Research Center for the Early Universe

Graduate School of Science

University of Tokyo

Annual Report

2016

東京大学大学院理学系研究科附属

ビッグバン宇宙国際研究センター

Version September 25, 2017

Preface

I am pleased to deliver the annual report of Research Center for the Early Universe (RESCEU) for the fiscal year of 2016 (from April 2016 to March 2017).

RESCEU was founded in 1999 as an institute belonging to Faculty of Science, the University of Tokyo, led by the first director, Prof. Katsuhiko Sato of Physics Department. In 2015 we reorganized the research projects in RESCEU, and now we have three major projects including (1) Evolution of the universe and cosmic structures (led by Prof. Jun'ichi Yokoyama), (2) Gravitational-wave astrophysics and experimental gravity (led by Prof. Kipp Cannon), and (3) Formation and characterization of planetary systems (led by myself). Those projects have been supported by a variety of collaboration among our research affiliates in Departments of Physics, Astronomy, and Earth and Planetary Sciences.

In 2016 RESCEU organized two workshops; APCosPA-Planet^2 RESCEU Summer School in Takayama for August 24 to 28, and the 9th RESCEU International Symposium on Gravitational-Wave Astrophysics in the High Event Rate Regime in the University of Tokyo for December 5 and 6.

RESCEU has a visiting profesor position, and we invited Prof. Michael Richmond for September to November 2016, and Prof. Alexei A. Starobinsky in February 2017. Also Dr. Sebastien Peirani in Institute d'Astrophysique de Paris stayed in my group as a visiting Fellow for December 2016 to January 2017 for collabotation.

An assistant professor, Takashi Hosokawa, was promoted to an ssociate professor in Department of Physics, Kyoto University in July 2016, and an secretary, Ms. Mieko Minamisawa, left RESCEU and a new secretary Ms. Chiyo Ueda joined us in June. We would like to thank Prof. Hosokawa and Ms. Minamisawa for their wonderful contributions to RESCEU over many years.

Finally we are pleased to announce that a former assistant professor in RESCEU, Prof. Atsushi Taruya (currently an associate professor in Yukawa Institute, Kyoto University) received the 10th Kimura prize in theoretical physics in January 2017, and that a former student in my group, Dr. Kento Masuda, received the 7th JSPS Ikushi prize in March 2017.

September 2017 Director Yasushi Suto

Contents

1 Members

RESCEU members

Yasushi Suto [須藤靖]	Director
Jun'ichi Yokoyama [横山順一]	Professor
Toshikazu Shigeyama [茂山俊和]	Associate Professor
Kipp Cannon	Associate Professor
Teruaki Suyama [須山輝明]	Assistant Professor
Takashi Hosokawa [細川隆史]	Assistant Professor (– 2016/7/15)
Masamune Oguri [大栗真宗]	Assistant Professor
Yousuke Itoh [伊藤洋介]	Assistant Professor
Michael Richmond	Visiting Professor (2016/9/19 – 2016/11/18)
Alexei A. Starobinsky	Visiting Professor (2017/2/1 – 2017/2/28)
Takuma Suda [須田拓馬]	Research Associate
Xian Gao	Research Associate (– 2016/8/31)
Yutaka Komiya [小宮悠]	Postdoctoral Fellow
Yuki Sakakihara [榊原由貴]	Research Fellow (2016/5/1 –)
Yi-Peng Wu	Research Fellow (2016/9/1 –)
Sayuri Nagano [永野早百合]	Secretary
Mieko Minamisawa [南澤三恵子]	Secretary (– 2016/7/15)
Chiyo Ueda [上田千代]	Secretary (2016/6/1–)

RESCEU affiliates

Naoki Yoshida [吉田直紀]	Professor, Dept. of Physics
Tomonori Totani [戸谷友則]	Professor, Dept. of Astronomy
Mamoru Doi [土居守]	Professor, Institute of Astronomy
Kotaro Kohno [河野孝太郎]	Professor, Institute of Astronomy
Motohide Tamura [田村元秀]	Professor, Dept. of Astronomy
Seiji Sugita [杉田精司]	Professor, Dept. of Earth and Planetary Science
Satoshi Yamamoto [山本智]	Professor, Dept. of Physics
Aya Bamba [馬場彩]	Associate Professor, Dept. of Physics
Kazuhiro Shimasaku [嶋作一大]	Associate Professor, Dept. of Astronomy
Masaki Ando [安東正樹]	Associate Professor, Dept. of Physics
Masahiro Ikoma [生駒大洋]	Associate Professor, Dept. of Earth and Planetary Science
Kazuhiro Nakazawa [中澤知洋]	Lecturer, Dept. of Physics
Hajime Kawahara [河原創]	Assistant Professor, Dept. of Earth and Planetary Science

2 Projects

Project 1. Evolution of the universe and cosmic structures

Name	Research thema
Jun'ichi Yokoyama	Physics of the Early Universe
Toshikazu Shigeyama	Coevolution of galaxies and stars
Naoki Yoshida	Evolution of compact objects and time domain astronomy
Tomonori Totani	Evolution of the universe probed by gamma-ray bursts and fast radio bursts
Aya Bamba	Chemical evolution of the universe with supernova remnant study
Kazuhiro Shimasaku	Galaxy Formation and Evolution
Kazuhiro Nakazawa	Evolution of Galaxy, Clusters of Galaxies and Black Holes
Masamune Oguri	Unveiling the nature of dark matter and dark energy

Project 2. Gravitational-wave astrophysics and experimental gravity

Name	Research thema
Kipp Cannon	Detection and interpretation of gravitational waves emitted by the collisions of compact objects
Mamoru Doi	Identifications of gravitational-wave sources by wide-field and multi-color optical observations
Kotaro Kohno	Radio/submm follow up of candidate sources of gravitational waves
Masaki Ando	Gravitational-Wave Experiment and Astrophysics
Teruaki Suyama	Test of theories of gravity in the strong gravity regime by using the gravitational waves
Yousuke Itoh	Gravitational wave data analysis and properties of compact stars

Project 3. Formation and characterization of planetary systems

Name	Research thema
Yasushi Suto	Dynamical evolution of orbit and angular momentum of exoplanetary systems
Motohide Tamura	Exoplanet observations and instrumentations
Seiji Sugita	An asteroid sample-return mission and feasibility study for an exoplanet observation satellite
Satoshi Yamamoto	Physics and chemistry of protoplanetary disk formation
Masahiro Ikoma	Diversity and origins of exoplanetary atmospheres
Hajime Kawahara	Exploring instrumentation and methods for characterizing exoplanets

3 Symposia and Meetings

3.1 APCosPA-Planet^2 RESCEU Summer School

Place: Garyu-no Sato, Takayama, Gifu Pref., Japan
Time: 2016/8/24 (Wed) – 2016/8/28 (Sun)

Program

8/24 (Wed)

14:30 – 14:35	Yasushi Suto	Welcom address
14:35 – 14:45	Seiji Sugita	Core-to-core Planet^2
14:45 – 16:15	David Ehrenreich	Exoplanet observations from space (Lecture)
16:15 – 16:30	Break	
16:30 – 18:00	Gonjie Li	Obliquity Variations of Stars and Planets (Lecture)
18:00 – 19:00	Poster viewing	

8/25 (Thu) morning

9:00 – 10:30	Olivier Barnouin	Asteroid sample-return mission OSIRIS-REx and its perspectives for Solar-System evolution (Lecture)
10:30 – 10:40	Break	
10:40 – 11:00	Yui Kawashima	Theoretical transmission spectra of transiting exoplanets with hazy atmospheres
11:00 – 11:20	Shunichi Kamata	Tidal interaction of satellite systems
11:20 – 11:40	Hikaru Yabuta	Dynamics observation of prebiotic microspheres through their chemical and morphological distributions: Attempt to define "Planetary Life"

8/25 (Thu) afternoon

13:00 – 14:30	Stefan Schröder	An overview for Rosetta mission and cameras for ESA's three landers (Huygens, Philae, and MASCOT) (Lecture)
15:00 – 15:20	Naoyuki Hirata	N/A
15:20 – 15:40	Break	
15:40 – 17:10	Seth Jacobson	From pebbles to planets: the story of the Solar System (Lecture)
17:10 – 17:20	Break	
17:20 – 17:40	Masataka Aizawa	Searching for exoplanetory rings via transit photometry
17:40 – 18:00	Gen Chiaki	Numerical studies of star formation in metal-poor clouds
18:00 – 19:00	Poster viewing	

8/26 (Fri)

9:00 – 10:30	Tristan Guillot	Interiors and atmospheres of giant planets: Present status and perspectives with Juno (Lecture)
10:30 – 10:40	Break	
10:45 – 12:15	Salvatore Vitale	Characterization of compact objects with gravitational wave detections (Lecture)
12:15 – 13:30	Lunch	
13:30 –	Free discussion	

8/27 (Sat) morning

9:00 – 9:55	Alexei Starobinsky	Recent results on R2 and related models of inflation I (Lecture)
9:55 – 10:10	Soichiro Morisaki	Gravitational-wave data analysis using independent component analysis
10:10 – 10:25	Hsu-Wen Chiang	Easing Supernovae-CMB H_0 tension through local inhomogeneity
10:25 – 10:45	Break	
10:45 – 11:00	Ryo Saito	Stars in Beyond Horndeski Theories
11:00 – 11:15	Sakine Nishi	Growing tensor perturbations on super horizon scales in Generalized Galilean Genesis
11:15 – 11:30	Yuki Watanabe	On post-inflation validity of perturbation theory in Horndeski scalar-tensor models
11:30 – 11:45	Yuki Sakakihara	Primordial fluctuations in bimetric gravity
11:45 – 12:00	Takahiro Hayashinaka	Quantum Anomalous Transportation of QED in Inflationary Universe

8/27 (Sat) afternoon

13:00 – 14:25	Robert Brandenberger	Approaches to Superstring Cosmology Preliminaries: Theory of cosmological perturbations (Lecture)
14:25 – 14:40	Kazufumi Takahashi	Relation between gauge fixing and DOFs in scalar-tensor theories
14:40 – 14:55	Daisuke Yoshida	Extended Vector-Tensor Theories
14:55 – 15:10	Junsei Tokuda	Statistical nature of infrared effects on de Sitter background
15:10 – 15:25	Yuichiro Tada	PBH Dark Matter in Supergravity Inflation Models
15:25 – 15:40	Ippei Obata	Oscillating Chiral Tensor Spectrum from Axionic Inflation
15:40 – 16:00	Break	
16:00 – 16:15	Naritaka Oshita	Correspondence between the decoherence of infalling Hawking particles and quantum fluctuations during inflation
16:15 – 16:30	Yao-Chieh Hu	Two Interpretations of Thin-Shell Instanton
16:30 – 16:45	Stefano Ansoldi	On Tunnelling with Wormhole Creation
16:45 – 17:00	Atsuhisa Ota	Cosmological constraints from μE cross-correlations
17:00 – 18:00	Robert Brandenberger	Approaches to Superstring Cosmology II String Gas Cosmology (Lecture)
18:00 – 19:00	Poster viewing	

8/28 (Sun)

9:00 – 9:55	Alexei Starobinsky	Recent results on R2 and related models of inflation II (Lecture)
9:55 – 10:10	Yota Watanabe	Is DBI as fragile as other k-essence fields?
10:10 – 10:35	Yousuke Itoh	iKAGRA data analysis
10:55 – 11:50	Robert Brandenberger	Approaches to Superstring Cosmology III Other approaches to superstring cosmology (Lecture)
11:50 – 12:05	Kazunari Eda	A chi-squared veto in semi-coherent F-statistic search for continuous gravitational wave

3.2 The 9th RESCEU International Symposium: Gravitational-Wave Astrophysics in the High Event Rate Regime

Place: Koshiba Hall, University of Tokyo (Hongo Campus)
Time: 2016/12/5 (Mon) – 2016/12/6 (Tue)

Program

12/5 (Mon) morning

9:50 – 10:00	LOC	Introduction
10:00 – 10:40	Jamie Rollins	Status and Future of the LIGO Detectors
10:40 – 11:20	Frederique Marion	Status of Virgo and a future European ground-based detector
11:20 – 12:00	Poster Sparkler	

12/5 (Mon) afternoon

14:00 – 14:40	Ed Porter	How do we resolve and analyse millions of simulataneous LISA sources?
14:40 – 15:20	Ben Farr	Constraining Binary Populations from GW Detections
15:20 – 16:00	Daniel Holz	Finding the One: Identifying the host galaxies of gravitational- wave sources
16:00 – 18:00	Poster Viewing	

12/6 (Tue) morning

10:00 – 10:40	Masaomi Tanaka	Kilonova/Macronova Emission from Compact Binary Mergers
10:40 – 11:20	Nozomu Tominaga	Transient Survey with Subaru/Hyper Suprime- Cam
11:20 – 12:00	Koutarou Kyutoku	Numerical-Relativity Simulations of Neutron- Star-Binary Mergers

12/6 (Tue) afternoon

14:00 – 14:40	Imre Bartos	Neutrinos astrophysics in the era of regular gravitational wave detections
14:40 – 15:20	Leo Singer	Advanced LIGO First Light: Multimessenger Astrophysics at the Birth of Gravitational-Wave Observatory
15:20 – 16:00	Michitoshi Yoshida	J-GEM: an EM Follow-up Network in Japan
16:00 – 18:00	Poster Viewing	

3.3 JSPS Core-to-Core Program "Planet^2" Symposium 2017: Origin and diversity of planetary systems from the microscope to the telescope

Place: Citadelle de Villefranche sur Mer, Nice, France
Time: 2017/2/20 (Mon) – 2017/2/23 (Thu)

Program

2/20 (Mon) morning

9:40 – 9:50	Seiji Sugita	Opening address
9:50 – 10:00	Patrick Michel	LOC announcement
10:00 – 10:40	Magali Deleuil	Planetary systems from the perspective of transiting planets
10:40 – 11:00	Hajime Kawahara	Transiting planets near and beyond the snow line
11:00 – 11:20	Masataka Aizawa	Searching for exoplanetary rings via transit photometry
11:20 – 12:00	Bun'ei Sato	Doppler planet searches targeting small and large stars

2/20 (Mon) afternoon

14:00 – 14:40	David Ehrenreich	Atmospheric escape of exoplanets
14:40 – 15:20	Giovanna Tinetti	Characterization of exoplanet atmospheres: Arie & Twinkle
15:20 – 15:40	Yui Kawashima	Transmission spectrum models of exoplanet atmospheres with haze: Effect of creation, growth, and settling of haze particles
15:40 – 16:00	Break	
16:00 – 16:20	Kiyoe Kawauchi	Detailed atmospheric investigation of HD189733b with high-resolution transmission spectroscopy
16:20 – 17:00	Paolo Tanga	Gaia mission

2/21 (Tue) morning

9:00 – 9:40	Francois Forget	Planetary habitability
9:40 – 10:10	Takanori Kodama	From aqua planet to land planet: Implication for inner edge of habitable zone
10:10 – 10:30	Akifumi Nakayama	Roles of high-pressure ice in ocean planet climate
10:30 – 10:50	Break	
10:50 – 11:10	Atila Poro	The feasibility of life in moons of Jupiter-like planets in habitable zone
11:10 – 11:30	Fatemeh Montazeri	Habitability in binary stars planets with focus on LEBM model
11:30 – 12:00	Poster presenters	Flash talks

2/21 (Tue) afternoon

14:00 – 14:40	Yann Alibert	Planet population synthesis
14:40 – 15:10	Masahiro Ogihara	Migration and accretion of close-in super-Earths
15:10 – 15:30	Masahiro Ikoma	Formation and evolution of polluted planetary envelopes
15:30 – 15:50	Yamila Miguel	Jupiter's interior and the Juno mission
15:50 – 16:10	Break	
16:10 – 16:50	Makiko Nagasawa	Formation of hot-Jupiters and binary planets due to planet-planet scattering
16:50 – 17:10	Shoya Kamiaka	Statistical analysis of spin-orbit angle in exoplanet systems applying asteroseismology
17:10 – 17:30	Yuhiko Aoyama	Hydrogen line emission from accreting gas giants

2/22 (Wed) morning

9:00 – 9:40	Chao-Chin Yang	Planetesimal formation
9:40 – 10:00	Jean-Francois Gonzalez	Self-induced dust traps: overcoming planet formation barriers
10:00 – 10:20	Tristan Guillot	The role of the ice-line in the formation of the first planetesimals
10:20 – 11:00	Alessandro Morbidelli	Grain migration and planet accretion
11:00 – 11:20	Break	
11:20 – 12:00	Wataru Fujiya	Primitive meteorites with abundant water
12:00 – 12:40	Pierre Beck	Infrared properties of primitive extra-terrestrial materials and their connections to small bodies

2/22 (Wed) afternoon

14:15 – 14:55	Tomoki Nakamura	Hydration and dehydration of primitive asteroids inferred from mineralogical and compositional properties of carbonaceous chondrites
14:55 – 15:30	Hikaru Yabuta	Organic materials in the Solar System small bodies: Preservation and transportation of life's building blocks, and its potential application to volatiles on exoplanets
15:30 – 15:50	Break	
15:50 – 16:30	Sei-ichiro Watanabe	The Hayabusa2 Mission and Formation of Solar System
16:30 – 17:10	Patrick Michel, Dante Lauretta	The OSIRIS-REx Mission – Sample return from the asteroid Bennu
17:10 – 17:50	Cécile Engrand	Cometary dust from the Rosetta mission and from Antarctic snow
17:50 – 18:10	Lydie Bonal	Antarctic Micrometeorites vs. carbonaceous chondrites: the organic point of view

2/23 (Thu)

9:30 – 10:10	Guy Libourel	Hyper-velocity impact experiments on metallic targets and implications on metallic asteroid histories
10:10 – 10:30	Eri Tatsumi	Collisional history of asteroid Itokawa revealed by remote sensing and sample analyses obtained by Hayabusa mission
10:30 – 10:50	Break	
10:50 – 11:20	Kazuo Yoshioka	Planetary missions with Ultra-small satellite
11:20 – 11:50	Tomohiro Usui	Martian Moons eXploration (MMX) mission: Science goals and objectives
11:50 – 12:20	Masahiro Ikoma	UV transit observation of exoplanet from space
12:20 – 12:50	Patrick Michel	AIDA mission (ESA/NASA): Asteroid Binary investigation and deflection test
12:50 – 13:10	Seiji Sugita	Closing address

4 RESCEU colloquia

- Surhud More (Kavli IPMU)
  "Detection of halo assembly bias and the splashback radius of galaxy clusters"
  April 21, 2016, 14:00-15:00

- Gonjie Li (Harvard University)
  "Interactions of Planetary Systems with passing Stars and Binaries"
  August 23, 2016, 16:00-17:00

- Stefan Ballmer (Syracuse University/LIGO)
  "What comes next for Gravitational-Wave Astronomy"
  December 15, 2016, 14:00-15:30

- Alexei Starobinsky (Landau Institute for Theoretical Physics RAS and RESCEU)
  "From generic classical curvature singularity in GR and f(R) gravity to inflation"
  February 20, 2017, 15:30-16:30

- Bernard Carr (Queen Mary University of London)
  "Primordial black holes as dark matter and seeds for cosmic structure"
  March 2, 2017, 16:00-17:00

5 Project 1. Evolution of the universe and cosmic structures

5.1 Activity Report

This project aims at clarifying the creation and evolution of the universe and its large scale structures from both theoretical and observational studies. It covers physics of the early universe including but not limited to inflation, cosmological phase transition, formation and evolution of density perturbation, as well as formation and evolution of the hierarchical structure of the universe, namely, stars, galaxies, and clusters of galaxies in terms of numerical simulations and optical and X-ray observations. These studies not only clarifies the evolution of our Universe but also provide us with invaluable information on the nature of dark matter and dark energy. Below are some highlights of the FY2016.

5.1.1 Inflation and phase transition

Conventional potential driven inflation is followed by field oscillation of the inflaton which decays to reheat the universe. In models where inflation is induced by the kinetic energy of the inflaton, such as k-inflation and G-inflation, inflation ends abruptly when the form of the kinetic term changes. In such models reheating takes place through gravitational particle production. We have studied reheating through direct coupling between matter fields and the inflaton field in such a way that shift symmetry is not broken, which requires higher order operator. We have shown that more efficient reheating is possible when the suppression energy scale is below the Planck scale.

Hawking-Moss transition describes phase transition from one de Sitter space to another with a larger cosmological constant. Traditionally it has been interpreted from energetic point of view. We have shown that the transition rate is given simply by the ratio of the entropy associated with the event horizon using the static coordinate. This suggests the importance of the gravitational entropy in cosmological phase transitions.

5.1.2 Observational cosmology

Following the discovery of gravitational-wave events by LIGO we proposed a new method to reproduce the distance-redshift relation by the cross correlation of galaxies with known redshift and gravitational-wave sources.

We have discovered a number of strong gravitational lensing events, including a double source plane event called “Eye of Horus”, and made models of mass distributions using the laser guide AO or spectroscopic data of SDSS-III BOSS survey.

We have proposed a new method to calculate the transfer function from the initial to the final power spectra of density fluctuations combining functional derivatives and numerical simulations, to show that observables in the larger scales are relatively insensitive to phenomena on smaller scales so that clean comparison between theories and large-scale observations is possible.

Cosmic microwave background radiation (CMB) is a useful probe of the physics of the early universe. By calculating the three point correlation function of the B-mode polarization of CMB, we have shown that it can be a useful probe of extended gravity theories if and only if there exists a large kinetic coupling of a scalar field to curvature tensor.

We constructed large samples of high-redshift galaxies from wide-field survey data obtained with Subaru Telescope, and studied their stellar populations, gas properties, and dark matter halo properties. We

derived the stellar-to-halo mass ratio of galaxies over a wide redshift range of $z = 0 - 7$ to discuss the star formation efficiency in dark haloes and its evolution. We also obtained the most accurate luminosity function of Lyman α emitters at $z \sim 2$. The spatial extent and the luminosity of diffuse Lyman α haloes around galaxies were measured and their origins were discussed. Lyman α and FUV spectra of galaxies with strong Lyman α emission were also studied to discuss the nature of those galaxies and constrain their ISM properties. Spectroscopy of very bright $z \sim 7$ galaxies was carried out to place a constraint on the fraction of neutral gas in the IGM.

We measured the redshift-space correlation function from a spectroscopic sample of 2783 emission line galaxies from the FastSound survey. The survey, which uses the Subaru Telescope and covers the redshift ranges of $1.19 < z < 1.55$, is the first cosmological study at such high redshifts. We detected clear anisotropy due to redshift-space distortions (RSD) both in the correlation function as a function of separations parallel and perpendicular to the line of sight and its quadrupole moment. RSD has been extensively used to test general relativity on cosmological scales at $z < 1$. Adopting a ΛCDM cosmology with the fixed expansion history, we obtain the first constraint on the growth rate at the redshift, $f(z)\sigma_8(z) = 0.482 \pm 0.116$ at $z \sim 1.4$ after marginalizing over the galaxy bias parameter $b(z)\sigma_8(z)$. This corresponds to 4.2σ detection of RSD. Our constraint is consistent with the prediction of general relativity $f\sigma_8 \sim 0.392$ within the $1 - \sigma$ confidence level. We also demonstrate that by combining with the low-z constraints on $f\sigma_8$, high-z galaxy surveys like the FastSound can be useful to distinguish modified gravity models without relying on CMB anisotropy experiments.

5.1.3 Origin of r-process elements in metal-poor stars

To investigate whether r-process elements ejected from binary neutron star mergers (NSMs) can reproduce the abundances of these elements observed in metal-poor stars in the halo of the Milky Way galaxy, we constructed a model to describe the temporal evolution of elemental abundance patterns of metal-poor stars, in which the propagation of r-process elements is treated as cosmic-ray particles. As a result, we found that a significant fraction of r-process elements escape from the host proto-galaxy and pollute the intergalactic matter and other proto-galaxies. Furthermore, we have succeeded in reproducing the observed abundance distribution of r-process elements of metal-poor stars by supplying these elements from NSMs.

Faint dwarf spheroidal galaxies can be a useful probe to identify the origin of r-process elements, because some of such galaxies have hosted a single NSM in their whole history. If r-process elements are supplied from NSMs, stars formed before the NSM do not have these elements and can be easily distinguished from younger stars formed from gas polluted by the ejecta of the NSM. Since we have identified such a signature in some faint dwarf spheroidal galaxies from already existing observational data, we have been trying to observe as many stars in such galaxies as possible with the Subaru telescope to strengthen the argument in collaboration with researchers working at NAOJ and Kavli IPMU.

5.1.4 2D radiation hydrodynamics in supernova shock breakout

We have constructed a code to calculate 2D radiation hydrodynamics including the special relativistic effects to investigate supernova shock breakout from stars with stripped envelopes (Wolf-Rayet stars). This project is a collaboration with A. Suzuki and K. Maeda (Kyoto University).

5.1.5 Signature of the companion stars in the early light of type Ia supernovae

Type Ia supernova is thought to be the explosion of a white dwarf in a binary system. There are two scenarios leading to type Ia supernova. One is the double-degenerate scenario in which the companion is also a white dwarf and eventually coalesces to explode without leaving no compact remnants. The other is the single-degenerate scenario in which the white dwarf accretes matter from a red-giant or main-sequence companion star. In this scenario, there remains the companion after the supernova explosion and the existence of the companion should affect the dynamics of the ejecta of the explosion. We have been investigating effects of the companion on the dynamics and the radiation by 2D numerical simulations taking into account the finite timescale of thermalization between gas and radiation and pointed out the possibility of the enhancement of blue radiation in the early phase. Our collaborators recently observed

such signatures in the early light curves of some supernovae. We are now investigating what types of companion stars can reproduce the observed features.

5.1.6 Influence of supernova explosions on the companion stars

Massive stars are usually formed in multiple stellar systems. Thus a supernova explosion can affect the surface layers of nearby stars. We are focusing on the change of the abundance of Li in solar type stars after the explosion of a nearby star because Li is known to exist only in the surface layer where the temperature is lower than 2.6 million K. This effect may account for the diversity of Li abundances observed in metal-poor dwarf stars. From the theoretical point of view, we are investigating the effects of a supernova on the surface layer of low mass stars by numerical simulations. This part is a collaboration with a researcher at Tokyo Institute of Technology. At the same time, we are searching binary systems composed of a massive star and a low mass star by performing spectroscopy observations for known massive stars in our galaxy using 1-m class telescopes. To investigate the population of this kind of binary systems in the current universe, we can infer the population of metal-poor counter parts in the ancient universe.

5.1.7 X-ray and γ-ray astrophysics

The radioactive decay of the freshly synthesized r-process nuclei ejected in compact binary mergers power optical/infrared macronovae (kilonovae) that follow these events. The light curves depend critically on the energy partition among the different products of the radioactive decay and this plays an important role in estimates of the amount of ejected r-process elements from a given observed signal. We study the energy partition and γ-ray emission of the radioactive decay. We have shown that 20 to 50% of the total radioactive energy is released in γ-rays on timescales from hours to a month.

We observed a nearby cluster CIZA J1358.9-4750 located at the distance 300 Mpc with Suzaku, XMM-Newton, and Chandra to find it is a cluster about to collide with another. The shock wave observed at its center is only 70 million years old and it has a sharp luminosity jump. We have probed physical processes there using X-ray observations.

5.1.8 Dark matter

We have derived constraints on dark matter annihilation cross section and decay lifetime from cross-correlation analysis of the data from Fermi-LAT and weak lensing surveys by using an updated extragalactic gamma-ray background data. As a result annihilation cross section of $\langle \sigma v \rangle \sim 10^{-23}\mathrm{cm}^3/\mathrm{s}$ is excluded for TeV-scale dark matter depending on channel. The lifetime of $\sim 10^{25}$s is also excluded for decaying TeV-scale dark matter.

We examined the possibility that the dark matter consists of charged massive particles (CHAMPs) using CMB anisotropies, tracing the evolution of cosmological perturbations without assuming that CHAMPs and baryons are tightly coupled. As a result we found that CHAMPs leave sizable effects if they are lighter than 10^{11}GeV.

As a way to solve the small-scale crisis of the standard cosmology, we considered dark matter interacting with light hidden fermions via well motivated fundamental operators showing the resultant matter power spectrum is suppressed on subgalactic scales.

5.2 Publication List

[1] Rieko Momose, et al. (including Kazuhiro Shimasaku): "Statistical properties of diffuse Lyα haloes around star-forming galaxies at $z \sim 2$", Monthly Notices of the Royal Astronomical Society, **457** (2016) 2318-2330

[2] Miyu Masuyama, Toshikazu Shigeyama, and Yoichiro Tsuboki: "Spherical explosion with a central energy source" Publication of the Astronomical Society of Japan, **68** (2017) 22

[3] H. Kuncarayakti, K. Maeda, J. P. Anderson, M. Hamuy, K. Nomoto, L. Galbany, and M. Doi: "Evolving into a remnant: optical observations of SN 1978K at three decades", Monthly Notices of the Royal Astronomical Society, **458** (2016) 2063-2073

[4] Cristian E. Rusu, Masamune Oguri, Yosuke Minowa, et al.: "Subaru Telescope Adaptive Optics Observations of Gravitationally Lensed Quasars in the Sloan Digital Sky Survey", Monthly Notices of the Royal Astronomical Society, **458** (2016) 2-55

[5] Y. Sofue, A. Habe, J. Kataoka, T. Totani, Y. Inoue, S. Nakashima, H. Matsui, and M. Akita: "Galactic Centre hypershell model for the North Polar Spurs", Monthly Notices of the Royal Astronomical Society, **459** (2016) 108

[6] Guillermo Barro, et al. (including Shigeki Inoue): "Caught in the Act: Gas and Stellar Velocity Dispersions in a Fast Quenching Compact Star-Forming Galaxy at $z \sim 1.7$", The Astrophysical Journal, **820** (2016) 120

[7] Masamune Oguri: "Measuring the Distance-Redshift Relation with the Cross-Correlation of Gravitational Wave Standard Sirens and Galaxies", Physical Review D, **93** (2016) 083511

[8] K. Hotokezaka, S. Wanajo, M. Tanaka, A. Bamba, Y. Terada, and T. Piran: "Gamma-ray line emission from neutron star merger ejecta and its effects on the heating rate", Monthly Notices of the Royal Astronomical Society, **459** (2016) 35-43

[9] Tomoki Morokuma, Nozomu Tominaga, Masaomi Tanaka, Naoki Yasuda, Hisanori Furusawa, Yuki Taniguchi, Takahiro Kato, Ji-an Jiang, Tohru Nagao, Hanindyo Kuncarayakti, Kana Morokuma-Matsui, Hiroyuki Ikeda, Sergei Blinnikov, Ken'ichi Nomoto, Mitsuru Kokubo, and Mamoru Doi: "An effective selection method for low-mass active black holes and first spectroscopic identification", Publication of the Astronomical Society of Japan, **68** (2016) 40

[10] Yuichi Harikane, et al. (including Kazuhiro Shimasaku): "Evolution of Stellar-to-Halo Mass Ratio at $z = 0 - 7$ Identified by Clustering Analysis with the Hubble Legacy Imaging and Early Subaru/Hyper Suprime-Cam Survey Data", The Astrophysical Journal, **821** (2016) 123

[11] Teppei Okumura, Chiaki Hikage, Tomonori Totani, Motonari Tonegawa, Hiroyuki Okada, Karl Glazebrook, Chris Blake, Pedro G. Ferreira, Surhud More, Atsushi Taruya, Shinji Tsujikawa, Masayuki Akiyama, Gavin Dalton, Tomotsugu Goto, Takashi Ishikawa, Fumihide Iwamuro, Takahiko Matsubara, Takahiro Nishimichi, Kouji Ohta, Ikkoh Shimizu, Ryuichi Takahashi, Naruhisa Takato, Naoyuki Tamura, Kiyoto Yabe, and Naoki Yoshida: "The Subaru FMOS galaxy redshift survey (FastSound). IV. New constraint on gravity theory from redshift space distortions at $z \sim 1.4$", Publication of the Astronomical Society of Japan, **68** (2016) 38

[12] Hisanori Furusawa, et al. (including Kazuhiro Shimasaku): "A New Constraint on the Lyα Fraction of UV Very Bright Galaxies at Redshift 7", The Astrophysical Journal, **822** (2016) 46

[13] Naritaka Oshita and Jun'ichi Yokoyama: "Entropic interpretation of the Hawking-Moss bounce", Progress of Theoretical and Experimental Physics, **2016** (2016) 051E02

[14] Akira Konno, Masami Ouchi, Kimihiko Nakajima, Florent Duval, Haruka Kusakabe, Yoshiaki Ono, and Kazuhiro Shimasaku: "Bright and Faint Ends of Lyα Luminosity Functions at $z = 2$ Determined by the Subaru Survey: Implications for AGN, Magnification Bias, and ISM HI Evolution", The Astrophysical Journal, **823** (2016) 20

[15] Y. Terada, K. Maeda, Y. Fukazawa, A. Bamba, Y. Ueda, S. Katsuda, T. Enoto, T.Takahashi, T. Tamagawa, F. K. Röpke, A. Summa, and R. Diehl: "Measurements of the Soft Gamma-ray Emission from SN2014J with Suzaku", The Astrophysical Journal, **823** (2016) 43

[16] Shotaro Yamasaki, Tomonori Totani, Norita and Kawanaka: "A blind search for prompt gamma-ray counterparts of fast radio bursts with Fermi-LAT data", Monthly Notices of the Royal Astronomical Society, **460** (2016) 2875

[17] Hiroyuki Okada, Tomonori Totani, Motonari Tonegawa, Masayuki Akiyama, Gavin Dalton, Karl Glazebrook, Fumihide Iwamuro, Kouji Ohta, Naruhisa Takato, Naoyuki Tamura, Kiyoto Yabe, Andrew J. Bunker, Tomotsugu Goto, Chiaki Hikage, Takashi Ishikawa, Teppei Okumura, and Ikkoh Shimizu: "The Subaru FMOS galaxy redshift survey (FastSound). II. The emission line catalog and properties of emission line galaxies", Publication of the Astronomical Society of Japan, **68** (2016) 47

[18] Aya Bamba, Makoto Sawada, Yuto Nakano, Yukikatsu Terada, John Hewitt, Robert Petre, and Lorella Angelini: "New Identification of the Mixed-Morphology Supernova Remnant G298.6-0.0 with Suzaku", Publication of the Astronomical Society of Japan, **68** (2016) S5

[19] Shigeo Yamauchi, Mayu Sumita, and Aya Bamba: "Suzaku observations of two diffuse hard X-ray sources G22.0+0.0 and G23.5+0.1", Publication of the Astronomical Society of Japan, **68** (2016) S6

[20] Sawako Takeda, Aya Bamba, Yukikatsu Terada, Makoto S. Tashiro, Satoru Katsuda, Ryo Yamazaki, Yutaka Ohira, and Wataru Iwakiri: "Suzaku observations of the hard X-ray spectrum of Vela Jr.", Publication of the Astronomical Society of Japan, **68** (2016) S10

[21] Katsuma Miyake, Hirofumi Noda, Shin'ya Yamada, Kazuo Makishima, and Kazuhiro Nakazawa: "The new primary X-ray component confirmed in the Seyfert I galaxy IC 4329A", Publication of the Astronomical Society of Japan, **68** (2016) S28

[22] Tomonori Totani: "Initial conditions of inhomogeneous universe and the cosmological constant problem", Journal of Cosmology and Astroparticle Physics, **06** (2016) 003

[23] Ken Osato, Toyokazu Sekiguchi, Masato Shirasaki, Ayuki Kamada, and Naoki Yoshida: "Cosmological Constraint on the Light Gravitino Mass from CMB Lensing and Cosmic Shear", Journal of Cosmology and Astroparticle Physics, **06** (2016) 004

[24] Yiping Shu, Adam S. Bolton, Christopher S. Kochanek, Masamune Oguri, et al.: "The BOSS Emission-Line Lens Survey. III. Strong Lensing of Lyα Emitters by Individual Galaxies", The Astrophysical Journal, **824** (2016) 86

[25] Akio K. Inoue, et al. (including Naoki Yoshida, Kotaro Kohno): "Detection of an oxygen emission line from a high-redshift galaxy in the reionization epoch", Science, **352** (2016) 1559

[26] Surhud More, et al. (including Masamune Oguri): "Detection of the Splashback Radius and Halo Assembly Bias of Massive Galaxy Clusters", The Astrophysical Journal, **825** (2016) 39

[27] Hitomi collaboration (including Aya Bamba, Kazuhiro Nakazawa): "The Quiet Intracluster Medium in the Core of the Perseus Cluster", Nature, **535** (2016) 117-121

[28] Akihiro Suzuki, Keiichi Maeda, and Toshikazu Shigeyama: "2D Radiation-hydrodynamic Simulations of Supernova Shock Breakout in Bipolar Explosions of a Blue Supergiant Progenitor" The Astrophysical Journal, **825** (2016) 92

[29] Yuya Sakurai, Kohei Inayoshi, and Zoltán Haiman: "Hyper-Eddington mass accretion on to a black hole with super-Eddington luminosity", Monthly Notices of the Royal Astronomical society, **461** (2016) 4496-4504

[30] Takahiro Hayashinaka, Tomohiro Fujita, and Jun'ichi Yokoyama: "Fermionic Schwinger effect and induced current in de Sitter space", Journal of Cosmology and Astroparticle Physics, **1607** (2016) 010

[31] Takahiro Hayashinaka and Jun'ichi Yokoyama: "Point splitting renormalization of Schwinger induced current in de Sitter spacetime", Journal of Cosmology and Astroparticle Physics, **1607** (2016) 012

[32] Chiaki Hikage and Masamune Oguri: "A Pseudo-Spectrum Analysis of Galaxy-Galaxy Lensing", Monthly Notices of the Royal Astronomical Society, **462** (2016) 1359-1370

[33] Jun'ichi Yokoyama: "Birth of the inflationary Universe and tensor fluctuations", International Journal of Modern Physics D, **25** (2016) 1645009

[34] Masayuki Tanaka, et al. (including Masamune Oguri): "A Spectroscopically Confirmed Double Source Plane Lens System in the Hyper Suprime-Cam Subaru Strategic Program", The Astrophysical Journal, **826** (2016) L19

[35] C. G. Bassa, R. Beswick, S. J. Tingay, E. F. Keane, S. Bhandari, S. Johnston, T. Totani, N. Tominaga, N. Yasuda, B. W. Stappers, E. D. Barr, M. Kramer, and A. Possenti: "Optical and radio astrometry of the galaxy associated with FRB 150418", Monthly Notices of the Royal Astronomical Society, **463** (2016) L36

[36] B. J. Carr, Kazunori Kohri, Yuuiti Sendouda, Jun'ichi Yokoyama: "Constraints on primordial black holes from Galactic gamma-ray background", Physical Review D, **94** (2016) 044029

[37] G. Sato, K. Hagino, S. Watanabe, K. Genba, A. Harayama, H. Kanematsu, J. Kataoka, M. Katsuragawa, M. Kawaharada, S. Kobayashi, M. Kokubun, Y. Kuroda, K. Makishima, K. Masukawa, T. Mimura, K. Miyake, H. Murakami, T. Nakano, K. Nakazawa, H. Noda, H. Odaka, M. Onishi, S. Saito, R. Sato, T. Sato, H. Tajima, H. Takahashi, T. Takahashi, S. Takeda, and T. Yuasa: "The Si/CdTe semiconductor camera of the ASTRO-H Hard X-ray Imager (HXI)", Nuclear Instruments and Methods in Physics Research Section A, **831** (2016) 235-241

[38] Hirofumi Noda, Takeo Minezaki, Makoto Watanabe, Mitsuru Kokubo, Kenji Kawaguchi, Ryosuke Itoh, Kumiko Morihana, Yoshihiko Saito, Hikaru Nakao, Masataka Imai, Yuki Moritani, Katsutoshi Takaki, Miho Kawabata, Tatsuya Nakaoka, Makoto Uemura, Koji Kawabata, Michitoshi Yoshida, Akira Arai, Yuhei Takagi, Tomoki Morokuma, Mamoru Doi, Yoichi Itoh, Shin'ya Yamada, Kazuhiro Nakazawa, Yasushi Fukazawa, Kazuo Makishima: "X-ray and Optical Correlation of Type I Seyfert NGC 3516 Studied with Suzaku and Japanese Ground-Based Telescopes", The Astrophysical Journal, **828** (2016) 78

[39] Yuki Sakakihara and Takahiro Tanaka: "Primordial fluctuations from inflation in dRGT bimetric theory of gravity", Journal of Cosmology and Astroparticle Physics, **1609** (2016) 033

[40] Masato Shirasaki, Oscar Macias, Shun Horiuchi, Satoshi Shirai, and Naoki Yoshida: "Cosmological constraints on dark matter annihilation and decay: Cross-correlation analysis of the extragalactic gamma-ray and cosmic shear", Physical Review D, **94** (2016) 3522

[41] Takahiro Sudoh, Tomonori Totani, Ryu Makiya, and Masahiro Nagashima: "Testing anthropic reasoning for the cosmological constant with a realistic galaxy formation model", Monthly Notices of the Royal Astronomical Society, **464** (2017) 1563

[42] Takahiro Nishimichi, Francis Bernardeau, and Atsushi Taruya: "Response function of the large-scale structure of the universe to the small scale inhomogeneities", Physics Letters B, **762** (2016) 247

[43] Tetsu Kitayama, et al. (including Kotaro Kohno, Yasushi Suto): "The Sunyaev-Zel'dovich Effect at Five Arcseconds: RXJ1347.5-1145 Imaged by ALMA", Publication of the Astronomical Society of Japan, **68** (2016) 88

[44] Joseph E. Coleman, Lindsay J. King, Masamune Oguri, et al.: "The Mass Distribution of the Unusual Merging Cluster Abell 2146 from Strong Lensing", Monthly Notices of the Royal Astronomical Society, **464** (2017) 2469-2480

[45] Daichi Suto, Tetsu Kitayama, Takahiro Nishimichi, Shin Sasaki, and Yasushi Suto: "Evolution and statistics of non-sphericity of dark matter halos from cosmological N-body simulation", Publications of the Astronomical Society of Japan, **68** (2016) 97

[46] M. A. Famiano, T. Kajino, W. Aoki, and T. Suda: "Dependence of the Sr-to-Ba and Sr-to-Eu Ratio on the Nuclear Equation of State in Metal-poor Halo Stars", The Astrophysical Journal, **830** (2016) 61

[47] Yutaka Komiya and Toshikazu Shigeyama: "Contribution of Neutron Star Mergers to the r-Process Chemical Evolution in the Hierarchical Galaxy Formation", The Astrophysical Journal, **830** (2016) 76

[48] Mikio Morii, et al. (including Naoki Yoshida): "Machine-learning selection of optical transients in the Subaru/Hyper Suprime-Cam survey", Publication of the Astronomical Society of Japan, **68** (2016) 104

[49] Kimihiko Nakajima, Richard S. Ellis, Ikuru Iwata, Akio K. Inoue, Haruka Kusakabe, Masami Ouchi, and Brant E. Robertson: "A Hard Ionizing Spectrum in z = 3-4 Lyα Emitters with Intense [O III] Emission: Analogs of Galaxies in the Reionization Era?", The Astrophysical Journal, **831** (2016) 9

[50] Hyunbae Park, Paul R. Shapiro, Junhwan Choi, Naoki Yoshida, Shingo Hirano, Kyungjin Ahn:"The hydrodynamic feedback of cosmological reionization", Astrophysical Journal **831** (2016) 86

[51] Takuya Hashimoto, Masami Ouchi, Kazuhiro Shimasaku, Daniel Schaerer, Kimihiko Nakajima, Takatoshi Shibuya, Yoshiaki Ono, Michael Rauch, and Ryosuke Goto: "Lyα emitters with very large Lyα equivalent widths, $\mathrm{EW}_0(\mathrm{Ly}\alpha) \simeq 200 - 400$ Å, at $z \sim 2$", Monthly Notices of the Royal Astronomical Society, **465** (2017) 1543-1562

[52] Anupreeta More, Chien-Hsiu Lee, Masamune Oguri, et al.: "A New Quadruple Gravitational Lens from the Hyper Suprime-Cam Survey: the Puzzle of HSC J115252+004733", Monthly Notices of the Royal Astronomical Society, **465** (2017) 2411-2419

[53] Tobias Binder, Laura Covi, Ayuki Kamada, Hitoshi Murayama, Tomo Takahashi, and Naoki Yoshida: "The matter power spectrum in hidden neutrino interacting dark matter models", Journal of Cosmology and Astroparticle Physics, **11** (2016) 043

[54] Tomohiro Nakama, Teruaki Suyama, amd Jun'ichi Yokoyama: "Supermassive black holes formed by direct collapse of inflationary perturbations", Physical Review D, **94** (2016) 103522

[55] Sunmyon Chon, Shingo Hirano, Takashi Hosokawa, and Naoki Yoshida: "Cosmological Simulations of Early Black Hole Formation: Halo Mergers, Tidal Disruption, and the Conditions for Direct Collapse", Astrophysical Journal, **832** (2016) 134

[56] James H. H. Chan, Sherry H. Suyu, Anupreeta More, Masamune Oguri, et al.: "Galaxy-Scale Gravitational Lens Candidates from the Hyper Suprime-Cam Imaging Survey and the Galaxy And Mass Assembly Spectroscopic Survey", The Astrophysical Journal, **832** (2016) 135

[57] Satoru Katsuda, Keiichi Maeda, Aya Bamba, Yukikatsu Terada, Yasushi Fukazawa, Koji Kawabata, Masanori Ohno, Yasuharu Sugawara, Yohko Tsuboi, and Stefan Immler: "Soft and Hard X-Ray Components from Type IIn Supernovae: Evidence for Asphericity in the Circumstellar Medium", The Astrophysical Journal, **832** (2016) 194

[58] Shogo B. Kobayashi, Kazuhiro Nakazawa, and Kazuo Makishima: "*Suzaku* Observations of Spectra Variations of the Ultra-Luminous X-ray Source Holmberg IX X-1", Publications of the Astronomical Society of Japan, **69** (2017) 4

[59] Naohiro Takanashi, Mamoru Doi, Naoki Yasuda, Hanindyo Kuncarayakti, Kohki Konishi, Donald P. Schneider, David Cinabro, and John Marriner: "Photometric properties of intermediate-redshift Type Ia supernovae observed by the Sloan Digital Sky Survey-II Supernova Survey", Monthly Notices of the Royal Astronomical Society, **465** (2017) 1274-1288

[60] S. Shibata, E. Watanabe, Y. Yatsu, T. Enoto, and A. Bamba: "X-ray and Rotational Luminosity Correlation and Magnetic Heating of the Radio Pulsars", The Astrophysical Journal, **833** (2016) 59

[61] Masato Shirasaki, Takahiro Nishimichi, Baojiu Li, and Yuichi Higuchi: "The imprint of f(R) gravity on weak gravitational lensing - II. Information content in cosmic shear statistics", Monthly Notices of the Royal Astronomical Society, **466** (2017) 2402-2417

[62] Yiping Shu, et al. (including Masamune Oguri): "The BOSS Emission-Line Lens Survey. IV. Smooth Lens Models for the BELLS GALLERY Sample", The Astrophysical Journal, **833** (2016) 264

[63] Daichi Suto, Sébastien Peirani, Yohan Dubois, Tetsu Kitayama, Takahiro Nishimichi, Shin Sasaki, and Yasushi Suto: "Projected axis ratios of galaxy clusters in the Horizon-AGN simulation: Impact of baryon physics and comparison with observations", Publications of the Astronomical Society of Japan, **69** (2017) 1

[64] Akihiro Suzuki, Keiichi Maeda, and Toshikazu Shigeyama: "Hydrodynamical Interaction of Mildly Relativistic Ejecta with an Ambient Medium", The Astrophysical Journal, **834** (2017) 32

[65] Kazuma Mitsuda, Mamoru Doi, Tomoki Morokuma, Nao Suzuki, Naoki Yasuda, Saul Perlmutter, Greg Aldering, and Joshua Meyers: "Isophote Shapes of Early-type Galaxies in Massive Clusters at $z \sim 1$ and 0", The Astrophysical Journal, **834** (2017) 109

[66] Patrick Valageas, Atsushi Taruya, and Takahiro Nishimichi: "Consistency relations for large-scale structures with primordial non-Gaussianities", Physical Review D, **95** (2017) 023504

[67] Ken-ichi Tadaki, et al. (including Shigeki Inoue): "Bulge-forming Galaxies with an Extended Rotating Disk at $z \sim 2$", The Astrophysical Journal, **834** (2017) 135

[68] Rui Marques-Chaves, et al. (including Masamune Oguri): "Discovery of a Very Bright and Intrinsically Very Luminous, Strongly Lensed Lyα Emitting Galaxy at $z = 2.82$ in the BOSS Emission-Line Lens Survey", The Astrophysical Journal, **834** (2017) L18

[69] Yoshio Tsubone, Makoto Sawada, Aya Bamba, Satoru Katsuda, and Jacco Vink: "A Systematic Study of the Thermal and Nonthermal Emission in the Supernova Remnant RCW 86 with Suzaku", The Astrophysical Journal, **835** (2017) 34

[70] Yoshiki Toba, Tohru Nagao, Masaru Kajisawa, Taira Oogi, et al.: "Clustering of infrared-bright dust obscured galaxies revealed by the Hyper Suprime-Cam and Wise", The Astrophysical Journal, **835** (2017) 36

[71] Satoshi Iso, Naritaka Oshita, Rumi Tatsukawa, Kazuhiro Yamamoto, and Sen Zhang: "Quantum radiateon produced by the entanglement of quantum fields", Physical Review D, **95** (2017) 023512

[72] Kengo Tomida, Masahiro N. Machida, Takashi Hosokawa, Yuya Sakurai, and Chia Hui Lin: "Grand-design Spiral Arms in a Young Forming Circumstellar Disk", The Astrophysical Journal, **835** (2017) L11

[73] Anupreeta More, Sherry H. Suyu, Masamune Oguri, Surhud More, and Chien-Hsiu Lee: "Interpreting the Strongly Lensed Supernova iPTF16geu: Time Delay Predictions, Microlensing, and Lensing Rates", The Astrophysical Journal, **835** (2017) L25

[74] Yoshiyuki Inoue, Shiu-Hang Lee, Yasuyuki T. Tanaka, and Shogo B. Kobayashi: "High energy gamma rays from nebulae associated with extragalactic microquasars and ultra-luminous X-ray sources", Astroparticle Physics, **90** (2017) 14-19

[75] Ko Ono, Kazuo Makishima, Soki Sakurai, Zhongli Zhang, Kazutaka Yamaoka, and Kazuhiro Nakazawa: "A Hard-to-Soft State Transition of Aquila X-1 Observed with Suzaku", Publications of the Astronomical Society of Japan, **69** (2017) 23

[76] Chon Sunmyon and Latif Muhammad: "The impact of ionizing radiation on the formation of a supermassive star in the early Universe", Monthly Notices of the Royal Astronomical Society, **467** (2017) 4293-4303

[77] Shigeki Inoue: "Emergence of a stellar cusp by a dark matter cusp in a low-mass compact ultrafaint dwarf galaxy", Monthly Notices of the Royal Astronomical Society, **467** (2017) 4491-4500

[78] M. Miceli, A. Bamba, S. Orlando, P. Zhou, S. Safi-Harb, Y. Chen, and F. Bocchino: "XMM-Newton observation of the supernova remnant Kes 78 (G32.8-0.1): Evidence for shock-cloud interaction", Astronomy & Astrophysics, **599** (2017) 45

[79] Hitomi Collaboration (including Aya Bamba, Kazuhiro Nakazawa): "Hitomi Constraints on the 3.5 keV Line in Perseus", The Astrophysical Journal, **837** (2017) L15

[80] Hossein Bazrafshan Moghaddam, Robert Brandenberger, and Jun'ichi Yokoyama: "Note on Reheating in G-inflation", Physical Review D, **95** (2017) 063529

5.3 International Conference Talks

5.3.1 Contributed talks

[81] Y. Kato, K. Nakazawa, L. Gu, T. Akahori, M. Takizawa, Y. Fujita, A. Simionescu, and K. Makishima: "Observation of a nearby early merging cluster of galaxies, CIZA J1358.9-4750: new born shocks in the ICM", 15th HEAD meeting of the American Astrophysics Society (Florida, USA, April 3-7, 2016)

[82] H. Murakami, K. Makishima, T. Enoto, U. Furuta, T. Nakano, and K. Nakazawa: "A new approach to observe toroidal magnetic fields of magnetars", XMM-Newton: The Next Decade (Madrid, Spain, May 9-11, 2016)

[83] K. Ono, S. Sakurai, Z. Zhang, K. Nakazawa, and K. Makishima: "Hard-to-soft state trainsition of the Neutron Star LMXB Aquila X-1", XMM-Newton: The Next Decade (Madrid, Spain, May 9-11, 2016)

[84] S. Kobayashi, K. Nakazawa, and K. Makishima: "A New Characterization of the ULX Spectra via Comptonization", ULXs and their environments (Strasbourg, France, June 13-16, 2016)

[85] Takahiro Nishimichi: "On the nonlinear mode coupling in the gravitational growth of cosmic structures", One-Day Workshop on New perspective on theory and observation of large-scale structure (Kyoto, Japan June 16, 2016)

[86] S. Yamasaki, T. Totani, & N. Kawanaka: "A Blind Search for Prompt Gamma-ray Counterparts of Fast Radio Bursts", 14th International Symposium on Nuclei in the Cosmos XIV (Niigata, Japan, June 19-24, 2016)

[87] Yutaka Komiya, Toshikazu Shigeyama, and Masayuki Fujimoto: "The Galactic chemical evolution of r-process elements by neutron star mergers", 14th International Symposium on Nuclei in the Cosmos XIV (Niigata, Japan, June 19-24, 2016)

[88] Ken Osato: "Cosmological Properties of Simulated Galaxies from Hydrodynamic N-body Simulations", Cosmic dawn of galaxy formation: linking observations and theory with new-generation spectral models (Paris, France, June 20-24, 2016)

[89] Yuya Sakurai: "Episodic accretion in supermassive star formation and formation of SMBH seeds in the early universe", European Week of Astronomy and Space Science 2016 (Athens, Greece, July 4-8, 2016)

[90] K. Ono, S. Sakurai, Z. Zhang, K. Nakazawa, and K. Makishima: "Estimation of the magnetic field and accretion flow geometry of Low Mass X-ray Binaries", European Week of Astronomy and Space Science 2016 (Athens, Greece, July 4-8, 2016)

[91] Y. Kato: "X-ray observation of shocks within the plasma in clusters of galaxies", th East-Asia School and Workshop on Laboratory, Space, Astrophysical Plasma (Tsukuba, Japan, July 11-16, 2016)

[92] S. Yamasaki and T. Totani: "Testing double neutron star merger model for FRBs with numerical-relativity hydrodynamical simulations", RIKEN-RESCEU Joint Seminar (Tokyo, Japan, July 25-27, 2016)

[93] Yutaka Komiya and Toshikazu Shigeyama: "Contribution of neutron star merger to the r-process chemical evolution", RIKEN-RESCEU Joint Seminar (Tokyo, Japan, July 25-27, 2016)

[94] Y. Wada, T. Yuasa, K. Nakazawa, K. Makishima, T. Hayashi, and M. Ishida: "NuSTAR observations of the Dwarf Nova GK Persei in 2015: comparison between outburst and quiescent phases", 20th European White Dwarf Workshop (University of Warwick, UK, July 25-29, 2016)

[95] Yuya Sakurai: "Supermassive star formation by episodic accretion: a highly unstable protostellar disk and UV feedback", First Stars V (Heidelberg, Germany, August 1-5, 2016)

[96] Takahiro Hayashinaka: "Fermionic Schwinger Effect and Induced Current in de Sitter spacetime", COSMO16 (Michigan, USA, August 8-12, 2016)

[97] Naritaka Oshita: "A baby universe from a black hole", COSMO16 (Michigan, USA, August 8-12, 2016)

[98] Takahiro Kato: "Superluminous supernova search with HSC SSP", HSC Collaboration Meeting (Kashiwa, Japan, August 22-26, 2016)

[99] Ryohei Nakatani: "Metallicity Dependence of Photoevaporation Rate in Protoplanetary Disks", APCosPA-Planet^2 RESCEU Summer School (Gifu, Japan, August 24-28, 2016)

[100] Naritaka Oshita: "Correspondence between the decoherence of infalling Hawking particles and quantum fluctuations during inflation", APCosPA-Planet^2 RESCEU Summer School (Gifu, Japan, August 24-28, 2016)

[101] Yuki Sakakihara and Takahiro Tanaka: "Primordial fluctuations in bimetric gravity", APCosPA-Planet^2 RESCEU Summer School (Gifu, Japan, August 24-28, 2016)

[102] Takahiro Hayashinaka: "Quantum Anomalous Transportation of QED in Inflationary Universe", APCosPA-Planet^2 RESCEU Summer School (Gifu, Japan, August 24-28, 2016)

[103] Takahiro Nishimichi: "A Galaxy(Cluster)-Galaxy Lensing Emulator from simulations", HSC Collaboration Meeting (Kavli IPMU, Japan, August 26, 2016)

[104] Taira Oogi: "AGN clustering in a semi-analytic model: current status", HSC-AGN face-to-face meeting (Kavli IPMU, Japan, August 27, 2016)

[105] K. Miyake, S. Saito, T. Nakano, K. Hagino, B. S. Kobayashi, K. Okuda, T. Mimura, G. Sato, S. Watanabe, M. Kokubun, K. Nakazawa, S. Takeda, H. Tajima, Y. Fukazawa, and T. Takahashi: "Effects on hard x-ray response of a double-sided Si strip detector caused by interstrip surface charge", SPIE Conferences + Exhibitions, Hard X-Ray, Gamma-Ray, and Neutron Detector Physics XVIII (San Diego, USA, August 28 - September 1, 2016)

[106] Yuya Sakurai: "Hyper-Eddington accretion onto a black hole with super-Eddington luminosity", Breaking the Limits: Super-Eddington Accretion on Compact Objects (Arbtax Park, Sardegna, Italy, September 19-23, 2016)

[107] S. Kobayashi, K. Nakazawa, and C. Done: "Comparing ULXs with the other High-Eddington Sources", Breaking the Limits: Super-Eddington Accretion on Compact Objects (Arbtax Park, Sardegna, Italy, September 19-23, 2016)

[108] Natsuki H. Hayatsu and ALMA Deep Field in SSA22 team: "A Search for z = 6 [CII] Emitters in ALMA Cycle 2 Deep Survey Data", Half a Decade of ALMA: Cosmic Dawns Transformed (California, USA, September 20-23, 2016)

[109] Kojiro Kawana, Ataru Tanikawa, and Naoki Yoshida: "A Variety of Nucleosynthesis in Tidal Disruptions of a White Dwarf by an Intermediate Mass Black Hole", The 7th East Asian Numerical Astrophysics Meating (Beijing, China, October 24-27, 2016)

[110] Yuki Sakakihara and Takahiro Tanaka: "Production of gravitons and cosmology in bimetric gravity", The 26th Workshop on General Relativity and Gravitation in Japan (Osaka City University, Japan, October 24-28, 2016)

[111] Naritaka Oshita: "Firewall paradox and decoherence inside a black hole", The 26th Workshop on General Relativity and Gravitation in Japan (Osaka City University, Japan, October 24-28, 2016)

[112] Rhota Kawamata: "The sizes of $z \sim 6-9$ lensed galaxies from the Hubble Frontier Fields", Chile-Japan Academic Forum at Patagonia 2016 (Puerto Natales, Chile, November 7-10, 2016)

[113] Takuma Suda: "Chemical Evolution History of Dwarf Spheroidal Galaxies using the SAGA database", Mini-workshop on Cosmic history of matter: Origin of heavy elements (ICU, Japan, November 14, 2016)

[114] Yutaka Komiya and Toshikazu Shigeyama: "Hierarchical galaxy formation and the r-process chemical evolution of the Milky Way", Galactic Archaeology & Stellar Physics (Canberra, Australia, November 21-25, 2016)

[115] Naoki Yoshida: "Statistical Computational Cosmology", JST/NSF Joint Symposium on Big Data (Tokyo, Japan, November 28, 2016)

[116] Taira Oogi: "Quasar clustering in a semi-analytic model based on ultra high-resolution N-body simulation", Panoramas of the Evolving Cosmos (Hiroshima, Japan, November 28 - December 2, 2016)

[117] Haruka Kusakabe: "Dark matter halo and stellar properties of extremely low-mass galaxies at $z \sim 2$", Panoramas of the Evolving Cosmos (Hiroshima, Japan, November 28 - December 2, 2016)

[118] Jun'ichi Yokoyama: "Tensor perturbations in spatially covariant gravity", CosPA 2016 (University of Sydney, Australia, November 28 - December 2, 2016)

[119] T. Shigeyama, K. Wada, and Y. Ohtani: "Bright novae - Indications of the spectrum of MAXI J0158-744", 7 years of MAXI: Monitoring X-ray Transients (Wako, Japan, December 5-7, 2016)

[120] K. Ono, K. Makishima, S. Sakurai, Z. Zhang, K. Yamaoka, and K. Nakazawa: "Unveiling the spectral transition of Aql X-1 from the hard to soft state", 7 years of MAXI: Monitoring X-ray Transients (Wako, Japan, December 5-7, 2016)

[121] K. Miyake, H. Noda, S. Yamada, K. Makishima, and K. Nakazawa: "The new primary X-ray spectral component of IC4329A confirmed with *Suzaku* and *NuSTAR*", 7 years of MAXI: Monitoring X-ray Transients (Wako, Japan, December 5-7, 2016)

[122] M. Seino, H. Noda, K. Miyake, K. Nakazawa, and K. Makishima: "X-Ray Spectral Variability of the Narrow-Line Seyfert 1 Galaxy NGC 4051 Observed with Suzaku", 7 years of MAXI: Monitoring X-ray Transients (Wako, Japan, December 5-7, 2016)

[123] Yuki Sakakihara and Takahiro Tanaka: "Cosmic evolution with bigravity", Symposium on New development in astrophysics through multimessenger observations of gravitational wave sources (YITP, Kyoto, Japan, December 26-28, 2016)

[124] Naoki Yoshida: "Cosmology with Subaru HSC survey", 2nd CREST Big Data Symposium (Tokyo, Japan, January 12, 2017)

[125] Yuki Sakakihara and Takahiro Tanaka: "Cosmology with bigravity theory", Testing Gravity 2017 (Simon Fraser University, Vancouver, Canada, January 26-28, 2017)

[126] Takahiro Nishimichi: "Dark Emulator Status Report", HSC Weak-Lensing Working Group face-to-face meeting (Princeton, USA, February 6, 2017)

[127] Y. Kato: "CIZA J1358.9-4750: an early-phase merger clusters of galaxies exhibiting a twin shocks", The workshop on the early-phase merging clusters (SRON, Netherlands, February 8, 2017)

[128] Taira Oogi: "Quasar clustering in a semi-analytic model of galaxy formation", Cosmology seminar (MPA, Germany, February 21, 2017)

[129] S. Yamasaki, T. Totani, K. Kiuchi, & M. Shibata: "Probing the Origin of Fast Radio Bursts by Simulations of Binary Neutron Star Mergers", Fast Radio Bursts: New Probes of Fundamental Physics and Cosmology (Aspen, USA, February 11-18, 2017)

[130] Takahiro Nishimichi: "Numerical cosmology with an ensemble of simulations", RIKEN International Symposium on Data Assimilation 2017, The 7th Annual Japanese Data Assimilation Workshop (RIKEN, Japan, February 27 - March 2, 2017)

[131] Takuma Suda: "SAGA database for dwarf galaxies", Galactic Archaeology Workshop 2017 (NAOJ, Japan, March 1, 2017)

[132] Haruka Kusakabe: "Mass Assembly Efficiency of LAEs at $z \sim 2$: Stellar & Halo Properties", The Snowbird Cosmic Lyman-Alpha Workshop (Salt Lake City, USA, March 19-24, 2017)

5.3.2 Invited talks

[133] Masamune Oguri: "Cluster searches with HSC", Follow-up of wide-area X-ray surveys: Science, Facilities, Programs (Ringberg Castle, Germany, April 25-27, 2016)

[134] Masamune Oguri: "Gravitational wave standard sirens", Astronomical Distance Determination in the Space Age (Beijing, China, May 23-27, 2016)

[135] Shigeki Inoue: "Disk instability of high-z clumpy galaxies"', The secular evolution of self-gravitating systems over cosmic ages (Paris, France, May 25, 2016)

[136] Naoki Yoshida: "Formation of Primordial Stars", Metals and Dust as Fuels of Star Formation (Santa Barbara, USA, June 21-24, 2016)

[137] Jun'ichi Yokoyama: "SUSY inflation? What else?", SUSY 2016 (University of Melbourne, Australia, July 3-8, 2016)

[138] Tomonori Totani: "Recent Topics on FRBs", RIKEN-RESCEU Joint Seminar (Tokyo, Japan, July 25-27, 2016)

[139] Takahiro Nishimichi: "Modeling issues using N-body simulations: a case for SUBARU HSC survey galaxy-galaxy lensing emulator", CosKASI-ICG-NAOC-YITP Workshop 2016 (KASI, South Korea, September 5-9, 2016)

[140] Aya Bamba: "X-ray observations of supernova remnants – environment study of acceleration sites –", Cosmic Ray Origin – beyond the standard models – (San Vito di Cadore, Italy, September 19-23, 2016)

[141] Yasushi Suto: "Impact of baryon physics on non-sphericity of galaxy clusters", The 7th KIAS workshop on Cosmology and Structure Formation (Seoul, South Korea, October 30 - November 4, 2016)

[142] Masamune Oguri: “Clusters of galaxies in Subaru Hyper Suprime-Cam survey”, The 7th KIAS workshop on Cosmology and Structure Formation (Seoul, South Korea, October 30 - November 4, 2016)

[143] Tomonori Totani: “An Introduction of Department of Astronomy, the University of Tokyo”, Chile-Japan Academic Forum, Workshop 01: Astronomy and Related Technologies (Punta Arenas, Chile, November 7-11, 2016)

[144] Naoki Yoshida: “Simulations of Cosmic Structure Formation”, The 1st Computer Alliance Symposium (Tokyo, Japan, November 20, 2016)

[145] Tomonori Totani: “Fast Radio Bursts”, The extreme Universe viewed in very-high-energy gamma rays 2016 (Kashiwa, Japan, December 15-16, 2016)

[146] Kazumi Kashiyama: “Electromagentic counterparts of massive stellar mass black hole formation”, Transient Universe in the Big Survey Era: Understanding the Nature of Astrophysical Explosive Phenomena (Kyoto, Japan, January 23-24, 2017)

[147] Shogo B. Kobayashi: “Ultra Luminous X-ray sources: one of the most curious objects in the universe”, Ultra Luminous X-ray sources workshop (ISAS, Japan, March 6-7, 2017)

[148] Nastuki H. Hayatsu and ALMA Deep Field in SSA22 team: “ALMA Deep Field in SSA22 (ADF22): Cosmic Molecular Gas Mass Density at z = 0.7 and 6.2”, East-Asian ALMA Science Workshop 2016-Taiwan (Hsinchu, Taiwan, March 10-12, 2017)

[149] Akira Harada and Shoichi Yamada: “Toward general relativistic supernovae simulations”, The Third ALPS Symposium on Photon Science (Tokyo, Japan, March 24, 2017)

[150] Natsuki H. Hayatsu and ALMA Deep Field in SSA22 team: “Search for mm/submm Line Emitting Galaxies in ALMA Deep Fields”, ALMA deep surveys and their synergies with HST and JWST (Tokyo, Japan, March 31 - April 1, 2017)

6 Project 2. Gravitational-wave astrophysics and experimental gravity

6.1 Activity Report

Our research group is focused on observational astrophysics using gravitational waves. Gravitational waves are radiative modes of spacetime curvature. Unlike electromagnetic waves like radio and light, which are produced by the movement of electric charges and currents, gravitational waves are produced by the movement of mass and momentum. There are many reasons why gravitational waves are an interesting way to explore the sky. Because of the different physics responsible for their production gravitational waves carry fundamentally different information about their sources than is carried by electromagnetic waves. Gravitational waves interact very weakly with matter allowing them to propagate unimpeded through material that would be completely opaque to electromagnetic energy, for example we believe gravitational waves can escape the dense deep cores of supernovae, and show us the earliest moments of the Big Bang. The Earth, too, is transparent to gravitational waves, so gravitational-wave telescopes can look straight down through the Earth as easily as they look up, allowing gravitational-wave telescopes to monitor the whole sky continuously, day and night. Gravitational waves are the only significant form of energy expected to be radiated by some of the most exotic events in the universe like the collisions of black holes.

Our research group's members are members of the LIGO Scientific Collaboration (LSC) and KAGRA Collaboration, and we analyze data collected by the two LIGO gravitational-wave antennas in the United States, the Virgo antenna in Italy, the GEO600 antenna in Germany, and (in the future) the KAGRA antenna being built in Japan. The LIGO Observatories began the second observing run of Advanced LIGO, "O2", during this past academic year. This will also mark the start of Advanced Virgo's first observations, although the newly-commissioned antenna won't join the effort until the 2017–2018 academic year. Members of our group are active in all aspects of observational gravitational-wave astronomy, the following are some highlights from FY2016.

6.1.1 Compact objects

When heavy stars exhaust their fuel supply they undergo gravitational collapse. The end state of this process can be a neutron star or a black hole. There are many of these in the Universe, and occasionally they collide with one another. These collisions are very powerful sources of gravitational radiation. Since the first detection of gravitational waves from the collision of a pair of black holes in September, 2015, we have been able to study the behaviour of strongly curve spacetime. In the future we hope to observe the collision of a pair of neutron stars and simultaneously observe the light emitted from the collision. Our group is leading this effort with the operation of the "GstLAL" based low-latency compact object detection pipeline. This system analyzes data collected by the LIGO and Virgo antennas and, within 10s of seconds, provides alerts to optical, radio, gamma ray, x-ray and neutrino astronomers all around the globe in the on-going effort to capture these elusive events. By studying compact object mergers we will learn about the properties of spacetime, and the properties of matter at extreme densities.

6.1.2 Other exotica

Cosmic strings are theoretical topological defect structures left over from the cooling process of the early Universe. Although none have ever been discovered, a broad spectrum of theories of fundamental physics predict their existence. Although they might exist, they might also be so rare that none are present in the part of the Universe visible to us. Either way, searching for them and either confirming their existence

or putting limits on their number will teach us a great deal about fundamental physics. Our group led the development of the LSC and Virgo Collaboration's cosmic string detection pipeline and we are in the process of upgrading it to improve its sensitivity.

6.1.3 Stochastic gravitational-wave background

While some gravitational wave sources are close, loud, and infrequent, we also expect various classes of gravitational wave sources to be far away, weak, but extremely numerous. Rather than distinct, impulsive, signals being detected from such sources we expect to observe them collectively as a diffuse "glow" of random gravitational radiation coming from all directions on the sky — a stochastic gravitational-wave background. While spacetime fluctuations in the very early Universe are expected to contribute to the gravitational-wave background, that is expected to be a very weak contribution. A detectable stochastic background of gravitational radiation would come from more recent astrophysical processes, for example black hole collisions in the early Universe, a population of cosmic strings, and so on. Many of the possible sources of a stochastic gravitational wave background are conjectural; their discovery would be a tremendous breakthrough. This past year our group has begun contributing to the effort to find such gravitational waves.

6.1.4 Infrastructure for future observations

As gravitational wave detectors are becoming more sensitive, the rate of detections is increasing, and we are quickly reaching the point at which it is no longer possible for people to manually study gravitational-wave candidates one at a time. It is critical to the progress of the field to automate the statistical analysis of signals to understand their properties, and our group is working to ensure we are ready for the "O3" and future observing runs of the Advanced LIGO, Advanced Virgo, and KAGRA detectors.

6.1.5 People and things

The 2016 through 2017 academic year saw our group grow in size significantly, with 3 new master's students and 1 new doctoral student. Our current members are Prof. Kipp Cannon, Prof. Yousuke Itoh, Mr. Soichiro Morisaki, Mr. Hiroaki Ohta, Mr. Leo Tsukada, and Mr. Daichi Tsuna.

Our group enjoyed substantial international conference participation in the 2016–2017 academic year. In December 2016 The Research Center for the Early Universe (RESCEU) hosted the gravitational-wave astrophysics symposium titled "Gravitational-Wave Astrophysics in the High Event Rate Regime". In 2017, Prof. Cannon served as a member of the Scientific Organizing Committee of the 2017 Gravitational-Wave Physics and Astronomy Workshop (GWPAW) hosted by The Laboratoire d'Annecy-le-Vieux de Physique des Particules (LAAP) in Annecy, France. As in the previous year, our group hosted a one-week gravitational-wave data analysis hack-a-thon attended by visitors from the University of Wisconsin-Milwaukee, and The Pennsylvania State University.

We benefited from an active visitor program. Mr. Giovanni Cerretani from the Università di Pisa, Italy, visited our group to collaborate on an on-going investigation into the possibility of using digital signal processors (DSPs) to accelerate gravitational-wave detection algorithms. Dr. Sarah Caudill of the University of Wisconsin-Milwaukee collaborated with several group members on a variety of issues affecting current detection algorithms. Dr. Aaron Zimmerman of The Canadian Institute for Theoretical Astrophysics (CITA) was one of three invited lecturers at RESCEU's annual Summer School, and bracketed his time at the school collaborating with group members on the problem of neutron star and black hole collision "parameter estimation". Ms. Heather Fong of CITA visited and collaborated on the incorporation of astrophysical models of source properties into the detection algorithms used for identifying neutron star and black hole collisions.

Finally, we are pleased to report that RESCEU acquired a new computer cluster, which is currently being commissioned and will join the LIGO Data Grid (LDG) to be used for gravitational-wave data analysis activities by our research group in the coming year.

6.2 Publication List

[1] Kazuyuki Muraoka, et al. (including Kotaro Kohno): "CO(J = 3-2) on-the-fly mapping of the nearby spiral galaxies NGC 628 and NGC 7793: Spatially resolved CO(J = 3-2) star-formation law", Publications of the Astronomical Society of Japan, **68** (2016) 18

[2] Takuma Izumi, Koichiro Nakanishi, Masatoshi Imanishi, and Kotaro Kohno: "ALMA observations of the submillimetre hydrogen recombination line from the type 2 active nucleus of NGC 1068", Monthly Notices of the Royal Astronomical Society, **459** (2016) 3629-3634

[3] Bunyo Hatsukade, Kotaro Kohno, et al.: "SXDF-ALMA 2-arcmin^2 deep survey: 1.1-mm number counts", Publications of the Astronomical Society of Japan, **68** (2016) 36

[4] Yuta Kato, et al. (including Kotaro Kohno): "Herschel protocluster survey: a search for dusty star-forming galaxies in protoclusters at $z = 2 - 3$", Monthly Notices of the Royal Astronomical Society, **460** (2016) 3861-3872

[5] B. P. Abbott, et al. (including Kipp Cannon): "Tests of general relativity with GW150914", Physical Review Letters, **116** (2016) 221101

[6] B. P. Abbott, et al. (including Kipp Cannon): "Characterization of transient noise in advanced LIGO relevant to gravitational wave signal GW150914", Classical and Quantum Gravity, **33** (2016) 134001

[7] B. P. Abbott, et al. (including Kipp Cannon): "GW150914: First results from the search for binary black hole coalescence with Advanced LIGO", Physical Review D, **93** (2016) 122003

[8] B. P. Abbott, et al. (including Kipp Cannon): "Observing gravitational-wave transient GW150914 with minimal assumptions", Physical Review D, **93** (2016) 122004

[9] B. P. Abbott, et al. (including Kipp Cannon): "Properties of the binary black hole merger GW150914", Physical Review Letters, **116** (2016) 241102

[10] B. P. Abbott, et al. (including Kipp Cannon): "GW151226: Observation of gravitational waves from a 22-solar-mass binary black hole coalescence", Physical Review Letters, **116** (2016) 241103

[11] B. P. Abbott, et al. (including Kipp Cannon): "Search for transient gravitational waves in coincidence with short-duration radio transients during 2007-2013", Physical Review D, **93** (2016) 122008

[12] S. Adrián-Martínez, et al. (including Kipp Cannon): "High-energy neutrino follow-up search of gravitational wave event GW150914 with ANTARES and IceCube", Physical Review D, **93** (2016) 122010

[13] Tomoki Morokuma, Masaomi Tanaka, Yuichiro Asakura, Fumio Abe, Paul J. Tristram, Yousuke Utsumi, Mamoru Doi, Kenta Fujisawa, Ryosuke Itoh, Yoichi Itoh, Koji S. Kawabata, Nobuyuki Kawai, Daisuke Kuroda, Kazuya Matsubayashi, Kentaro Motohara, Katsuhiro L. Murata, Takahiro Nagayama, Kouji Ohta, Yoshihiko Saito, Yoichi Tamura, Nozomu Tominaga, Makoto Uemura, Kenshi Yanagisawa, Yoichi Yatsu, and Michitoshi Yoshida: "J-GEM Follow-Up Observations to Search for an Optical Counterpart of The First Gravitational Wave Source GW150914", Publications of the Astronomical Society of Japan, **68** (2016) L9

[14] Ben Farr, Christopher P. L. Berry, Will M. Farr, Carl-Johan Haster, Hannah Middleton, Kipp Cannon, Philip B. Graff, Chad Hanna, Ilya Mandel, Chris Pankow, Larry R. Price, Trevor Sidery, Leo P. Singer, Alex L. Urban, Alberto Vecchio, John Veitch, and Salvatore Vitale: "Parameter estimation on gravitational waves from neutron-star binaries with spinning components", The Astrophysical Journal, **825** (2016) 116

[15] B. P. Abbott, et al. (including Kipp Cannon, Mamoru Doi): "Localization and Broadband Follow-up of the Gravitational-wave Transient GW150914", The Astrophysical Journal, **826** (2016) L13

[16] B. P. Abbott, et al. (including Kipp Cannon, Mamoru Doi): "Supplement: "Localization and Broadband Follow-up of the Gravitational-wave Transient GW150914" (2016, ApJL, 826, L13)", The Astrophysical Journal Supplement Series, **225** (2016) 8

[17] Hayato Motohashi, Karim Noui, Teruaki Suyama, Masahide Yamaguchi, and David Langlois: "Healthy degenerate theories with higher derivatives", Journal of Cosmology and Astroparticle Physics, **1607** (2016) 033

[18] Misao Sasaki, Teruaki Suyama, Takahiro Tanaka, and Shuichiro Yokoyama: "Primordial Black Hole Scenario for the Gravitational-Wave Event GW150914", Physical Review Letters, **117** (2016) 061101

[19] Tomohiro Nakama and Teruaki Suyama: "Primordial black holes as a novel probe of primordial gravitational waves. II: Detailed analysis", Physical Review D, **94** (2016) 043507

[20] Takuma Izumi, Nozomu Kawakatu, and Kotaro Kohno: "Do Circumnuclear Dense Gas Disks Drive Mass Accretion onto Supermassive Black Holes?", The Astrophysical Journal, **827** (2016) 81

[21] B. P. Abbott, et al. (including Kipp Cannon): "Comprehensive all-sky search for periodic gravitational waves in the sixth science run LIGO data", Physical Review D, **94** (2016) 042002

[22] Yuki Yamaguchi, Yoichi Tamura, Kotaro Kohno, et al.: "SXDF-ALMA 2 arcmin^2 deep survey: Resolving and characterizing the infrared extragalactic background light down to 0.5 mJy", Publications of the Astronomical Society of Japan, **68** (2016) 82

[23] Yuya Kuwahara, Ayaka Shoda, Kazunari Eda, and Masaki Ando: "Search for a stochastic gravitational wave background at 1-5 Hz with a torsion-bar antenna", Physical Review D, **94** (2016) 042003

[24] Nobuyuki Matsumoto, Kentaro Komori, Sosuke Ito, Yuta Michimura, and Yoichi Aso: "Direct measurement of optical-trap-induced decoherence", Physical Review A, **94** (2016) 033822

[25] B. P. Abbott, et al. (including Kipp Cannon): "Directly comparing GW150914 with numerical solutions of Einstein's equations for binary black hole coalescence", Physical Review D, **94** (2016) 064035

[26] Takashi Nakamura, Masaki Ando, Tomoya Kinugawa, Hiroyuki Nakano, Kazunari Eda, Shuichi Sato, Mitsuru Musha, Tomotada Akutsu, Takahiro Tanaka, Naoki Seto, Nobuyuki Kanda, and Yousuke Itoh: "Pre-DECIGO can get the smoking gun to decide the astrophysical or cosmological origin of GW150914-like binary black holes", Progress of Theoretical and Experimental Physics, **2016** (2016) 093E01

[27] Daisuke Iono, et al. (including Kotaro Kohno): "Clumpy and Extended Starbursts in the Brightest Unlensed Submillimeter Galaxies", The Astrophysical Journal, **829** (2016) L10

[28] B. P. Abbott, et al. (including Kipp Cannon): "The basic physics of the binary black hole merger GW150914", Annalen der Physik, **529** (2016) 1600209

[29] Soichiro Morisaki, Jun'ichi Yokoyama, Kazunari Eda, and Yousuke Itoh: "Toward the detection of gravitational waves under non-Gaussian noises II. Independent Component Analysis", Proceedings of the Japan Academy ser B, **92** (2016) 336-345

[30] B. P. Abbott, et al. (including Kipp Cannon): "An improved analysis of GW150914 using a fully spin-precessing waveform model", Physical Review X, **6** (2016) 041014

[31] B. P. Abbott, et al. (including Kipp Cannon): "Binary black hole mergers in the first Advanced LIGO observing run", Physical Review X, **6** (2016) 041015

[32] B. P. Abbott, et al. (including Kipp Cannon): "First targeted search for gravitational-wave bursts from core-collapse supernovae in data of first-generation laser interferometer detectors", Physical Review D, **94** (2016) 102001

[33] B. P. Abbott, et al. (including Kipp Cannon): "Results of the deepest all-sky survey for continuous gravitational waves on LIGO S6 data running on the Einstein@Home volunteer distributed computing project", Physical Review D, **94** (2016) 102002

[34] B. P. Abbott, et al. (including Kipp Cannon): "Upper limits on the rates of binary neutron star and neutron-star-black-hole mergers from Advanced LIGO's first observing run", The Astrophysical Journal, **832** (2016) L21

[35] B. P. Abbott, et al. (including Kipp Cannon): "The rate of binary black hole mergers inferred from Advanced LIGO observations surrounding GW150914", The Astrophysical Journal, **833** (2016) L1

[36] Michitoshi Yoshida, Yousuke Utsumi, Nozomu Tominaga, Tomoki Morokuma, Masaomi Tanaka, Yuichiro Asakura, Kazuya Matsubayashi, Kouji Ohta, Fumio Abe, Sho Chimasu, Hisanori Furusawa, Ryosuke Itoh, Yoichi Itoh, Yuka Kanda, Koji S. Kawabata, Miho Kawabata, Shintaro Koshida, Naoki Koshimoto, Daisuke Kuroda, Yuki Moritani, Kentaro Motohara, Katsuhiro L. Murata, Takahiro Nagayama, Tatsuya Nakaoka, Fumiaki Nakata, Tsubasa Nishioka, Yoshihiko Saito, Tsuyoshi Terai, Paul J. Tristram, Kenshi Yanagisawa, Naoki Yasuda, Mamoru Doi, Kenta Fujisawa, Akiko Kawachi, Nobuyuki Kawai, Yoichi Tamura, Makoto Uemura, Yoichi Yatsu: "J-GEM follow-up observations of the gravitational wave source GW151226", Publications of the Astronomical Society of Japan, **69** (2017) 9

[37] Hayato Motohashi, Teruaki Suyama, and Kazufumi Takahashi: "Fundamental theorem on gauge fixing at the action level", Physical Review D, **94** (2016) 124021

[38] Wei-Hao Wang, Kotaro Kohno, et al.: "The SXDF-ALMA 2-arcmin^2 Deep Survey: Stacking Rest-frame Near-infrared Selected Objects", The Astrophysical Journal **833** (2016) 195

[39] Ken-ichi Tadaki, et al.: "Bulge-forming Galaxies with an Extended Rotating Disk at $z \sim 2$" The Astrophysical Journal, **834** (2017) 135

[40] Hideki Umehata, et al. (including Kotaro Kohno): "ALMA Reveals Strong [CII] Emission in a Galaxy Embedded in a Giant Lyα Blob at $z = 3.1$", The Astrophysical Journal, **834** (2017) L16

[41] Tatsuya Takekoshi, et al. (including Kotaro Kohno): "The 1.1 mm Continuum Survey of the Small Magellanic Cloud: Physical Properties and Evolution of the Dust-selected Clouds", The Astrophysical Journal, **835** (2017) 55

[42] Hideki Umehata, Yoichi Tamura, Kotaro Kohno, et al.: "ALMA Deep Field in SSA22: Source Catalog and Number Counts", The Astrophysical Journal **835** (2017) 98

[43] B. P. Abbott, et al. (including Kipp Cannon): "Exploring the sensitivity of next generation gravitational wave detectors", Classical and Quantum Gravity, **34** (2017) 044001

[44] Kazufumi Takahashi and Teruaki Suyama: "Linear perturbation analysis of hairy black holes in shift-symmetric Horndeski theories: Odd-parity perturbations", Physical Review D, **95** (2017) 024034

[45] Soh Ikarashi, et al. (inluding Kotaro Kohno): "Extremely Red Submillimeter Galaxies: New $z > 4 - 6$ Candidates Discovered using ALMA and Jansky VLA", The Astrophysical Journal, **835** (2017) 286

[46] Cody Messick, Kent Blackburn, Patrick Brady, Patrick Brockill, Kipp Cannon, Romain Cariou, Sarah Caudill, Sydney J. Chamberlin, Jolien D. E. Creighton, Ryan Everett, Chad Hanna, Drew Keppel, Ryan N. Lang, Tjonnie G. F. Li, Duncan Meacher, Alex Nielsen, Chris Pankow, Stephen Privitera, Hong Qi, Surabhi Sachdev, Laleh Sadeghian, Leo Singer, E. Gareth Thomas, Leslie Wade, Madeline Wade, Alan Weinstein, and Karsten Wiesner: "Analysis framework for the prompt discovery of compact binary mergers in gravitational-wave data", Physical Review D, **95** (2017) 042001

[47] B. P. Abbott, et al. (including Kipp Cannon): "All-sky search for short gravitational-wave bursts in the first Advanced LIGO run", Physical Review D, **95** (2017) 042003

[48] B. P. Abbott, et al. (including Kipp Cannon): "Upper limits on the stochastic gravitational-wave background from Advanced LIGO's first observing run", Physical Review Letters, **118** (2017) 121101

[49] B. P. Abbott, et al. (including Kipp Cannon): "Directional limits on persistent gravitational waves from Advanced LIGO's first observing run", Physical Review Letters, **118** (2017) 121102

[50] B. P. Abbott, et al. (including Kipp Cannon): "Calibration of the Advanced LIGO detectors for the discovery of the binary black-hole merger GW150914", Physical Review D, **95** (2017) 062003

[51] Ayaka Shoda, Yuya Kuwahara, Masaki Ando, Kazunari Eda, Kodai Tejima, Yoichi Aso, and Yousuke Itoh: "Ground Based Low-Frequency Gravitational-wave Detector With Multiple Outputs", Physical Review D, **95** (2017) 082004

[52] B. P. Abbott, et al. (including Kipp Cannon): "Erratum: Upper limits on the stochastic gravitational-wave background from Advanced LIGO's first observing run [Phys. Rev. Lett. 118, 121101 (2017)]", Physical Review Letters, **119** (2017) 029901

6.3 International Conference Talks

6.3.1 Contributed talks

[53] Kotaro Kohno: "Ten parsec scale view of dense molecular medium in the active galaxy NGC 1097", Molecular Gas in Galactic Environments (Charlottesville, USA, April 4-7, 2016)

[54] Mamoru Doi, on behalf of TAO project: "The University of Tokyo Atacama Observatory (TAO) project", Chajnantor Working Group 2016 (OSF-ALMA, Chile, April 21-22, 2016)

[55] Naoki Aritomi, et al.: "Coil-Coil Actuator for reduction of magnetic noise", Gravitational Wave Advanced Detector Workshop (Elba, Italy, May 22-28, 2016)

[56] Tomofumi Shimoda, et al.: "Reduction of Seismic Coupling Noise for TOBA", Gravitational Wave Advanced Detector Workshop (Elba, Italy, May 22-28, 2016)

[57] Soichiro Morisaki: "Removing Non-Gaussian Noise Using Independent Component Analysis", The 2016 Gravitational Wave Physics and Astronomy Workshop (Hyannis, Massachusetts, USA, June 15-18, 2016)

[58] Kazunari Eda and Yousuke Itoh: "A chi-squared veto for semi-coherent $\mathcal{F}$-statistic search in continuous gravitational waves", The 2016 Gravitational Wave Physics and Astronomy Workshop (Hyannis, Massachusetts, USA, June 15-18, 2016)

[59] Takafumi Ushiba: "Mechanical loss measurement for KAGRA sapphire suspension system", The 1st international meeting on KAGRA (KISTI, Daejeon, South Korea, June 23-25, 2016)

[60] Soichiro Morisaki: "Removing Non-Gaussian Noise Using Independent Component Analysis", The 1st international meeting on KAGRA (KISTI, Daejeon, South Korea, June 23-25, 2016)

[61] Kazunari Eda and Yousuke Itoh: "A chi-squared discriminator for continuous gravitational wave detection in all-sky search", The 1st international meeting on KAGRA (KISTI, Daejeon, South Korea, June 23-25, 2016)

[62] Kazuma Mitsuda, Yasuhito Hashiba, Yosuke Minowa, Yutaka Hayano, Hajime Sugai, Atsushi Shimono, Kazuya Matsubayashi, Takashi Hattori, Yukiko Kamata, Shinobu Ozaki, Mamoru Doi, and Shigeyuki Sako: "CCD system upgrading of the Kyoto3DII and integral field spectroscopic observation with the new system", Ground-based and Airborne Instrumentation for Astronomy V (Edinburg, UK, June 26 - July 1, 2016)

[63] Kazufumi Takahashi: "Relation between gauge fixing and DOFs in scalar-tensor theories", APCosPA-Planet^2 RESCEU Summer School (Gifu, Japan, August 24-28, 2016)

[64] Kazunari Eda and Yousuke Itoh: "A chi-squared veto in semi-coherent $\mathcal{F}$-statistic search for continuous gravitational wave", APCosPA-Planet^2 RESCEU Summer School (Gifu, Japan, August 24-28, 2016)

[65] Soichiro Morisaki: "Gravitational-wave data analysis using independent component analysis", APCosPA-Planet^2 RESCEU Summer School (Gifu, Japan, August 24-28, 2016)

[66] Yuta Michimura: "KAGRA MIF Status Report", 14th KAGRA Face to Face Meetin (Toyama, Japan, August 25-27, 2016)

[67] Yuta Michimura: "Summary of iKAGRA Run", 14th KAGRA Face to Face Meeting (Toyama, Japan, August 25-27, 2016)

[68] Kazunari Eda: "Searches for continuous GWs from known pulsars with iKAGRA data", 14th KAGRA Face to Face Meetin (Toyama, Japan, August 25-27, 2016)

[69] Teruaki Suyama: "Primordial Black Hole Scenario for the Gravitational-Wave Event GW150914", Spanish-Portuguese relativity meeting (Lisbon, Portugal, September 12-15, 2016)

[70] Ryo Ando, Kotaro Kohno, et al.: "Five parsec view of the diverse starburst activities in the heart of NGC 253", Half a Decade of ALMA: Cosmic Dawns Transformed (Indian Wells, USA, September 20-23, 2016)

[71] Akio Taniguchi, Kotaro Kohno, et al.: "ALMA Study of the shocked gas property around the nucleus of NGC 1068 by the observations of multi-transition SiO lines", Half a Decade of ALMA: Cosmic Dawns Transformed (Indian Wells, USA, September 20-23, 2016)

[72] Yuki Yamaguchi, Yoichi Tamura, Kotaro Kohno, et al.: "SXDF-ALMA 2 arcmin^2 Deep Survey: Characterizing of ALMA-Detected Continuum Sources and Millimeter line-Emitter Search", Half a Decade of ALMA: Cosmic Dawns Transformed (Indian Wells, USA, September 20-23, 2016)

[73] Tomofumi Shimoda, Naoki Aritomi, and Masaki Ando: "Current Status of TOBA experiment at Univ. of Tokyo", E-GRAAL (Earthquake GRAvity ALerts) 2nd meeting (Institut de physique du globe de Paris, France, October 6, 2016)

[74] Kazufumi Takahashi: "Relation between gauge fixing and DOFs in scalar-tensor theories", The 26th Workshop on General Relativity and Gravitation in Japan (Osaka City University, Japan, October 24-28, 2016)

[75] Kazufumi Takahashi: "Relation between gauge fixing and DOFs in scalar-tensor theories", CosPA 2016 (University of Sydney, Australia, November 28 - December 2, 2016)

[76] Yuta Michimura: "KAGRA MIF Status Report", 15th KAGRA Face to Face Meeting (Tokyo, Japan, December 7-8, 2016)

[77] Kazunari Eda: "Known pulsar search using the iKAGRAdata", 15th KAGRA Face to Face Meeting (Tokyo, Japan, December 7-8, 2016)

[78] Teruaki Suyama: "Primordial Black Hole Scenario for the Gravitational-Wave Event GW150914", Symposium on New development in astrophysics through multimessenger observations of gravitational wave sources (YITP, Kyoto, Japan, December 26-28, 2016)

[79] Takafumi Ushiba: "Development of cryogenic system in KAGRA", Workshop on Gravitational Wave activities in Taiwan (Academia Sinica, Taipei, Taiwan, January 15, 2017)

[80] Yuta Michimura for the KAGRA Collaboration: "Status of KAGRA", The 5th ELiTES general meeting (Tokyo, Japan, February 8-10, 2017)

[81] Takafumi Ushiba: "Status on Cryogenic payload of KAGRA", The 5th ELiTES general meeting (Toyama, Japan, February 8-10, 2017)

[82] Yuki Yamaguchi, Yoichi Tamura, Kotaro Kohno, Masamune Oguri et al.: "A blind CO line-emitter search using ALMA data toward gravitational lensing clusters", East-Asian ALMA Science Workshop 2016 (National Tsing Hua University, Hsinchu, Taiwan, March 10-12, 2017)

[83] Tsuyoshi Ishida, Yoichi Tamura, Kotaro Kohno, Masamune Oguri et al.: "A New Algorithm of Source Plane Reconstruction and Resolved Star-Formation Properties of a Highly Lensed Submillimeter Galaxy", East-Asian ALMA Science Workshop 2016 (National Tsing Hua University, Hsinchu, Taiwan, March 10-12, 2017)

[84] Yuta Michimura: "KAGRA+ planning", 16th KAGRA Face to Face Meeting (Niigata, Japan, March 28-30, 2017)

[85] Yuta Michimura: "KAGRA MIF Status Report", 16th KAGRA Face to Face Meeting (Niigata, Japan, March 28-30, 2017)

6.3.2 Invited talks

[86] Masaki Ando: "KAGRA : a Gravitational-Wave Antenna in Japan", Korean Physical Society Spring Meeting (Daejon Convention Center, Daejon, South Korea, April 21, 2016)

[87] Masaki Ando: "The First Direct Detection of Gravitational Wave", Space Science Colloquium (ISAS-JAXA, Japan, April 27, 2016)

[88] Kipp Cannon: "GW151226: Observation of Gravitational Waves from a 22-Solar-Mass Binary Black Hole Coalescence", Cosmological Frontiers in Fundamental Physics 2016 (Perimeter Institute, Ontario, Canada, June 14-17, 2016)

[89] Masaki Ando: "Space Gravitational-Wave Antenna: DECIGO and Pre-DECIGO", The 2016 Gravitational Wave Physics and Astronomy Workshop (Hyannis, Massachusetts, USA, June 15-18, 2016)

[90] Kotaro Kohno: "Roles of ULTIMATE-Subaru in the ALMA era", ULTIMATE-Subaru science workshop 2016 (NAOJ, Mitaka, Japan, June 16-17, 2016)

[91] Yuta Michimura for the KAGRA Collaboration: "Recent news and status of the KAGRA gravitational wave telescope", Optical Society of Korea Summer Meeting 2016 (Busan, South Korea, July 14, 2016)

[92] Kotaro Kohno: "Millimeter/Submillimeter galaxy surveys using ALMA and future facilities", Astronomy Development in Vietnam: Challenges and Opportunities (Quy Nhon, Vietnam, July 31 - August 2, 2016)

[93] Masaki Ando: "KAGRA : a Cryogenic Interferometric Gravitational-Wave Antenna", Gravitational Wave Astronomy with Present and Future Detectors (Yangpyeong, South Korea, August 22-26, 2016)

[94] Kipp Cannon: "Current results and status of LIGO and Virgo", Hanoi Internation Workshop"Gravitation and the Universe" (Hanoi, Vietnam, October 30 - November 1, 2016)

[95] Kipp Cannon: "Current results and status of LIGO and Virgo", Irago Conference 2016 (Chofu, Tokyo, Japan, November 1-2, 2016)

[96] Kotaro Kohno: "Deep galaxy surveys using ALMA", Space Science Colloquium (ISAS-JAXA, Japan, December 14, 2016)

[97] Teruaki Suyama: "Primordial Black Hole Scenario for the Gravitational-Wave Event GW150914", Workshop on primordial black hole (Taipei, Taiwan, January 6, 2017)

[98] Masaki Ando: "Observation of Gravitational Waves", Physics in LHC and the Early Universe (Univ. of Tokyo, Japan, January 9-11, 2017)

[99] Kotaro Kohno: "Molecular line observations of galaxies near and far using ALMA Band 1", ALMA Band 1 Science Workshop (ASIAA, Taipei, Taiwan, January 16-20, 2017)

7 Project 3. Formation and characterization of planetary systems

7.1 Activity Report

Project 3 "Formation and characterization of planetary systems" approaches the problem both theoretically and observationally through the collaboration with members in Departments of Physics, Astronomy, and Earth and Planetary Sciences. We show several highlights of our research this year.

7.1.1 Solar System Explorations

We are engaged in missions for both small and large bodies in the solar system. As a part of small-body mission activities, we are fully engaged in Hayabusa2 mission to C-type asteroid, Ryugu. We conducted a series of calibration observations/analyses for multi-band camera on Hayabusa2 in 2016, using Mars and stars. We also conducted detailed analyses of data of Moon and Earth obtained in late 2015. The calibrated parameters include distortion, point-spread function (PSF), relative spectral sensitivity, absolute radiometric sensitivity, and flat-field calibration. Inflight calibration observations of Haybusa2 indicate that the camera system is in a good condition without any noticeable damage or major change since the preflight calibrations. Result from our detailed analyses of the inflight spectral data strongly suggest that ONC-T can achieve visible spectroscopic observation of C-type asteroid Ryugu with high enough accuracy to detect signature of hydrated minerals, such as 0.7-micron absorption, particularly when a few tens by few tens of area is binned.

As for large body missions, we are developing an in-situ age measurement system for future lander missions for Moon and Mars. In 2016, we conducted laboratory experiments for establishing good isochron measurements using the K-Ar system by creating vacuum conditions in a chamber onboard Mars lander. First, we investigated vacuum seals for mass spectrometric measurements, particularly for in situ K-Ar dating on Mars. Thermal cycle tests revealed that low-temperature-resistant O-rings can maintain pressure $< 10^5$ Pa at 60 C under 1 bar ambient pressure. Also, the measured amounts were $< 1\%$ of that a target rock with 5000 ppm K_2O and an age of 4.2 Ga would yield. These results suggest that a Viton O-ring can maintain the Ar blank low under the Mars atmospheric pressure when temperatures are higher than 25 C. A double O-ring seal using the low-temperature- resistant elastomers would be an alternative approach at lower temperatures. The elastomeric O-rings would be useful for constructing a small and light-weighted mass spectrometric instrument for in situ K-Ar dating on Mars. Second, we obtained various calibration curves for K using internal normalization with the oxygen line at 777 nm and continuum emission from the laser-induced plasma. Experimental results indicate a detection limit of 88 ppm and 20% of error at 2400 ppm of K_2O foe 30mJ laser. Error assessments using obtained calibration models indicate that a 4 Ga rock with 3000 ppm K_2O would be measured with 8% (30mJ) of precision in age when combined with mass spectrometry of 40Ar with 10% of uncertainty.

7.1.2 A possible ringed-planet candidate from the Kepler data

While over 3500 exoplanets have been detected by the Kepler satellite launched in 2009, no evidence of a Saturnian ring around exoplanets has been reported yet. We developed a methodology to identify exoplanetary rings, applied it to the Kepler data, and consequently, found a possible ringed-planet candidate for the first time. The left figure shows the transit light curves and the residuals obtained from models fitted to the data. While a ringless planet does not explain the data, a ringed planet fits the data consistently. In addition to the planetary ring hypothesis (A in right panel), there remain two alternative scenarios: a

transiting binary planet like the system of Pluto and Charon (B in right panel) and an eclipsing binary star with a circumstellar disk (C in right panel). If our candidate is confirmed as a ringed planet or a binary planet, it is the first detection of such objects outside the Solar System. We will continue to study this candidate in various ways including the spectroscopic follow-up with the Subaru telescope. This result was featured by American Astronomical Society on the web; AAS NOVA Features, "The Search for Ringed Exoplanets", http://aasnova.org/2017/04/07/the- search-for-ringed-exoplanets/.

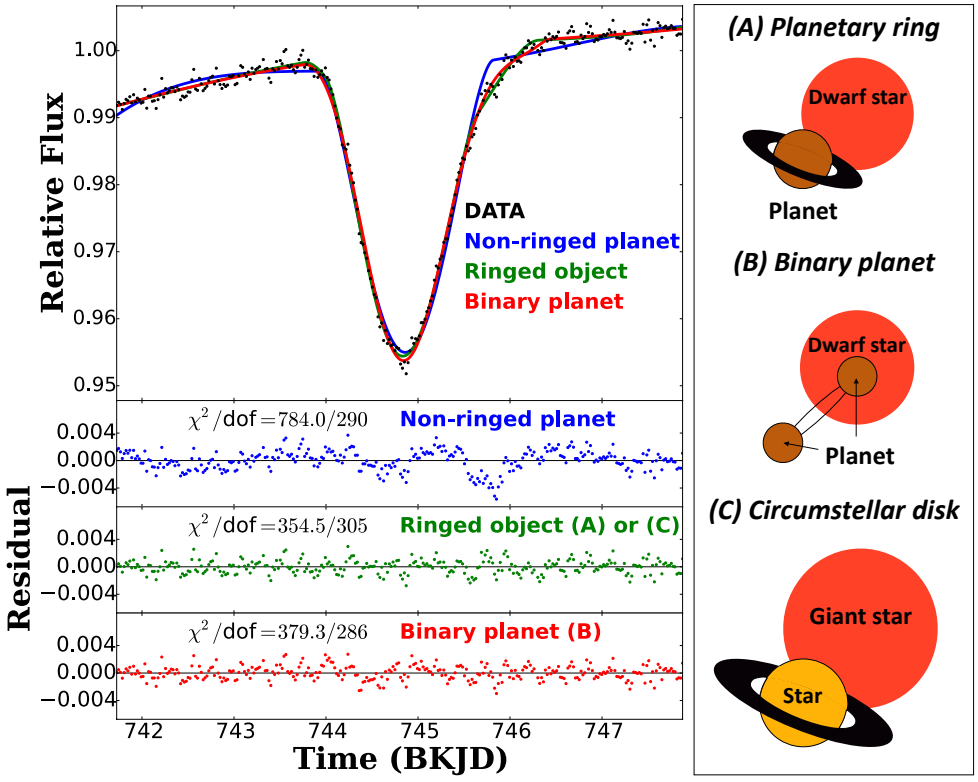

Figure 7.1: Three possible interpretations of an anomalous photometric signal that we found from the Kepler data.

7.1.3 Transiting Planets beyond the Snow Line

The transiting planetary system provides an excellent opportunity for the planet characterization. However, it was difficult to identify long-period transiting planets because of a limited number of transits in observing period. We searched for single transiting events in $\sim$ 8000 light curves of the Kepler data by visual inspection. It enabled us to identify seven long period planets with periods of a few to 20 yr. We also estimate that $\gtrsim$ 20% of the compact multi-transiting systems host cool giant planets with periods $\gtrsim$ 3yr by their occurrence in the KOIs with multiple candidates, assuming the small mutual inclination between inner and outer planetary orbits [7].

7.1.4 Methodology of Characterization of Directly Imaged Exoplanets

The surface mapping technique using amplitude modulation (AM) of scattered lights is one of the promising methods to characterize Earth-like planets in future. An estimate of planet tilt is crucial for this mapping method (Spin-Orbit Tomography; SOT). In this FY, we focused on the other side, frequency modulation (FM) to extract the information on the tilt [10]. We found that the instantaneous frequency (IF) curve

depends on the tilt and the orbital inclination and one can recover the geometric information from the IF-curve using the Wigner-Ville distribution.

7.1.5 Post-Coronagraphic Injection

Direct imaging with coronagraphs (HCI) has been considered as the most important technique for planet characterization as well as transit spectroscopy. Recently, high-dispersion spectroscopy has also been recognized as a powerful method for planetary atmosphere characterization. We are developing a device to combine both instruments, i.e. IRD and SCExAO on Subaru telescope. In this FY, we made this device, post-coronagraphic injection (PCI) [50]. We also started to develop a new method for PCI technique in RESCEU cleanroom.

7.1.6 Formation and evolution of planetary atmospheres

Recent exoplanet observation has revealed that the composition and mass of planetary atmospheres diverse greatly. This year we have first investigated how much hydrogen is gained by accreting protoplanets. Also, we have explored the possibility that the composition of water-rich atmospheres is largely modified by the giant collision fragments of metallic cores of terrestrial planets. Furthermore, we have found that the evolution of the atmospheres of ice giants is accelerated by water condensation of the upper atmospheres. Observationally, we have conducted multi-wavelength transit observations at Okayama Observatory and demonstrated that our observational instrument is powerful enough to constrain the atmospheric composition of exoplanet atmospheres.

7.1.7 Exoplanet Observations and Instrumentations

Direct imaging of exoplanets and their forming regions such as circumstellar disks is technically challenging but an important step from detection to characterization of exoplanets and disks. The SEEDS project using the HiCIAO camera on the 8.2m Subaru telescope has been successful to study young stars in very high-contrast since 2009. After its main survey phase, we are engaged in extending this study using new direct imaging instruments, SCExAO and CHARIS. The former is an extreme adaptive optics system and the latter is a near-infrared integral field unit (IFU) spectrometer dedicated for high contrast imaging and spectroscopy. In this year, we have published the first SCExAO science paper as well as many SEEDS papers using the main survey data and their follow-up data. In particular, the SEEDS YSO survey result (Uyama et al. 2016) is one of the largest and deepest surveys in star forming regions. We are also developing several other instruments for exoplanet observations: (a) an Earth-like planet hunting radial velocity instrument working at near-infrared and combined with a laser-frequency comb (IRD) for the Subaru telescope, which will be very powerful to detect habitable planets around nearby M stars, (b) a TESS-follow-up optical transit camera, MuSCAT2 for the TCS 1.52m telescope at Teide Observatory in the Canary Islands, Spain, (d) a coronagraph for earth-like planet imaging on the 30m telescope TMT, SEIT, and (e) a coronagraph for NASA WFIRST 2.4m space telescope mission. We also jointly operate the 1.4m IRSF telescope, the SIRIUS camera, and its polarimeter SIRPOL in South Africa with the Nagoya and other universities, and conducting a near-infrared polarization survey of various targets. This is the most extensive near-infrared polarization study ever made and providing useful astronomical data for astrobiology such as life homochirarity.

7.2 Publication List

[1] Daehyeon Oh, Jun Hashimoto, Motohide Tamura, John Winsiewski, Eiji Akiyama, Thayne Currie, Satoshi Mayama, Michihiro Takami, Christian Thalmann, Tomoyuki Kudo, Nobuhiko Kusakabe, Lyu Abe, Wolfgang Brandner, Timothy D. Brandt, Joseph C. Carson, Sebastian Egner, Markus Feldt, Miwa Goto, Carol A. Grady, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Saeko S. Hayashi, Thomas Henning, Klaus W. Hodapp, Miki Ishii, Masanori Iye, Markus Janson, Ryo Kandori, Gillian R. Knapp, Masayuki Kuzuhara, Jungmi Kwon, Taro Matsuo, Michael W. Mcelwain, Shoken Miyama, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura,

Tae-Soo Pyo, Eugene Serabyn, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Yasuhiro H. Takahashi, Naruhisa Takato, Hiroshi Terada, Edwin L. Turner, Makoto Watanabe, Toru Yamada, Hideki Takami, and Tomonori Usuda: "Near-infrared imaging polarimetry of LkCa 15: A possible warped inner disk", Publications of the Astronomical Society of Japan, **68** (2016) L3

[2] Akihiko Fukui, Norio Narita, Yui Kawashima, Nobuhiko Kusakabe, Masahiro Onitsuka, Tsuguru Ryu, Masahiro Ikoma, Kenshi Yanagisawa, and Hideyuki Izumiura: "Demonstrating High-precision, Multiband Transit Photometry with MuSCAT: A Case for HAT-P-14b", The Astrophysical Journal, **819** (2016) 27

[3] Shogo Nishiyama, Rainer Schoedel, Tatsuhito Yoshikawa, Tetsuya Nagata, Yosuke Minowa, and Motohide Tamura: "Spectroscopically identified intermediate age stars at $0.5 - 3$ pc distance from Sagittarius A*", Astronomy & Astrophysics, **588** (2016) A49

[4] Kento Masuda and Yasushi Suto: "Transiting planets as a precision clock to constrain the time variation of the gravitational constant", Publications of the Astronomical Society of Japan, **68** (2016) L5

[5] M. Honda, T. Kudo, S. Takatsuki, A. K. Inoue, T. Nakamoto, M. Fukagawa, M. Tamura, H. Terada, and N. Takato: "Water Ice at the Surface of the HD 100546 Disk", The Astrophysical Journal, **821** (2016) 2

[6] Peng K Hong, Hideaki Miyamoto, Takafumi Niihara, Seiji Sugita, Kenji Nagata, James M Dohm, and Masato Okada: "An Automatic Deconvolution Method for Modified Gaussian Model using the Exchange Monte Carlo Method: Application to Reflectance Spectra of Synthetic Clinopyroxene", Journal of Geology & Geophysics, **5** (2016) 243

[7] Sho Uehara, Hajime Kawahara, Kento Masuda, Shin'ya Yamada, and Masataka Aizawa: "Transiting Planet Candidates Beyond the Snow Line Detected by Visual Inspection of 7557 Kepler Objects of Interest", The Astrophysical Journal, **822** (2016) 2

[8] Hideaki Miyamoto, Takafumi Niihara, Takeshi Kuritani, Peng K. Hong, James M. Dohm, and Seiji Sugita: "Cluster analysis on the bulk elemental compositions of Antarctic stony meteorites", Meteoritics & Planetary Science, **51** (2016) 906-919

[9] Ana López-Sepulcre, Yoshimasa Watanabe, Nami Sakai, Ryuta Furuya, Osamu Saruwatari, and Satoshi Yamamoto: "The Role of SiO As a Tracer of Past Star Formation Events: The Case of the High-Mass Protocluster NGC2264-C", The Astrophysical Journal, **822** (2016) 85

[10] Hajime Kawahara: "Frequency Modulation of Directly Imaged Exoplanets: Geometric Effect as a Probe of Planetary Obliquity", The Astrophysical Journal, **822** (2016) 112

[11] Zhiwei Chen, Shaobo Zhang, Miaomiao Zhang, Zhibo Jiang, Motohide Tamura, and Jungmi Kwon: "Coeval Intermediate-mass Star Formation in N4W", The Astrophysical Journal, **822** (2016) 114

[12] Yuichiro Cho, Seiji Sugita, Yayoi N. Miura, Ryuji Okazaki, Naoyoshi Iwata, Tomokatsu Morota, and Shingo Kameda: "An in-situ K-Ar isochron dating method for planetary landers using a spot-by-spot laser-ablation technique", Planetary and Space Science, **128** (2016) 14-29

[13] Wisniewski, Jeremy R. Swearingen, Hiroshi Shibai, Takahiro Sumi, Jun Hashimoto, Tomoyuki Kudo, Nobuhiko Kusakabe, Munetake Momose, Yoshiko Okamoto, Takayuki Kotani, Michihiro Takami, Thayne Currie, Christian Thalmann, Markus Janson, Eiji Akiyama, Katherine B. Follette, Satoshi Mayama, Lyu Abe, Wolfgang Brandner, Timothy D. Brandt, Joseph C. Carson, Sebastian E. Egner, Markus Feldt, Miwa Goto, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Saeko S. Hayashi, Thomas Henning, Klaus W. Hodapp, Miki Ishii, Masanori Iye, Ryo Kandori, Gillian R. Knapp, Masayuki Kuzuhara, Jungmi Kwon, Taro Matsuo, Michael W. McElwain, Shoken Miyama, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura, Tae-Soo Pyo, Eugene Serabyn, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Yasuhiro H. Takahashi, Hideki Takami, Naruhisa Takato, Hiroshi Terada, Daigo Tomono, Edwin L. Turner, Tomonori Usuda, Makoto Watanabe, Toru Yamada, and Motohide Tamura: "Extreme asymmetry in the polarized disk of V1247 Orionis", Publications of the Astronomical Society of Japan, **68** (2016) 53

[14] S. Kameda, H. Suzuki, T. Takamatsu, Y. Cho, T. Yasuda, M. Yamada, H. Sawada, R. Honda, T. Morota, C. Honda, M. Sato, Y. Okumura, K. Shibasaki, and S. Ikezawa: "Preflight calibration test results for optical navigation camera telescope (ONC-T) onboard the Hayabusa2 spacecraft", Space Science Reviews, **208** (2016) 17-31

[15] Yoko Oya, Nami Sakai, Ana López-Sepulcre, Yoshimasa Watanabe, Cecilia Ceccarelli, Bertrand Lefloch, Cécile Favre, and Satoshi Yamamoto: "Infalling-Rotating Motion and Associated Chemical Change in the Envelope of IRAS 16293-2422 Source A Studied with ALMA", The Astrophysical Journal, **824** (2016) 88

[16] Jungmi Kwon, Motohide Tamura, James H. Hough, Tetsuya Nagata, Nobuhiko Kusakabe, and Hiro Saito: "Near-infrared Imaging Polarimetry of GGD 27: Circular Polarization and Magnetic Field Structures", The Astrophysical Journal, **824** (2016) 95

[17] Teruyuki Hirano, Grzegorz Nowak, Masayuki Kuzuhara, Enric Palle, Fei Dai, Liang Yu, Vincent Van Eylen, Yoichi Takeda, Timothy D. Brandt, Norio Narita, Sergio Velasco, Jorge Prieto Arranz, Roberto Sanchis-Ojeda, Joshua N. Winn, Tomoyuki Kudo, Nobuhiko Kusakabe, Akihiko Fukui, Bun'ei Sato, Simon Albrecht, Ignasi Ribas, Tsuguru Ryu, and Motohide Tamura: "The K2-ESPRINT Project IV. A Hot Jupiter in a Prograde Orbit with a Possible Stellar Companion", The Astrophysical Journal, **825** (2016) 53

[18] R. Jaumann, N. Schmitz, A. Koncz, H. Michaelis, S. E. Schroeder, S. Mottola, F. Trauthan, H. Hoffmann, T. Roatsch, D. Jobs, J. Kachlicki, B. Pforte, R. Terzer, M. Tschentscher, S. Weisse, U. Mueller, L. Perez-Prieto, B. Broll, A. Kruselburger, T.-M. Ho, J. Biele, S. Ulamec, C. Krause, M. Grott, J.-P. Bibring, S. Watanabe, S. Sugita, T. Okada, M. Yoshikawa, and H. Yabuta: "The Camera of the MASCOT Asteroid Lander on Board Hayabusa 2", Space Science Reviews, **208** (2016) 375-400

[19] Tsuguru Ryu, Bun'ei Sato, Masayuki Kuzuhara, Norio Narita, Yasuhiro H. Takahashi, Taichi Uyama, Tomoyuki Kudo, Nobuhiko Kusakabe, Jun Hashimoto, Masashi Omiya, Hiroki Harakawa, Lyu Abe, Hiroyasu Ando, Wolfgang Brandner, Timothy D. Brandt, Joseph C. Carson, Thayne Currie, Sebastian Egner, Markus Feldt, Miwa Goto, Carol A. Grady, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Saeko S. Hayashi, Krzysztof G. Helminiak, Thomas Henning, Klaus W. Hodapp, Shigeru Ida, Miki Ishii, Yoichi Itoh, Masanori Iye, Hideyuki Izumiura, Markus Janson, Eiji Kambe, Ryo Kandori, Gillian R. Knapp, Eiichiro Kokubo, Jungmi Kwon, Taro Matsuo, Satoshi Mayama, Michael W. McElwain, Kyle Mede, Shoken Miyama, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura, Tae-Soo Pyo, Eugene Serabyn, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Michihiro Takami, Naruhisa Takato, Yoichi Takeda, Hiroshi Terada, Christian Thalmann, Edwin L. Turner, Makoto Watanabe, John Wisniewski, Toru Yamada, Michitoshi Yoshida, Hideki Takami, Tomonori Usuda, and Motohide Tamura: "High-contrast Imaging of Intermediate-mass Giants with Long-term Radial Velocity Trends", The Astrophysical Journal, **825** (2016) 127

[20] Toshimori Sekine, Norimasa Ozaki, Kohei Miyanishi, Yuto Asaumi, Tomoaki Kimura, Bruno Albertazzi, Yuya Sato, Youichi Sakawa, Takayoshi Sano, Seiji Sugita, Takafumi Matsui, and Ryosuke Kodama: "Shock compression response of forsterite above 250 GPa", Science Advances, **2** (2016) e1600157

[21] Glenn Schneider, Carol A. Grady, Christopher C. Stark, Andras Gaspar, Joseph Carson, John H. Debes, Thomas Henning, Dean C. Hines, Hannah Jang-Condell, Marc J. Kuchner, Marshall Perrin, Timothy J. Rodigas, Motohide Tamura, and John P. Wisniewski: "Deep HST/STIS Visible-light Imaging of Debris Systems around Solar Analog Hosts", The Astronomical Journal, **152** (2016) 64

[22] Jamie R. Lomax, John P. Wisniewski, Carol A. Grady, Michael W. McElwain, Jun Hashimoto, Tomoyuki Kudo, Nobuhiko Kusakabe, Yoshiko K. Okamoto, Misato Fukagawa, Lyu Abe, Wolfgang Brandner, Timothy D. Brandt, Joseph C. Carson, Thayne M. Currie, Sebastian Egner, Markus Feldt, Miwa Goto, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Saeko S. Hayashi, Thomas Henning, Klaus W. Hodapp, Akio Inoue, Miki Ishii, Masanori Iye, Markus Janson, Ryo Kandori, Gillian R. Knapp, Masayuki Kuzuhara, Jungmi Kwon, Taro Matsuo, Satoshi Mayama, Shoken Miyama, Munetake Momose, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura, Tae-Soo Pyo, Glenn H Schneider, Eugene Serabyn, Michael L. Sitko, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Yasuhiro H. Takahashi, Michihiro Takami, Naruhisa Takato, Hiroshi Terada, Christian Thalmann, Daigo Tomono, Edwin L. Turner, Makoto Watanabe, Toru Yamada, Hideki Takami, Tomonori Usuda, and Motohide Tamura: "Constraining the Movement of the Spiral Features and the Locations of Planetary Bodies within the AB Aur System", The Astrophysical Journal, **828** (2016) 2

[23] Jungmi Kwon, Motohide Tamura, James H. Hough, Tetsuya Nagata, and Nobuhiko Kusakabe: "Near-infrared Circular and Linear Polarimetry of Monoceros R2", The Astronomical Journal, **152** (2016) 67

[24] Mihoko Konishi, Taro Matsuo, Kodai Yamamoto, Matthias Samland, Jun Sudo, Hiroshi Shibai, Yoichi Itoh, Misato Fukagawa, Takahiro Sumi, Tomoyuki Kudo, Jun Hashimoto, Masayuki Kuzuhara, Nobuhiko Kusakabe, Lyu Abe, Eiji Akiyama, Wolfgang Brandner, Timothy D. Brandt, Joseph C. Carson, Markus Feldt, Miwa Goto, Carol A. Grady, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Saeko S. Hayashi, Thomas Henning, Klaus W. Hodapp, Miki Ishii, Masanori Iye, Markus Janson, Ryo Kandori, Gillian R. Knapp, Jungmi Kwon, Michael W. Mcelwain, Kyle Mede, Shoken Miyama, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura, Daehyeon Oh, Tae-Soo Pyo, Eugene Serabyn, Joshua E. Schlieder, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Yasuhiro H. Takahashi, Michihiro Takami, Naruhisa Takato, Hiroshi Terada, Christian Thalmann, Edwin L. Turner, Makoto Watanabe, John P. Wisniewski, Toru Yamada, Hideki Takami, Tomonori Usuda, and Motohide Tamura: "A substellar companion to Pleiades HII 3441", Publications of the Astronomical Society of Japan, **68** (2016) 92

[25] R. Asensio-Torres, M. Janson, J. Hashimoto, C. Thalmann, T. Currie, E. Buenzli, T. Kudo, M. Kuzuhara, N. Kusakabe, L. Abe, E. Akiyama, W. Brandner, T. D. Brandt, J. Carson, S. Egner, M. Feldt, M. Goto, C. Grady, O. Guyon, Y. Hayano, M. Hayashi, S. Hayashi, T. Henning, K. Hodapp, M. Ishii, M. Iye, R. Kandori, G. Knapp, J. Kwon, T. Matsuo, M. McElwain, S. Mayama, S. Miyama, J. Morino, A. Moro-Martin, T. Nishimura, T.

Pyo, E. Serabyn, T. Suenaga, H. Suto, R. Suzuki, Y. Takahashi, M. Takami, N. Takato, H. Terada, E. Turner, M. Watanabe, J. Wisniewski, T. Yamada, H. Takami, T. Usuda, and M. Tamura: "Polarimetry and flux distribution in the debris disk around HD 32297", Astronomy & Astrophysics, **593** (2016) A73

[26] H. Massol, K. Hamano, F. Tian, M. Ikoma, Y. Abe, E. Chassefire, A. Davaille, H. Genda, M. Gdel, Y. Hori, F. Leblanc, E. Marcq, P. Sarda, V. I. Shematovich, A. Stkl, and H. Lammer: "Formation and Evolution of Protoatmospheres", Space Science Reviews, **205** (2016) 153-211

[27] Yuri Nishimura, Takashi Shimonishi, Yoshimasa Watanabe, Nami Sakai, Yuri Aikawa, Akiko Kawamura, and Satoshi Yamamoto: "Spectral Line Survey toward a Molecular Cloud in IC10", The Astrophysical Journal, **829** (2016) 94

[28] Takayoshi Kusune, Koji Sugitani, Fumitaka Nakamura, Makoto Watanabe, Motohide Tamura, Jungmi Kwon, and Shuji Sato: "Magnetic Field of the Vela C Molecular Cloud", The Astrophysical Journal, **830** (2016) L23

[29] Muneaki Imai, Nami Sakai, Yoko Oya, Ana López-Sepulcre, Yoshimasa Watanabe, Cecilia Ceccarelli, Bertrand Lefloch, Emmanuel Caux, Charlotte Vastel, Claudine Kahane, Takeshi Sakai, Tomoya Hirota, Yuri Aikawa, and Satoshi Yamamoto: "Discovery of a Hot Corino in the Bok Globule B335", The Astrophysical Journal, **830** (2016) L37

[30] Calen B. Henderson, et al. (including Motohide Tamura): "Campaign 9 of the K2 Mission: Observational Parameters, Scientific Drivers, and Community Involvement for a Simultaneous Space- and Ground-based Microlensing Survey", Publications of the Astronomical Society of the Pacific, **128** (2016) 124401

[31] Daehyeon Oh, Jun Hashimoto, Joseph C. Carson, Markus Janson, Jungmi Kwon, Takao Nakagawa, Satoshi Mayama, Taichi Uyama, Yi Yang, Tomoyuki Kudo, Nobuhiko Kusakabe, Lyu Abe, Eiji Akiyama, Wolfgang Brandner, Timothy D. Brandt, Thayne Currie, Markus Feldt, Miwa Goto, Carol A. Grady, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Saeko S. Hayashi, Thomas Henning, Klaus W. Hodapp, Miki Ishii, Masanori Iye, Ryo Kandori, Gillian R. Knapp, Masayuki Kuzuhara, Taro Matsuo, Michael W. Mcelwain, Shoken Miyama, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura, Tae-Soo Pyo, Eugene Serabyn, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Yasuhiro H. Takahashi, Naruhisa Takato, Hiroshi Terada, Christian Thalmann, Edwin L. Turner, Makoto Watanabe, Hideki Takami, Tomonori Usuda, Motohide Tamura: "Resolved Near-infrared Image of the Inner Cavity in the GM Aur Transitional Disk", The Astrophysical Journal, **831** (2016) L7

[32] Yuichiro Cho, Shingo Kameda, Yayoi N. Miura, Yoshifumi Saito, Shoichiro Yokota, Satoshi Kasahara, Ryuji Okazaki, Kazuo Yoshiok, Kazuo Shibasaki, Takahiro Oishi, and Seiji Sugita: "Conceptual Design of an In Situ K-Ar Isochron Dating Instrument for Future Mars Rover Missions", Transactions of the Japanese Society for Aeronautical and Space Sciences, **14** (2016) 89-94

[33] T. Mizuki, T. Yamada, J. C. Carson, M. Kuzuhara, T. Nakagawa, J. Nishikawa, M. L. Sitko, T. Kudo, N. Kusakabe, J. Hashimoto, L. Abe, W. Brander, T. D. Brandt, S. Egner, M. Feldt, M. Goto, C. A. Grady, O. Guyon, Y. Hayano, M. Hayashi, S. S. Hayashi, T. Henning, K. W. Hodapp, M. Ishii, M. Iye, M. Janson, R. Kandori, G. R. Knapp, J. Kwon, T. Matsuo, M. W. McElwain, S. Miyama, J. Morino, A. Moro-Martin, T. Nishimura, T. Pyo, E. Serabyn, T. Suenaga, H. Suto, R. Suzuki, Y. H. Takahashi, M. Takami, N. Takato, H. Terada, C. Thalmann, E. L. Turner, M. Watanabe, J. Wisniewski, H. Takami, T. Usuda, and M. Tamura: "High-contrast imaging of epsilon Eridani with ground-based instruments", Astronomy & Astrophysics, **595** (2016) A79

[34] K. G. Hełminiak, M. Kuzuhara, K. Mede, T. D. Brandt, R. Kandori, T. Suenaga, N. Kusakabe, N. Narita, J. C. Carson, T. Currie, T. Kudo, J. Hashimoto, L. Abe, E. Akiyama, W. Brandner, M. Feldt, M. Goto, C. A. Grady, O. Guyon, Y. Hayano, M. Hayashi, S. S. Hayashi, T. Henning, K. W. Hodapp, M. Ishii, M. Iye, M. Janson, G. R. Knapp, J. Kwon, T. Matsuo, M. W. McElwain, S. Miyama, J.-I. Morino, A. Moro-Martin, T. Nishimura, T. Ryu, T.-S. Pyo, E. Serabyn, H. Suto, R. Suzuki, Y. H. Takahashi, M. Takami, N. Takato, H. Terada, C. Thalmann, E. L. Turner, M. Watanabe, J. Wisniewski, T. Yamada, H. Takami, T. Usuda, and M. Tamura: "SEEDS Direct Imaging of the RV-detected Companion to V450 Andromedae, and Characterization of the System", The Astrophysical Journal, **832** (2016) 33

[35] E. Akiyama, J. Hashimoto, H. B. Liu, J. I.-H. Li, M. Bonnefoy, R. Dong, Y. Hasegawa, T. Henning, M. L. Sitko, M. Janson, M. Feldt, J. Wisniewski, T. Kudo, N. Kusakabe, T. Tsukagoshi, M. Momose, T. Muto, T. Taki, M. Kuzuhara, S. Mayama, M. Takami, N. Ohashi, C. A. Grady, J. Kwon, C. Thalmann, L. Abe, W. Brandner, T. D. Brandt, J. C. Carson, S. Egner, M. Goto, O. Guyon, Y. Hayano, M. Hayashi, S. S. Hayashi, K. W. Hodapp, M. Ishii, M. Iye, G. R. Knapp, R. Kandori, T. Matsuo, M. W. McElwain, S. Miyama, J.-I. Morino, A. Moro-Martin, T. Nishimura, T.-S. Pyo, E. Serabyn, T. Suenaga, H. Suto, R. Suzuki, Y. H. Takahashi, N. Takato, H. Terada, D. Tomono, E. L. Turner, M. Watanabe, T. Yamada, H. Takami, T. Usuda, and M. Tamura: "Spiral Structure and Differential Dust Size Distribution in the LKHα 330 Disk", The Astronomical Journal, **152** (2016) 222

[36] Yi Yang, Jun Hashimoto, Saeko S. Hayashi, Motohide Tamura, Satoshi Mayama, Roman Rafikov, Eiji Akiyama, Joseph C. Carson, Markus Janson, Jungmi Kwon, Jerome de Leon, Daehyeon Oh, Michihiro Takami, Ya-wen Tang, Tomoyuki Kudo, Nobuhiko Kusakabe, Lyu Abe, Wolfgang Brandner, Timothy D. Brandt, Sebastian Egner, Markus Feldt, Miwa Goto, Carol A. Grady, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Thomas Henning, Klaus W. Hodapp, Miki Ishi, Masanori Iye, Ryo Kandori, Gillian R. Knapp, Masayuki Kuzuhara, Taro Matsuo, Michael W. Mcelwain, Shoken Miyama, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura, Tae-Soo Pyo, Eugene Serabyn, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Yasuhiro H. Takahashi, Naruhisa Takato, Hiroshi Terada, Christian Thalmann, Edwin L. Turner, Makoto Watanabe, John Wisniewski, Toru Yamada, Hideki Takami, and Tomonori Usuda: "Near-infrared Imaging Polarimetry of Inner Region of GG Tau A Disk", The Astronomical Journal, **153** (2017) 7

[37] Eugenio V. Garcia, et al. (including Motohide Tamura): "SCExAO and GPI YJH Band Photometry and Integral Field Spectroscopy of the Young Brown Dwarf Companion to HD 1160", The Astrophysical Journal, **834** (2017) 162

[38] Nami Sakai, Yoko Oya, Aya E. Higuchi, Yuri Aikawa, Tomoyuki Hanawa, Cecilia Ceccarelli, Bertrand Lefloch, Ana López-Sepulcre, Yoshimasa Watanabe, Takeshi Sakai, Tomoya Hirota, Emmanuel Caux, Charlotte Vastel, Claudine Kahane, and Satoshi Yamamoto: "Vertical Structure of the Transition Zone from Infalling Rotating Envelope to Disc in the Class 0 Protostar, IRAS 04368+2557", Monthly Notices of the Royal Astronomical Society, **467** (2017) L76-L80

[39] Robin Kooistra, Inga Kamp, Misato Fukagawa, Francois Ménard, Munetake Momose, Takashi Tsukagoshi, Tomoyuki Kudo, Nobuhiko Kusakabe, Jun Hashimoto, Lyu Abe, Wolfgang Brandner, Timothy D. Brandt, Joseph C. Carson, Sebastian E. Egner, Markus Feldt, Miwa Goto, Carol A. Grady, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Saeko S. Hayashi, Thomas Henning, Klaus W. Hodapp, Miki Ishii, Masanori Iye, Markus Janson, Ryo Kandori, Gillian R. Knapp, Masayuki Kuzuhara, Jungmi Kwon, Taro Matsuo, Michael W. McElwain, Shoken Miyama, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura, Tae-Soo Pyo, Eugene Serabyn, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Yasuhiro H. Takahashi, Michihiro Takami, Naruhisa Takato, Hiroshi Terada, Christian Thalmann, Daigo Tomono, Edwin L. Turner, Makoto Watanabe, John Wisniewski, Toru Yamada, Hideki Takami, Tomonori Usuda, Motohide Tamura, Thayne Currie, Eiji Akiyama, Satoshi Mayama, Katherine B. Follette, and Takao Nakagawa: "Radial decoupling of small and large dust grains in the transitional disk RX J1615.3−3255", Astronomy & Astrophysics, **597** (2017) A132

[40] Yuxin Xue, Kento Masuda, and Yasushi Suto: "Possible Outcomes of Coplanar High-eccentricity Migration: Hot Jupiters, Close-in Super-Earths, and Counter-orbiting Planets", The Astrophysical Journal, **835** (2017) 204

[41] Taichi Uyama, Jun Hashimoto, Masayuki Kuzuhara, Satoshi Mayama, Eiji Akiyama, Thayne Currie, John Livingston, Tomoyuki Kudo, Nobuhiko Kusakabe, Lyu Abe, Wolfgang Brandner, Timothy D. Brandt, Joseph C. Carson, Sebastian Egner, Markus Feldt, Miwa Goto, Carol A. Grady, Olivier Guyon, Yutaka Hayano, Masahiko Hayashi, Saeko S. Hayashi, Thomas Henning, Klaus W. Hodapp, Miki Ishii, Masanori Iye, Markus Janson, Ryo Kandori, Gillian R. Knapp, Jungmi Kwon, Taro Matsuo, Michael W. Mcelwain, Shoken Miyama, Jun-Ichi Morino, Amaya Moro-Martin, Tetsuo Nishimura, Tae-Soo Pyo, Eugene Serabyn, Takuya Suenaga, Hiroshi Suto, Ryuji Suzuki, Yasuhiro H. Takahashi, Michihiro Takami, Naruhisa Takato, Hiroshi Terada, Christian Thalmann, Edwin L. Turner, Makoto Watanabe, John Wisniewski, Toru Yamada, Hideki Takami, Tomonori Usuda, and Motohide Tamura: "The SEEDS High-Contrast Imaging Survey of Exoplanets Around Young Stellar Objects", The Astronomical Journal, **153** (2017) 106

[42] Thayne Currie, Olivier Guyon, Motohide Tamura, Tomoyuki Kudo, Nemanja Jovanovic, Julien Lozi, Joshua Schlieder, Timothy Brandt, Jonas Kuhn, Eugene Serabyn, Markus Janson, Joseph Carson, Jeremy Kasdin, Tyler Groff, Michael McElwain, Garima Singh, Taichi Uyama, Masayuki Kuzuhara, Eiji Akiyama, Carol Grady, Saeko Hayashi, Gillian Knapp, Jungmi Kwon, Daehyeon Oh, John Wisniewski, Michael Sitko, and Yi Yang: "Subaru/SCExAO First-light Direct Imaging of a Young Debris Disk around HD 36546", The Astrophysical Journal, **836** (2017) L15

[43] Satoshi Yamamoto: "Introduction to Astrochemistry", Springer (2017)

[44] Ruobing Dong, Nienke van der Marel, Jun Hashimoto, Eugene Chiang, Eiji Akiyama, Hauyu Baobab Liu, Takayuki Muto, Gillian R. Knapp, Takashi Tsukagoshi, Joanna Brown, Simon Bruderer, Shin Koyamatsu, Tomoyuki Kudo, Nagayoshi Ohashi, Evan Rich, Mayama Satoshi, Michihiro Takami, John Wisniewski, Yi Yang, Zhaohuan Zhu, and Motohide Tamura: "The Sizes and Depletions of the Dust and Gas Cavities in the Transitional Disk J160421.7−213028", The Astrophysical Journal, **836** (2017) 201

[45] Jaeyeong Kim, Woong-Seob Jeong, Jeonghyun Pyo, Soojong Pak, Won-Kee Park, Jungmi Kwon, and Motohide Tamura: "Near-infrared Polarimetric Study of the N159/N160 Star-forming Complex in the Large Magellanic Cloud", The Astronomical Journal, **153** (2017) 126

[46] Yoko Oya, Nami Sakai, Yoshimasa Watanabe, Aya E. Higuchi, Tomoya Hirota, Ana López-Sepulcre, Takeshi Sakai, Yuri Aikawa, Cecilia Ceccarelli, Bertrand Lefloch, Emmanuel Caux, Charlotte Vastel, Claudine Kahane, and Satoshi Yamamoto: "L483: Warm Carbon-chain Chemistry Source Harboring Hot Corino Activity", The Astrophysical Journal, **837** (2017) 174

[47] Zachary C. Long, Rachel B. Fernandes, Michael Sitko, Kevin Wagner, Takayuki Muto, Jun Hashimoto, Katherine Follette, Carol A. Grady, Misato Fukagawa, Yasuhiro Hasegawa, Jacques Kluska, Stefan Kraus, Satoshi Mayama, Michael W. McElwain, Daehyeon Oh, Motohide Tamura, Taichi Uyama, John P. Wisniewski, and Yi Yang: "The Shadow Knows: Using Shadows to Investigate the Structure of the Pretransitional Disk of HD 100453", The Astrophysical Journal, **838** (2017) 62

[48] Masataka Aizawa, Sho Uehara, Kento Masuda, Hajime Kawahara, and Yasushi Suto: "Towards Detection of Exoplanetary Rings Via Transit Photometry: Methodology and a Possible Candidate", The Astronomical Journal, **153** (2017) 193

[49] Hauyu Baobab Liu, Eduard I. Vorobyov, Ruobing Dong, Michael M. Dunham, Michihiro Takami, Roberto Galván-Madrid, Jun Hashimoto, Ágnes Kóspál, Thomas Henning, Motohide Tamura, Luis F. Rodríguez, Naomi Hirano, Yasuhiro Hasegawa, Misato Fukagawa, Carlos Carrasco-Gonzalez, and Marco Tazzari: "A concordant scenario to explain FU Ori from deep centimeter and millimeter interferometric observations", Astronomy & Astrophysics, **602** (2017) A19

[50] Nemanja Jovanovic, Olivier Guyon, Hajime Kawahara, and Takayuki Kotani: "Application of Multicore Optical Fibers in Astronomy", the Optical Fiber Communications conference 2017, OFC, paper W3H.3, (2017)

7.3 International Conference Talks

7.3.1 Contributed talks

[51] Yoko Oya: "Infalling-Rotating Envelopes and Disks around Low-Mass Protostars", The Early Phase of Star Formation 2016 (Ringberg Castle, Germany, June 26 - July 1, 2016)

[52] Y. Ebisawa, N. Sakai, K. Menten, and S. Yamamoto: "Exploring Molecular-Cloud formation with OH 18 cm transition", Star Formation in Different Environments 2016 (Quy Nhon, Vietnam, July 25-29, 2016)

[53] Y. Nishimura, T. Shimonishi, Y. Watanabe, N. Sakai, Y. Aikawa, A. Kawamura, and S. Yamamoto: "Spectral Line Survey toward Molecular Clouds in the Large Magellanic Cloud", Star Formation in Different Environments 2016 (Quy Nhon, Vietnam, July 25-29, 2016)

[54] H. Yabuta, A. Nakato, M. Komatsu, T. Morota, M. Matsuoka, S. Sugita, To. Hiroi, K. Kitazato, T. Okada, H. Senshu, S. Sasaki, T. Nakamura, N. Kobayashi, and S. Watabnabe: "Hayabusa2 Landing Site Selection Team, Scientific Strategy of Landing Site Selection for Hayabusa2", 79th Annual Meeting of the Meteoritical Society (Berlin, Germany, August 7-12, 2016)

[55] Masataka Aizawa: "Searching for exoplanetory rings via transit photometry", APCosPA-Planet^2 RESCEU Summer School (Gifu, Japan, August 24-28, 2016)

[56] Y. Nishimura, T. Shimonishi, Y. Watanabe, N. Sakai, Y. Aikawa, A. Kawamura, and S. Yamamoto: "Chemical Composition in Low-Metallicity Dwarfs: Spectral Line Survey Observations toward the Large Magellanic Cloud and IC10", Half a Decade of ALMA: Cosmic Dawns Transformed (Indian Wells, USA, September 20-23, 2016)

[57] Y. Watanabe, Y. Nishimura, N. Sakai, K. Sorai, N. Harada, and S. Yamamoto: "CH_3OH Enhancement in the Bar of M83 Observed with ALMA", Half a Decade of ALMA: Cosmic Dawns Transformed (Indian Wells, USA, September 20-23, 2016)

[58] M. Ikoma and Y. Kawashima: "Theoretical transmission spectra of warm super-Earths with hazy atmospheres", Japan-Germany Planet & Disk Workshop (Ishigaki, Japan, September 26-30 2016)

[59] K. Yoshida, N. Sakai, Y. Watanabe, B. Lefloch, C. Ceccarelli, and S. Yamamoto: "Molecular isotopic ratios in the low-mass protostar L1527", Fractionation of isotopes in space: from the solar system to galaxies (Arcetri Astrophysical Observatory, Italy, October 10-13, 2016)

[60] Y. Ebisawa, N. Sakai, Y. Watanabe, K. Menten, and S. Yamamoto: "Exploring Molecular-Cloud formation with OH 18 cm transition", Workshop on Interstellar Matter 2016 (Sapporo, Japan, October 19-21, 2016)

[61] Y. Chiba, N. Sakai, Y. Ebisawa, K. Yoshida, T. Sakai, Y. Watanabe, and S. Yamamoto: "A new terahertz emission spectrometer at RIKEN", Workshop on Interstellar Matter 2016 (Sapporo, Japan, October 19-21, 2016)

[62] Y. Nishimura, Y. Watanabe, N. Harada, T. Shimonishi, N. Sakai, Y. Aikawa, A. Kawamura, and S. Yamamoto: "Molecular-Cloud-Scale Chemical Composition: Mapping Spectral Line Survey toward W3(OH)", Workshop on Interstellar Matter 2016 (Sapporo, Japan, October 19-21, 2016)

[63] K. Yoshida, T. Tokudome, N. Sakai, Y. Watanabe, S. Takano, and S. Yamamoto: "Spectral Line Survey Observation toward Low-mass Star-forming Region L1527 with Nobeyama 45-m Telescope", Workshop on Interstellar Matter 2016 (Sapporo, Japan, October 19-21, 2016)

[64] Y. Watanabe, N. Sakai, A. López-Sepulcre, T. Sakai, T. Hirota, S.-Y. Liu, Y.-N. Su, and S. Yamamoto: "Spectral Line Survey toward NGC 2264 CMM3 with ALMA", Workshop on Interstellar Matter 2016 (Sapporo, Japan, October 19-21, 2016)

[65] Y. Oya, N. Sakai, A. López-Sepulcre, Y. Watanabe, C. Ceccarelli, B. Lefloch, C. Favre, and S. Yamamoto: "Infalling-Rotaing Motion and Associated Chemical Change in the Envelope of IRAS 16293-2422 Source A Studied with ALMA", Workshop on Interstellar Matter 2016 (Sapporo, Japan, October 19-21, 2016)

[66] M. Imai, N. Sakai, Y. Oya, A. López-Sepulcre, Y. Watanabe, and S. Yamamoto: "Discovery of a Hot Corino in the Bok Globule B335", Workshop on Interstellar Matter 2016 (Sapporo, Japan, October 19-21, 2016)

[67] Y. Cho, S. Sugita, Y. N. Miura, R. Okazaki, N. Iwata, and S. Kameda: "End-to-End Validation of an In-Situ K-Ar Isochron Dating Method for Planetary Landers: Isochron Analysis of Natural Rocks", 3rd International Workshop on Instrumentation for Planetary Mission (Pasadena, USA, October 24-27, 2016)

[68] S. Kameda, M. Horiuchi, Y. Cho, K. Ishibashi, K. Wada, T. Mikouchi, T. Nakamura, and S. Sugita: "LIBS for Martian Moons eXploration (MMX)", (Pasadena, USA, October 24-27, 2016)

[69] Y. Ebisawa, N. Sakai, Y. Watanabe, K. Menten, and S. Yamamoto: "Exploring Molecular-Cloud formation with OH 18 cm transition", The Hydride Toolbox 2016 (UPMC, Paris, France, December 12-15, 2016)

[70] Masataka Aizawa: "Searching for exoplanetary rings via transit photometry", JSPS Core-to-Core Program "Planet2" Symposium 2017 (Nice, France, February 20-23, 2017)

[71] Shoya Kamiaka, Othman Benomar, and Yasushi Suto: "Statistical analysis of spin-orbit angle in exoplanet systems applying asteroseismology", JSPS Core-to-Core Program "Planet2" Symposium 2017 (Nice, France, February 20-23, 2017)

[72] M. Ikoma: "Formation and evolution of giant planets with snowy envelopes", Planet2 Symposium 2017: Origin and diversity of planetary systems from the microscope to the telescope (Villefranche-sur-Mer, France, February 21-23, 2017)

[73] M. Ikoma: "UV transit observation from space", Planet2 Symposium 2017: Origin and diversity of planetary systems from the microscope to the telescope (Villefranche-sur-Mer, France, February 21-23, 2017)

[74] S. Sugita, H. Suzuki, E. Tatsumi, M. Yamada, H. Sawada, S. Kameda, T. Kouyama, R. Honda, T. Morota, C. Honda, K. Ogawa, K. Shirai, M. Hayakawa, N. Ogawa, Y. Iijima, and ONC Team: "Inflight spectroscopic calibration of Hayabsusa2 optical navigation caemras (ONC) using Earth, Moon, Mars, and stars", Lunar Planet. Sci. Conf., XXXXVIII (Houston, USA, March 20-24, 2017)

[75] Tatsumi, E. and S. Sugita: "New Crater scaling law for corase-grained targets based on dimensional analysis", Lunar Planet. Sci. Conf., XXXXVIII (Houston, USA, March 20-24, 2017)

[76] T. Kouyama, Y. Yokota, Y. Ishihara, R. Nakamura, S. Yamamoto, T. Matsunaga, M. Yamada, S. Kameda, H. Sawada, H. Suzuki, R. Honda, T. Morota, C. Honda, K. Ogawa, E. Tatsumi, N. Sakatani, M. Hayakawa, and S. Sugita: "Investigation of Hayabusa-2/ONC sensitivity variation based on observed Moon images", Lunar Planet. Sci. Conf., XXXXVIII (Houston, USA, March 20-24, 2017)

[77] Y. Oya: "Chemical Change in the Disk Forming Region of IRAS 16293–2422 Studied with ALMA", IAU Symposium 332: Astrochemistry VII (Puerto Varas, Chile, March 20-24, 2017)

[78] Y. Ebisawa, Y. Watanabe, N. Sakai, K. Menten, and S. Yamamoto: "OH 18 cm Transition as a Thermometer of Molecular Cloud", IAU Symposium 332: Astrochemistry VII (Puerto Varas, Chile, March 20-24, 2017)

[79] M. Imai, N. Sakai, Y. Oya, A. López-Sepulcre, Y. Watanabe, C. Ceccarelli, B. Lefloch, E. Caux, C. Vastel, C. Kahane, T. Sakai, T. Hirota, and S. Yamamoto: "Discovery of a Hot Corino in the Bok Globule B335", IAU Symposium 332: Astrochemistry VII (Puerto Varas, Chile, March 20-24, 2017)

[80] Y. Watanabe, Y. Nishimura, N. Sakai, K. Sorai, N. Harada, and S. Yamamoto: "Molecular-Cloud-Scale Chemical Compositions in W51", IAU Symposium 332: Astrochemistry VII (Puerto Varas, Chile, March 20-24, 2017)

[81] K. Yoshida, N. Sakai, Y. Watanabe, A. López-Sepulcre, B. Lefloch, S. Takano, and S. Yamamoto: "The molecular isotopic ratios in the low-mass protostar L1527", IAU Symposium 332: Astrochemistry VII (Puerto Varas, Chile, March 20-24, 2017)

7.3.2 Invited talks

[82] M. Ikoma: "Internal structure of Jupiter: Implication for planet formation", JOVIAL Kick-off Meeting (Nice, France, April 18-20, 2016)

[83] Yasushi Suto: "Colors of a second earth: from exoplanets to astrobiology", Introductory Astronomy Class for undergraduates in Sejong University (Seoul, South Korea, September 5, 2016)

[84] Yasushi Suto: "Colors of a Second Earth: A Future Path Towards Astrobiology From Space", 2016 Inter-Academy Seoul Science Forum (Seoul, South Korea, November 3, 2016)

[85] Satoshi Yamamoto: "Chemical Tracers of Dynamics in Low-Mass Protostellar Objects", IAU Symposium 332: Astrochemistry VII (Puerto Varas, Chile, March 20-24, 2017)