COSMIC DUST ABSTRACTS

Dust Evolution in Debris Discs

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Debris discs have been detected, as dust-induced infrared excesses, around an important fraction of main sequence stars. For some bright and/or nearby systems, these discs have also been imaged, often revealing pronounced radial and azimuthal structures. Contrary to that observed in the much younger proto-planetary discs, debris-disc dust is probably not primordial and has to be replenished, most likely by erosive or destructive collisions (hence the term « debris ») from much larger parent bodies stretching up to km-sizes or even more. Unfortunately, this population of large bodies, which probably contains most of the disc's mass and also controls its dynamics, remains undetectable, leaving the dust population as the sole observable component. As an example, for many systems, the potential presence of unseen planets can only be indirectly inferred by the spatial structure of the dust.
Understanding the evolution of this dust is thus of crucial importance. However, modelling the dust population is a very challenging task, because of the complex interplay between all the processes affecting small grains in such systems: fragmenting collisions, dynamical perturbations, radiation pressure, stellar winds, possible sublimation or vaporization. As a consequence, most debris disc studies have so far focused on specific aspects of the problem, like planet-induced dust dynamics, collision-induced mass loss, dust/gas interactions, or the balance between silicates and water or CO ices, etc. I will review the main results obtained in recent years and the progress that have been made in understanding what is going on in debris discs. I will also present some crucial, yet still pending issues that need to be investigated in the close future with the help of both unprecedented observational facilities like ALMA and new generations of numerical codes that aim to perform self-consistent all-encompassing studies of debris discs.

Dust features and gas in debris disks

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Debris disks are gas-poor, optically thin circumstellar dust components around main-sequence stars. We found more than 50 debris disk candidates from AKARI 9 and 18 μm observations. About 20 of the disks may have dust features, which may come from dust much grains smaller than 10 μm. If all gas in the debris disk is depleted, the smaller dust grains than 10 μm are quickly blown out by stellar radiation pressure from the typical debiris-disk host star that is about 10 times more luminous than the sun (e.g., Burns et al. 1979). The dust features can be explained only by very recent dust production events, such as giant impacts that formed Earth-Moon system in the solar system. On the other hand, if gas exists with more than 10^{-17} g/cm^3, small dust can stay in the disks. We investigate the archive data of ALMA. We newly found CO gas in two debris disks. Taking into account the dust feature and the gas existence, we discuss the amount of hydrogen molecular, which is critically important for planet formation.

Discovery of a 17 Myr old Debris Disk System in Lower Centaurus Crux by SPHERE

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ABSTRACT

We present the discovery images in H-band of a debris disk around a 17 Myr old star obtained by SPHERE. The star is at a distance of 96±6 pc in the Lower Centaurus Crux molecular cloud. We determined using Bayesian Markov Chain Monte Carlo methods that debris is likely in the form of a dust ring with inner edge of 24.5±1AU, position angle -74±1 ◦ and an inclination to the line of sight of 17±2 ◦ . The disk imaged in scattered light is likely as narrow as the resolution of the images, roughly 5 AU (55 mas). We further estimate an eccentricity of 0.1±0.03, which could be caused by an unseen orbiting companion, a scenario similar to the HR 4796A debris disk. The disk has also roughly the same fractional luminosity compared to star (Ldisk/Lstar=3.3×10^{-3}) as HR 4796A and β Pictoris, however was not detectible by previous telescope facilities because of its very small angular size (radius∼0.5 ″) and faintness (constrast∼10 magnitudes) compared to the star. With the arrival of extreme adaptive optics systems like SPHERE and GPI, the morphology of smaller, fainter and more distant debris disks are being revealed, providing clues to the dust dynamics with proto-planetary bodies. We also review the nature of these newly discovered debris disks.

On the photoelectric quantum yield of small dust particles

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Photoelectron emission is crucial to electric charging of dust particles around main-sequence stars and gas heating in various dusty environments. An estimate of the photoelectric processes contains an ill-defined parameter called the photoelectric quantum yield, which is the total number of electrons ejected from a dust particle per absorbed photon. Here we revisit the so-called small particle effect of photoelectron emission and provide an analytical model to estimate photoelectric quantum yields of small dust particles in sizes down to nanometers. We show that the small particle effect elevates the photoelectric quantum yields of nanoparticles up to by a factor of 10^3 for carbon, water ice, and organics, and a factor of 10^2 for silicate, silicon carbide, and iron. We conclude the surface curvature of the particles is a quantity of great importance to the small particle effect, unless the particles are submicrometers in radius or larger.

Impact cratering of porous targets in the strength dominated regime

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Most of small solar system bodies are porous, that means, the bulk density of the bodies is smaller than those of the component materials of the bodies. The response of porous bodies to impact depends not only on porosity but also on other physical properties. An S-type asteroid Itokawa was shown to be a rubble-pile, a re-accumulated body, and has macroporosity of 40% by Hayabusa's exploration. When impacted, such a body is expected to behave as granular targets in the laboratory, for which, gravity largely plays a role. A C-type asteroid Mathilde is also a body explored by a space mission, NEAR Shoemaker. The bulk density 1300 kg m^{-3} of this body shows that the macroporosity is about 40% if we exclude possibility of ice in the interior. Although the expected porosity is similar to Itokawa, Mathilde has a distinct appearance. Large craters of diameters comparable to the diameter of the asteroid co-exist. Why large craters can co-exist and the body was not disrupted and dispersed is probably because of the porosity that effectively attenuates the shock wave via compaction. Blocks were not observed on the surface of this body, while ejecta blocks are common on other small bodies in the vicinity of craters (e.g., on Martian moon, Phobos) and even wide spread on the surface (e.g., on asteroid Eros). The observational evidence shows that impact processes on Mathilde were not simple granular, but compaction, or in other words, strength that resists compaction, played a role. Because primordial small bodies would have been very porous, impact process of porous bodies associated with compaction is of importance in the collisional evolution of porous primitive bodies.

Laboratory impact experiments of porous targets in the strength regime have been performed using different materials, such as sintered-glass bead targets, gypsum targets, natural porous rocks, and blocks of chondrites. In some of previous experiments, spatial extent and the degree of compaction were observed using transmission X-ray imaging or SEM. Crater diameter data can be compiled using conventional cratering scaling (Holsapple, 1993) with an empirical modification for porosity, while depth data cannot be compiled in the same manner. The results including those in literatures and some new ones of a set of impact experiments which were focused on using porous projectiles will be reviewed and presented with a discussion in terms of possible scaling for application to primitive small bodies.

Mechanical strength of chondrules

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Chondrules embedded in chondrites recorded physical processes in the early solar system such as impact compression of the chondrite parent-bodies. Some fractions of chondrules were found to be fractured in chondrites (Nelson and Rubin, 2002). If such fraction and the strength of chondrules are combined, the level of the applied stress to the chondrite parent-body due to impact compression could be inferred (Beitz et al., 2013). Here we report the results of our laboratory study on the strength of chondrules and compare them with those of specimens of dunite, basalt, and two different sandstones.

We conducted static and dynamic compression tests of chondrules and rock specimens, because brittle materials tend to respond differently to the static stress and dynamic stress. Chondrules of Allende (CV3) were removed from a block using tweezers and files, while those of Saratov (H4) were separated from a block by means of freeze-thaw method. Crushing strength of chondrule was determined using a compression testing machine installed at Kobe University with loading rate of 1 μm s^{-1}. Crushing strength Y_c is determined as follows:

$$Y_c=2.8F/\pi d^2, \qquad (1)$$

where F is the peak value of the applied force and d is the mean diameter of chondrule or rock specimen.

Impact disruption experiments of chondrules and rock specimens were conducted using a gas-gun with 3 mm bore diameter at Kobe University. Chondrules and rock specimens were impacted onto plate targets. Those smaller than 2 mm in diameter were accelerated using polycarbonate sabots of 3 mm in diameter. The material of the plate targets were nylon, aluminum, and stainless-steel to cover a range of impact pressure. The impact velocities for the chondrules were from 25 to 101 m s^{-1}. We defined the impact strength as the impact pressure at which the maximum fragment mass fraction to the initial mass of chondrule or rock specimen becomes 0.5.

Fracture patterns varied depending on materials in both static and dynamic tests. For example, as for impact disruption, specimens of two sandstones were more finely fragmented than other materials and numerous sand grains were generated. We found that the crushing strength of chondrules was roughly 10 MPa and lower than igneous rocks, i.e., dunite (13 MPa) and basalt (17 MPa), but higher than two sandstones (both ~3 MPa). We also found that the impact strength of chondrules was about 160 MPa and more than a magnitude larger than the static strength as are the cases of rock specimens. The strength of chondrules determined in this study would give the lower limit to those of the initial ones because the chodrules would have been weakened by stresses they have experienced in the chondrites.

Solar-wind contribution to the current measured in Lunar Dust Experiment†

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New evidences for impact-generated dust exosphere come from the LDEX on board the Lunar Atmosphere and Dust Environment Explorer (LADEE), including a permanent, asymmetric dust cloud around the Moon and a correlation between density enhancements and annual meteor showers [Horányi et al., 2015]. However, the density of 0.1-μm-sized grains that were measured as integrated current [Horányi et al., 2014] showed no dependence on the altitude, which was inconsistent with previous observations and suggested there should be some other current sources [Szalay and Horányi, 2015]. Actually, ions with energy less than 30 eV can also contribute to the measured current of LDEX, which come from several sources such as lunar ionosphere, backscattered SW protons and sputtering of ENAs [Horányi et al., 2015]. Ions from lunar ionosphere can be accelerated into LDEX by the convection electric field of solar wind (SW) and detected as current [Poppe et al., 2014]. But near the terminator, the electric field is almost perpendicular to the LDEX boresight and the current should be very small, then other sources, such as SW, get important. Szalay and Horányi [2015] reported a correlation between the current and SW density, but without a further discussion.

Here we present evidences for SW-generated current. We show that direct SW influx on the night side can cause large current, while the backscattered energetic neutral atoms (ENAs) on the dayside can bring a good correlation between the current and SW density. It is found that the current favors a lower SW speed and a smaller SW incident angle, but the dependences are also affected by solar zenith angle (SZA) and the scattering function of ENAs. Picked-up ions can enhance the current when the angle between the convection electric field and LDEX's normal is larger than 90°. But when the angle is smaller than 90°, the enhancement is negligible.

Since the current is mainly caused by backscattered SW ENAs, the dust density should be further smaller than the value of 10^2 m^{-3} estimated by Szalay and Horányi [2015] and closer to the recent measurements from Clementine and LRO, which provides a positive evidence for impact-generated dust exosphere.

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The effect of high energy photoelectrons on the structure of photoelectric sheath and dynamics of dust grains in the sheath

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When an air-less body's surface is irradiated from solar UV photoelectrons are emitted. Although each photoelectrons eventually comes back to the surface due to electrostatic force from the positively charged surface, static electric field is formed above the surface. The layer which contains photoelectrons is called a photoelectric sheath. The thickness and vertical structure of the photoelectric sheath is decided by the energy distribution function of photoelectrons. The energy distribution function of photoelectrons depends on the composition of surface layer, however, there are one and only one study on the energy distribution function of photoelectrons emitted from astronomically relevant material [1]. We showed that the energy distribution function of photoelectrons obtained from laboratory experiments had been used inadequately in the previous studies [2]. Although the energy distribution function was experimentally measured for integrated value only in the emission angle from the normal to the surface to about π/4 [1], some of previous studies used the energy distribution function as a vertical component and others assumed the Maxwellian energy distribution function for photoelectrons using the mean energy obtained from the laboratory experiment. Thus we developed a new analytical method to calculate an angle-resolved velocity distribution function of photoelectrons from the energy distribution function of photoelectrons obtained from laboratory experimental [2].

We omitted the high energy (> 6 eV) component of photoelectrons in the previous work [2] because the fraction of high energy component was too low to be evaluated from the original figure. However, irradiation of high-energy photons to an air-less body's surface should emit photoelectrons beyond 6 eV. Indeed, the Apollo 14 charged-particle lunar environment experiment (CPLEE) on the moon revealed the presence of high-energy photoelectrons between 40 and 200 eV emitted from the lunar surface [3].

The high energy component of photoelectrons extends the photoelectric sheath above the surface. The dynamics of dust grains above the surface is known to be affected by the vertical structure of photoelectric sheath [2]. Thus in this study we extrapolate the energy distribution function of photoelectrons assuming some types of functions and investigate the effect of high energy component of photoelectrons on the vertical structure of photoelectric sheath and the dust motion in it.

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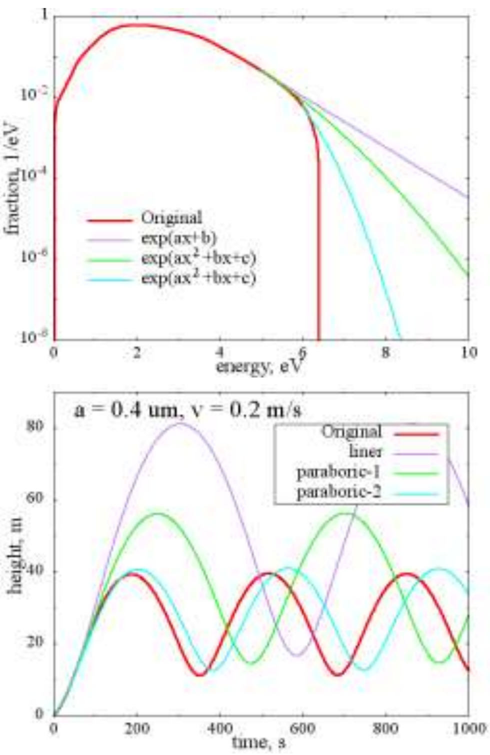

Figures: Examples of extrapolated energy distribution function of photoelectrons (top) and the resunting dynamics of a dust grain launched with 0.2m/s from the surface of Eros (bottom).

Polarization of dust and molecular bands in comets: effects of mutual contamination

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The spectra of comets are composed of emission lines of atoms, ions, and neutral molecules as well as of a continuum produced by the solar light scattered by dust particles in the coma or tail. Öhman (1941) revealed that there are two different types of polarization behavior in comets. The polarization of continuum was explained by the scattering of sunlight on dust particles, while the polarization in molecular emissions is due to the resonance fluorescence mechanism. Polarimetry of the continuum is a recognized tool for the study of physical properties of dust particles and light scattering mechanisms in comets. However, there are still unsolved problems in the interpretation of the available data. In particular, there are different approaches to explain the observed differences in the maximum polarization of comets. On one hand the observed dispersion of $P_{\max}$ results from different physical properties in cometary dust. On the other hand this difference can be explained by the gas contamination of the continuum polarization. Less attention has been paid to polarimetry of cometary molecular emissions. However, the linear and circular polarimetry of molecular bands can be used to clarify the mechanism of the fluorescence polarization of different emissions and as a diagnostic of the presence or absence of a magnetic field in comets. In addition, since the molecular emissions are observed in the continuum background, there is an effect of continuum contamination of the polarization in molecular emissions. As a result, the observed polarization of the light emitted from molecules is higher than theoretical values for the resonance fluorescence mechanism. It is shown that the effects of mutual gas and dust contamination on the observed polarization of the continuum and molecular emissions depend on the dust-to-gas ratio in different comets.

Volatile and Dusty: The NEOWISE comet survey.

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The 163 comets observed during the WISE/NEOWISE prime mission represent the largest infrared survey to date of comets, providing constraints on dust, nucleus size, and CO + CO_2 production. The sample includes 57 long-period comets, as well as over 106 short-period comets, from a variety of cometary dynamical sub-classes. We present detailed analyses of the WISE/NEOWISE comet discoveries, and discuss observations of the active comets showing 4.6 micron band excess. We determine size constraints for the majority of the comets in the sample using coma extraction techniques. We also discuss dust tail analysis determining particle size and ejection time constraints. Finally, find a possible relation between dust and CO + CO_2 production, as well as possible differences in the sizes of long and short period comet nuclei.

Cometary dust as seeing by the Rosetta mission

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At the previous Cosmic Dust meeting there were four presentations, where leading scientists of the Rosetta dust instrument teams presented the first results of the mission. Since that time Rosetta has accumulated far more data, allowing a comprehensive analysis of the cometary dust characteristics. To the data of the dust instruments (COSIMA, MIDAS, GIADA, and DIM/SESAME) the dust data obtained by other instruments (OSIRIS, VIRTIS, ROSINA) have been added. The accumulated data reveal information on velocity, size, structure, and composition of the cometary dust particles, and their variations depending on the heliocentric distance, insolation, and the areas on the nucleus from which the dust was lifted or dust jets originated. I will present an overview of the Rosetta results, trying to summarize the obtained knowledge on the dust in comet 67P/Churyumov-Gerasimenko. Then I will analyze existing theoretical and laboratory models of light scattering, formation, and evolution of the cometary dust to identify which models are most consistent with the Rosetta findings. The Rosetta dust data have raised some new questions which I will also outline.

Laboratory Analysis of Silicate Stardust Grains of Diverse Stellar Origins

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Silicate dust is ubiquitous in a multitude of environments across the cosmos, including evolved oxygen-rich stars, interstellar space, protoplanetary disks, comets, and asteroids. The identification of *bona fide* silicate stardust grains in meteorites, interplanetary dust particles, micrometeorites, and dust returned from comet Wild 2 by the Stardust spacecraft has revolutionized the study of stars, interstellar space, and the history of dust in the Galaxy. These stardust grains have exotic isotopic compositions that are records of nucleosynthetic processes that occurred in the depths of their now extinct parent stars. Moreover, the chemical compositions and mineralogies of silicate stardust are consequences of the physical and chemical nature of the stellar condensation environment, as well as secondary alteration processes that can occur in interstellar space, the solar nebula, and on the asteroid or comet parent body in which they were incorporated.

In this talk I will discuss our use of advanced nano-scale instrumentation in the laboratory to conduct coordinated isotopic, chemical, and mineralogical analyses of silicate stardust grains from AGB stars, supernovae, and novae. By analyzing the isotopic compositions of multiple elements in individual grains, we have been able to constrain their stellar sources, explore stellar nucleosynthetic and mixing processes, and Galactic chemical evolution. Through our mineralogical studies, we have found these presolar silicate grains to have wide-ranging chemical and mineral characteristics. This diversity is the result of primary condensation characteristics and in some cases secondary features imparted by alteration in space and in our Solar System. The laboratory analysis of actual samples of stars directly complements astronomical observations and astrophysical models and offers an unprecedented level of detail into the lifecycles of dust in the Galaxy.

Presolar grains in the Galaxy formation

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I will discuss the origin of chemical abundances of presolar grains (e.g., Si isotope ratios in SiC grains) based on the results of chemo-dynamical simulations of the Galaxy formation and evolution. The new simulations enable us to investigate the interaction between dust ejected from supernovae (SN) and AGB stars and a giant molecular cloud (GMC) that formed our Sun. Therefore the simulations can predict (i) how many AGB stars could interact with the Sun-hosting GMC and chemically pollute the GMC about 4.6-4.7 Gyr ago, (ii) whether or not mergers between neutron stars (NSM) that create r-process elements could interact with the GMC, and (iii) what the chemical abundances are for the SNe and AGBs that polluted the early solar systems. I mainly compare the observed Si three-isotope diagram with the simulated one in order to discuss where the Sun was born in the Galaxy. The main results from these simulations are as follows:

(1) The observed 29Si and 30Si higher than the solar values in presolar SiC can be explained if the Sun originates from a GMC orbiting the Galaxy at R~ 6 kpc (not ~ 8kpc, which is the present location). This is because the Sun-hosting GMC needs to interact with more metal-rich AGB stars that can produce higher 29Si and 30Si. If the Sun was born in the inner region of the Galaxy, then the Sun needs to migrate to the outer region of the Galaxy through some dynamical process.

(2) However, the simulations predict many SiC grains with 29Si and 30Si significantly lower than the solar values, because the inner Galactic regions can include old, metal-poor stars that interact with the Sun-hosting GMC. These metal-poor SiC grains are not observed, which implies either that SiC grains cannot be formed from metal-poor AGB stars or that the present chemo-dynamical model of the Galaxy formation is not so realistic.

(3) There are many possible candidates of the Sun-hosting GMC in the simulations (i.e., there are many stars that were formed in GMCs 4.6 Gyr ago and reside at R ~ 8 kpc at the present). Each GMC interacts with many AGB stars with different metallicities and ages, which means that presolar grains have diverse stellar origins. The interaction histories of these GMCs with existing AGB stars, SNe, and NSM are also quite diverse (e.g., some GMCs are influenced by NSM whereas some are not). I will discuss the implications of these in my talk.

Theoretical Models of Complex Molecule Formation

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Pathways leading to the formation of complex organic molecules will be described. Gas phase processes that may build large carbon-chain species in cold molecular clouds will be summarised. Catalytic reactions on grain surfaces can lead to a large variety of organic species, and models of molecule formation by atom additions to multiply-bonded molecules will be presented. The subsequent desorption of these mixed molecular ices can initiate a distinctive organic chemistry in hot molecular cores.

The predictions of this theory will be compared with observations to show how possible organic formation pathways in the interstellar medium may be constrained. In particular, the success of the theory in explaining trends in the known interstellar organics, in predicting recently-detected interstellar molecules, and, just as importantly, non-detections, will be discussed. The most urgently needed laboratory data required by these and future theoretical models, both for gas-phase and solid-phase reactions, will be emphasized.

Simulations of Extinction Laws toward Steady Sources Surrounded by Circumstellar Dust

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Multiple scattering processes are important in considering the nature of extinction by circumstellar (CS) dust. For example, it has been shown that multiple scattering may explain the unusual extinction law toward Type Ia supernovae (SNe Ia) (Wang 2005; Goobar 2008). In this study (Nagao, Maeda, Nozawa, 2016, ApJ, accepted), we systematically study effects of multiple scattering on extinction laws for bright point sources surrounded by dusty CS medium using Monte Carlo simulations, adopting various dust models. We find that behaviors of the resulting extinction laws are dependent on the properties of CS grains, and therefore the extinction laws toward such dusty objects could be used to constrain the properties of dust they have produced. If applied to SNe Ia, we find that either silicate grains of small size or PAH (Polycyclic Aromatic Hydrocarbon) are important to realize the low values of R_V observed for SNe Ia.

Ultraviolet Extinction of a Few Supernova Remnants

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Supernova is one of the major contributors to interstellar dust, and the supernova-produced dust may be different from AGB stars due to its violent activity in the explosion. In order to understand the characteristics of supernova-produced dust, ultraviolet (UV) extinction is determined to a few supernova remnants which are optically very thin, because UV band is very sensitive to interstellar extinction and the UV band extinction is important to constrain the properties of sub-um-sized dust grains. In combination of the data from the UV photometric survey (GALEX) and from the optical spectroscopic surveys (RAVE and LAMOST), the extinction in the GALEX/NUV and GALEX/FUV bands relative to the selective extinction E(B-V) are determined to a few supernova remnants, which is compared with the average extinction over the entire sky. In addition, the relation of intrinsic stellar color indexes with the GALEX/NUV and GALEX/FUV bands are determined with stellar effective temperature. The dust model will be constructed to explain the derived UV extinction law.

Carbon-Rich Dust in Evolved Stars: from AGB, Post-AGB to Planetary Nebulae

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Carbon-rich dust generated by evolved stars can take many forms in circumstellar and interstellar environments. In the outflows from stars on the asymptotic giant branch (AGB), amorphous carbon dominates, but tracers like carbides and sulfides form as well, most notably SiC and MgS. The behavior of these dust species is consistent with layered grain structures. Dust in post-AGB objects and planetary nebulae (PNe) can take even more exotic forms: polycyclic aromatic hydrocarbons (PAHs), aliphatic hydrocarbons, and fullerenes. Photo-processing appears to play a dominant role in determining which carbonaceous species we see in different post-AGB environments, but it is likely that the story is more complex.

Constraining dust properties in Circumstellar Envelopes of C-stars in the Small Magellanic Cloud: optical constants and grain size of carbon dust

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We present our recent investigation aimed at constraining the typical size and optical properties of carbon dust grains in Circumstellar envelopes (CSEs) of C-stars in the Small Magellanic Cloud.

To achieve this goal, we apply our recent dust growth model, coupled with a radiative transfer code, to the CSEs of C-stars evolving along the TP-AGB, for which we compute spectra and colors. We then compare our modeled colors in the NIR and MIR bands with the observed ones, testing different assumptions in our dust scheme and employing several optical constants data sets for carbon dust available in the literature. Different assumptions adopted in our dust model change the typical size of the carbon grains produced. We finally constrain carbon dust properties by selecting the combination of typical grain size and optical constants which best reproduces several colors in the NIR and MIR at the same time. The approach is new and has never been adopted so far.

We conclude that the complete set of selected NIR and MIR colors are best reproduced by small grains, with sizes between 0.06 and 0.1 microns, rather than by large grains of 0.2-0.4 microns. Remarkably, the inability of large grains to reproduce NIR and MIR colors seems independent of the adopted optical data set. We also find a possible trend of the typical grain size with the dust reddening in the CSEs of these stars.

We finally emphasize that this work is preparatory to follow-up studies aimed at calibrating the TP-AGB phase through resolved stellar populations in star clusters and galaxies which include dusty, mass-losing evolved stars.

The Icy Universe

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Volatile molecules and refractory dust are the building blocks of dense clouds, protoplanetary envelopes and disks, and planetary systems. Their formation pathways hold key information on the formation of astronomical objects, and, eventually, life. Telescope observations, laboratory simulations, and model calculations show that icy grain mantles (H_2O, NH_3, CO, CO_2, CH_3OH, et cetera) play an important role in molecule, and possibly dust formation. I will discuss how observations constrain the molecule formation pathways and how the ice absorption, scattering, and emission bands can be used to trace the physical history of their environment.

Analysis of Ice Absorption Features towards YSOs Candidates Using AKARI

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We present a study of near- to mid-infrared spectra (2.5—12μm) of two galactic YSO candidates, which have been identified in serendipitous spectroscopy in the Galactic plane using the slit-less mode of the InfraRed Camera (IRC) on board AKARI. Absorption bands of molecular species, including solid phase H_2O, CO_2, CO, XCN-, silicates, and possibly gas phase CO, are seen in the spectra towards both sources.

We estimate the column densities of the above detected species and found the quite large column densities of XCN-. These results suggest that the objects are highly embedded class I protostars. However, these sources do not belong to any known star-forming region. Their SEDs are peculiar as YSOs since their peaks are located at around 4μm, while usual YSOs show a peak at a much longer wavelength. Their spectral energy distributions (SED) are quite blue as YSOs and no FIR emission has been detected. Existing SED models of YSOs cannot account for them. On the other hand, the presence of the XCN- feature and no apparent associated nebulosity in the regions suggest that they are not likely background stars.

In this presentation, we will discuss the properties of these objects and their physical implications.

Grain surface chemistry in PDRs

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With the advent of the new generation of mm and sub-mm detectors (ALMA, NOEMA), molecules are detected in a large variety of galactic and extra-galactic interstellar environments. These molecules are unique probes to investigate the physical processes in interstellar gas and on grains. Theoretical models and laboratory experiments show that many of these molecules are efficiently formed on grains (H_2O, H_2CO, CH_3OH, CO_2, ...) and released in the gas. State-of-the-art astrochemical models have to take into account consistently both gas phase and surface chemistry to interpret observations and, to do so, they must rely on theoretical and laboratory experiments results. However, surface processes are complex to implement in astrophysical codes in which grain models are necessarily simplified.

We have implemented surface chemistry in a new version of the Meudon PDR code (Le Petit et al. 2006, Le Bourlot et al. 2012), one of the state-of-the-art public astrochemical code (http://ism.obspm.fr). In the Meudon PDR code, grains are represented by distributions of amorphous carbonate, silicates and PAHs that contribute to the radiation field absorption, photo-electric effect, continuum emission and surface reactions. The grain surface model takes into account adsorption, formation of mantles, reactions as well as several desorption processes: thermal, photodesorption, chemical desorption, cosmic rays desorption. Because the Meudon PDR code is a 1D code that solves in a coupled way the radiative transfer from far UV to sub-mm, thermal balance and chemistry for several hundred chemical species in the gas and on grains, it is possible to have access to grain mantle compositions and to efficiencies of the various surface processes as a function of depth taking into account the grain temperature and the intensity of the radiation field at each position.

In this talk, I will present this new model of grain surface chemistry. I will show how uncertainties on surface chemical reaction thresholds affect grain mantle composition and chemical abundances in PDRs. I will highlight the effect of competitive desorption processes (thermal, photon, chemistry, cosmic rays), in different environments to the light of new laboratory experiment results. Indeed, the latest photo-desorption experiments show this process may be less efficient on H_2O ices by one order of magnitude than commonly thought. This is a new challenge for astrochemical models since the common picture was that molecules such as CH_3OH is formed on grains and release in the gas by photo-desorption due to primary or secondary UV photons (Guzman et al. 2013). The role of cosmic rays on grains (Munoz Caro et al. 2014, Dartois et al. 2015) and exothermicity of chemical reaction in grain mantles (Dulieu et al. 2013, Minissale et al. 2016) will be investigated to determine if they can be competitive enough to reach an agreement between astrochemical models, observations and laboratory experiments results.

Astrochemical modelling: Coupling physical and chemical properties of interstellar gas and dust

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Low-mass protostars form from the collapse of dense cores in clouds of molecular gas. In the very early stages, the protostar is deeply buried in an envelope of gas and dust. The material of the envelope is later accreted onto a protoplanetary disc around the protostar and onto the protostar itself. The molecular line emission from star-forming regions can be used to probe the physical characteristics of the region, both directly, through excitation analysis, and indirectly, through studies of the chemical reactions that form the observed molecules. Such an analysis heavily relies on inclusion of the reactions on the icy surfaces of interstellar dust grains, where e.g. hydrogenation reactions contribute to the formation of more complex molecules.

Our own Solar System is known to have formed in the presence of several massive stars – meteoritic evidence shows that short-lived radionuclides were injected from a nearby supernova explosion, or even multiple supernova events. It is therefore extremely important to investigate the influence of external effects on the chemistry of cores which can form low-mass protostars, like the Sun. Our previous observations show that increased temperatures resulting from the irradiation from nearby luminous stars have effects on the chemistry of the star-forming core due to evaporation of key species such as carbon monoxide and methane from the dust grains.

We here demonstrate the early results of our new time-dependent astrochemistry code which couples an advanced gas-chemistry code (based on the reactions in the UMIST database) with freeze-out and evaporation of molecules onto dust grains as well as grain-surface chemistry. The code also treats the temperatures of gas and dust separately, includes the relevant heating and cooling terms for both gas and dust (cosmic ray heating, spectral line cooling, UV irradiation, etc.), and couples the physical properties of gas and dust through gas-grain interactions.

With our code we have first studied how the chemistry of a dense dusty core is affected by a nearby supernova explosion, resulting in an increase in the cosmic-ray ionisation rate. The results from our code will be used to thoroughly investigate the impact supernovae have on the chemistry of star-forming regions, and be compared with observations of protostellar envelopes in supernova remnants. Ultimately, the code will help us to identify tracers showing the irradiation history of protostellar clouds.

The origin of the broad $22\,\mu$m dust feature and its association with the molecular gas: a study of the PDR in the Great Nebula in Carina

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With the ISO/SWS observations, Chan and Onaka (2000) have identified a broad (width $\sim 10\,\mu$m) emission feature with unknown carrier(s) at $22\,\mu$m in the Great Nebula of Carina. This feature resembles what has been observed in Cas A and may relate to the dust grains formed in supernova ejecta. In order to invesitate the physical conditions of the region, where the $22\,\mu$m has been detected, we observe the CO and ^{13}CO gas in a wide range of excitation states (from $J = 4-3$ to $J = 13-12$), spatially–resolved down to ~ 0.5 pc. The observation targets at an area of $2' \times 7'$ (2 pc $\times$ 7 pc), which covers a part of the PDR in the Great Nebula of Carina, by the *Herschel* Space Observatory. The ionization front of this PDR sits at a projected distance of ~ 2 pc from the young ($1-2$ Myr) OB-star cluster, Trumpler 14 (Tr 14), which provides its dominant UV input.

Tr 14 hosts a dozen of O-stars and more than a hundred of B-stars, and its stellar components have been well studied. The estimated UV input by Tr 14 to this PDR is 10^3 to $10^4\,G_0$, which is slightly weaker than that by Trapezium to the famous Orion Bar, yet comparable to that found in the extragalactic starburst region, 30 Doradus. In the Carina Nebula, the brightest $3.29\,\mu$m emission, attributed to the polycyclic aromatic hydrocarbons (PAH), a major component of dust grains, is found here. Such a region is likely a representation of prototypical PDRs near star–forming sites that dominate the extragalactic observations of starburst systems where individual PDRs are mostly unresolved with our current technology in the infrared and submm.

Based on the spatially resolved physical parameters derived from the CO spectral line energy distribution (SLED) and the spectral energy distribution (SED) of dust, I will present

1. a comparison of the physical states of the molecular gas and dust at the sub-parsec scale

2. heating and cooling of the PDR under the effects of local star–forming activities

3. the distribution of the 22 μm dust feature and its relation to the physical states of the surrounding PDR.

The Dust Properties of Nearby Galaxies as Seen by *Herschel*

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The *Herschel* space observatory has delivered a wealth of data on the infrared-(IR)-to-submillimeter-(submm) emission of the Universe, that is still being analyzed. Among its targets, nearby galaxies provide particularly relevant constraints on the processes controlling dust evolution. Indeed, they exhibit a diversity of environmental physical conditions (star formation activity, metallicity, *etc.*) that are not encountered in our own Galaxy, therefore allowing us to explore the dust properties in extreme environments and at different stages of their evolution. Most of these objects can be studied in details as they are spatially resolved, even at submm wavelengths, they are usually well detected and have a full ancillary database for complete spectral energy distribution (SED) modelling and for estimating the gas content of the different interstellar phases.

In this talk, I will review several studies illustrating the challenges and breakthroughs of this topic. I will first discuss the methodological improvements that have been necessary to properly interpret the *Herschel* data, analyzing several problems encountered with dust SED fitting. I will then talk about the important degeneracy between grain emissivity and dust mass estimates, and show cases where this degeneracy can be broken. I will illustrate dust evolution over cosmic time by presenting the most up-to-date trends of dust-to-gas mass ratio with metallicity, and the constraints they provide on dust evolution models. Finally, I will show that dust tracers are useful to refine our understanding of the gas diagnostics, and reversely.

On the light scattered by porous particles

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Natural dust particles are known to display very disordered shapes. Generic examples are fractal aggregates of grains, which are made in the shape of fluffy disordered structures. In these cases, it is uneasy to find direct reliable information about the complicated particle morphologies from the light scattering patterns. Consequently, analysis of the light scattered by such particles is often frustrating regarding the good quality of the observational data.

In this context, the fractal dimension is a central structural parameter. It is important characteristic indeed, because estimated value of that dimension can provide insight into the mechanisms forming the particles. Recently, we showed that the so-called "fractal regime" in the Rayleigh-Gans-Debye (RGD) theory was much more robust than commonly accepted, provided definite observational conditions are fulfilled. As a result, we now know when the possible fractal dimension of the scattering dust particles can be deduced in a reliable way. The explicit conditions were deduced from the analytical mean-field T-Matrix theory, and substantiated from the compared analysis of the light scattered by a number of numerically-generated finite particles of various fractal dimensions. Light scattering computations were performed using the RGD and the T-Matrix methods.

Another parameter of interest is the porosity. This physical quantity is amazingly very difficult to define unambiguously, though porosity is expected to play a central role in the scattering of light since related to another form of mass correlation inside the particle. For example, a sphere can be of high porosity even with effective fractal dimension equal to 3. Moreover, the porosity of fractal particles of fractal dimension < 3 is ill-defined as it goes to 1 when the particle size grows. Then, it is natural to wonder if any signature of porosity can be deduced from the scattering plots of porous particles, and which is the proper definition of the porosity relevant for light scattering. These questions have been addressed recently for model particles in the shape of spheres of various inner open porosities. Here, the porosity is controlled and the particles are connected, like for grain aggregates. We will discuss and compare results of (DDSCAT and T-Matrix) light scattering by porous particles built using different models, and with same porosities.

This kind of approach builds little by little a bundle of tools for direct analysis of the electromagnetic waves scattered by disordered dust particles, though we are still far from the extensive tools existing when the RGD theory applies. By the way, we will also review these unique tools within the RGD theory and how they could be applied for the data (from SWIFT or CHANDRA space observatories) of X-ray radiation scattered by dust particles surrounding X-ray source.

Dust in the wind: the mineralogy of newly formed dust in Active Galactic Nuclei

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The detection of large amounts of dust (Priddey et al. 2003; Beelen et al. 2006) in the early universe still remains largely unexplained. The traditional (stellar) dust sources do not produce enough dust during the first Gyr to explain the reservoir of dust observed (Morgan & Edmunds 2003; Rowlands et al. 2014), and, furthermore, the extinction curves at high redshift are markedly different from those observed in the local universe (Maiolino et al. 2004; Stratta et al. 2007). Therefore, additional dust sources have been invoked, such as interstellar grain formation and grain growth (Martini et al. 2013). Additionally, by comparison with the dust forming environments around evolved low mass stars, Elvis et al. (2002) argue that the conditions in the wind coming off Active Galactic Nuclei (AGN) accretion disks allow for the formation of significant amounts of dust. This dust source would not only help explain the so-called *dust budget crisis* at high redshift, but also provides a natural explanation for the origin of the dusty AGN torus (Elitzur & Shlosman 2006).

We have started a rigorous program to determine the dust mineralogy towards a number of quasars where the dust features are seen in emission, which is predicted to be the case for certain viewing angles (Pier & Krolik 1992). We follow our earlier analysis of broad absorption line (BAL) quasar PG 2112+059 for which we have determined the mineralogical composition of dust using mid-infrared spectroscopy obtained with the Spitzer Space Telescope (Markwick-Kemper et al. 2007). From spectral fitting of the solid state features seen towards this object, we identify Mg-rich amorphous and crystalline silicates with olivine stoichiometry, as well as the more primitive condensates alumina (Al_2O_3) and periclase (MgO), probing the conditions in the dust condensation zone.

We have selected a sample of Palomar Green (PG) quasars with Herschel and AKARI photometry from the sample of Petric et al. (2015), and required their archival Spitzer spectra to show the 9.7 micron silicate feature in emission. The Herschel photometry will constrain the far-infrared continuum, enabling us to repeat the analysis by Markwick-Kemper et al. (2007) for this sample. We will chart the variety in mineralogy present in quasar winds, and compare the results with other work present in the literature (e.g. Köhler & Li 2010; Smith et al. 2010; Xie et al. 2014), studies which all have targeted single objects, or very small samples.

The other side of the equation: Systematic effects in the determination of dust masses

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In recent years, major difficulties have emerged in attempts to reconcile observed interstellar dust reservoirs with the rates of dust production from known sources, both locally and in the early universe (e.g. Jones et al., 1996; Morgan & Edmunds, 2003); this has become known as the "dust-budget crisis". This is a particular problem for high-redshift submillimetre galaxies, as the youth of the universe prohibits AGB stars from contributing.

Previous attempts to tackle this issue have focussed on the sources of dust, invoking dust production by massive stars (0.1–$1\,M_\odot$ per supernova, Gall et al. (2011) and references therein) or dust formation in the interstellar medium itself (e.g. Jones et al., 2001; Michalowski et al., 2010, Krasnokutski et al., 2014) to explain the large observed dust masses. However, the systematic effects involved in determining dust masses from observations have been poorly studied. In particular, dust masses are measured in the far-IR and sub-mm, where observers must generally rely upon poorly-constrained extrapolations of mid-IR opacities, while dust production rates are usually measured in the mid-IR for AGB stars and supernovae. To alleviate this deficiency, we are exploring the effects of realistic ranges of the dust composition, emissivity, structure, temperature and size distributions on synthetic observations.

Dust masses are usually determined at (sub-)mm wavelengths, and therefore depend critically on the assumed dust properties in this range. However, the availability of good quality laboratory data is still limited, so many studies rely on dust models that extrapolate optical properties from shorter wavelengths. Laboratory studies have shown that these extrapolations perform rather poorly (e.g. Mennella et al., 1998, Coupeaud et al., 2011), and that the long-wavelength optical properties of interstellar dust analogues have a significant temperature dependence. Our study exploits these measurements as well as modern methods for determining dust cross-sections from optical constants which have been shown to provide more realistic output than compact spherical dust grains (Min et al., 2003, 2004).

Our preliminary results show that the mass-absorption coefficients typically used in astronomy may be underestimated by a factor $\gtrsim 4$, implying that interstellar dust masses are overestimated by a similar amount. Although this is significant, it is not by itself sufficient to eliminate the dust-budget problem in the early universe (Rowlands et al., 2014). Further work will consider the temperature dependence of the far-IR and sub-mm opacities. We will quantify any systematic biases in the dust mass determination by applying standard techniques to synthetic data.

Dust Processing in Elliptical Galaxies

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Dust evolves in galaxies through various processes. Since dust attenuation is more prominent in late-type galaxies than in early-type (or elliptical) galaxies, more efforts have been made on modeling dust evolution in late-type galaxies (e.g., Dwek 1998; Asano et al. 2013). On the other hand, dust has also been observed in elliptical galaxies through infrared emission and optical extinction (e.g., Goudfrooij et al. 1994). The physical state of the interstellar medium (ISM) in elliptical galaxies is different from that in late-type galaxies (smaller amount of cold gas and existence of prominent hot X-ray emitting component; e.g., O'Sullivan, Forbes & Ponman 2001). Thus, studying the dust in elliptical galaxies will potentially give us a clue for some processing mechanisms that can be only poorly constrained for late-type galaxies.

In this presentation, we reconsider the origin and processing of dust in elliptical galaxies (Hirashita et al. 2015). We theoretically formulate the evolution of grain size distribution, taking into account dust supply from asymptotic giant branch (AGB) stars and dust destruction by sputtering in the hot ISM, whose temperature evolution is treated by including two cooling paths: gas emission and dust emission (i.e., gas cooling and dust cooling). With our new full treatment of grain size distribution, we confirm that dust destruction by sputtering is too efficient to explain the observed dust abundance even if AGB stars continue to supply dust grains, and that, except for the case where the initial dust-to-gas ratio in the hot gas is as high as ~ 0.01, dust cooling is negligible compared with gas cooling. However, we show that, contrary to previous expectations, cooling does not help to protect the dust; rather, the sputtering efficiency is raised by the gas compression as a result of cooling.

We additionally consider grain growth after the gas cools down, in order to investigate the origin of the dust observed in elliptical galaxies. Dust growth by the accretion of gas-phase metals in the cold medium increases the dust-to-gas ratio up to $\sim 10^{-3}$ if this process lasts $\gtrsim 10/(n_{\rm H}/10^3\ {\rm cm}^{-3})$ Myr, where $n_{\rm H}$ is the number density of hydrogen nuclei. We show that the accretion of gas-phase metals is a viable mechanism of increasing the dust abundance in elliptical galaxies to a level consistent with observations, and that the steepness of observed extinction curves is better explained with grain growth by considering accretion.

In summary, a large fraction of dust is still destroyed in the hot ISM in elliptical galaxies even if we consider enhanced cooling by dust. However, the existence of dust in elliptical galaxies may be explained by subsequent dust growth by the accretion of gas-phase metals in the cooled gas, although we do not intend to deny a possibility that the dust is transported from outside by merging galaxies or accreting satellites.

Spatial distributions of dust in dusty galaxies at $z \sim 1$

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Do spatial distributions of dust grains in galaxies have typical forms, as do spatial distributions of stars? We investigate whether or not the distributions resemble uniform foreground screens, as commonly assumed by the high-redshift galaxy community. We use rest-frame infrared, ultraviolet, and Hα line luminosities of dust-poor and dusty galaxies at $z \sim 0$ and $z \sim 1$ to compare measured Hα escape fractions with those predicted by the Calzetti attenuation formula. The predictions, based on UV escape fractions, overestimate the measured Hα escape fractions for all samples. The interpretation of this result for dust-poor $z \sim 0$ galaxies is that regions with ionizing stars have more dust than regions with nonionizing UV-emitting stars. Dust distributions for these galaxies are nonuniform. The interpretation of the overestimates for dusty galaxies at both redshifts is less clear. If the Calzetti attenuation formula is inapplicable to these galaxies, perhaps the disagreements are unphysical; perhaps dust distributions in these galaxies are uniform. If the attenuation formula does apply, then dusty galaxies have nonuniform dust distributions; the distributions are more uniform than they are in dust-poor galaxies. A broad range of Hα escape fractions at a given UV escape fraction for $z \sim 1$ dusty galaxies, if real, indicates diverse dust morphologies and the implausibility of the screen assumption.

Dust in the Epoch of Cosmic Reionization:
a dust-poor galaxy at z=7.2

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Dust formation and evolution in the early Universe is now becoming a hot topic in galaxy evolution studies thanks to ALMA. We have recently observed a young star-forming galaxy at the redshift z=7.2, when Cosmic Reionization was thought to happen, with ALMA. We have successfully detected the [OIII] 88 micron emission line from HII regions in this galaxy, suggesting an oxygen abundance in this galaxy of ~10% of the Sun. On the other hand, no dust continuum emission is detected, contrary to a dust-rich galaxy found at a similar redshift z=7.5. This indicates a very low dust-to-metal mass ratio in the galaxy we observed, namely <20%. We will discuss a physical mechanism why there are dust-poor and -rich galaxies in the early Universe.

Observations of a hot molecular core in a nearby low metallicity galaxy

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Because cosmic metallicity is increasing in time with the evolution of our universe, interstellar chemistry in low metallicity environments is crucial to understand chemical processes in the past universe. Hot molecular cores are one of the early stages of high-mass star formation and they are one of the key astronomical objects to investigate complex gas-grain chemistry in dense interstellar medium. Gaseous molecules and atoms are frozen onto dust grains and experience grain surface chemistry in cold molecular clouds. As the core is heated by star-formation activities, reactions among heavy species become active on grain surfaces to form larger molecules, and various molecular species are released into the gas-phase in a warm and dense hot core region.

The Large Magellanic Cloud (LMC) is an excellent target to study chemistry in different metallicity environments thanks to its proximity (~50 kpc) and low metallicity (about one third of the solar neighborhood). However, observations of hot cores have been limited to Galactic sources due to lack of spatial resolution and sensitivity of radio telescopes.

Here we report the first detection of a hot molecular core outside our Galaxy based on radio observations with ALMA toward a high-mass young stellar object (YSO) in the LMC (Shimonishi et al. 2016, submitted). Molecular emission lines of CO, $C^{17}O$, HCO^+, $H^{13}CO^+$, H_2CO, NO, SiO, H_2CS, ^{33}SO, $^{32}SO_2$, $^{34}SO_2$, and $^{33}SO_2$ are detected from a compact region (~0.1 pc) associated with a high-mass YSO, ST11. The temperature of molecular gas is estimated to be higher than 100 K based on rotation diagram analysis of SO_2 and $^{34}SO_2$ lines. The compact source size, warm gas temperature, high density, and rich molecular lines around a high-mass protostar suggest that ST11 is associated with a hot molecular core.

We find that the molecular abundances of the LMC hot core are significantly different from those of Galactic hot cores. The abundances of CH_3OH, H_2CO, and HNCO are remarkably lower compared with Galactic hot cores by at least 1--3 orders of magnitude. In contrast, it is interesting that NO shows the higher abundance in ST11 than in Galactic counterparts despite the notably low abundance of elemental nitrogen in the LMC. We suggest that these abundances are characterized by the deficiency of molecules whose formation requires the hydrogenation of CO on grain surfaces. The observed characteristic chemical compositions of the LMC hot core are consistent with warm ice chemistry, which is suggested in previous infrared observations of ices in the LMC (Shimonishi et al. 2016).

In this presentation, we discuss physical and chemical characteristics of a hot molecular core in the LMC, particularly focusing on importance of grain surface chemistry on chemical processing in metal-poor environments.

Fitting extinction and polarization spectra of the diffuse ISM

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We present a model for the diffuse interstellar dust that explains the observed wavelength-dependence of extinction and linear polarisation of light. The model is set-up with a small number of parameters. It consists of a mixture of amorphous carbon and silicate grains with sizes from the molecular domain of 0.5nm up to about 500nm. Dust grains with radii larger than 6nm are spheroids. In the presence of a magnetic field, spheroids may be partly aligned and polarise light. We find that the spectra help to determine the upper particle radius of the otherwise rather unconstrained dust size distribution. Stochastically heated small grains of graphite, silicates and polycyclic aromatic hydrocarbons (PAHs) are included. For each dust component its relative weight is specified, so that absolute element abundances are not direct input parameters.

The dust model (2014A&A...561A..82S) is confronted against new FORS polarization spectra taken within the ongoing Large Interstellar Polarization Survey at the VLT. At present for 9 of these sight lines UV extinction properties are known from IUE. The polarization and extinction curves are fit simultaneously by the model. This allows deriving typical parameters of the dust in the diffuse ISM. We find that prolate rather than oblate grains gives a better fit to the observed spectra; the axial ratio of the spheroids is typically two and aligned silicates are the dominant contributor to the polarisation.

Development of the galactic dust emission code based on stochastic heating model and application to the AKARI far-infrared all-sky map

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In 2014, it was announced that cosmic microwave background (CMB) B-mode polarization generated by primordial gravitational wave was detected by BICEP2. However, it has been revealed that the detected B-mode signal had originated from dust emission. It showed that the targeted B-mode signals are embedded in the dust signal. In order to detect the CMB B-mode signal, improvement of all-sky dust emission map is mandatory. In same year, far-infrared all-sky image was revised by AKARI. AKARI has much better sensitivity, spatial resolution and wider wavelength coverage than those of the previous instrument, IRAS. The purpose of this study is revising dust emission map by fitting AKARI data with physical model of the Galactic dust emission.

Interstellar dust grains are heated primarily by absorption of ultraviolet, optical and near infrared photons of the interstellar radiation field (ISRF) which is an aggregation of photon fields emitted from Galactic stars, and loose their thermal energy by thermal emission in mid and far infrared wavebands. For large grains, since time interval between absorbing one photon and next photon is much shorter than radiative cooling time, temperatures of the large grains stay almost constant and their temperatures are defined by energy balance between heating and cooling. In other word, large dust grains stay in thermal equilibrium immersed in the ISRF. On the other hand, for smaller grains, time interval of photon absorption is much longer than radiative cooling time. Therefore, thermal state of small grains is far from thermal equilibrium. Usually, thermal state of the large grains is calculated under thermal equilibrium assumption and thermal state of the small grains is calculated by using stochastic treatment of absorption of ISRF photon. Since the border of the small and the large grains depends on the intensity of the ISRF, self consistent treatment of the border of the small and the large grains depending on the intensity of the ISRF is required.

In this study, we treat heating processes stochastically for all sizes of grains. We are developing the scheme to calculate the spectrum of the dust emission based on the results obtained by the above mentioned full stochastic treatment of thermal states of the dust grains. In order to obtain all sky distributions of dust column density and ISRF intensity, we are fitting these spectra to AKARI FIS all sky maps. In this presentation, we introduce this stochastic calculation method, obtained spectra and fitting results to the AKARI FIS maps. We also report that there is deviation of the dust emission spectrum from a single power law spectrum in mm-wave bands.

Silicate mineralogy of embedded YSOs and the ISM as revealed by mid-IR spectroscopy and spectropolarimetry

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Utilizing a range of instruments on 4-10 m telescopes we observed a large sample of objects in the mid-infrared (8-13 μm) in conventional spectroscopic as well as spectropolarimetric modes, with a spectral resolution of around 100. The target list comprises a few OH/IR stars where dust is formed, many envelopes or disks of embedded Young Stellar Objects (YSOs) where dust may begin its transformation into eventual planetary systems, and several objects viewed though dense and diffuse sight-lines of the interstellar medium (ISM). The latter is where dust resides between its formation in evolved stellar outflows and deposition in molecular clouds. In all objects we detect the typical absorption feature of amorphous silicates around 9.7 um. But clearly apparent in most objects is a second absorption band centred around 11.1 μm. Using a variety of approaches we confidently assign this feature to crystalline olivine, and probably the Mg-rich end-member forsterite. In some targets which have high S/N we also detect features around 10.4 and 11.9 um, supported by ISO and/or Spitzer observations of the same and/or related (by class) objects and all but confirming the forsterite identification. Modelling using a mixture of dust components and sizes shows that in most YSO and ISM cases the abundance of forsterite is around 1-2%. However, several sources show much stronger features and thus higher abundances. This includes the BN Object in Orion, the archetypal cold molecular cloud source, the massive YSO AFGL 2591, as well as the supposed Herbig Be star AFGL 2789 (V645 Cyg). We propose that crystalline silicates are essentially ubiquitous in the embedded YSO phase. Along with its presence in the ISM toward the Galactic Centre, particularly intriguing is the first detection of crystalline silicate in the diffuse ISM, toward the Wolf-Rayet star AFGL 2104. In discussing the significance of our findings in the context of the cosmic dust life-cycle we pose the following questions i) do they set back the evolutionary stage in which silicates are crystallized, perhaps to the embedded phase or even before within the ISM, and if so then how given the expected low temperature means the annealing time -scale is prohibitively long , or ii) do silicates ejected from the outflows of evolved stars retain some of their crystalline identity during their long residence in the ISM, and if so then how given the expected fast-acting amorphization processes, or iii) do silicates formed within the ISM – which they must do based on lifetime estimates – condense as partially crystalline and if so then how given the probable low temperature?

The Growth of Grains in the Interstellar Medium: Experimental Evidences

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Astronomical observations consistent with the growth of interstellar dust grains by accretion of gas-phase species are growing in number. They motivate the development of models that describe this stage in the life cycle of cosmic dust, and consequently laboratory experiments to determine the value of the parameters used by these models.

Our group is carrying out experiments on the condensation of refractory solids at temperatures relevant to the ISM. We have found that atomic and molecular species could react at cryogenic temperatures ($\leq$ 13 K) and accrete into solid, amorphous grains, without the need for an external source of energy. Thus were formed aggregates of SiO grains (Rouillé et al. 2013, Krasnokutski et al. 2014) and also aggregates of complex silicate grains (Rouillé et al. 2014), which exhibited a 10 μm absorption band similar to the corresponding feature attributed to interstellar silicate grains.

Consecutively we have started experiments on the co-condensation of atomic and molecular precursors of silicate and carbonaceous grains. Our goal is to determine whether the precursors would condense into mixed compounds or into separate phases. First experiments have shown that the co-condensation of $(SiO)_k$ ($k \geq 1$) and C_n ($n \geq 1$) leads to the formation of amorphous SiO grains that give rise to the typical 10 μm feature. The SiO grains show some signs of disproportionation with the presence of silicon nanocrystals $\approx$2 nm in size. The separate carbon phase of the condensate is also amorphous. The results of our latest experiments, which involve atomic and molecular precursors of a magnesium silicate together with C_n species ($n \geq 1$), will be presented and discussed.

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Hunting for invisible dust in the Milky Way

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Interstellar extinction is being used interchangeably with the term ``reddening'' as a light beam, crossing an interstellar cloud, losses relatively much more violet than red photons and thus a star, seen through a cloud seems redder than it is in fact. The photometric equation defines the main parameters which determine the apparent magnitude of a star: its absolute magnitude, distance and extinction along the sightline.

$$m - M = 5\log D - 5 + A_V$$

where the extinction term A_V is usually replaced by $R*E(B-V)$ where R is called the total-to-selective extinction ratio. In the earliest efforts to establish the above equation Trumpler (1930, Lick Obs. Bull., 14, 154) allowed also an additional, neutral (grey) term in the interstellar extinction, i.e. $A_V = R*E(B-V)+C$. He estimated the value of $C=0.19$ mag./kpc. The lack of reliable method of separation of both extinction terms affects strongly determination of distances to stars. The neutral term in the above equation is usually neglected.

Andriesse et al. (1978, MNRAS, 185, 771) considered condensation of dust around η Car and concluded that the condensate consists in part of large particles with a size of about 1 micron which can give an almost grey circumstellar extinction of 3 - 4 mag in the visual and UV range. I have considered the stars of the Orion Trapezium where distances were recently measured using the VLBI trigonometric parallaxes (Menten et al. 2007, Astr. Ap. 474, 515). Comparing two stars: HD37020 and HD37022 which should be at the same distance (~414pc) we found that the distances measured using our method, based on interstellar CaII lines (Megier et al. 2009, Astr. Ap., 507, 833), coincide with the trigonometric ones while the spectrophotometric distance of HD37020 is twice as big. Very good spectra from HARPS-N leave no doubt that the Sp/L's of both stars are correct and very similar. In this situation the only factor explaining the observed inconsistency is the grey extinction term.

An extensive survey of the O star's spectra demonstrates also that CaII distances usually agree with the trigonometric ones while spectrophotometric distances are often much larger (never smaller). Also this phenomenon may be interpreted only in terms of the additional, grey, extinction, observable in some of targets. The latter must be caused by relatively big size dust grains. The grey term does not seem to be related to any other interstellar features, currently observable. This fact proves that spectrophotometric measurements of distance, necessary to study the Galactic structure, are very unreliable because we never know the amount of possible grey extinction which acts in the photometric equation exactly in the same way as distance, attenuating all wavelengths.

A Look at Galactic Dust Emission via the *Akari* All-Sky Surveys and the *Planck* Anomalous Microwave Emission Map

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The anomalous microwave emission (AME) continues mystify those studying dust at both the infrared wavelengths, and on into the microwave domain. What physical mechanism/s produce this strongly dust-correlated foreground to pervade in the microwave domain? While we are not able to answer this question yet, we do provide evidence against one of the popular hypotheses: electric dipole emission from spinning polycyclic aromatic hydrocarbon molecules (PAHs). The AKARI space telescope, during its lifetime up until the cryogen depletion, contributed a wealth of data across the whole sky. This includes near to mid-infrared spectroscopy, an all-sky point-source catalog, and most important for this study – seven all-sky imaging surveys. The Far Infrared Surveyor maps provided (with their release in 2014) maps covering the typical thermal peak of dust emission (at 65, 90, 140, and 160 μm), though with higher angular resolution and a longer wavelength reach than IRAS. More critical for this study, are the Infrared Camera (IRC) all-sky maps, centered at 9 and 18 μm, which have just undergone a pre-release, and are in the community data-verification phase. The 9 μm band offers unique wavelength coverage, including several major unidentified infrared band (UIR) features, otherwise called "the PAH features". We have undertaken a comparison of the AKARI 9 μm data, as well as the other 6 AKARI all-sky maps, with the AME map released as part of the Planck Collaboration Public Release 2 data set. IRAS data, and Planck/High Frequency Instrument data, are incorporated as well for comparison and for constraining the Rayleigh-Jeans tail of the dust SED. Via 1-degree-scale aperture photometry, we demonstrate that, for 98 galactic AME hot-spot coordinates highlighted by the Planck Collaboration, there is no preferential correlation between the AME and the AKARI 9 μm band (or the IRAS 12 μm band). We do however find a peculiar pattern among all of the mid infrared bands sampled, wherein the relationship between the AME and the MIR has a slightly different trend for regions towards the Galactic center than for longitudes towards the outer galaxy. As a side-product of the investigation, we provide a look at the AKARI/IRC data quality relative to the IRAS all-sky maps.

Deuterated organic dust in space

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Deuterium (D) is one of the light elements created in the big bang. D is destroyed by nuclear reactions in stellar interiors, a process called astration. Its abundance is thus directly related to the primordial nucleosynthesis and the chemical evolution of the Galaxy. However, the observed D to hydrogen (D/H) ratio of the interstellar gas does not show any systematic trend with metallicity but shows a considerable scatter, which cannot be accounted by any chemical evolution models. In fact, UV observations suggest that D may be deleted onto dust grains (Linsky et al. 2006), leading to a hypothesis that missing D may be harbored in interstellar polycyclic aromatic hydrocarbons (PAHs) and 30% of PAHs may contain D (Draine 2006). While ISO/SWS observations report marginal detection of bands attributable to deuterated PAHs, suggesting that 30% of PAHs may have D in them (Peeters et al. 2004), being in agreement with the hypothesis, recent observations of AKARI put a more stringent upper limit on the content of D in PAHs as 3% (Onaka et al. 2014). Further investigations on a larger sample suggest that deuterated PAHs are not commonly present in the ISM (Doney et al. 2016). Accurate measurements of the band strengths of deuterated PAHs support the conclusion (Mori et al. in prep.), while deteronated PAHs may account for the observations (Buragohain et al. 2015). In this presentation, the latest results of AKARI observations of possible deuterated PAH features are discussed together with absorption spectroscopy of organic features in the ISM, investigating a possibility of D hiding in larger organic materials in the ISM.

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Structure and chemistry of dust from laboratory perspective

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From observations, chemical composition of crystalline silicate is known that concentration of Mg is high and Fe is extremely low. On the other hand, from vast studies of meteorites, Mg/Fe ratio of olivine and pyroxene in meteorite is not converged to a certain value. Why observed crystalline silicate shows chemistry of Mg-condensed and Fe-depleted is one of the biggest unsolved problem from early days of astromineralogy. So, we prepared amorphous pyroxene with chondritic Mg/Fe ratio, and then heated it to crystallize. On several steps of crystallization (heating) process, Mg/Fe ratios in crystalline and amorphous phases were analyzed from IR spectroscopy. As a result, we found that Mg is moved into the crystalline phase and Fe is remained in the amorphous phase. This results suggested that crystallization process itself is the origin of fractionation of Mg and Fe in cosmic dust.

Another topic is on anomalous structure of pyroxene crystallized from amorphous phase. We gave this sample the name of HAS (Heated Amorphous Silicate). Well known structures of normal pyroxene are proto-, clino- and ortho-pyroxene. Difference of these structures is originated from the stacking sequence along to a*-axis. We can identify these structures from the FIR features. However, HAS shows different FIR spectrum from any of these types. And, from the TEM analysis of HAS, we confirmed that the stacking sequence of a*-axis was disordered. In other words, HAS has a very peculiar structure in which an axis is amorphous and others are crystalline. More interestingly, we found that HAS can fit some spectra of observed AGB stars better than other pyroxenes. FIR observations with Herschel have found the 69 micron feature of forsterite in some objects. However, at this moment, we do not have any positive report which confirmed detections of FIR feature of clino- and ortho-enstatite. This can be explained, if pyroxene grain in space would be crystallized from amorphous phase, and it would have an HAS-like structure.

Silicon carbide in a protoplanetary disc: the peculiar case of SVS13

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We report the detection of silicon carbide, amongst other materials such as amorphous silicates, crystalline forsterite, crystalline enstatite, and annealed SiO_2, in the circumstellar environment of the low-mass, embedded pre-main-sequence close binary system SVS13. These dust species are clearly detected in absorption and SiC is required to model adequately both N-band (8−13 μm) total intensity and polarisation spectra. SVS13 is the first young star ever to have been associated with the dust component which has so far only been detected in the spectra of C-rich evolved star atmospheres. The uniqueness of the spectrum suggests that we are either catching SVS13 in a short-lived evolutionary phase and/or that there is something special about this object. We are now embarking on the search for similar sources in order to gain clearer insight into the mechanism behind the very unusual spectrum.

Probing magnetic fields and dust content in Protoplanetary Disks using mid-infrared imaging polarimetry

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Polarimetry is a powerful tool to probe both magnetic fields and dust content in protoplanetary disks. As part of our broad program to understand the properties of magnetic fields in young disks and their environments, we carried out mid-IR polarimetric observations with CanariCam at the GTC of several Herbig Ae star disks, including AB Aur, HL Tau, and CQ Tau providing new insights into their physical properties.

AB Aurigae newly obtained datasets allow both to estimate stringent boundaries on the magnetic strength in the inner ~70 AU region and its spatial structure at a ~35 AU angular resolution. In the cases of CQ Tau and HL Tau, we also tentatively detect in the polarimetric signal signposts of the presence of magnetic fields in the inner regions.

In this paper, we will present the latests results from the analysis of CanariCam polarimetric data with emphasis on the key information they provide about the inferred magneto-rotational instability (MRI) mechanism, currently the best candidate for the source of disks viscosity. Finally, we show how the detection; or not; of 10 um scattered light by dust grains located at the surface of the disks carries also very new and crucial information about the size of the largest dust particles in these regions; establishing another possible connection with the MRI process through vertical mixing efficiency.

Properties of circumstellar matter around RW Aur A deduced from visible light photometry and polarimetry during dimming in 2014-2016

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RW Aur is binary star consisting of two T Tauri stars. Separation of components is relatively small — 1.4 arcsec, which complicates study of individual stars. There is also evidence for interaction between components. Component A underwent recently 2-year long dimming presumably induced by a dust cloud passing in line of sight. We present results of RW Aur resolved UBVRI photometry and VRI polarimetry campaign performed during dim state in 2014-2016 with the 2.5-m telescope of Caucasian Observatory of SAI MSU. In maximum eclipse magnitude dropped by more than 5^m meanwhile polarization increased up to 30% in I band. Our data indicates that in maximum eclipse most of optical radiation from component A is coming from circumstellar disk. Color-magnitude and polarization-magnitude curves allow to make conclusions about obscuring and scattering matter.

Dust Growth in Protoplanetary Disks and Reexamination of the Particle Interaction Model

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In protoplanetary disks, fluffy dust aggregates are formed as a result of their collisional growth. Our recent numerical simulations of dust aggregate collisions have shown that dust aggregates are surprisingly sticky. For example, dust aggregates made of sub-micron icy monomer particles can stick to each other even at high-speed collisions with v ~ several tens m/sec. This sticky property of dust aggregates is very helpful for their growth and/or planetesimal formation in protoplanetary disks. However, collisional outcomes in the numerical simulations would be dependent on the particle interaction model used in the simulations.

In this study, we reexamine the previous particle interaction model to construct a better interaction model and a more accurate numerical simulation of dust aggregate collisions.

For the reexamination, we perform molecular dynamics simulations describing a collision between monomer particles. In these MD simulations, each spherical solid particle consists of a large number of molecules ($N \sim 10^5$-10^8). Our MD simulations show that collisions between monomer particles always cause stronger energy dissipation than the predictions by the previous interaction model. Using the results of a large number of MD simulation runs with various particle sizes and collision speeds, we construct a better particle interaction model, by including an additional energy dissipation term in it. The additional energy dissipation in the particle interaction model is expected to make the dust aggregates more sticky.

Next, by implementing the new particle interaction model to the simulation code, we perform numerical simulation of dust aggregate collisions to see how the additional energy dissipation enhances the stickiness of dust aggregates. All these results will be reported in detail in my presentation.

Dust properties of the zodiacal dust bands observed with AKARI

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The zodiacal emission is the thermal emission from the interplanetary dust and the dominant diffuse radiation in the mid- to far-infrared (IR) wavelength region. It was found that there are many small-scale structures in the zodiacal emission distribution, such as dust band pairs at the ecliptic latitudes of $\pm 1.4^\circ$, $\pm 2.1^\circ$, and $\pm 10^\circ$, apart from a smooth background distribution. It has been proposed that recent disruption events among multi-kilometer bodies in the main asteroid belt, which would have occurred within the last several million years, may be major supply sources of dust particles.

The dust properties of the asteroidal dust bands at the far-IR wavelengths remain poorly known because the zodiacal emission rapidly becomes faint at longer far-IR wavelengths. We investigate the geometry of the small-scale dust-band structures in the far-IR all-sky maps observed with the Japanese infrared satellite AKARI. AKARI clearly detects the zodiacal dust-band structure at 65 and 90 μm bands. We derived the heliocentric distances of dust bands from the phase difference based on the AKARI 90 μm map: 1.86 au and 2.16 au for the $\pm 1.4^\circ$ and the $\pm 10^\circ$ bands, respectively. Although the heliocentric distances estimated with the AKARI far-IR data are consistent with that of previous studies, the results of the $\pm 1.4^\circ$ band is slightly larger than those derived in previous studies. This suggests that the larger grains at > 2 au are dominant for the $\pm 10^\circ$ band, while smaller dust grains at < 2 au contribute to the $\pm 1.4^\circ$ dust band. Since AKARI results are mainly based on the 90 μm and 140 μm band data, large dust particles at further heliocentric distances (> 2 au) contribute to the AKARI results more significantly than that in the previous results based on the observations at 25 μm and 60 μm.

We will show faint dust-band structures in the AKARI maps, in addition to major 3 bands, by using image-enhancing techniques, and discuss the dust properties of the zodiacal dust bands based on the far-IR observations.

Physical Properties of Zodiacal Dust Estimated from AKARI Observations and Orbital Calculations

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In our solar system, there are many interplanetary dust particles (IDPs) originating mainly from asteroid collisions and activity of comets. These particles gradually decrease its angular momentum and drift radially due to the absorption and re-radiation of the sunlight (Poynting-Robertson effect; e.g. Burns et al. 1979). Investigating the properties of the zodiacal dust particles may reveal the properties of parent bodies and the creation process of them.

The thermal emission from the IDPs is called the zodiacal light. AKARI, the first Japanese infrared astronomical satellite, has observed the zodiacal light in the leading and trailing direction of the Earth orbit during a period from 2006 May 8 to 2007 August 28. From analysis of AKARI data, we found that the observed surface brightness in the trailing direction of the Earth orbit is greater than that in the leading direction by 3.7% in band at 9μm and 3.0% in band at 18μm. This result is consistent with previous observations with IRAS (Dermott et al. 1994). This asymmetry is thought to come from the asymmetric dust distribution made by the IDPs trapped by MMRs of Earth orbit.

In order to reveal dust properties resulting in the asymmetry of dust distribution, we numerically integrated dust orbits for restricted three body problem of Sun, Earth and a dust particle. The orbital evolution can be characterized by the parameter β which represents the strength of the radiation force compared to the gravitational force from the Sun. The parameter β can be defined as a function of dust properties such as dust radius s and material density ρ. In our calculations, particles are set to be 0.001-0.1 in β (corresponding to 3-300μm in radius with $\rho = 2$g/cc) and their initial orbits are determined according to the origins of main-belt asteroids and Jupiter-family comets.

We found that larger particles are easier to be trapped by MMRs and make high density region in the dust distribution. However, larger particles are easier to be trapped by outer resonances which hardly contribute to the asymmetry in the surface brightness. In consequence, the observational asymmetry can be explained by particles with radius $s \lesssim 2.9\mu$m for main-belt origins and with $s \lesssim 7.2\mu$m and $s \gtrsim 285\mu$m for cometary origins.

In this poster, we show the results of analysis of AKARI observations and orbital calculations and discuss the origin and typical size of zodiacal dust. We also would like to discuss the effect of the gravity from other planets such as Jupiter using additional calculations.

The Effect of Oscillation Sheath on the Movement of Lunar Dust

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Dust levitation on the lunar surface can cause troubles, such as abrading key component, compromising seals, disabling sensitive materials and so on, for astrovehicle and astronaut. The main reason for the levitation of lunar dust is electrostatic transport which caused by the intense electric field in lunar terminator region. It can be found that the sheath on lunar surface is an oscillation sheath and it plays a significant role in the movement of lunar dust in terminator region. In order to study the effect of oscillation sheath on the movement of lunar dust, a finite element numerical simulation method, which is based on Immersed Finite Element Particle-In-Cell method, is developed. The Immersed Finite Element method adapts Cartesian meshes which is independent of the interface for resolving the electric fields accurately in a domain with complex boundary/interface geometry and the Particle-In-Cell method is one of the major methods for electromagnetic field simulations. The research work on the oscillation sheath in lunar terminator region and its effect on the movement of lunar dust has a significant meaning for the dust removal/prevention design of spacecraft.

Experimental study on compression property of regolith analogues

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Porosity structure inside a planetary body and of surface regolith plays important role in collisional and thermal evolution of the body. The porosity structure is changed by presence of rocks, seismic shaking, thermal evolution, and self-gravity in particular. Porosity structure caused by soil pressure due to self-gravity gives an initial, most-possible porous structure of the body consisting of granular material. Therefore, understanding compression property of granular material and obtaining general formula for the compression property of granular material in various environments is required to estimate the porosity structure of planetary bodies.

We conducted compression experiments of various kinds of samples. Each sample had different composition and size distribution. Main compositions of the samples were Al_2O_3 and SiO_2 and the particle size is smaller than 100 μm. We sieved these samples into cylindrical container and the top part of the bed over the height of the container was leveled off. The initial porosity of the granular bed was different for different samples and it was in the range of 0.54-0.86. Then we compressed the sample by compressive testing machine. The applied pressure was ranged from 10^4 to 2×10^6 Pa. It was shown that the slope of compression curve becomes shallower as the frictional force between particles increases. The samples with wider size distribution were compressed easier (Omura et al., ISTS, 2015).

The soil pressure is lower than 10^4 near the surface of small bodies or in the bodies with diameter less than ~20 km. Therefore, we conducted new compression experiments. We expanded the pressure range to lower than 10^2 Pa and we found that compaction process of granular bed is divided into following three regimes: (1) Pressure is lower than the strength of granular bed accordingly the granular bed isn't compacted, (2) Granular bed is compacted but the decrease in porosity is gradual, and (3) The porosity decline-rate becomes larger than the regime 2. For example, in case of silica sand of 18 μm median diameter, the threshold pressure between regime 1 and regime 2 was ~50 Pa and that between 2 and 3 was ~200 Pa.

Physical Conditions of Supernova Ejecta as Viewed from the Measured Sizes of Presolar Al_2O_3 Grains

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A few particles of presolar Al2O3 grains with sizes larger than 0.5 μm are considered to have been formed in the ejecta gas of core-collapse supernovae (SNe). With the aim at clarifying the formation condition of such submicron-sized presolar Al2O3 grains, we calculate the condensation process of Al2O3 grains for wide ranges of the density and cooling rate of the gas. We first show that the average radius and condensation efficiency of newly formed Al2O3 grains are nicely described by a non-dimensional quantity Lamda_on, defined as the ratio of the timescale on which the supersaturation ratio increases to the collision timescale of reactant gas species at dust formation. Then we find that the formation of submicron-sized Al2O3 grains requires at least 10 times higher gas densities than those obtained from one-dimensional SN models. This indicates that presolar Al2O3 grains identified as SN-origin might be formed in dense gas clumps, allowing us to propose that the measured sizes of presolar grains can be a powerful tool for constraining the physical conditions in which they formed. We also briefly discuss the survival of newly formed Al2O3 grains against destruction in the shocked gas within supernova remnants.

Dust Disks around Pulsars

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The possible presence of a dust disk around pulsars has been suggested by the detection of planets first around PSR B1257+12 and then around PSR B1620-26 and PSR J1719-1438. Such a disk could be formed from the fallback of supernova ejecta, i.e., the ejecta from a core-collapse supernova could be captured by the gravitational field of the newly formed neutron star and therefore fall back onto the star and form an orbiting disk, provided that the angular momentum of the fallback material is sufficiently large so as to prevent direct infall onto the star. Heated by the ultraviolet and X-ray photons converted from the spin-down energy of the pulsar, the dust in the disk is expected to radiate thermally in the infrared (IR). However, the search for dust thermal emission from the near-IR to millimeter (mm) so far has mostly been unsuccessful, except the *Spitzer*/IRAC detection of the 4.5 and 8μm dust emission in two magnetars.

We perform a thorough examination of the IR-to-mm observational data reported for pulsars in the literature and present a physical dust model for the disks around pulsars, with reasonable dust compositions, size distributions, dynamics, and heating and cooling mechanisms taken into account. We place upper limits on the dust masses of pulsar disks and discuss their implications for the formation of planets around pulsars.

Radiation feedback in dusty clouds with two-fluid

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Abstract & Conclusions: We have investigated the impact of photoionization and radiation pressure on a dusty star-forming cloud by one-dimensional radiation two-fluid (gas and dust) hydrodynamic simulations, which include absorption and re-emission of photons by dust. We find that, when dust-to-gas mass ratio is low, radiation pressure creates dust-free gas-rich regions. This state has been predicted by Inoue (2002). For a high dust-to-gas mass ratio, a dust-free gas-rich region is not created and a dust-gas-free region (a vacuum region) is created. This difference seems to be caused by the amount of dust and the optical depth of dust within an expanding shell. First, when there is not enough dust to drag gas, the gas is left behind by dust. Second, when the optical depth of dust is not large enough and radiation pressure gradient force is not much stronger than thermal pressure gradient force, dust-free gas flows back to a vacuum region and the dust-free gas-rich region is created.

Methods: In our simulations, we place a radiation source at the centre of a spherically symmetric gas distribution. We solve the radiation transfer equation including following processes: chemical reactions, heating-cooling processes of gas, and radiation pressure. The species we include in our simulations are H, He, electrons, and dust. Since it is difficult to calculate the differential velocity between dust and gas, we use a first order approximation described by Laibe & Price 2014.

Results: To study radiation feedback in star-forming clouds, we model each cloud as a Bonnor-Ebert sphere. We present density and dust-to-gas mass ratio profiles of each cloud at $t = 0.18$ Myr in Fig. 1. The difference between Cloud 1 and 2 is the initial condition of dust-to-gas mass ratio. To investigate the effect of two-fluid treatment, we perform simulations with one-fluid and two-fluid. Simulations in which we solve hydrodynamics with two-fluid are labelled "two-fluid". Simulations in which we solve hydrodynamics with one-fluid are labelled "one-fluid". Our results show that the dust-free gas-rich region is created in Cloud 1 inside 12 pc. On the other hand, a dust-free gas-rich region is not created and simulation results with one-fluid and two-fluid are indistinguishable in Cloud 2.

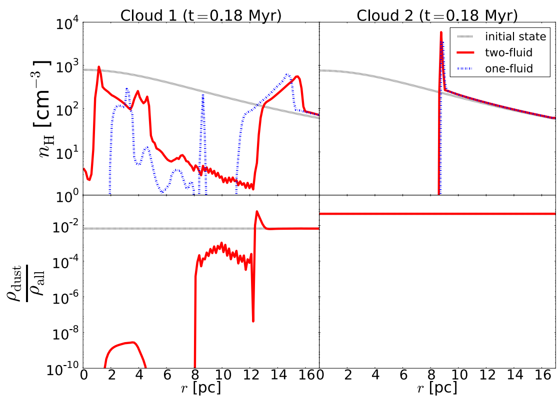

Figure 1: Density (top) and dust-to-gas mass ratio (bottom) profiles at t=0.18 My.

Crystalline silicates in external galaxies

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Observational evidence has long supported that most of the interstellar silicates in galaxies are *amorphous*, meaning that while the basic silicate tetrahedra are present to give rise to the 9.7 and 18 μm Si-O stretching and O-Si-O bending modes, the lattice shows defects, and the chemical composition may be non-stoichiometric. While crystalline silicates may form around evolved stars at temperatures sufficiently high to allow for annealing, it is thought that the harsh interstellar environment quickly amorphitizes any crystalline silicates, most likely through bombardment by the heavy ions in cosmic rays (Demyk et al. 2001; Jäger et al. 2003; Brucato et al. 2004; Bringa et al. 2007; Szenes et al. 2010), and a firm upper limit of 2% on the crystalline fraction of silicates was derived based on the absence of substructure in the 9.7 μm feature (Kemper et al. 2004; Kemper et al. 2005).

Traditionally, silicates in the interstellar medium of external galaxies were also assumed to be completely amorphous. The first detection of crystalline silicates in external galaxies was reported by Spoon et al. (2006) in 12 out of a sample of 77 starbursting Ultraluminous Infrared Galaxies (ULIRGs), with Roussel et al. (2006) adding a 13th galaxy, NGC 1377, to this sample. More recently, Willett et al. (2011) analysed mid-infrared spectra of 51 OH megamaser galaxies, finding that 19 of them show one or more of the crystalline silicate features between 11 and 28 μm in absorption, while Stierwalt et al. (2014) report the detection of crystalline silicates in 6% of the objects in a sample of 244 LIRG nuclei. The most spectacular detection is done by Aller et al. (2012), who report interstellar silicates with a crystallinity of ~95% in a foreground absorbing galaxy towards a quasar background source. The only other study quantifying the crystalline fraction is the aforementioned work by Spoon et al. (2006), who report a crystalline fraction of 6-13% in their interstellar silicates (when detected), using the definition for crystallinity by Kemper et al. (2004). A very simple model of the production of crystalline silicate dust by evolved stars, at a level of 10-20% of the total silicate dust production by these stars, is able to explain the observed crystallinities at about 30 Myr after the start of a starburst (Kemper et al. 2011). In general, the model can be used to estimate the transition time and interstellar conditions, such as cosmic ray fluence, based on observational constraints on the crystalline fraction.

However, the small number of known interstellar crystalline silicate fractions in star-forming galaxies limits the usefulness of such a model. We have devised a method to measure the crystalline fraction of silicates in a large number of galaxies quickly and easily. For this purpose, we are performing radiative transfer models of starburst galaxies, with varying crystalline fractions of their interstellar silicates using the SKIRT radiative transfer code (Camps & Baes 2015), and identified a method to determine the crystallinity of silicates in starburst galaxies directly from (archival) infrared spectroscopy.

Silicate Dust Extinction of Active Galactic Nuclei

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AGNs are thought to be surrounded by an optically thick dust torus. Correction for the torus extinction is crucial to recovering the AGN intrinsic spectral energy distribution and to revealing nature of the central engine. In the diffuse interstellar medium of the Milky Way, $A_V/\Delta\tau_{9.7}$, the ratio of the visual extinction (A_V) to the optical depth of the silicate absorption at 9.7μm ($\Delta\tau_{9.7}$) is about 18, and to the Galactic center direction, this ratio is smaller by a factor of two, $A_V/\Delta\tau_{9.7} \approx 9$. In AGNs, this ratio is substantially reduced to approximately 6.4, only a third of the Galactic value, probably due to the preferential destruction of small grains by X-ray/UV photons from the central engine and/or the coagulational growth of dust in the dense circumnuclear regions of AGNs. In this work, we investigate how the ratio $A_V/\Delta\tau_{9.7}$ changes over a wide range of silicate dust sizes. It is found that $A_V/\Delta\tau_{9.7}$ peaks at $a \approx 0.2$μm, with a peak value of ~5.6, confirming that the observed small ratio $A_V/\Delta\tau_{9.7}$ in AGNs could be explained in terms of larger grains. In view of the presence of carbonaceous dust and its contribution to the visual extinction, we argue that the observed low $A_V/\Delta\tau_{9.7}$ ratio of AGNs could be explained by dust with a>0.2μm. The effects of the silicate dust shape and composition on $A_V/\Delta\tau_{9.7}$ are also discussed and found to be negligible.

A systematic study on dust in early-type galaxies

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Historically early-type galaxies (ETGs) are thought to be almost devoid of dust because their interstellar space is likely to be dominated by hot X-ray plasma, which provides harsh environments for survival of dust. In addition the bulk of stars in ETGs are uniformly old, which cannot efficiently replenish dust to the interstellar medium. However recent mid- and far-infrared (IR) observations, including Spitzer, AKARI, and Herschel, have confirmed that some ETGs contain an observable amount of dust, conflicting with the above expectation. Although some mechanisms for providing ETGs with dust are proposed, their origins are not fully understood.

With the AKARI mid- and far-IR all-sky surveys, we performed a systematic study of dust in ETGs in order to reveal their origins. We study a volume-limited (D<100 Mpc), unbiased sample of 7857 nearby ETGs, selected from the HyperLeda catalogue. For example, among the sample galaxies, 2703 and 1593 ETGs are significantly detected in the 90 μm and 140 μm bands, respectively. Combining the AKARI result with other wavelength data obtained by near-IR, CO and 5 GHz observations, the properties of dust in ETGs such as dust temperature, dust mass and the dust-to-gas mass ratio are investigated. We also discuss a possible connection between dust and nuclear activities in ETGs.

Understanding the evolution of galaxies in HCG92 (Stephan's Quintet) based on AKARI, Spitzer and Herschel observations

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Galaxy evolution plays a major role in the evolution of the Universe. Observations have shown that interactions with nearby galaxies have a great impact on the star-formation and nuclear activities of an individual galaxy. It is therefore important to understand the effects of interactions for the study of galaxy evolution.

Hickson Compact Groups (HCGs) provides a good collection of targets for studying interacting galaxies. The number densities of HCGs are as compact as the center of a cluster of galaxies, and 43% of HCG galaxies show tidal structures such as bridges or tails.

HCG92 (Stephan's Quintet) is the best studied compact group of galaxies and numerous observations at various wavelengths have been carried out. However, the physical properties of the interstellar dust have yet to be explored. In this work, we combined AKARI, Spitzer and Herschel data to derive their NIR to MIR spectra and fit their SED with dust models in a wide infrared range to study the properties of dust in the member galaxies.

In the HCG92c central region, there is no clear detection of the Unidentified InfraRed (UIR) feature, but the 9.7μm silicate absorption band and red continuum are observed, indicating the existance of the AGN. On the other hand, we detected a weak sign of star-formation in the outskirts of HCG92c. We also analyzed a tidal dwarf galaxy candidate ISOCAM SOURCE-B (SQ-B) and detected UIR band emission, but the derived dust temperate is low ($\sim$18K) and no other clear evidence for the star-forming activity is found at SQ-B.

In this presentation, we will discuss the impact of the interaction on the galaxy evolution based on the infrared observations of HCG92.

Measurement of Near-Infrared Diffuse Galactic Light

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We present new results of near-infrared diffuse Galactic light (DGL) from our recent study[1,2,3]. The DGL consists of scattered light and thermal emission from interstellar dust grains illuminated by the interstellar radiation field. Therefore, the DGL measurement is useful in constraining some properties of interstellar dust, such as size distribution, albedo, and scattering asymmetry of dust grains.

In the diffuse interstellar medium in high Galactic latitudes, the DGL observation has been limited due to its faintness, particularly in the near-infrared wavelengths. We thus reanalyze all-sky maps obtained from Diffuse Infrared Background Experiment (DIRBE) onboard the *Cosmic Background Explorer* (*COBE*) satellite in the four near-infrared photometric bands (1.25, 2.2, 3.5, and 4.9 μm). As a result, we succeed in detecting the near-infrared DGL as a component that linearly correlates with interstellar 100 μm emission.

At 1.25 and 2.2 μm, our results are marginally consistent with the expected spectrum of scattered light assuming a recent interstellar dust model[4]. At 3.5 and 4.9 μm, thermal emission from stochastic heating of very small grains and fluorescence of polycyclic aromatic hydrocarbon (PAH) dominate the DGL. Compared with a recent thermal emission model in the diffuse interstellar medium[5], we constrain the mass fraction of very small grains and PAH to the total dust to be more than $\sim 2\%$.

We also find that the intensity ratios of DGL to 100 μm emission are higher toward low Galactic latitudes at 1.25 and 2.2 μm. Since this trend is expected from the forward scattering characteristic of dust grains, we compare the obtained latitude dependence with the scattered light model taking into account the scattering asymmetry. The derived forward scattering characteristic is several times stronger than that expected from the recent dust model[4]. In addition to the scattered light component, latitude dependence of possible thermal emission in the diffuse interstellar medium may contribute to the obtained latitude dependence.

[1]Sano et al. 2015, ApJ, 811, 77
[2]Sano et al. 2016, ApJ, 818, 72
[3]Sano et al. 2016, ApJL, 821, L11
[4]Weingartner & Draine 2001, ApJ, 548, 296
[5]Draine & Li 2007, ApJ, 657, 810

Modelling the Diffuse Ultraviolet Emission around Orion

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We have studied the diffuse Ultraviolet (UV) radiation near M42 using All-Sky Imaging Surveys (AIS) of Galaxy Evolution Explorer (GALEX) in the Far-UV and Near-UV. The main source of this diffuse emission is the scattering of starlight from the Trapezium stars by dust in front of the nebula. The dust grains are known to be anomalous in Orion with $R_V = 5.5$. We compare the UV diffuse emission with the Mid-Infrared (MIR) and Far-Infrared (FIR) diffuse emission observed by the Hershel Space Observatory and the Akari satellite for the same locations. The intensity ratios in the different MIR and FIR bands for each of the locations enable us to determine the type of dust contributing to the diffuse emission as well as to derive a more accurate 3D distribution of stars and dust in the region. We have used these results to model the NUV and FUV scattering around Orion and to test the validity of existing models.

Grain alignment in the protoplanetary disks

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Magnetic fields play crucial roles in the evolution of accretion disks; however, the structure and strength of magnetic field have not yet been constrained well by observations. In the ISM field, the polarized emission from dust grains is often used as a diagnosing tool of the magnetic field, since non-spherical grains tend to be aligned with respect to the magnetic field. If dust grains in protoplanetary disks are actually alined with the magnetic field, we can constrain the magneticfield in disks by using dust polarimetry observations. This motivated us to study the grain alignment in the disks. We estimate several timescales relevant for the grain alignment in disks based on the state-of-the-art alignment theory of the radiative torque. As a result, we show that the grain alignment is not expected at the midplane of the disk owing to the strong damping effect of gas drag force as well as an inefficiency of internal relaxation. However, in the surface layer of disks, dust grains might be aligned with magnetic fields depending on the amount of superparamagnetic, or ferromagnetic, inclusions.