Cometary Volatiles: Icy Grains and Drivers of Activity

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We have understood for some time that the activity of most comets is driven by the sublimation of H_2O ice, at least when they are near the sun, say within 2.5 ot 3 AU. The identification of icy grains in cometary comae has been reported occasionally over a few decades for comets active at large distances. In the absend of IR spectra, we have no way of distinguishing "dust" from icy grains in cometary comae, although a bluish color in the visible and near-IR would suggest ice. We have also observed outbursts of comets at large heliocentric distance, during which gaseous CO has been detected, suggesting that CO is the driver of activity at heliocentric distance beyond 3 AU.

Although observations of CO_2 go back to comet Halley, the usually high abundance of CO_2 was only realized with the *AKARI* survey and the role of CO_2 in driving the activity of comets that release even more H_2O became clear from the *EPOXI* flyby of 103P/Hartley 2. The frequent, high abundance of CO_2 is an interesting constraint on the formation of comets, because gaseous CO_2, unlike CO and H_2O, is not generally observed in the interstellar medium or protoplanetary disks.

The observations of Hartley 2 also showed that a significant part of the "dust" in the cometary coma could be ice, even at 1 AU from the sun. Furthermore, the ice in the coma comes primarily from the interior of the nucleus rather than from the ice that is observed on the surface, but only in parts of the nucleus that have just passed sunrise (on both 9P/Tempel 1 and Hartley 2). There are still issues with the current modeling of the icy grains but the data are being analyzed in multiple ways in order to get a clearer picture.

This talk will provide a more detailed overview of the abundances of volatiles in various comets and the processes that lead to the grains in the coma.

Comet Dust, and Comet ISON, Too

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Solar system formation is an engine that simultaneously preserves and transforms interstellar medium (ISM) dust grains into planetesimals and, ultimately, planets. Comets are the preserved relics from our own solar system's formation. If comets are a mixture of ISM dust and solar nebula processed material, they would allows us to investigate both the inputs and outputs of dust transformation in the young Solar System. If, instead, ISM dust is completely processed in the disk, comets would more directly reflect the diversity of the dust forming processes and environment. Whichever the case, the diversity of dust in comets, as individuals and throughout the whole population, can be used to test dust formation scenarios and transportation throughout the disk.

Dust grains in the ISM are dominated by "amorphous" silicates, i.e., they have chemical composition (stoichiometry) similar to pyroxene ($[Mg_x,Fe_{1-x}]SiO_3$) and olivine ($[Mg_y,Fe_{1-y}]_2SiO_4$). Studies of silicates in the galaxy constrain the crystalline silicate fraction to $\leq 5\%$ by mass (Li & Draine 2001; Kemper et al. 2004). In contrast, dust ejected by comets, such as C/1995 O1 (Hale-Bopp) and 9P/Tempel 1, have significant crystalline mass fractions: 60–80% of Hale-Bopp (Harker et al. 2002; Moreno et al. 2003, Lisse et al. 2007), and ≈30% of 9P (Harker et al. 2005). Taken together, the observations of the ISM and of comets strongly suggest that amorphous ISM dust was either destroyed and re-condensed as crystals, or that it was annealed (crystallized), prior to the accretion of planetesimals in the icy outer-disk. Determining the dust composition of comet nuclei helps us understand how dust formed in the inner-Solar System, and how that dust was transported to the outer-Solar System; processes that are apparently ubiquitous in observations of external protoplanetary disks (e.g., Olofsson et al. 2010).

I have been a part of a team surveying the dust properties of comets through mid-infrared spectra of comet comae (e.g., Harker et al. 2002, 2005, 2011; Wooden et al. 2004; Kelley et al. 2006; Woodward et al. 2011). In this talk, I review the current status of our survey, and our observations of comet C/2012 S1 (ISON) from the SOFIA telescope.

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The Submillimeter Continuum of Cometary Dust

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Comets are perhaps the least altered building blocks from the early solar nebula and hold important clues to the main chemical and physical processes of that period. Cometary dust probably consists of both presolar particles and solids condensed from the solar nebula. Dust properties (i.e. structure and mineralogy) reflect the extent of mixing of material between the warm inner regions and cold outer regions of the nebula at the time of comet formation.

The apparition of comet C/2011 L4, one of the brightest in the last two decades, provides an unique opportunity to study a dynamically new comet in unprecedented detail. We imaged the dust coma of C/2011 L4 using the new SCUBA-2 camera at the James Clerk Maxwell Telescope and simultaneously detected the dust emission at 450 μm and 850 μm. Our submillimeter observations are sensitive to large dust particles similar to grains in extrasolar circumstellar dust disks. In this talk we will present the long-wavelength observations of three comets with a special focus on the comet C/2011 L4. We will discuss the implications of our derived mass loss rates and how cometary dust is related to its precursor materials in the solar accretion disk.

Curation and characteristics of the Hayabusa-returned particles

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Asteroids are one of the main sources of interplanetary dust, although their contributions on it are still under discussion [1]. JAXA sent the spacecraft Hayabusa to the S-type Near-Earth Asteroid (NEA) 25143 Itokawa. It reached the asteroid in Sep. 2005, and performed twice touchdowns onto it in Nov. 2005 in order to obtain samples on its surface [2, 3]. It returned to the Earth in Jun. 2010, sending back its reentry capsule to the desert in Australia [4].

All the processes for sample recovery are detailed in [5]. After we received the reentry capsule to the Extraterrestrial Sample Curation Center (ESCuC), a sample container, which was situated inside the reentry capsule, was extracted from the capsule, cleaned its outer surface, and introduced into a specific vacuum chamber called as “clean chamber No.1.” It was disclosed in static vacuum condition and extracted a sample catcher inside the container in purified nitrogen condition of the chamber No.1. The catcher was sent to a clean chamber No.2, which is designed to handle small samples with an electrostatically controlled micromanipulator in purified nitrogen gas condition. The sample catcher is separated into three areas, room A, room B and a rotational cylinder. Then particles inside the catcher have been recovered and described with a field-emission type scanning electron microscope with an energy dispersive X-ray spectroscopy (FE-SEM/EDS) without conductive coating and exposure to terrestrial atmosphere.

The Hayabusa-returned samples have been recovered from the catcher in the three different methods in the following. At first, we scraped inside the catcher room A with a small Teflon spatula to recover particles on the spatula and observe them with the FE-SEM/EDS. More than 1000 of silicate particles on the spatula were described and firstly considered as Itokawa origin because its modal abundance of minerals was comparable to that of equilibrated LL chondrite [6]. Secondary, we prepared synthetic quartz glass disks to be set to the openings of both room A and B and tapped it to let particles inside fall onto them. Then we picked up particles on the disks one by one with the micromanipulator to analyze them with the FE-SEM/EDS. We also picked up particles from a cover of room B, which was recovered when we opened the room B. Third, we developed a special sample holder for FE-SEM to introduce the cover of room A into the FE-SEM and described particles on it directly with the FE-SEM/EDS in order to save time picking up particles.

So far, more than 400 particles, which size from 8 to 310 μm in major axes, have been described with the FE-SEM/EDS. 80% of them are silicate particles, which are estimated to be Itokawa origin. The rest of them are those consist mainly of carbon, whose origins are unknown, and artificial ones. More than 60% of the silicate particles are composed mainly of olivine, and more than 20% of them are dominated by pyroxene, and less than 10% of them consist mainly of plagioclase. Those dominated by iron sulfide or iron-nickel metal is around 1%, respectively.

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Photoelectron emission from an airless body and dust motion above the surface of the body

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When an airless body such as asteroids, Moon and Mercury, is irradiated with solar EUV, photoelectrons emitted from the surface of the body form a thin electron sheath above the surface. The vertical structure of the photoelectron sheath, namely, the electron density and the electrostatic potential, are determined by the vertical component of the velocity distribution function (VDF) of photoelectrons.

The VDF is to be obtained by laboratory experiments. Feuerbacher et al. (1972) performed one and only measurement of the VDF of the surface material analogous to a regolith of airless bodies (see also Willis et al. 1973). They measured the energy distribution function of photoelectrons from lunar soil as a function of light wavelength and calculated the VDF of the regolith analogue under irradiation of the solar spectrum. Previous numerical studies of the motion of a dust grain in a photoelectron sheath assumed a Maxwellian VDF for photoelectrons and used the root-mean-square velocity of photoelectrons calculated by Feuerbacher et al. (1972) as the mean vertical velocity (e.g., Colwell et al. 2005, Poppe et al. 2012, Hirata and Miyamoto 2012). However, the VDF given in Feuerbacher et al. (1972) is clearly non-Maxwellian and, moreover, the root-mean-square velocity given by Feuerbacher et al. (1972) is not a vertical component of photoelectron velocity (see Fig. 1 of Feuerbacher et al, 1972).

To correctly understand the dynamical behavior of dust grains above the surfaces of airless bodies in the Solar System, we derive the vertical component of the VDF from the energy distribution function given by Feuerbacher et al. (1972) and revise the motion of a dust grain in a photoelectron sheath above the surface as a function of the size of the grain and its initial vertical velocity.

We found that our model results in a thinner electron sheath than the ones previously predicted by the models using the Maxwellian VDF. We show that our model predicts electrostatic levitation of a grain with radius of 1 μm above the surface of Eros is possible as long as the initial velocity is less than 0.4 m/s which is much lower than the previous estimates of about 2 m/s.

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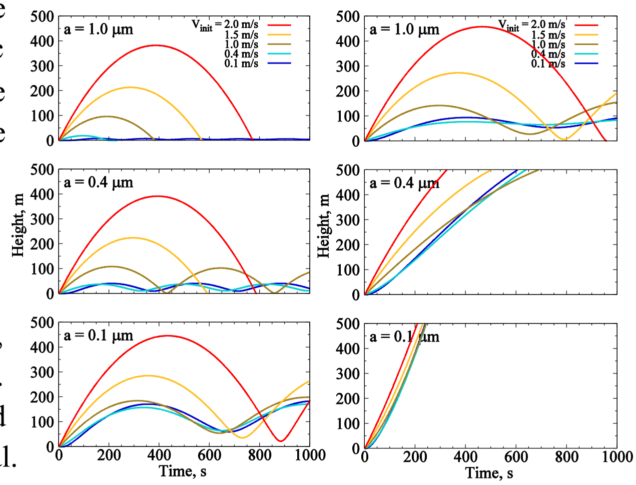

Figures: Motion of dust grains above the surface of asteroid Eros launched with various velocities (left: this study; right: Maxwellian VDF model).

Progress in modeling polarization of cosmic dust using MSTM code

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Aggregated particles play a crucial role in the formation of observed characteristics of dust in interstellar medium, molecular clouds, circumstellar disks, comets, planetary atmospheres and on surfaces. Thus, modeling their interaction with radiation has a fundamental astrophysical value. Recent years have been marked by a significant development of one of the most popular codes to model light scattering by aggregates - Multi Sphere T-Matrix code (MSTM), and by its numerous applications to cosmic dust.

Parallelized version of the MSTM code [1]. It made computations possible for aggregates of thousands of constituent particles (monomers) comparable with wavelength. Such large aggregates played a crucial role in our analysis of near-infrared polarization and modeling spectral dependence of polarization in comets and debris disks.

MSTM code for optically active material [2]. This version has a significant astrobiological value; it allows consideration of dust that includes homochiral organics. We used this code to interpret cometary circular polarization and for exploring circular polarization as a biosignature. The most recent development of this version of MSTM code considers a system where any of the spheres can be located at points that are either internal or external to the other spheres [3], enabling consideration of inclusions or core-mantle particles. See the latest MSTM code at www.eng.auburn.edu/users/dmckwski/scatcodes/ .

A new version of the code, **MSTM4**, **considers large thick slabs of spheres** [4], i.e. it can model planetary regolith. MSTM4 is significantly different from the versions described above. It adopts a discrete Fourier convolution (DFC), implemented using a fast Fourier transform (FFT), for evaluation of the exciting field. This approach is similar to that used in DDA codes, but considers multipole nature of the translation operators and does not require the spheres to be located on a regular lattice. MSTM4 is capable to consider dozens of thousands of monomers and is also about 100 times faster than the original MSTM code. The code is in its testing stage now, however we have already successfully applied it to model polarization and spectra of icy bodies (satellites of giant planets and KBOs).

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Optical Properties of Porous Aggregates: Toward the Better and Simple Understanding

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Porosity evolution is a key process to overcome the radial drift barrier, which is a major problem of planet formation theory (e.g., Okuzumi et al. 2012, Kataoka et al. 2013 a,b). Since the optical properties of porous aggregates is not completely understood, the presence of such porous aggregates is not clearly shown by observation. Thus, our goal is to attain better understanding of optical properties of porous aggregates such as phase function, polarization, absorption and scattering cross-section and construct the model that is much easier to use than cost numerical method.

We calculated the absorption and scattering cross sections of porous aggregates with fractal dimension of two using the T-Matrix Method that is one of most rigorous method. Our results show that absorption cross-section of porous aggregates are same as monomer's absorption cross-section at the longer wavelength compare to the monomer radius. This is already shown by Kolokolova et al. (2007) and more recently by Kataoka et al. (submitted to A&A) using approximate method, Effective Medium Theory (EMT). We also find simple scaling relations for the scattering cross section in the limits of long and short wavelengths. If the wavelength is much longer than the characteristic radius of aggregates, scattered lights are coherently superposed, then $C_{\rm sca}(N) = N^2 C_{\rm sca}(N = 1)$ where $C_{\rm sca}(N)$ is the scattering cross section of an aggregate consisting of N monomers. In the opposite limit, scattered lights are incoherently superposed then the scattering cross-section obeys $C_{\rm sca}(N) = N C_{\rm sca}(N = 1)$. In the intermediate wavelength regime, the scattering cross-section can be described by the combination of coherent and incoherent scattering, and we derived the fitting formula that can reproduce the result obtained by T-Matrix Method. We also investigate its dependence on the fractal dimension of the aggregates. In addition, in the talk we compare these results with EMT and discuss the condition where the EMT approximation breaks down.

Hot Debris Disks Formation Caused by Giant Impacts for Terrestrial Planet Formation

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For terrestrial planet formation, dozens of Mars-sized bodies are produced from planetesimals until depletion of these planetesimals and substantial collisions between these large bodies construct larger planets such as Earth and Venus. The total mass of fragments produced by such a giant impact is only 10% of colliders but comparable to or larger than that of bodies in typical debris disks. Therefore, giant impacts result in debris disks. We numerically integrate orbits of Mars-sized bodies to obtain the collisional history of these bodies. Simultaneously collisional outcomes between these bodies are calculated by high-resolution hydrodynamic simulations. We finally obtain the brightness evolution of debris disk using these data in collision cascade model. We discuss our model comparing with observed debris disks.

Dust mineralogy in proto-planetary and debris disks

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The initial conditions of planetary formation are governed by the evolution of initially (sub)μm-sized silicate dust grains in the early phases of young circumstellar disks. Dust grains are the building blocks of planets (which requires growth spanning over several orders of magnitude), and they provide clues to the dynamical evolution of the disk at all stages of the planet-forming process. Our knowledge about dust, and its evolution, has significantly improved during the past years, thanks to statistical studies at mid- and far-infrared wavelengths based on space-based missions such as *Spitzer* and *Herschel*. The mineralogical information (lattice structure, chemical composition, and grain morphology), as determined by spectroscopic observations, provide valuable constraints on the dynamical evolution of disks at various ages (e.g., radial and vertical transport, coagulation, fragmentation, and crystallisation). I will summarize our findings for circumstellar disks at different key steps of the planet-forming process, trying to connect them with our understanding of the solar system.

The Offset Dust Ring of HR 4796A and Other Debris Disks as Revealed by NICI.

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We present adaptive optics images of the dust disks around the 7 young stars, HR 4796 A, β Pictoris, AU Mic, HD 141569, HD 32297, HD 15115 and HD 61005, where the relative position of the star and disk clumps and warps are captured at high-resolution (0.05″). These images were obtained using the Near Infrared Coronagraphic Imager (NICI) on the Gemini-South 8.1 meter Telescope. For HR 4796 A, we present J, H, CH_4 short (1.578 μm), CH_4 long (1.652 μm) and K_s-band images of the dust ring around the 10 Myr old star HR 4796 A. Our images clearly show for the first time the position of the star relative to its circumstellar ring thanks to NICI's translucent focal plane occulting mask. We employ a Bayesian Markov Chain Monte Carlo method to constrain the offset vector between the two. The resulting probability distribution shows that the ring center is offset from the star by 16.7±1.3 milliarcseconds along a position angle of 26±3°, along the PA of the ring, 26.47±0.04°. We find that the size of this offset is not large enough to explain the brightness asymmetry of the ring. The ring is measured to have mostly red reflectivity across the JHK_s filters, which seems to indicate micron-sized grains. Just like Neptune's 3:2 and 2:1 mean-motion resonances delineate the inner and outer edges of the classical Kuiper Belt, we find that the radial extent of the HR 4796 A and the Fomalhaut rings could correspond to the 3:2 and 2:1 mean-motion resonances of hypothetical planets at 54.7 AU and 97.7 AU in the two systems, respectively. A planet orbiting HR 4796 A at 54.7 AU would have to be less massive than 1.6 M_{Jup} so as not to widen the ring too much by stirring (Wahhaj et al. 2014). We also present our findings on the other debris disks, especially, the spiral dust sturcture in HD 141569 (Biller et al. 2014), and the orbit of the β Pictoris planet and its relative inclination to the inner and outer disks (Nielsen et al. 2014).

Dust in Protoplanetary Disks

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The early evolution of solids in protoplanetary disks is governed by dust aggregate collisions and by the interaction between the solids and the gas through drag forces. The complicated interplay between these effects determines the sizes of the solid particles and their distribution within the disk. This distribution of solid material sets the initial condition for planet formation, it represents an important ingredient for the chemical evolution of the disk, and furthermore it determines the observational appearance of protoplanetary disks. This way, solids enable us to observationally probe the physical processes involved in the formation of planets and the evolution of disks.

This review summarizes our current understanding of the evolution of dust aggregates in protoplanetary disks, taking into account insights from laboratory experiments and recent modeling efforts. Methods to constrain these effects through observations are discussed and recent observational studies that probe the mechanisms of dust evolution, planet formation, and disk evolution are summarized.

“Particules traps” at planet gap edges in disks : effects of grain growth and fragmentation

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We model dust evolution in protoplanetary disks with 3D, SPH, two-phase (gas+dust) hydrodynamical simulations. The gas+dust dynamics, where aerodynamic drag leads to the vertical settling and radial migration of grains, is consistently treated. In a previous work, we characterized the spatial distribution of non-growing dust grains of different sizes in a disk containing a gap-opening planet and investigated the gap’s detectability with ALMA. Here, we take into account the effects of grain growth and fragmentation and study their impact on the distribution of solids in the disk. We show that the ability of “particle traps” at the gap edges to favor grain growth is strongly affected by fragmentation. We discuss the consequences on observations with ALMA and NOEMA.

Interstellar Ices: From Clouds to Disks to Comets

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Icy mantles on interstellar dust grains are the repository for a significant amount of the oxygen and carbon in dark molecular clouds and star forming environments. Much of the chemistry of these regions, where gas phase reactions are expected to be inefficient, is thought to occur in the icy mantles. Spacecraft missions, such as Spitzer and the earlier workhorse of interstellar ice observations, the Infrared Space Observatory, have dramatically improved our understanding of how ices form and evolve. In general, ice evolution can be divided into an early phase of hydrogenation reactions, a CO freeze-out phase, and a phase of UV and/or thermal processing in a protostellar environment. Observations of complex molecules in the gas phase around protostars suggest that production of complex species also occurs on grain surfaces. There is also evidence that ices are present in the midplanes of protoplanetary disks, though it is often to disentangle the signal from intervening cloud material. In the case of our solar system, comets are thought to retain a record of the midplane ices during the planet formation time, though the extent to which cometary ices have been reprocessed in the protostellar disk is unclear. In this talk, I review what is known about ices in the various environments and how it is thought to evolve from initial freeze-out and formation in the dark cloud through the star formation process and potential incorporation into comets.

Cohesion of Amorphous Silica Spheres: Toward a Better Understanding of Growth of Silicate Dust Aggregates via Coagulation in Protoplanetary Disks and Molecular Clouds

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Adhesion forces between submicrometer-sized silicate grains play a crucial role in the formation of silicate dust agglomerates, rocky planetesimals, and terrestrial planets. The surface energy of silicate dust particles is the key to their adhesion and rolling forces in a theoretical model based on the contact mechanics. Here we revisit the cohesion of amorphous silica spheres by compiling available data on the surface energy for hydrophilic amorphous silica at various circumstances. It turned out that the surface energy for hydrophilic amorphous silica in vacuum is a factor of 10 higher than previously assumed. Therefore, the previous theoretical models underestimated the critical velocity for sticking of amorphous silica spheres as well as the rolling friction forces between them. With the most plausible value of the surface energy for amorphous silica spheres, theoretical models based on the contact mechanics are in harmony with laboratory experiments. Consequently, we conclude that silicate grains with a radius of 0.1 μm could grow to planetesimals via coagulation in a protoplanetary disk. We argue that the coagulation growth of silicate grains in a molecular cloud require organic refractory mantles rather than icy mantles.

Study on absorption feature at 11.2 µm in spectra of young forming stars

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There is a feature at a wavelength around 11.2µm in absorption spectra of many astronomical objects, including forming stars, and the candidate for it is still debated. Possibilities include water ice, silicon carbide, PAHs or crystalline silicates, all of which are known and abundant constituents of cosmic dust. In this paper, we systematically investigate spectra of many young stellar objects – primarily obtained with Michelle and T-ReCs on Gemini-N and Gemini_S respectively – to find if there is a relationship between this feature and the one at 9.7µm, which is caused by amorphous silicates. The problem is approached with two methods, firstly comparing the observed optical depths at the two wavelengths and secondly modeling of a mixture of amorphous and crystalline silicates. In most of the objects, there is a weak correlation between the peak optical depths of the amorphous and possible crystalline silicates; meanwhile, our two-component models fit well with the observations. We conclude it is indeed crystalline silicates which exist in those objects, with an abundance of 2% to 8.5%, compared to that of amorphous silicate. Unless there is some remnant crystallinity of silicate dust in the interstellar medium, at odds with published upper limits, our observations suggest that the crystallization phase of silicate dust may occur much earlier than currently thought.

Dust temperature fluctuations and surface chemistry : H_2 formation

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Among dust grains, very small grains and PAHs are known to be of dominating importance for various physical processes, such as the photoelectric heating of the gas. The dust size distribution in the interstellar medium is believed to be so that despite big grains making up most of the dust mass, the smallest grains dominate the total available dust surface. Small grains are thus also the principal substrate for surface reactions, the most important of which is the formation of H_2.

Due to the small heat capacity of small grains, individual UV photons cause large spikes of their temperature. Such fluctuations have been studied in details for the purpose of modeling dust emission in the NIR. Yet surface chemistry models almost always assume a non-fluctuating grain temperature. While this assumption is reasonable for the complex surface chemistry occurring in dark cloud cores, it is much less justified for the formation of H_2 in UV-rich environments such as diffuse gas or bright PDRs.

Various mechanisms can contribute to H_2 formation. The Langmuir-Hinshelwood mechanism involves physisorbed atoms migrating on the surface, and was experimentally found to have a limited temperature range of efficiency (typically 10-20K), while ISO and Spitzer observations of PDRs found efficient formation despite warmer dust. Other mechanisms were proposed such as the Eley-Rideal mechanism, involving direct reaction between a chemisorbed atom and a gas atom, and insensitive to grain temperature.

We present here the first complete analytical treatment of the statistical problem of surface chemistry with fluctuating temperatures, using a master equation approach to follow exactly both the temperature and the population of adsorbed atoms. We apply this treatment to the Langmuir-Hinshelwood mechanism and find it to be much more efficient than expected in unshielded environments under moderate UV fields, as the grain average temperature is actually not representative of the cold state in which the grain spends most of its time between the short spikes. Another mechanism is still necessary to account for formation under strong UV fields, and the Eley-Rideal mechanism is found to retain most of its efficiency when temperature fluctuations are taken into account. Fast approximations of the exact results are also constructed. This method could be generalized to other surface reactions.

The effects of this new formalism on full cloud simulations are explored using the Meudon PDR code. Effects are found in tracers of the cloud edge (H_2, CH^+) but remain limited as the improved Langmuir-Hinshelwood formation is partly masked by the already efficient Eley-Rideal formation. The increase in Langmuir-Hinshelwood efficiency nevertheless allows more flexibility in the choice of the poorly known microphysical parameters of the Eley-Rideal mechanism, as will be demonstrated using the constraints of the observations of a few well known PDRs.

Spatial Distribution of Ices in a High-mass Star-forming Region

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Infrared absorption spectroscopy toward molecular clouds suggests that the bulk of heavy elements exist in the solid-phase as ice mantle. Chemical reactions in the solid-phase differ from gas-phase reactions in various aspects and they play an essential role in the chemical evolution of star-/planet-forming regions. Understanding the effect of star-formation activities on properties of ices is one of the key issues for ice chemistry. For this purpose, spectroscopic mapping observations provide us important information on processing of ice mantles in star-forming regions. However, almost previous observations of ices are limited to single line-of-sight spectroscopy, and so-called “ice mapping” observations are currently very few. Thus we have to say that our knowledge about spatial distribution of ices in star-forming regions is still poor.

Cepheus A East, one of the closest high-mass star-forming regions to the sun (~650 pc), is a prime target of this study. Previous infrared observations by ISO reported a wealth of ice absorption bands toward this region, suggesting its chemically-rich nature. In this study, we performed near-infrared (2 - 5 micron) imaging and spectroscopic observations toward Cepheus A East with the spatial resolution much higher than ISO by using AKARI/IRC, IRTF/SpeX and Subaru/IRCS. We detected absorption bands of major ice species (H_2O, CO_2, CO) as well as P- and R-branch lines of gas-phase CO toward various regions in Cephes A East. This enabled us to map the spatial distribution of ice mantles and spatial variation of ice chemical compositions around high-mass protostellar objects. In this presentation, we discuss the effect of radiation and outflows from protostellar objects on the chemical and physical properties of circumstellar ices based on the infrared spectroscopic data.

Dust emission and scattering in dense interstellar clouds

Mika Juvela

University of Helsinki, Department of Physics, Finland

I will discuss ongoing studies where near-infrared, mid-infrared, and submillimetre observations are used to investigate dust properties in dense interstellar clouds and cloud cores. The work is done partly within the framework of the Planck-Herschel programme Galactic Cold Cores. The increase of submillimetre dust opacity and the detection of mid-infrared scattered light are both seen as evidence of dust evolution. I will present some observational results and work done in modelling the data.

C_{60} as a probe for astrophysical environments

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After having been searched for three decades in the ISM, fullerene detection in a planetary nebula was reported in 2010 (Cami et al. 2010) and, later on, fullerenes have been found in a variety of space environments (Roberts et al. 2012). From the very first report and in successive publications, the C_{60} molecule has been used by astronomers to probe the conditions of astrophysical environments.

The use of fullerenes as a probe for astrophysical environments is possible because the observed emission in the mid-infrared ultimately depends on the intrinsic strength of the vibrational bands and the excitation mechanism of the fullerenes. The accuracy of the estimations therefore relies on the laboratory spectroscopic data of the fullerenes. In particular, when the excitation has a thermal origin, the intrinsic strength of the bands obtained in the laboratory is used to estimate the temperature of the molecules in the ISM (Cami et al. 2010; Bernard-Salas et al. 2012; Garcia-Hernandez 2012). Unfortunately, the data on the relative strengths of the main IR-bands of C_{60} published so far is limited, and shows a considerable amount of disagreement (Bernard-Salas et al. 2012). In fact, we have observed in the laboratory a high variability of the mid-IR features in solid C_{60} films, which can be due to a size effect of the solid particles and other reasons such as the interaction between the fullerene and the substrate or the presence of amorphous carbon produced during the thermal deposition of the fullerene films.

We have developed a technique to produce fullerene films, which delivers highly reproducible spectroscopic data suitable for astrophysical application. We have considered in our studies the effects of temperature and interaction with the substrate and other carbonaceous particles. We discuss the impact of the application of our data to probe the excitation mechanism in astrophysical environments.

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Intensity Variations of the 3.3 μm Complex Feature in AKARI Data with Galactic Environment

Mark Hammonds, Tamami Mori, Fumihiko Usui, Takashi Onaka

University of Tokyo, Japan

The study of carbon in our galaxy is an important pursuit in astronomy, remaining relevant to a number of astronomical fields, including the study of interstellar dust, spectroscopic puzzles such as the diffuse interstellar bands, and newer fields such as astrobiology. A considerable fraction of carbon in the galaxy is expected to exist as polycyclic aromatic hydrocarbon (PAH) molecules, emphasizing the importance of studying these and other hydrocarbons to further our understanding.

In particular, the many sub-features of the 3.3 μm complex are highly specific to the type of emitting molecule, making the respective intensities of these emission bands of great use in determining the variety of PAHs being observed. The work presented here incorporates and corroborates the recent proposal that the main emission band at 3.3 μm is caused by two underlying sub-features at 3.28 μm and 3.3 μm, arising from different chemical environments within the carrier molecules. We include these two features in modeling work performed on high resolution AKARI NIR data and find a good fit with the observational data.

The ratios of intensities between sub-features of the 3.3 μm complex are discussed in terms of the morphology and stability of the molecular carriers. Implications regarding PAH growth and destruction mechanisms are addressed with respect to galactic environment. Spatial variations in emission band intensity ratios within specific astronomical objects such as HII regions and supernova remnants are also discussed.

Implications of detailed modeling of surface chemistry in PDR codes on the processes in the Interstellar Medium

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It is well recognized that chemical reactions on dust grains are central processes to understand the molecular composition of interstellar gas. Several experiments in laboratory have been set up to study such processes. The first experiments have been dedicated to H2 formation. They allowed to understand the detail of mechanisms on grains surfaces, to determine reactions energy thresholds as well as excitation states of newly formed H2. New experiments focus on complex species as the ones associated to oxygen chemistry providing invaluable data for the modeling of interstellar chemistry. These works are motivated by new detections of molecules done thanks to a new generation of instruments (Herschel, ALMA, APEX, IRAM/Noema). Many recent observations of molecules in star forming regions, dark clouds and diffuse clouds, in our local environment but also in the Galactic Center and in distant galaxies are directly or indirectly related to surface chemistry. The interpretation of these new observations require that results obtained in laboratory experiments be implemented in state-of-the-art numerical models of interstellar clouds.

Among the state-of-the-art codes modeling interstellar chemistry, the Meudon PDR Code (pdr.obspm.fr) is a public 1D code that computes consistently 1) radiative transfer from far UV to sub-mm taking into account absorption and emission of photons by grains and in atomic and molecular lines, 2) individual heating and cooling mechanisms for non LTE systems, 3) chemistry of hundred chemical species related by thousands reactions. Recently, we implemented in this code the detailed mechanisms on grains surfaces based on the new laboratory experiments results. We introduced the formation of H2 in physisorption and chemisorption sites following Eley-Rideal and Langmuir-Hinshelwood mechanisms. We also introduced oxygen surface reactions network taking into account adsorption, formation of mantles, and desorption: thermal, driven by photons and cosmic rays, as well as chemi-desorption.

In this talk, we will show that, the importance to use a proper grain size distribution to reproduce well known properties of diffuse clouds as H2 excitation observed by FUSE in the far UV. We will also show that modeling precisely the chemical processes on grains surfaces in a comprehensive code as the Meudon PDR Code allow to answer to some of the key questions in the field of the interstellar medium. We will show how detailed treatment of H2 formation on grains reconcile numerical models and H2 emission observed in PDRs by ISO and Spitzer. We will show that when recent laboratory / theoretical results on H2 formation on grains are implemented in comprehensive numerical models solving both surface chemistry and radiative transfer, H2 formation on grains can become a major heating mechanism that competes with photoelectric effect and may explain the high CO excitation observed in some PDRs by Herschel. We will also show the importance to treat in detail the coupling of radiative transfer and surface chemistry to understand how molecules as methanol and formaldehyde formed on grains are released from mantles to the gas phase thanks to different mechanisms depending on the position in clouds. We will illustrate this by comparisons of our models to recent Herschel and IRAM observations in PDRs as NGC 7023 and the Orion Bar as well as the Horse Head.

A Bottom-up Computional Modelling Approach to the Formation and Properties Silicate Dust

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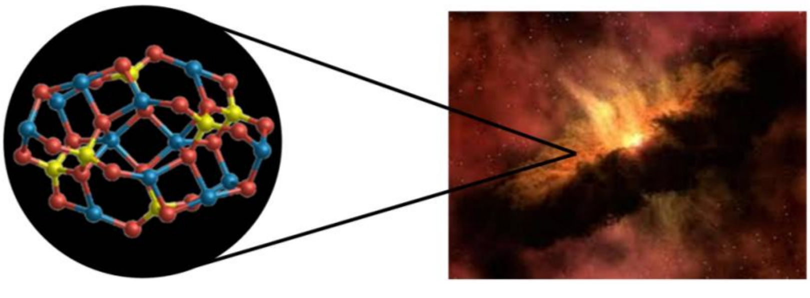
While dust takes up only one mass percent of the total matter in the interstellar medium (ISM), it plays a crucial role in its chemical evolution by catalyzing molecule formation and, through scattering the strong interstellar radiation, preventing molecular photodissociation in denser regions. Via a combination of lab characterization of pristine material, astronomical observations, the general properties of dust particles in various environments have been reasonably well discerned. Fitting the observed spectra with a combination of lab spectra of materials of different crystallinity, shape, size and composition gives valuable insight into the possible identity of dust particles in space.

We present a complementary approach to understanding the formation, structure and properties of small dust grains based on a bottom-up (i.e. starting from the atomistic and electronic level) computational modelling. Crucially, our approach is independent of assumptions based on bulk materials properties (as is the case for classical nucleation theory), is not limited to particular chemistry or specific thermodynamic conditions, and provides a solid basis for subsequent kinetic modelling for longer timescales associated with larger dust particle species.

Specifically we outline our approach for the example cases of (i) the initial stages silicate dust formation based on combining SiO, Mg, H_2O (and TiO_2) monomeric species [1,2], and the reactivity of ultra small dust grains (nanosilicates) with respect to H_2 formation and dissociation [3] and their role as ice condensation nuclei [4]. The thermal stability and IR vibrational spectra of nanosilicate dust precursors is also examined using the same modelling methods.



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Interstellar Polarization in the Optical/NIR/sub-mm: A Tool for Studying the ISM Magnetic Field Structure (and more…)

Antonio Mario Magalhães, Antonia J. F. B. Barbosa, Tibério Ferrari, Jessica F. Oliveira, Edgar Ramirez, Nadili L. Ribeiro, Marcelo S. Rubinho, and Daiane B. Seriacopi

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We will show some recent results of optical/NIR/sub-mm polarization data towards several interstellar environments. This polarization is produced by dust grains aligned by a magnetic field and can be used as a tracer of the latter. We discuss results of our ISM Survey data and its unveiling of the magnetic field structure in the Galaxy at small and large scales and at high Galactic latitudes. We also explore the relationship between the magnetic field in the local Interstellar Medium (ISM) and the heliosphere. We discuss the nature of the SMC dust and its magnetic field structure. We then look into intriguing data concerning the relationship between the ambient magnetic field direction and that of disks around young stars in the Galaxy. Finally, we describe SOUTH POL, a forthcoming survey of the Southern sky in optical polarized light with a robotic telescope. SOUTH POL will impact several areas, from Cosmology to Solar System studies.

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All-sky dust modelling with Planck, IRAS and WISE observations

G. Aniano, B. T. Draine, M.-A. Miville-Deschenes, F. Boulanger, Planck collaboration

We present an all-sky dust modeling of the high resolution , *IRAS* and *WISE* infrared observations using the physical dust model presented by Draine & Li (DL07). We study its performance in modeling the observational data, and present implications for future dust modelling. The present work extends to the full sky the dust modelling done on nearby galaxies with *Herschel* and *Spitzer* data.

We employ the DL07 dust model to generate maps of the dust mass surface density Σ_{M_d}, the dust optical extinction A_V, the polycyclic aromatic hydrocarbon (PAH) molecules mass fraction q_PAH, and the starlight intensity heating the bulk of the dust, parametrized by U_min. We test the model by comparing these maps with independent estimates.

The DL07 model reproduces the observed spectral energy distribution (SED) satisfactorily in most of the sky, with small deviations in the inner Galactic disk, and in low Ecliptic latitude areas, presumably due to zodiacal light contamination. In the Andromeda galaxy (M31), the present dust mass estimates agree remarkably well (within 10 %) with DL07 estimates based on independent *Spitzer* and *Herschel* data. The DL07 A_V estimates agree with those generated by Planck Collaboration XI using a modified black body approach, although DL07 suffers from a global normalization discrepancy. In molecular clouds, we compare the DL07 A_V estimates with maps generated from stellar optical observations from the 2MASS survey. The DL07 A_V estimates are a factor ~ 3 larger than values estimated from 2MASS observations. In the diffuse interstellar medium (ISM), we compare the DL07 optical extinction A_V estimates with optical estimates from $\sim 2 \times 10^5$ quasi stellar objects (QSOs) observed in the Sloan digital sky survey. The DL07 A_V estimates are larger than those estimated from the QSOs, and this discrepancy depends strongly on U_min. The shape of the optical extinction curve appears to be independent of U_min.

We investigate the dependence of the A_V mismatch as a function of the DL07 fitted parameters. We propose an empirical renormalization of the DL07 A_V estimate, dependent of U_min, that compensates for the systematic differences found here. The renormalization, bringing into agreement the A_V estimates on QSOs, also brings into agreement the A_V estimates on molecular clouds. In the diffuse ISM, the DL07 fitting parameter U_min, effectively determined by the wavelength where the SED peaks, appears to trace variations in the FIR opacity of the dust grains. We find strong evidence for dust evolution.

We provide a family of SEDs per unit optical reddening, parameterized by U_min; these will be the constraints for a next generation of dust models. In order to generate the first all-sky q_PAH maps, we had reprocessed the full WISE 12 μm dataset, removing artifacts caused by the Moon, solar system objects and other artifacts. We publicly release the corresponding artifact -free WISE maps.

Interstellar dust in the solar system: The Ulysses perspective

Veerle Sterken[1], Peter Strub[2], Harald Krüger[2], Rudolf von Steiger[1], Eberhard Grün[3,4]

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Trajectories of Interstellar dust (ISD) passing through the solar system and originating from the local interstellar cloud were studied in detail in the late 1970s. These trajectories mainly influenced by solar radiation pressure force, gravity and the magnetic field in the heliosphere and in its boundary regions. In 1992, interstellar dust was measured for the first time directly by in-situ measurements with the dust detector onboard Ulysses. The Ulysses data from 1992 until 2002 were analyzed by Landgraf et al. and the observed ISD flux was compared to the ISD flux in numerical simulations. From this, a rough estimate of the maximum β-value (the ratio of solar radiation pressure force to gravity for a specific particle) for the ISD was determined and one could constrain the particle properties by comparing simulations to observational data. Remarkable were the observations of 'big' interstellar dust particles with a mass of 10^{-15}-10^{-14} kg which are not compatible with astronomical observations of the wavelength-dependence of the extinction of starlight and the total dust mass as derived from cosmic abundances and measurements in the gas phase.

Since then Ulysses continued to measure interstellar dust until 2007 when the operation of the dust instrument was terminated. Krüger et al. reported a temporary shift in the flow direction of the dust in 2005. In 2012, Sterken et al. described the general flow and filtering characteristics of ISD in the solar system and took preparations for further analysis of - and comparison of simulations with - the Ulysses data [Sterken et al. 2014, in prep.]. Meanwhile, Strub and Krüger re-analyzed the whole dataset until the end of the Ulysses mission: from February 1992 until November 2007 [Strub et al. and Krüger et al., 2014, in prep.].

In this talk we briefly give an overview of the recent research on ISD in the solar system. We then focus on what we can learn from ISD trajectory simulations at Ulysses orbit and we propose possible solutions for understanding the observations and in specific the shift of dust that occurred in 2005 and the big masses as observed by Ulysses. We report on the current status of on-going projects and the steps needed to a thorough understanding of the ISD data by Ulysses.

Mid-Infrared Extinction and Far Infrared Emission: Evidence for a Population of Large, Micrometer-Sized Dust in the Interstellar Medium

Aigen Li, Shu Wang and Biwei Jiang
(University of Missouri, Beijing Normal University)

Interstellar grains span a wide range of sizes from a few angstroms to a few micrometers. The ultraviolet/optical extinction constrains the dust in the size range of a couple hundredth micrometers to several sub-micrometers. The near- and mid-infrared emission including the IRAS and COBE-DIRBE broadband photometry and the PAH emission spectroscopy constrains the nanometer-sized grains and angstrom-sized large molecules. However, the quantity and the size distribution of the micrometer-sized dust remain unknown as it is gray in the ultraviolet/optical extinction and it is too cold to be detected by IRAS or Spitzer/MIPS. In this talk we argue that the ~3-8 micrometer mid-infrared extinction which is flat in various regions including the Galactic plane, the Galactic center and the Large Magellanic Cloud is a powerful tool for constraining the quantity, size, and composition of the micrometer-sized dust component. The cold thermal emission from this dust component will also be discussed and compared with Herschel observations.

Probing the Role of Carbon in the Interstellar Ultraviolet Extinction

Ajay Mishra and Aigen Li (University of Missouri)

We model the ultraviolet/optical extinction curves between 0.3 to 8 μm^{-1} of 16 Galactic sight lines which exhibit variable strengths and widths of the 2175Å bump, in terms of standard silicate/graphite interstellar grain model. We find that the C abundance required to be locked up in dust correlates with the strength of the 2175Å bump, while the abundance of Si depleted in dust shows no correlation with the 2175Å bump. This supports graphite or PAHs as the possible carrier of the 2175Å bump. We also see a weak correlation between the C depletion and $1/R_V$ suggesting the far-UV extinction is more likely produced by small carbon dust.

Lifecycle of dust grains in the interstellar medium

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While processing of dust grains in the interstellar medium (ISM) has been investigated theoretically, it has not been studied observationally until the advent of the recent infrared satellite missions, *Spitzer*, *Herschel*, and *AKARI*. Several studies with these satellites suggest that a large fraction of dust grains are formed in dense ISM regions rather than stellar sources and they are subsequently processed and altered to a more invulnerable form in the ISM in a galactic scale. In particular, observations of aromatic emission features, which are generally attributed to polycyclic aromatic hydrocarbons or related materials, clearly indicate the variations in the size distribution and the properties of dust grains with different physical environments for the first time. Recent theoretical and observational studies suggest that fragmentation or shattering is a more efficient process than evaporation as interstellar processing, which changes the size distribution of dust grains. In this review, the latest observations of dust processing in the ISM with recent infrared satellites are reviewed together with theoretical implications.

Dust dynamics in the interstellar medium

Tom Hendrix[1] and Rony Keppens[1]

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Dust particles have a large (and often unknown) variety of sizes and compositions, therefore including the effect of dust in the analysis of the dynamics of dust containing systems causes a significant increase in the complexity of numerical and analytical analysis. This often results in assuming either strong coupling between dust and gas fluids or a single dust grain size in the calculations. In this way, the importance of the size distribution and different compositions of dust grain is ignored. Including these in full dynamical simulations is an important step for understanding the effect of dust on the dynamics of astrophysical fluids on the one hand, and on the other hand is of importance in confronting simulations with observations of dust emission.

To study the effect of dust on the dynamics of astrophysical fluids, we use the multi-fluid gas+dust MPI-AMRVAC[1] code, which allows including a dynamical size distribution and different dust compositions. This is done by allowing for multiple dust fluids in a single simulation, each having different dust grain properties. We will elaborate on how dust tends to alter the formation of one of the most frequently encountered instabilities in astrophysical fluid dynamics, the Kelvin-Helmholtz instability (KHI). From both 2D and 3D simulations we infer how these instabilities can increase the local dust density by several orders of magnitude[2]. Also, a clear dependency on dust sizes is seen, with larger dust particles displaying significantly more clumping than smaller ones. We connect our finding of the dusty KHI to observations of molecular clouds and see how the KHI may explain some of the features in these observations. To do so, we have coupled the output of the MPI-AMRVAC code with the SKIRT radiative transfer code[3] which allows us to compare observations and simulations directly.

Ultimately we take the lessons learned from studying dusty instabilities and apply these to the dynamics of dust formation in binary Wolf-Rayet star systems, where colliding wind interactions give rise to dusty spiral patterns observed at infrared wavelengths.

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Dust production in a variety of types of supernovae

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Dust production by supernovae is one of the most important subjects for understanding the origin and evolution of dust in galaxies. In particular, core-collapse supernovae generating from short-lived massive stars are considered to be dominant sources of interstellar dust in the early universe. Therefore, many studies have been devoted to this topic for the last decade to disclose the enrichment history of dust grains from the early epochs through the present times of the universe.

In this talk, I address the current understandings of the composition, size, and mass of dust formed in supernovae, from both theoretical and observational points of view. I show that the formation site and properties of dust are likely to be different, depending on the types of supernovae. For normal core-collapse supernovae, dust grains condense in the inner metal-rich ejecta, where a sub-solar mass of dust can be produced, as was revealed by the observations with *Herschel* and *ALMA*. Theoretical studies predict that the typical size of dust formed in the ejecta is affected by the mass of the outer envelopes; relatively large grains form in Type II-P supernovae with massive hydrogen envelopes, whereas small grains form in envelope-stripped ones such as Type IIb and Ib supernovae. The other site of dust formation in supernovae is the cool dense shell resulting from the interaction between the ejecta and the circumstellar medium. In this case, the mass and size of newly formed dust are not known very well, but the condensation of dust in the cool dense shell is believed to happen for Type IIn supernovae that are surrounded by massive circumstellar gas at the explosions. I will present the observational evidence for dust formation in such dense shells. I will also discuss the dust formation in Type Ia supernovae arising from thermonuclear explosion of white dwarfs.

A study of iron and dust in the supernova remnant IC443

Takuma Kokusho[1], Takahiro Nagayama[2], Hidehiro Kaneda[1], Daisuke Ishihara[1], Ho-Gyu Lee[3], and Takashi Onaka[4]

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IC443 is a Galactic supernova remnant (SNR) , where shocks strongly interact with the surrounding interstellar medium. In general, the gas components of the elements that are depleted onto dust grains are not able to be detected in their line emission. In SNR shock regions, however, they are released to the interstellar space through dust destruction by shocks, and can be observed with their line emission. Therefore IC443 is an excellent laboratory to study chemical compositions of dust.

We observed IC443 with the IRSF/SIRIUS, a near-infrared camera on the 1.4-m telescope, using the narrow-band filters tuned for the [Fe II] 1.257 and 1.644 μm, Paβ, and H_2 1-0 S(1) lines. As a result, we find that the [Fe II] and Paβ line emissions show filamentary structures all over the observed region (30’ x 35’). In contrast, the H_2 line emission is detected mainly in the southern region. We also derived the distributions of dust and highly-ionized iron in IC443 with AKARI and Suzaku, respectively. We reveal that the dust in IC443 is distributed in shell-like structures, while the highly-ionized iron concentrates in the central region.

Using the above results, we investigate the chemical composition of dust, focusing on the distribution of iron in shocked regions. We compare our observational results with model calculations to verify our hypothesis.

The dusty torus of the AGN unified model

Rachel Mason[1]

[1]*Gemini Observatory*

The small-scale (< few tens of pc) characteristics of active galaxies form an important part of our picture of the growth of black holes and their effects on their host galaxies. One of the major small-scale components of an AGN is the dusty torus of the AGN unified model, and understanding the characteristics and behavior of dust in the torus is therefore a key part of understanding AGN as a whole. In this talk I will review current ideas about the torus: its possible roles in both inflow to and outflow from the nucleus; its chemical makeup; and evidence for dust destruction and formation that demonstrates the dynamical, changing nature of this structure.

AKARI observations of interstellar ices in nearby galaxies: variations in CO_2/H_2O ice abundance ratios

Mitsuyoshi Yamagishi[1], Hidehiro Kaneda[1], Shinki Oyabu[1], Daisuke Ishihara[1], Takashi Onaka[2], Takashi Shimonishi[3], and Toyoaki Suzuki[4]

[1]*Nagoya University, Japan,* [2]*The University of Tokyo, Japan,* [3]*Kobe University, Japan,* [4]*SRON, the Netherlands*

Near- and mid-infrared wavelength ranges include absorption features due to interstellar ices (e.g., H_2O ice at 3.05 μm and CO_2 ice at 4.27 μm) which are important probes of the interstellar environment. Among them, CO_2 ice is the most important one because CO_2 ice is thought to be a secondary product unlike H_2O ice which is primarily formed on dust grains. Therefore, a CO_2/H_2O ice abundance ratio effectively reflects the ice-forming interstellar environment. In the ice study, CO_2/H_2O ratios in our Galaxy and the Magellanic Clouds have been intensively observed to date, which show large variations from object to object. The cause of the large variations is, however, still under debate.

In this presentation, we report CO_2/H_2O ratios in nearby galaxies based on the AKARI near-infrared (2.5–5.0 μm) spectra for 1031 regions in 158 galaxies. The CO_2/H_2O ratios in our sample are in a range of 0.05–0.30. We find a positive correlation between the CO_2/H_2O ratios and the Brα/PAH 3.3 μm ratios, indicating that hard UV radiation due to massive stars is important to enhance the CO_2/H_2O ratios. Furthermore, we find a positive correlation between the CO_2/H_2O ratios and the specific star formation rates of the galaxies, suggesting that the evolutionary stage of a galaxy is also an important factor to determine the CO_2/H_2O ratio of a galaxy. Based on the results, we discuss implications of the variations in CO_2/H_2O ice abundance ratios for the ice-forming interstellar environment and the galaxy evolution.

Probing the impact of metallicity on the dust properties in galaxies

Aurélie Rémy-Ruyer[1,2], Suzanne Madden[1], Frédéric Galliano[1], Vianney Lebouteiller[1], Anthony Jones[2]

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As galaxies evolve, their Interstellar Medium (ISM) becomes continually enriched with metals, and this metal enrichment influences the subsequent star formation. Low-metallicity dwarf galaxies of the local Universe are ideal candidates to study the influence of this metal enrichment on the ISM properties of galaxies. Previous studies have shown that the ISM of dwarfs galaxies poses a number of interesting puzzles in terms of the abundance of dust grains, the dust composition and even the far-infrared (FIR) emission processes. Before the advent of Herschel, these studies were limited to the warmer dust emitting at wavelengths shorter than 200 microns and were done only on a small number of dwarf galaxies. Thanks to its increased sensitivity and resolution in FIR and submillimeter (submm) wavelengths, Herschel gives us a new view on the cold dust properties in galaxies and enables us to study the lowest metallicity galaxies in a systematic way.

To study the influence of metal enrichment on the ISM properties, we use two Herschel surveys spanning a wide variety of galactic properties in terms of metallicity, but also morphological type, stellar mass, star formation activity, etc. After discussing the motivations for my work, I will present these two samples. After collecting data over the full IR-to-submm wavelength range, realistic dust models are applied to analyse the dust properties (in terms of temperature, mass, luminosity and star formation activity) and their evolution with metallicity. Our study reveal different dust properties in low-metallicity environments compared to those observed in more metal-richs systems (e.g., an overall warmer dust component). An excess submm emission is often apparent near and/or beyond 500 microns rendering large uncertainties in the dust properties, even for something as fundamental as dust masses. We will thus discuss the appearance of this submm excess in our sample and test alternative dust composition, with more emissive grains, to explain this excess emission. Ideal tracer of the chemical evolutionary stage of a galaxy, the gas-to-dust mass ratios (G/D) is found to be much higher than what is expected by simple chemical evolution models. We will thus focus on the relation between G/D and metallicity and interpret it with the aid of different chemical evolution models to explain this unexpected trend. Finally perspectives to this work will be discussed.

Spatially Resolved Dust Properties in the Magellanic Clouds

Frédéric Galliano[1]

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Interstellar dust properties depend on the environmental conditions they are exposed to, and on the star formation and subsequent elemental enrichment history of the galaxy. However, the individual processes controlling these dust properties are not known accurately enough to predict their variations between regions. Fortunately, we can draw observational relations between the main grain parameters (abundance, size distribution, chemical composition, etc.) and the parameters quantifying the physical conditions of the environment (density, temperature, metallicity, etc.). These observed relations are crucial to constrain dust evolution models.

The Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC) are ideal laboratories to perform this type of study. Indeed, they are nearby (50–60 kpc), and have been mapped in details with *Spitzer* and *Herschel*, as part of the SAGE/HERITAGE programs (P.I. Meixner). Moreover, they present a larger range of variations of the physical conditions than inside the Milky Way. In particular, their sub-solar metallicity (1/2 $Z_\odot$ for the LMC, and 1/6 $\mathrm{Z}_\odot$ for the SMC) allows us to explore the effect of elemental enrichment. In addition, they exhibit several regions of massive star formation that can be used to understand the impact of hard radiation fields on the grains.

In this talk, I will summarize the results of several studies of the *Spitzer* and *Herschel* observations of the Magellanic clouds. I will discuss the unveiled peculiarities of the dust properties in these environments, concerning their chemical composition, the PAH properties, and the enigmatic submillimeter excess. I will also discuss about the methodology of spectral energy distribution (SED) modelling, demonstrating the effectiveness of hierarchical bayesian approaches.

PAH destruction and formation processes in HII complexes

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This work is devoted to evolution of polycyclic aromatic hydrocarbons (PAHs) and carbonaceous grains in HII complexes. Observations indicate that strength of PAH emission correlates with metallicity and hardness of the interstellar radiation field (ISRF) in HII complexes and also varies from young to old objects. The goal of the work is to trace an evolution of the PAH abundance and emission in HII complexes at different values of metallicity, the ISRF intensity and hardness and to determine the most relevant processes responsible for variations in PAH parameters. We consider the most significant processes, namely, – photodestruction of PAHs, aromatisation of carbonaceous grains, destruction by the most abundant ions (H, He, C) and electrons, fragmentation due to collisions between grains.

The major role is played by a destruction of PAHs by an intense ultraviolet ISRF inherent to HII complexes. A bombardment of PAH surface by photons leads to a gradual destruction of PAHs through a dissociation of hydrogen atoms and acetylene groups. The efficiency of the dissociation depends on properties of ISRF and sizes of PAHs and can be estimated for typical parameters of HII complexes. Small PAHs (up to 50 carbon atoms in a skeleton) are completely destroyed in HII complexes with typical ultraviolet component of ISRF while larger molecules survive.

Along with the PAH destruction process of PAHs by strong UV field, they can also be produced due to transformation of carbonaceous grains from an aliphatic structure to an aromatic one (in other words, their aromatisation) under the influence of ultraviolet photons. Small grains (~ 10Å) may be fully restructured at an evolutionary time scale of an HII complex, and, thus, number of PAHs increases. Aromatisation of larger grains within a few millions years can only be significant in their outer layers, but a spectrum of a large grain with an aliphatic core and aromatic envelope will have aromatic features in the IR range as well.

Shock waves related to the expansion of HII regions inside a complex can accelerate ions up to relatively high velocities (> 50 km/s). Collisions between a PAH molecule and energetic ions may result in a destruction of a PAH molecule through a direct ejection of a carbon atom from a skeleton at a nuclear interaction or dissociation of a C_2 fragment at an electronic interaction. Also collisions of PAHs with fast electrons can be crucial at high temperatures. At temperatures higher than 10^4 K this process begins to play a role and becomes the most important when massive stars explode.

Apart from processes of grain interaction with energetic photons, ions and electrons, larger impacts, grain-grain collisions, can occur in interstellar medium and in HII complexes as well. Depending on a strength of a shock wave and grain velocities these collisions may lead to redistribution of grain sizes. Specially, number of small grains including PAHs can grow at the expense of shattering of large carbonaceous grains.

All these processes are put together to model the evolution of PAHs/small grains at different physical parameters of HII complexes. Kinematical velocities of grains and ions are determined using gas-dust dynamic model. Theoretical magnitudes in infrared bands corresponding to Spitzer and Herschel detectors are calculated and compared with observations of extragalactic HII complexes.

Simulating the life cycle of dust in star-forming galaxies

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Previous numerical simulations of galaxy formation and evolution did not incorporate self-consistently dust growth and destruction in ISM of galaxies at all. I show some results of my original simulations of galaxy formation and evolution which include, for the first time, dust growth and destruction in ISM, formation of molecular hydrogen on dust grains, and star formation in molecular hydrogen. I mainly discuss spatial and temporal variations of interstellar dust (e.g., dust-to-gas-ratios and dust depletion levels) and other galaxy properties in a self-consistent manner. The preliminary results are as follows. The star formation histories of disk galaxies are regulated by dust, mainly because the formation efficiency of molecular hydrogen is controlled by dust. The observed correlation between dust-to-gas-ratio and gas-phase oxygen abundance can be reproduced by the present simulations, though strong supernova feedback effects and density-dependent dust accretion model need to be adopted. The simulated disk galaxies can have extended dusty gaseous halo (>20 kpc) and the mass fraction of such dusty halo is significant (up to 50%). The galaxies show negative radial gradients (i.e., larger in inner regions) of dust-to-gas-ratio and molecular gas fraction. The surface mass densities of dust in disk galaxies are correlated more strongly with the total gas densities than with molecular hydrogen densities. More massive disk galaxies are more likely to show higher dust-to-gas ratios and higher molecular hydrogen fraction. Galaxy merging between disk galaxies can significantly reduce the dust mass fraction owing to consumption of dust in active star formation during merging. I briefly discuss how galaxy-scale star formation and chemo-dynamical evolution of forming galaxies depends on modeling of interstellar dust.

ABSTRACT

Dust and other phases of ISM in early-type galaxies

S K Pandey & S Kulkarni
Pt Ravishankar Shukla University, Raipur, India

We have an ongoing research program on detailed investigations of dust properties in extragalactic environment with focus on nearby dusty early-type galaxies. Here we report the results based on CCD broad band as well as narrow band optical observations on a sample of dusty E/SO galaxies carried out at Indian observatories. Prime objective was to investigate properties of dust and ionized gas in the sample galaxies. The archival data at X-ray and FIR wavelengths were also used to further examine relationship between dust, ionized gas as well as hot gas present in them. Dust extinction studies were used to obtain extinction curves and compare them with that of the Milky Way. It turns out that the extinction curves run parallel to that of the Milky Way implying that properties of dust in nearby galaxies are similar to our galaxy. Further, the ratio of total-to-selective extinction R_V for sample galaxies varies from 2.1 to 3.8 with an average of 2.95 fairly close to the canonical value of 3.1 for the Milky Way. The morphology and extent of ionized gas match with those of dust as well as diffuse X-ray emission maps for several galaxies in our sample, pointing to their possible physical coexistence.

Infrared Spectra of LIME olivine

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[1]*Osaka Sangyo University*, [2]*Osaka University*, [3]*Ritsumeikan University*, [4]*Kyoto Univerisity*

From observational and experimental works, infrared spectra of solid-solution of Mg-Fe olivine were well investigated after Infrared Space Observatory (ISO). Here we will report infrared spectra of Mg-Mn olivine, $(Mg, Mn)_2SiO_4$, for the first time. This type of solid solution is known as "Low Iron Manganese Enriched (LIME) silicate", and has often discovered characteristically in the primitive interplanetary dust particles (IDPs). The formation of LIME olivine also can be explained by the condensation sequence theory. In this work we carried out synthesis of some Mg-Mn olivine solid solutions with various Mn concentrations, and measured the infrared absorption spectra (8 μm $\sim$ 100 μm).

From results, we found that the spectra of the samples have great resemblance to those of Mg-Fe olivine, as a whole. But, it can be distinguished from each other by use of correlation of peak positions between 49 μm and 69 μm features. From the view point of the solar abundance, the abundance of Mn is roughly 1 % of those of Mg and Fe. In general, 1 % is the lowest limit of detection in infrared spectroscopy. But, upcoming high sensitivity space observatory mission with SPICA could detect the LIME olivine and distinguish the difference between Fe and Mn contents.

Probing the different dust grain populations by ejecta curtain modeling

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Abstract

An ejecta curtain is produced as a result of impact cratering of celestial bodies that excavates and ejects their surface and underground material. As seen in laboratory impact experiments, ejecta particles often fly collectively, making an inverted cone like structure. Since ejecta particles are thought to reflect the interior materials and structures of celestial bodies, ejecta and ejecta curtains provide us with valuable information about the interior of the bodies. Following the Deep Impact mission, more and more in-situ data on ejecta curtains are expected to become available in future space missions. To draw valuable information from such insitu measurements, a radiative transfer model of the ejecta curtain plays an important role. This urges us to calibrate the model parameters with experimental results as well as understand the contribution of each model parameter to the predicted intensities of the radiative calculations. In this work, we study the dependences of the scattering phase function and the geometry of an ejecta curtain produced by impact on an airlessbody's surface, on the projected intensity images of the ejecta, as a first step toward a correct interpretation of ejecta observations. In our model, we consider the detector to be 1 km away from the surface of the body irradiated by sunlight at 1AU from the Sun, as a typical case in exploration missions. We assume an ejecta curtain cone with a height of 10m and opening angle 90°. The thickness of the curtain is 0.1m. Using the Monte Carlo multiple scattering method, we have calculated the scattered intensities for three different orientations of the ejecta curtain (Figure 1).

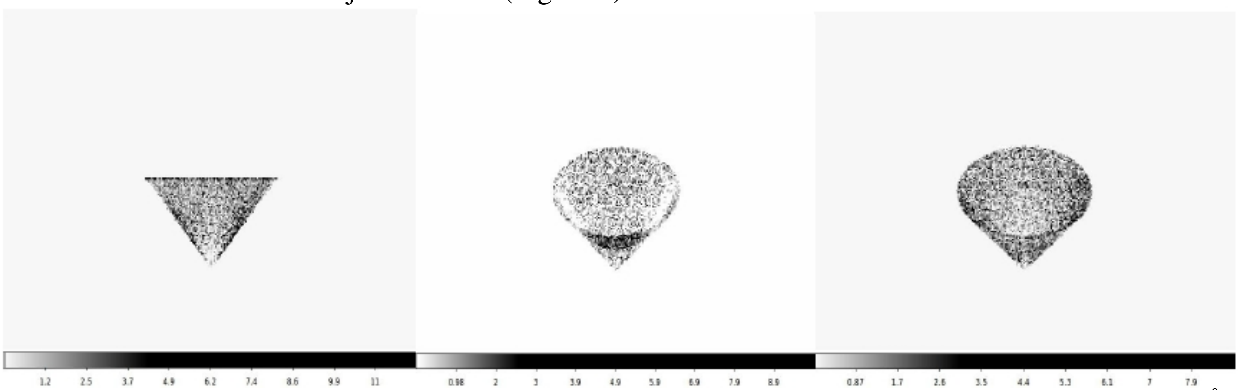

Figure1.Scattered intensities for three different orientations of the ejecta cone in units of 10^{15}photons/cm2/s/sr/Å.

The dependence of the optical depth, τ, of the curtain has been studied by considering the values in the range of $0.1 < \tau < 1000$. The scattering phase function is a very important parameter in our model and is dependent on the grain composition and size distribution. Here we have computed the intensities for ejecta material using three different phase functions (isotropic, Henyey Greenstein phase function and the cometary phase function). We find that the scattered intensities are highest for isotropically scattering grains irrespective of the orientation of the ejecta cone. This could imply that if small isotropically scattering grains are the predominant constituents, we can use our model predictions to deduce the column densities of these small grains from in-situ observations. There is also a significant variation in the intensity for different phase functions or grain sizes with the orientation, which can be used to derive the sizes of the scattering dust grains in the ejecta curtain.

Modeling photopolarimetric characteristics of cosmic dust using rough porous spheroid model

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Abstract

The studies of a cosmic dust in a variety of environments (interstellar, circumstellar interplanetary and cometary dust) indicate that their light scattering properties are dominated by porous, fluffy particles, composed of many small grains coalesced together due to grain-grain collisions, dust-grain interactions and various other processes. Using aggregate dust model, several investigators have successfully modeled extinction properties of interstellar dust and photopolarimetric properties of cometary dust. The main disadvantage of aggregate dust model is that one cannot consider particle size larger than couple of microns due to limitations of computer memory and speed of currently available computers, whereas IR observations and in situ data indicate a significant number of rather large particles in the cometary dust. In this study, we use the software package developed by Dubovik et al. (2006, J. Geophys. Res., 111, D11208) to check whether rough porous spheroid particle could reproduce the optical characteristics of aggregates. We start with a systematic study of light scattering characteristics of a single aggregate and equal-volume spheroid of corresponding porosity. We explored different light scattering properties, viz. scattering efficiency, albedo, color and polarization, of single aggregates using rough spheroid model. Then we consider a mixture of randomly oriented spheroids with 25 bins of the axis ratio from 0.3 (oblate spheroids) to 3.0 (prolate spheroids) and 41 size bins covering the size parameter from 0.012 to 625 ($0.001\mu m \leq r \leq 65\mu m$ for $\lambda = 0.65\mu m$). The pre-calculated kernels in the software package allow fast, accurate, and flexible modeling of different size and shape distributions. The roughness of spheroids is defined by a normal distribution of the surface slopes and its degree depends on the standard deviation of the distribution, which is zero for smooth surface and greater than zero for rough surface. We present our results of a systematic investigation of the angular and spectral dependencies of intensity and polarization obtained with the rough spheroids model and discuss possible application of this model to cometary dust. We have found that the rough spheroid model could reproduce observational results using a mixture of porous spheroids made of absorbing material (compositionally similar to the comet Halley dust) and compact silicate spheroids that is consistent with the findings of the missions to comet Halley and analysis of the Stardust returned samples.

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Bright 22 μm Excess Candidates from WISE Survey

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We present a catalog which includes 141 bright candidates ($\leq$ 10.27 mag, V band) showing the infrared (IR) excess at 22 μm. Of which, 38 stars are known IR excess stars or disk, 23 stars are double or multiple stars and 4 are Be stars. While the remaining more than 70 stars are identified as the 22 μm excess candidates in our work. The criterion of selecting candidates is $K_s - [22]_{\mu m}$. All these candidates are selected from *WISE* All-sky data cross-correlated with *Hipparcos* Main Catalog and the likelihood-ratio technique is employed. Considering the effect of background, we introduce the *IRAS* 100 μm level to exclude the high background. We also estimated the coincidence probability of these sources.

In addition, we presented the optical to mid-infrared SEDs and optical images of all the candidates, and gave the observed optical spectra of 6 stars with NAOC's 2.16-m telescope. To measure for the dust amount around each star, the fractional luminosity is also provided. We also test whether our method of selecting IR excess stars can be used to search for extra-solar planets, we cross-matched our catalog with known IR-excess stars having planets but none is matched. Finally, we give the fraction of stars showing IR-excess for different spectral type of main-sequence stars.

Formation of Fe_3C Ultrafine Grains Covered with Carbon Layer

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To produce ultrafine grains covered with carbon of about 5 nm thick, an Fe wire of 5 mm length was inserted into a small carbon rod, as shown in Fig. 1 in the previous experiment on Si. The carbon hole was heated to 2968 K at a vapor pressure of 1 Torr. The TEM image and diffraction pattern of ultrafine fcc-Fe particles covered with an amorphous carbon layer are shown in Fig. 2. Ultrafine particles of less than 100 nm diameter are produced. The diffraction pattern confirms the fcc Fe particle and amorphous C growth. The surfaces of Fe particles are covered with the carbon layer. As indicated in Fig. 2(a), ultrafine fcc particles of less than 100 nm diameter were composed of 12 planes including {100} and {111} planes, as is the case for all metallic particles.

A typical image and diffraction pattern of Fe_3C are shown in Fig.3. The diffraction pattern indicates the formation of cementite (a=0.50896 nm, b=0.67433 nm, c=0.45248 nm) as reported on Metallurgy and Metallurgical Engineering series (353-365) and International Series of monographys on Metal physics and Physical Metallugge (919-923).. Since the heating temperature for forming particles shown in Fig. 2 is 950^{o}C by reported carbon atom in Fe particle of fcc structure. Since the (111) plane has the fcc packing structure, C atoms are introduced into Fe_3C, which contains 4 molecules in a unit cell. Therefore, the surface amorphous carbon layer is maintained.

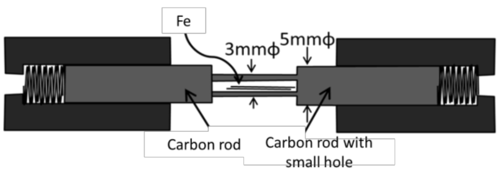

Fig. 1

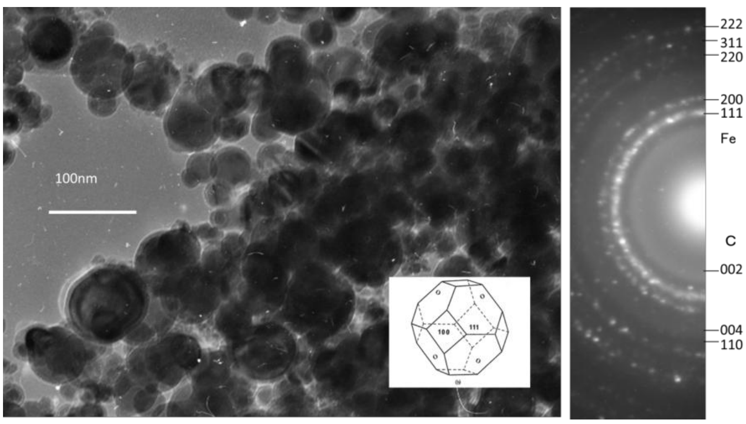

Fig. 2

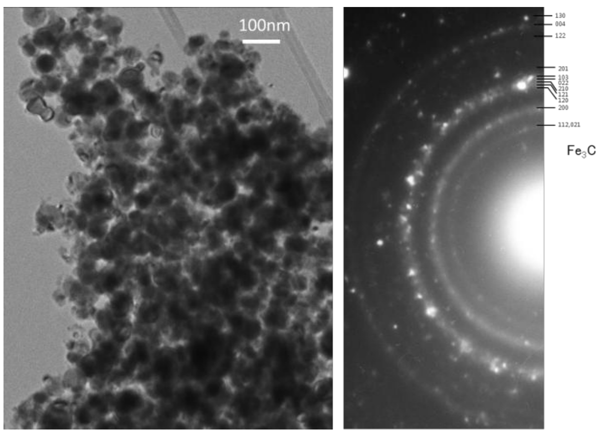

Fig .3

Prediction of observational results of fluffy aggregations in protoplanetary disks

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The dust growth and settling is the first step in planet formation. In this phase, the dust, which initially has the interstellar population, grows in size or mass by collisional coalescence and evolves to planetesimals in protoplanetary disks. However, some problems such as radial drift and fragmentation of dust particles have been pointed out, which prevent the formation of polanetesimals. These are critical issues in the dust growth and settling theory. Okuzumi et al. 2012 performed numerical simulations of fluffy aggregation of the dust existing outsize the snow line in the minimum mass solar nebula. They found that high porous aggregation in the disks cause a rapid collisional growth, which overcomes the radial drift. It should be interesting and important to reproduce the observational results to justify and improve the proposed theoretical models. In order for this, we have performed radiative transfer calculations of their fluffy aggregation models. In our presentation, the results of the spectral energy distribution and the images in the infrared and millimetre waves are presented. We also discuss how the region where planetesimals form can be detected in the model images and SEDs.

Ejecta Mass at Collisions of Dust Aggregates

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Collisional growth of dust aggregates is one of the essential processes to form planetesimals. High-velocity collisions produce a large number of small aggregates as ejecta fragments. Since ejecta would play an important role in dust growth and the total ejecta mass is a key to determine the mass loss rate through collisional cascades, we need a model of ejecta mass at high-velocity collisions of dust aggregates [1]. The amount of ejecta mass is also important for understanding the evolution of debris disks but still remains unclear because we do not know the ejection process in high velocity collisions of such small dust aggregates. In this study we carried out numerical simulations of dust aggregate collisions, focusing on the ejecta mass. In particular, we investigate the effect of the mass ratio between colliding two aggregates and of the monomer size distribution of aggregates on the ejecta mass. These two factors should be taken into account in considering actual collisions in the disks and the former cases are already done in the previous study [2]. In this paper we introduce the results in the previous study and report new results on the effect of monomer size distribution. As a result, we obtain a scaling relation such that ejecta mass averaged over the impact parameter is proportional to the projectile's momentum. Combining this scaling relation with the fragmentation model of Kobayashi & Tanaka (2010) [1], we also obtain a formula of the specific energy for ejecting the half mass of colliding bodies. These relations are useful for understanding planetesimal formation and fragment production rate in protoplanetary disks and debris disks.

[1] Kobayashi, H., & Tanaka, H. 2010, Icarus, 206, 735.

[2] Wada, K., Tanaka, H., Okuzumi, S., Kobayashi, H., Suyama, T., Kimura, H., & Yamamoto, T., 2013, A&A, 559, A62.

Interplay between dust and MHD turbulence in protoplanetary disks: electric-field heating of plasmas and its effect on the ionization balance of dusty disks

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Magnetorotational instability (MRI) is a viable mechanism of driving turbulence in protoplanetary disks. The activity of MRI depends largely on the ionization degree of the disk gas, which in turn depends on the amount of tiny dust grains that efficiently capture ionized gas particles (e.g., Sano et al. 2000). Understanding the interplay between dust and MRI turbulence is essential for understanding dust evolution and subsequent planetesimal formation in the disks.

In this study, we focus on the heating of electrons by turbulent electric fields and investigate how this affects the ionization balance of protoplanetary disks containing small grains. Previous studies have assumed that electrons in the disks have the same temperature as the neutral gas. However, this is not necessarily the case in MRI-driven turbulence, in which turbulent electric fields can significantly heat up electrons (Inutsuka & Sano 2005). This heating promotes collisions between the electrons and grains, leading to a reduction of the ionization degree (Okuzumi & Inutsuka, in prep.). We have studied how this effect limits the saturation level of MRI turbulence in protoplanetary disks. For a minimum-mass solar nebula with the grain radius of 0.1μm and dust-to-gas mass ratio of 0.01, we find that the saturation level of MRI turbulence is significantly lowered inside 70 AU from the central star. We also find that the grains in the region are so charged up negatively that the resulting electrostatic repulsion likely affects the their collisional growth.

AKARI observations of massive star-forming regions indicative of large-scale cloud-cloud collisions

Yasuki Hattori[1], Hidehiro Kaneda[1], Daisuke Ishihara[1], Toru Kondo[1] and Mitsuyoshi Yamagishi[1]

[1]*Nagoya University, Japan*

The formation process of massive stars is still poorly understood, although many studies on massive star formation processes have been performed. One of compelling scenarios is a large-scale cloud-cloud collision which leads to an effective gas compression triggering massive star-formation activities. Many pieces of observational evidence for cloud-cloud collisions have been found in massive star-forming regions by CO observations with NANTEN/NANTEN2 radio telescopes. Infrared observations of such star forming regions would provide information on dust and polycyclic aromatic hydrocarbons (PAHs) which absorb ultraviolet photons emitted from young massive stars. The total dust emission indicates the energy of embedded energy sources in the regions. Because PAH emission indicates the distribution of photo-dissociation regions (PDRs) as boundary of heating sources and molecular clouds, we can reveal complicated geometry of star-forming regions.

Among the massive star-forming regions indicative of large-scale cloud-cloud collisions, we carry out mid- and far-infrared surface photometry toward RCW 38, RCW 49, NGC 6334 and NGC6357, using AKARI all-sky survey data. Fitting the spectral energy distribution of each pixel and decomposing dust emission into PAHs, warm dust and cold dust, we investigate spatial distributions of these components. From the total luminosity of the dust emission, we estimate the number of embedded massive stars formed in these regions. In particular, we report details of the results on RCW 38 where about ten O-type stars are formed. In this star-forming region, the above three components show spatially distinct distributions, suggesting complicated geometry of the clouds associated with RCW 38.

The effect of grain growth on star formation in low-metallicity collapsing gas clouds

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Recent studies have revealed that first stars (Population III or Pop III stars), which are formed in metal-free gas clouds, are predominantly massive (several 10–1000 $M_{\odot}$). On the other hand, present-day stars are typically solar- or subsolar-mass. Some researchers have investigated the transition of stellar mass scale. Omukai et al.(2005) perform one-zone semi-analytic collapse calculations. They show that additional gas cooling, other than primordial elements, owing to heat transfer from hot gas to cold dust can trigger gas fragmentation at high densities ($n_{\rm H} = 10^{12}$–10^{15} cm^{-3}). They therefore conclude that low-mass fragments can be formed at metallicities $Z > 10^{-5.5}\ Z_{\odot}$. However, they assume that the fraction of heavy elements condensed into the solid phase (depletion factor) is fixed to the value in the local universe (~ 0.5). Dust grains in the early universe is supplied mainly by supernovae because their progenitors have short lifetime less than the cosmic age where mass transition would occur. Grains are also destroyed by reverse shocks penetrating in supernova ejecta, where grains are formed. Theoretical approaches show that the depletion factor is at least 0.01. Observations of damped Lyman alpha systems also reveal that this ratio is below the present-day value in the metal-deficient environments. Then, Schneider et al.(2006, 2012) study the fragment properties of clouds, setting the initial dust amount self-consistently calculated by their Pop III supernova models. They find that the critical condition can be described as the dust-to-gas mass ratio to trigger the dust-induced fragmentation. This means that the critical metallicity depends on supernova models (the initial depletion factor). So far, the dust amount is assumed to be fixed in the course of collapse. However, Nozawa et al.(2012) find that accretion of heavy elements in the gas phase onto dust grains (grain growth) can alter the thermal properties of gas even with the small initial depletion factor in metal-deficient clouds.

We perform one-zone collapse calculations, taking grain growth into consideration in order to reveal its effect on the cloud fragmentation. We employ the dust models (composition and size distribution predicted by early supernova models) as the initial condition of our calculations with low-metallicity. We find that growth of dust grains can enhance dust cooling especially for the small initial depletion factor (~ 0.01), and the critical metallicity is altered to smaller value. Also, the dependence of the critical metallicity on the initial depletion factor becomes milder.

Modeling the Infrared Emission of High-Latitude Molecular Cirrus Clouds

Ajay Mishra and Aigen Li (University of Missouri)

The exact amount and nature of interstellar matter at high Galactic latitudes is a subject of ongoing scrutiny. The IRAS observations at 60 and 100 micrometer first revealed the prevalence of large-scale, extended filamentary emission (known as ``infrared cirrus'', see Low et al. 1984) at high Galactic latitudes. The presence of significant quantities of CO gas at high Galactic latitudes (|b|>25 degree) was first reported by Blitz et al. (1984) and Magnani et al. (1985). These high latitude molecular clouds can be identified with the cores of the IRAS infrared cirrus (Weiland et al. 1986).

Little is known about the dust properties of these high latitude molecular cirrus clouds. We model the infrared emission of nine representative clouds (Verter et al. 2000) for which the visual extinction (A_V) was known from star counts (Magnani & de Vries 1986). All the selected clouds, with A_V <1 mag, are "translucent" to the interstellar radiation. They represent a class of objects intermediate between the properties of diffuse clouds and dark molecular clouds (van Dishoeck & Black 1988). They exhibit notable cloud-to-cloud variations in the mid-infrared, with the ratio of the IRAS 12 micrometer intensity to the IRAS 25 micrometer intensity varying by up to one order of magnitude.

The silicate-graphite-PAH model successfully reproduces the infrared emission of all the selected clouds observed by IRAS. We find that all clouds are rich in PAHs as traced by the IRAS 12 micrometer data. They are heated by the local interstellar radiation field, but with the radiation intensity reduced by a factor of about 2 to 3.

Optical and Near-Infrared Polarimetry of Reddened Type Ia Supernova 2014J: Peculiar Properties of Dust in M82

Koji S. Kawabata[1], et al.

[1]*Hiroshima Astrophysical Science Center, Hiroshima University*

We performed optical and near-infrared multi-band linear polarimetry for highly reddened Type Ia SN 2014J appeared in M82. SN 2014J exhibits large polarization at shorter wavelengths, reaching $p \cong 4.8\%$ in B band, and it steeply decreases with wavelength to $\cong 0.1\%$ in Ks band, while the position angle $\sim 40°$ is almost constant over the observed wavelength range.

The polarization is likely predominantly caused by the interstellar media within M82 because of i) no significant temporal variation, ii) small Galactic extinction toward SN 2014J, and iii) generally less polarization seen in continuum light of normal Type Ia supernova, although we cannot exclude the possibility by circumstellar media completely. The wavelength dependence of polarization can be explained by the empirical Serkowski-law at shorter wavelengths $(\lambda < 1\ \mu m)$ and by an inverse power-law at longer wavelengths $(\lambda > 0.5\mu m)$. The peak polarization wavelength λ_{max} is quite short, $\leq 0.4\ \mu m$, suggesting the mean radius of aligned aspherical grains contributing to the polarization is small. The empirical law between K and λ_{max} for the Galactic interstellar polarization is apparently broken, although the positive correlation between $R_V = A_V/E_{B-V}$ and λ_{max} seems to still holds. These facts suggest the nature of the dust grains in M82 is essentially different from that in our Galaxy. The polarization property of SN 2014J is similar to those in other highly reddened Type Ia SNe 1986G and 2006X that have been polarimetrically observed, and this high probability suggests such dust grains are rather common in extragalaxies.

The infrared spectra of iron oxides particles II
-------In the case of wustite

Chiyoe Koike[1], Hiroki Chihara[2] , Junya Matsuno[3],

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The mysterious 21 μm emission feature seen in C-rich proto-planetary nebulae remains unidentified since its discovery in 1989 (Kwok, Volk and Hrivnak, 1989), and the candidate carriers have long been the subject of discussion.

Among many carrier candidates, the calculated spectra of FeO nano particles closely matched the observed 21 μm emission features and seems to be a viable candidate (Zhang et al. 2009). As for the calculated 21 μm spectra of FeO (wustite), the optical constants were derived with the reflectance of synthesized FeO bulk (Begemann et al. 1995, Henning and Mutschke 1997). But, the peak position of the measured spectra of FeO particles in another labs shifted to longer wavelength than 21 μm.

We measured infrared spectra of wustite of commercial samples and synthesized sample by chemical reaction in laboratory, and found the peak shifted from sample to sample. Further, we synthesized wustite in laboratory with another method, and compared these spectra.

We will discuss about difference of spectra among wustite samples and those crystal structure connected defects. As FeO (wustite) is non-stoichiometric with some iron deficiency, the difference of infrared spectra among wustite samples may be due to some iron deficiency. Further, we will discuss about 21 μm emission feature compared with the results of the present iron oxide particles.

IR EVOLUTION OF CONDENSING SILICATE NANOPARTICLES: EFFECTS OF IRON ON THE 10 μm BAND AND CRYSTALLIZATION

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Silicate dust is observed ubiquitously in the universe, and, therefore, the IR evolution of silicate is the key for understanding of life cycle of dust. Though the great majority of silicate is composed of amorphous, crystalline is also found at the several astronomical environments e.g. dust shell around evolved stars [1], disk around young stars [2], and comets [3]. Interestingly, crystalline silicate, which is a higher temperature products, has been observed in a dust shell at relatively lower temperature (< 300 K) around oxygen-rich stars. The formation scenario of crystalline silicate is still unknown [1, 4]. In contrast to amorphous silicate, crystalline silicate shows a sharp IR feature depending on the chemical composition [5, 6], crystallinity, shapes [7, 8], size and temperature [9] of dust. However, no one has succeeded in reproducing astronomical observation completely and in revealing the formation process of crystalline silicate in oxygen-rich shell. During the nucleation from the hot gas and subsequent growth around oxygen-rich stars, dust particles contain inhomogeneous structure and high surface/volume ratio due to its nanosize, which will show different spectra from simply calculated spectra using optical constants of bulk. Therefore, we considered it is valuable to measure IR spectra during nucleation and growth of nano particle *in-situ*, which have never been measured. Recently, we developed an original IR measurement system named Free-flying *In-situ* infrared measurement of Nucleating nanoparticles Experimental (FINE) system, which enables *in-situ* IR measurement of directly condensed silicate from hot vapor. IR spectra obtained by the FINE system can be compared directly with that of astronomical observation. Applying FINE system, we succeeded to measure the IR evolution accompaning with the nucleation and growth of Mg bearing silicate analogue particles of cosmic dust.

FINE system revealed quite different crystallizatioin scequence of nanoparticles from that we assumed previously. Silicate nucleates as a droplet and crystallizes ~500 K lower than the crystallization temperature of bulk material [10]. Futhermore, 10 μm band had different peak wavelengths and FWHM from that obtained by the KBr embedding method [5] or calculation [7]. Peak positions of 10 μm band has been considered as an indicator of iron content. Therefore, we focus on the dependence of the 10 μm band structure on the concentration of iron in silicate particles. Two peaks in the 10 μm band shifted toward longer wavelength from 9.7 to 10.0, 10.8 to 11.2 μm relatively as iron content increase. We will give a new discussion on chemical composition of circumsteller silicate based on 10 μm band obtained by FINE system.

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An AKARI PAHrange Analysis of Probable Electric Dipole Emitting Regions

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Our understanding of dust emission, interaction, and evolution, is evolving. In recent years, electric dipole emission by spinning dust, has been suggested to explain the anomalous microwave excess (AME), appearing between 10 and 90Ghz (Draine & Lazarian, 1998). The observed frequencies suggest that spinning grains should be on the order of 10nm in size, hinting at poly-cyclic aromatic hydrocarbon molecules. We present data from the AKARI/Infrared Camera (IRC, Onaka, et al. 2007), due to its effective PAH/Unidentified Infrared Band (UIR) coverage, and the AKARI/Far Infrared Surveyor(FIS, Doi et al., in prep) to investigate PAHs within a few regions showing strong AME. We use the DustEM code by Compiegne et al. (2011) to predict an SED and compare the AKARI data to that of IRAS and the Planck Observatory. We also describe some variation in the AKARI 9/18um band ratio for AME regions. Part of the AME in these regions may in fact be due to thermal dust emission. In some star-forming regions, the vibrational modes of PAHs may be masked, suggesting further investigation for various galactic environments.

Dust-to-metal ratio in galaxies

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The mass fraction of dust in metals (elements heavier than helium in the astronomy), so-called the dust-to-metal ratio (DTM), is now becoming a standard *observational* quantity in the field of the galactic and extragalactic astronomy. DTM in galaxies is determined by the formation, evolution, and destruction processes of dust in the interstellar medium of galaxies. Thus, it is very important quantity to understand these processes which are still largely uncertain. In this work, I try to compile DTM and related measurements for various galaxy populations from the local Universe to high redshift reported in the literature and to extract some trends from them. Then, I will discuss the physical and chemical implications from the trends.

MULTIPHASE ISM IN RADIO LOUD EARLY TYPE GALAXIES

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Abstract

We present optical, IR and X-ray photometric study of a sample of radio loud early type galaxies chosen from B2 sample.To get radial profiles of various photometric and geometrical parameters, We performed multiband surface photometry on CCD images of our sample galaxies in 'BVR' broad band filter and Hα narrow band filter obtained from IUCAA Girawali Observatory(IGO 2m telescope) Pune(India) and 2m Himalyan Chandra Telescope(HCT) at IAO(Indian Astronomical Observatory) Hanle, remotely operated from CREST, Hosakote(India), that describe elliptical isophotes fitted to the 2D light distribution of the galaxies. The main focus of our study is to analyze radial profiles of quantities such as the (local) surface brightness, the ellipticity, and the deviations from elliptical isophotes parametrized by the Fourier coefficients. We generated color maps, residual maps,dust extinction maps, Hα emission maps and x-ray diffuse maps (obtained from CHANDRA data archive) of the galaxies to study the morphology of the dust, ionized and hot gas content present in the galaxies. We carried out detailed analysis of the dust properties(mass and temperature of the dust) for sample galaxies. We also made use of the HST(WFPC2) archival optical images to investigate properties of the dust in the central region($\sim$10 arcsec) of our sample galaxies,including this we also estimated molecular gas mass, mass loss by red giant stars and mass loss rate from evolved stars in the sample galaxies obtained from IRAS fluxes.

This multiwavelength study of our sample galaxies enabled us to find physical correlation among different phases of ISM also to address various issues related to dust i.e origin, nature and fate(evolution) of dust in radio-loud early type galaxies, coexistence of multiphase ISM in extra-galactic environment and its possible implications for the scenarios of formation and evolution of galaxies.