227). The increase of size, however, is supported by the drop of $|\mathbf{B}|$ by 2–5 nT. The magnetically "quiet" region in front of the onset of the cloud (≈250.92–251.14) has

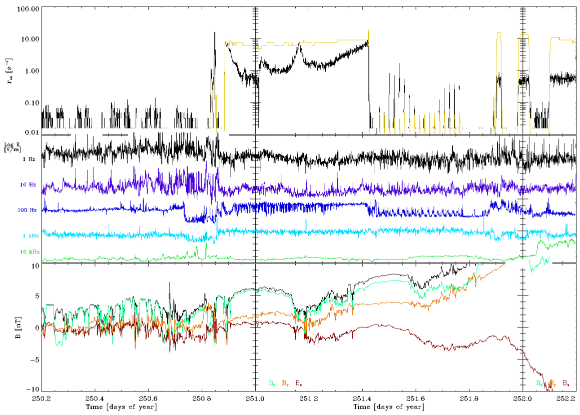

Figure 4: Panels same as in Figures 2 and 3 for Revolution #28. The ring plane crossing happened on 250.89.

also diminished by 1 nT. The bulk of solid particles (CDA) appears compressed and shifted further from the deepest point of the magnetic field. This deviation seems to grow.

There exist indications for two more clouds during the Revolution #26: from T = 202.95 to 203.05 and from T = 203.65 to 203.95. Both can be re-discovered at the next but one flyby: in Revolution #28, they peak around 250.80 and 251.50, respectively.

Table 1: Time stamps T of the dust cloud as seen by different instruments. D = distance of the pattern peak from Saturn. Brackets reflect very uncertain data.

Instr.	T (enter)	T (leave)	D [R_S]
Revolution 26			
CDA	203.32	203.52	17.69
MAG	203.33	203.50	17.64
$\mathrm{RPWS}_{1\mathrm{Hz}}$	203.36	(203.53)	
$\mathrm{RPWS}_{100\mathrm{Hz}}$	203.36	203.56	17.64
$\mathrm{RPWS}_{10\mathrm{kHz}}$	203.31	203.56	17.71
Revolution 27			
CDA	(227.10)	(227.39)	(18.78)
MAG	227.11	227.42	18.93
$\mathrm{RPWS}_{1\mathrm{Hz}}$	(227.06)	(227.28)	
$\mathrm{RPWS}_{100\mathrm{Hz}}$	227.09	227.39	18.70
$\mathrm{RPWS}_{10\mathrm{kHz}}$	(227.00)	227.31	
Revolution 28			
CDA	251.11	251.25	18.48
MAG	251.13	251.29	18.34
$\mathrm{RPWS}_{1\mathrm{Hz}}$	(251.13)	(251.26)	
$\mathrm{RPWS}_{100\mathrm{Hz}}$	—	—	
$\mathrm{RPWS}_{10\mathrm{kHz}}$	—	—	

4. Discussion

It is still not certain whether or not such coherent swarms of dust can exist for long in the magnetosphere of Saturn. From the theoretical point of view, small dust particles are quickly ionised (UV-radiation, solar wind) and carried away by the magnetic field. Various other effects like shock waves, gravitational drags, evaporation, and Kepler shear will also lead to a disruption of the cloud. It will preferably be the debris larger than $\approx$1 mm in size that may endure several crossing times, r/v, where r is the projected radial distance and v the velocity dispersion of the particles. Such larger particles are not recorded though. However, the most intriguing evidence for the supposed clouds of small dust particles comes from the CDA. Further detailed investigation is envisaged and more cases like this one have to be found. Since the trajectory of *Cassini* changes too frequently, it will be challenging to trace a particular cloud for more than two or three revolutions of the spacecraft. Within that period of time, we expect the cloud to change its shape. More evidence for the dust clouds is in preparation.

Acknowlegements

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References

[1] Goertz C.K. (1983): Detached Plasma in Saturn's Front Side Magnetosphere. Geophysical Research Letters 10, p455–458.

[2] Grün E., Dikarev V., Frisch P.C., Graps A., Kempf S., Krüger H., Landgraf M., Moragas-Klostermeyer G., Srama R. (2004): Dust in Interplanetary Space and in the Local Galactic Environment. *ASP Conference Series 309*, p245–263.

[3] Kennedy G.M., Wyatt M.C., Su K.Y.L., Stansberry J.A. (2011): Searching for Saturn's dust swarm: limits on the size distribution of irregular satellites from km to micron sizes. *Monthly Notices RAS 417*, p2281–2287.

[4] Khalisi E., Srama R., Grün E. (2015): Counter data of the Cosmic Dust Analyzer aboard the *Cassini* spacecraft and possible "dust clouds" at Saturn. *Advances in Space Research 55*, p303–310.

[5] Kurth W.S., Averkamp T.F., Gurnett D.A., Wang Z. (2006): *Cassini* RPWS observations of dust in Saturn's E-Ring. *Planetary and Space Science 54*, p988–998.

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Elemental Composition of Primitive Anhydrous IDPs

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Abstract

We measured elemental compositions of five large anhydrous cluster interplanetary dust particles (IDPs) that show no evidence of significant thermal alteration during atmospheric entry and found their mean composition to be very similar to that of primitive CI meteorites. Our results indicate that the enrichment in moderately volatile elements and the depletion in S found in the ~10 μm anhydrous, chondritic porous (CP) IDPs, the matrix of these cluster IDPs, are not representative of the composition of their parent body. The inclusion of larger (>10 μm) volatile-poor silicates as well as sulfides in the large anhydrous cluster IDPs, which sample the CP IDP parent body at a larger size scale, suggests the large cluster IDPs are unbiased samples of the condensable material of the Solar Nebula.

1. Introduction

The ~10 μm chondritic porous interplanetary dust particles (CP IDPs), dust from asteroids and comets collected by NASA from the Earth's stratosphere, are anhydrous aggregates of $>10^4$ individual grains. On average these CP IDPs are enriched in many moderately volatile elements, including Mn, Cu, Zn, Ga, Ge, Se, and Br, generally by a factor of ~2 to 4 over the CI meteorites, while another moderately volatile element, S, is depleted relative to CI [1, 2, 3]. Various reasons for enrichment of the moderately volatile elements have been proposed. Van der Stap et al. [1] suggested the CP IDPs might be late-stage condensates, sampling a region of the Solar Nebula already depleted in higher temperature condensates. Jessberger et al. [2] suggested the additional volatiles were contaminants acquired while the particles resided in the Earth's atmosphere. Flynn et al. [3] suggested the CP IDPs might be a new type of extraterrestrial material, not represented in the meteorite collection. However, NASA's stratospheric collections include many non-chondritic, mono-mineralic grains -- volatile-poor olivine and pyroxene as well as calcophile-rich sulfides -- collected along with the fine-grained chondritic IDPs. Some of these larger mineral grains (many >10 μm in size), have fine-grained, chondritic material (i.e., small bits of typical CP IDPs) adhering to their surfaces, indicating they are larger fragments of the same parent as the ~10 μm, fine-grained CP IDPs. Thus, the bulk composition of the CP IDP parent body can only be determined by adding to the fine-grained, CP IDPs the *correct amount* of this non-chondritic material. The collection of cluster IDPs, larger IDPs that fragment on impact with the collector, which include both fine-grained CP IDP material and larger mineral grains provides the opportunity to determine the elemental composition of the CP IDP parent body at a significantly larger size scale, since a single large cluster IDP contains >100 times the mass of one ~10 μm CP IDP.

2. Measurements and Results

Using the ~8 μm monochromatic x-ray beam of the X26A microprobe at the National Synchrotron Light Source (Brookhaven National Laboratory), we performed x-ray fluorescence (XRF) and x-ray diffraction (XRD) on all of the material from 8 large cluster IDPs from NASA's L2005, L2008, and L2009 stratospheric collectors. We obtained the bulk composition by adding the point spectra and the bulk mineralogy by adding the x-ray diffraction patterns acquired by raster scanning the entire cluster particle.

Five of the eight cluster IDPs showed minimal evidence of thermal alteration during atmospheric deceleration, i.e., only a very minor amount of magnetite detected by XRD and Zn/Fe >0.3xCI, criteria previously identified as correlating with a low degree of thermal alteration [4]. These five cluster IDPs are dominated by anhydrous phases, since hydrous minerals were below the detection threshold in XRD. The fraction of cluster IDPs that show no evidence of significant atmospheric entry heating (five of eight) is much larger than predicted by modelling, suggesting these anhydrous cluster IDPs have a much lower density than the 1 to 3 gm/cm^3 generally assumed in the modelling.

The XRD patterns of the cluster IDPs show d-spacings consistent with a mixture of pyrrhotite, forsterite and enstatite, which, along with amorphous silicate that gives no XRD pattern, are the common minerals in IDPs. Of the elements enriched over CI in the ~10 µm CP IDPs, Zn is present in the highest amount and is most accurately determined in our XRF analysis. While Zn/Fe in ~10 µm CP IDPs is ~4xCI, the mean Zn/Fe of these five cluster IDPs is ~1.2xCI (Figure 1), presumably from the inclusion of volatile-poor silicates in these large cluster IDPs. This requires that large olivine, pyroxene, and sulfide grains, plus any amorphous silicate, constitute >70% of the mass of the anhydrous cluster IDPs, although the volume fraction of the large mineral grains would smaller because of the density difference between the crystalline grains and the more porous, fine-grained material. The S depletion seen in the CP IDPs is not seen in the large cluster IDPs, presumably from the addition of large sulfide grains. The CP IDPs appear to sample the matrix of a parent body that is dominated by larger crystalline grains, so, like the matrix of chondritic meteorites, the CP IDPs do not reflect the bulk composition of the parent body.

3. Summary and Conclusions

Based on the similarity of the elemental composition of the hydrous CI meteorites to that of the Sun, except for extremely volatile elements (e.g., H, He, and noble gases), the CI meteorites are believed to preserve the elemental composition of the Solar Nebula. The ~10 µm CP IDPs, aggregates of $>10^4$ unequilibrated, mostly sub-micron grains, have been recognized as even more primitive samples of Solar Nebula condensates [5], preserving the mineralogy because they have not experienced aqueous alteration. However the observed enrichment in the moderately-

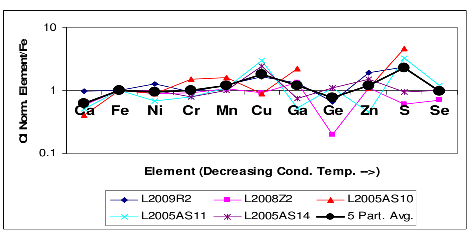

Figure 1. CI- and Fe-normalized element abundances for five large, normal-Zn cluster IDPs and the mean composition of the group of five large, normal-Zn, anhydrous cluster interplanetary dust particles.

volatile elements and the depletion of S relative to CI in CP IDPs has been difficult to understand for particles that are believed to be essentially unmodified samples of the Solar Nebula. Our results on large anhydrous cluster IDPs, which are mixtures of CP IDP material with larger mineral grains, mostly pyrrhotite, which increases bulk S, and volatile-poor silicates, which reduce the bulk volatile content, indicates the parent body of the CP IDPs is CI-like in composition, and is likely the best surviving reservoir of essentially unprocessed material from the early Solar System. The parent bodies of these anhydrous cluster IDPs would be an important target for spacecraft missions designed to collect unprocessed samples of Solar Nebula material.

Acknowledgements

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References

[1] van der Stap, C. C. A. H., Vis, R. D. and Verheul, H.: Interplanetary Dust: Arguments in Favour of a Late Stage Nebular Origin of the Chondritic Aggregates, Lunar & Planetary Science XVII, pp. 1013-1014, 1986.

[2] Jessberger, E. K., Bohsung, J., Chakaveh, S., and Traxel, K.: The volatile element enrichment of chondritic interplanetary dust particles, Earth and Planetary Science Letters, 112, pp. 91-99, 1992.

[3] Flynn, G. J., Bajt, S., Sutton, S. R., Zolensky, M. E., Thomas, K. L., and Keller, L. P.: The Abundance Pattern of Elements Having Low Nebular Condensation Temperatures in Interplanetary Dust Particles: Evidence for a New Chemical Type of Chondritic Material, in Physics; Chemistry; and Dynamics of Interplanetary Dust, Astronomical Society of the Pacific Conference Series, San Francisco, 1996.

[4] Flynn, G. J., Sutton, S. R., Thomas, K. L., Keller, L. P. and Klöck, W.: Zinc Depletions and Atmospheric Entry Heating in Stratospheric Cosmic Dust Particles, Lunar & Planetary Science XXIII, pp. 375-376, 1992.

[5] Ishii, H. A., Bradley, J. P., Dai, Z. R., Chi, M., Kearsley, A. T., Burchell, M. J., Browning, N. D. and Molster, F.: Comparison of Comet 81P/Wild 2 Dust with Interplanetary Dust from Comets, Science, 319, pp. 447-450, 2008

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New algorithms for faint traces detection on CCD images of 'all-sky' cameras

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Abstract

Several algorithms have been developed, depending of camera and sky conditions. In general, main steps applied are the following:

CCD image is decomposed in a mosaic of square zones (tilts). This way the checking of the process is simple and can be applied to different image zones.

The following steps ere applied in each tilt:

- Getting of 'limit' signal value, between 'active' and non significant signal points. Zones with active points more frequent than a given number is considered as 'saturated' and eliminated (all points are set to zero).

- A new 'limit' signal is obtained and isolated active points are eliminated.

- Each tilt is divided in N by N small zones and active points in each zone are counted. Zones are ordered and selected those N with more active points. Points of other zones are set to zero.

- A strait line is 'fitted' to active points in the tilt. Points far from the line are eliminated.

Algorithm applies the following steps to detected traces:

- Strait lines of tilts are analyzed searching for connectivity. When several lines are connected, middle and external segments are search for.

- After traces detection, an estimation of trace magnitude can be obtained by 'reading' signals in the detected trace and its adjacent zones.

- Total signal of new traces and signal per length unit is obtained. From this value, an estimation of trace magnitude can be got.

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Understanding the organo-carbonate associations in carbonaceous chondrites with the use of micro-Raman analysis

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Abstract

Carbonates can potentially provide sites for organic materials to accrue and develop into complex macromolecules. This study examines the organics associated with carbonates in carbonaceous chondrites using μ-Raman imaging.

1. Introduction

Carbonaceous chondrites are primitive meteorites that contain a large variety of carbon- and nitrogen-bearing compounds, which have been widely investigated for life's origins in past decades. While <5 wt% of bulk meteorite is carbon-bearing materials, including organic matter (~2 wt%), carbonate, diamond, silicon carbide, and graphite, carbonates only make up <0.2 wt% [8, 9]. Meteoritic carbonates are thought to be formed on primitive parent bodies through aqueous alteration [5]. Aqueous processing also synthesizes organic molecules and results in molecular asymmetry that depicts life on Earth [4]. Organo-carbonate associations in aqueous setting allow the adsorption of organic matter onto carbonate mineral surfaces, which make carbonate an effective medium for the accumulation and concentration of organic matter, including carboxylic acids, amino acids, fatty acid etc. [2, 10-12]. Properly performed Raman spectroscopy provides a non-destructive technique for characterizing meteorites. It is sensitive to carbon phases, and allows the differentiation of organic and inorganic materials as well as the interpretation of their spatial distribution.

2. Samples

We prepared polished thin sections of five CM2s: Jbilet Winselwan (hereafter, Jbilet) (Find, Western Sahara, 2013), Murchison (Fall, Australia, 1969), Nogoya (Fall, Argentina, 1879), Santa Cruz (Fall, Mexico, 1939), and Wisconsin Range (WIS) 91600 (Find, Antarctica, 1991). We identified carbonates in each meteorite sample with an optical microscope.

3. Methods

Raman analyses were performed at the Department of Geosciences, Virginia Tech. with a Jobin-Yvon Horiba LabRam HR μ-Raman spectrometer, equipped with a Modu-Laser Stellar Pro-L Argon laser (514 nm) (laser spot diameter was ~1 μm). Wavelength calibration was checked daily prior to sample analyses against a silicon wafer sample. The peaks were determined by simultaneous peak fitting to six pure Lorentzian profiles (one calcite, one G and four D bands, see Figure 1) and linear baseline correction accomplished using a custom software written in the Python programming language.

4. Results

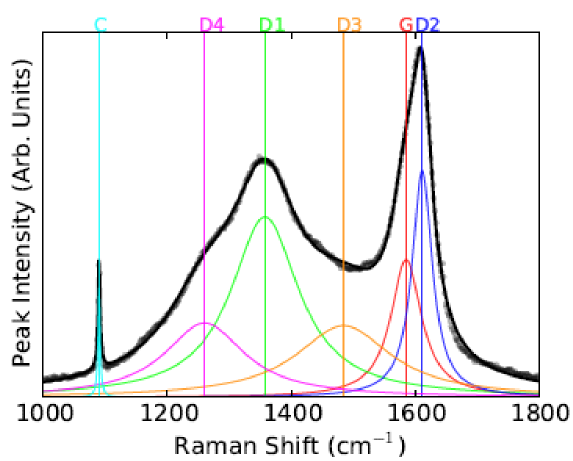

Figure 1: Peak-fitting result with pure Lorentzian profiles showing the first-order region (1000 to 1800 cm^{-1}) of Jbilet. (●): Background-corrected data. Black solid line: Peak-fitting result. C: calcite; G:

graphite band; D1-D4: disordered (defect-activated) bands.

Representative Raman spectra of the carbonates in CM2 meteorite samples are shown in Figure 2. Carbonates were identified with optical examination and confirmed by the distinctive Raman band in the ~1100 cm^{-1} region which corresponds to the symmetric stretch mode of the $(CO_3)^{2-}$ anion [3]. The typical first-order D bands at ~1350 cm^{-1} and G band at ~1580 cm^{-1} were detected in the carbonates in Jbilet, Nogoya and WIS 91600. On the contrary, while carbon peaks are observable in the matrixes of Murchison and Santa Cruz, the carbonate crystals are clearly devoid of organic matter. Linear Raman analysis from the center of a >40 μm carbonate grain extending into the fine-grained matrix also shows that the center of carbonate is deprived of organic matter, while the D and G bands can be observed at and beyond the crystal boundary.

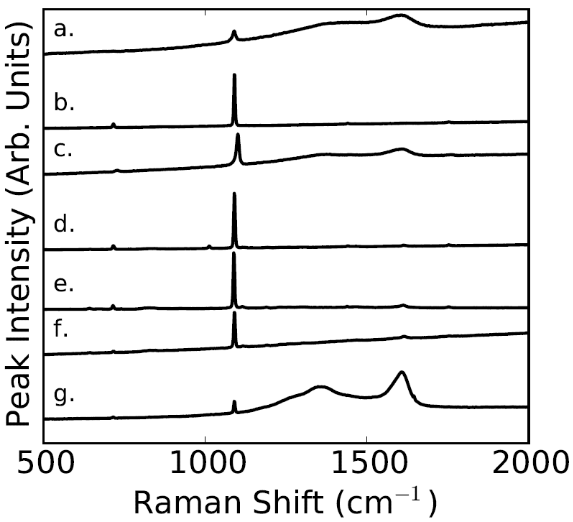

Figure 2: Raman spectra showing the first-order regions of the carbonates in the CMs: (a) WIS 91600; (b) Santa Cruz; (c-d) Nogoya; (e) Murchison; (f-g) Jbilet.

The spectra of the carbonates in Jbilet, Nogoya and WIS 91600 are characterized by their broad D and G bands, which indicate the presence of highly disordered aromatic materials. Visual examination of the overall shape of the Raman spectra shows that these chondrites have experienced low peak metamorphic temperatures (PMT). Jbliet has experienced the lowest PMT among the analyzed CMs (~200°C, which is calculated with the full width at half maximum [FWHM] of the D1 band ~130 cm^{-1}, and applying the geothermometer derived by Kouketsu et al. [6] for the PMT range of 200–400°C).

The occurrence of organic matter in carbonates can be correlated to the degree of alteration. Nogoya and WIS 91600 have experienced higher thermal (<500°C) and aqueous alteration as oppose to Murchison [1, 13]. The Poorly Characterized Phases (PCP) index in Jbilet also supported a more extensive aqueous alteration than other CMs [7]. The organic materials could have been produced prior to or concurrently with the alteration process in Jbilet, Nogoya and WIS 91600, when the carbonates were formed as late-stage alteration replacement product. These carbonates probably served to entrain or adsorb organic materials during or after their formation.

Acknowledgements

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References

[1] Bunch T.E. and Chang S.: Geochimica et Cosmochimica Acta, Vol. 44, pp. 1543-1577, 1980.
[2] Carter P.W. and Mitterer R.M.: Geochimica et Cosmochimica Acta, Vol. 42, pp. 1231-1238, 1978.
[3] Cloots R.: Spectrochimica Acta Part A: Molecular Spectroscopy, Vol. 47, pp. 1745-1750, 1991.
[4] Cronin J.R. and Pizzarello S.: Science, Vol. 275, pp. 951-955, 1997.
[5] Grady M.M. *et al.*: Geochimica et Cosmochimica Acta, Vol. 52, pp. 2855-2866, 1988.
[6] Kouketsu Y. *et al.*: Island Arc, Vol. 23, pp. 33-50, 2014.
[7] Pernet-Fisher J. *et al.* (2014) Lunar and Planetary Institute Science Conference Abstracts,2386.
[8] Sephton M.A. *et al.*: Geochimica et Cosmochimica Acta, Vol. 67, pp. 2093-2108, 2003.
[9] Smith J. and Kaplan I.: Science, Vol. 167, pp. 1367-1370, 1970.
[10] Suess E.: Geochimica et Cosmochimica Acta, Vol. 34, pp. 157-168, 1970.
[11] Suess E.: Geochimica et Cosmochimica Acta, Vol. 37, pp. 2435-2447, 1973.
[12] Thomas M.M. *et al.*: Chemical Geology, Vol. 109, pp. 201-213, 1993.
[13] Yabuta H. *et al.*: Meteoritics & Planetary Science, Vol. 45, pp. 1446-1460, 2010.

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Compositional and textural data of a new ungrouped iron meteorite from Oglat Sidi Ali, Morocco

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Abstract

In the present paper compositional and textural data on a recently found iron meteorite are provided. The meteorite was recovered near the locality of Oglat Sidi Ali, Maatarka, Morocco, in 2013 by Hassane Nachit during an expedition for meteorite recovery. Field data on the recovered samples suggest that the meteorite might be part of a strewn field produced by a single body that broke up in the lower atmosphere. Analytical data performed on an etched and polished section suggest a classification as ungrouped iron meteorite.

1. Introduction

About thirty small pieces from 3 to tens of grams each of an iron meteorite, totally weighing 240 grams, were recovered by Hassane Nachit, IZU in april 2013 during two expeditions of exploration fieldwork for meteorite recovery in the Maatarka region (Eastern Highlands) of Morocco (coordinates 33°31'45’ N 02°37'01" W). Many other pieces, including a 190 kg piece, are reported to have been picked up by nomads in the area and sold to meteorite merchants but no certain information of the relationship with this meteorite is available. The coordinates of the recovered specimens plot in an ellipsoidal area that may describe a strewn field. The main mass, weighing 70 g, is moderately weathered (figure 1) and is on deposit at Ibn Zohr University. Three small pieces, totally weighing 30 g, are on deposit at the Museo di Storia Naturale dell’Università di Firenze, Italy. The type specimen, totally weighing 14.5 g, including an etched and polished piece is on deposit at Museo di Scienze Planetarie of Prato, Italy. The meteorite has been submitted to the Meteoritical Society for approval.

2. Experimental results

A cut surface of a hand size specimen of the meteorite displays no traces of staining. The etched surface shows exsolution lamellae with 3 prominent directions, at 60° intersection angles, displaying a distinctive Widmanstätten pattern (figure 2). The lamellae have an average bandwidth of 0.2±0.1 mm, pointing to a very fine octahedrite [1]. Scanning electron microscope analyses performed at the Dipartimento di Chimica dell’Università di Firenze allowed to determine a much finer scale pattern of these lamellae consisting of multiple tiny kamacite spindles roughly parallel to each other and ranging in width from 30 to 80 μm, separated by thin, Ni-rich taenitic spindles both forming a plessitic octahedrite arrangement (figure 3). SEM-EDX analyses performed on the Ni-rich phase allowed to determine a mean Ni content of 14.7 ± 0.2 wt.%, with a maximum Ni content of 45.2 ± 0.3 wt. % at spindle border, while the Ni-poor phase has a mean Ni content of 6.7 ± 0.1 wt.%. In order to determine the minor and trace elements contents of the meteorite, ICP-MS analyses have been performed at the Department of Earth and Atmospheric Sciences, University of Alberta laboratories. The analyses allowed to determine remarkably high Ni, Ga, Ru, Pd and Pt, and relatively low Ir contents. Table 1 reports the reliable values obtained for all the elements analyzed.

3. Figures

Figure 1: Field image of the main mass of Maatarka.

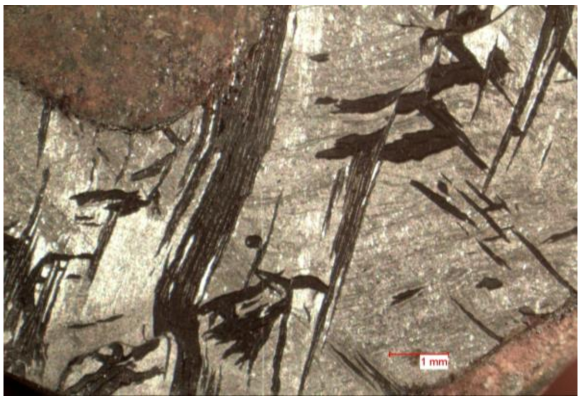

Figure 2: Image of the cut and etched surface of a hand size specimen.

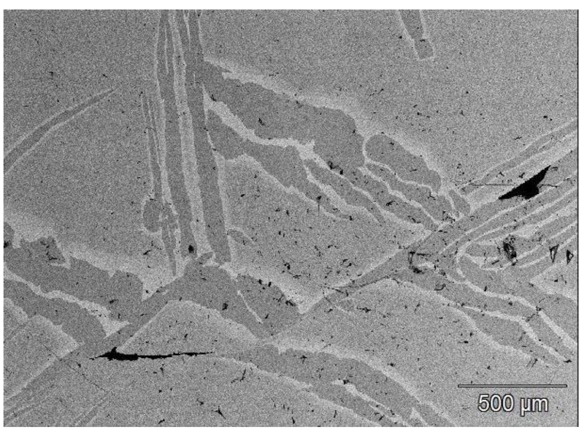

Figure 3: SEM-BSE image of an area of a polished sample; dark grey is kamacite; pale grey is taenite.

4. Tables

Table 1: Trace elements contents of Maatarka bulk.

Element	Amount (µg/g)	Amount (mg/g)
Ni	-	140.7
Co	-	11.7
Cu	249.4	
Ga	79.1	
As	10.0	
Ru	53.2	
Pd	8.8	
W	5.8	
Re	0.3	
Ir	2.5	
Pt	43.9	

5. Summary and Conclusions

Although textural data suggest similarities of this meteorite with plessitic octahedrites, pointing to a classification as IIC ([2], [3], [4]), compositional data do not support this hypothesis, due to the high Ni, Ga, Ru, Pd, Pt, and relatively low Ir contents. These data are outside the limits for the IIC group, therefore suggesting a classification as ungrouped, plessitic octahedrite. Further field research and the recovery of other specimens will provide more detailed topographic information about the scattering of the fragments and the characteristics of the fall (direction, fragmentation altitude etc.), allowing to fully determine the physical parameters of the supposed strewn field.

Acknowledgements

The authors wish to thank prof. Mario di Martino of INAF-OATO for kindly providing the specimen for textural and compositional analyses.

References

[1] Grady, M., Pratesi, G. and Moggi Cecchi, V.: Atlas of Meteorites. Cambridge University Press, Cambridge, UK, 384 pp., 2014.

[2] Buchwald, V.F.: Handbook of Iron Meteorites I-III., Univ. California Press, Berkeley, 1418 pp., 1975.

[3] Wasson, J.T.: Meteorites. Their Record of Early Solar-System History, W. H. Freeman, San Francisco. 267 pp., 1985.

[4] Scott, E.R.D. & Wasson, J.T.: Classification and properties of iron meteorites, Rev. Geophys. Space Phys., Vol. 13, pp. 527–546, 1975.

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Numerical model for the acceleration of a dust cloud by the solar wind

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Abstract

In this study we investigate the behavior of two massive fluids: protons in the solar wind and charged dust. For simplification we temporarily ignore the charging process of dust particles. The mass of charged dust can be 10^3 amu to grams, but we only model the lighter ones because the behavior of grains more massive than 10^5 are similar. A multi-fluid MHD code is used to simulate the large scale structure formed around a dust cloud released into the solar wind, and its evolution. Dust clouds as we are simulating can be made by meteoroid-meteoroid collisions with size from 1 to 100 m in diameter. These are dangerous if they hit the Earth's atmosphere. Detecting them in space can help detect where such objects are in near Earth space.

1. Introduction

Charged dust has been found in many places in the space. The number density of such fine particles often well exceeds one per Debye sphere, thus, such interactions can be treated as a dusty plasma problem. The most common interaction in such dusty plasma is the evolution of a dust cloud in a plasma flow. Such a cloud can be produced by meteoroid collisions in space.

An interplanetary field enhancement (IFE) event was observed by 5 spacecraft simultaneously, and believed to be the result of such dust cloud accelerations. In this study, we investigate our 3-D field draping result and compare it with the field measured during the IFE.

2. The model

Protons, dust, and electrons are treated as an individual fluid, respectively. The multi-fluid MHD equations are used to simulate the conservation of mass, momentum, and energy, in perfectly conducting plasma. A dust cloud is sitting still at time zero, in a solar wind flow with nominal parameters at 1 AU. Dust particles get accelerated along the electric field, while the head of the cloud is accelerated downstream by the tension force. Figure 1 and 2 shows the dust structure and magnetic field perturbation about 4 hours after the release.

3. Figures

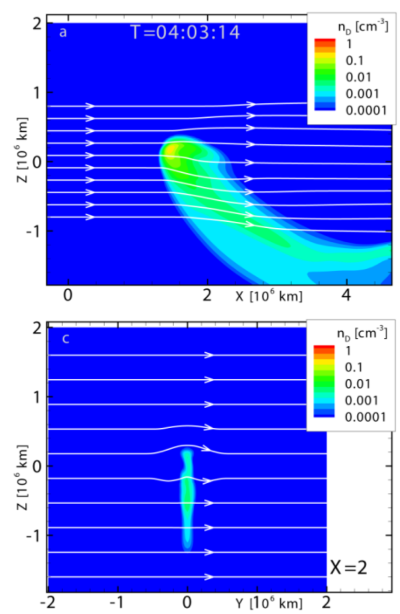

Figure 1. Acceleration of a dust cloud in the solar wind. Dust density contours are shown in two plane projections. White lines are proton stream lines.

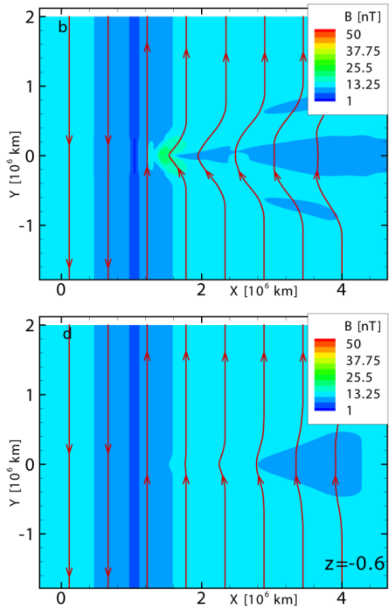

Figure 2. The magnetic field perturbation shown in colour contours projected into the z=0 and z=-0.6 planes. Red lines are magnetic field lines.

4. Summary

In this study we study the 3-D distribution of the dust cloud during its pickup process by the solar wind, generated by our 3-D multi-fluid model. The disturbed magnetic field is compared to the observed IFE field.

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Laboratory investigations of electrostatic dust lofting on comet and asteroid surfaces

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Abstract

We conduct laboratory experiments to demonstrate that dust particles (mostly in the form of clumps) as large as > 100 microns are mobilized and lofted on a surface exposed to plasmas. The electric force on a dust particle due to plasma charging is found too small to overcome even the gravitational force. We propose a new so-called "patched charge model". The dust particles can collect secondary electrons (SEs) emitted from their neighbors, creating the patched charge in the shadowed areas of the plasma. The Coulomb force between dust particles is found significant. The total charge and electrostatic force may thus be largely enhanced. The effects of surface roughness and topology are also tested.

1. Introduction

Electrostatic dust lofting has been a long-standing problem that is related to many dust phenomena, including the lunar horizon glow, the dust ponds on asteroid Eros, and the spokes in the Saturn's rings. Recently, the COSIMA instrument onboard Rosetta spacecraft has collected dust particles larger than 50 microns (fluffy and many are the conglomerates of smaller dust particles) coming off Comet 67P /Churyumov–Gerasimenko. It is yet a puzzle how these dust particles are released from the comet surface. Electrostatic dust lofting may be partially responsible for this observation. However, the mechanism of the electrostatic dust lofting still remains a mystery. We conducted laboratory experiments to investigate the dust lofting due to the electrostatic force and its mechanisms.

2. Laboratory experiments

The experiments were performed in a cylindrical vacuum chamber. Plasmas were created by primary beam electrons emitted from a hot filament on the top of the chamber. The dust particles were spread on an electrically floated graphite surface in the center of the chamber. A video camera was used to record the dust moves and hopping trajectories. Various sizes (25 – 70 microns in diameter) and shapes (irregular and spherical) of dust particles were used in the experiments. Potentials above the dust surface were measured.

Our preliminary results showed that the dust particles were moved and lofted when the primary electron energy was 120 eV. The lofted particles were mostly in the form of clumps with the diameter as large as 160 microns. However, set a similar or larger magnitude of the electric field above the dust surface, the dust particles did not move when the primary electron energy was 35 eV. The potential measurements indicate that the SEs were emitted from the dust surface in the former case. It is also known that the SEs emitted from a dust particle can be collected by its neighbors. We propose a new so-called "patched charge model". The bottom areas on a dust particle surface are in the plasma shadow and can collect the SEs emitted from its neighbors while the top area is charged mainly by plasma electrons. The total charge (i.e., the sum of these patched charge) can significantly increase, depending on the surface morphology. The Coulomb force between dust particles was also found significant in addition to the electric force due to the sheath electric field. The total electrostatic force will be largely enhanced. It was also found that the dust particles resting on a rougher surface were lofted more easily.

Acknowledgements

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Cometary dust organics analogues: production, composition and scattered light

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Abstract

Polarimetric observations of cometary comae may be used to infer dust particles properties through experimental simulations. Cometary organic solid materials are poorly known. Here different organic materials found in nature or synthetic are studied. Their light scattering response was correlated to their chemical composition (under heating or not). Some cometary dust analogues were obtained by mixing them with silicates and lifted in the PROGRA2 light scattering experiment.

1. Introduction

Cometary dust is mainly composed of silicates and carbon-bearing compounds. Infrared spectra observations provide important knowledge about the temperature conditions of their formation or their evolution through the determination of the ratio of crystalline/amorphous varieties in the silicates. Up to now, it is more difficult to disentangle the numerous organics. When comets approach to the Sun, the volatile ices and refractory organic compounds are heated and they release compounds, which are retrieved in the gas phase. However, the source materials are still only poorly known. Some information can be inferred by the study of the IOM (insoluble organic matter) in meteorites or IDPs captured in the Earth atmosphere and supposed to be of cometary origin. Organics were also found in the particles captured by the STARDUST spacecraft. The particles captured by the COSIMA instrument of the Rosetta mission in the coma of 67P/Churyumov-Gerasimenko [1] revealed very fluffy and large aggregates of carbonaceous compounds with sizes larger than 50 μm made of sub-micron-sized grains. The dust optical scattering done by the ejected particles at 3.7-3.4 au is dominated by 100 μm to millimeter-sized particles ([2], GIADA-OSIRIS results).

Laboratory simulations of light scattering by cometary analogue particles help to disentangle different physical properties by comparison to observational data. The linear polarization depends on the geometry of observations (phase angle) and on the particles properties (size and size distribution, structure and refractive indices). It also depends on the wavelength of observations. Our PROGRA2 light scattering experiment is perfectly adapted to study particles between 20 and 500 μm, levitating in a cloud, or in microgravity conditions, or by an air-draught [3]

2. Samples

This study aims to test how the nature and composition of organics materials from different origins relate to their light scattering response as cometary analogues. We hence used different organics: natural coals (State University Coal Bank and Data Base), industrial carbon blacks, laboratory-synthesized organics. Four types of synthetic organics were produced, with relevance for cometary study: (1) polymers of HCN synthesized in solution at the LISA laboratory [4], (2) solid organic particles synthesized in an electric discharge from mixtures of N2:CH4 gases at room temperature with the PAMPRE experiment at LATMOS laboratory [5], and (3) solid organic particles synthesized in an electric discharge from mixtures of $CO:N_2:H_2:H_2O$ gases at temperatures higher than 500°C in the Nebulotron instrument at CRPG laboratory [6]. The last two types of organics differ in size distribution and shape of the grains and structure of the particles and in their elemental composition (e.g. N related to C) depending on their formation conditions [6,7]. Some of these organics were heated ex-situ at 200-500°C; leading to progressive carbonization and increase of polyaromatics components. (4) Organic-coated silicates were produced by Fischer-Tropsch reaction of CO, N2, H2 gas on amorphous Fe-silicate grains at 560°C (NASA/Goddard Space Flight Center). Different classes of organic compounds were identified: saturated and unsaturated hydrocarbons, alkyl-benzenes, phenols, styrenes, and traces of polycyclic aromatic hydrocarbons [8].

Each organic material was characterized by infrared and/or Raman spectroscopy. The shape and size distribution of the grains is measured on SEM images. The size distribution of the lifted agglomerates is directly measured on the PROGRA2 images.

3. Light scattering results

Most of the heated materials present a higher polarization in the red wavelength than in the green one, corresponding to a change in the composition of the materials, i.e., a change in the refractive indices (at room temperature the wavelength effect is inverse or neutral). Under heating (from 200°C to 550°C), organic bearing materials become darker and the spectra bluer, consistently with aromatization of the organic fraction [9]. The analysis of our heated samples shows similar results [10].

Analogues of cometary particles, will be made by mixing organic particles of different origins with silicates of different shapes, structures and compositions (Mg and Fe-rich) and results will be compared to those obtained for coated silicates. The results obtained with PROGRA2 will be compared to observational results.

6. Summary and Conclusion

The production of cometary dust analogues, made of silicates, mixed or not with organics, are detailed. Their composition is compared to materials found in meteorites and IDPs. Some of these materials were heated, simulating organic formation in warm regions of the solar nebula [6]; or their heating after ejection from the nucleus in the coma when the comets are close to the Sun. Their composition is compared to materials found in meteorites and IDPs.

Acknowledgements

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References

[1] Schultz et al. Comet 67P/Churyumov-Gerasimenko sheds dust coat accumulated over the past four Years. Nature L. 518, 216-218 (2015).

[2] Rotundi et al. Dust measrments in the coma of comet 67PChuryulov-Gerasimenko inbound to the Sun, Science 347, 6220 (2015)

[3] Hadamcik et al. Laboratory measurements of light scattered by clouds and layers of solid particles using an imaging technique. In: Polarimetric detection, characterization, and remote sensing (Mishchenko, et al. Eds.), Springer, Dordtecht pp. 137-176 (2011).

[4] Fray et al. Experimental study of the degradation of polymers: Application to the origin of extended sources in comeary atmospheres, M&PS 39, 581-587 (2004)

[5] Szopa et al. PAMPRE: a dusty plasma eperiment for Titan’s tholins production and study, PSS 54, 394)404 (2006).

[6] Kuga et al. Synthesis of refractory organic matter in the ionized gas phase of the Solar Nebula, PNAS, accepted for publication.

[7] Hadamcik et al. Optical properties of analogues of Titan’s aerosols produced by dusty plama, EPS 65, 1175-1184 (2013)

[8] Johnson et al. Organics on Fe-silicate grains: potential mimicry of meteoritic processes? LPI 35, 1876 (2004)

[9] Cloutis et al. Spectral reflectance properties of carbonaceous chondrites 4: aqueously altered and thermally metamorphosed meteorites, Icarus 220, 586-617 (2012)

[10] Bonnet et al. Formation of analogues of cometary nitrogen-rich refractory organics from thermal degradation of tholin and HCN polymer, Icarus 250, 53-63 (2015).

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Heterogeneity in IDPs and comparison with comet 67P/Churyumov-Gerasimenko dust

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Abstract

Some interplanetary dust particles (IDPs) have revealed heterogeneity at multiple scales, as recorded in their mineralogy and also isotopic signatures that reflect the reservoirs from which they accreted. Detailed observations of the dust generated by comet 67P/Churyumov-Gerasimenko (67P/C-G) provides new insight into the origin of the variations observed in the IDPs that in turn may provide details of the processes observed by Rosetta.

1. Introduction

IDPs collected in the stratosphere by NASA high flying aircraft have offered detailed insight into some of the most primitive materials present in the solar system. The mineralogy, textures, grain sizes and isotopic signatures of many of these particles have long indicated a cometary origin [e.g. 1], and are derived from a dust population dominated by cometary sources [2]. However, direct evidence of their origin has remained elusive, and even the returned samples from comet Wild 2 by the NASA Stardust mission provided limited confirmation as the high speed collection dispersed or obliterated the most primitive, fine-grained material.

The recent optical images of cometary dust grains collected by the COSIMA instrument on Rosetta have revealed several particles that are loosely bound fluffy aggregates of dust that crumbled or shattered upon their low velocity (1-10 ms^{-1}) impact with the collection plate [3]. These particles likely represent parent material for interplanetary dust particles [3]. The fragmented particles reveal a wide range of sub-component sizes down to the resolution of the imaging. IDPs offer the opportunity to explore sub-components at scales beyond that which can be obtained by COSIMA and therefore provide a complementary insight into the nature and origin of these grains.

2. Heterogeneity in IDPs

Chondritic-porous IDPs (CP-IDPs) contain a mix of many different minerals and grain sizes, and contain both fine-grained amorphous materials and fragments of components (e.g. chondrules and refractory inclusions) that have been processed in the hot, inner regions of the protoplanetary disk [e.g. 4]. With grain-sizes down to a few 10s nm, many grains are present even within the ~10 micron particle fragments that make up the larger cluster particles collected in the stratosphere. However, even within the fine-grained material heterogeneity, as tracked by isotopic signatures, exists at several scales. Hot spots of minor isotope enrichments exist in the organic matter [e.g. 5] and pre-solar grains with nucleosynthetic signatures are also often observed [6], although both are usually present at low abundance and the bulk of the material is generally thought to have a solar system origin.

However, the accretion of the fine-grained material of largely solar system origin shows considerable complexity. Starkey and Franchi [7] demonstrated with high precision O-isotope measurements by NanoSIMS that the individual fragment grains of the same cluster particles had similar bulk O-isotope compositions – indicating that the particles were composed of well-mixed fine-grained material. However, in a detailed O-isotope investigation of some large cluster particle fragments Starkey et al [8] revealed that some fragments record a more complex history of formation. These fragments appear to largely consist of regions, on the scale of 5-10 microns, with distinct O-isotope compositions and usually correlating with variations in D/H, C/H (indicative of fluid alteration) and $^{13}C/^{12}C$. One example shows that one of the areas has the form of a clast, with distinct boundaries and isotopic variation and elemental composition that indicates that it had experienced mild aqueous processing prior to incorporation into the cluster particle. This was taken to indicate a multi-stage accretion-disruption-accretion history [8].

3. Discussion

The particles observed by the COSIMA instrument collected at ≈3.5 AU are thought to originate from an ice-free dust layer accumulated during the long passage through aphelion [3]. As the comet approaches the inner solar system, this dust layer should be lost and ice-rich dust particles may be lifted from the comet's surface. Although we await the results of the Rosetta investigation of the two populations of grains, do the differences in the grain histories create differences that can be observed in the IDPs?

CP-IDPs with homogeneous O-isotopic signatures indicate accretion from a well-mixed reservoir of dust. With little evidence of modification or they may be samples of materials from pristine regions of the comet liberated as ice-rich particles during the parent comet's passage through perihelion and reflect accretion of a well-mixed reservoir. CP-IDP material containing clasts such as that in the Balmoral IDP reported by Starkey et al [8] may be the result of a complex accretion history, involving some accretion phase with ice that then allowed some reaction with liquid water followed by disruption and re-accretion. While such a mechanism is apparent in stony meteorites, evidence for this in cometary materials is harder to identify. Alternatively, the incorporation of clasts may have occurred as a result of transport of grains from different parts of the comets surface during its passage through aphelion. Regions of the cometary surface may have experienced some interaction with liquid water prior to contributing to the dust layer. Some mobilization on the surface of 67P/C-G [9] would offer the opportunity for mixing of different materials in the dust layer. Therefore, some of the mixing observed in the IDPs may occurred in the recent past shortly before the dust was ejected from the comet's surface. Details of the processes and signatures associated with these scenarios will be presented and discussed.

References

[1] Brownlee, D. E. Cosmic dust - Collection and research, Annual Review of Earth and Planetary Sciences, Vol 13, 147–173, 1985.

[2] Nesvorný, D. et al. Cometary origin of the zodiacal cloud and carbonaceous micrometeorites. Implications for hot debris disks, Astrophysical Journal, vol 713, 816–836 2010.

[3] Schulz, R. et al. Comet 67P/Churyumov-Gerasimenko sheds dust coat accumulated over the past four years, Nature, vol 518, 216–218, 2015.

[4] Nakashima, D., Ushikubo, T., Zolensky, M. E. & Kita, N. T. High precision oxygen three-isotope analyses of anhydrous chondritic interplanetary dust particles, Meteoritics & Planetary Science, vol 47, 197–208, 2012.

[5] Davidson, J., Busemann, H. & Franchi, I. A. A NanoSIMS and Raman spectroscopic comparison of interplanetary dust particles from comet Grigg-Skjellerup and non-Grigg Skjellerup collections, Meteoritics & Planetary Science, vol 47, 1748–1771, 2012.

[6] Busemann, H. et al. Ultra-primitive interplanetary dust particles from the comet 26P/Grigg–Skjellerup dust stream collection, Earth and Planetary Science Letters, vol 288, 44–57, 2009.

[7] Starkey, N. A. & Franchi, I. A. Insight into the silicate and organic reservoirs of the comet forming region, Geochimica et Cosmochimica Acta, vol 105, 73–91, 2013.

[8] Starkey, N. A., Franchi, I. A. & Lee, M. R. Isotopic diversity in interplanetary dust particles and preservation of extreme ^{16}O-depletion, Geochimica et Cosmochimica Acta, vol 142, 115–131, 2014.

[9] Thomas, N. et al. The morphological diversity of comet 67P/Churyumov-Gerasimenko, Science, vol 347, article id. aaa0440.

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Dust Populations in the Outer Solar System: 10 years of monitoring by CASSINI-CDA

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Abstract

The analysis of different CDA subsystems data, acquired since SOI, reveals that the Saturnian system is permanently crossed by dust grains originating from the Interplanetary medium, as well as from the neighboring interstellar medium surrounding the Solar System. We observe two main types of particles: on the one hand, those with low injection velocity with respect to Saturn, and whose flux is significantly enhanced by gravitation focusing. On the other hand, particles with fast injection velocities, essentially unperturbed by gravitation focusing. The fast grains are found to be interstellar dust (ISD) from the Local Interstellar Cloud (LIC), as well as particles on retrograde orbits around the Sun, most likely dust released by Halley-type comets. The dynamics of the slow grains is found to be compatible with collisional debris from the Kuiper-Belt, migrating inward the Solar System under influence of the Poynting-Robertson drag. Alternatively, we show that the origin of the slow grains entering the Saturnian System can be the recently discovered cometary activity of Centaurs.

1. Introduction

We report in this paper on the analysis of 10 years of Cassini-Cosmic Dust Analyser (CDA) data obtained in the Saturn's system. The signature of exogenic dust in the Saturnian System has been confirmed by different subsystems of CDA, including the Impact Ionization Detector (IID), the Chemical Analyser Target (CAT), as well as the Entrance Grid detector (EG). Each subsytem has a different sensitivity, opening a window on the different dust populations at, and beyond Saturn's orbit. We review the knowledge gained so far, combining the data from all CDA subsystems.

2. Data analysis

The major difficulty we are facing is the identification of comparatively very rare exogenous particles in an environment dominated by E ring particles. In the densest regions of the E ring, the CDA instrument is saturated by E ring impactors, therefore 'masking' contributions from other sources. Fortunately, the Cassini spacecraft has been flying on orbits for a wide range of inclinations and eccentricities while touring Saturn during the past seven years such that regions with reduced E ring contribution can be exploited for our study. Regions more favorable for the search of exogenous particles are typically as far as possible from Saturn, or, 'far enough' from the equatorial plane of Saturn, in order to avoid the bulk of the E ring particles. Having measured nearly continuously for over 10 years provides enough integration time in these regions for our study to be done with reliability. We use in this paper the data of the EG, IID and CAT subsystems of CDA.

3. Results and Discussion

We find the signature of exogenous dust in the dataset of all CDA subsystems. This fact by itself is an important result that will constrain evolutionary processes in the Saturnian System, like, for example, the compositional evolution of atmosphere-less icy surfaces (icy moons and Saturn's main ring system) and of the atmospheres of Titan and Saturn.

Our data suggest two main dynamical types of exogenous particles crossing the Saturnian system: the 'slow' and 'fast' populations, in term of injection velocity when entering Saturn's Hill sphere. The fast populations contains ISD grains from the contemporary Local Insterstellar Cloud, as they cross the Solar System on hyperbolic orbits. These grains could be identified by their directionality and impact speed de-

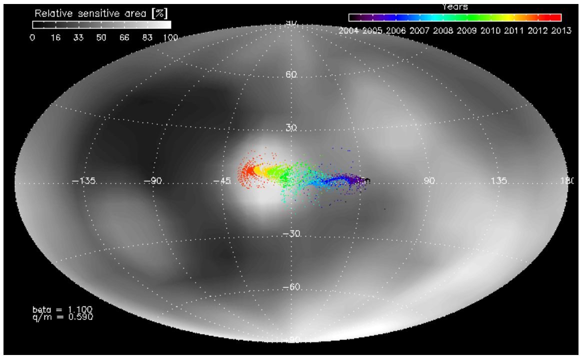

Figure 1: Integrated sensitive area achieved by Cassini-CDA monitoring the different directions on the sky sphere. The directions expected for the fast population of ISD grains is shown as dots, whose color coding is function of the elapsed time.

rived from CAT time-of-flight spectra signals (Fig. 1). The chemical composition appear to be consistent with silicates-magnesium-iron signature. A second component of the fast exogenous population, identified in the EG data appears to consist of grains on nearly parabolic, prograde and retrograde solar orbits. However, such grains are rare in the EG data compared to heliocentric bound particles, with low injection speeds at Saturn, a result also supported by our modeling of the CDA-IID data.

The heliocentric orbital elements of the grains detected by the EG detector were derived (Fig. 2). Three main known types of grains in the outer Solar System were discussed to explain our observations. We find that JFC comet cannot be a dominant source for the dust that CDA measures at Saturn. In turn, our measurements appear in good qualitative and quantitative agreement with the dynamical signature of KBO dust expected at Saturn that can explain the bulk of our 'slow' population. We find, however, that KBO dust cannot be distinguished at Saturn dynamically from particles released by Centaurs/TNOs, whose cometary-like activity at large heliocentric distances has been recently discovered.

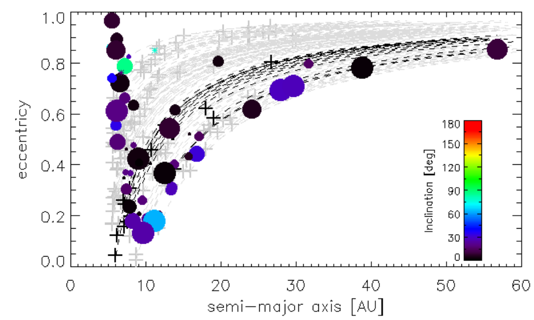

Figure 2: This plot shows the distribution of the semi-major axis and eccentricity values for the exogenic particles detected by the EG subsystem. The radius of the circle symbols is proportional to the logarithm of measured grain radius, the color code stands for the heliocentric inclination values. The grey crosses show the konwn Centaurs (lower panel). The black crosses indicate the Centaurs for which a cometary activity has been reported from ground-based observations. The dashed lines indicate the possible (a,e) values for dust grains released by the parent body, parameterized by the solar radiation pressure efficiency.

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A microscopy study of the NWA2086 and NWA7043 meteorites

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Abstract

In this work a study of the NWA2086 and NWA7043 meteorites based on microscopy analysis is presented. These meteorites are carbonaceous chondrites whose meteoritic matrix has micro-sized elongated bodies. Additionally, the NWA2086 and NWA7043 contains many chondrules rich in olivine and clinopyroxene. According to the Scott-Taylor-Jones classification, these chondrules are type I. Many of these chondrules have thin rims probably created by heating events in the solar nebula.

1. Introduction

The meteorites NWA2086 and NWA7043 were collected in the Sahara desert of Northwestern Africa and have been classified as carbonaceous chondrites by the Meteoritical Society. One main characteristic of carbonaceous chondrites is that they contain millimeter sized quasi-spherical objects called chondrules whose mineralogy and specific characteristics where produced during their formation in the proto-planetary accretion disc when planets have not been yet accreted. The chemical abundances in carbonaceous chondrites are very similar to those in the solar photosphere except by the hydrogen and helium abundances [1]. Carbonaceous chondrites also have the oldest calcium-aluminum rich inclusions (CAI´s) bodies with 4,567.2 My of antiquity [2] which corresponds to the solar system age. This is why the chondrule textures are related with the processes in the early stages of the planetary solar system [3].

In this work we present a study of the NWA2086 and NWA7043 meteorites under the Scott-Taylor-Jones scheme [4,5,6,7]. The study is based on the analysis of their matrices and chondrules using Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray Spectroscopy (EDS), Wave Dispersive X- Ray Spectroscopy (WDS) and X-Ray Diffraction (XRD) techniques.

2. Experimental procedures

Prior to the SEM analysis, the meteorites samples were cut and mirror-polished, and were cleaned for 10 minutes in an ultrasonic bath using ethyl alcohol.

Samples of the NWA2086 and NWA7043 meteorites were analyzed primarily by light microscopy using a Carl Zeiss Axiotech microscope at 10X and 20X. In order to study in detail the differences and similarities between the two meteorites, the samples were analyzed by Low Vacuum Scanning Electron Microscope JSM-5600LV equipment with a Noran X-ray microanalysis detector. The SEM analysis was performed at 20 kV acceleration voltage and at 12 Pa of pressure in the specimen chamber. SEM images were obtained with backscattered electrons (BSE).

A chemical analysis of minerals was also done using a JEOL scanning electron microprobe JXA8900-R, equipped with EDS and WDS analysis.

The quantitative analysis by WDS was performed at 20 KeV acceleration voltage, probe current of 2.0×10^{-8} A, with a beam diameter (P Dia) of 1 µm and an acquisition time of 40 seconds for each element except for K and Na. For these last elements the time was 10 seconds.

The more abundant crystalline phases present in the samples were identified by X-Ray Diffraction analysis (XRD) using an equipment SHIMADZU with Cu-Kα radiation (λ=0.15405 nm) in the interval 2θ of 4 to 70°, steps of 2°/s.

3. Results

The matrices of both meteorites are mineralogically similar, but present a small difference in the bulk elemental composition which is probably related to the aqueous alteration and/or to the processes experienced in the meteorite formation. On the other hand, the NWA2086 matrix is richer on chemical compounds than the one of the NWA7043, indicating that the former could probably come from C-type and D-type asteroids located around 3 AU and beyond 4 AU, respectively.

The chondrules present different appearances which could be produced by collisions and remelting processes if considering that collisions are associated with the coagulation of dust particles or with very small bodies in the solar nebula and the remelting processes modify the chemical, mineralogical and oxygen isotopic compositions as a result of gas-melt reactions as in the case of chondrules type I found in both meteorites (Scott-Taylor-Jones scheme*)* (Figure1).

Since there is a multiplicity of chondrules in both meteorites, the associated matrix could be thermally modified during transient heating events in which thick and fine-grained rim chondrules were probably created. Whereas the fine-grained rim could be built by regolith breccia that in turn result from multiple collisions between the embryos in the solar nebula; the thick rim could be formed by brecciation or accretion of mineralogical and/or compositional distinct materials in the solar nebula. Otherwise, the thick rim could be created during the growing and evolution of major bodies.

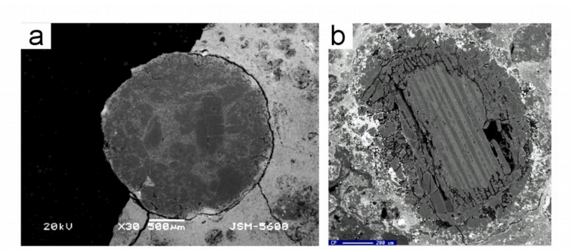

Figure 1. Type I chondrules in (a) NWA2086 and (b) MWA7043 meteorites.

4. Conclusions

1. The matrices of both meteorites have similar features and are formed by irregular and elongated grains. The NWA7043 meteorite has grain sizes <10 µm, while the NWA2086 has grains ≤ 2 µm. Both matrices are Fe, Si and Mg rich. The mackinawite and crystalline phases of clinopyroxene were identified in the NWA2086 matrix, meanwhile clinopyroxene, magnetite and magnesioferrite were identified in the NWA7043 by XRD analysis.

2. Both meteorites contain chondrules <2.5 mm in diameter. The chondrules surface number density is 1.94×10^{-3} chondrules/μm^2 for the NWA7043 and 1.93×10^{-3} chondrules/μm^2 for the NWA2086 meteorite.

3. Significant similarities were found in the chondrules: both are chondrules type I (according to the classification of Scott-Taylor-Jones) mainly compound by olivine and clinopyroxene. Additionally, some chondrules have Fe-rich inclusions.

4. The majority of the chondrules here studied have a thin rim probably formed by heating events in the solar nebula.

5. The thick rims in some chondrules could be formed by accreted breccia in the solar nebula. This process was perhaps a first step in the formation of major-sized bodies.

Acknowledgements

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References

[1] Amelin Y., Krot A. N., Hutcheon I. D. and Ulyanovet A. A.: Lead isotopic ages of chondrules and calcium-aluminum-rich inclusions, Science, Vol. 297, no. 5587, pp. 1678-1683, 2002.

[2] Bernatowicz T. J., Croat T. K. and Daulton, T. L.: Origin and Evolution of Carbonaceous Presolar Grains in Stellar Environments. In Meteorites and the Early Solar System II, Dante S. Lauretta and Harold Y. McSween Jr. (Eds.), University of Arizona Press, Tucson, AZ, USA, pp. 109-126, 2006.

[3] Kerridge J. F. and Matthews M. Sh.: Meteorites and the early solar system, University of Arizona Press, Tucson, AZ, USA, pp. 1286, 1988.

[4] Jones, R. H. : Petrology and mineralogy of type II chondrules in Semarkona (LL3.0): Origin of closed-system fractional crystallization, with evidence for supercooling. Geochim.Cosmochim. Acta, 54: 1785–802, 1990.

[5] Jones, R. H. : Petrology of FeO-poor, porphyritic pyroxene chondrules in the Semarkona chondrite. Geochim.Cosmochim. Acta, 58: 5325–40, 1994.

[6] Jones, R. H. & Scott, E. R. D. : Petrology and thermal history of type IA chondrules in the Semarkona (LL3.0) chondrite. Proc. 19Th Lunar Planet. Sci. Conf. Lunar and Planetary Institute, 523–36, 1989.

[7] Scott, E. R. D. & Taylor, G. J. : Chondrules and other components in C, O, and E chondrites; Similarities in their properties and origins. Proc. 14th Lunar Planet. Sci. Conf. J.Geophys. Res. 88, B275–B286, 1983.

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FRIPON, the French fireball network

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Abstract

FRIPON (Fireball Recovery and InterPlanetary Observation Network) [4](Colas et al, 2014) was recently founded by ANR (Agence Nationale de la Recherche). Its aim is to connect meteoritical science with asteroidal and cometary science in order to better understand solar system formation and evolution. The main idea is to set up an observation network covering all the French territory to collect a large number of meteorites (one or two per year) with accurate orbits, allowing us to pinpoint possible parent bodies. 100 all-sky cameras will be installed at the end of 2015 forming a dense network with an average distance of 100km between stations. To maximize the accuracy of orbit determination, we will mix our optical data with radar data from the GRAVES beacon received by 25 stations [5](Rault et al, 2015). As both the setting up of the network and the creation of search teams for meteorites will need manpower beyond our small team of professionals, we are developing a citizen science network called Vigie-Ciel [6](Zanda et al, 2015). The public at large will thus be able to simply use our data, participate in search campaigns or even setup their own cameras.

1. Scientific goals

The aim of the project FRIPON is to answer questions that arise about the connections between meteorites and asteroids. It is easy to study a meteorite in the laboratory but we cannot tell where it came from, because its orbit is most of the time unknown. On the other hand, we currently have more than 700,000 asteroid orbits with almost no physical information. However these parameters are crucial for understanding the origin and evolution of the solar system. In recent years the planet migration theory showed that it is possible to find very primitive objects in the main asteroid belt, and that these things may hit the Earth due to Yarkovsky non-gravitational forces. It is therefore essential to know the orbits of the meteorites we find to connect their dynamical history and composition. The main goals of FRIPON are to recover fresh meteorites fallen in France and to compute accurate orbits of fireballs whether or not they are connected with a meteorite.

2. The network

To allow triangulation measurements of fireballs we decided to implement one observatory every 80-100 km. As France has an area of 650 000 km^2, we need about 100 cameras to cover the whole territory.

2.1 Optical network

As with other fireball networks we decided to use fish-eye lenses to cover the whole sky. Our cameras are based on Sony chip ICX445, allowing a good efficiency for low light measurements at night but also a very short exposure time for daytime observations. Compared to older networks mainly based on video analogical devices, the improvements of FRIPON are:

- Digital cameras
- 1.2 megapixel chips
- 10^{-6} sec exposure time for day time
- 30 fps
- GigE Vision protocol
- PoE allowing 100 m single cable

2 Radio network

An optical network is very efficient for measuring fireball geometry, but determination of velocity is less easy with only a few points on fish eye images. However, speed is essential for semi-axis measurement and, therefore, fundamental for pinpointing the origin of fireballs and their possible parent bodies. We will use radar echoes of the

GRAVES beacon dedicated to measuring low altitude satellites [5] (Rault et al, 2015). The beacon is usable all over France, a 200 km spacing being sufficient for radio observatories, so only ¼ of the optical stations will have radio equipment. The goal is to measure relative speed with the Doppler effect.

3. Reduction pipeline

The FRIPON project is open source both for hardware (distribution of the cameras by Shelyak Instruments, though compatible cameras can be used) and software (http://fripon.github.io/freeture/). We developed a pipeline based on GigE Vision cameras, but it will be easy to use other cameras drivers.

3.1 Acquisition

The FreeTure software [1](Audureau et al, 2015) is developed on Linux and Windows. It is nominally written for GigE Vision cameras. Our hardware configuration is: i3 processor, 8Gb of RAM (for image buffering), 32Gb SSD for system installation and 1Tb HDD for data.

3.2 Detection

For detection FreeTure will use the subtraction of two consecutive frames with a detection threshold. It will analyze the pixels detected on several consecutive frames to determine the speed of the object and hence the reality of a meteor observation. As the software stores previous images, it can store images centered on each detection.

3.3 Orbits and strewn fields

Presently, we are using standard two location algorithms. As the FRIPON network will allow multi detection, we will develop in the next months a dedicated method. Our code is based on a robust method [2] (Borovicka, 1990).The orbit is calculated using SPICE Toolkit developed by NAIF-NASA. To start our pipeline we used a standard model [3] (Ceplecha 1987) for dark flight computation and strewn field determination.

3. Conclusion and evolution

At present, the hardware is completely defined and tested. 60 locations are under installation, and we hope to have the whole network set up for the end of 2015. FreeTure source is already distributed on-line and an official release will be available soon, to be fully operational for the end of 2015. One goal of this "open project" is that it can be easily copied, first in Europe to build a network unprecedented in size and eventually worldwide.

Acknowledgements

The FRIPON project is founded by ANR (Agence nationale de la recherche: www.anr.fr). The Vigie-Ciel project is founded by ANRU (Agence Nationale pour la Rénovation Urbaine:www.anru.fr as a part of the 65 millions d'Observateurs project led by Muséum National d'Histoire Naturelle, Paris).

References

[1] Audureau, Y., Marmo, C., Bouley, S., Kwon, M.K., Colas, F., Vaubaillon, J., Birlan, M., Zanda, B., Vernazza, P., Caminade, S., Gattacceca, J.: FreeTure a Free software to capTure meteors for FRIPON, Proceedings of the 2014 International Meteor Conference pp 39-41, IMO, 2015.

[2] Borovicka, J.: The comparison of two methods of determining meteor trajectories from photographs, Astronomical Institutes of Czechoslovakia, Bulletin, 1990.

[3] Ceplecha , Z.: Geometric, dynamic, orbital and photometric data on meteoroids from photographic fireball networks, Astronomical Institutes of Czechoslovakia, Bulletin, 1987.

[4] Colas, F., .Zanda, B., Bouley, S., Vernazza, P., Gattacceca, J., Vaubaillon, J., Marmo, C., Kwon, M.K., Audureau, Y., and Rotaru, M.: FRIPON, a French fireball network for the recovery of both fresh and rare meteorite types, Asteroids, Comets, Meteors 2014

[5] Rault, J.L., Colas, F. and Vaubaillon, J.: Radio set-up design for the FRIPON project, Proceedings of the 2014 International Meteor Conference pp 185-186, IMO, 2015.

[6] Zanda, B., Bouley, S., Colas, F., Marmo, C., Rotaru, M., Lewin, E., Rault, J.L., Maquet, L., Birlan, M., Audureau, Y., Kwon, M.K., Vernazza, P., Gattacceca, J., Julien, J.F., Steanhauser, A., Linares, M., Birnbaum, C., Cochard, F.and Thizy, O.: Vigie-Ciel project, EPSC 2015.

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The nature of (sub-)micrometre cometary dust particles detected with MIDAS

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Abstract

The MIDAS Atomic Force Microscope (AFM) onboard Rosetta collects dust particles and produces three-dimensional images with nano- to micrometre resolution. To date, several tens of particles have been detected, allowing determination of their properties at the smallest scale. The key features will be presented, including the particle size, their fragile character, and their morphology. These findings will be compared with the results of other Rosetta dust experiments.

1. The MIDAS atomic force microscope

MIDAS (Micro-Imaging Dust Analysis System) [1] is an AFM combined with a dust collection and handling mechanism. MIDAS exposes slightly sticky targets in the vicinity of comet 67P to collect cometary dust. After every exposure, a section of the target is imaged and, if a particle is detected, a follow-up scan performed with optimised parameters. After continuous operation since Summer 2014, MIDAS has detected several tens of particles and is expecting to detect many more around perihelion.

2. Properties of (sub-)micrometre cometary dust particles

The dust particles collected so far are larger and less numerous than initially expected. However, MIDAS' grain detections are in agreement with measurements of other dust experiments on Rosetta if a relatively shallow dust size distribution is assumed.

An overview and a first interpretation of the particle properties is given, focussing especially on the large particles that show fluffy surfaces and very fragile morphology and the smaller particles that are possibly fragments. Comparisons will also be made to the findings of other Rosetta dust experiments.

References

[1] Riedler, W., Torkar, K., Jeszenszky, H., Romstedt, J., et al. MIDAS The Micro-Imaging Dust Analysis System for the Rosetta Mission, Space Science Reviews 128 (1-4), p. 869-904 (2007). doi:10.1007/s11214-006-9040-y

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Magnetite in Stardust Terminal Grains: Evidence for Hydrous Alteration in the Wild2 Parent Body

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Abstract

We use synchrotron X-ray Diffraction and other techniques to show the presence of magnetite in terminal grains from *Stardust* cometary tracks. This suggests that the parent body of Comet Wild2 underwent hydrous alteration, and gives further evidence for the varied mineralogical history of this early Solar System body from the Outer Solar System.

1. Introduction

At the time of the preliminary *Stardust* examination work summarised in [1,2] no obvious signs of aqueous alteration had been identified within Wild2 samples. However, as more tracks have been harvested (~200 in total to date) we are gaining a more complete inventory of minerals upon which to base our comparisons and we are now in a position to make direct links to known planetary materials, such as different chondrite groups, with more confidence. In particular, the presence of significant quantities of Fe oxide and magnetite that we have identified here and previously [3] argues strongly for some water-rock interaction. Here we report on recent synchrotron analyses of magnetite terminal grains in Type B Stardust tracks – which are thought to be relatively volatile rich [4] – to show the growing evidence for this mineral signature on the Wild2 parent body.

1.1 Samples and Methods

A set of terminal grains found in tracks C2112,4,187,0,0; C2045,4,178,0,0 178 (Fig. 1) and also C2112,4,170,0,0; C2045,3,177,0,0; C2045,3,189,0,0; C2045,4,190,0,0 (Tracks #187, #178, #170, #177, #189, #190) were taken from the cometary side of NASA's *Stardust* mission sample collector. In order to maximise the scientific return, it is vital that analyses of the samples are undertaken using as many different, non-destructive, techniques as possible - preferably on particles whilst they are still embedded in aerogel using, for example, microRaman spectroscopy [5]. Here we report on Fe-K absorption edge X-ray Absorption Analyses (XAS) and synchrotron X-ray Diffraction (SR-XRD) measurements at Beamline I18 of the *Diamond* synchrotron, UK. A spot size of 2.5 × 2.5 μm was used and Fe-K XAS was measured with the highest resolution over the Fe-K XANES region (7090-7125 eV), from which an absorption edge was estimated at 0.5 normalized intensity, and the 1s→3d centroids were estimated as the intensity-weighted average of baseline-subtracted pre-edge peaks. The transmission SR-XRD measurements were taken between 9 - 15 keV, with a 2θ range of ~4.3° to ~41.7° corresponding to d-spacings of ~1 Å up to ~18 Å.

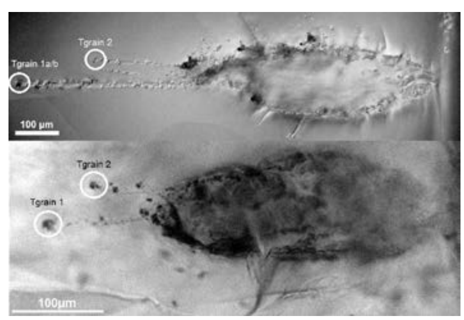

Fig. 1: (Top) Terminal grains 1a/b, 2 from track #178. (Bottom) Terminal grains 1 and 2 from track #187. Both are Type B tracks [4].

2. Results

Track #178: X-ray data confirms the presence of magnetite for the main terminal grain 1a and terminal grain 2 (Fig. 2). Terminal grain 1a has a 1s→3d pre-edge centroid position nearly identical to magnetite, although the absorption edge measures ~2eV higher than that of the magnetite (Fig. 3). MicroRaman analyses at the University of Kent revealed significant carbonaceous content around the subgrain bulb region of this track, implying an organic rich particle embedded with magnetite, perhaps holding it together like a ‘glue’ [5]. **Track #187**: The main terminal grain 1 has an iron-oxide type composition, with a (degraded) Raman spectrum indicative of magnetite mixed with some hematite. X-ray data confirms the presence of magnetite (Fig. 2). Fe-K XANES shows it has a 1s→3d pre-edge centroid position within 0.3 eV of magnetite, although the absorption edge measures ~3 eV higher than that of the magnetite (Fig. 3).

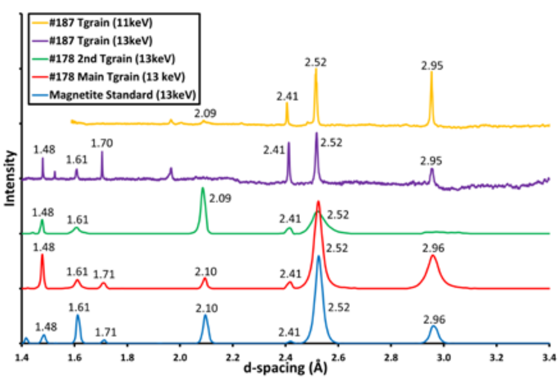

Fig. 2: SR-XRD identification of magnetite in the terminal grains of Tracks #178 and #187 by comparison of the 2θ peaks to a powdered magnetite standard.

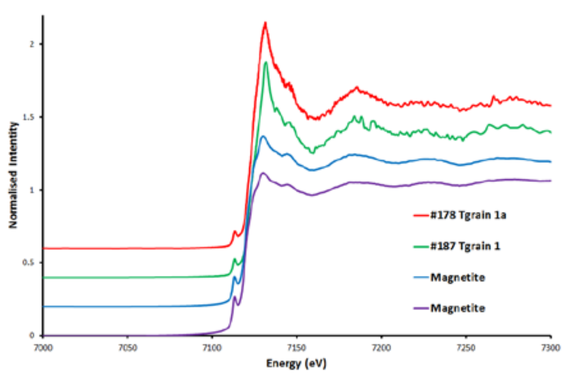

Fig. 3: Fe-K XANES plots of Track #178, #187 terminal grains compared to a powdered magnetite standard.

Other mineralogy identified: Fe-K XANES features and Raman spectrums [5] show the terminal grain in track #177 and terminal grain 1b in track #178 to be olivine. Similarly, terminal grains in tracks #189 and #190 have Fe-K XANES features corresponding to pyroxene. The terminal grain in track #170 shows near-identical Fe-K XANES and EXAFS comparisons to a Fe-metal foil standard, while XRF maps reveal Cr-rich content and a trace of calcium, thought to be a Cr-bearing silicate phase [6]. A Raman spectrum revealed a close match between forsterite and the silicate phase in this terminal grain [7].

3. Discussion

The presence of magnetite in Wild2 is similar to its occurrence within the matrices of many carbonaceous chondrites. It is assumed to be the result of the hydrous alteration of co-existing ferromagnesian minerals, which are also present in the Wild2 terminal grains analysed here and by others [1,2]. There is a variety of growing evidence for both low temperature hydrous processes such as magnetite formation, and also high temperature processing and the formation of chondrules in the Wild2 solid precursors [8]. This new understanding of the composition of comets will inform models of the early Solar System which require either radial mixing from the inner Solar System [9] or melting and alteration processes on planetesimals in the outer Solar System [1,10].

References

[1] Brownlee D.: The Stardust Mission: Analyzing Samples from the Edge of the Solar System, A. Rev. EPS 42, 179–205, 2014. [2] Zolensky M. et al.: Mineralogy and Petrology of Comet 81P/Wild2 Nucleus Samples, Science, 314, pp. 1735-1739, 2006. [3] Changela H.G., Bridges J.C. and Gurman S.J.: Extended X-ray Absorption Fine Structure (EXAFS) in Stardust Tracks: Constraining the origin of ferric iron-bearing minerals.: GCA 98, 2012. [4] Burchell M.J. et al.: Characteristics of cometary dust tracks in Stardust aerogel and laboratory calibrations, MAPS, 43, 23-40, 2008. [5] Price M.C. et al.: Results from Raman Analyses of Thirty-six Stardust Cometary Grains from Tracks 170, 176, 177, 178, 45th LPSC #1252, 2014. [6] Bridges et al.: Space weathering preserved in *Stardust* comet Wild2 samples, 43rd LPSC #2214, 2012. [7] Price M.C. et al.: Raman analyses of *Stardust* terminal grain in Track 170, EPSC, 23-28 September 2012, Madrid, Spain, EPSC2012-333, 2012. [8] Bridges J.C. et al.Chondrule Fragments from Comet Wild2: Evidence for High Temperature Processing in the Outer Solar System, EPSL 341–344: 186–194, 2012. [9] Ciesla F.J.: The distributions and ages of refractory objects in the solar nebula, Icarus, pp 455-467, 2010. [10] Nayakshin S., Cha S-H and Bridges J.C.: The tidal downsizing hypothesis for planet formation and the composition of Solar system comets, MNRAS, 416, L50-54, 2011.

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Physical properties of dust particles in cometary comae: from clues to evidence with the Rosetta mission

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Abstract

Physical properties of dust in cometary comae have first been approached through unique flyby missions and numerous remote observations of the intensity and polarization of the solar light they scatter. Clues to size distribution, morphology, refractive index of dust particles, and to their variations within comae have been derived from polarimetric data.

The Rosetta rendezvous mission to 67P/Churyumov-Gerasimenko (hereafter 67P) is now confirming previous estimations and providing detailed evidence about the dust physical properties, through sophisticated measurements obtained in different regions of the coma and for different solar distances.

1. Clues from previous studies

1.1. In situ studies

Changes in polarization, and thus in dust properties, within 1P/Halley coma had been discovered through observations of HOPE instrument on-board the Giotto spacecraft. For a fixed phase angle, the polarization was higher in red than in blue, except in the innermost coma, increased when Giotto crossed a jet-like feature and decreased in the innermost coma [e.g. 1]. Comparing intensities of light scattered by dust and dust fluxes led us to estimate that the dust particles were very porous and dark, with densities about 100 kg m^{-3} and albedos about 0.04 [2]. More recently, the Stardust mission provided evidence for dust fragmentation during its flyby of 81P/Wild 2 [3] and for the presence of both compact grains and aggregates, impacting aluminum foils of the sample return capsule [4].

1.2. Remote observations

Numerous remote polarimetric observations in the visible and near-IR domains have shown that, in the visible, the polarization at a fixed phase angle usually increases with increasing wavelength [e.g., 5]. They have also provided, through polarimetric imaging techniques, clues to the presence of heterogeneities in the dust properties within a coma, with an increase of polarization in jet-like features and a possible decrease in near-nucleus polarimetric halos. Such trends have typically been pointed out for 67P after its 2009 perihelion passage [6] and for C/1995 O1 Hale Bopp [7], respectively.

Numerical and experimental simulations are needed to interpret polarimetric observations, over a large range of phase angles in different colors, in terms of physical properties. Numerical fitting of 1P/Halley and C/1995 O1 Hale-Bopp data suggests i) a size distribution with a power law index of about -2.9, ii) the presence of aggregates and compact particles, iii) silicates and more absorbing organics with comparable contributions [8]. Experimental simulations, as developed for low spatial-density dust samples [9], lead to satisfactory fits for fluffy aggregates of Mg-silicates, C aggregates, with some compact Mg-silicates [10]. In 67P coma at its 2009 return, the presence of rather-large slow-moving absorbing particles before perihelion, and of fluffy aggregates of submicron-sized grains in jets after perihelion, is suspected [6]. Changes from innermost to outer coma are attributed to evolution processes, related to the alteration or evaporation of material partly constituting dust particles.

2. Evidence with Rosetta mission

While Rosetta rendezvous mission is still in its escort phase, the on-board dust instruments, i.e. GIADA, COSIMA and MIDAS, have already given remarkable evidence about the physical properties of dust, together with their variations, in the inner coma of comet 67P [e.g., 11, 12]. The morphology of dust particles reveals both compact (either almost spherical or quite irregular) and flocculent (some of them most likely agglomerates at very small scales) particles. Compact particles detected by GIADA and OSIRIS range in size from 0.03 to 1 mm [11], while fluffy aggregates of sub-micron grains detected by GIADA range in size from 0.2 to 2.5 mm [13].

Rosetta thus gives evidence for a significant amount of fluffy particles in the solid material ejected by comets. Such particles would be more resistant to atmospheric entry ablation than compact ones [14], thus enabling a larger mass of cometary material enrichment on the surface of early terrestrial planets.

4. Summary and Conclusions

Rosetta mission is now providing, thanks to its dust experiments, a fabulous wealth of information about dust particles released from 67P nucleus. While results already confirm previous indirect clues, mostly derived from polarimetric observations of comets, a significant evolution may be expected, not only while the comet gets closer to the Sun, but also after it has passed its perihelion [6].

Numerous remote polarimetric observations (including HST observations) should take place later on this year, allowing us to link the properties derived from remote observations to those accurately measured in the nucleus environment.

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References

[1] Levasseur-Regourd, A.C., McBride, N., Hadamcik, E., Fulle, M., Similarities between in situ measurements of local dust scattering and dust flux impact data within the coma of 1P/Halley, A. & A. 348, 636-641, 1999.

[2] Fulle, M., Levasseur-Regourd, A.C., McBride, N., Hadamcik, E., In situ dust measurements from within the coma of 1P/Halley, Astron. J. 119, 1968-1977, 2000.

[3] Tuzzolino, A.J., Economou, T.E., Clark, B.C., et al., Dust measurements in the coma of comet 81P/Wild 2 by the dust flux monitor instrument, Science 304, 1776-1780, 2004.

[4] Hörz, F., Bastien R., Borg, J. et al., Impact features on Stardust: Implications for comet 81P/Wild 2 dust, Science 314, 1716-1719, 2006.

[5] Kiselev, N., Rosenbush, V., Levasseur-Regourd, A.C., Kolokolova, L., Comets. In Polarization of stars and planetary systems (Kolokolova et al. Eds.) Cambridge University Press, pp. 379-404, 2015.

[6] Hadamcik, E., Sen, A.K., Levasseur-Regourd, A.C., et al., Polarimetric observations of comet 67P/Churyumov-Gerasimenko during its 2008-2009 apparition, A. & A. 517, A86, 2010.

[7] Hadamcik, E. and Levasseur-Regourd, A.C., Imaging polarimetry of cometary dust: different comets and phase angles. JQSRT, 79−80, 661–678, 2003.

[8] Lasue, J., Levasseur-Regourd, A.C., Hadamcik, E., et al., Cometary dust properties retrieved from polarization observations, Application to C/1995 O1 Hale-Bopp and 1P/Halley, Icarus, Vol. 199, 129-144, 2009.

[9] Levasseur-Regourd, A.C., Renard, J.-B., Shkuratov, Y, Hadamcik, E., Laboratory studies. In Polarization of stars and planetary systems (Kolokolova et al. Eds.) Cambridge University Press, pp. 62-80, 2015.

[10] Hadamcik, E., Renard, J.-B., Rietmeijer , F.J.M., Light scattering by fluffy Mg–Fe–SiO and C mixtures as cometary analogs, Icarus 190, 660-671, 2007.

[11] Rotundi, A., Sierks, H., Della Corte, V., et al., Dust measurements in the coma of comet 67P/Churyumov-Gerasimenko inbound to the Sun, Science 347, aaa3905 1-6, 2015.

[12] Schulz, R., Hilchenbach, M., Langevin, Y., et al., Comet 67P/Churyumov-Gerasimenko sheds dust coat accumulated over the past four years, Nature 518, 216-218, 2015.

[13] Fulle, M., Della Corte, V., Rotundi, A., et al., Density and charge of pristine fluffy particles from comet 67P/Churyumov-Gerasimenko, Astrophys. J. Letters 802, L12, 2015.

[14] Levasseur-Regourd, A.C., Lasue, J., Desvoivres, E., Early solar system impactors: Physical properties of comet nuclei and dust particles revisited, Origin. Life Evol. Biosph. 36, 5, 507-514, 2006.