"Progress and Perspective of Solar System Science using Subaru"

Invited talk

11/21/2019, 13:30 - 14:00

Fumi Yoshida

(Planetary Exploration Research Center, Chiba Institute of Technology)

Title: **Solar System sciences with Subaru telescope**

Abstract: We will review the achievement in the solar system conducted with the Subaru Telescope. We will discuss what has been achieved as well as what should be achieved in the future.

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11/21/2019, 14:00 - 14:30

Hideyo Kawakita
(Kyoto Sangyo University Koyama Astronomical Observatory)

Title: **Cometary Science from the Subaru Telescope**

Abstract: The Subaru Telescope has been used for the observations of comets in these 20 years. Not only HDS but also IRCS and other instruments have been used for achieving various scientific goals. Here we concentrate on the high-resolution spectroscopic observations in optical and near-infrared wavelength regions.

Nuclear spin isomers (ortho and para) ratio of ammonia in comet has been derived at the first time in comet C/1999 S4 (LINEAR) in 2000. The ratio could be used to infer the formation conditions of cometary molecules. Many comets have been observed to derive the ortho-to-para ratio of ammonia in comet until now. We summarize our survey for OPR of cometary ammonia in collaboration with VLT/UVES and discuss about their meaning based on recent laboratory studies. The survey for isotropic ratio of nitrogen (14N/15N) in cometary ammonia is also conducted in collaboration with VLT/UVES since 2014. We also report the latest results and discuss about the relationship between solar system materials and the interstellar matters. Finally, we also present some other results in cometary science, derived from the Subaru Telescope.

"Progress and Perspective of Solar System Science using Subaru"
Invited talk
11/21/2019, 14:30 - 15:00

Takafumi Otsubo
(ISAS/JAXA)

Title: **Mid-infrared observations and mineralogy of comet dust grains with Subaru/COMICS**

Abstract: A silicate feature is often observed in comet spectra as a 10-μm resonant feature. In most cases, the feature shows the existence of crystalline silicates together with amorphous silicates. Since the crystalline silicate grains generally require high processing temperatures above 800K, it is believed that they formed in the warm inner regions, and there should have been radial transportation of the materials in the proto-solar disk. Comets are believed to be the remnant of the planetesimals swept away by the giant planet migration, and dust grains in comets preserve the information on the physical condition around the giant planet formation region in the early solar nebula.
From this point of view, we have made efforts to increase mid-infrared observational samples of comets with Subaru+COMICS, mainly for studying the crystalline fraction in silicate grains, which may be a clue to the efficiency of the radial transportation and the birthplace of the individual comets. In this talk, we summarize the COMICS observations of about 20 comets. We will show the results of comet dust properties, including size distribution, mineralogy, and the crystalline fraction in silicate grains, and discuss the differences between two dynamical groups: Oort cloud comets and Jupiter-family comets.

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11/21/2019, 15:30 - 16:00

JJ Kavelaars
(National Research Council of Canada)

Title: **Observing the distant solar system with Subaru and the New Horizons spacecraft.**

Abstract: On 1-January-2019 the New Horizons spacecraft had an historic and flawless encounter with the outer solar system object 2014 MU69. This encounter was achieved by bringing together preparatory observations from telescopes around the world and in space. First with efforts to discover a target that New Horizons could reach for a close encounter and then the intensive effort to determine the orbit and physical characteristics of the encounter target. Along the way many new TNOs, not encounterable but observable from New Horizons, were discovered and tracked, enabling the first ever measurement of large phase-angle observations of these members of the distant solar system. The discovery of many of these distant KBOs was achieved using the Subaru SuprimeCam and HyperSuprimeCam. New Horizons observations, of both the close encounter target 2014 MU69 and the more distantly observed KBOs, are transforming our understanding of the primordial solar system and the physics at work during planetesimal formation.

I will review the road that led to the discovery and tracking of these distant Kuiper belt objects and the transformative information that their observation from New Horizons is revealing. In particular I will focus on knowledge gained from the comparison between the phase functions of the different distant KBOs that have been observed and on the cratering frequency observed on the surface of 2014 MU69.

"Progress and Perspective of Solar System Science using Subaru"
Invited talk
11/21/2019, 16:00 - 16:30

Glenn Orton
(Jet Propulsion Laboratory, California Institute of Technology)

Title: **Ground-Based Thermal-Infrared Investigations of Planetary Atmospheres**

Abstract: Insightful investigations of planetary atmospheres have been made by a combination of instruments on interplanetary spacecraft, spaceborne Earth-proximal instruments and ground-based telescopes. This presentation will concentrate on spatially resolved thermal-infrared observations from ground-based observatories, among which the Subaru COMICS instrument has provided outstanding contributions. These observations map the temperature, cloud and compositional fields across planetary atmospheres that is a unique capability of the 5-25 μm spectral region. Both by themselves and in conjunction with interplanetary spacecraft data, they have yielded unexpected insights into atmospheric processes, both internal and in response to external forces, including impacts by both icy and rocky bodies. Ground-based observations determined that the Galileo probe descended into a very anomalous region of Jupiter, forming one of the motivations for the current Juno mission. Other investigations include verification and expansion of results from the Cassini mission showing the effects of a spectacular storm reaching into Saturn's stratosphere. Long-term studies have revealed long-term non-seasonal quasi-periodic structure in both Jupiter and Saturn. One current challenge is the determination of long-term trends in the atmospheres of Uranus and Neptune in preparation for JWST observations and future missions to these icy giants.

"Progress and Perspective of Solar System Science using Subaru"
Invited talk
11/21/2019, 16:30 - 17:00

Ruobing Dong
(University of Victoria)

Title: **Observing the Formation of Solar System Planet Analogs**

Abstract: Planets form in gaseous protoplanetary disks surrounding newborn stars. As they form, they gravitationally perturb the disk, and produce structures. A fleet of new instruments with unprecedented resolving power, such as Subaru/HiCIAO/SCExAO and ALMA, have come online in the past decade. They have discovered rich structures in disks, such as gaps and spiral arms, which are most likely associated with embedded (unseen) planets. By comparing observations with theoretical models of planet-disk interactions, the properties of the still forming planets may be constrained. Such studies help us understand how planets form. Specifically, some of the structures produced by the formation of solar system planet analogs in nearby protoplanetary disks are already detectable using current instruments, and some more will become detectable in the next decade. By searching for and observing those structures, we will be able to witness and study the birth of solar system analogs.

"Progress and Perspective of Solar System Science using Subaru"
Invited talk
11/22/2019, 9:00 - 9:30

Dave Tholen
(University of Hawaii)

Title: **Asteroids Near and Far**

Abstract: The availability of wide-field imaging instruments on Subaru has enabled searches for a variety of different asteroid orbital types. One of my earliest surveys involved the use of Suprime-Cam to look for asteroids with orbits entirely interior to Earth's orbit. The geometry constrained the observations to an hour or two after evening twilight or before morning twilight, with the telescope pointed at low altitudes. Perhaps the most famous discovery to result from this effort is 2004 XZ130, which at the time held the record for smallest semimajor axis of 0.617 AU.

Beyond the classical Kuiper belt, Subaru/HSC has added a northern hemisphere component to a search for objects in the Inner Oort Cloud (IOC) region started by colleagues Scott Sheppard and Chad Trujillo on the Blanco telescope with DECam. The first few discoveries have revealed a curious alignment of orbital major axes, leading to the suggestion that a massive object is lurking somewhere in fringes of the solar system, its gravitational pull shepherding these smaller objects into aligned orbits. Ongoing search efforts allow us to potentially find both additional extreme objects as well as the proposed massive body. The status of this effort will be presented at the conference.

"Progress and Perspective of Solar System Science using Subaru"
Invited talk
11/22/2019, 9:30 - 10:00

Rosemary Pike
(ASIAA)

Title: **Mapping Surface Colors of TNOs through Large Surveys**

Abstract: The Outer Solar System Origins Survey (OSSOS) and its companion surveys discovered approximately 1000 TNOs. We have measured the surface properties of more than 100 of these objects through the Colours of the Outer Solar System (Col-OSSOS) survey and discovered that TNO surfaces can be classified based on g-r and r-z colors. This inspired observations dedicated to mapping the fraction of each of the three surface types throughout the Kuiper belt, to provide constraints on Neptune's migration. The distribution of surface colors of TNOs and Jovian Trojans (JTs) is a key component of our proposed large survey (Formation of the Outer Solar System: an Icy Legacy, FOSSIL). This survey is designed to illuminate how our Solar System formed and evolved, by using the unique capabilities of Subaru's Hyper Suprime-Cam to survey ~1.5 magnitudes deeper than all previous efforts. By incorporating surface color measurements, we will be able to understand the intrinsic distribution of surface properties of TNOs and JTs. The FOSSIL sample is predicted to be 2-4 times the current sample and will enable significant insight into the surface property distribution of small bodies and other unsolved questions about the formation and evolution of the Solar System.

"Progress and Perspective of Solar System Science using Subaru"
Contribution talk
11/22/2019, 10:00 - 10:30

Shuya Tan
(Earth-Life Science Institute, Tokyo Institute of Technology)

Title: **Observations of Europa's surface materials with Subaru/IRCS and its comparison with laboratory experiments**

Abstract: The Jovian icy satellite, Europa possesses an interior ocean that is believed to be one of the most habitable environments beyond Earth. Reflectance spectra of those materials using Keck and VLT at wavelengths of 1.5–2.5 μm suggest the existence of Na/Mg hydrochlorides on Europa's geologically-active regions. Although those salts would reflect the chemical compositions of the ocean, they could experience oxidation to form oxychlorine, such as chlorate and perchlorate, triggered by high-energy irradiation. If oxychlorine is generated on Europa and provided into the interior ocean, this would be important oxidants to provide redox disequilibrium energy for life. Given the low eutectic temperatures of oxychlorines, such as perchlorate, this would also play a key role in tectonics of Europa's icy crust, Here, we conduct high-spectral resolution observations for Europa's surface in wavelength of 0.95−1.5 μm with Subaru/AO188+IRCS. This provides further information on the salt compositions and formation of oxychlorines. We also perform laboratory experiments to simulate oxidation of surface hydrochlorides. By irradiations of electron onto hydrochlorides, we examine oxidation processes of hydrochlorides on Europa's surface. Comparing the telescope observations and laboratory experiments, we interpret the oxidation processes on Europa's surface.

"Progress and Perspective of Solar System Science using Subaru"
Contribution talk
11/22/2019, 10:30 - 11:00

Stefanie Milam
(NASA/GSFC)

Title: **Detailed Studies on Small Bodies in the Solar System with Subaru and WFIRST synergies**

Abstract: Solar System observations with astrophysics facilities offers not only advancement in the field and planetary science and solar system evolution, but also considerable public outreach. Here we investigate the contribution to small body science from joint efforts with WFIRST and Subaru. The combination of WFIRST and HSC SSP data will provide significant data including orbit solutions, spectral gradients at visible wavelengths, and evaluation of surface H2O ice for a number of faint Trans-Neptunian Objects (TNOs) with diameters between 100-1000 km. The results will significantly to our understanding of the origin, dynamical history, and chemical evolution of primordial small bodies in the outer solar system.
A further benefit of using these two facilities in conjunction is for following up observations of serendipitously detected small bodies in the WFIRST surveys, including new minor bodies (e.g. Near-Earth Asteroids, main-belt asteroids, hyperbolic asteroids, comets, active asteroids, Jupiter Trojans, Centaurs, etc.) and irregular satellites of the giant planets (see Holler et al. 2018). Subaru follow-up can help further constrain the orbits and measure optical colors.