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Preface

For dust you are and to dust you will return

Genesis 3:19

Dust exists everywhere—in inter- and circum-planetary, inter- and circum-stellar, and even intergalactic, space—since its first creation in the Universe. The first generation of cosmic dust must have been produced less than 1 Gyr after the Big Bang, for the reason that more than 10^8 solar masses of dust has been found in distant QSOs powered by super-massive black holes sitting at the center of a galaxy at that age of the Universe. Since then dust has been continuously produced, processed, and destroyed in every single phase of the Universe. Dust forms by condensation out of rapidly cooling materials that flow outward from a dying star. Once injected into the interstellar medium or even into intergalactic space, dust suffers a variety of processes: ultraviolet irradiation, sputtering by cosmic rays, and shattering in a turbulent diffuse medium. In a dense medium, dust grows due to the accretion of atoms and molecules as well as coagulation, it catalyzes molecular reactions on its surface, and occasionally encounters the formation of a star. Star formation is both a sink and a source for cosmic dust; A portion of materials left over from star formation condenses into dust, which subsequently conglomerates into planetesimals. After the dissipation of the leftover materials, comets and asteroids supply dust into a circumstellar disk by ice sublimation and mutual collisions until the death of the star, which is, in turn, a sink and a source for cosmic dust. This is the life cycle of cosmic dust.

To fully understand the life cycle of cosmic dust resembles putting together all the pieces of a jigsaw puzzle, because there is a considerable diversity of information on dust-related phenomena. Such diversity prevents the depiction of a complete picture of cosmic dust, due to the fact that many dust researchers are working independently in each field without any collaboration on the different aspects of cosmic dust. To overcome this adverse situation, we have been organizing a “Cosmic Dust” meeting as a session of the annual meeting of the Asia Oceania Geosciences Society (AOGS) since 2006. The Cosmic Dust series has been recognized as the most successful session of the AOGS Planetary Sciences Section. In 2012, the time was ripe for being free of the organizing restrictions of the AOGS meeting. Therefore, the 5th meeting of the Cosmic Dust series was totally independent of any international conference. As with the past meetings, the 5th meeting on Cosmic Dust was held in a relaxed and joyful atmosphere at the Center for Planetary Science (CPS), Kobe, Japan, between August 6–10, 2012. Seventy one experts in a variety of cosmic dust fields attended the meeting from Japan, Mainland China, Taiwan, Hong Kong, India, USA, France, Germany, Italy, Denmark, Finland, Poland, and Russia. The meeting ended with great success in achieving its primary objective, which was to provide an opportunity to develop human relations and scientific interactions among the participants. We should, however, mention that it was not straightforward to organize such a great international meeting by ourselves from scratch. We are very indebted to the local organizing committee of the meeting: Carsten Güttler, Hiroshi Kobayashi, Hiroki Senshu, Aki Takigawa, Koji Wada, and Tetsuo Yamamoto, for their dedication to make the meeting successful, and to the staff members of Kobe Convention & Visitors Association: Katsuhiko Fujita and Yoshihiro Hayashi for providing a number of services under the “MEET IN KOBE 21st Century” program, as well as the secretaries at CPS for their warm hospitality.

Thanks to a word of encouragement by Mike Zolensky during the first “Cosmic Dust” meeting, we were determined to publish the proceedings of the Cosmic Dust series. The proceedings of the previous meetings have been published as special issues of Earth, Planets and Space (EPS) (see the previous prefaces: Vol. 62, p. 3; Vol. 63, p. 1019; Vol. 65, p. 127). As a natural consequence, this special issue of EPS serves as the proceedings of the 5th “Cosmic Dust” meeting. Although paper submission was not obligatory for the participants of the meeting, nineteen manuscripts were submitted to this special issue and underwent a review and revision process with the help of two reviewers for every manuscript. The subjects of the papers accepted for publication are as diverse as the topics covered by the meeting, owing to the ubiquity of dust in the Universe. As in the program of the meeting, the papers could be categorized into particular dusty environments: evolved stars (Yong Zhang and Sun Kwok), galaxies (Veronique Buat; Hiroyuki Hirashita and Hiroshi Kobayashi; Katarzyna Małek *et al.*; Agnieszka Pollo *et al.*; Enrique Lopez-Rodriguez *et al.*; Puthiyaveettil Shalima *et al.*), the interstellar medium (Jian Gao *et al.*), star-forming regions (Robert S. Botet and Rakesh K. Rai), debris disks (Harald Mutschke *et al.*), and the solar system (Jamey R. Szalay *et al.*; Nikolai Kiselev *et al.*; George J. Flynn *et al.*; Lev Nagdimunov *et al.*; Edith Hadamcik *et al.*). It is, however, worth pointing out that the categorization is not unique and should be used with caution, since some of the studies are essentially interdisciplinary.

To help the reader become aware of the new findings of the papers included in this issue, we briefly summarize the contents here. Reliable corrections to the attenuation of stellar radiation by dust in galaxies are mandatory for measuring the star-formation rate and its evolution with redshift. The wavelength dependence of mean dust attenuation on a galactic scale has been derived from a statistical sample of galaxies at redshift from 1 to 2 at ultraviolet to far-infrared wavelengths in the rest frame of the galaxies and has been shown to have a stronger wavelength dependence than the dust extinction law in the Milky Way (Buat, this issue). This result is of great importance for recovering intrinsic stellar radiation spectra, which provide information on the star-formation history in galaxies. Since infrared emission from galaxies is a good tracer of star-formation activity, the large-scale structure of dusty galaxies represents the star-formation density field in the Universe. Thermal emission from dust in nearby star-forming galaxies, detected by the Japanese satellite AKARI's All-Sky Far-Infrared Survey, was used to measure the angular and spatial clustering of such galaxies (Pollo *et al.*, this issue). The resulting clustering properties indicate that AKARI All-Sky galaxies are essentially a star-forming population of nearby galaxies. Because most of the dust in galaxies is cold and emits far-infrared radiation, AKARI's data are suitable for studying star-formation activities in galaxies. Far-infrared emission from dust was examined in detail through the spectral energy distribution (SED) of galaxies detected by AKARI in order to derive average SEDs as a function of infrared luminosity (Małek *et al.*, this issue). Since the SEDs of galaxies are determined by the formation and evolution of dust in the galaxies, the SEDs reflect various physical processes of dust occurring in the interstellar medium. Among the processes that determine the size distribution of interstellar dust, shattering is one of the most effective mechanisms to feed small grains into the interstellar medium. Theoretical predictions for shattering were examined in detail to investigate how shattering affects the evolution of the dust size distribution in the interstellar medium (Hirashita and Kobayashi, this issue). The size distribution of interstellar dust seems to approach the same power-law distribution under shattering, irrespective of the size distribution of shattered fragments. A typical size of interstellar dust could be constrained by the forward scattering of starlight by interstellar dust observed as ultraviolet halos around bright stars. The scattering properties of interstellar dust in a thin foreground cloud of the bright star Spica were derived from numerical simulations of its UV halo which is located near the interaction zone between the Local Bubble and the Loop I superbubble (Shalima *et al.*, this issue). The best-fit parameters might be interpreted as light scattering by abundant small grains produced by shock waves that formed the bubbles. The smallest end of the grain size distribution may be linked to long-chain carbon molecules, a study of which provides useful information on dust processing occurring in the interstellar medium and circumstellar environments. The wavelengths and band strengths observed in the infrared spectra of circumstellar shells around evolved stars may be accounted for by the excitation of C_{60} in a cluster state (Zhang and Kwok, this issue). UV-induced processing and dehydrogenation of mixed aromatic and aliphatic organic nanoparticles during the post-AGB phase of stellar evolution are the most likely formation route of fullerenes, which are then ejected into the interstellar medium. Since the properties of interstellar clouds vary from one line of sight to another, the size distribution of interstellar dust derived from an observation depends on the line of sight of the observation. The observed extinction curve toward the Galactic Center (GC) within the 1–19-μm spectral range is not well simulated by a model of dust in the diffuse interstellar medium (Gao *et al.*, this issue). This suggests that the extinction toward the GC is caused by a combination of interstellar dust in diffuse clouds and dense clouds. Interstellar dust is known to align in magnetic fields and polarize stellar radiation by dichroic absorption, because of its non-sphericity. The magnetic field strength in the dusty torus around the active galactic nuclei IC 5063 was estimated through the near-infrared polarization caused by aligned, non-spherical dust (Lopez-Rodriguez *et al.*, this issue). A simple model was sufficient to fit the near-infrared polarimetric data, but the dust alignment mechanism remains unknown and the dust properties are not well constrained. Dust coagulation in dense interstellar clouds results in non-spherical dust; in particular, aggregates of small grains whose light-scattering properties are of great importance for interpreting observational data. Optical properties of composite aggregates were studied in consideration of two coagulation processes for forming dust aggregates (Botet and Rai, this issue). The similarity, or dissimilarity, in the optical properties between composite aggregates and coated spheres might provide clues about coagulation processes in star-forming regions and protoplanetary disks. A spectral slope of the continuum absorption at far-infrared wavelengths is a diagnostic tool to infer dust masses, temperatures, and spatial distributions in protoplanetary disks and debris disks. A drastic change in the spectral slope for the continuum of far-infrared absorption was measured with olivine plates at low temperatures (Mutschke *et al.*, this issue). Their results reveal that the crystalline silicate components of cold dust in the outer regions of protoplanetary disks and debris disks are hidden in the amorphous silicate components. While crystalline and amorphous silicates are important constituents of cometary dust, the major constituents are organic-rich carbonaceous materials encasing the silicates. Nanoscale organic coatings around mineral components of interplanetary dust particles (IDPs) were discovered by a synchrotron X-ray based STXM instrument (Flynn *et al.*, this issue). Their findings are crucial to an understanding of how small grains grow into larger aggregates against high collisional velocities expected in protoplanetary disks. The presence of organic coatings most likely affects the light-scattering properties of cometary dust in the visible wavelength range, because silicates are transparent in the optical wavelength domain. The degree of linear polarization typical for dusty comets and left-handed circular polarization were observed for the recent comet C/2009 P1 (Garradd) (Kiselev *et al.*, this issue). The measured circular polarization confirms the predominance of left-handed circular polarization in comets, which suggests the presence of chiral molecules in the organic refractory component of cometary dust. Circular polarization might be a powerful tool to identify prebiological organic matters in cosmic dust because the presence of homochirality in dust may result in circular polarization. A computer simulation of circular polarization by aggregates containing a homochiral biomolecule demonstrated that circular polarization increases with the size of aggregates (Nagdimunov *et al.*, this issue). As the detection of extraterrestrial life is one of the driving forces behind astrobiology, circular polarization by prebiological organic matters in cosmic dust is of topical interest. Since organic compounds are also major constituents of aerosols in the atmosphere of Titan, their composition plays an important role in the optical properties of Titan's aerosols. Light scattering by Titan aerosols was simulated by laboratory measurements of tholin particles with various CH_4/N_2 ratios and well-defined size distributions (Hadamcik *et al.*, this issue). Linear polarization of Titan's aerosols measured by Pioneer 11, Voyager 2, and DISR/Huygens is consistent with light scattering by aggregates of 100-nm-diameter grains. Pioneer 10 and 11 measured dust fluxes in interplanetary space up to 18 AU from the Sun, while the flux at larger heliocentric distances is of great interest to better understand the structure of the cold debris disk of our own planetary system. The Student Dust Counter on board the New Horizon Mission to Pluto provides the first in-situ measurements of dust fluxes beyond 18 AU from the Sun (Szalay *et al.*, this issue). The good agreement between the dust production rate of Kuiper Belt objects derived from the measured fluxes, and the previous theoretical estimates, implies that interstellar dust is a minor component even in the outer solar system.

The papers contained in this issue certainly add valuable pieces of information to a global picture of cosmic dust, but we are still missing a great number of pieces to complete the jigsaw puzzle of dust life cycles. This is the reasoning behind our motivation to continue organizing the Cosmic Dust meetings and publishing the meeting proceedings. We thank all the authors and the reviewers, as well as the editorial board of EPS and Terra Scientific Publishing Company (TERRAPUB), for their efforts regarding this special issue. We will be glad if this EPS special issue, as well as the Cosmic Dust meeting Series, will help the field of cosmic dust research take root in Asia and Oceania and flourish worldwide.

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