

PPS004-01

Room:101

Time:May 27 14:15-14:30

Two-dimensional Paths of Particles in the Solar Nebula: Irradiation Exposure and Processing

Fred Ciesla^{1*}

¹University of Chicago

The dynamic evolution of a protoplanetary disk is critical to understand as it determines the physical and chemical environments in which planet formation would take place. Along with the dynamical evolution of the disk as a whole, solids within the disk undergo dynamical evolution, leading to the large-scale transport and redistribution of materials throughout the solar nebula. It is this dynamical transport that is needed to explain the presence of high-temperature minerals in the Stardust sample collected from Comet Wild 2 and the preservation of CAIs in the solar nebula for periods of millions of years.

The extent of transport that has been inferred for these primitive materials suggests that solid particles would be exposed to a wide array of physical and chemical environments within the solar nebula—environments in which the minerals in the particle could be destroyed, undergo chemical alteration, or be physically altered due to exposure to high-energy particles and photons. As such, the solid materials that we see in comets and chondritic meteorites should not be considered the products of a given formation environment, but rather each grain was shaped by the integrated path it took through the solar nebula.

I have developed a Monte Carlo Model that tracks the radial and vertical motions of solids throughout a protoplanetary disk, allowing the entire, pressure, temperature, and irradiation history to be determined. Such information is critical to determining the extent and types of chemical processing that different grains would have experienced. For example, gas-solid reaction kinetics can be compared to the residence time of particles in regions where such reactions could occur. Further, the formation of organics can require the cycling of icy grains from the deep interior of the disk to the surface where they would be exposed to irradiation by energetic particles. I will report early results from studies of these types.

Keywords: solar nebula, meteorites, comet, irradiation

PPS004-02

Room:101

Time:May 27 14:30-14:45

Heating and cooling in protoplanetary disks driven by magnetic turbulent stresses

Shigenobu Hirose^{1*}, Neal Turner²

¹JAMSTEC, ²JPL

We examine heating and cooling in protostellar disks that are driven by magnetic turbulent stress, contrasting them with those in protostellar disks based on the alpha model. We use 3D radiation-MHD calculations of a small patch of the Solar nebula at 1 AU, employing the shearing-box and flux-limited radiation diffusion approximations. The disk atmosphere is ionized by the stellar X-rays, well-coupled to magnetic fields, and sustains a turbulent accretion flow driven by the magneto-rotational instability, while the disk interior is highly resistive and magnetically dead. The turbulent layers are optically-thin to their own radiation, and cool inefficiently. They heat by absorbing the light from the central star, and by dissipating the turbulent magnetic fields. The location of the starlight absorption is 0.1AU higher than that in the alpha model due to an extra support of the gas by magnetic forces. Another contrast with the alpha model is that the accretion heating occurs higher in the atmosphere than the accretion stresses due to magnetic buoyancy. In the atmosphere, the irradiation heating is 33 times greater than the magnetic dissipation when averaged over time and space, and thus the averaged temperature, 410K, is the same as that in the alpha model. However, owing to the fluctuations in the turbulent fields, the local temperature reaches at least 600K, and a small fraction of the volume becomes hotter still, considering that a similar power should dissipate in a current sheet thinner than the grid spacing. The optically-thick, magnetically-dead interior is weakly heated by Silk damping of compressive disturbances, and is almost isothermal at a temperature of 130 K. In contrast, in the alpha model, there is a temperature bump of 20K near the midplane due to concentration of the accretion heating there.

Keywords: protoplanetary disk, radiative transfer, magnetic turbulence

Japan Geoscience Union Meeting 2011

(May 22-27 2011 at Makuhari, Chiba, Japan)

©2011. Japan Geoscience Union. All Rights Reserved.



PPS004-03

Room:101

Time:May 27 14:45-15:00

Iron sulfide formation in protoplanetary disks

Shogo Tachibana^{1*}

¹Dept. Earth Planet. Sci., Univ. Tokyo

Sulfur is a major volatile element in the solar system, and it shows various degrees of depletion in chondrites reflecting fractionation of volatile elements between solids and gas in the early solar system. Elemental fractionation of volatile elements may be attributed to incomplete condensation of volatiles into solids due to dispersal of disk gas. In order to discuss incomplete condensation of volatiles, it is of much importance to understand kinetics of volatile condensation, i.e., sulfidation kinetics of metallic iron in case of sulfur. I will report results on kinetics of nucleation and growth of iron sulfide on Fe metal, and discuss its effects on cosmochemical fractionation.

Keywords: iron sulfide, metal, kinetics, protoplanetary disk

PPS004-04

Room:101

Time:May 27 15:00-15:15

Oxygen isotopic distributions in the solar nebula: insights via sample return miAl-Mg systematics in planetary materials

Marc Chaussidon¹, Kevin McKeegan^{2*}

¹CNRS, Nancy, ²University of California, Los Angeles

NASA's Genesis and Stardust Discovery Missions have returned materials from the center and the periphery of the planetary formation region, in the form of solar wind and of dust from a Jupiter family comet, respectively [1,2]. The oxygen isotopic compositions of both samples measured by secondary ion mass spectrometry [3,4] show interesting similarities to some components of chondritic meteorites and also important differences to the O isotopic compositions of planetary materials. The solar wind is strongly enriched in ¹⁶O compared to bulk meteorites and inner solar system rocks, demonstrating that essentially all inner solar system materials have had their oxygen isotopic compositions affected by one or more non-mass-dependent fractionation processes prior to accretion. The existence of ¹⁶O-enrichments in calcium-aluminum-rich inclusions in meteorites, interplanetary dust, and comet Wild 2 (sampled by Stardust) broadly similar to that inferred for the Sun implies that these phases sampled solar material and then escaped thorough mixing with the isotopically heavy reservoir, characteristic of planetary dust [5] or ices [6-9]. The timescale of the mixing process must have been rapid and must have incurred in such a way as to preserve size-sorting and mineralogical differences in CAI and refractory inclusion type over different asteroidal (and perhaps cometary) parent bodies. Measurements of O isotopes [10] in low-density (porous) chondritic interplanetary dust particles (IDPs) do not show the ¹⁶O-enrichments that would be expected if isotope-specific CO photolysis generated the O isotopic shift from solar values by a self-shielding mechanism. This expectation is based on an assuming that these IDPs represent primitive outer solar system dust, which, while plausible, is not proven. It is ironic that the Stardust mission to bring back material from the outer solar system has, so far, been dominated by analyses of materials from the inner solar system. A direct measurement of O isotopes in either ice or dust from a comet would provide strong constraints on mixing and transport mechanisms in the solar accretion disk.

References: [1] D. S. Burnett et al., (2003) *Space Science Reviews*105, 509. [2] Brownlee, D.E., et al (2004). *Science* 304, 1764. [3] K. D. McKeegan et al., (2006) *Science*314, 1724. [4] K. D. McKeegan et al., in review. [5] A. N. Krot et al., (2010) *Ap. J.* 713, 1159. [6] N. Sakamoto et al., (2007) *Science*317, 231. [7] R. N. Clayton, (2002).*Nature*415, 860. [8] J. R. Lyons, E. D. Young, (2005) *Nature*435, 317. [9] H. Yurimoto, K. Kuramoto, (2004) *Science*305, 1763. [10] J. Aleon et al., (2009) *Geochim. Cosmochim. Acta*73, 4558.

Keywords: ²⁶Al, irradiation, nucleosynthesis

PPS004-05

Room:101

Time:May 27 15:15-15:30

The Activity of Liquid Water in the Early Solar System

Michael Zolensky^{1*}

¹ARES, NASA Johnson Space Center, Houston

We are exploring the earliest history of water in the solar system through direct analysis of the oldest surviving samples of solar system aqueous fluids. Our ultimate goal is to understand how the solar system evolved to its current state, including the activity of liquid water in the early solar system, and its influence on the origin and evolution of the biosphere of the Earth and the character and extent of prebiotic chemistry on Mars and the moons of the outer planets.

Ten years ago we found the first analyzable, verifiable aqueous fluid inclusions in any extraterrestrial sample (Zolensky et al., 1999, 2000). These fluid inclusions were in halite (NaCl) and sylvite (KCl) crystals in two H chondrite regolith breccias, Monahans 1998 (H5) and Zag (H3-6). At that time we could do very little with the samples, so we carefully preserved them in dry nitrogen cabinets and waited. Finally, analytical techniques have caught up with these critical samples.

Recently we have located fluid inclusions in several other classes of meteorites, especially carbonaceous chondrites. We are collaborating with Y. Yurimoto and S. Itoh (Hokkaido University) in measuring the hydrogen and oxygen isotopic composition of the fluid inclusions aqueous solutions. Yurimoto and Itoh have already reported the first results of their studies (Yurimoto et al., 2010). We will use the O and H isotopic composition of the aqueous fluids to identify the bodies that were the parent objects, and to better understand the source for water on the Earth. We are measuring the bulk composition of the fluid inclusion-bearing phases in each meteorite, as a further guide to the aqueous fluid bulk composition and origin. We suspect that small solid grains from the halite parent body have been deposited in the halite, adjacent to the fluid inclusions, where they must have been preserved against any thermal metamorphism. We are testing this hypothesis using Raman microscopy, in collaboration with M. Fries (Planetary Science Institute) and A. Steele (Carnegie Institution). We will compare these solid inclusions with minerals from chondrites and comet Wild-2 to determine whether these phases had a common origin.

References:

Zolensky et al. (1999) *Science* 285, 1377-1379.

Zolensky et al. (2000) *Antarctic Meteorites XXV: Twentyfifth Symposium on Antarctic Meteorites*, 193-195.

Yurimoto et al. (2010) *Meteoritics and Planetary Science* 45, A222.

Keywords: water, fluid inclusions, meteorites

Japan Geoscience Union Meeting 2011

(May 22-27 2011 at Makuhari, Chiba, Japan)

©2011. Japan Geoscience Union. All Rights Reserved.



PPS004-06

Room:101

Time:May 27 15:30-15:45

Evolution of organic compounds in disks: Implications for habitable planets

Monika Kress^{1*}

¹Dept. Phys. Astron., San Jose State U.

A major component of refractory carbon in planet-forming disks is in the form of polycyclic aromatic hydrocarbons, or PAHs. These compounds withstand temperatures up to ~1000 K in the disk environment. In hotter gas, they break down into volatile compounds including acetylene (C₂H₂), methane (CH₄), CO and CO₂ on timescales shorter than dynamical timescales of the disk. In my talk, I will discuss disk chemistry in light of what is known about the physical evolution of disks, with particular emphasis on the implications for the carbon content of habitable worlds.

Keywords: organics, evolution, protoplanetary disk, habitable planet

PPS004-07

Room:101

Time:May 27 15:45-16:00

The origin of meteoritic organics deciphered by the oxygen and carbon isotopes.

Ko Hashizume^{1*}, Naoto Takahata², Hiroshi Naraoka³, Yuji Sano²

¹Earth & Space Sci., Osaka Univ., ²AORI, Univ. of Tokyo, ³Earth & Planet. Sci., Kyushu Univ.

Organic matter abundantly found in primitive meteorites may represent one of the important sources of volatiles on Earth present as ocean, atmosphere and lives. Part of the meteoritic organic matter possibly preserves primordial compositional records acquired upon its birth in the outer region of the proto-solar nebula and/or in the ancestral molecular cloud, though the exact origins remain open issues.

The isotope imaging of acid-insoluble organic matters (IOM) extracted from carbonaceous chondrites was carried out in this study [1]. We performed the imaging using the Cameca NanoSIMS50 ion-microprobe equipped at the Atmosphere and Ocean Research Institute, University of Tokyo. The same area was rastered four times to respectively obtain (1) the D/H ratio; (2) the ¹³C/¹²C and ¹⁵N/¹⁴N ratios, (3) the OH/O ratio; and (4) the ¹⁷O/¹⁶O and ¹⁸O/¹⁶O ratios.

Anomalous $\delta^{17,18}\text{O}(\text{rel.SMOW})$ values as high as $+534 \pm 109$ permil were observed among the organic phases extracted from an Antarctic CR2 chondrite Yamato-793495. The $\delta^{17}\text{O}$ and $\delta^{18}\text{O}$ showed paralleled values, plotted in the three isotope diagram slightly above the slope-1 line, with an inclination of 1.057 ± 0.015 . The ^{17,18}O-rich domains showed positive $\delta^{13}\text{C}(\text{rel.PDB})$ values, up to $+288 \pm 45$ permil.

The positive correlation between the $\delta^{17,18}\text{O}$ and $\delta^{13}\text{C}$ is explained in principle by the self-shielding effect of CO. The reduced photodissociation rate of the major isotopologue, ¹²C¹⁶O, may result in the coherent enrichment in the organic matter of the three minor isotopes, ^{17,18}O and ¹³C. However, a warm environment, as high as 60 Kelvin, is necessary to expect the ¹³C-enrichment by the self-shielding effect to overcome the opposite fractionation effect by the competing reaction, namely the ion molecule reaction (¹²CO + ¹³C⁺ = ¹²C⁺ + ¹³CO + 35K). Therefore, we propose that the organic matter exhibiting the non-mass-dependent O-isotope signature was formed in a rather warm gas medium, at temperatures of about 60 Kelvin or higher, such as the envelope of the solar-nebula illuminated by the proto-Sun.

The non-mass-dependent O-isotope anomaly, broadly observed among the solid planetary materials, was originally considered to represent the origins or formation processes of a subset of the rocky planetary materials. However, recent studies [1,2] suggest that the O-isotope anomaly is deeply connected to the origins of the low-temperature condensates, represented by the water ice and the organic matter. The oxygen isotope may become one of the most important tools to trace the entire history of the important ingredients for a habitable planet: from their origins; their circulation in the solar nebula; accretion to planets/asteroids; and the processes within the planets, namely the water-organics-rock interactions, possibly including the life-formation process.

[1] Hashizume K., Takahata N., Naraoka H. and Sano Y. (2011) Extreme oxygen isotope anomaly with a solar origin detected in meteoritic organics. *Nature Geoscience*. doi:10.1038/ngeo1070.

[2] Sakamoto, N. et al. (2007) Remnants of the early solar system water enriched in heavy oxygen isotopes. *Science* 317, 231-233.

Keywords: Organic Matter, Meteorite, Oxygen Isotope, Photodissociation, Isotope Imaging

PPS004-08

Room:101

Time:May 27 16:00-16:15

The intriguing character of the macromolecular organic matter from ungrouped C2 WIS91600

Hikaru Yabuta^{1*}, Conel M.O'D. Alexander², Marilyn L. Fogel², David Kilcoyne³, George D. Cody²

¹Osaka Univ., Dept. Earth and Space Sci., ²Carnegie Institution of Washington, ³Advanced Light Source, LBNL

Insight into the chemical history of an ungrouped type 2 carbonaceous chondrite meteorite, Wisconsin Range (WIS) 91600, is gained through molecular analyses of insoluble organic matter (IOM) using solid-state ¹³C nuclear magnetic resonance (NMR) spectroscopy, X-ray absorption near edge structure spectroscopy (XANES), and pyrolysis gas chromatography coupled with mass spectrometry (pyr-GC/MS), and our previous bulk elemental and isotopic data. The IOM from WIS 91600 exhibits similarities in its abundance and bulk $\delta^{15}\text{N}$ value with IOM from another ungrouped carbonaceous chondrite Tagish Lake, while it exhibits H/C, $\delta^{13}\text{C}$, and δD values that are more similar to IOM from the heated CM, Pecora Escarpment (PCA) 91008. The ¹³C NMR spectra of IOM of WIS 91600 and Tagish Lake are similar, except for a greater abundance of CH_xO species in the latter and sharper carbonyl absorption in the former. Unusual cross-polarization (CP) dynamics is observed for WIS 91600 that indicate the presence of two physically distinct organic domains, in which the degrees of aromatic condensation are distinctly different. The presence of two different organic domains in WIS 91600 is consistent with its brecciated nature. The formation of more condensed aromatics is the likely result of short duration thermal excursions during impacts. The fact that both WIS 91600 and PCA 91008 were subjected to short duration heating that is distinct from the thermal history of type 3 chondrites is confirmed by Carbon-XANES. Finally, after being briefly heated (400 degrees C for 10 s), the pyrolysis behavior of Tagish Lake IOM is similar to that of WIS 91600 and PCA 91008. We conclude that WIS 91600 experienced very moderate, short duration heating at low temperatures (less than 500 degrees C) after an episode of aqueous alteration under conditions that were similar to those experienced by Tagish Lake.

Keywords: macromolecular organic matter, ungrouped carbonaceous chondrite, metamorphosed CM, shock heating, WIS 91600, Tagish Lake

PPS004-09

Room:101

Time:May 27 16:30-16:45

CALCICUM-41 REVISITED: DEVELOPMENT OF POTASSIUM ISOTOPE MASS SPECTROMETRY ON CAMECA 1280HR2

Ming-Chang Liu^{1*}, Marc Chaussidon¹

¹CRPG-CNRS, ²ASIAA

Introduction: Amongst the short-lived radionuclides whose prior existence has been inferred in meteoritic components, ⁴¹Ca plays a crucial role in understanding the timescale between its nucleosynthesis and incorporation into the oldest Solar System solids because of its extremely short half-life (0.1 Myr). The initial abundance of ⁴¹Ca relative to ⁴⁰Ca in the solar nebula was found to be 1.4×10^{-8} , as first demonstrated by [1-2] through the detection of large excesses of radiogenic ⁴¹K in Efremovka CAIs. Combined with nucleosynthesis models, such a low abundance implies that the timescale for the transit from the nucleosynthetic site of ⁴¹Ca to the solar nebula should be less than 2 Myr. Soon after the initial discovery, ⁴¹Ca was also found to be correlated with the presence or absence of another short-lived radionuclide ²⁶Al in CM hibonite grains, implying that ⁴¹Ca and ²⁶Al have a common stellar origin [3-5]. However, neither the initial ⁴¹Ca/⁴⁰Ca ratio nor the correlation between ⁴¹Ca and ²⁶Al has been independently confirmed by other laboratories. Several attempts made by [6-8] failed to provide a conclusive answer for the level of ⁴¹Ca/⁴⁰Ca, primarily due to large systematic uncertainties in the mass spectrometry (corrections for doubly ionized species and for peak tailing). In this study, we propose to use the latest generation of large geometry ion microprobe CAMECA 1280HR2, newly installed at CRPG, Nancy, to reinvestigate the initial abundance and distribution of ⁴¹Ca in meteoritic refractory inclusions.

Mass Spectrometry: The mass spectrometry for potassium isotope measurements with the CRPG 1280HR2 is still under development. We have characterized several important factors of the instrument that have crucial impacts on the accuracy of ⁴¹Ca/⁴⁰Ca determination. The tailing effect of ⁴⁰Ca at mass 41 (scattered ⁴⁰Ca ions on ⁴¹K) was found to be about a few tenth of ppb under the mass resolution of 7500. The contribution of the ⁴⁰CaH⁺ tail at mass 41 was estimated to be $\sim 2 \times 10^{-5} \times ^{40}\text{CaH}^+$ by obtaining the count rate at mass 41.95 and assuming the following relationship:

$$(^{40}\text{CaH})_{\text{tail}} = [41.95]/[^{42}\text{Ca}^+] \times [^{40}\text{CaH}^+]$$

The dynamic background of the counting system was also measured overnight when analyses were not performed, and is within the range of 0.003 to 0.009 counts per second. One parameter, which requires special attentions in every measurement, is the $(^{40}\text{Ca}^{43}\text{Ca})^{++}/^{43}\text{Ca}^+$ ratio. It is used to assess the magnitude of the unresolvable interference $(^{40}\text{Ca}^{42}\text{Ca})^{++}$ at mass 41. In the phases where ⁴¹Ca/⁴⁰Ca was inferred (i.e., fassaite), the high ⁴⁰Ca/³⁹K ratio ($> 1 \times 10^6$) would result in that $> 80\%$ of the signal measured at mass 41 is derived from $(^{40}\text{Ca}^{42}\text{Ca})^{++}$. Therefore, having an accurate assessment of $(^{40}\text{Ca}^{42}\text{Ca})^{++}$ is critical for accurate determinations of ⁴¹Ca/⁴⁰Ca. We will report some preliminary results of the K isotopic compositions in CAIs by the time of the conference.

References: [1] Srinivasan et al. (1994) ApJL, 431, 67-70 [2] Srinivasan et al. (1996) GCA, 60, 1823-1835 [3] Sahijpal et al. (1998) Nature, 391, 559-562 [4] Sahijpal et al. (1998) ApJL, 509 137-140 [5] Sahijpal et al. (2000) GCA, 64, 1989-2005 [6] Ireland et al. (1999) MAPS, 34, A57 [7] Ito et al. (2006) MAPS, 1871-1882 [8] Liu et al. (2008) LPS, 39, #1895 (abstract)

Keywords: short-lived radionuclide, secondary ion mass spectrometry

PPS004-10

Room:101

Time:May 27 16:45-17:00

Petrological characteristics of TIL 07007, a highly deformed CV3 chondrite

Byeon-Gak Choi^{1*}, Hwayoung Kim¹, Jung-Eun Choi¹, Jangmi Han²

¹Seoul National University, ²University of New Mexico, Albuquerque

Thiel Mountains (TIL) 07007 is a CV3 chondrite found at the blue ice field near Thiel Mountains, West Antarctica by the 2nd Korea Expeditions for Antarctic Meteorites (Weisberg et al., 2010; the official Meteoritical Bulletin website). It weighs 18 gram. Terrestrial weathering grade of the meteorite is W1 and shock stage is S2. A thin section of the meteorite (SNU-T068) having $\sim 266\text{mm}^2$ was studied for petrological characteristics with an optical microscope, scanning electron microscope and electron microprobe analyzer. In the thin section, TIL 07007 consists of ~ 53 vol. % of chondrules, $\sim 17\%$ of refractory inclusions and $\sim 28\%$ of matrix. The chondrules and refractory inclusions are elongated and aligned to form foliation. Several micro-faults are recognized in some chondrules.

Total 170 chondrules (not including fragments) were recognized using backscattered electron images taken from the thin section. Majority of chondrules are porphyritic olivine chondrules having low-FeO contents in olivine (Fa contents < 6.5).

More than 20 refractory inclusions are found in the thin section. Majority of them are type-B Ca-Al-rich inclusions (CAIs); there are also a few melilite-rich type-A CAIs and ameboid olivine inclusions. In the type-A CAIs ~ 20 micron-size euhedral spinel grains enclosed by coarse grained melilite grains occur along with hibonite and perovskite. Akermanite contents in melilite vary from 5.4 to 16.8%. In the type-B CAIs, smaller (1-5 micron) spinel grains occur in Ti-Al-diopside and melilite grains. Some type-B CAIs have core and mantle structures. Melilite in type-B CAIs has wide range of Akermanite contents from 6.4 to 79.8%.

Average of areas occupied by single chondrule in the thin section is $\sim 0.75\text{mm}^2$, which is somewhat larger than that we measured in Allende ($\sim 0.49\text{mm}^2$). Averages of major and minor axes are 1.13 and 0.67mm respectively giving the eccentricity of ~ 0.75 (aspect ratio of ~ 1.7).

These elongated chondrules are aligned with a preferred orientation: standard deviation in degree from the average elongation angle is 30. Refractory inclusions are also strongly elongated and aligned to the same direction with the chondrules. Only known chondrites having such a strong foliation structure by elongated chondrules (and/or CAIs) are Leoville (CV3, e.g., Cain et al., 1986) and Ghubara (L5). Cain et al. (1986) suggested that compaction due to overburden from progressive accretion caused the deformation of Leoville, while Nakamura et al. (1992) interpreted as the results of multiple impacts with relatively mild pressures (5-20 GPa).

In TIL 07007, chondrules, CAIs and AOIs are all elongated to the similar shape and aligned with the same orientation, suggest that they deformed in situ in the parent body, possibly by impacts. Micro-faults in chondrules were probably formed by the same impact events.

References:

- Cain, P. et al. (1986) *Earth and Planetary Science Letters* 77, 165-175.
- Nakamura, T. et al. (1992) *Earth and Planetary Science Letters* 114, 159-170.
- Weisberg, M. K. et al. (2010) *Meteoritics and Planetary Science* 45, 1530-1551.

Keywords: meteorites, chondrites, chondrules, Ca-Al-rich inclusions, deformation