Exoplanets and Disks: Their Formation and Diversity II

The 5th Subaru International Conference in Keauhou Kona, Hawaii
Sunday, December 8, 2013 – Thursday, December 12, 2013
Sheraton Kona Resort & Spa at Keauhou Bay, The Big Island of Hawaii

ABSTRACT BOOK

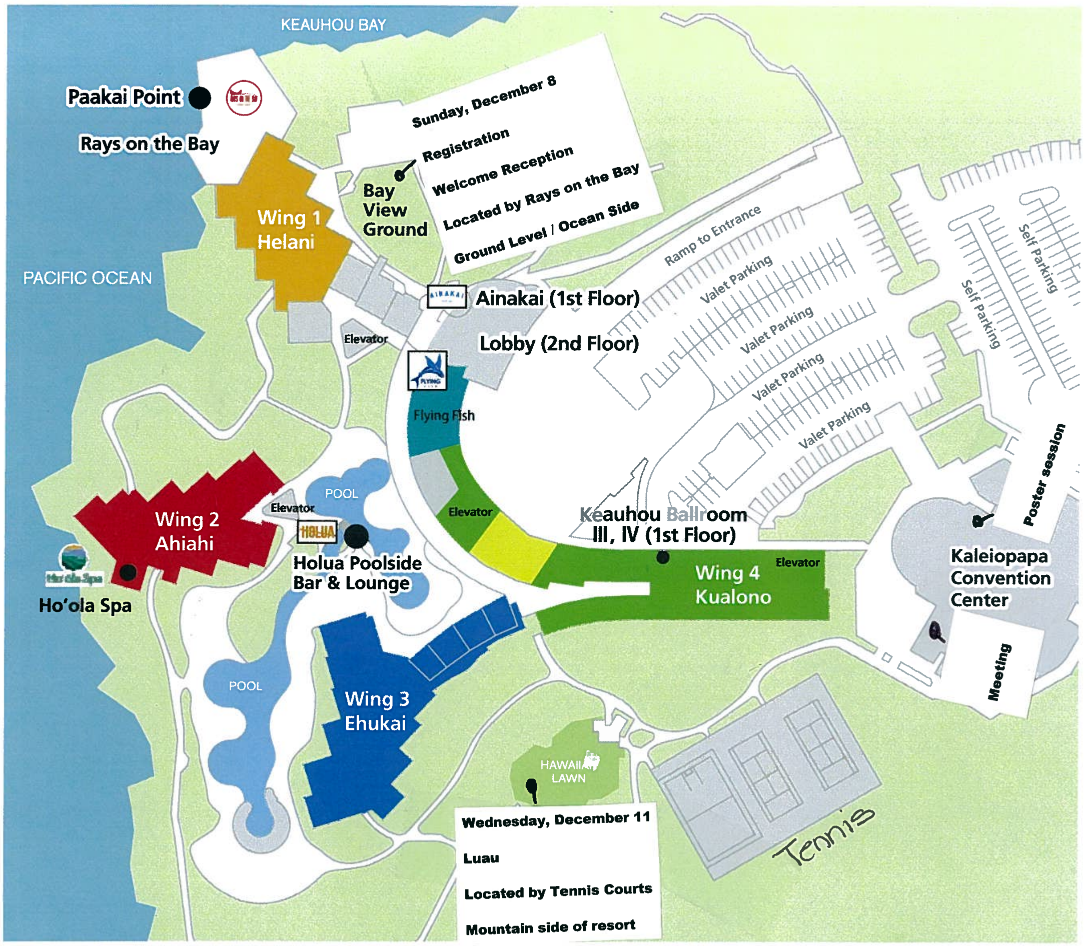
Purpose

Protoplanetary disks around young stars are the sites of planetary formation. Their detailed information has been obtained by recent high spatial resolution infrared and optical observations from both ground and space, and wide varieties of disk morphology and disk composition are uncovered. At longer wavelengths, ALMA has started its early science operation and will explore physical and chemical processing of gas and dust components in the disks. This diversity of disk properties is certainly the "seeds" for the well known diversity of more than 800 exoplanets so far detected. Therefore, deep understanding of the link between the protoplanetary disks and exoplanets is becoming more and more important. New coronagraphs on the 8-m class telescopes such as Subaru/HiCIAO/AO188 (the SEEDS project) and Gemini/NICI are currently exploring these areas, and Subaru/SCExAO, Gemini/GPI, and VLT/SPHERE will come very soon. Besides observations, both theoretical simulations for planet formation and theories and laboratory experiments for dust formation/evolution also play crucial roles for the interpretation of the link. In addition to the above direct explorations of giant exoplanets and disks, more interests are now concentrating on detection of extrasolar terrestrial planets. In order to promote the discussion of the diversity of disks and exoplanets among related researchers, we would like to host an international workshop. This conference is the second one covering the similar topic held in 2009 (hosted by NAOJ). This is also recognized as the 5th of the Subaru International Conference Series. Researchers in the fields of protoplanetary/debris disks, exoplanets, dust, and related instrumentation are encouraged to attend.

Major Topics

1. Direct imaging of disks/exoplanets
2. Spectroscopy of disks/exoplanets
3. Various approaches toward earth-like planet detection
4. Theory for planet formation
5. Theory and simulation of exoplanet atmospheres
6. Dust formation and evolution in disks
7. Current/future instrumentation for direct observations

Sheraton Kona Resort & Spa at Keauhou Bay Hotel Map



Exoplanets and Disks: Their Formation and Diversity II

Scientific Program

Registration and Reception: Sunday, December 8

17:00–19:30 Registration (17:30–19:30 Reception)

Day 1: Monday, December 9

Session: From Disks to Planets

7:30–	Registration (cont.)
8:30–8:40	Opening by Nobuo Arimoto (Subaru Director)
8:40–9:10	Nienke van der Marel (Leiden Observatory)
	"Resolved gas and dust observations of a transitional disk and its cavity"
9:10–9:40	Jeroen Bouwman (MPIA)
	"Solids in protoplanetary disks"
9:40–10:10	Jun Hashimoto (Oklahoma Univ.)
	"NIR observations of protoplanetary disks"
10:10–10:30	Break
10:30–10:45	Satoshi Okuzumi (TITECH)
	"The fate of planetesimals in turbulent protoplanetary disks"
10:45–11:00	Karl Stapelfeldt (Goddard)
	"HST Imaging of New Edge-on Circumstellar Disks"
11:00–11:15	Shu-ichiro Inutsuka (Nagoya Univ.)
	"The Fate of the Rings in Protoplanetary Disks"
11:15–11:30	Michihiro Takami (ASIAA)
	"Vertical structures of protoplanetary disks inferred from near-IR imaging polarimetry"
11:30–11:45	Carol Grady (Eureka Scientific and GSFC)
	"Transitional Disks Associated with Intermediate-Mass Stars: Results of the SEEDS Intermediate-Mass Star"
11:45–12:00	Flavien Kiefer (IAP)
	"New insights on beta Pictoris comets: discovery of two different populations"
12:00–14:00	Lunch
14:00–14:30	Masahiro Ikoma (University of Tokyo)
	"Composition and Origin of Short-Period Low-Mass Planets: The Importance of Observation of Their Atmospheres"
14:30–15:00	Masao Saito (JAO/NAOJ)
	"Recent Progress of Observations of Protoplanetary Disks at mm – submm"
15:00–15:30	Nagayoshi Ohashi (Subaru)
	"Disk formation revealed with ALMA"
15:30–16:00	Break
16:00–16:30	Andrew N. Youdin (Univ. of Colorado)
	"The Origin and Early Evolution of Planetesimals in Gas Disk"
16:30–16:45	David Wilner (CfA)
	"Imaging the CO Snow Line in the TW Hya Disk"
16:45–17:00	Takayuki Muto (Kougakuin Univ.)
	"ALMA Observations of the Asymmetrically Gapped Disk around HD 142527"
17:00–17:15	Yuri Aikawa (Kobe Univ.)
	"Water in protoplanetary disks"
17:15–17:30	Wlad Lyra (Caltech)
	"Vortex theory meets observations: is ALMA seeing vortices in transitional disks?"
17:30–17:45	Akimasa Kataoka (NAOJ)
	"Fluffy dust forms icy planetesimals by static compression"
17:45–18:00	Kyoko Tanaka (ILTS, Hokkaido Univ.)
	"Evaporation of icy planetesimals and recondensation of icy particles due to bow shocks"
20:00–22:00	Bar & Poster

<u>Day 2: Tuesday, December 10</u>

Session: From Disks to Planets (cont.)

8:30–9:00 Hiroshi Kobayashi (Nagoya Univ.)
"Critical Effects of Collisional Fragmentation on Planet Formation"

9:00–9:30 Mark C. Wyatt (Cambridge Univ.)
"Observations and theory of debris disks"

Session: Planets and Disks Imaging

9:30–10:00 Ben Oppenheimer (AMNH)
"Project 1640: Results and Status of the Planet Characterization Survey"

10:00–10:30 Break

10:30–10:45 Michael Liu (UH)
"The Gemini NICI Planet-Finding Campaign"

10:45–11:00 Thayne Currie (Univ. Toronto)
"Properties of the First Directly-Imaged Planets"

11:00–11:15 Olivier Absil (Univ. Liege)
"Hitting the diffraction limit: first results of the AGPM-VORTEX project"

11:15–11:30 Sasha Hinkley (Caltech)
"An AO Survey Spanning Two Hemispheres of the First Sample of Debris Disk Stars from WISE"

11:30–11:45 Timothy Rodigas (Arizona/Carnegie DTM)
"High-Contrast LBTI/MagAO Images of Debris Disks at 2-4 microns"

11:45–12:00 Beth Biller (MPIA)
"Statistical Analysis of Exoplanet Populations from Large-Scale Direct Imaging Survey"

12:00–14:00 Lunch

14:00–14:30 Masayuki Kuzuhara (TITECH)
"SEEDS Direct Imaging Survey for Exoplanets"

14:30–15:00 Markus Feldt (MPIA)
"The Status of the VLT Planet Finder Instrument SPHERE"

15:00–15:10 Short Break

15:10–15:40 Tyler Groff (Princeton)
"The CHARIS High Contrast Imaging Spectrograph"

15:40–16:10 Christian Thalmann (Swiss Federal Institute of Technology)
"The Tools of High-Contrast Imaging"

16:10– Free Time

<u>Day 3: Wednesday, December 11</u>

Session: Planet Characterization and New Developments

8:30–9:00 Travis Barman (Lowell Observatory)
"Exoplanet Atmospheres and Direct Spectroscopy"

9:00–9:30 Kevin C. France (Univ. of Colorado)
"Molecular Gas in the 0.1-10 AU Circumstellar Environments around Young Stars"

9:30–10:00 Matteo Brogi (Leiden Observatory)
"Exoplanet atmospheres at high spectral resolution"

10:00–10:30 Break

10:30–10:45 Vincent Bourrier (IAP/CNRS)
"3-D model of atmospheric escape: hot Jupiters characterization and beyond"

10:45–11:00 Kiyoshi Kuramoto (Hokkaido Univ.)
"Hydrodynamic escape of hydrogen from early Earth atmosphere"

11:00–11:15 Pedro Figueira (Centro de Astrofisica da Universidade do Porto)
"Spectroscopic Direct Detection of an Exoplanet's Reflected Light"

11:15–11:30 Thomas Henning (MPIA)
"From protoplanetary gas disks to exoplanet atmospheres"

11:30–11:45 Deborah Padgett (NASA/GSFC)
"HST Imaging of WISE Debris Disks"

11:45–12:00 Jean-Charles Augereau (IPAG, U. Grenoble)
"Exozodiacal dust around nearby stars"

12:00–14:00 Lunch

14:00–14:30 Andreas Seifahrt (Univ. Chicago)
"Near infrared radial velocities – current state and future prospects"

14:30–15:00 Masahiro Ogihara (Nagoya Univ.)

	"Crowding Out of Giants by Dwarfs: an Origin for the Lack of Companion Planets in Hot Jupiter Systems"
15:00–15:30	Nader Haghighipour (UH) *"Dynamics of planet formation – in binaries and outside"*
15:30–16:00	Break
16:00–16:30	Olivier Guyon (Arizona/Subaru) *"High contrast imaging: technology and scientific opportunities from ground and space"*
16:30–16:45	Takashi Onaka (UTokyo) *"Disk lifetime and the disk fraction"*
16:45–17:00	Tobias Schmidt (Astrophysical Institute and University-Observatory Jena) *"Mass determination of young directly imaged planet candidates and brown dwarfs"*
17:00–17:15	Takayuki Kotani (NAOJ) *"IRD: InfraRed Doppler Instrument for Subaru Telescope"*
17:15–17:30	Erika Nesvold (University of Maryland) *"SMACK: A New Algorithm for Modeling Collisions and Dynamics of Planetesimals in Debris Disks*
17:30–17:45	Shin-ichi Takehiro (Kyoto Univ.) *"Diversity of atmospheric circulations of synchronized rotating Jovian type planets"*
17:45–18:00	Norio Narita (NAOJ) *"Transiting Exoplanet Search and Characterization with Subaru's New Infrared Doppler Instrument (IRD)"*
19:00–21:00	Banquet

Day 4: Thursday, December 12

Session: Earth-like, Habitable Planets and Future Missions

8:30–9:00	Keiko Hamano (UTokyo) *"Emergence of two types of terrestrial planet on solidification of magma ocean"*
9:00–9:30	Ravi K. Kopparapu (Pennsylvania State Univ.) *"Habitable Zone Limits and the Occurrence of Potential Habitable Planets"*
9:30–10:00	Taro Matsuo (Kyoto Univ.) *"Direct Imaging of Exoplanets on ELTs"*
10:00–10:30	Break
10:30–10:45	Yutaka Abe (UTokyo) *"Variety of water planets"*
10:45–11:00	Jay Farihi (Univ. of Cambridge) *"Archaeology of Extrasolar Terrestrial Planetary Systems"*
11:00–11:15	Eiichiro Kokubo (NAOJ) *"Formation of Terrestrial Planets from Protoplanets: Effects of System Size and Position"*
11:15–11:30	Ramon Brasser (Acdemia Cinica) *"Long-term insolation variations on habitable exoplanets"*
11:30–11:45	Jeremy Kasdin (Princeton) *"Coronagraphy on AFTA-WFIRST"*
11:45–12:00	Takahiro Sumi (Osaka Univ.) *"Current and Future of Microlensing Exoplanet Search"*
12:00–14:00	Lunch
14:00–14:30	Mark Clampin (STScI) *"JWST"*
14:30–15:00	Wesley Traub (JPL) *"Future Coronagraph Missions"*
15:00–15:10	Short Break
15:10–15:40	Keigo Enya (JAXA) *"Exoplanet studies with SPICA mission"*
15:40–16:10	David Bennett (Univ. of Notre Dame) *"The WFIRST Cool and Cold Exoplanet Survey"*
16:10–	Closing Remark and adjourn

Poster Presentations

[P01] Masahiko Arakawa (Kobe University)
″Impact strength of small icy bodies experienced multiple collisions″

[P02] Kevin Baillie (Universite Paris)
″Protoplanetary disk characteristics as a function of the turbulent viscosity parameter and influence of deadzones″

[P03] Christoph Baranec (Univ. Hawaii / IfA)
″PULSE: Palomar Ultraviolet Laser for the Study of Exoplanets″

[P04] Charles Beichman (NASA)
"Brown Dwarf Parallax Program"

[P05] Mickael Bonnefoy (Institut de Planétologie et d'Astrophysique de Grenoble)
″Characterization of gaseous companion to the B-type star Kappa Andromedae″

[P06] Mickael Bonnefoy (Institut de Planétologie et d'Astrophysique de Grenoble)
″Direct imaging discovery of a probable 4-5 MJup″

[P07] Mickael Bonnefoy (Institut de Planétologie et d'Astrophysique de Grenoble)
″Properties of the distant brown-dwarf binary companion to the young and dusty A-type star HR6037″

[P09] Anthony Cheetham (University of Sydney)
″Companions to Ultracool Dwarfs at the diffraction limit″

[P10] Minho Choi (Korea Astronomy and Space Science Institute)
″Magnetic Activities of Class 0 Protostars″

[P11] Valentin Christiaens (University of Chile)
″Spirals in the disk of HD 142527 from CO emission lines with ALMA″

[P12] Christophe Sebastien Jean Claude (Subaru Telescope / Paris Observatory)
″The Subaru Coronagraphic Extreme AO High Sensitivity Visible Wavefront Sensors″

[P13] Ian Crossfield (MPIA)
″Dusty Atmospheres of Cool, Low-Mass Planets″

[P14] Kate Brutlag Follette (University of Arizona)
″Sub-mm vs Scattered Light Transitional Disks: Structural Discrepancies in Oph IRS 48 and SR21″

[P15] Yuri I. Fujii (Nagoya University)
″On the Origin of Angular Momentum Transfer in Circumplanetary Disks″

[P16] Yuka Fujii (TITECH)
″Photometric Variability of Solar System Solid Bodies: Implications for Rocky/Icy Exoplanets″

[P17] Akihiko Fukui (NAOJ)
″Atmospheric Study of Transiting Planets through Optical and Infrared Observations″

[P18] Antonio Garufi (ETH Zurich)
″The interplay between disks and (forming) planets from VLT/NACO PDI and ADI observations″

[P19] Andras Gaspar (Steward Observatory)
″The Collisional Evolution of Debris Disks: Connecting Observations with Theory″

[P20] Adam Hardy (Universidad de Valparaiso)
″SAM observations of the transition disk MY Lup″

[P22] Yukihiko Hasegawa (Osaka University)
″Kelvin-Helmholtz Instability in Multi-sized Dust Layers″

[P23] Kanae Haze (ISAS/JAXA)
"Laboratory experiments with the free-standing binary-pupil mask coronagraphs for SPICA"

[P24] Teruyuki Hirano (TITECH)
"Probing Stellar Obliquities for Transiting Exoplanetary Systems with Subaru"

[P25] Peng Hong (The University of Tokyo)
"Reducing atmospheres and habitability of deep-ocean exoplanets"

[P26] Yasunori Hori (NAOJ)
"Characterizing Low-mass Planets Orbiting Cool Stars With Water and Hydrogen"

[P27] Daiki Ishimoto (Kyoto University)
"Chemistry in protoplanetary disks with the effects of disk wind and grain growth"

[P28] Masaki Ishiwatari (Hokkaido University)
"Numerical experiments on atmospheres of synchronously rotating planets: a case with a non-gray radiation scheme and a cloud scheme"

[P29] Yuichi Ito (Tokyo Tech, The University of Tokyo)
"Thermal structure and detectability of atmospheres of hot rocky super-Earths"

[P30] Nemanja Jovanovic (Subaru Telescope)
"Status of the Subaru Coronagraphic Extreme Adaptive Optics System for high contrast imaging"

[P31] Nemanja Jovanovic (Subaru Telescope)
"Detecting Earth-like planets in the habitable zone around M-dwarfs with photonic technologies"

[P32] Kazuhiro Kanagawa (ILTS / Hokkaido University)
"Gap formation around a planet in protoplanetary disks"

[P33] Akihiro Kikuchi (TITECH)
"Orbital evolution of eccentric, gas-accreting protoplanets: Formation of distant jupiters in nearly circular orbits"

[P34] Shigeo Kimura (Osaka University)
"Role of the inner region of a circumstellar disk for understanding episodic accretion"

[P35] Takanori Kodama (The University of Tokyo)
"Evolution of terrestrial planets with water loss"

[P36] Mihoko Konishi (Osaka University)
"Direct Imaging Search for Extrasolar Giant Planets around 100 Myr-old Stars with Subaru Telescope"

[P37] Yuji Matsumoto (TITECH)
"The behavior of critical numbers of the orbital stability of planets trapped in the mean-motion resonances"

[P38] Jae-Min Lee (University of Zurich)
"Spectral Retrieval Analysis of the Directly Imaged exoplanets around HR 8799"

[P39] Karen Michelle Lewis (TITECH)
"Constraining Gas Giant Formation: Robust exo-moon radius and semi-major axis limits"

[P40] Naohiko Maeshima (Nagoya University)
"The numerical calculations and analitycal evaluations of type I migration in protoplanetary disks heated by stellar irradiation"

[P41] Alexis Matter (IPAG)
"Evidence of a discontinuous disc structure around the Herbig Ae star HD 139614"

[P42] Michael W. McElwain (NASA Goddard)
"Science with CHARIS: A high contrast integral field spectrograph for Subaru"

[P43] Kyle Aaron Mede (The University of Tokyo)
"The CHARIS Data Extraction Software: Integral Field Spectroscopy at High Contrast"

[P44] Farisa Y. Morales (NASA/JPL)
"HERSCHEL-RESOLVED OUTER BELTS OF TWO-BELT DEBRIS DISKS AROUND A-TYPE and SOLAR-TYPE STARS"

[P45] Tamami I. Mori (The University of Tokyo)
"Experimental Study on deuterated hydrocarbon materials"

[P46] Claire Moutou (CFHT)
"Planet-Finder survey with SPHERE/IRDIFS"

[P47] Eric Ludwig Nielsen (University of Hawai'i at Mānoa)
"A Unified Analysis of Brown Dwarf and Exoplanet Companions from Direct Imaging Surveys"

[P48] Ricky Nilsson (American Museum of Natural History)
"Panning for Planets in Stellar Glare: Methods for High-Contrast Imaging with Project 1640 "

[P49] Jun Nishikawa (NAOJ/GUAS)
"A coronagraph system with unbalanced nulling interferometer : upgrade of 2013"

[P50] Masashi Omiya (TITECH)
"A precise Doppler survey of late-M dwarfs using IRD"

[P51] Masanori Onishi (Kobe University)
"Development of radiative transfer model for exoplanets with steam atmospheres"

[P52] Shoichi Oshino (NAOJ)
"N-body simulations for planetary accretion in the presence of hot Jupiter"

[P53] James Owen (CITA)
"Models of transition discs: success and failures"

[P54] Masahito Oya (Nihon University, NAOJ)
"Adaptive optics operation with a focal plane wavefront sensing in a coronagraph"

[P55] Itsuki Sakon (The University of Tokyo)
"Challenges towards the Identification of the Unidentified Infrared Bands from the Laboratory Experimental Approaches"

[P56] Graeme Stanley Salter (University of New South Wales)
"Direct Imaging of Long Period Radial Velocity Targets"

[P57] Takao Sato (TITECH)
"Possibilities of water supply to the Earth with "icy-dust filtering"

[P58] Guillaume Schworer (Observatoire de Paris, University of Sydney)
"Time-Contrast-Separation-Polarization Diagrams to predict exoplanet visibility"

[P59] Garima Singh (Subaru Telescope, Observatoire de Paris)
"Phase mask coronagraphs ultra-fine pointing control system"

[P60] Satoko Sorahana (Nagoya University)
"Evidence of Chromospheric Activity in three brown dwarfs from 2.5-5.0μm AKARI spectra"

[P61] Esther Taillifet (AIM CEA Saclay/ Université Paris Diderot)
"Formation of the first Solar System solids in a turbulent protoplanetary disk"

[P62] Sanemichi Takahashi (Nagoya University, Kyoto University)
"An Origin of Ring Structures in Protoplanetary Disks"

[P63] Yasuto Takahashi　(Hokkaido University)
"Comparison of Jupiter and GJ504b : similarity and differences in vertical structure and thermal radiation spectrum"

[P64] Yoshiyuki O. Takahashi　(Kobe University)
"Development of a general circulation model for earth-like planetary atmospheres and its application"

[P65] Taku Takeuchi　(TITECH)
"Transport of Magnetic Flux in Protoplanetary Disks as a Cause of the Transitional Phase"

[P66] Yuki Tanaka　(Nagoya University)
"Magnetically driven wind from gas-giant planets"

[P67] Takayuki Tanigawa　(Hokkaido Univeristy)
"Structure of Circum-Planetary Disks embedded in Protoplanetary Disks"

[P68] Takashi Tsukagoshi　(Ibaraki University)
"High-resolution Submillimeter and Near-infrared Studies of the Transition Disk around Sz 91"

[P69]Yusuke Tsukamoto　(Nagoya University)
"Formation, orbital and thermal evolution, and survival of planetary-mass clumps in the early phase of circumstellar disk evolution"

[P70] Barnaby Norris　　(University of Sydney)
"VAMPIRES - Probing the innermost regions of protoplanetary systems with polarimetric aperture-masking"

[P71] Yuta Ueda　(University of Tokyo, TITECH)
"Collisional growth of organic mantle structured dusts"

[P72] Shoji Ueta　(TITECH)
"Surface H_2O layers of ice-covered terrestrial planets"

[P73] Stephen C. Unwin　(JPL/Caltech)
"High Contrast Imaging of Debris Disks from a High Altitude Balloon"

[P74] Chiaki Uyeda　(Osaka University)
"Magnetic Orientation of Amorphous Silicate Grain in the PPD Region"

[P75] Arthur Vigan　(Laboratoire d'Astrophysique de Marseille)
"The VLT/NaCo large program to probe the occurrence of exoplanets and brown dwarfs at wide orbits - Survey results and statistical analysis"

[P76] Koji Wada　(PERC / Chiba Inst.Technology)
"Amount of ejecta mass at dust aggregate collisions"

[P77] John Wisniewski　(University of Oklahoma)
"Near-IR Scattered Light Imagery of the DoAr 28 Transitional Disk"

[P78] Duncan John Wright　(UNSW)
"The Search for The Search for Habitable-Zone Super-Earths Orbiting M Dwarfs at the Anglo-Australian Telescope"

[P79] Tetsuo Yamamoto　(CPS, Kobe University)
"A new method of estimating the cooling rate experienced by chondrules in the early solar nebula"

[P80] Chikako Yasui　(University of Tokyo)
"Rapid Evolution of the Innermost Dust Disk of Protoplanetary Disks Surrounding Intermediate-mass Stars"

[P81] Takashi Mikami　 (Hokkaido University)
"Proto-atmospheres on giant icy-satellite forming within low-temperature disk"

[P82] Masanobu Kunitomo　 (TITECH)
"Photoevaporating Disk Dispersal around Intermediate-mass stars"

[P83] Takatsuki Shoma （TITECH）
"A detectability of photosputtering for H2O ice on the protoplanetary disk"

[P84] Catherine Walsh （Leiden Observatory）
"Complex Organic Molecules in Protoplanetary Disks"

[P85] Tetsuo Taki （TITECH）
"Evolution of Dust and Gas Density Distribution and Effect of the Streaming Instability at the Radial Pressure Bump in Protoplanetary Disks"

ABSTRACTS (Oral Presentations)

Session: From Disks to Planets

"Resolved gas and dust observations of a transitional disk and its cavity"

Nienke van der Marel (Leiden Observatory)

Planet formation by dust coagulation in protoplanetary disks is one of the long standing problems in disk evolution theory. Dust grains must grow from submicron sizes to ~10 M_{Earth} rocky cores within the ~10 Myr lifetime of the circumstellar disk. However, this growth process is hindered by collisional fragmentation and rapid inward radial drift. A possible solution in dust evolution theory is dust trapping in local pressure maxima in the disk, where dust particles pile up and grow. Transitional disks with large inner dust cavities have been suggested to contain these dust traps. I present the first results of our ALMA Cycle 0 program using Band 9, imaging the Herbig Ae star Oph IRS 48 in CO 6--5, $C^{17}O$ 6--5 and the sub-millimeter continuum in the extended configuration. The resulting ~0.2" spatial resolution completely resolves the cavity of this disk in the gas and the dust. The gas cavity of IRS 48 is only half as large as the dust cavity and the gas surface density inside this gas cavity is at least two orders of magnitude lower than the gas in the surrounding ring. The micrometer-sized dust grains follow a large ring-like structure as well. On the other hand, the continuum emission, tracing the millimeter-sized dust, reveals an unexpected huge asymmetry and steep edges in the dust distribution along the ring. The difference in distribution of big grains versus small grains/gas can be modeled with a vortex-shaped dust trap triggered by a companion. I will discuss the implications for the dust trapping scenario in transitional disks, compare IRS 48 with other ALMA Cycle 0 results and discuss future possibilities with ALMA.

"Solids in protoplanetary disks"

Jeroen Bouwman (MPIA)

The discovery of a large variety of exoplanetary systems in the last decade has triggered many new questions about their formation. Of particular interest is the availability of ingredients for building planets and small icy bodies in planetary systems. During the formation of stars and planetary systems, the dust, ice,and gas experience a rich array of transformations in physical and chemical state. While the refractory dust provides the building block of planetary cores, ices survive in parts of the disk, providing the volatiles for atmospheres, oceans, and possible life on rocky planets. Tracing this chemical and physical evolution in its diversity requires a combination of observations from infrared (IR) to millimeter (mm) wavelengths, where dust, ice and gas have their principal spectroscopic features. In this review I present an overview of the results obtained during the last decade with mayor space observatories like Spitzer and Herschel and ground based facilities like the VLT and Subaru telescopes, and discuss the constraints these observations place on evolutionary models of protoplanetary disks.

"NIR observations of protoplanetary disks"

Jun Hashimoto (Oklahoma Univ.)

Protoplanetary disks are considered to be the birthplace of planets. In theory, planets can open gaps when they form in a disk (e.g., Zhu et al. 2011). Recently, a deficit of near- and mid-infrared excess in a spectral energy distribution of a object has been observed so far (e.g., Strom et al. 1989), and disks with an inner hole have been also detected with a radio interferometry (e.g., Andrews et al. 2011). These objects, so-called transitional disk, might be a signature of recent planet formation in these systems. As mentioned above, the inner region ($r < 100$ AU) of the protoplanetary disk are considered to be deeply related to planet formation. Thus, there have been many observational investigations of protoplanetary disks. However, for optical and near-infrared observations, it is quite difficult to observed such inner regions due to bright central star (e.g., Grady et al. 1999). Also, for radio interferometry observations, its spatial resolution is limited to 40 AU, and thus, it is difficult to conduct detailed direct observations (Andrews et al. 2011). In order to observe planet-forming region ($r< 100$AU) in protoplanetary disks with higher spatial resolution (< 10AU), we developed a new high contrast instrument HiCIAO (Tamura et al. 2006). HiCIAO employs dual-beam polarimetry, which suppress speckle noise of the central star. In addition, combining with adaptive optics, HiCIAO achieves higher resolution of less than 10 AU. Using HiCIAO, we have observed protoplanetary disks as a strategic project in Subaru Telescope (SEEDS; Tamura 2009). As a result of high-resolution near-infrared polarimetric observations, we achieved a spatial resolution of less than 10 AU, and accessed planet-forming regions ($r< 100$AU) of protoplanetary disks. We divided observed about 20 transitional disks into three categories based on their near-infrared polarimetric morphologies; (1) disks with no cavity in NIR, but clear cavity in sub-mm, (2) disks with clear cavity in NIR, (3) disks with complicated radial profile. In the talk, I would like to review the SEEDS disk observations, and discuss a disk evolution to a planetary system.

"The fate of planetesimals in turbulent protoplanetary disks"

Satoshi Okuzumi (TITECH)

Turbulence in protoplanetary disks affects planet formation in many ways. While small dust particles are mainly affected by the aerodynamical coupling with turbulent gas velocity fields, planetesimals and larger bodies are more affected by gravitational interaction with gas density fluctuations. It has been suggested that turbulence driven by magnetorotational instability (MRI) is strong enough to inhibit the runaway growth of planetesimals. In this study, we explore the viability of the runaway growth scenario in protoplanetary disks with an MRI-inactive dead zone. Based on the results of previous MHD simulations, we identify two important mechanisms that lead to the suppression of the planetesimal stirring rate in a dead zone. We provide a semi-analytic recipe that quantifies these effects as a function of the dead zone size and the net vertical field strength. We then apply the recipe to coagulation--fragmentation calculations where the size distribution of solid bodies and the size of the dead zone are determined in a self-consistent way. However, the results show that the runaway growth of sub-100 km-sized bodies is inhibited even in the presence of the dead zone, except in inner or weakly-magnetized regions of the disks. We conclude that the classical, planetesimal-dominated model for planet formation is not viable in the outer regions of moderately magnetized disks.

"HST Imaging of New Edge-on Circumstellar Disks"

Karl R. Stapelfeldt (Goddard)

We report on the results of our HST program to image twenty-one edge-on disk candidates selected from their far-infrared spectral energy distributions. Eleven are well-resolved with radii ranging from 30-400 AU, nine for the first time and six showing highly collimated jets. Outstanding individual sources include a large and symmetric new template object, a highly flattened disk not accreting onto its central star, and an asymmetric disk with a misaligned jet which likely traces tidal perturbations in a binary system. Follow-up work to obtain ancillary data and perform scattered light modeling of the most symmetric disks is now being pursued. The results of this program will guide a new round of searches for these rare but important snapshots of protoplanetary disk evolution.

"The Fate of the Rings in Protoplanetary Disks"

Shu-ichiro Inutsuka (Nagoya Univ.)

Protoplanetary disks are supposed to be the sites of planet formation, and thus, understanding of the evolution of the disk is crucial in understanding of the planet formation. Recent progress in high-resolution imaging techniques has enabled us to observe remarkable structures in protoplanetary disks, such as rings, spirals, and bananas. Takahashi et al. (2013) propose a robust mechanism to create ring-like structures in the disks. This paper describes stability of the ring and shows the criterion for the gravitational stability of the ring. The further evolution of the ring is also discussed and a possible scenario for the formation of rocky objects at outer regions of the disks is outlined.

"Vertical structures of protoplanetary disks inferred from near-IR imaging polarimetry"

Michihiro Takami (ASIAA)

Structures in protoplanetary disks are of particular interest for investigating ongoing planet formation and understanding their formation mechanism. Coronagraphic imaging at optical and near-infrared wavelengths has been used extensively, revealing such structures in disks at the highest angular resolutions currently available (~0.1″). This technique has allowed observations of faint scattered light on dust grains from the star via the disk surface. We present our recent studies for vertical structures of the disks using the observed distribution of near-infrared polarized intensity (PI) with Subaru-HiCIAO. (A) We perform comparisons between the observed PI distribution in RY Tau and models with: (1) full radiative transfer, using the spectral energy distribution (SED) to constrain the disk parameters; and (2) monochromatic simulations of scattered light which explore a wide range of parameters space. The PI distribution in this object shows a butterfly-like distribution of bright emission offset toward the blueshifted jet. Throughout, we suggest that the scattered light in this object is associated with an optically thin and geometrically thick layer above the disk surface, with the surface responsible for the infrared SED. Half of the scattered light and thermal radiation in this layer illuminates the disk surface, and this process may significantly affect the thermal structure of the disk (Takami et al. 2013, ApJ, 772, 145). (B) We present our new analysis for the surface geometry of several disks observed using HiCIAO. We derive the geometry using the observed PI distribution and a differential equation obtained with the following feasible assumptions: i.e., (1) they are a geometrically thin and optically thick; and (2) the geometrical width of the scattering layer and the effect of multiple scattering to the polarized intensity are negligible. We then discuss the implications for spiral or ring structures observed in these disks (Takami et al., in prep.).

"Transitional Disks Associated with Intermediate-Mass Stars: Results of the SEEDS Intermediate-Mass Star"

Carol Grady (Eureka Scientific and GSFC)

Protoplanetary disks are where planets form, grow, and migrate to produce the diversity of exoplanet systems we observe in mature systems. Disks where this process has advanced to the stage of gap opening, and in some cases central cavity formation, have been termed pre-transitional and transitional disks in the hope that they represent intermediate steps toward planetary system formation. Recent reviews have focussed on disks where the star is of solar or sub-solar mass. Recently, the Meeus Group I Herbig stars, intermediate-mass PMS stars with IR spectral energy distributions often interpreted as flared disks, have been proposed to have transitional and pre-transitional disks similar to those associated with solar-mass PMS stars, based on thermal-IR imaging, and sub-millimeter interferometry. We have investigated their appearance in scattered light as part of the Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS), obtaining H-band polarimetric imagery of ~10 intermediate-mass stars with Meeus Group I disks. Augmented by other disks with imagery in the literature, the sample is now sufficiently large to explore how these disks are similar to and differ from T Tauri star disks. The disk morphologies seen in the T Tauri disks are also found for the intermediate-mass star disks, but additional phenomena are found; a hallmark of these disks is remarkable individuality and diversity which does not simply correlate with disk mass or stellar properties, including age, including spiral arms in remnant envelopes, arms in the disk, asymmetrically and potentially variably shadowed outer disks, gaps, and one disk where only half of the disk is seen in scattered light at H. We will discuss our survey results in terms of spiral arm theory, dust trapping vortices, and systematic differences in the relative scale height of these disks compared to those around Solar-mass stars. For the disks with spiral arms we discuss the planet-hosting potential, and limits on where giant planets can be located. We also discuss the implications for imaging with extreme adaptive optics instruments. Grady is supported under NSF AST 1008440 and through the NASA Origins of Solar Systems program on NNG13PB64P. JPW is supported NSF AST 100314.

"New insights on beta Pictoris comets: discovery of two different populations"

Flavien Kiefer (IAP)

High resolution spectroscopic observations of beta Pictoris made with HARPS bring new informations on the exocomets falling onto the star (FEB scenario). With more than thousand spectra gathered between 2003 and 2011 we have around 6000 variable absorptions detected. Using this huge catalogue of events we achieved an unprecedented statistical and temporal study of beta Pic comets. We will present the results of this statistical analysis, and display the evidences that allowed us to discover two very different populations of comets in this young planetary system.

"Composition and Origin of Short-Period Low-Mass Planets: The Importance of Observation of Their Atmospheres"

Masahiro Ikoma (The University of Tokyo)

Transit photometry, which measures drops in apparent brightness of stars due to planets in transit, opened a new window to the interior of exoplanets. From the transit depth, we can estimate the planet's radius. With the planet's mass measured via another technique, we could infer the planet's bulk composition. Thus, we can now argue the origins of exoplanets from the compositional point of view, in addition to planet masses and orbital elements. The large variation in the mass and radius relationship implies that low-mass exoplanets with various compositions are orbitig close to host stars. This may be consistent with recent theories of planet formation and evolution. However, because of degeneracy in composition that we often suffer from when inferring the planet composition only from the mass and radius relationship, we are unable to derive robust conclusions. Recently, as for some low-mass planets (e.g., GJ 1214 b), the transit depths have been measured at different wave

lengths; the method is called transmission spectroscopy. Comparison with observed and theoretical transmission spectra has been demonstrated to be helpful in removing the degenerary in bulk composion. In this talk, I will give an overview of current understanding of compositions and origins of short-period low-mass planets from theoretical and observational points of view.

"Recent Progress of Observations of Protoplanetary Disks at mm – submm"

Masao Saito (JAO/NAOJ)

I review the recent progress of protoplanetary observations conducted at millimeter and submillimeter. Since the discovery of the gaseous disks having a Keplerian motion around young stars in 90's, notable sources have been extensively and repeatedly observed because of limited sensitivities. Sub-arcsec observations successfully imaged a hole in the transitional disks and also revealed the chemical composition in the disk. The Atacama Large Millimeter and Submillimeter Array (ALMA) started its early science operation since Oct. 2011. The high sensitivity at sub-arcsec resolution pushes the edge of the protoplanetary disk study from detection of diffuse CO emission, vertical structure of the gaseous disk, asymmetric distribution of large grains, chemistry in the disk. ALMA's capabilities are still evolving and some new capabilities are expected in the next cycle, which enable us to explore more about the disks. I show very recent images with ALMA and other radio telescopes in line, continuum, and polarization emissions and also introduce on-going commissioning capabilities and future prospects in the coming years. Finally, the ALMA science verification data of disk sources and early science data expiring proprietary period are available to public through the ALMA portal site. Thanks to high sensitivity, treasures may be untouched in such public data.

"Disk formation revealed with ALMA"
Nagayoshi Ohashi (Subaru)
[TBD]

"The Origin and Early Evolution of Planetesimals in Gas Disk"
Andrew N. Youdin (Univ. of Colorado)
The theory of plantesimal formation is informed by observations of protoplanetary disks, Solar System minor planets, and meteorites. This talk will review the mechanisms responsible for the growth of planetesimals from smaller solids, including coagulation, aerodynamic concentration and gravitational collapse. The streaming instability will be emphasized as a promising route to the rapid formation of large (>100 km) planetesimals. Observational tests and implications for later stages of planetary growth will be discussed.

"Imaging the CO Snow Line in the TW Hya Disk"
David Wilner (CfA)
In protoplanetary disks, the boundaries where common volatile species like H2O, CO2, and CO freeze out from the gas phase have been long thought to be important in theories of planet formation. These "snow lines" enhance the efficiency of planetesimal building by increasing the reservoir of solids, their stickiness, and regulating their bulk compositions. While the snow lines are difficult to detect directly, their presence can be revealed through chemical effects. In particular, the reactive ion N2H+ is present in large abundance only in regions where CO freezes out. We present ALMA observations of the disk around TW Hya in N2H+ emission that show a ring with a 30 AU radius inner boundary that matches predictions for the CO snow line location. This observation provides a verification of the snow line concept, and offers new constraints on the formation dynamics of Solar Systems.
[Qi, C., Oberg, K.I., Wilner, D.J. et al. 2013, Science, 341, 630]

"ALMA Observations of the Asymmetrically Gapped Disk around HD 142527"
Takayuki Muto (Kougakuin Univ.)
We report the results of ALMA Cycle 0 observations for the gapped protoplanetary disk around the Herbig Fe star, HD 142527, of lines of $^{13}CO(3-2)$ and $C^{18}O(3-2)$ as well as the continuum in Band 7, with the spatial resolution of ~0.4 arcsec. HD 142527 is one of the best targets to investigate disk-planet interaction and disk clearing mechanism in ALMA early science. The disk is known to have the wide gap ($\Delta r \sim 100$ AU = 0.7 arcsec) extending over the beam size achievable in Cycle 0. In addition, the non-circular gap and the spiral features detected in the previous infrared imaging suggest the presence of (an) unseen companion(s). The most striking result is found in the continuum. The radial profiles of the surface brightness are well approximated by Gaussian function at all azimuth, in contrast to more extended profiles that are expected from standard disk models. Moreover, the surface brightness shows a strong asymmetry in the azimuth: the northern part of the outer disk (~150 AU from the star) is brighter than the southern part by more than one order of magnitude. Gas observations indicate that the disk is optically thick even with $C^{18}O(3-2)$ in the northern part. $^{13}CO(3-2)$ and $C^{18}O(3-2)$ are detected within the dust cavity and exterior to the dust ring. The velocity field seems to follow Keplerian rotation, although small deviation is hinted. In our presentation, we show the measurement of basic physical properties of the disk and gas, present various disk models with different dust opacity models, compare observations at infrared and sub-mm, and discuss about dust growth and/or gas-to-dust ratio. If we assume that the standard gas-to-dust ratio of 100 and large dust opacity of 0.034{cm^2/g}, the disk mass is ~$0.08M_*$. In this case, the local free-fall velocity is comparable with Kepler velocity in the northern part and gravitational instability may lead to the formation of (a) new object(s) in the disk. If we assume that grains are concentrated in the northern part, the disk mass is smaller, but the gas-to-dust ratio in the northern part should be more than ten times smaller than that in the southern part. In this case, it is expected that dust grains can easily coagulate to form larger bodies. The disk around HD142527, therefore, may be an active birthplace of planets.

"Water in protoplanetary disks"

Yuri Aikawa (Kobe Univ.)

We investigate molecular evolution and D/H ratio in plotoplanetary disks irradiated by UV and X-ray from a central T Tauri star. Chemical rate equations are solved with the diffusion term, mimicking the turbulent mixing in vertical direction. We pay special attention to evolution of water. Water near the midplane is transported to the disk surface by turbulence and destroyed by photoreactions, while atomic oxygen is transported from the disk surface to the midplane, and reform water and/or other molecules. As long as the dust grains are small enough to be well mixed with turbulent gas, this cycle decreases column densities of water ice at $r \leqq 30$ AU, where dust temperatures are too high to reform water ice effectively. The outer edge of such region moves to 20 AU, if the desorption energy of atomic hydrogen is as high as 600 K. Outside this radius, the cycle decreases the D/H ratios of water ice from $\sim 2\times10^{-2}$, which is set by the collapsing core model, to 10^{-4}–10^{-2} in 10^6 yr, without significantly decreasing water ice column densities. The resultant D/H ratios depend on the strength of mixing and the radial distance from the central star. Inside the snow line, the D/H ratio of water vapor becomes lower than the cometary value. We will discuss the dependence of our results on model parameters, such as diffusion coefficient, and implications to origin of water in the Solar system. We found that the D/H ratios of water vapor and ice are significantly different especially in the inner regions ($r \leqq 30$ AU), regardless of the strength of vertical mixing. Our finding suggests that it is difficult to constrain the D/H ratios of water ice in the midplane of the inner disks from the observations of D/H ratios of water vapor in protoplanetary disks. If time allows, we will also present our results on other molecules such as organic molecules.

"Vortex theory meets observations: is ALMA seeing vortices in transitional disks?"

Wlad Lyra (Caltech)

The Atacama Large Millimeter Array (ALMA) has been returning images of transitional disks in which large asymmetries are seen in the dust distribution of mm-size in the outer disk. The explanation in vogue borrows from the vortex literature by suggesting that these asymmetries are the result of dust trapping in giant vortices, excited via Rossby wave instability at planetary gap edges. These vortices are well known in numerical studies of protoplanetary disks, where their ability to trap rocks and boulders has been invoked to speed up planet formation. While the motivation and particle sizes are different, the relevant physics is scale-free, and thus identical, making transitional disks an attractive venue where to test our theories of disk vortices. In this talk, I will contrast the observed properties of these structures with the hydrodynamical understanding of disk vortices gathered through over ten years of numerical simulations. I will present steady-state solutions of dust trapping in vortices that are general and can be applied to observations, free of degeneracies. The model was applied to the recent observations of IRS Oph 48, finding remarkable agreement. I will conclude by outlining results of 3D MHD numerical simulations that address the possible vortical nature of these structures.

"Fluffy dust forms icy planetesimals by static compression"

Akimasa Kataoka (NAOJ)

In planetesimal formation theory, several barriers have been proposed, which are bouncing, fragmentation, and radial drift problems. To understand the structure evolution of dust aggregates is a key in the planetesimal formation. Dust grains become fluffy by coagulation in protoplanetary disks. However, once they become fluffy, they are not sufficiently compressed by collisional compression to form compact planetesimals (Okuzumi et al. 2012). Therefore, other compression mechanisms are required to form compact planetesimals. We investigate static compression of porous dust aggregates in protoplanetary disks. First, we perform numerical N-body simulations of static compression of porous dust aggregates. As a result, we derive the compressive strength formula of highly porous aggregates (Kataoka et al. 2013). Then, using the compressive strength formula, we analytically investigate how fluffy dust aggregates are compressed by static compression due to ram pressure of the disk gas and self gravity of the aggregates in protoplanetary disks. In this way, we reveal the overall porosity evolution from dust grains via fluffy aggregates to form planetesimals. Moreover, we also show that the fluffy aggregates circumvent the barriers in planetesimal formation. The aggregates are compressed by the disk gas to the density of 10^{-3} {g/cm^3} in coagulation, which is more compact than the case with collisional compression. Then, they are compressed more by self gravity to 10^{-1} {g/cm^3} when the radius is 10 km. Although the gas compression decelerate the growth, they grow enough rapidly to avoid the radial drift barrier when the orbital radius is less than 6 AU in a typical disk. In addition, fluffy aggregates avoid bouncing and fragmentation barriers (Wada et al. 2009, 2011). In conclusion, we propose fluffy dust growth scenario from grains to planetesimals. It enables the icy planetesimal formation in a wide range beyond the snowline in protoplanetary disks. This result proposes a concrete initial condition of planetesimals for the later stages of the planet formation.

"Evaporation of icy planetesimals and recondensation of icy particles due to bow shocks"

Kyoko Tanaka (ILTS, Hokkaido Univ.)

In protoplanetary disks, planetesimals grow to planets through their mutual collisions and accumulations. The gravitational interactions among planetesimals increase the eccentricities of their orbits. When the relative velocity between a planetesimal and the disk gas exceeds the speed of sound of the gas, a bow shock is produced on the leading side of the planetesimal. Recently we have shown that the bow shocks lead to the heating and evaporation of icy planetesimals in the stage of formation of protoplanets, where strong bow shocks are produced by gravitational perturbations by the protoplanets (Tanaka et al. 2013, ApJ, 764, 120). In this study, we investigate the recondensation process of dust particles after the planetesimal evaporations. The vapor evaporating from the surface re-condenses as it cools, and eventually forms icy dust particles if the evaporation produces a sufficient amount of the vapor for their condensation. We calculate the condensation process of water vapor based on the nucleation theory, where we use the semi-phenomenological model giving better predictions of the nucleation rate than the classical nucleation theory. Our results show that ultra-fine particles of nm-size form as a result of the evaporation of the planetesimals with radius ~100 km.

"Critical Effects of Collisional Fragmentation on Planet Formation"

Hiroshi Kobayashi (Nagoya Univ.)

In the classical theory of planet formation, the final embryo mass is determined only by the solid surface density. However, embryos can stir surrounding planetesimals, leading to destructive collisions and fragmentation. Radial drift of small fragments reduces the solid surface density. On the other hand, embryo growth is accelerated by fragment accretion. Since collisional fragmentation efficiency depends on the initial size of planetesimals, the final embryo mass and its growth time are determined by the initial planetesimal size and disk surface density. Small initial planetesimals are prone to fragmentation, so mass loss occurs through gas-induced drift of fragments. As a result, small planetesimals tend to produce small embryos (and vice versa). The eccentricities and inclinations of fragments produced by collisions between small planetesimals are damped by interaction with the gas. The resulting reduction in relative velocities increases the gravitational cross section of embryos for fragments, so small planetesimals allow rapid embryo growth (and vice versa). Therefore, initial planetesimal sizes as well as disk masses constraint final planet masses.

"Observations and theory of debris disks"

Mark C. Wyatt (Cambridge Univ.)

The simplest description of a debris disk is that it is the extrasolar equivalent to the Solar System's asteroid and Kuiper belts. This implies that imprinted in the structure of such a disk is information about the dynamical architecture of its planetary system as well as clues to that systems' formation history. As such high resolution imaging (e.g. with ALMA) is key to unravelling the relationship of debris dust to planets. Far-IR surveys (e.g. with Herschel) have also played a fundamental role by being the main route to discovery of debris disks, and so can for example be used to assess the frequency of disks with planetary systems discovered by other means, and to identify new regimes of debris disk physics. As each disk becomes characterised in ever greater detail at a multitude of wavelengths, this pushes models used to interpret both asymmetries and radial structures within them to their limits, leading to questions about their underlying nature, and about our understanding of dust physics. Recent discoveries of gas in debris disks also lead to questions about the protoplanetary disk dispersal process and collision physics. This talk will review the latest developments in our understanding of debris disks.

Session: Planets and Disks Imaging

"Project 1640: Results and Status of the Planet Characterization Survey"
Ben Oppenheimer (AMNH)
Project 1640 is the first of several new projects that combine extremely high-order adaptive optics with precision coronagraphy, integral field spectroscopy and internal wave front calibration to achieve contrast ratios of 10^{-6} to 10^{-7}. In addition to pioneering many new instrumentation aspects the project includes experts in computer vision to explore and implement new types of post-processing for speckle removal. I will describe the project and recent results in the remote reconnaissance of exosolar systems using spectroscopy, astrometry and photometry simultaneously to study exoplanetary systems.

"The Gemini NICI Planet-Finding Campaign"
Michael Liu (UH)
We have completed a 250-star high-contrast observing campaign using the Near-Infrared Coronagraphic Imager (NICI) on the Gemini-South 8.1-meter telescope. The NICI Campaign represents the largest and most sensitive survey to date for young brown dwarfs and gas-giant planets around other stars, with a ~3x larger sample and ~2 magnitudes more sensitive contrast than previous surveys. We describe the Campaign's individual discoveries, including a high-eccentricity young brown dwarf and a new benchmark L dwarf that reveals the spectral evolution of young dusty objects is more complicated than previous believed. In addition, we use the large, homogenous Campaign dataset to establish strong statistical constraints on the exoplanet population at >10 AU in semi-major axis. Using both hot-start and cold-start models, we find that massive planets at such separations are rare, disfavoring gravitational instability as a common mode of gas-giant planet formation.

"Properties of the First Directly-Imaged Planets"
Thayne Currie (Univ. Toronto)
In this talk, I describe recent/new results elucidating the properties of the first directly-imaged planets using data from Subaru, Keck, VLT, etc., focusing on planets/planet candidates orbiting HR 8799, Fomalhaut, kappa And, and a newly-confirmed imaged exoplanet. We recently confirm that a candidate object Fomalhaut b is likely a dust-enshrouded planet and present new results further constraining Fomalhaut b's nature and the existence of other planets orbiting the star. HR 8799 bcde, kappa And b and our newly-confirmed exoplanet provide a critical probe of the atmospheric evolution of young jovians. I summarize recent results on and present new data clarifying the cloud structure, atmospheric chemistry, temperature and surface gravity of these objects, how their properties compare with those for brown dwarfs, and how these objects fit within the context of the core accretion and disk instability planet formation theories. Finally, I close by briefly describing how Subaru/SCExAO and other facilities (GPI and SPHERE) will better study the atmospheric evolution of jovian planets and provide overlap between the population of directly-imaged planets and those detected by the radial velocity method.

"Hitting the diffraction limit: first results of the AGPM-VORTEX project"
Olivier Absil (Univ. Liege)
During the last 8 years, we have been developing an implementation of the vector vortex coronagraph based on sub-wavelength gratings, referred to as the Annular Groove Phase Mask (AGPM). Science-grade mid-infrared AGPMs were produced in 2012, and three of them have recently been installed on world-leading diffraction-limited infrared cameras (VLT/NACO, VLT/VISIR and LBT/LMIRCam). In this talk, we will present the first results of this endeavor. During science verification observations with our L-band AGPM on VLT/NACO, we observed the beta Pictoris system and obtained unprecedented sensitivity limits to planetary companions down to the diffraction limit (0.1"). We also obtained new images of the beta Pic debris disk at L band, which nicely bridge the gap between images obtained at shorter and longer wavelengths. These results urged us to reconsider the very definition of companion detection limits at very short angles, which will become more and more critical as next-generation high-contrast imaging instruments come online. We will conclude by discussing the future orientations of the AGPM-VORTEX project, including the development of second-generation vector vortex phase masks providing an even deeper and more achromatic starlight cancellation for ELT applications.

"An AO Survey Spanning Two Hemispheres of the First Sample of Debris Disk Stars from WISE"

Sasha Hinkley (Caltech)

Circumstellar debris disks are the signposts of planet formation: the presence of bright dust in the vicinity of nearby stars is a strong indicator of planetary mass companions, which serve as agents of gravitational stirring. I will describe a multi-year, Keck, VLT, and Palomar Adaptive Optics imaging survey for planetary mass companions to a new sample of debris disks stars recently identified by the NASA WISE mission. Our goal is to discover, or place limits on, planetary mass companions that could be stirring and regenerating these disks. We have obtained deep, coronagraphic, angular differential imaging of over 200 stars, typically reaching contrasts between 10^5 and 10^6 at one arcsecond. Thus, the sensitivity reached in our survey provides sufficient contrast to identify objects with brightnesses comparable to HR 8799b in only a few minutes. Importantly, nearly all of our targets have not been targetted by other comparable-sized surveys (IDPS, SEEDS, NICI, etc.). All the stars in our sample show excess infrared emission at 22 microns and we have focussed primarily on stars with A and F spectral types, with a smaller number of G, K, and M stars. Further, the mean [3.6] - [22] micron WISE color for our ensemble of stars is similar to that of HR 8799, indicating that our targets have debris levels comparable to that of HR 8799, or even higher. We have identified roughly 100 candidate companions to our sample, many of which would be planetary mass companions if they are determined to be co-moving. I will give an update on the status of common proper motion follow-up observations for these candidates. If time allows, I will also briefly mention a smaller, ongoing survey, focusing on a sample of stars identified by the Spitzer and Herschel Space Telescopes to possess debris disks organized into multiple belts, strongly indicating planetary mass companions are present and sculpting the disk.

"High-Contrast LBTI/MagAO Images of Debris Disks at 2-4 microns"

Timothy Rodigas (Arizona/Carnegie DTM)

Understanding a debris disk's morphology, dust grain sizes, and composition can indirectly tell us about the properties of any hidden planets in the system. Spatially resolved images of debris disks at 2-4 microns can help provide this information. We are conducting a high-contrast 2-4 micron imaging survey of bright debris disks using the Large Binocular Telescope Interferometer (LBTI) and the newly-commissioned Magellan adaptive optics (MagAO) system. In this talk, I will show new images of the debris disks around the F star HD 15115 (Rodigas et al. 2012, ApJ), the A star HD 32297 (Rodigas et al., in prep.), and the A star HR 4796A (Rodigas et al., in prep.). The LBTI images were acquired using just a single primary mirror of the LBT, with exceptional AO correction (200-400 modes). For HD 15115, we obtained Ks (2.15 microns) and L' (3.8 microns) images of the disk, both new detections at these wavelengths. These high-contrast images reveal for the first time that the disk is bowed, most likely due to viewing geometry and forward-scattering grains. The overall gray disk color reveals that the dust grains are primarily 1-10 microns in size--a surprise given the disk's formerly blue colors from HST at shorter wavelengths. I will also present evidence for a disk gap near 45 AU, possibly due to dynamical sculpting by an (undetected) planet. For HD 32297, we obtained 3 hours of LBTI AO images of the disk at L' (detected at this wavelength for the first time). We detect the disk at high S/N from ~ 0.2-1″ (20-110 AU) from the star. I will present ongoing dust grain modeling for this system using 1-4 micron spatially-resolved images, including archival HST data, which we use to constrain the typical dust grain composition and size. I will also present limits on any planets in the system. Finally, I will show brand new MagAO images of the HR 4796A debris disk at seven new wavelengths spanning the visible (using VisAO) to 4 microns (using Clio). We detect the disk at unprecedented angular resolution and S/N and use our images to constrain the amount of water ice/organic materials in the dust. This program demonstrates the exceptional ability of the LBTI/MagAO systems, which can provide spatially-resolved information on targets (disks and planets) at wavelengths that were previously difficult to accomplish from the ground.

"Statistical Analysis of Exoplanet Populations from Large-Scale Direct Imaging Survey"

Beth Biller (MPIA)

Currently ~10 planets have been directly imaged. From this small but growing population, combined with contrast curves and statistics from large scale, deep surveys to directly image exoplanets, we can already place constraints on planet populations at wide separations (>20 AU). Future surveys with next-generation coronagraphs such as SPHERE, GPI, and SCExAO will detect many more planets and allow much stronger constraints, down to considerably smaller separations. Here I present 1) statistical analysis of simulated surveys using the upcoming SPHERE planetfinder and 2) statistical analysis of a SPHERE simulated survey combined with data from archival direct imaging surveys: i.e. what the combination of current large scale surveys with relatively large fields of view and future surveys with much better inner working angles and contrasts but quite small fields of view (0.8″ in the case of SPHERE) will tell us about the population of directly imaged exoplanets.

"SEEDS Direct Imaging Survey for Exoplanets"

Masayuki Kuzuhara (TITECH)

High-contrast direct imaging observations enable the discovery and characterization of exoplanets on wide-orbits from their host stars, whose detections are impractical with indirect methods. SEEDS campaign, which is currently in its fourth year, aims at directly imaging and characterizing giant exoplanets with the Subaru 8-m telescope. The total SEEDS sample will reach 500 targets, selected from the solar neighborhood, moving groups, open clusters, and star-forming regions. SEEDS also surveys exoplanets in the planetary systems with debris disks. This target sample adequately covers stellar ages ranging from 1 Myr to a few Gyr. SEEDS has detected new substellar companions including planets with properties that have not been known. These include a massive planetary companion orbiting the B-type star kappa And and several Jupiter-mass planet orbiting a nearby Sun-like star GJ 504. The planet in the GJ 504 system has unique properties compared with the previously directly imaged planets, which are highlighted in this talk. High-contrast imaging by SEEDS has also provided better characterizations of the exoplanet systems detected by indirect observation techniques. The surveys ever performed for each SEEDS target category have been summarized in several papers, providing important clues to constrain the statistical populations of young Jupiter analogues. Here, we report and discuss these achievements and summarize the SEEDS exoplanet survey.

"The Status of the VLT Planet Finder Instrument SPHERE"

Markus Feldt (MPIA)

The SPHERE instrument, a high-contrast exo-planetary imager for the VLT capable of achieving contrast beyond 10^{-5} at 0.5 seconds of arc, is currently passing the final stage of its preliminary acceptance procedure in Europe. Shipping is foreseen for the end of this year, and commissioning should commence in spring 2014. SPHERE consists of an extreme AO system and three focal plane instruments: An integral field spectrograph, a dual-band imager and spectrograph, and a visual differential polarimeter based on the ZIMPOL technique. I will describe in some detail the properties that were measured during the lab integration and acceptance tests during the past months. Additionally, I will sketch the timeline of the upcoming commissioning runs and detail the application procedure with special emphasis on the possibilities for the Subaru community. A brief overview of potential science overlap and the chance of e.g. using the system for follow-up observations of SEEDS targets will form the last part of my talk.

"The CHARIS High Contrast Imaging Spectrograph"

Tyler Groff (Princeton)

Princeton University is building the Coronagraphic High Angular Resolution Imaging Spectrograph (CHARIS), an integral field spectrograph (IFS) funded by the National Astronomical Observatory of Japan. It will be integrated with the Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) and the AO188 adaptive optics system on the Subaru telescope. The spectrograph has just completed its critical design review and is entering the build and test phase of the project. CHARIS is designed to image disks and take high contrast spectra of brown dwarfs and hot Jovian planets in a coronagraphic image across J, H, and K bands. SCExAO+CHARIS will detect objects five orders of magnitude dimmer than their parent star down to an 80 milliarcsecond inner working angle. The challenge with exoplanet imaging are the quasi-static speckles, which make it difficult to achieve detection, but the close packing of spectra in an IFS means neighboring speckles can contaminate the signal from the planet. The result is lower detection limits and uncertainty in the planetary spectrum due to diffractive cross-contamination, commonly referred to as crosstalk. SCExAO has a wavefront control system to suppress quasi-static speckles and CHARIS will address their effect on through hardware design, which drives the optical performance and mechanical design of the instrument. In addition to providing better spectral certainty in the science data, mitigating crosstalk in hardware decreases the computational overhead required to use CHARIS images as feedback in the focal plane wavefront control loop being operated by SCExAO. Here we present the science case, and design of CHARIS from its critical design review. This highlights the choices that must be considered to design an IFS for high signal-to-noise spectra in a coronagraphic image. The design considerations and lessons learned are directly applicable to future exoplanet instrumentation for extremely large telescopes and space observatories capable of detecting rocky planets in the habitable zone..

"The Tools of High-Contrast Imaging"

Christian Thalmann (ETH Zurich)

In the past decade, ground-based high-contrast imaging efforts have yielded a wealth of discovery and characterization studies of extrasolar planets, brown dwarfs, protoplanetary disks, and debris disks. This success is not only based on the advent of modern adaptive optics facilities, but also on the corresponding advances in observation techniques and data-reduction methods. Now that a next generation of "extreme" adaptive optics systems is being commissioned, it is all the more important to continue to evolve and adapt our high-contrast tools to make the most of the data. This talk will review the most popular high-contrast imaging methods in use, and provide an outlook over ongoing developments.

Session: Planet Characterization and New Developments

"Exoplanet Atmospheres and Direct Spectroscopy"

Travis Barman (Lowell Observatory)

Gas giants in wide orbits have now been directly imaged around young nearby stars. This, however, is just the beginning. New instruments, tailor-made for high-contrast imaging, are coming online this year and will reveal dozens of young planets. These instruments will also provide low-resolution near-IR spectra of each new planet, revealing a wealth of information across a wide range of masses and ages. To illustrate the power of direct exoplanet spectroscopy, this talk will focus on recent observations of the planets orbiting the young (~30 Myr) star HR8799. Ground-based observations have allowed the characterization of the planets' bulk properties along with their atmospheric structure. More recent spectroscopic data of HR8799b and HR8799c will be presented that contain numerous, well-resolved, molecular lines. These data reveal the chemical composition of the planet's atmosphere (in particular the carbon and oxygen abundances) and may help distinguish between formation mechanisms.

"Molecular Gas in the 0.1-10 AU Circumstellar Environments around Young Stars"

Kevin C. France (Univ. of Colorado)

The composition and spatial distribution of molecular gas in the inner few AU of young (< 10 Myr) circumstellar disks are important components to our understanding of the formation and evolution of planetary systems. At the distances of typical star-forming regions (e.g., Taurus-Auriga or the Orion Nebula Cluster), 1 AU corresponds to an angular scale of < 10 milliarcseconds. Therefore, if one wishes to probe molecules in the region of terrestrial and giant planet-formation, UV and IR spectroscopy will be the technique of choice for the foreseeable future. In this talk, I will review the most widely used spectral diagnostics of the inner disk, with an emphasis on recent observations of H2 and CO emission made by the Hubble Space Telescope. I will describe how the kinematic and excitation properties of these emission lines are used to constrain the distribution of gas in the inner disk. I will conclude by discussing the relationship between gas and dust during the epoch of giant planet formation and disk dissipation; including implications for planetary formation and migration around young stars.

"Exoplanet atmospheres at high spectral resolution"

Matteo Brogi (Leiden Observatory)

In this talk I highlight the advantages, successes, and prospects of ground-based, high-resolution (R$¥sim$100,000) spectroscopy for characterizing exoplanet atmospheres. At such high resolution, the molecular bands are resolved into the individual lines, meaning that the identification of molecular species by line-matching is very robust. Moreover, due to the orbital motion of the planet, atmospheric signatures from the exoplanet are Doppler-shifted, meaning that planet signal can be efficiently disentangled from the telluric and stellar contamination, and the planet radial velocities can be directly measured. In addition, when targeting the thermal dayside emission near superior conjunction, this method can be applied to non-transiting planets as well, opening atmospheric characterization to this yet-unexplored sample, for which we can now determine masses and orbital inclinations. With this technique we have now detected carbon monoxide in transmission spectroscopy and in dayside spectroscopy, the latter for transiting and non-transiting planets. Recently, we have also identified water vapour in dayside spectroscopy. In the coming years, by combining high- and low-resolution spectra, many of the degeneracies affecting the estimates of molecular abundances and temperature-pressure profiles can in principle be solved. Furthermore, with the next generation of ELTs telescopes, high-resoluton spectroscopy promises to reveal atmospheric dynamics (global circulation patterns, weather), phase curves (strength of molecular feature as function of orbital phase) and energy redistrubution (day- to night-side contrasts).

"3-D model of atmospheric escape: hot Jupiters characterization and beyond"

Vincent Bourrier (IAP/CNRS)

Transit observations of the hot Jupiter HD209458b with HST/STIS led to the detection of neutral hydrogen and magnesium escaping the planet upper atmosphere. Atmospheric escape of neutral hydrogen was also observed in the case of HD189733b, with significant temporal variations in the evaporating process. We developed a 3-D particle model of the dynamics of the escaping gas, which is used to calculate theoretical absorption line profiles to be directly compared to transit observations. I will show that the velocities of the atoms escaping HD209458b are naturally explained by radiation-pressure acceleration, while the higher velocities of the hydrogen gas surrounding HD189733b require an additional acceleration mechanism, which could be interactions with stellar wind protons. We put constraints on the planetary mass loss and electron density in the exosphere, as well as on the stellar ionizing flux or stellar wind properties. Our model can thus be used to study different scenarios of evaporation and analyze star-planet interactions. It is also a tool of prediction. Simulations showed that observations of the atmospheric escape with time during the transit are a way to probe the spatial and velocity structure of the extended atmosphere. On a larger scale, our model can be applied to any type of escaping element, and predict the evaporation state of exoplanets from hot gaseous giants to Earth-size planets enshrouded in a superheated envelope.

"Hydrodynamic escape of hydrogen from early Earth atmosphere"

Kiyoshi Kuramoto (Hokkaido Univ.)

Reconstruction of the ancient Earth atmosphere may be valuable as a reference for observational studies of Earth-like exoplanets in various evolutionary stages. As for the Earth atmosphere prior than the rise of oxygen at 2.5 Ga, it remains controversial whether the air was poor or rich in hydrogen molecules. This comes from the conflicting results of modeling studies about hydrodynamic escape from a hydrogen-rich atmosphere. Classic semi-analytical models (solving steady flow equations) had suggested effective conversion of absorbed EUV energy to the kinetic energy of escaping hydrogen molecules, whereas a recent direct numerical simulation model (performing time integration until steady flow establishes) showed sluggish escape with flux smaller about two orders of magnitude than that deduced from the semi-analytical models. The former implies a hydrogen-depleted atmosphere through the rapid loss of hydrogen within about 100 Myr after the end of the main phase of planetary accretion. On the other hand, the latter suggests the sustenance of molecular hydrogen more than about 10 volume percents in the atmosphere for a long period, possibly as long as a few billions of years. In order to resolve the discrepancy in the results between those models, we construct a new direct numerical simulation code for hydrodynamic hydrogen escape by employing numerical schemes with higher-accuracy than that of the previous simulation model. We confirmed that our code reproduces almost exactly the analytical solution of steady isothermal outflow for a wide range of escape parameter. Then, we performed a series of calculations given the same boundary conditions and settings as the previous direct simulation study. Each of our simulations is found to well converge into a steady flow. In such steady flows, more than half of EUV heating energy is converted to the kinetic energy of escaping gas. This result strongly supports the results from the classic semi-analytical studies. The previous direct simulation underestimates the escape rate because of numerical diffusion which is intensified in the lower atmosphere with small atmospheric scale height. By combining with the model describing the diffusive separation of hydrogen molecules from heavier background gas species, we also estimate hydrogen escape flux as a function of the EUV flux and the molecular hydrogen mixing ratio at the homopause. Assuming that the volcanic hydrogen degassing rate is balanced with our escape rate, the atmospheric hydrogen content in the anoxic Earth atmosphere was likely kept less than about 1 volume percent before 2.5 Ga. This result seems consistent with several lines of geochemical evidence for atmospheric composition of ancient Earth. Our escape model may also be useful to simulate the hydrogen escape from exoplanet atmospheres. Some examples will be presented in our presentation.

"Spectroscopic Direct Detection of an Exoplanet's Reflected Light"

Pedro Figueira (Centro de Astrofisica da Universidade do Porto)

The direct detection of an extrasolar planet's light provides a unique insight into its atmospheric properties. And in spite of a long history of attempts, it was only very recently that we were able to measure the high-resolution spectrum of an extrasolar planet for the first time. This remarkable result was achieved by observing in the near infra-red, where the contrast between the planet and the star is larger, and a snapshot of the planetary emission spectrum was for the first time recorded. In our work we explore a different approach, more conventional in a sense, and that astronomers have been attempting for a long time: to detect the planetary's reflected light. We performed detailed simulations using HARPS spectra which show that we can detect an extrasolar planet's signal for some favourable yet realist cases using current instrumentation. We also concluded that high-significance results can be obtained for a wider range of stellar and orbital configurations -- including those corresponding to several well-known systems -- using upcoming spectrographs such as ESPRESSO. In this talk we will present our methodology, the results of our simulations, and our first observational results. We explore the pros and cons of the different spectroscopic direct detection techniques, and what can we learn about the planet's atmosphere and orbital properties using each approach.

"From protoplanetary gas disks to exoplanet atmospheres"

Thomas Henning (MPIA)

The talk will first summarize the most important properties of the gas component of protoplanetary disks. It will then develop a research program how the properties of disks can be connected with the properties of the atmospheres of giant planets. First results of calculations for atmosphere compositions and spectra of giant extrasolar planets will be presented.

"HST Imaging of WISE Debris Disks"

Deborah Padgett (NASA/GSFC)

Using 22μm data from the Wide Field Infrared Survey Explorer (WISE), we have completed a sensitive all-sky survey for Hipparcos and Tycho catalog stars within 120 pc with debris disks. This warm excess emission traces material in the circumstellar region likely to host terrestrial planets. Several hundred previously unknown debris disk candidates were identified. We are currently performing follow-up observations to characterize the stars, companions, and circumstellar material in these systems. Eleven WISE debris disks have been observed to date using HST/STIS coronagraphy. Three of these disks have been detected in scattered light. One is a large and highly asymmetric edge-on disk which appears to be both warped and bifurcated.

"Exozodiacal dust around nearby stars"

Jean-Charles Augereau (IPAG, U. Grenoble)

High levels of warm dust observed in the inner regions of planetary systems are known as exozodis, reflecting their similarities with the Solar System's zodiacal cloud. Whilst the population of cold, outer debris discs is well characterised observationally and understood theoretically, many mysteries remain regarding the observations of exozodiacal dust. The observed small dust grains have a short lifetime against collisions and radiative forces. Even if they were resupplied from the collisional grinding of a population of larger parent bodies, as commonly suggested to explain cold, outer debris discs, the parent bodies could not sustain the observed dust levels in steady-state for anywhere near the age of the system. Further theoretical investigations, alongside observations of the population of exozodis, are required in order better understand the origin of the exozodiacal dust. Interferometry is perfectly suited to better characterising this population, as the emission from the exozodi can be readily disentangled from the stellar emission. We present results of a statistical survey that aims to characterise the population of exozodis around nearby stars using CHARA/FLUOR and VLTI/PIONIER, alongside theoretical investigations into the manner in which the observed exozodiacal dust may be linked with the dynamical evolution of the planetary system.

"Near infrared radial velocities – current state and future prospects"

Andreas Seifahrt (Univ. Chicago)

Precise radial velocity measurements at near infrared wavelength offer a unique opportunity to tackle two important aspects in the field of extrasolar planets. (1) By enabling radial velocity measurement of very low mass stars, they offer a shortcut to the identification of Earth-like planets in the solar neighborhood with RV precisions achievable today. (2) Comparing optical and near infrared radial velocity amplitudes allows to discriminate between activity induced signals and bona-fide planetary signals for young and active stars. In this overview talk, I will summarize the state state of the field and the latest results obtained with different instruments and calibration methods. I will also give an outlook of where the next generation of infrared radial velocity spectrographs will take us and what technical challenges we have to overcome to realize these goals.

"Crowding Out of Giants by Dwarfs: an Origin for the Lack of Companion Planets in Hot Jupiter Systems"

Masahiro Ogihara (Nagoya Univ.)

Recent observations have revealed several properties of the orbital architecture of multiple planet systems whose architectures differ strikingly from that of our solar system. One of the most distinctive features is a lack of companion planets in hot Jupiter (HJ) systems. In this work, we perform N-body simulations of planetary accretion in the presence of an HJ that show the effect of the HJ on the planet formation process. Our simulations show that several terrestrial planets that undergo inward migration relax to a quasi-steady state making a chain of resonant planets outside the orbit of the HJ and, in certain circumstances, all of them gravitationally interact with the HJ through resonance, which leads to inward migration of the HJ. The HJ is eventually lost by collision with the central star. We can give several possible explanations for the origin of properties of observed exoplanet systems. In particular, our model naturally explains the lack of additional observed planets in orbits close to HJs.

"Dynamics of planet formation – in binaries and outside"
Nader Haghighipour (UH)
The discovery of exoplanets in multiple star systems, especially those around the primaries of close-binaries (i.e. separations smaller than 50 AU), and the recent discoveries of circumbinary planets with the *Kepler* space telescope have triggered many studies on the formation, evolution, and habitability of planets in and around binary stars. Planet formation is a complex process, believed to be the succession of several stages, each of which could be affected in very different ways by the perturbations of a secondary star. How such planets form, and how the binarity of the system affects their formation are difficult questions that require deep understanding of the growth and evolution of solid objects in circumstellar and circumbinary environments. The habitability of planet-hosting binary systems is also complicated and requires developing new models of the calculation of the habitable zone for multiple star systems. I will review the current state of research on the formation of planets in and around binary stars, and discuss the new developments on the calculation of the habitable zone in binary stars systems. These studies are of great interest, not only to explore the history of specific planets-in-binaries, but also for our understanding of planet formation in general. They can also be used as a test bench for planet formation models, by confronting them to an unusual and sometimes "extreme" environment where some crucial parameters might be pushed to extreme values.

"High contrast imaging: technology and scientific opportunities from ground and space"
Olivier Guyon (Arizona/Subaru)
High contrast imaging techniques have advanced considerably in the last decade, and will continue to do so. Their development is motivated by the scientific perspective of directly imaging and characterizing exoplanets with ground-based and space-based telescopes, with a long term goal of identifying signs of biological activity on rocky planets in the habitable zones of nearby stars. In space, thanks to the absence of atmospheric turbulence, future missions (such as the WFIRST coronagraph) will reach deep contrast at optical wavelengths, allowing direct imaging of starlight reflected by exoplanets. Spectroscopic characterization of Earth-like planets around sun-like stars will be possible with large space-based telescopes. Ground-based telescope have a considerable size advantage, but must overcome atmospheric effects. Adaptive optics techniques specifically optimized for high contrast imaging are therefore essential: high speed high sensitivity wavefront sensing, predictive adaptive optics control, and speckle control/calibration. Such techniques are currently under development and test. The Subaru Coronagraphic Extreme AO (SCExAO) system serves as a technology pathfinder for several of these techniques. Detection of ~10^{-8} contrast planet at ~1 to 2 λ/D separation may be achievable with ELTs with a combination of high performance coronagraphy, high sensitivity extreme-AO, and speckle residual calibration. This performance level will reveal a large sample of giant planets, and allow their spectroscopic characterization. More interestingly, habitable planets around nearby M-type stars are ideal targets for ELTs. Thanks to the ELTs' high angular resolution, the small angular size of the habitable zone around these targets is well resolved, and the planet-to-star contrast is favorable thanks to the relatively faint stellar brightness. I will conclude that through direct imaging and spectroscopic characterization of rocky planets in the habitable zones of nearby M-type stars, ELTs can provide scientific evidence for (or against) the presence of life outside our solar system. Technologies requiring further maturation to enable these observations will be discussed.

"Disk lifetime and the disk fraction"
Takashi Onaka (UTokyo)
The lifetime of the protoplanetary disk provides an important constraint on the planet formation process. The variation of the disk fraction with the cluster age is often used to estimate the disk lifetime (e.g. Sung et al. 2009, AJ, 138, 1116; Yasui et al. 2010, ApJ, 723, L113). However, the disk fraction is estimated from the presence or absence of a disk and does not directly indicate the variation of the disk mass with time. In this presentation, we investigate the relation of the apparent time variation of the disk fraction to the true disk lifetime. Assuming a simple model with a power-law distribution of the initial disk mass, we found that the apparent time constant of the disk fraction can either overestimate or underestimate the true disk lifetime depending on the value of the power-law index. The mass range of the distribution also affects the estimate. Therefore, if the disk mass distribution changes with physical parameters, such as metallicity, it could affect the apparent time constant of the disk fraction. We also found that the apparent functional form of time variation of the disk fraction depends on the observational threshold for the disk detection. While the present analysis is made with a simple model, the qualitative conclusions are rather robust and thus should be taken into account carefully in the estimation of the true disk lifetime.

"Mass determination of young directly imaged planet candidates and brown dwarfs"

Tobias Schmidt (Astrophysical Institute and University-Observatory Jena)

About 25 sub-stellar companions with large separations (>~50 AU) to their young primary stars and brown dwarfs are confirmed by both common proper motion and late-M / early-L type spectra. The origin and early evolution of these objects is still under debate. While often these substellar companions are regarded as brown dwarfs, they could possibly also be massive planets, the mass estimates are very uncertain so far. They are companions to primary stars or brown dwarfs in young associations and star forming regions like Taurus, Upper Scorpius, the TW Hya association, Beta Pic moving group, TucHor association, Lupus, Ophiuchus, and Chamaeleon, hence their ages and distances are well known, in contrast to free-floating brown dwarfs. Here we present how mass estimates of such young directly imaged companions can be derived, using e.g. evolutionary models, which are however currently almost uncalibrated by direct mass measurements of young objects. An empirical classification by medium-resolution spectroscopy is currently not possible, because a spectral sequence that is taking the lower gravity into account, is not existing. This problem leads to an apparent mismatch between spectra of old field type objects and young low-mass companions at the same effective temperature, hampering a determination of temperature and surface gravity independent from models. We show that from spectra of the objects, using the advantages of light concentration by an AO-assisted integral field spectrograph, temperature, extinction, metallicity and surface gravity can be derived using non-equilibrium radiative transfer atmosphere models as comparison and that this procedure as well allows a mass determination in combination with the luminosities found by the direct observations, as has recently been done by us for several young sub-stellar companions, as e.g. GQ Lup, CT Cha or UScoCTIO 108 and PZ Tel.

"IRD: InfraRed Doppler Instrument for Subaru Telescope"

Takayuki Kotani (NAOJ)

Infrared Doppler (IRD) is the near-infrared, high-spectral resolution spectrometer for the Subaru telescope, which aims at detecting Earth-mass planets around M-type stars via high-precision radial velocity measurements. We will present the current development status of IRD and future prospects. The expected RV measurement accuracy of IRD is about 1m/s, thanks to many newly developed technologies. The spectrometer employs compact echelle and VPH gratings covering 0.97 to 1.75μm with the spectral resolution of 70000. The infrared detector is the state-of-the-art, large format 4096x4096 pixel HdCdTe Array (HAWAII4 RG-15) under testing at IfA, University of Hawaii. For the wavelength calibration, we have been developing laser frequency comb, which is extremely stable wavelength standard with the wide spectral coverage, in collaboration with Tokyo University of Agriculture and Technology. To achieve ultimate thermal stability of the instrument, the optical bench and most of the optical components consist of material with very low thermal expansion coefficient and there are no moving parts. We also present the result of the laboratory experiments to demonstrate a capability of detecting 1m/s RV shift by using a prototype spectrometer system and the characterization of multi-mode fibers used for IRD.

"SMACK: A New Algorithm for Modeling Collisions and Dynamics of Planetesimals in Debris Disks

Erika Nesvold (University of Maryland)

We present the Superparticle Model/Algorithm for Collisions in Kuiper belts and debris disks (SMACK), a new method for simultaneously modeling, in 3-D, the collisional and dynamical evolution of planetesimals in a debris disk with planets. SMACK can simulate azimuthal asymmetries and how these asymmetries evolve over time. We show that SMACK is stable to numerical viscosity and numerical heating over 10^7 yr, and that it can reproduce analytic models of disk evolution. We use SMACK to model the evolution of a debris ring containing a planet on an eccentric orbit. Differential precession creates a spiral structure as the ring evolves, but collisions subsequently break up the spiral, leaving a narrower eccentric ring.

"Diversity of atmospheric circulations of synchronized rotating Jovian type planets"

Shin-ichi Takehiro (Kyoto Univ.)

Atmospheric circulation simulations of synchronized rotating Jovian type planets (so called hot Jupiters) are performed so far using three-imensional primitive models which assume the fluid motions are concentrated in a thin layer near the planetary surface and neglect the horizontal components of Coriolis force. These assumptions are considered to be valid when the advective time scale by the horizontal flows is shorter than the radiative cooling time scale; the air mass heated at the front side covers the whole surface of the planet and a stable layer is globally formed. However, when the incident radiation from the central star is insufficient, the induced atmospheric flows may not create a global stable layer. Here, we are now constructing an atmospheric circulation model which can describe not only shallow but also deep fluid motions of the planet in order to examine possibility of deep atmospheric circulations of hot Jupiters. The model is consist of a three-dimensional Boussinesq fluid in a rotating spherical shell. Heating near the day hemisphere surface and cooling near the night hemisphere surface are implemented in the model. A convective adjustment scheme is adapted in order to allow a longer time step for integrations. Preliminary results of numerical integrations show that, when the Rossby deformation radius is similar to the planetary radius (as expected for many hot Jupiters), the planetary surface is covered with a stable layer and westerly jets emerge at the surface of the mid-latitudes rather than the equatorial surface. This longitudinal jet profile is in contrast with that obtained by the shallow models where the equatorial jet is prominent.

"Transiting Exoplanet Search and Characterization with Subaru's New Infrared Doppler Instrument (IRD)"

Norio Narita (NAOJ)

A new instrument, IRD, is expected to be installed on the Subaru telescope in 2014. The IRD-transit group aims to maximize scientific benefits of the IRD by searching new transiting exoplanets in combination with the IRD's RV survey and by characterizing discovered transiting exoplanets. For this purpose, we are exercising high precision transit photometry with current instruments, which enable us to follow-up the presence of transits for planets discovered by IRD7s RV survey. In this talk, we will report such efforts and related science cases which we plan to do in the near future.

Session: Earth-like, Habitable Planets and Future Missions

"Emergence of two types of terrestrial planet on solidification of magma ocean"

Keiko Hamano (UTokyo)

Understanding the origins of the diversity in terrestrial planets is a fundamental goal in Earth and planetary sciences. In the Solar System, Venus has a similar size and bulk composition to those of Earth, but it lacks water. Because a richer variety of exoplanets is expected to be discovered, prediction of their atmospheres and surface environments requires a general framework for planetary evolution. Here we show that terrestrial planets can be divided into two distinct types on the basis of their evolutionary history during solidification from the initially hot molten state expected from the standard formation model. Even if, apart from their orbits, they were identical just after formation, the solidified planets can have different characteristics. A type I planet, which is formed beyond a certain critical distance from the host star, solidifies within several million years. If the planet acquires water during formation, most of this water is retained and forms the earliest oceans. In contrast, on a type II planet, which is formed inside the critical distance, a magma ocean can be sustained for longer, even with a larger initial amount of water. Its duration could be as long as 100 million years if the planet is formed together with a mass of water comparable to the total inventory of the modern Earth. Hydrodynamic escape desiccates type II planets during the slow solidification process. Although Earth is categorized as type I, it is not clear which type Venus is because its orbital distance is close to the critical distance. However, because the dryness of the surface and mantle predicted for type II planets is consistent with the characteristics of Venus, it may be representative of type II planets. The short timescale for planetary solidification on type-I planets suggests that exoplanet observations would have a chance to detect ocean covered planets even in young systems where planet formation is ongoing. Also, the presence of a long-lived magma ocean on type-II planets is encouraging for future detection of molten terrestrial planets.

"Habitable Zone Limits and the Occurrence of Potential Habitable Planets"

Ravi K. Kopparapu (Pennsylvania State Univ.)

Identifying terrestrial planets in the habitable zones (HZs) of other stars is one of the primary goals of ongoing exoplanet surveys and proposed space-based flagship missions. In this talk, I will discuss about our recent results on the new estimates of HZs around Main-sequence stars. According to our new model, the inner (moist greenhouse) and outer (maximum greenhouse) HZ limits for our Solar System are at 0.99 AU and 1.67 AU, respectively, suggesting that the present Earth lies near the inner edge. Our model does not include the radiative effects of clouds; thus, the actual HZ boundaries may be broader than our estimates. Applying the new HZ limits to cool, low mass stars (M-dwarfs) in NASA's "Kepler" data, we find that potentially habitable planets around M-dwarfs are more common than previously reported.

"Direct Imaging of Exoplanets on ELTs"

Taro Matsuo (Kyoto Univ.)

The next generation 30m class telescopes, called Extremely Large Telescopes (ELTs), will see the first lights in early 2020's. Thanks to the large aperture, ELTs enable to explore a new discovery space toward mature Jovian planets and potentially habitable planets around late-type stars. In terms of also characterization, a simultaneous spectroscopy of the central star and the planet can remove an impact from the telluric absorption and then detect oxygen molecules on the habitable planets. The key requirement to achieve the ultimate goal is high contrast (1e-5 raw contrast) at small inner working angle (1-2 lambda/D). Several favorable technical concepts to push small inner working angle are proposed and demonstrated both in laboratory and on sky. Thus, ELTs would provide a first opportunity to directly detect and characterize the mature planets including the habitable planets. In this talk, I will review the science cases and the technical concepts for the future 30m class telescopes.

"Variety of water planets"

Yutaka Abe (UTokyo)

Real necessary and sufficient conditions for life are not well constrained yet. However, terrestrial-life requires existence of liquid water during at least some periods of their life. Therefore, we may consider existence of liquid water as a conventional necessary condition. In the following, we call rocky planets with substantial amount of liquid water on their surface 'water planets.' We discuss possible variety of water planets. Most of previous studies on habitable planets implicitly assume Earth-like water planets. However, there are other possible types of water planets. We can distinguish three types of water planets depending on the distribution water on the surface: "ocean planet," "partial-ocean planets" and "land planets". On the ocean and the partial-ocean planets, the distribution of liquid water is controlled by the distribution of oceans irrespective of local balance between precipitation and evaporation. The difference between the ocean planets and the land-ocean planets is that the former have no lands while the latter have some. On the other hand, the land planets are defined as the planets on which the distribution of liquid water is controlled by the atmospheric circulation so that precipitation locally balances with evaporation (Abe et al., 2005). Thus, on a land planet, liquid water disappears from the regions where evaporation exceeds precipitation, but on a landocean planet, it may not. The Earth is one of partial-ocean planets. Ocean, partialocean, and land planets have very different climates (Abe et al., 2005; 2011). Therefore, it is important to clarify the condition dividing these three types of planet as the amount of liquid water. The purpose of this study is to clarify the conditions dividing them. In the presentation, we briefly discuss differences of climate among these three types of planets first. Second, we discuss the dividing condition in terms of the fraction of the water covered areas. Third, we discuss the condition in terms of water amount on the surface. Earth-like partial-ocean planets are expected only for rather narrow range of water amount; only in the order range from 1/10 to 10 Earth ocean mass.

"Archaeology of Extrasolar Terrestrial Planetary Systems"

Jay Farihi (Univ. of Cambridge)

We now stand firmly in the era of solid exoplanet detection via Kepler and other state of the art facilities. Yet the empirical characterization of these most intriguing planets is extremely challenging. Transit plus radial velocity information can yield planet mass and radius, and hence planet density, but the bulk composition remains degenerate and completely model—dependent. Currently, the abundances of a handful of exoplanet atmospheres can be estimated from transit spectroscopy, or observed directly via spectroscopy, but probing only the most tenuous outer layers of those planets. Fortunately, as demonstrated by Spitzer, AKARI, and complementary ground—based observations, debris disk—polluted white dwarfs can yield highly accurate information on the chemical structure of rocky minor planets (i.e. exo—asteroids), the building blocks of solid exoplanets. The white dwarf distills the planetary fragments, and provides powerful insight into the mass and chemical structure of the parent body.This archaeological method provides empirical data on the assembly and chemistry of exo-terrestrial planets that is unavailable for any planetary system orbiting a main —sequence star. In the Solar System, the asteroids (or minor planets) are leftover building blocks of the terrestrial planets, and we obtain their compositions -- and hence that of the terrestrial planets -- by studying meteorites. Similarly, one can infer the composition of exo-terrestrial planets by studying tidally destroyed and accreted asteroids at polluted white dwarfs. I will present ongoing, state of the art results using this unconventional technique, including ALMA Cycle 0 data and the lasting impact of infrared space missions like Spitzer and AKARI. Some highlights will include the recent detection of terrestrial-like debris in the Hyades star cluster, as well as the detection of water-rich planetesimals that may represent the building blocks of habitable exoplanets.

"Formation of Terrestrial Planets from Protoplanets: Effects of System Size and Position"

Eiichiro Kokubo (NAOJ)

The final stage of terrestrial planet formation is known as the giant impact stage where protoplanets collide with one another to form planets. We have been investigating this final assemblage of terrestrial planets from protoplanets using N-body simulations. So far we have systematically changed the surface density and orbital separation of an initial protoplanet system, and the bulk density of protoplanets, while the initial system radial range has been fixed as 0.5-1.5 AU. For the standard disk model, typically two Earth-sized planets form in the terrestrial planet region. In the present paper, we systematically change the initial system radial range and position to investigate how they affect terrestrial planet formation. We find that as we increase the radial range with the fixed inner edge, the number of Earth-sized planets increases, while the number of planets per radial width decreases. The mass of planets and their radial accretion ranges increase with the system radial range. We also find that as we shift the inner edge outward with the fixed system radial range, the numbers of Earth-sized planets and planets per radial width decreases. The position of the inner most planet almost corresponds to the initial system inner edge. From all simulation results, we confirm that it is the system total mass that determines the mass of large planets. The masses of the largest and second-largest planets increase almost linearly with the system total mass. The typical mass ratio between the largest and second-largest planets is about 0.6.

"Long-term insolation variations on habitable exoplanets"
Ramon Brasser (Acdemia Cinica)
[TBD]

"Coronagraphy on AFTA-WFIRST"
Jeremy Kasdin (Princeton)
In May, 2013 NASA approved pre-formulation studies of a version of WFIRST, the Wide Field Infra-Red Space Telescope, using the recently donated 2.4 m telescopes, dubbed AFTA (for Astrophysics Focused Telescope Assets). That mission study includes a coronagraph instrument for imaging of giant planets and disks. In this talk I'll describe the coronagraph architecture being studied, including wavefront control, and the types of coronagraphs being considered. This will include an update on the study status and the potential high-contrast capabilities of the instrument. A two-year study is planned with a decision by NASA to continue forward with a flight mission expected in late 2015.

"Current and Future of Microlensing Exoplanet Search"
Takahiro Sumi (Osaka Univ.)
Gravitational microlensing has an unique sensitivity to exoplanets at outside of the snow-line down to the Earth-mass. Because of the rarity and short timescale of the planetary signal, the survey groups carry out the wide field survey observation towards the galactic bulge to issue alerts in realtime. Then telescopes of the follow-up groups conduct high cadence follow-up observation to get dense sampling of the short planetary signal. The second phase of Microlensing Observations in Astrophysics (MOA-II) carries out survey observations toward the Galactic Bulge (GB) to find bound and unbound exoplanets via the gravitational microlensing using a 1.8m telescope in New Zealand. We observe target fields very frequently (every 15~90 min) and analyze data in realtime to issue alerts. This high cadence is specifically designed to find the short timescale signature of bound and unbound planets. Recent high cadence survey observations by MOA-II and OGLE-IV in Chile has started to find exoplanets without follow-up observation systematically. Next generation 24-hour high cadence survey observations can reveal the mass function of exoplanets down to Earth mass outside of the snow-line. The Wide Field Infrared Survey Telescope (WFIRST) is the highest ranked recommendation for a large space mission in the recent New Worlds, New Horizons (NWNH) in Astronomy and Astrophysics 2010 Decadal Survey. Exoplanet microlensing program is one of the primary science of WFIRST. WFIRST will find about 3000 bound planets and 2000 unbound planets by the high precision continuous survey 15 min. cadence. WFIRST can complete the statistical census of planetary systems in the Galaxy, from super-Earths beyond the snow-line to gravitationally unbound planets - a discovery space inaccessible to other exoplanet detection techniques.

"JWST"
Mark Clampin (STScI)
[TBD]

"Future Coronagraph Missions"
Wesley Traub (JPL)
The prospects for observing and spectroscopically characterizing exoplanets and disks, with future coronagraph missions, are brighter today than ever before. The relevant missions and expected launch dates are JWST (2018), AFTA (2024), Exo-C (TBD), and Exo-S (TBD). In this talk, I will outline the coronagraphic capabilities of these missions, and will discuss the types of science to be expected from each. Each of these will have the ability to discover exoplanets and disks around nearby stars, including the ability to validate some of the known RV planets. However since many of these planets will already have been discovered by RV by the time these missions are launched, a more important capability will be to characterize these planets and disks with spectroscopy, so I will discuss the prospects for these observations.

"Exoplanet studies with SPICA mission"

Keigo Enya (JAXA)

Space Infrared telescope for Cosmology and Astrophysics (SPICA) is a space-borne telescope mission with 3m class telescope cooled to 6K. The core wavelength for observation is 5-200 micron. SPICA will gives us a valuable opportunity for studies of exoplanets thanks to the large telescope aperture, the capability of wideband infrared observations, high sensitivity and high stability. SPICA will carry mid- and far-infrared instruments. Especially, the SPICA Coronagraph Instrument (SCI) is primarily designed for the study of exopalnets. A unique function of the SCI, coronagraphic spectroscopy, will provide spectrum of Jovian exoplanets in 4-28 micron. Such spectrum is useful for understanding of formation history of expolanets, composition and structure of exoplanet atmosphere. Also, SPICA carries the Mid-infrared Camera and Spectrometer (MCS), the far-infrared instrument (SAFARI), and Focal Plane Camera (FPC). Using complemental instruments, SPICA will contribute for study of exoplanets and extrasolar disks.

"The WFIRST Cool and Cold Exoplanet Survey"

David Bennett (Univ. of Notre Dame)

The WFIRST-AFTA mission has to two complementary exoplanet programs: a wide-field, near-infrared microlensing survey and an internal coronagraph for high contrast imaging and speectra, which was described in a previous talk. The WFIRST-AFTA exoplanet microlensing survey will complete the statistical census of exoplanets in our Galaxy that was begun by Kepler. The WFIRST-AFTA microlensing survey will detect exoplanets down to the mass of Mars from the habitable zone through the snow line and beyond, including rogue planets that have been enjected from the planetary systems of their birth. When combined with the Kepler results, WFIRST-AFTA will provide a comprehensive picture of the demographics of planetary systems in our Galaxy.

ABSTRACTS (Poster Presentations)

[P01] ″Impact strength of small icy bodies experienced multiple collisions″
Masahiko Arakawa (Kobe University)

Small bodies in the solar system have experienced mutual collisions in many times, so that the cumulative damage in these bodies is expected to affect their evolutions significantly. Thus, it is important to study the effects of pre-impacts on the impact strength and the ejection velocity of impact fragments. Multiple impact experiments were conducted for a polycrystalline water ice target in the impact number of times from 1 to 10 times. An ice cylindrical projectile was impacted at 84 to 502 m s^{-1} by using a single-stage gas gun in a cold room between −10 and −15 ℃. The relationship between the largest fragment mass normalized by the initial target mass, ml/Mt0, and the total energy density, ΣQ, for multiple impacts was found to be very similar to that of polycrystalline water ice by single impact experiments obtained by Kato et al. (1995), then the impact strength of the pre-impacted target was found to be expressed by ΣQ, and it was obtained to be ΣQ*=77.6 J kg^{-1}. The cumulative number of fine impact fragments at m/Mt0~10^{-6}, Nm, had good correlation with the single energy density at each shot, Qj, and the relationship could be written by Nm = 101.02±0.22・Qj1.31±0.12. We estimated the cumulative damage of icy bodies by past impacts according to the crater scaling law of ice and the crater size distributions observed on the actual icy satellites. As a result, we found that the cumulative damage of Phoebe, Saturnian icy satellite, depended significantly on the impact speed of impactor, and it was about 1/3 of impact strength ΣQ* at 500 m s^{-1} while it was almost zero at 3.2 km s^{-1}.

[P02] ″Protoplanetary disk characteristics as a function of the turbulent viscosity parameter and influence of deadzones″
Kevin Baillie (Universite Paris)

We designed a 1D-hydrodynamical numerical model for the spreading of protoplanetary disks based on a self-consistent coupling between the disk thermodynamics, photosphere geometry and dynamics (Baillie et al., 2013 submitted to Astrophysical Journal). We found that the evolution timescale increases for a more massive disk or for a steeper surface density disk, and decreases for more massive stars or lower turbulent viscosity parameters. It is found in particular that there is a strong dependency of the mass accretion rate versus the disk mass and a weaker dependency versus the star mass. Coupled with observed similar conclusions, we derived that the disk mass is scaling as M*^1.5. Using a more advanced prescription for the turbulent viscosity parameter, we model the numerical evolution of a disk with a non-uniform alpha parameter. In particular, using the criterions identified by Terquem et al., 2009, we define deadzones and model their influence on the disk evolution and especially its midplane temperature.

[P03] ″PULSE: Palomar Ultraviolet Laser for the Study of Exoplanets″
Christoph Baranec (Univ. Hawaii / IfA)

PULSE is a new concept to augment the currently operating 5.1-m Hale PALM-3000 exoplanet adaptive optics system with an ultraviolet Rayleigh laser and associated wavefront sensor. By using an ultraviolet laser to measure the high spatial and temporal order turbulence near the telescope aperture, where it dominates, one can extend the faintness limit of natural guide stars needed by PALM-3000. Initial simulations indicate that very-high infrared contrast ratios and good visible-light adaptive optics performance will be achieved by such an upgraded system on stars as faint as mV = 16-17 using an optimized low-order NGS sensor. This will enable direct imaging searches for, and subsequent characterization of, companions around cool, low-mass stars for the first time, as well as routine visible-light imaging twice as sharp as HST for fainter targets. PULSE will reuse the laser and wavefront sensor technology developed for the automated Robo-AO laser system currently operating at the Palomar 60-inch telescope, as well as take advantage of pending optimization of low-order NGS wavefront sensing and planned new interfaces to the PALM-3000 real-time reconstruction computer. A copy of the Robo-AO laser will be installed in the prime focus cage of the 5.1-m, and a new ultraviolet high-order wavefront sensor, fed by an ultraviolet dichroic, will be installed in the space above the PALM-3000 optical bench near the calibration sources. The laser measurements will drive the 3,388 active element high-order deformable mirror in open-loop, while an adaptive optics sharpened faint natural source will be measured by the current PALM-3000 wavefront sensor in its lowest spatial sampling mode, with commands sent in closed-loop to the 241 active element low-order deformable mirror. The natural guide star loop corrects for both the relatively weak low-order high-altitude turbulence as well as functioning as both the tip-tilt and low-bandwidth `truth' sensor loops in a traditional laser adaptive optics system.

[P04] "Brown Dwarf Parallax Program"
Charles Beichman (NASA)
TBD

[P05] ″Characterization of gaseous companion to the B-type star Kappa Andromedae″
Mickael Bonnefoy (Institut de Planétologie et d'Astrophysique de Grenoble)
In the course of the Strategic Explorations of Exoplanets and Disks on the Subaru telescope (SEEDS), we imaged a low mass

companion at a projected separation of 55 +- 2 AU around the B9 type star Kappa Andromedae. The companion was confirmed to be co-moving with the star by follow-up observations made at J (1.25μm), H (1.635μm), Ks (2.150μm), and L' (3.77μm) bands. Age estimates of the system, and evolutionary models with ``hot-start" initial conditions, placed the companion at the typical planet/brown-dwarf boundary. The extreme properties of the system (mass ratio, projected separation) make it a benchmark for formation and evolution models of very low mass companions placed on wide-orbits. We obtained new high-contrast images of the system at 2.146, 3.776, 4.052 and 4.78 microns obtained with NIRC2 at Keck and the near-infrared camera LMIRCam at LBT as well as revised near-infrared photometry of the star. These new data complete the near-infrared (1-5 μm) spectral energy distribution (SED) of the companion. The SED enables to give more robust estimates of the physical (luminosity, Teff) properties of the object. We used various sets of evolution tracks ("cold-start", "warm-start", "hot-start") with different initial conditions to derive new mass estimates based on the measured properties, and more conservative estimate of the age of the system. I will discuss how these revised properties compare to predictions of formation models.

[P06] "Direct imaging discovery of a probable 4-5 MJup"

Mickael Bonnefoy (Institut de Planétologie et d'Astrophysique de Grenoble)

Understanding planetary systems formation and evolution has become one of the challenges in as- tronomy, since the discovery of the first exoplanet around the solar-type star 51 Peg in the 90's. While more than 800 planets (mostly giants) closer than a few AU have been identified with radial velocity and transit techniques, very few have been imaged and definitely confirmed around stars, at separations below a hundred of astronomical units. Direct imaging detection of exoplanet is indeed a major frontier in planetary astrophysics. It surveys a region of semi-major axes (> 5 AU) that is almost inaccessible to other methods. Moreover, the planets imaged so far orbit young stars; indeed the young planets are still hot and the planet-star contrasts are compatible with the detection limits currently achievable, in contrast with similar planets in older systems. Noticeably, the stars are of early-types, and surrounded by debris disks, i.e. disks populated at least by small grains with lifetimes so short that they must be permanently produced, probably by destruction (evaporation, collisions) of larger solid bodies. Consequently, every single discovery has a tremendous impact on the understanding of the formation, the dynamical evolution, and the physics of giant planets. In this context, I will present our recent discovery of one faint companion to a nearby, dusty, and young A-type star (at 56 AU projected separation). Background contaminants are rejected with high confidence level based on both astrometry and photometry with three dataset at more than a year-time-laps and two different wavelength regimes. From the system age (10 to 17 Myr) and from model-dependent luminosity estimates, we derive mass of 4 to 5 Jupiter mass. This planet is therefore the one with the lowest mass ever imaged around a star. Given its orbital and physical properties, I will discuss the implication on its atmosphere with respect to other imaged companions but also on its formation.

[P07] "Properties of the distant brown-dwarf binary companion to the young and dusty A-type star HR6037"

Mickael Bonnefoy (Institut de Planétologie et d'Astrophysique de Grenoble)

We imaged in 2010 a brown dwarf companion at a projected separation of 348 AU to the nearby (d = 52.2±1.2 pc) A6-type star HR6037. The star is known to be surrounded by dust. It has been proposed as a kinematic member of the ~40 Myr old Argus association. More recently, Nielsen et al. 2013 resolved the companion as a tight (3 AU) equal-mass binary of brown-dwarfs. The orbit, and dynamical mass of the pair, could be measured within a few years. The peculiarities of the HR6037 system make it a benchmark for planet/brown-dwarf formation models, atmospheric models, and possibly evolutionary models. We present new multi-epoch near-infrared photometry (1-5μm) and medium-resolution (R=2000-2700) 1-2.5μm spectra of the companion. We use these data to refine the spectral type, effective temperature, surface gravity, and mass of the binary components. We discuss the possible formation history of HR 6037 BaBb based on formation models and on the comparison of the binary properties to those of other famous companions (HR8799bcde, Beta Pictoris b, HR7329 B, HD 1160 B & C, HD95086 b) orbiting dusty A-type stars on wide-orbits.

[P09] "Companions to Ultracool Dwarfs at the diffraction limit"

Anthony Cheetham (University of Sydney)

Unlike conventional star formation which rests on a foundation of decades of observational and theoretical study, the formation and evolution of ultracool dwarfs at or below the hydrogen burning limit remains poorly understood. Their individual masses are well below the standard Jeans mass, making it difficult to explain their prevalence with standard formation mechanisms. Several hypotheses have been put forward, but scant evidence is available to test their predictions. In addition, very little observational evidence is available to tie down models of their evolutionary tracks. Multiplicity studies of such ultracool dwarfs provide a wealth of information about such systems, and allow for stringent testing of these theoretical formation and evolutionary models. In Pope et al (2013), the relatively new technique of kernel phase interferometry was applied to archival Hubble Space Telescope data of nearby brown dwarfs. This new analysis yielded dramatically improved astrometry for several known binaries and the discovery of multiple new binary candidates. Here we present the results of a follow up survey using conventional imaging with the NACO instrument on the Very Large Telescope. Our analysis of this data has verified the kernel phase technique through independent detection of a sample of these newly detected binaries and provided further detection epochs for several known binaries. For systems with previous astrometric data from 2 or more epochs, these measurements allow orbit fitting and calculation of dynamical masses, while for the remaining detections they contribute a second epoch for future characterisation.

[P10] ″Magnetic Activities of Class 0 Protostars″

Minho Choi (Korea Astronomy and Space Science Institute)

Magnetosphere is an integral part of a star and plays important roles in the dynamics of ionized gas in and around the star. The magnetosphere manifests itself through powerful outbursts of energy such as radio and X-ray flares, and such magnetic activities start well before the onset of stable hydrogen burning. The magnetic fields of young stellar objects may be seeded by the interstellar magnetic fields in the natal cloud. However, the origin of stellar magnetic fields has been difficult to study because class 0 protostars are surrounded by opaque layers of gas that block the radio and X-ray emission from the view of outside observers. Recently discovered very-low-luminosity protostars may have relatively transparent outer layers and present a new opportunity to directly observe the protostellar magnetic activities. We detected a radio outburst of the class 0 protostar IRAM 04191+1522 IRS in the Taurus star-forming region. The outburst timescale of 20 days is consistent with magnetic flares. Since this protostar is too young and small to develop an internal convective dynamo, the flare may be caused by the magnetic fields of interstellar origin. The flares of such fossil magnetic fields may be a dominant source of high-energy photons, ionizing the circumstellar disk and the protostellar envelope.

[P11] ″Spirals in the disk of HD 142527 from CO emission lines with ALMA″

Valentin Christiaens (University of Chile)

In view of both the size of its gap and the previously reported asymmetries and spiral arms, the transition disk of Herbig Fe star HD 142527 constitutes a remarkable case study in the context of planetary formation. Despite those hints, no companion could be successfully detected so far. A significant fraction of the gas in the disk taking the form of molecular CO, observations of ^{12}CO J=2-1, ^{12}CO J=3-2 and ^{13}CO J=2-1 emission lines were carried out with ALMA, in order to better characterize the morphology of the outer disk. Moment maps were computed. Among them, the problem of segmentation of the peak intensity maps is briefly addressed. Results from the moment maps show spiral features of different sizes for both ^{12}CO J=2-1 and ^{12}CO J=3-2. The outest spiral, well seen in ^{12}CO J=2-1 peak intensity map, had never been detected before, and corresponds probably to a cold density structure, as the ^{12}CO J=3-2 counterpart is much fainter. A counterarm axisymmetrical with respect to the star is also discerned. A third spiral, more inward, is detected and matches relatively well the one already previously observed in near-infrared. Those spirals are subsequently modelled with two different mathematical formalisms. The quality of the fits varies with both the considered spiral and the mathematical formalism. Finally, various scenarios concerning the origin of the spiral arms are briefly considered.

[P12] ″The Subaru Coronagraphic Extreme AO High Sensitivity Visible Wavefront Sensors″

Christophe Sebastien Jean Claude (Subaru Telescope / Paris Observatory)

A diffraction-limited 30-meter telescope theoretically provides a 10 mas resolution limit in the near infrared. Modern coronagraphs offer the means to take full advantage of this angular resolution allowing to explore at high contrast, the innermost parts of nearby planetary systems to within a fraction of an astronomical unit: an unprecedented capability that will revolutionize our understanding of planet formation and evolution across the habitable zone. A precursor of such a system is the Subaru Coronagraphic Extreme AO project. SCExAO uses advanced coronagraphic technique for high contrast imaging of exoplanets and disks as close as 1 lambda/D from the host star. Achieving high contrast at this small angular separation requires a wavefront sensing and control architecture which is optimized for exquisite control and calibration of low order aberrations. To complement the current near-IR wavefront control system driving a single MEMS type deformable mirror mounted on a tip-tilt mount, two high order and high sensitivity visible wavefront sensors have been designed and integrated to SCEXAO: - a non modulated Pyramid wavefront sensor which is a sensitivity improvement over modulated Pyramid systems now used in high performance astronomical AO, - a non linear wavefront sensor designed in 2012 by Subaru Telescope with the collaboration of the NRC-CNRC which is expected to improve significantly the achieved sensitivity of low order aberations measurements. During this conference, I will present the state of progress of the SCExAO non modulated pyramid WFS performance evaluation first performed in laboratory and then downstream the Subaru adaptive optics system (AO188) at the Nasthmyth floor. To finish, I will introduce the primary prototype of the SCExAO non linear curvature wavefront sensor.

[P13] ″Dusty Atmospheres of Cool, Low-Mass Planets″

Ian Crossfield (MPIA)

The frequency of planets around main sequence stars increases toward smaller planetary radii and cooler temperatures, and there is considerable interest in determining the origin, composition, and atmospheric structure of such planets. However, the high-precision measurements necessary to characterize such planets' atmospheres are currently feasible for only a small number of planets with temperatures <1000 K and sizes smaller than Jupiter. I will present our recent observations of the 700 K, Uranus-mass planet GJ~3470b, which exhibits an essentially featureless transmission spectrum likely indicative of dust or clouds at high altitudes in the planet's atmosphere. This result suggests that featureless spectra may be ubiquitous for small, cool planets, which would have important consequences for future efforts to characterizize potentially habitable planets with JWST.

[P14] "Sub-mm vs Scattered Light Transitional Disks: Structural Discrepancies in Oph IRS 48 and SR21"
Kate Brutlag Follette (University of Arizona)
We present Subaru HiCIAO Polarized Differential Imaging (PDI) results on two interesting transitional disks taken through the Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) program. The first, Oph IRS 48, was recently revealed through ALMA observations to have a large asymmetric dust trap (van der Marel et al., 2013). The SEEDS data also show asymmetric scattered light structures, and we will discuss whether or not these can be explained with an axisymmetric inclined disk model. The second disk, SR21, has also been imaged in both sub-mm thermal emission (Andrews et al. 2011) and in NIR scattered light (Follette et al. 2013). The sub-mm data reveal a large r~36AU cavity that is not present in the HiCIAO scattered light data. We will discuss discrepancies between scattered light and sub-mm data in a general sense, as well as how these discrepancies fit into the broader picture of disk clearing mechanisms and exoplanet formation scenarios.

[P15] "On the Origin of Angular Momentum Transfer in Circumplanetary Disks"
Yuri I. Fujii (Nagoya University)
Gaseous disks formed around newborn gas giants are called circumplanetary disks. Satellites are thought to form in circumplanetary disks during mass supply to gas giants, thus the disk properties determine the initial conditions for satellite formation. We investigate the viscous evolution of disks with infalling mass flux. At present, the most promising mechanism of angular momentum transport in accretion disks is magnetic turbulence driven by the magnetorotational instability (MRI). For a disk to be MRI-active, gas in the disk must be sufficiently ionized. We calculated the ionization degree in circumplanetary disks to investigate MRI activity and found that they are mostly MRI-inactive if we only consider cosmic rays, X-rays, and radionuclides as ionization sources. This means that mass piles up until the disk becomes gravitationally unstable unless some other mechanisms promote mass accretion. When the disk becomes gravitationally unstable, spiral arms of density waves transfer angular momentum and the disk may readily heat up because of its large optical depth. We discuss whether thermal ionization triggers the MRI and promotes mass accretion in circumplanetary disks.

[P16] "Photometric Variability of Solar System Solid Bodies: Implications for Rocky/Icy Exoplanets"
Yuka Fujii (TITECH)
Future direct imaging observations of Earth-size exoplanets will play an essential role in investigating their detailed properties including surface geology and habitability. While properties of disk-averaged signals of Earth-twins have been of particular interest in term of habitability and thus investigated at length, a diversity of exoplanetary surface geologies is likely.
In order to explore our potential to observationally identify various geological features of solid exoplanets, we survey spectroscopic and photometric properties as point sources of rocky/icy planets/satellites (e.g. Mars, Moon, Mercury, Galilean Satellites) in the Solar System. We simulate their multi-band photometry using publicly available data. We find up to ~40% variation amplitude in 1 spin rotation associated with non-uniformity of surface composition, grain size, and volcanic activity. In the case of icy satellites rotating synchronously with their orbital motion, the dichotomy between leading/trailing hemispheres may lead to relatively large variations. The wavelength dependence of the variation would be crucial in clarifying the origins of non-uniform surfaces. We also discuss the detectability of spin rotation rate and possible detection methods of companions (e.g. moons) based on periodogram analysis of time series data.

[P17] "Atmospheric Study of Transiting Planets through Optical and Infrared Observations"
Akihiko Fukui (NAOJ)
Atmospheric nature of transiting planets can be examined through transit spectrum, which is expressed as planet-to-star radius ratio as a function of wavelength. From multi-band photometric observations, one can trace Rayleigh scattering due to molecular hydrogen or Haze in optical wavelength range, as well as molecular features such as water and methane in infrared wavelength range. Our team has conducted optical and infrared photometric observations of two super-Earths, GJ1214b and GJ3470b, and one warm Jupiter WASP-80b, by using several Japanese facilities, such as 1.4m IRSF, OAO 188cm tel., 50cm MITSuME, and 8.2m Subaru. From these observations, we found that GJ1214b has a flat transit spectrum possibly due to high-molecular-weight atmosphere, GJ3470b could have a sunny sky (no thick-cloud layer), and the spectrum of WASP-80b shows a rise toward shorter wavelength possibly due to Rayleigh scattering by Haze. In this talk, we present these observational results and possible interpretations.

[P18] "The interplay between disks and (forming) planets from VLT/NACO PDI and ADI observations"
Antonio Garufi (ETH Zurich)
The most promising explanation for the large cavities observed in transitional disks is the gravitational interaction with orbiting companion(s). It has been shown that, in a scenario where a planet is carving out the disk, the cavity edge may act as a filter, allowing micron-size particles only to drift inward (Rice et al. 2006). Therefore, orbiting companions are expected to leave their marks in the disk by differentiating the spatial distribution of dust grains. Recently, discrepant distributions of small and large dust particles have been observed at the cavity edge of some transitional disks by comparing Polarimetric Differential Imaging (PDI) and sub-mm observations (e.g. Dong et al. 2012). However, in most cases no evidence of a cavity edge was found as down as the inner working

angle whereas sub-mm observations resolved it at much larger radii. We present our VLT/NACO PDI images in H and Ks band of one transitional disk showing a cavity edge located at radii much smaller than what is inferred for large dust grains (Garufi et al. submitted). Numerical simulations have shown that this discrepancy can be ascribed to the presence of a giant planet which is sculpting the disk in a grain size-dependent way (Pinilla et al. 2012b, de Juan Ovelar et al. 2013). We show how the dimensions of the cavity for small and large dust grains can help us constrain the properties of the potential companion. Besides that, we illustrate the results from our Angular Differential Imaging (ADI) L' band observations (Quanz et al. 2013a, Reggiani et al. in prep.), performed with VLT/NACO to search for (proto)planets there were peculiar structures in the disk (holes, rings, spirals...) were resolved in complementary PDI observations (Quanz et al. 2013b, Avenhaus et al. submitted). These outstanding results are considerably enhancing our knowledge of the interplay between disks and forming planets.

[P19] "The Collisional Evolution of Debris Disks: Connecting Observations with Theory"

Andras Gaspar (Steward Observatory)

With their discovery, debris disks gave the first proof of existence of extrasolar planetary systems (Aumann et al. 1984, Smith & Terrile 1984). Although extrasolar planets are now readily detected, the importance of debris disks in characterizing their host systems is not diminished. Debris disks are relatively easy to detect at infrared wavelengths, independent of their viewing angle; they enable the study of the dynamical evolution of their host systems; they are able to reveal the outer regions of the systems where planets are difficult to detect; and coronagraphic scattered light images show the active sites of major dust production within the systems. During their operational lifetime, the Spitzer Space Telescope and the Herschel Space Observatory have observed many hundreds of resolved and unresolved debris disks. These detections have helped us characterize the thermal emission and also location of the disks. The observations have also shown a general decay in the observed infrared luminosity of the debris disks as a function of system age and disk location. This evolution must be understood thoroughly before probing other parameters, such as their dependence on stellar metallicity or binarity. A second critical parameter is the shape of the particle size distribution, which can strongly influence conclusions from spectral energy distribution models. In my talk I will introduce our collisional cascade model (CODE-M, Gaspar et al. 2012a), developed to study the time evolution of the dust distribution as a function of various system parameters. I will show that the rate of the decay varies throughout the evolution of the disks, increasing its rate up to a certain point, which is followed by a leveling off to a value of Lir(t) ∝-0.6. This is slower than the ∝-1 decay given by traditional analytic models. I will show how our numerical code can reproduce the fraction of detected debris disk sources within an extensive catalog of Spitzer and Herschel 24, 70, and 100 μm observations (Gaspar et al. 2013). I will also summarize results from the code that show in detail the evolution of the particle size distribution, compare it to traditional analytic results, and also show the resulting spectral energy distributions from the two approaches (Gaspar et al. 2012b). Finally, I will show our latest results on the correlation between system metallicity and initial zero-age system parameters.

[P20] "SAM observations of the transition disk MY Lup"

Adam Hardy (Universidad de Valparaiso)

Giant planet formation is an intriguing explanation for the accreting class of transition-disks. If forming giant planets which are still embedded in their parent disk could be detected, they would provide the most direct observational constraints on planet formation theories. Here, we present multi-epoch SAM observations of the accreting transition-disk, MY Lup. We detected a moving asymmetry in both H and K bands which is likely to be related to the final stages of planet formation.

[P22] "Kelvin-Helmholtz Instability in Multi-sized Dust Layers"

Yukihiko Hasegawa (Osaka University)

We examine the effect of the dust size distribution on the Kelvin-Helmholtz instability in the protoplanetary disk with dust sedimentation. With newly taking into account the dust size distribution, the growth rate of Kelvin-Helmholtz instability is calculated using the linear stability analysis with the dust density distribution consistent with sedimentation. The dust abundance required for the gravitational instability before Kelvin-Helmholtz instability is derived from the linear stability analysis, and it is found that the required dust abundance significantly coincides with that estimated from the Richardson number. It is also found that when the dust size distribution is taken into account, the critical Richardson number for the onset of Kelvin-Helmholtz instability tends to increase with the dust abundance. This result is different from that in the case without the dust size distribution. We will discuss the effect of this difference on planetesimal formation.

[P23] "Laboratory experiments with the free-standing binary-pupil mask coronagraphs for SPICA"

Kanae Haze (ISAS/JAXA)

Direct observation of exoplanets is important to understand their formation process, evolution and diversity. However, the enormous contrast in flux between the central star and its associated planets is the primary difficulty in direct observation. Thus, the development of stellar coronagraphs, which can improve the contrast between the star and the planet, is needed. We study binary-shaped pupil mask coronagraphs, which is planned to apply to the SPICA coronagraph instrument (SCI). Adopting a checkerboard design (a classical design of binary pupil mask), we systematically developed various masks including free-standing masks and masks on substrates with various material and thickness. Our laboratory experiments demonstrated their coronagraphic performance reaching the contrast of ~10^{-7} at visible wavelengths. Experiments at visible wavelengths are easier than in the mid-IR, but reliable enough to check the error of the mask shape, and more sensitive to wave-front errors than in the mid-IR. We started demonstration of our idea of mask designs for the pupil of SPICA. We have developed new free-standing masks (Mask-A, Mask-B and Mask-C) using thin sheet of nickel. These mask have general advantages of a binary pupil mask, i.e., (1) it is robust against pointing errors, and (2) it can, in principal, make observations over a wide range of wavelengths. Furthermore, the design of these masks have remarkable advantages: (3) it is applicable for the pupil of the SPICA telescope, which is partially obscured by a secondary mirror and spiders. The Mask-A is an example design of the integral 1-D binary-pupil mask coronagraph with generalized darkness constraints. The Mask-B is a solution intended for a small IWA. Therefore, The mask is useful for direct observation of a young Jovian planet very close to the star. The Mask-C realizes a wide-field coronagraphic image. Therefore, the Mask-C is useful for efficient survey of unknown exoplanets far from their star and observation of a diffuse target such as a circumstellar disk relating to planetary formation. We obtained our first results of laboratory coronagraphic experiments using the Mask-A, Mask-B and Mask-C.

[P24] "Probing Stellar Obliquities for Transiting Exoplanetary Systems with Subaru"

Teruyuki Hirano (TITECH)

Since the discovery of 51 Peg b, many migration processes have been discussed to explain the presence of close-in massive planets, but which of the proposed scenarios is the dominant channel for their formation is still an open question. In this context, stellar obliquities of exoplanets' host stars with respect to planets' orbital planes are supposed to carry important information to study the dynamical history of the planetary systems; different distributions of stellar obliquities are predicted depending on the migration models. Here we report the observational status on the measurements of stellar obliquities for transiting systems with Subaru. Specifically, we focus on the stellar obliquities for systems with smaller planets (Earth-sized or Neptune-sized ones), for which the stellar obliquities have not been intensely investigated. We also mention the future prospect on this subject using the new instrument (e.g., Subaru/IRD).

[P25] "Reducing atmospheres and habitability of deep-ocean exoplanets"

Peng Hong (The University of Tokyo)

Considering a rapid development of observational technique, transition spectra of terrestrial exoplanets will be obtained in the future. Evaluating their surface environments from the observations of exoplanets is essential to assess the habitability. There are few studies, however, to connect the chemical compositions of upper atmospheres to the surface environments of terrestrial exoplanets. In this study, we investigated how the surface inventory of H_2O affects the atmospheric compositions and climates of Earth-sized habitable exoplanets. This is because terrestrial exoplanets would have a wide range of H_2O inventory, which significantly affects the redox state of the degassing compositions from the interior and thus affects their atmospheric compositions. The chemical equilibrium calculations show that the redox states of degassing components become highly reducing (CH_4/CO_2 > 10) under high-pressure conditions (> 7000 bar). This means that in contrast to terrestrial planets in the solar system, CH_4 would be predominant in carbon-bearing species degassing from the interior when the surface oceans are deeper than about 70 km on terrestrial exoplanets. Our 1-D photochemical calculations show that the CH_4 partial pressures at the surface reach high levels (> 10^{-4} bar) with significant concentrations of H_2 and CO, when the CH_4 degassing flux from the surface reaches a few times that of Earth. It is expected that organic aerosols could be formed in such reducing atmospheres with high CH_4/CO_2 ratios and, through its radiative effect, the aerosol layers would affect the habitability and photochemistry. The optical depths of organic layers are sensitive to the monomer production rates, although the chemical reactions leading to monomer production have not been experimentally constrained yet. In order to put a constraint on the limiting reactions, we also conducted laboratory experiments of UV irradiation onto gas mixtures of CH_4 and CO_2. Unlike many previous studies using deuterium lamps, we used a newly developed H_2/He UV lamp as an UV source that can simulate solar-type UV spectrum more accurately. We measured the dependences of aerosol production rate on UV flux and CH_4/CO_2 gas ratio and interpreted the results with our one-box photochemical model. On the basis of the experimental results, we will discuss the possible presence of Titan-like, hazy atmospheres on such a deep-ocean exoplanets, as well as their climatic stability and feedback mechanisms in the atmosphere-ocean system.

[P26] "Characterizing Low-mass Planets Orbiting Cool Stars With Water and Hydrogen"

Yasunori Hori (NAOJ)

Low-mass exoplanets orbiting cool stars increase in number. In the foreseeable future, ongoing and upcoming near-infrared surveys of planets around cool stars should accelerate the pace of discovery of super-Earths. Recently, transmission spectra during primary eclipses have allowed us to explore atmospheric compositions of super-Earths. Clues on their habitability and origin can be extracted from the volatile-element inventories, including that of water and hydrogen. Thus, based on standard models of planetary accretion, we have examined the acquisition and retention of water and primitive, H/He-dominated atmosphere for sub- and super-Earths around cool stars, i.e., the asymptotic amount of water and hydrogen-rich atmospheres. We find that super-Earths with 10-30 times Earth-mass are likely to acquire and retain more than 20-30wt% water mantle surrounded by thick hydrogen-rich blankets. Less massive (1-10 times Earth-mass) close-in (inside 0.1AU) planets (such as GJ 1214b) may have 0.1-20wt% H-He atmospheres today. The atmosphere of relatively-massive short-period super-Earths (such as GJ 436b) may be > 50wt%. We have also shown that close-in (with semi major axis < 1 AU), sub-Earths with masses in the range of 0.1-1 Earth-mass may retain < 1 wt% H-He atmosphere, regardless their initial water content. Thus, sub-Earths in the habitable zone are expected to be wet but have little or no primitive atmosphere, whereas super-Earths in the same region (such as GJ 581d and GJ 667Cc), are likely to contain abundant water and sufficient hydrogen-rich atmospheres. A small fraction of the planets near the inner edge of the habitable zone (at ~1 AU) have moderately-wet (~0.001-1wt%) Earth-like water composition.

[P27] "Chemistry in protoplanetary disks with the effects of disk wind and grain growth"

Daiki Ishimoto (Kyoto University)

In this study, we calculate the chemical evolution of plotoplanetary disks considering disk winds and grain growth, and investigate the influences of these physical processes on chemical structure of disks. In the case of disk winds, abundances of some molecules increase at the boundary between intermediate and upper layers. It is because molecular hydrogen is transferred into hot layer where molecules such as OH, H2O, and HCN are produced via gas-phase reactions with H2 which have potential barrier. In the case of grain growth, abundances of molecules which are produced via photochemistry increase because UV photons penetrate deeper in the disk. And also, molecules can exist in the gas-phase to some extent by photodesorption near the midplane of cold outer disk. We also calculate molecular line emission and line profile, and discuss which lines are affected by disk winds and grain growth.

[P28] "Numerical experiments on atmospheres of synchronously rotating planets: a case with a non-gray radiation scheme and a cloud scheme"

Masaki Ishiwatari (Hokkaido University)

Numerical experiments are performed on synchronously rotating planets by the use of a general circulation model, dcpam5. For simulating synchronously rotating planet atmospheres, the axial inclinations of the planets are set to be zero. The value of solar constant is set to be 1380 W/m^2, the Earth's value.Four values of planetary rotation rate Ω are adopted: Ω/Ω_E\$ = 0, 0.05, 0.5, 1.0, where Ω_E is the rotation rate of the Earth ($2\pi/86400$ [s^{-1}] = 7.272×10^{-5} [s^{-1}]). All of the planetary surface is assumed to be always in heat balance. Two kinds of experiments are performed: one is a set of runs with a non-gray radiation scheme and a cloud scheme for the Earth's atmosphere, and another is a set of runs with a gray radiation scheme under the cloud-free condition. The results of the experiments show that the horizontal distributions of outgoing longwave fluxes at the top of atmosphere (OLR) are almost the same between the two experiments except for the subsolar region. In the subsolar region, the values of OLR obtained by the experiment with a cloud scheme are smaller than corresponding values obtained by the cloud-free experiment. In the experiment with a cloud scheme, the formation of dense cloud which influences the values of OLR is restricted to the subsolar region, and the occurrence condition of the runaway greenhouse state might not be significantly changed from that for the cloud-free condition.

[P29] "Thermal structure and detectability of atmospheres of hot rocky super-Earths"

Yuichi Ito (Tokyo Tech, The University of Tokyo)

Recently, low-mass exoplanets with masses of 1-10 Earth masses or with radii of 1-2 Earth radii have been discovered. Those planets are often called super-Earths. Some of the super-Earths (e.g., CoRoT-7 b, 55Cnc e and Kepler-78 b) are likely to be rocky planets orbiting near the host stars. Since their surface temperatures are probably higher than the melting temperature of rock because of strong stellar irradiation, their atmospheres include components from rocky melts. Performing gas-melt equilibrium calculations, Schaefer and Fegley (2009) showed that the main constituents of the "mineral" atmosphere are Na, O2, O, and SiO gas in the case of no highly volatile elements such as H, C, N, S, and Cl. Thus, detection of such an atmosphere would provide definitive evidence that the planet is a rocky planet. Also, identifying the mineral atmosphere composition may give constraints on the planet's bulk composition and formation process. However, the property and detectability of such atmospheres of hot super-Earths with molten surfaces have not been studied well. In this study, we focus on the temperature-pressure structure, radiative property and detectability of the mineral atmosphere. We calculate the gas-melt equilibrium composition of the mineral atmosphere, using a MELTS model that is different from Schaefer and Fegley (2009). The MELTS model is based on Ghiorso and Sack (1995) and Asimow and Ghiorso (1998). While the atmospheric compositions we obtain are similar to those from Schaefer and Fegley (2009), our calculation yields abundant K in addition to Na, O2, O, and SiO. Additionally we calculate the absorption cross-sections of those species, and the vertical thermal structure and secondary eclipse depths of the model atmosphere that is composed of Na, K, O2, O, and SiO. We show that these absorption cross-sections consist mainly of the Na D-lines, electron transitions of SiO in the UV wavelength region, and rotation-vibration transitions of SiO in the IR wavelength region. We find isothermal structure for lower planetary equilibrium temperature and thermal inversion structure for higher planetary equilibrium temperature. In the case of that thermal inversion structure, the secondary eclipse depths show SiO feature in the IR wavelength region and Na and K features in the visible wavelength region. The SiO feature is stronger for higher planetary equilibrium temperature, because the SiO abundance increases with temperature. Our feasibility assessment demonstrates that identification of such mineral atmospheres of hot rocky super-Earths in secondary transit is possible via observation from space telescopes.

[P30] ″Status of the Subaru Coronagraphic Extreme Adaptive Optics System for high contrast imaging″

Nemanja Jovanovic (Subaru Telescope)

The Subaru Coronagraphic Extreme AO (SCExAO) instrument consists of a high performance Phase Induced Amplitude Apodisation (PIAA) coronagraph combined with an extreme Adaptive Optics (AO) system operating in the near-infrared (H band). The extreme AO system driven by the 2000 element deformable mirror will allow for Strehl ratios>90% to be achieved in the H-band when it goes closed loop in early 2014. This makes the SCExAO instrument a powerful platform for high contrast imaging especially at angular separations of $1\lambda/\Delta$ which are currently inaccessible to GPI and SPHERE. In this paper we report on the recent progress in regards to a complete optical rebuild which includes the implementation and initial results with the 2k DM, off-axis parabolic relay optics and new low-noise IR detectors. In addition we outline two new modules: VAMPIRES and FIRST which were recently tested on-sky and make use of the light at shorter wavelengths not currently utilized by SCExAO. The SCExAO platform is a versatile high contrast imaging platform which will give access to the inner part of disks and planetary systems and is on target to begin science observations from S14B.

[P31] ″Detecting Earth-like planets in the habitable zone around M-dwarfs with photonic technologies″

Nemanja Jovanovic (Subaru Telescope)

A key technique used to detect, characterize and and indeed confirm exoplanets is Doppler spectroscopy. One of the main limitations in the accuracy with which one can confidently detect a radial velocity (RV) signature however, is modal noise which is due to the temporal fluctuations in the injected point spread function. This can be overcome by injecting light into a spectrograph with a single-mode fiber. To date, this has been an extremely inefficient endevour as it demands high Strehl ratios (>90%) and an apodized pupil. With extreme adaptive optics systems such as SCExAO currently coming online, it is now a possibility. We are currently developing a single-mode injection module within the SCExAO instrument. This will exploit the 2000 element deformable mirror which the pyramid wavefront sensor will eventually drive in closed loop to obtain on-sky Strehl ratios >90%. In addition, SCExAO is the ideal platform to host this module as it also allows the injection unit to utilise the phase induced amplitude apodization lenses which boosts the theoretical coupling efficiency to 100%. With the light efficiently coupled into a single-mode fiber, we plan to utilize a newly designed R=60000, photonic spectrograph. This device has an average throughput of ~55% in the H-band for both p and s polarization's which can not be rivaled by conventional dispersor designs. In addition, the inherent stability of the compact footprint coupled with a fiber Fabry-Perot interferometer make it possible to obtain m/s levels of precision from this high throughput, photonic instrument. This level of performance will be critical to studying Earth-like analogs, in the habitable zone around M-dwarfs.

[P32] ″Gap formation around a planet in protoplanetary disks″

Kazuhiro Kanagawa (ILTS / Hokkaido University)

In a protoplanetary disk, a large planet is able to create a gap, which is a low surface density annulus region along the planet orbit, by a gravitational interaction with the disk. If the planet is massive enough, the gap limits the gaseous inflow across the orbit of planet. Thus, the gap formation is thought to be a possible mechanism that creates the transitional disks with the inner holes, which have been revealed by SED observations and direct imaging. The formation of the disk gap also influences the planet itself. Because of the gap formation, the mode of the planet migration changes from Type I to II. The gap also fairly reduces the gas accretion into the planet. Since such a co-evolution of a protoplanetary disk and planets would be a key process that governs the origin of the diversity of exoplanetary systems, it has been studied by many authors. However, the co-evolution of a protoplanetary disk and planets still has a large uncertainty because of the complexity of the gap formation. In this study, we examined the surface density profile of the gap, by using one-dimensional viscous accretion disk model with a simple model of a planet torque. In our calculation, we did not assume the Keplerian disk rotation, and took into account the disk rotation law altered by the steep surface density gradient in the gap, in a self-consistent way. We found that the altered rotation law significantly affects the resultant surface density profile especially for narrow and deep gaps. Furthermore, we checked our one-dimensional gap calculation by performing two-dimensional hydrodynamical simulations of gap formation with the FARGO code, for various planet masses, and disk parameters (i.e., the disk scale height and the viscosity). Our one-dimensional gap calculation can reproduce precisely results of the hydrodynamic simulations for wide range of the planet mass and disk parameters.

[P33] ″Orbital evolution of eccentric, gas-accreting protoplanets: Formation of distant jupiters in nearly circular orbits″

Akihiro Kikuchi (TITECH)

Recently, distant extrasolar gaseous giant planets in nearly circular orbit have been detected by direct imaging observations. Formation of these planets is not well explained in the standard planet formation theory. In the standard planet formation scenario, first, protoplanet is formed by accretion of planetesimals. Once the mass of the protoplanet exceeds a critical mass, gas accretion becomes very rapid, and leads to a runaway accretion of gas. The timescale of planetesimal accretion depends on the dynamical timescale and the disk property. The larger the distance from the central star, the longer the accretion timescale. If the gas disk disappears before the protoplanet attains the critical mass, this distant protoplanet cannot be a gas giant. We propose a new scenario of distant and circular gas giant formation: (1) an inner gas giant transports a protoplanet outward by gravitational scattering, (2) the protoplanet evolves into a circular orbit by eccentricity damping due to gas accretion. We investigate the second stage. We calculate the orbital evolution of the protoplanet caused by accreting the local gas in a gas disk that is truncated at some radius. We have succeeded to derive these orbital evolution perfectly by analytic solution under the assumption of constant gas accretion rate in a orbit. In the derivation, we average the energy and angular momentum obtained by gas accretion over one Kepler period. The averaged energy and momentum changes give the differential equations of orbital elements. Integrating these equations numerically, we obtain the formulae giving the final orbital elements after eccentricity damping. From this formulae, we find that even highly eccentric protoplanet can evolve into a nearly circular orbit by gas accretion. On the other hand, the decay of semimajor axis is not so efficient. Therefore, we conclude that our new scenario works for formation of distant and circular gas giants, although the validity of the assumption of gas accretion process in this scenario needs to be examined by hydrodynamic simulations.

[P34] "Role of the inner region of a circumstellar disk for understanding episodic accretion"

Shigeo Kimura (Osaka University)

A physical mechanism which drives FU Ori outbursts is reconsidered. Usually, FU Ori outbursts are considered as evidence that the mass accretion from a protoplanetary disk becomes episodic. In this contribution, we consider the effect of the inner region of a disk, which is typically from the central star to the radius less than ten au. This region has been often treated as a sink cell or a sink particle in hydrodynamical simulations of protoplanetary disks. First, we calculate the evolution of the inner disk to show the response of the accretion luminosity against the accretion rate onto the disk. Using the oscillated accretion mass flux onto the disk, we calculate the simple viscous evolution using a constant alpha viscosity with a fixed temperature. As a result, it is found that if the oscillation period of mass flux onto the disk is shorter than viscous time scale, the oscillation of mass flux strongly decays during transmitting the disk. Thus, it can be said that the mass flux onto the central star does not always equals to that from the sink radius. Second, we study whether a spontaneous outburst occurs in the inner region of the disk assuming that mass accretion rate onto the disk is constant. In protoplanetary disks, angular momentum is mainly transported by gravitational instability (GI) and/or magnet rotational instability (MRI). It is suggested that mismatches in the mass flux between the GI and MRI can lead to outbursts of accretion (MRI model, e.g. Armitage et al. 2001). We consider these transport mechanisms of angular momentum by using alpha prescription, and confirm that the spontaneous outburst occurred in MRI model with the constant mass flux onto the disk. The conditions for the spontaneous outburst are newly investigated in detail for large parameter space. Finally, if possible, we will discuss the time variability of accretion luminosity as a result of combination of outer episodic accretion and inner spontaneous outburst.

[P35] "Evolution of terrestrial planets with water loss"

Takanori Kodama (The University of Tokyo)

Liquid water on the planetary surface is thought to be important for the origin and evolution for life. Planets with liquid water on their surface are classified in two modes: the aqua planet mode and the land planet mode. An aqua planet is a planet covered with ocean globally. On a land planet, the distribution of ground water is controlled by the atmospheric circulation, thus, water accumulates in the cool region of the planet. Although occurrence condition of the land mode are not well constrained yet, the land mode is expected when the amount of water is less than about 5% of the present Earth ocean. Because of the difference in the water distribution, a land planet maintains liquid water at much larger isolation than an aqua planet. The increase of stellar luminosity causes warning of the planets and enhancement of water vapor in their atmosphere and drives the loss of water into the space and the complete evaporation of water through the runaway greenhouse. For the evolution path of an aqua planet, both of them are thought to terminate the habitable world. However, if an aqua planet evolves to a land planet by a rapid water loss before the onset of the runaway greenhouse, it can maintain liquid water on its surface for another 1Gyr or so, because the land planet is strongly resistance to both the water loss and the runaway greenhouse. Therefore, for the evolution path from the aqua planet mode to the land planet mode, there is the race between the rapid water loss and the increase of the luminosity from the central star that triggers the runaway greenhouse. Whether an aqua planet follows such an evolution path or not is controlled by the race, which is depended on the evolution of stellar luminosity and EUV flux, the initial amount of water and so on. Therefore, we focus on a change of the amount of water by the water loss and the stellar evolution and discuss the planetary evolution path from the aqua planet mode to the land planet mode. From our results, an aqua planet with 0.1 present Earth's ocean on its surface can evolve to a land planet and maintains liquid water on its surface for about another 2Gyrs. Our results mean that the amount of water, which planets have initially, is important for their evolution paths and for their habitability.

[P36] "Direct Imaging Search for Extrasolar Giant Planets around 100 Myr-old Stars with Subaru Telescope"

Mihoko Konishi (Osaka University)

We have carried out a direct imaging survey of extrasolar planets to reveal the general formation and evolution process of planets. We focus on ~100 Myr stars. This has the benefit that the uncertainty in planetary mass is smaller when using absolute magnitudes and evolution models. Furthermore, planets in this age range are much brighter in the infrared as they still retain heat from their formation. Target objects are members of the Pleiades open cluster and the nearby Ursa Major moving group, with an age of 125 Myr and ~500 Myr, and a distance of 135 pc and ~25 pc (average), respectively. The H-band images were obtained with Subaru+HiCIAO/AO188 using ADI (Angular Differential Imaging) mode. This study is conducted as a part of SEEDS (Strategic Exploration of Exoplanets and Disks with Subaru) project. In this presentation, we mainly focus on the results of the Pleiades. Observation of the Pleiades sample resulted in fifteen companion candidates around nine host stars out of twenty observed stars. Eleven candidates were confirmed background stars. Two were brown dwarf companions which have been reported by previous studies (HD 23514 and HIP 1348). The remaining two candidates were found to be possibly co-moving. Their projected separation is ~810 AU and ~1150 AU, their estimated mass 21 M_J and 18 M_J, respectively. It is remarkable from a formation-theoretical standpoint that these two systems likely have brown dwarf at separations of several hundred AU. In our observations, the detection efficiency was 90% for a planet with 6 to 12 M_J and a semi-major axis of 50 to 1000 AU. Considering the non-detection of planets with these parameters, we show that the frequency of stars having such giant planets is less than 17.9% within 2σ. This is the first time a survey with a sample of stars of the same age was conducted. Our study showed that the planetary frequency in the Pleiades agrees with that of other previous direct imaging surveys which observed stars of various age.

[P37] "The behavior of critical numbers of the orbital stability of planets trapped in the mean-motion resonances"

Yuji Matsumoto (TITECH)

Kepler mission has reported a large number of planet pairs near mean motion resonances (e.g., Baruteau & Papaloizou 2013). However, many exoplanets are not near mean motion resonances (e.g., Mayor et al. 2009). Recent numerical simulations proposed a mechanism to form resonant planets near the disk inner edge. Due to type-I migration, protoplanets migrate toward their central stars in a protoplanetary disk. The migration is stopped when a protoplanet arrives at the inner edge of the gas disk. N-body simulations (Terquem and Papaloizou 2007; Ogihara and Ida 2009) considering type-I migration show protoplanets are trapped in resonances, after some close scatterings and collisions. In some cases, planets in resonances cause orbital instability after disk gas depletion. The number of planets in resonances decides whether planets in resonances cause instability or planets are stable in resonances (Matsumoto et al., 2012). When the number of planets in the first-order resonances (p+1:p) is small, the planets are orbital stable over 10^8 orbits. In this case, resonant systems are more stable than non-resonant systems. However, when the number of planets is over the critical number, the stability timescale decreases by several orders of magnitude. In this case, the stability timescales are almost equal to those in non-resonant systems. We investigate the behavior of the critical number of planets with a wider parameter range. We calculate the stability of planets in first-order resonances whose period ratios are equal and less than 3/2 with changing planetary masses ($10^{-6} < M/M* < 10^{-4}$) and the orbital separations in mutual Hill radii. The critical number increases with increasing the orbital separations fixed planetary mass and increases with increasing planetary mass with fixed the orbital separation. When $10^{-4}M*$ mass planets are in 3:2 resonances, the critical number is over 20, while the critical number is 4 when the same mass planets are in 4:3 resonances. The critical number of 3:2 resonances is much larger than that of the other resonances in our parameter range. The studies of the trapping condition into first-order resonances (e.g., Ogihara and Kobayashi 2013) suggest that the longer timescale ($>10^5$ Kepler time) is needed to capture planets into 3:2 or 2:1 resonances. When the migration time scale is small ($<10^5$ Kepler time) and the number of planets in resonances is more than about 10, the planets cause instability and non-resonant systems are formed.

[P38] "Spectral Retrieval Analysis of the Directly Imaged exoplanets around HR 8799"

Jae-Min Lee (University of Zurich)

The direct-imaged exoplanets around HR 8799 are photometrically distinct from its parent star. Spectroscopic measurements along with photometric points between 1 and 5μm provide vital new information on the thermal and chemical structure of the atmosphere, which have never been made from transiting planets. However, it is still mysterious that the characteristics of the atmosphere show a mixture of brown dwarf and gas giant features, calling its radius, surface gravity and mass into a question. Moreover, the photometric radius is larger than the model radius, which we call the "radius ratio problem", and which remains unsolved. Here, we perform inverse modelling by exploiting an optimal estimation retrieval technique and sweep the parametrized radius and surface gravity space with phenomenological cloud scenarios. Unlike previous approaches, in which the cloud models are rather sophisticated, we minimise the number of cloud parameters, e.g., mono-disperse cloud particle size and optical depth of cloud. We find that the identity of the cloud material gives a non-detectable effect to our results because the refractive indices of most of materials plausible in this class of atmosphere are not distinguishable at these wavelengths. We find that an additional opacity from uniformly extended (UC) and intermediate (IN) cloud improves the goodness-of-fit over a clear atmosphere case. Also, we report constrained physical properties of these planets, such as radius, surface gravity and mass, which are still in question.

[P39] "Constraining Gas Giant Formation: Robust exo-moon radius and semi-major axis limits"

Karen Michelle Lewis (TITECH)

Moons of extrasolar planets are a vital link in understanding the structure and formation of planetary systems, for example, their number and properties provide constraints on the structure and composition of circumplanetary disks. Transiting planets are one of the best places to look for moons, as simulations have predicted that moons well into the terrestrial mass regime could be detectable using photometry from space telescopes, especially for Saturn-like planets. However spots on the host star can mimic certain moon transit features, such as mutual events, making moon detection difficult. In this context we present a method that allows radius limits to be placed on moons of transiting planets, even for the case of highly spotted stars. Using this method we calculate a new set of moon radius and semi-major limits for a range of different-sized Kepler transiting gas giant planet candidates. This is the first set of moon limits calculated where the effect of starspots has robustly been taken into account.

[P40] "The numerical calculations and analitycal evaluations of type I migration in protoplanetary disks heated by stellar irradiation"

Naohiko Maeshima (Nagoya University)

More than 700 extrasolar planets have been discovered using radial velocity as now. There are numerical simulations to reproduce these distributions, but it was a problem of traditional studies that planets fall into central stars with very short timescale due to type I migration in isothermal disks. On the other hand, recent studies have revealed that planets can move outward due to corotation torque in adiabatic disks, and suggested that the problem is likely to be solved. However, it is known that corotation torque saturates. There are studies that calculated type I migration in non-isothermal disks, but the model in these studies are very simple, neglecting stellar irradiation as a heating mechanism of disk and saturation of corotation torque, for example. In this study, we calculated type I migration in non-isothermal disks heated by stellar irradiation considering the effect of saturation of corotation torque.

[P41] "Evidence of a discontinuous discstructure around the Herbig Ae star HD 139614"

Alexis Matter (IPAG)

A new class of pre-main sequence objects has been recently identified as pre-transitional discs. They present near-infrared excess coupled to a flux deficit around 10 microns and then a rising mid-infrared and far-infrared spectrum. Such features suggest a disc structure with inner and outer dust components, separated by a dust-depleted region (or gap). This could be the result of an on-going planet formation process. We here report on the first interferometric observations of the disc around the Herbig Ae star HD 139614. Its infrared spectrum suggests a flared disc, and presents `pre-transitional' features, namely a substantial near-infrared excess accompanied by a dip around 6 microns, and then followed by a rising mid-infrared part. In this framework, we performed a study of the broadband SED and the near-infrared and mid-infrared interferometric data acquired with the VLTI instruments PIONIER, AMBER, and MIDI. The aim is to constrain the spatial structure of the inner dust disc region, and assess its possibly multi-component structure. In a first step, we used a temperature-gradient disk model to attempt to reproduce the SED and the mid-infrared visibilities. A good agreement was obtained with a two-component disc model composed of an unresolved component followed by a gap extending to 5.9 AU, and an outer temperature-gradient disc. The latter is characterized by a very steep temperature profile and a temperature higher than 300 K at its inner edge. This suggests that the outer disc's inner edge would be directly illuminated by the central star and therefore significantly hotter. This is an expected consequence of the presence of a gap, thus indicative of a 'pre-transitional' structure. In parallel, our best-fit two-component model underestimated the measured near-infrared excess, which suggests the existence of an extended near-infrared emitting region. In a second step, we performed a radiative transfer modeling of the whole set of near-infrared and mid-infrared interferometric data coupled to the broadband SED using the Monte Carlo code RADMC2D (Dullemond et al. 2004, A&A 417, 159-168). This allowed us to constrain further the spatial structure of the near-IR and mid-infrared emission and to confirm the discontinuous structure and thus 'pre-transitional' structure of the disk. HD139614 may thus turn into a significant candidate for future planetary companion investigations.

[P42] "Science with CHARIS: A high contrast integral field spectrograph for Subaru"

Michael W. McElwain (NASA Goddard)

We present the science capabilities for the CHARIS infrared, integral field spectrograph to be integrated into the 3rd generation suite of high contrast instrumentation at the Subaru Telescope. CHARIS, the Coronagraphic High Angular Resolution Imaging Spectrograph, will operate behind the AO188 and SCExAO adaptive optics system that will create a high contrast scene (~10^{-6}) with small inner working angles (~100 mas). CHARIS will observe across the J-, H-, and K-bands (λ=1.15-2.25μm) in low spectral resolution (R~18) or in any single band in moderate spectral resolution (R~73). The near-infrared is rich in diagnostic spectral features for young Jupiters, and the CHARIS spectral samplings will enable the characterization of atmospheric temperature, composition, and structure. CHARIS is scheduled to achieve first light at the Subaru telescope at the end of 2015.

[P43] "The CHARIS Data Extraction Software: Integral Field Spectroscopy at High Contrast"

Kyle Aaron Mede (The University of Tokyo)

I will present the design of a custom data extraction software package for the Coronagraphic High Angular Resolution Imaging spectrograph (CHARIS) under development for the Subaru Telescope. Integral field spectrographs (IFSs) are the instrument of choice for high contrast imaging. With both spatial and spectral information, IFS data cubes can both suppress starlight to increase contrast beyond the limits of simple cameras, and directly measure exoplanet spectra. Current IFSs gain an order or magnitude or more in contrast from post-processing of the data cubes, making both hardware and software critical to their success. I will describe the data extraction software to reconstruct ~20,000 spectra from each raw detector readout, producing a 3-dimensional (x, y, λ) data cube that will achieve a high level of spectrophotometric precision (~0.06 mag) for atmospheric characterization, astrometric precision (~3 mas) for orbital characterization, with a fast reconstruction (< 5 s) for focal plane wavefront sensing. Direct imaging offers one of the only ways to take spectra of, and to characterize, young gas giant exoplanet atmospheres. A key goal for the field is to use high-contrast integral-field spectroscopy to detect, and understand, young analogs to the gas giants in the solar system. CHARIS has been design for these goals, and in combination with the AO188 and SCExAO adaptive optics systems, the suite of high contrast instrumentation at Subaru will form the premier high contrast imaging system. CHARIS recently passed its Critical Design Review and will be added to the Subaru Telescope in late 2015.

[P44] "HERSCHEL-RESOLVED OUTER BELTS OF TWO-BELT DEBRIS DISKS AROUND A-TYPE and SOLAR-TYPE STARS"

Farisa Y. Morales (NASA/JPL)

We present dual-band Herschel/PACS imaging for four stars whose SEDs suggest two-ring disk architectures that mirror that of the asteroid?Kuiper belt geometry of our own solar system. The Herschel observations at 100 μm spatially resolve the cold/outer dust component for each star-disk system for the first time, finding evidence of planetesimals at >100 AU, i.e. larger size than assumed from a simple blackbody fit to the SED. By breaking the degeneracy between the grain properties and the dust's radial location, the resolved images constrain the dust grain size distribution for each system. Three of the observed stars are A-type and one solar-type. Based on the combined Spitzer/IRS+MIPS (5 to 70 μm) and Herschel/PACS (100 and 160 μm) dataset, we find that the cold/outer belts are well fit with a mixed ice/rock composition. In the absence of spectral features for ice, we find that the behavior of the continuum can help constrain the composition of the grains (of icy nature and not pure rocky material) given the Herschel-resolved locations of the cold/outer dust belts.

[P45] "Experimental Study on deuterated hydrocarbon materials"

Tamami I. Mori (The University of Tokyo)

Deuterium (D) was created in the era of the big bang, and has been gradually destroyed in the stellar interior. Therefore, the cosmological constants and chemical evolution of the Galaxy must be imprinted in the present deuterium abundance. However, recent ultraviolet observations suggest that some of them are depleted onto dust grains and the D abundance does not directly related to the chemical evolution. Interstellar polycyclic aromatic hydrocarbons (PAHs) attract attention as one of the possible carrier of D in the interstellar medium (ISM), but recent observations do not indicate evidence for a large abundance of deuterated-PAHs (PADs) in the ISM (Onaka et al. 2013 submitted). There still remains a mystery about the refuge of D in the ISM. In recent years, much attention has been paid to deuterium fractionation in protoplanetary disks. Revealing the refuge of D in the ISM will lead to comprehensive understanding of chemical evolution in protoplanetary disks. For in-depth analysis and search for PAD features in the ISM, we experimentally synthesize deuterated quenched carbonaceous composites (QCCs, Sakata et al. 1983), which show the infrared spectrum remarkably resembling the observed unidentified infrared bands, and measure the absorbance from 2 to 25μm with a Fourier transform infrared spectrophotometer. By using a mixture of methane and perdeuterated methane gas with several different mixing rates as the starting material, we investigate spectral transition from non-deuterated to perdeuterated material. With the increase of D/H ratio of the synthesized material, band features approximately at 4.3-4.5, 9.5-12.0, and 13.5-17.9μm become more intense, and each of them is assigned to C-D stretching, in-plane bending, and out-of-plane bending mode respectively. In this poster, we present the laboratory results, and discuss its applicability for observation together with the results of the AKARI infrared satellite.

[P46] "Planet-Finder survey with SPHERE/IRDIFS"

Claire Moutou (CFHT)

The new VLT instrument SPHERE is finishing its integration and laboratory test period and will soon be shiped to Paranal Observatory. Two near-infrared focal instruments, IRDIS and IFS, will be used together to reach the highest constrast around bright and nearby stars, in search for their planetary companions. In this poster, we will show the latest laboratory performances of the SPHERE/IRDIS+IFS combination of instruments and describe the future planet-finding survey strategy.

[P47] "A Unified Analysis of Brown Dwarf and Exoplanet Companions from Direct Imaging Surveys"

Eric Ludwig Nielsen (University of Hawai'i at Mānoa)

While brown dwarfs and exoplanets are currently distinguished by the deuterium-burning limit, the observed distribution of substellar companions over the full range of masses (~1-75 Mjup) is a promising path to understanding the origin of these objects. To this end, we present a unified analysis of the populations of brown dwarf and exoplanet companions, based on the results from several large-scale direct imaging surveys conducted with high-contrast imaging on 8-10 meter class telescopes. Altogether, these surveys have obtained high-contrast imaging of several hundred stars, spanning a wide range of stellar spectral types (BAFGKM) and age. To account for inhomogeneities in the surveys (including contrast and FOV) and the uncertain properties of the target stars and detected substellar companions, we have developed a new Bayesian framework melded with detailed Monte Carlo simulations in order to measure the frequency of substellar objects, the distributions that describe their masses and semi-major axes, and the associated covariances. Through such a unified analysis, we are able to for the first time examine the interplay between brown dwarf and giant planet populations orbiting nearby stars.

[P48] "Panning for Planets in Stellar Glare: Methods for High-Contrast Imaging with Project 1640 "

Ricky Nilsson (American Museum of Natural History)

As more instrumentation for direct imaging of exoplanets is coming online, the importance of efficient data reduction and immediate feed-back for fast detection and follow-up is becoming increasingly important. In this poster we present the data processing techniques employed by Project 1640 to sift through stellar light and speckle noise in order to quickly find those golden nuggets -- planets around nearby stars -- and retrieve information about their atmospheric composition by extracting low resolution (R ~ 35) spectra. Specifically, we describe the pipeline modules used for cube extraction, atmospheric dispersion correction, speckle suppression, planet detection, and spectral extraction. Our capability is demonstrated by examples from a recent observing run, displaying a progression from obtained raw data at the telescope to an initial planetary spectrum within a few hours. Apart from providing technical insights on optimal high-contrast image processing, results from Project 1640 will yield a more complete description of the diversity in exoplanetary system architectures (masses and orbits) and atmospheric composition (from strong molecular absorption features) of massive Jupiters and brown dwarfs. An additional science goal is dynamical studies of orbital stability in exoplanetary systems derived from masses and precise astrometry at different epochs.

[P49] "A coronagraph system with unbalanced nulling interferometer : upgrade of 2013"

Jun Nishikawa (NAOJ/GUAS)

We proposed a coronagraph system with an unbalanced nulling interferometer (UNI). The coronagraph system can be composed using the UNI effectively as a following configuration after collimation from a telescope focus. It consists of a first adaptive optics (AO), the UNI, a second AO, and a coronagraph. Here wavefront corrections and star light rejections are made twice in turn in the four-stage optics. The UNI stage can be composed by not only a standard nulling interferometer but also a nulling coronagraph. One of many kind of coronagraph can be selected as the last stage. The most interesting and important phenomenon is a magnification of the wavefront aberrations in the UNI stage which can be explained by changes of the mean complex amplitude of the electric field, which enable us to compensate for the wavefront aberrations beyond the AO systems capabilities. In our previous experiments, we observed the aberration magnification of about 6 times and compensated to about $\lambda/100$ rms which means that we reached to lambda/600 level virtually. At the focal plane of the coronagraph we confirmed a further speckle reduction of better than 1/10 with the UNI. Recently we are introducing new items, a four-quadrant phase mask coronagraph at UNI stage, an 8-octant phase mask coronagraph at the final stage, a dark-zone control at the AO stage, etc.

[P50] "A precise Doppler survey of late-M dwarfs using IRD"

Masashi Omiya (TITECH)

We are planning to perform a precise radial velocity (RV) survey using the InfraRed Doppler (IRD) instrument for the Subaru to search for low-mass planets around nearby late-M dwarfs. Sample of the RV survey are about 300 late-M dwarf stars that have a flux peak in near infrared wavelength region. IRD is a planet hunting instrument with a laser frequency comb and a high-resolution spectrograph in near infrared, and suitable for the search for low-mass planets around late-M dwarfs. RV measurements of late-M dwarfs with IRD would achieve the precision of about 1 m s^{-1} by producing extremely stable reference for accurate wavelength calibration using the astro-comb. Thus, we expect to detect a few Earth-mass planets in habitable zone and some rocky planets in close-in orbits around low-mass M dwarfs. The RV survey aims to understand and discuss statistical properties of low-mass planets around very low mass stars compared with those derived from theoretical simulations. In the IRD project, we also have plans to curry out RV and transit follow-up observations of planet candidates detected by IRD using other Japanese facilities. We present observational simulations and strategies of our survey, and discuss expected fruits.

[P51] "Development of radiative transfer model for exoplanets with steam atmospheres"

Masanori Onishi (Kobe University)

We have been developing a radiative transfer model in order to acquire an ability to investigate possible diversity of atmospheric structures of exoplanets. A comprehensive and flexible radiative transfer model is necessary as a fundamental tool for researches on the atmospheres of exoplanets in the following two aspects; 1). spectral analyses of radiation from a planet which give us information about temperature and composition of its atmosphere, 2). energy budget calculations with which we can proceed to discuss such as circulation of an atmosphere and evolution of a planet. These two aspects demand us different characteristics of calculation methods; a high resolution spectral calculation is required for the former, while a high speed calculation covering a wide spectral range is required for the latter. Moreover, a calculation code for exoplanet atmospheres should be flexible in dealing with wide ranges of temperature and pressure, and a variety of composition. In order to calculate radiative processes in exoplanetary atmospheres, we have been developing a model which calculates optical depth in line-by-line method. The model can calculate any required atmosphere, if you give vertical profiles of temperature and compositions. Now our model is applicable to the temperature range of 70 to 3000 [K] and can treat 47 species in HITRAN database. In order to calculate an atmospheric structure, we have been developing a 1-dimensional radiative-convective equilibrium model. By using this model, clarifying an energy budget and profiles of molecular composition enables to discuss evolution of planetary atmospheres. To estimate the distribution of water vapor is especially important. If the vertical profile is estimated, it can argue about whether the planet is a runaway greenhouse state or not and a loss rate of water from the water vapor content in stratosphere. In order to perform this calculation, we need to reduce large calculation cost. A calculation of absorption cross section takes time particularly. To challenge the problem, we prepare the table of absorption cross sections and the model we are developing calculates required absorption cross sections from the table. In near future, we aim to calculate a radiative transfer in an exoplanet around an M-type star. Many of habitable planets around M-type stars have the potential of tidal locking planets. Since these planets have day and night hemisphere, an atmospheric GCM is required in order to calculate the atmospheric structure. We aim to develop the radiative transfer model which can combine with GCM.

[P52] ″N-body simulations for planetary accretion in the presence of hot Jupiter″

Shoichi Oshino (NAOJ)

In recent years, a lot of exoplanets have been found due to improved observation technology. The Kepler mission already found more than 3000 exoplanet candidates. In addition, observations of multiple planets are increasing. There are several Exoplanet systems which are different from the solar system are found. It is important that considering the effect of migration and gravitational interaction from gas giants to discover the difference between standard planet formation theory of the solar system and that of the exoplanets systems. We examine the difference of planetesimal accretion process with Hot Jupiter using N-body simulations

[P53] ″Models of transition discs: success and failures″

James Owen (CITA)

Transition discs now represent an important class of observed discs. However, they are yet to be fully understood with several possible origins of the structures. I will discuss the success and failures of both the photoevaporation and planet formation model of transition discs in explaining transition discs both for individual well characterised objects, along with the entire populations.

[P54] ″Adaptive optics operation with a focal plane wavefront sensing in a coronagraph″

Masahito Oya (Nihon University, NAOJ)

A stellar coronagraph system for direct observations of extra solar planets is under development by combining unbalanced nulling interferometer (UNI) using the four-quadrant phase-mask, adaptive optics (AO), and a focal plane coronagraph. It can reach a high contrast as using lambda/10000 precision optics by lambda/1000 quality ones. However, a sufficiently high contrast has yet to be obtained for the experiment. It is thought that the remaining speckle noise at the final coronagraph focal plane detector is produced by a “non-common path error” of lambda/100 level, which is a wave front error of differences between the coronagraph and a wave front sensor (WFS) of AO, even when the WFS indicates lambda/1000 conversion. The non-common path error can be removed by the focal plane sensing method of wave front correction by wave front sensing at the final focal plane detector, although it has an issue of operation for very faint targets because of a slow feedback loop. In this announcement, we describe how our coronagraph system becomes practically higher contrast by upgrading the Dark-Zone method using a focal plane wave front sensing. Then, we control a wave front error by two feedback loops, the first of which uses a WFS to make fast control for telescope optics deformation and the second of which uses a focal plane detector to compensate for the non-common path error with slow control. We show simulation and experiment results of the reduction of the remaining speckle noise at the final focal plane detector using the Dark-Zone methods. In the simulation, it was reduced to the contrast of 8.5 figures compared with intensity of a star at 2 to 10 lambda/D. In the experiment, it was reduced to the contrast of 6 figures at 2 to 3 lambda/D from the center of the optical axis.

[P55] ″Challenges towards the Identification of the Unidentified Infrared Bands from the Laboratory Experimental Approaches″

Itsuki Sakon (The University of Tokyo)

Unidentified infrared (UIR) bands have been observed in various circumstellar and interstellar environment. Although the observed behavior of the UIR bands is usually interpreted based on the polycyclic aromatic hydrocarbon (PAH) hypothesis, the firm identification of the carriers of the UIR bands has not yet been made perfectly. We have started the laboratory experiments to examine alternation processes of PAH molecules in circumstellar environment. Our preliminary experiment was performed to examine the effect of plasma ion irradiation to coronene ($C_{24}H_{12}$) by using the experimental apparatus to generate 2.45GHz plasma, which was originally designed to produce quenched carbonaceous composite (QCC) and reported by Sakata et al. (1983). After irradiating the nitrogen plasma on coronene, the infrared spectrum of the residual denaturing sample measured with IR spectrometer (JASCO FT/IR 6200) with attenuated total reflectance (ATR) attachment was found to be remarkably similar to the observed spectra of UIR bands. In this poster presentation, the latest results of our experimental studies aiming to identify even more realistic carrier of the UIR bands are shown. A better understanding of the carrier of the UIR bands will help us correctly understand the geometry and physical condition of the protoplanetary disks from the mid-infrared spectroscopic observation.

[P56] ″Direct Imaging of Long Period Radial Velocity Targets″

Graeme Stanley Salter (University of New South Wales)

We are finally entering an era where radial velocity and direct imaging parameter spaces are starting to overlap. Radial velocity measurements provide us with a minimum mass for an orbiting companion (the mass as a function of the inclination of the system). By following up these long period radial velocity detections with direct imaging we can determine whether a trend seen is due to an orbiting planet at low inclination of an orbiting brown dwarf at high inclination. In the event of a non-detection we are still able to put a limit on the maximum mass of the orbiting body. The Anglo-Australian Planet Search (AAPS) is one of the longest baseline radial velocity planet searches in existence, amongst its targets are many that show long period trends in the data. I will present our direct imaging survey of these objects with our results to date. Angular Differential Imaging Observations have been made using NICI (Near Infrared Coronagraphic Imager) on Gemini South and analysed using an in house, LOCI-like, post processing.

[P57] ″Possibilities of water supply to the Earth with "icy-dust filtering″

Takao Sato (TITECH)

A lot of possible sources of water on the Earth have been proposed so far (Matsui & Abe, 1986; Gomes et al., 2005; Ikoma & Genda, 2006). The amount of water accumulated into terrestrial planets is considered to be a fundamental question. Recently, it has shown that the snow line necessarily passes the heliocentric distance of 1 AU (Oka et al., 2011) when the Earth was formed. The Earth is unavoidable to have much more water than now in this situation. Even if the Earth is considered to be formed before the snowline migrated inside the Earth's orbit, the growth timescale of dust and planetesimals would be too short to growth. And, even if the Earth is considered to be formed after the snowline migrated inside the Earth's orbit and migrated outside again, the amount of solid material would be too small to form the Earth.

[P58] ″Time-Contrast-Separation-Polarization Diagrams to predict exoplanet visibility″

Guillaume Schworer (Observatoire de Paris, University of Sydney)

Observational technologies to detect the light reflected from an exoplanet are reaching a level of precision that makes direct imaging of exoplanets a realistic possibility over the coming decade or so. It is therefore an opportune moment to produce detailed predictions for exactly how the expected signals should appear, which will be of critical importance to inform the designs and observational strategies of tomorrow's telescopes. This work aims at accurate determination of the magnitudes and the evolution of the main observational signatures of an exoplanet: contrast ratio to the host-star and polarization, as a function of the basic parameters of the exoplanetary system. These parameters, the star-exoplanet orbital parameters and the optical properties of both star and planet (incorporating polarization based on Rayleigh scattering) are applied to a newly developed polarized-reflectance model. It is able to compute a variety of observational criteria of the exoplanet at a given observation time. The inter-dependency between the three main observational criteria -- angular separation, contrast ratio and polarization -- are much more complex than previously reported. They greatly impact the viability of observation of extra-terrestrial planets by direct imaging. Indeed, while a high polarisation is roughly linked to an intermediate-to-best angular separation, the most favorable contrast ratios are only reached when the angular separation is least favorable: the observer then faces a choice where compromise is inevitable. This work is already amongst the most comprehensive and detailed treatments to date, and is a major step towards a full comprehensive simulation tool for predicting and interpreting the results of future observational exoplanetary discovery campaigns.

[P59] ″Phase mask coronagraphs ultra-fine pointing control system″

Garima Singh (Subaru Telescope, Observatoire de Paris)

High throughput, low inner working angle (IWA) coronagraphs are essential to directly image and characterize (spectroscopy) exoplanets. Low-IWA coronagraph's performance is however limited by the lack of accurate pointing errors. Addressing this issue is essential for preventing coronagraphic leaks, and we have thus developed a new concept, the Lyot-based Pointing Control System (LPCS), to control pointing errors and other low order aberrations within a coronagraph. The LPCS uses residual starlight reflected by the Lyot stop at the pupil plane. Our simulation has demonstrated pointing errors measurement between 2-12 nm for tip-tilt at 1.6 micron with a four quadrant phase mask coronagraph. We have done the early implementation of our new concept at Observatoire de Paris and demonstrated the open loop measurement accuracy of 10^{-3} λ/D at 0.638 micron. To further demonstrate our concept, we have installed a reflective lyot stop (RLS) on the Subaru Telescope Coronagraphic Extreme AO (SCExAO) of Subaru Telescope and modified the system to support phase mask coronagraphs such as four quadrant phase mask, eight octant phase mask, vortex coronagraph, phase induced amplitude apodization complex mask coronagraph with a goal of obtaining milli arcsecond pointing accuracy to support small IWA (< 1 λ /D) coronagraph. We will present the implementation of LPCS on SCExAO in the laboratory as well as early on-sky data from July 2013.

[P60] ″Evidence of Chromospheric Activity in three brown dwarfs from 2.5-5.0μm AKARI spectra″

Satoko Sorahana (Nagoya University)

Recently, many kind of planetary systems have been discovered. Some of these exoplanets are similar to brown dwarfs in mass and temperature. Thus our studies will complement exoplanet studies. We propose that the 2.7μm H_2O, 3.3μm CH_4 and 4.6μm CO absorption bands can be good tracers of chromospheric activity in brown dwarfs. In our previous study, we found that there are difficulties in fitting entire spectra between 1.0 and 5.0μm with the Unified Cloudy Model (UCM), a brown dwarf atmosphere model. To overcome this problem, we consider chromospheric activity in brown dwarfs, which has been suggested by some previous observational studies. The temperature in the upper atmosphere of such brown dwarfs is expected to increase with height. In our current study, we first determine the structures of inner atmospheres unrelated to chromospheric activity by model fittings to spectra shorter than 2.5μm, which are sensitive to relatively inner atmospheres. We find that the derived best-fit model spectra show stronger 2.7μm H_2O, 3.3μm CH_4 and 4.6μm CO bands than those in the AKARI spectra. We then take into account a temperature floor in an upper atmosphere under the assumption of heating associated with chromospheric/coronal activities, instead of a monotonic decrease with increasing altitude based on simple radiative equilibrium. Because of the higher temperatures in upper atmospheres, CH_4 molecules are reduced and the absorption band strengths become weaker. Furthermore, the strengths of the absorption bands of H_2O and CO become weaker because of the anticorrelations of the absorption coefficients with temperature, in spite of the moderate increase of their abundances. As a result, the model spectra of 3 brown dwarfs are considerably improved by the including of chromospheric heating and successfully match the AKARI spectra. Furthermore, these objects show Hα emission, which is an indicator of chromospheric activity. On the other hand, objects in which Hα emission is weaker or not detected, are not successfully fit using our treatment. Thus chromospheric activity is very important for understanding brown dwarf atmospheres. Finally, we briefly discuss magnetic heating processes which possibly operate in upper atmospheres, by extending our numerical simulations for the Sun and stars with surface convection to brown dwarf atmospheres.

[P61] "Formation of the first Solar System solids in a turbulent protoplanetary disk"
Esther Taillifet (AIM CEA Saclay/ Université Paris Diderot)
Calcium and aluminum rich inclusions (CAIs) found in chondritic meteorites are known to be the oldest solids formed in our solar system, 4.567 billion years ago (Connelly, 2012). Constraining their formation is thus essential to unravelling the very first stages of planet formation. Calculations (Grossman, 1972) and experiments (Toppani et al., 2006) showed that their refractory mineralogy is well accounted for by equilibrium condensation from a cooling gas of solar composition. Condensation of refractory elements requires high temperatures (>1200 K) suggesting that CAIs formed under one Astronomical Unit (AU) from the Sun before being accreted into chondrites. While all CAIs appear to have a common age, refractory mineral composition and solar (rather than terrestrial) oxygen isotopic composition, they appear with a large diversity in size and petrology, ranging from barely reprocessed micrometer-sized inclusions, to extensively molten centimeter-sized objects. This diversity attests for fairly diverse thermal histories that are challenging our current protoplanetary disk understanding. The X-wind model explored the transport of CAIs through disk bipolar outflows (Shu et al., 1997) stating below 0.1 AU from the star (the X-point). The major issue with this scenario is that this environment may be too hot and too accreting for solids to survive (Desch et al.,2010). The FU-Orionis model explored the consequences of the gravitational instability of the disk on grains. However, it is still unclear if young protoplanetary disks are gravitationally unstable especially below 1 AU, a region where the high temperature acts to inhibit gravitational instability. Thus, we explored another scenario relying on the fact that the inner regions of a protoplanetary disk have been long thought to be turbulent (Shakura & Sunyaev, 1973) due to the magnetorotational instability (MRI) (Balbus & Hawley, 1991). We designed a two-dimensional hybrid model of the Solar Nebula that takes into account the viscous and radiative heatings (Hueso et al., 2005; Calvet et al., 1991). With this gas model, we simulated the transport of grains ranging from micrometer to centimeter in size using LIDT3D (Lagragian Implicit Dust Transport 3D). We showed that formation of CAIs in a turbulent and viscously expanding disk naturally leads to a range of thermal histories, consistent with meteoritic data in terms of timescales and petrography. The CAI diversity could be a signature that our solar nebula was initially. We found that the required intensity of the turbulence lies within a range compatible with current knowledge of protoplanetary disks.

[P62] "An Origin of Ring Structures in Protoplanetary Disks"
Sanemichi Takahashi (Nagoya University, Kyoto University)
Recent high-angular-resolution direct imaging techniques have found remarkable structures in protoplanetary disks, such as rings and spirals. These structures may provide clues to understand an evolution of protoplanetary disks and formation processes of planets. Therefore, it is important to investigate the mechanism to form those structures. One candidate of the formation mechanism for rings is the viscous overstability. We have performed the liner analysis of axisymmetric viscous overstabilities and found that the ring structure can be formed in 100,000 years. We have also performed axisymmetric hydrodynamical simulations to investigate the non-linear evolution of viscous overstability. Even when the initial wavelength is much larger than that of the most unstable mode in linear analysis, the characteristic wavelength of the non-linear oscillation become about the wavelength of the most unstable mode. The maximum surface density in oscillation is about twice the initial unperturbed one. The result suggests that if observed rings structure is formed by viscous overstability, the density structures oscillate in dynamical timescale. To explain the observed structures, it is important to investigate the behavior of dust particle in the oscillating gas disk, since the concentrations of large dust grains are also expected.

[P63] "Comparison of Jupiter and GJ504b : similarity and differences in vertical structure and thermal radiation spectrum"
Yasuto Takahashi (Hokkaido University)
Recently, the SEEDS project discovered a new exoplanet candidate GJ504b, which is one of the coolest (effective temperature ~ 510K) Jovian exoplanet ever detected (Kuzuhara et al., 2013). Such a planet may provide us a better opportunity to explore the comparative atmospheric study with the solar Jovian planets which have cold atmospheres. We have been developing a numerical model to calculate radiative-convective equilibrium for hydrogen-rich atmospheres, starting from the reproduction of the current Jovian atmosphere. Given the potential temperature and chemical abundance in deep atmosphere, our model deduces the profiles of temperature and elemental distribution (if condensation occurs) between the levels of 10bars and 0.01bars and the radiation spectrum emitted from the top of the atmosphere with the assumption of local thermodynamic equilibrium. The collision-induced absorption of H2 and He (Borysow 1989, 2002) and line absorptions of H_2O, CH_4 and NH_3 (HITRAN2008) are implemented in this model. When we apply this model to Jupiter, the thermal radiation in the Jovian atmosphere is confirmed to be mainly governed by the H2-H2 collision-induced absorption. The Jovian effective temperature ~125K is corresponding to the peak wavelength of thermal radiation to be near 23 micron meters. Around this wavelength, the absorption is dominated by the H2-H2 collision-induced absorption, whereas the other species show little absorption. On the other hand, the case of a hotter planet like GJ504b, the peak of thermal radiation will

be shifted to shorter wavelength and the line absorptions by the minor species becomes important. As for the thermal radiation spectrum from the top of the atmosphere, the component in the atmospheric window at 4-5 micron meters becomes significant. We will present the result of systematic analysis of model atmospheres including that of GJ504b, and discuss about the effect of its potential temperature and metallicity on the atmospheric structure and thermal radiation spectrum.

[P64] "Development of a general circulation model for earth-like planetary atmospheres and its application"

Yoshiyuki O. Takahashi (Kobe University)

In order to understand the diversity of atmospheric circulations and surface environments of planets, we have been developing an atmospheric general circulation model (GCM), which is applicable to exoplanets as well as planets in the solar system. Targets of the model experiments in this study are shallow atmospheres. The shallow atmosphere is a type of planetary atmosphere where its effective thickness is much smaller than its planetary radius like those of earth-like planets, while the deep atmosphere is that whose thickness is comparable to its planetary radius. Our group, dcmodel project, is working on both types of planetary atmospheres by constructing corresponding two types of models with the same coding rule; the model for deep atmospheres and its example applications will be described by Takehiro et al. (this conference). The shallow atmosphere model used in this study calculates global atmospheric wind, temperature, and density distributions by solving hydrodynamic equations with a shallow atmosphere approximation, radiative transfer equations, and several parameterizations for subgrid scale motions, such as turbulent mixing, cumulus convection, and cloud formation. The processes implemented in the model are based on those used in the Earth's climate studies, but have been carefully reexamined to be not specialized to the Earth's atmospheric condition. The model has been applied to the atmospheres of Venus, Earth, Mars, and cloud layers of outer planets of our solar system. It has also been applied to atmospheres with the possible parameters for those in exoplanetary systems, such as a co-rotation atmosphere (e.g., Ishiwatari et al., this conference). Especially for planets in the solar system, the calculations have been performed not only to understand differences of those planetary atmospheres but also to validate the model. The current model shows atmospheric circulations qualitatively and, to some extent, quantitatively similar to observations of Earth's and Mars' atmospheres. However, the current model has a clear limitation of applicability; among the many ambiguous physical processes implemented in the GCM, the limit caused by the applicability of radiation model is currently most serious. In order to overcome this limitation, we are also working on the development of a radiation model for planetary atmospheres (Onishi et al. in this conference). In near future, the radiation model will be included in our GCM to perform experiments of a various kinds of exoplanets. In the presentation, we will describe current status of our GCM, some results of its simulations, and a future view of our activity.

[P65] "Transport of Magnetic Flux in Protoplanetary Disks as a Cause of the Transitional Phase"

Taku Takeuchi (TITECH)

We study evolution of large-scale magnetic field threading a protoplanetary disk. Recent MHD simulations have shown that mass accretion due to MHD turbulence or to disk wind is controlled by the strength of the mean vertical field threading the disk. This shows importance of quantifying the magnetic field strength in study of disk evolution. We analyzed evolution of mean poloidal field in a thin disk. First, an analytic solution of the static magnetic field is obtained. Second, we show that relaxation time of the magnetic field is probably much shorter than the viscous evolution timescale of the gas disk, meaning that quasi-static field is naturally expected. The analytic solution shows that the strength of the mean magnetic field has an upper limit that is determined by the external field strength and the disk size. This maximum strength is about 0.1G at 1AU. Because the mass accretion rate due to MHD turbulence or wind depends on the magnetic field strength, it also has an upper limit. The maximum field strength mentioned above suggests that the accretion rate caused by magnetic field cannot be greater than $10^{-7} M_{sun}$/yr. Finally, we apply our findings to evolution of protoplanetary disks that contain a dead zone in their inner part. We find that, contrary to previous expectations, dead zones do not always suppress the mass accretion rate. Even in an inner part where a dead zone exists, if the magnetic field is strong enough, the mass accretion rate can be as high as or even higher than that at the outer active region. Such stronger accretion at the inner part is expected especially at late stages of disk evolution. This mechanism possibly explains an inner hole of some transitional disks.

[P66] "Magnetically driven wind from gas-giant planets"

Yuki Tanaka (Nagoya University)

Recently theoretical studies on thermal evolution of hot jupiters invoked Ohmic dissipation to account for extraordinary large radii of some objects. Those analyses suggest the existence of significantly strong magnetic fields in hot jupiters. To test this hypothesis it is important to investigate possible consequence of magnetic fields in gaseous giant planets. Since gaseous giant planets are supposed to have large convection zones, magnetic field mediates energy transfer from the interior to the exterior of the atmosphere. Atmospheric escape from hot Jupiters have been observed in some exoplanets by using transit method. But there are no previous works about magnetically driven wind from a gaseous planet. In this poster we develop a model of magnetically driven wind from a gaseous planet and investigate the resultant mass loss. We applied the theory of mass loss from the Sun to calculate mass loss rate from gaseous planet, especially from hot Jupiters. We got mass loss rate which is consistent with observational mass loss rate when we use parameters which are assumed to be typical value for hot Jupiters. This work may provide a possible consistency check of theories with observations of hot Jupiters.

[P67] "Structure of Circum-Planetary Disks embedded in Protoplanetary Disks"

Takayuki Tanigawa (Hokkaido Univeristy)

Regular satellites of the giant planets in our solar system are believed to be formed in circum-planetary disks during the final stage of the formation of the planets. Recent hydrodynamic simulations have revealed that gas disks around giant planets are inevitably formed in the course of gas accretion growth phase. However, accretion of solid particles, which is building material of the regular satellite, have not been understood.

[P68] "High-resolution Submillimeter and Near-infrared Studies of the Transition Disk around Sz 91"

Takashi Tsukagoshi (Ibaraki University)

Transition disks are protoplanetary disks with inner gaps and are crucial targets for investigating the planet formation process as well as the disk evolution. To reveal the structures of a transition disk around the young stellar object in Lupus, Sz 91, we have performed aperture synthesis 345 GHz continuum and CO(3–2) observations with the Submillimeter Array (~1"–3" resolution), and the high-resolution imaging of polarized intensity at the Ks-band by using the HiCIAO instrument on the Subaru Telescope (0.25" resolution). Our observations successfully resolved the inner and outer radii of the dust disk to be 65 and 170 AU, respectively, making Sz 91 a transition disk source with one of the largest known inner holes. The model fitting analysis of the spectral energy distribution reveals an H_2 mass of 2.4×10^{-3} $M_{\odot}$ in the cold ($T<30$ K) outer part at $65<r<170$ AU by assuming the canonical gas-to-dust mass ratio of 100, although a small amount ($>3 \times 10^{-9}$ $M_{\odot}$) of hot ($T \sim 180$ K) dust likely remains inside the inner hole of the disk. The structure of the hot component could be interpreted as either an unresolved self-luminous companion body (not directly detected in our observations) or a narrow ring at 2.3 AU from the star. Significant CO(3–2) emission with a velocity gradient along the major axis of the dust disk is concentrated on the Sz 91 position, suggesting a rotating gas disk with a radius of 420 AU. The Sz 91 disk is likely a rare disk in a evolutionary stage just about to complete the planet formation because of their large inner hole and lower disk mass than other transition disks studied so far, and will be a crucial target to investigate the evolution of transition disks with Atacama Large Millimeter/submillimeter Array (ALMA).

[P69] "Formation, orbital and thermal evolution, and survival of planetary-mass clumps in the early phase of circumstellar disk evolution"

Yusuke Tsukamoto (Nagoya University)

We report the results of our three-dimensional radiation hydrodynamics simulation of collapsing molecular cloud cores. We investigate the formation and evolution of the circumstellar disk and the clumps formed by disk fragmentation. Our simulation shows that disk fragmentation occurs in the early phase of circumstellar disk evolution and clumps form. Once the clump forms, its central density and temperature rapidly increase and it undergoes a second collapse within the next 1000–2000 years. The clump can be represented by a polytrope sphere of index $n \sim 3$ and $n \gtrsim 4$ at central temperature $T_c \lesssim 100$ K and $T_c \gtrsim 100$ K, respectively. We demonstrate, numerically and theoretically, that the maximum mass of the clump, beyond which it inevitably collapses, is $\sim 0.03 M_{\odot}$. The entropy of the clump increases during its evolution, implying that evolution is chiefly determined by mass accretion from the disk rather than by radiative cooling. In our simulation, three second cores of masses $0.2 M_{\odot}$, $0.15 M_{\odot}$, and $0.06 M_{\odot}$ formed. These are protostars or brown dwarfs rather than protoplanets. For the clumps to survive as planetary-mass objects, the rapid mass accretion should be prevented by some mechanisms.

[P70] "VAMPIRES - Probing the innermost regions of protoplanetary systems with polarimetric aperture-masking"

Barnaby Norris (University of Sydney)

VAMPIRES (Visible Aperture Masking Polarimetric Interferometer for Resolving Exoplanetary Signatures) is a high-angular resolution imager being developed as part of the SCExAO project at the Subaru telescope, in conjunction with the University of Sydney. In contrast to conventional coronographic techniques, aperture masking interferometry has demonstrated the ability to image faint companions at resolutions well beyond the diffraction limit. VAMPIRES leverages this technique in combination with polarimetry, to directly image structure in the inner-most regions of preplanetary systems, at visible wavelengths. VAMPIRES will use starlight scattered by dust in the inner region of such systems to precisely map the disk, gaps, knots and waves that are key to understanding disk evolution and planet formation. With a spatial resolution of ~10 mas but with a maximum field of view of ~500 mas, VAMPIRES perfectly compliments coronographic observations in the near-IR, and in fact can operate simultaneously with IR coronographic observations by utilising the otherwise unused visible wavelengths. High resolutions and dynamic ranges are enabled by VAMPIRES' unique triple-layered polarimetric differential calibration system, using simultaneous polarised channel splitting, fast liquid-crystal channel switching and half-wave-plate based channel switching. The first on-sky tests were conducted at the Subaru telescope in July 2013, with further observations planned for early 2014.

[P71] "Collisional growth of organic mantle structured dusts"

Yuta Ueda (University of Tokyo, TITECH)

The Collisional growth of dusts from submicron to kilometer size is one of the most important issues for planetesimal formation in protoplanetary disks, but there doesn't exist a perfect theoretical clarification. Existing theoretical studies are only about silicate or

H_2O ice dusts. But interstellar dusts don't have only silicates and H_2O ices, but also organic matters as principal components. Kudo et al. (2002) showed that the critical velocity of collisional growth of millimeter sized organic dusts depended on temperature by analog experiments. It had maximum peak at 250K, because of viscosity. But in the case of submicron size, the critical velocity of organic dusts has not been clarified. The purpose of this study is showing the probability of collisional growth of aggregates consisting of submicron sized organic dust particles. It is expected that the result of this study will constrain the theory of planetary formation. In this study, we considered the dusts consisting of organic mantles and we calculated the critical velocity of collisional growth of them. At first, we calculated it by JKR theory. JKR theory is the contact mechanics of elastic bodies with adhesion. The result showed that the critical velocity increases with increasing temperature above 200K. This was because higher temperature made elasticity so weak and contact area so extended, that adhesion force became strong. The result of this study showed that in the region where organic mantles can exist on dust surfaces, collisional growth of dusts is more efficient than other regions and it takes shorter time for dusts to grow.

[P72] "Surface H_2O layers of ice-covered terrestrial planets"

Shoji Ueta (TITECH)

A lot of extrasolar terrestrial planets and free-floating planets have been discovered. Whether terrestrial planets with liquid water exist is an important question to consider, especially in terms of their habitability. Even in a globally ice-covered state, geothermal heat from the planetary interior is likely to melt the interior ice, so that an internal ocean beneath the surface ice shell could exist. In this work, we argue the conditions for terrestrial planets to have an internal ocean on the timescale of planetary evolution. In addition, we verify the structure of surface H_2O layers of ice-covered planets with considering effects of ice under high pressure (high-pressure ice). At 1 AU from the central star, a $1M_{\oplus}$ planet with 0.6-25 times H_2O mass of the Earth could have an internal ocean. When the planet has an H_2O mass over 25 times that of the Earth, high-pressure ice layers may appear between the internal ocean and the rock-part of the planet. The planetary mass and water abundance on the surface strongly restrict the conditions that an extrasolar terrestrial planet has an internal ocean and hold no high-pressure ice layers under the ocean. The habitability of a planet might be influenced by the existence of such high-pressure ice layers under the internal ocean.

[P73] "High Contrast Imaging of Debris Disks from a High Altitude Balloon"

Stephen C. Unwin (JPL/Caltech)

Debris disks are an important constituent of exoplanet systems because they provide indications of the formation and evolution of planetary systems. Several questions regarding disks can be addressed with images of disks: What can we learn about planetary system evolution; what materials are the disks made of; and can they reveal the presence of planets? Only a handful of the brightest and extended disks, such as Fomalhaut, have been observed from the ground. HST has made many images, but these are of systems with much more dust than the analogs in our Solar System – the asteroid belt and Edgeworth-Kuiper belt. Debris disks are relatively common, as they have been revealed through IR excesses measured by Spitzer and Herschel, but most are beyond the imaging capability of current instruments. Imaging at very high contrast requires observation above the disturbing effects of the Earth's atmosphere, which limits the achievable contrast for detection of faint dust disks – and also exoplanets. High altitude balloons offer the opportunity to conduct coronagraphic experiments above the atmosphere, but at a fraction of the cost of an equivalent space experiment. A large number of debris disks can be detected by a 1-m class telescope that can operate at contrast levels of ~3 x 10^{-8} or better. The instrument would be capable of imaging many such debris disks, with the ability to measure dust color, and substructures such as warps and clumps that may be indicative of interactions with planets. In this paper, we describe a balloon-borne telescope and coronagraph concept that would address these key questions in the formation and evolution of planetary systems. Besides a major advantage of being much cheaper than an equivalent orbital mission, a long-duration balloon offers to opportunity to refurbish and re-fly the payload for a small incremental cost. In addition to making important science measurements, this coronagraph would serve as a testbed for understanding the challenges of ultra high contrast imaging. It provides a demonstration of coronagraph techniques in a regime where performance is limited by our ability to measure and correct for slowly varying imperfections in the optical system – on the ground, compensating atmospheric fluctuations is the major design challenge. Such experiments are precursors to a more ambitious space coronagraph designed to achieve contrast levels that allow direct detection and spectroscopy of an exo-Earth.

[P74] "Magnetic Orientation of Amorphous Silicate Grain in the PPD Region"

Chiaki Uyeda (Osaka University)

Magnetic field is considered to play an important role in the formation of stars and planets. The direction of magnetic field is estimated from polarimetry data that is considered to originate by dust alignment. However, the mechanism of alignment is not clear as yet in the dense region. The estimated field direction leaves room for discussion, because relationship between field and polarization may change by the adopted model of alignment. The major dust materials in the PPD region have been identified from infrared emission as crystalline forsterite and pyroxene as well as amorphous silica (Honda et al. 2003). In order to examine the effectiveness of a dust alignment model based on field-induced anisotropy energy, paramagnetic anisotropy $\Delta\chi$para was previously measured for forsterite and pyroxene (Uyeda et al. 2006). In the present study, $\Delta\chi$para was detected for the first time on a small piece of amorphous silicate having a sub-millimeter size. The piece was collected from the surface of a tektite sample, namely moldavite, which was formed by rapid cooling of molten silica. The $\Delta\chi$para measurement of a sub-millimeter sized sample was realized by observing the rotational oscillation of its magnetically stable axis with respect to magnetic field; here the sample piece was released in a microgravity area (Uyeda et al. 2013). Electron-spin-resonance (ESR) signal was detected from the above-mentioned sample piece. The results indicated that the observed $\Delta\chi$para originated from magnetic anisotropy of isolated Fe ion included at surface region of the amorphous silica. The reproducibility of the above-mentioned correlation between $\Delta\chi$para and ESR data was confirmed on several different areas of the tektite surface. It is deduced from the present measurement that the surface of an amorphous silica produced by rapid cooling may generally posses an uni-axial type of paramagnetic anisotropy with the unstable axis directed normal to surface plane. This means that a magnetic stable axis of a rod-shaped grain, which is frequently assumed in a alignment model, is always parallel to the axis of rod irrespective of its chemical composition; the above stable direction is deduced by assigning the above-mentioned uni-axial anisotropy on individual local surface of the rod and integrating them over the entire surface of rod. Accordingly, direction of polarization is always diagonal to field when the grain is in a state of partial alignment. This property serves as a basis to consider a mechanism of amorphous-dust alignment caused by field-induced anisotropy.

[P75] "The VLT/NaCo large program to probe the occurrence of exoplanets and brown dwarfs at wide orbits - Survey results and statistical analysis"

Arthur Vigan (Laboratoire d'Astrophysique de Marseille)

In the recent years, deep imaging surveys have started to provide meaningful constraints on the population of extrasolar giant planets at large orbital separation. Primary targets for these surveys have been carefully selected based on their age, distance and spectral type, and often on their membership to young nearby associations where all stars share common kinematics, photometric and spectroscopic properties. The next step after the first detections of planet mass companions around most favorable targets is a wider statistical analysis of the frequency and properties of low mass companions as a function of stellar mass and orbital separation. In late 2009, we initiated a coordinated European Large Program using angular differential imaging in the H band (1.66μm) with NaCo at the VLT. Our aim is to provide a comprehensive and statistically significant study of the occurrence of extrasolar giant planets and brown dwarfs at large (5-500 AU) orbital separation around 200 young, nearby stars, a large fraction of which have never been observed at very deep contrast. The survey has now been completed and we present the results of the survey for our observed sample, in which we reach the planetary-mass domain at separations of $\gtrsim$ 30 AU on average. Then we present the results of the statistical analysis that has been performed over the targets newly observed at high-contrast and the archive sample of 150 stars observed previously in other deep imaging surveys. We discuss the details of the analysis and the physical constraints that our survey provides for the frequency and formation scenario of planetary mass companions at large separation.

[P76] "Amount of ejecta mass at dust aggregate collisions"

Koji Wada (PERC / Chiba Inst.Technology)

Collisional growth of dust aggregates is one of the essential processes to form planetesimals. High-velocity collisions produce a large number of small aggregates as ejecta fragments. Since ejecta would play an important role in dust growth and the total ejecta mass is a key to determine the mass loss rate through collisional cascades, we need a model of ejecta mass at high-velocity collisions of dust aggregates. In this study we carried out numerical simulations of dust aggregate collisions, focusing on the ejecta mass. In particular, we investigate the effect of the mass-ratio between colliding two aggregates and of the monomer size distribution of aggregates on the ejecta mass. As a result, we obtain a scaling relation such that ejecta mass averaged over the impact parameter is proportional to the projectile's momentum. Combining this scaling relation with the fragmentation model of Kobayashi & Tanaka (2010), we also obtain a formula of the specific energy for ejecting the half mass of colliding bodies. These relations are useful for understanding planetesimal formation and fragment production rate in protoplanetary disks and debris disks.

[P77] "Near-IR Scattered Light Imagery of the DoAr 28 Transitional Disk"

John Wisniewski (University of Oklahoma)

We report the detection of the DoAr 28 transitional disk in H-band polarized scattered light using the HiCIAO coronagraph as part of the Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) survey. The system has an inferred gap based on an observed deficit in its infrared spectral energy distribution; however, we do not detect this gap in our scattered light imagery down to our effective inner working angle of ~23 AU. We discuss the morphology and overall surface brightness of our data, and compare our results to 3D Monte Carlo Radiative Transfer simulations.

[P78] "The Search for The Search for Habitable-Zone Super-Earths Orbiting M Dwarfs at the Anglo-Australian Telescope"

Duncan John Wright (UNSW)

Finding Earth-like planets orbiting in the 'habitable zone' of other stars is one of the major goals of modern astronomy. Indications from both Doppler planet searches and Kepler are that rocky planets around low-mass stars are very common. With modern high-precision spectrographs it is possible to detect these planets using the Doppler velocity technique. A new program searching for habitable-zone exoplanets orbiting M4-M6 dwarfs on the Anglo-Australian Telescope began in late 2012. This program uses the new CYCLOPS fibre-feed working in the near infra-red to obtain high-precision velocities. This presentation outlines the techniques developed specifically to detect these planets and the current results from this survey.

[P79] "A new method of estimating the cooling rate experienced by chondrules in the early solar nebula"

Tetsuo Yamamoto (CPS, Kobe University)

We investigate growth of olivine crystals from a silicate melt and propose a fractional crystallization model that provides a relation between the zoning profile and the cooling rate. In our model, we take elemental partitioning at growing solid-liquid interface and time-dependent solute diffusion in the liquid into consideration. The model assumes a local equilibrium condition, namely, the concentrations at the interface are equal to equilibrium concentrations at a given temperature. We carry out numerical simulations of the fractional crystallization in one-dimensional planar geometry, and reveal that, under a constant cooling rate, the growth velocity of solid increases exponentially with time and a linear zoning profile forms in the solid as a result. We derive analytic formulae of the zoning profile, which reproduce the numerical results for wide ranges of crystallization conditions. Applying the formulae to low-FeO relict olivine grains in chondrules, we estimate the cooling rate to be ~200--2000Ks^{-1}, which is greater than that expected from furnace-based experiments by orders of magnitude. We discuss solar nebula environment appropriate for such rapid cooling.

[P80] "Rapid Evolution of the Innermost Dust Disk of Protoplanetary Disks Surrounding Intermediate-mass Stars"

Chikako Yasui (University of Tokyo)

To quantitatively and comprehensively study the lifetime of protoplanetary disks surrounding intermediate-mass (IM) stars (≈1.5-7M_*), we derived the intermediate mass disk fraction (IMDF) in the near-infrared JHK photometric bands as well as in the MIR bands for a large number (~20) of well-established nearby (D≲1.5 kpc) young clusters in the age range of 0 to ~10 Myrs. The IM stars were selected from each cluster by making use of published spectral types in the literature, and the IMDF was derived assuming a single age per cluster. The derived JHK IMDF, which traces the innermost dust disk (hereafter the K-disk), and MIR IMDF, which traces the inner disk at radii larger than the K-disk (hereafter the MIR-disk), appear to approximately follow an exponential decay with cluster age. The disk lifetime of the K-disk for IM stars is estimated to be ~3Myr, while that for low-mass (LM) stars is estimated to be ~10 Myr from the data in the literature. This suggests a stellar mass (M_*) dependence of K-disk lifetime $\propto M_*^{-0.6}$. However, for the MIR disk, we found that the disk lifetimes for the IM-stars (~7Myr) and the LM-stars (~9 Myr) are similar, so that the stellar mass dependence is very weak ($\propto M_*^{-0.1}$). The much shorter K-disk lifetime compared to the MIR-disk lifetime suggests that IM stars with *transition disks*, having no K-band excess emission but only MIR excess emission, is more common compared to classical Herbig Ae/Be stars, which exhibit both. We suggest that this prominent early disappearance of the K-disk for IM stars is due to dust settling/growth in the protoplanetary disk. If this is confirmed, our results set the timescale of dust settling/growth in the K-disk of the IM stars at ~4Myr. We also discuss the possible implications of our results on the lack of close-in planets and the high frequency of Jupiter-mass planets around IM stars. Our results, the earlier dispersal of the K-disk around IM stars, could be one of the major reasons for the paucity of close-in planets around IM stars.

[P81] "Proto-atmospheres on giant icy-satellite forming within low-temperature disk"

Takashi Mikami (Hokkaido University)

Icy satellites in the solar system, Ganymede, Calisto, and Titan have the great simi-larity of radius(~2,500 km) and Density(2,000 kg/m^3). However, only Titan has very thick atmospheres(~1.5 bar), this origin is unknown. According to the regular satellites formation theory (e.g., Canup and Ward 2002), It is indicated that Icy-satellite slowly formed within very low-temperature disk (formation time ~10^{5-6} yr, mid-plane temperature ~50-200 K). In this situation, it is expected that satellites had very compressed atmospheres composed almost of nebula gas, and we can't neglect the blanket effect of atmospheres. So, we researched for blanket effect of disk gas around icy-satellites. Using radiative transfer calculation, we estimated blanket effect of proto-atmospheres on satellites which connected with nebula gas at their hill radius. We considered nebula gas (H_2 and He) and H_2O which is generated by evaporating com-posed block of satellites as absorption gas. As a function of surface temperature of body, we calculated the radiative convective equilibrium structure of proto-atmosphere and heat flux at top of the atmospheres. Based on satellites formation theory, we give disk temperature and pressure condition as a parameter of calculation (P=0.1-10 Pa, T=50 K(Titan), 150 K(Ganymede)) With high disk temperature (150 K), satellites may hold optically thin atmospheres with weak gravity constraint. At then, by dissipation of disk gas after accretion, effective escape of atmospheres results in losing the most of them. On the other hand, with low disk temperature (50 K), they may hold optically thick atmospheres with strong gravity constraint. Such as proto-atmospheres with strong gravity constraint may survive after disk gas dissipation. Then, holding optically thick atmospheres can be achieved by low temperature of disk environment. The existence or non-existence of icy-satellites atmospheres could be explained by difference of disk temperature. Titan held very thick atmospheres in formation era and may keep large amount of atmospheres after disk gas dissipation, but Ganymede couldn't because of the difference.

[P82] "Photoevaporating Disk Dispersal around Intermediate-mass stars"

Masanobu Kunitomo (TITECH)

Recent observations have revealed that the lifetime of protoplanetary disk around intermediate-mass stars is shorter and the duration of the transition disk phase is longer compared to low-mass stars. Although these features are important for planet formation

around intermediate-mass stars, the reason for them has not been revealed. In this study we investigate how the host star's mass affect the disk dispersal. We integrate the viscous evolution and photoevaporation. In particular, we consider the effect of the evolution of the host star and the X-ray luminosity. We found that X-ray luminosity of intermediate-mass stars can change significantly and become very small within the disk lifetime. After the decrease of X-ray luminosity, the dominant source of photoevaporation is changed to UV and the transition-disk-like structure can exist for a long period. It is different feature from the evolution of protoplanetary disks around low-mass stars. We compare the results with the observational results.

[P83] "A detectability of photosputtering for H_2O ice on the protoplanetary disk"

Takatsuki Shoma (TITECH)

In protoplanetary disks, water ice is an important factor involved in planet formation and disk evolution. Currently, water ice distribution of the disk surface layer can be detected from the observation in the scattered light in the infrared. On the other hand, the effect of the photosputtering is important for the water ice distribution. So far, the photosput-tering has never been detected, because the detection method has not been estab-lished.We examine the detectability of the photosputtering. We focus on the ob-servational method using the absorption of water ice in the 3μm, that is H_2O band. If the water ice is present in the disk surface, the absorption depends on the amount of water ice in the disk surface, because the intensities of scattered light are reduced by the absorption of the water ice. On the other hand, whether the photosputtering works or not also depends on the amount of water ice disk surface. Therefore, we can explore the detectability of the potosputtering from the absorption in the H_2O band. In this study, first we assume the same environment as the protoplanetary disk around Herbig Be star HD 100546, and calculate the water ice distribution with or without the effect of the water ice photosputtering. Second, we simulate the expected observational results for the two cases by Monte-Carlo radiative transfer calculations. As a result, we found that the absorption rate of the light in the H_2O band in the case without the effect of photosputtering can be larger than the case with the effect of photosputtering. Furthermore, the difference of the absorption rate increases as the dust size increases. For a few μm dust, the absorption in the H_2O band cannot be detected in the case without photosputtering, while it can be clearly detected in the case with photosputtering. We conclude that the effect of photosputtering can be detected by the absorption in the H_2O band.In addition, the difference in the reduced amount of light became larger as the dust size increases. Extinction of intensity in H_2O band cannot be seen clearly in the model with the dust size of a few μm, while it can be seen obviously in the model with the photosputtering. Therefore, we conclude that the detection of the photosputtering is possible based on the reduced light intensity of the H_2O band.

[P84] "Complex Organic Molecules in Protoplanetary Disks"

Catherine Walsh (Leiden Observatory)

We investigate the synthesis of complex organic molecules (COMs) in protoplanetary disks using a large gas-grain chemical network including COMs together with a 2D steady-state physical model of a disk irradiated by UV and X-rays from the central star. We find COMs are efficiently formed on cold and warm grains in the disk midplane via grain-surface reactions through efficient migration of icy species on grain surface. Radiation processing on ice forms reactive radicals and helps build further complexity. Part of the icy molecules are photodesorbed into gas and their transition lines become observable. We also perform ray-tracing calculations to predict line spectra of complex organic molecules and suggest CH_3OH should be readily observable in nearby protoplanetary disks with ALMA. We also find the grain-surface abundances predicted by our calculations are consistent with those derived from cometary comae observations providing an evidence for the hypothesis that comets and other planetesimals formed via the coagulation of icy grains in the Sun's natal disk..

[P85] "Evolution of Dust and Gas Density Distribution and Effect of the Streaming Instability at the Radial Pressure Bump in Protoplanetary Disks"

Masaki Fujimoto (ISAS/JAXA, ELSI/Tokyo Tech)

In the process of planetesimal formation, "radial-drift" of dust boulders toward the host star is the most serious difficulty. One of the mechanisms to halt the drift is a radial pressure bump in the disk, at which the boundary between local super/sub-Keplerian flow exists. However, according to accumulation of dust boulders at the super/sub-Keplerian transition point, the dust frictional force alters the gas density profile (e.g., Kato et al., 2012). Moreover, the region at which dust boulders are highly condensed drives an instability of dust density, called streaming instability (hereafter SI, Youdin & Goodman, 2005). We think that accumulation processes of the dust boulders at the pressure bump, which is simply borne by the gas azimuthal velocity profile. To investigate the time evolution of the dust and the gas density profiles and the effect of SI, we conduct the local 2.5-D hybrid simulations, which take into account the backreaction from the dust to the gas consistently. In our simulations, we confirm the driving of streaming instability in the one-dimensionally dust dense region, formed by the radial pressure bump. Though, The dust-to-gas density ratios, which is enhanced by the SI, is too small to form the planetesimals. We found that the radial pressure bump is deformed by the dust frictional force and leaves behind the dust dense region. Such dust dense region has the weak homogeneous radial pressure gradient. SI is driven by differences of radial drift velocities, and radial drift velocity is driven by the angular momentum exchange caused by radial pressure gradient. Then, the weak pressure gradient inhibits the growth of SI, and the dust density is not enhanced strongly. Therefore, we conclude that the halting mechanism of pressure bump is not able to form the planetesimals very well by itself. Then we suggest the possibility that the effect of the maintenance or restoration to the pressure bump might increase the dust density and form the planetesimals via gravitational instability.

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