The 2nd Subaru International Conference

Keauhou, Hawaii, 9-12 March 2009

Exoplanets and Disks
∼ Their Formation and Diversity ∼

Programme and Abstract book

Conference Programme

Mar 8 (Sun)

16:00		Registration & Reception (–20:00)

Mar 9 (Mon) 9:00-12:00, 13:30-18:35

8:00		Registration
9:00		Welcome by Subaru Director Masahiko Hayashi

I. Disk session

Chair: Thomas Henning

9:10	E. E. Mamajek	Structure and Evolution of Circumstellar Disks Around Young Stars: The Initial Conditions of Planet Formation *(REVIEW)*
9:50	M. Tamura	Subaru Explorations of Disks and Exoplanets so far and "SEEDS"
10:15	M. Perrin	Investigating Disk Geometries and Dust Properties with Coronagraphic Polarimetry *(INVITED)*
10:40		COFFEE BREAK
11:00	M. Machida	Protoplanetary disk formation in molecular cloud cores
11:15	S. Watanabe	Thermally induced waves in protoplanetary disks and its implication for planetary formation
11:30	F. Menard	Multi-Scale modelling of protoplanetary disks
11:45	S. Inutsuka	A Hybrid Scenario for Planet Formation
12:00		LUNCH

Chair: Shigeru Ida

13:30	A. Moro-Martin	Modeling and observations of (mostly unresolved) debris disks *(REVIEW)*
14:10	K. Stapelfeldt	Modeling of Debris Disks Resolved with Spitzer and HST
14:25	M. Kuchner	Signatures of Planets In Debris Disks
14:40	H. Rein	On the formation of multi-planetary systems in turbulent disks
14:55	S. Sirono	Planetesimal formation induced by sintering
15:10		COFFEE BREAK
15:30	M. Wyatt	Dynamical theory for debris disks: planets, planetesimals and dust *(REVIEW)*
16:10	P. Kalas	Imaging debris disks: A path to finding exosolar planets *(INVITED)*
16:35		Poster talks (3min $\times$ 10, for those who are interested in)
17:05		COFFEE BREAK
17:25	S. Wolf	Multi-wavelength observations and modeling of circumstellar disks *(INVITED)*
17:50		Poster talks (3min $\times$ 15, for those who are interested in)

Mar 10 (Tue) 9:00-12:05, 13:20-18:30

Chair: Doug Lin

9:00	M. Goto	Protoplanetary disk spectroscopy *(INVITED)*
9:25	C. Chen	Characterizing the Dust and Gas Around Main Sequence Stars *(INVITED)*
9:50	H. Fujiwara	AKARI/IRC Survey of Hot Debris Disks
10:05	T. Yamamoto	Physical processes of dust aggregates in protoplanetary disks
10:20		Coffee Break
10:40	H. Tanaka	Dust Growth in Protoplanetary DIsks *(INVITED)*
11:05	K. Wada	Numerical Simulation of Dust Aggregate Collisions: Growth and Disruption of Dust Aggregates
11:20	T. Hanawa	Gas Accretion from a Circumbinary Disk to Protoplanetary Disks
11:35	J. Hashimoto	Polarimetry for the Disks around Young Brown Dwarfs
11:50		Poster talks (3min × 5, for those who are interested in)
12:05		LUNCH

II. Planet Session

Chair: Motohide Tamura

13:20	B. Sato	RV observations review *(REVIEW)*
14:00	G. Chauvin	Exoplanet imaging *(INVITED)*
14:25	D. Apai	Exoplanet thermal imaging *(INVITED)*
14:50		COFFEE BREAK
15:10	E. Thommes	Gas disks to gas giants: Simulating the birth of planetary systems *(INVITED)*
15:35	N. Narita	Past and Future Studies of Transiting Extrasolar Planets *(INVITED)*
16:00	T. Henning	Binarity among Transit Host Stars
16:15	T. Dall	Radial velocity studies and their limits – the need for synergy
16:30	N. J. Kasdin	THEIA: Telescope for Habitable Exoplanets and Interstellar/Intergalactic Astronomy
16:45		COFFEE BREAK
17:00	S. Ida	Formation of short-period terrestrial planets
17:15	B. Ayliffe	Gas accretion onto planetary cores: three-dimensional self-gravitating radiation hydrodynamical calculations
17:30	D. Lin	Formation of super earths
17:45	M. Janson	4 micron direct imaging search for the dynamically implied planet or brown dwarf companion to Eps Ind
18:00	J. Carson	A Spitzer IRAC Substellar Companion Search Around 88 MLT Dwarfs: Observational Results and Monte Carlo Population Analyses
18:15	T. Schmidt	Mass determination and homogeneous comparison of planet candidates imaged directly

Mar 11 (Wed) 9:00-11:55, 13:50-15:25

III. Instrumentation and Future Mission session

Chair: Karl Stapelfeldt

9:00	M. Feldt	Adaptive Optics for Exo-Planet Observations *(REVIEW)*
9:40	O. Guyon	Coronagraph *(REVIEW)*
10:20		COFFEE BREAK
10:40	M. Liu	The Gemini NICI Planet-Finding Campaign *(INVITED)*
11:05	R. Suzuki	HiCIAO: High Contrast Instrument for the Subaru Next Generation Adaptive Optics *(INVITED)*
11:30	J. Graham	Direct planet detection with the Gemini Planet Imager *(INVITED)*
11:55		LUNCH
13:30		**Conference Photo**

Chair: Michael Liu

13:50	J.-L. Beuzit	SPHERE, a "Planet Finder" instrument for the VLT *(INVITED)*
14:15	R. Joseph	The Stratospheric Observatory for Infrared Astronomy (SOFIA)
14:30	E. Tatulli	Interferometer review *(REVIEW)*
15:10		Poster talks (3min $\times$ 10, for those who are interested in)
15:40		FREE TIME for local meetings & J-FUND Steering meeting (–18:00)
18:30		**Conference Dinner (–20:30)**

Mar 12 (Thu) 9:00-12:20, 13:30-17:00

Chair: Francois Menard

9:00	G. Serabyn	Nulling at the Keck Interferometer and Palomar *(INVITED)*
9:25	P. Hinz	Detecting debris disks and wode-orbit planets with the Large Binocular Telescope Interferometer *(INVITED)*
9:50	N. Ohash	The ALMA Project *(INVITED)*
10:15		COFFEE BREAK
10:35		Poster talks (3min $\times$ 10, for those who are interested in)
11:05	D. Mawet	Imaging disks using a small, well-corrected telescope subaperture and a phase-mask coronagraph
11:20	V. Coude du Forest	ALADDIN: a nulling interferometer dedicated to the characterization of faint circumstellar material & An interferometric survey of hot dust around debris disk and solar type stars
11:35	F. Martinache	The Subaru Coronagraphic Extreme AO Project (SCExAO)
11:50	S. Hippler	Characterization of Exoplanets and Protoplanetary Disks with the proposed E-ELT instrument METIS
12:05	A. Seifahrt	Measuring radial velocities in the near Infrared
12:20		LUNCH

Chair: Ed Turner

13:30	W. Traub	SIM/TPF *(INVITED)*

13:55	M. Fridlund	The European Space Agency's plans for studies of exoplanets and their formation *(INVITED)*
14:20	E. Kokubo	Formation of Terrestrial Planets from Protoplanets
14:35	J. Nishikawa	Coronagraph methods on precise wavefront compensation (UNI-PAC) and deep achromatic nulling
14:50		COFFEE BREAK
15:10	T. Sumi	Exoplanet search via Gravitational Microlensing
15:25	V. Coude du Foresto	Search for life on exoplanets: toward a coordinating international institution
15:40	C. Beichman	International collaboration on exoplanet missions *(INVITED)*
16:05		Discussion
16:40	M. Tamura	Concluding Remark
17:00		Adjourn

Review Talks: 40 min each = 35 min (talk) + 5 min (discussion)
Invited Talks: 25 min each = 20 min (talk) + 5 min (discussion)
Contributed Talks: 15 min each = 12 min (talk) + 3 min (discussion)
Poster Talks: 3 min each, for those who are interested in

Posters

Disk Session

P.01	M. Arakawa	Experimental study on the sticking velocity of rimmed chondrules: implication for the formation of planetesimal precursor
P.02	M. Choi	Protostellar Accretion Disks of the NGC 1333 IRAS 4A Binary System
P.03	S. Cortes	Grain Growth and Global Structure in Protoplanetary Disks: The Case of the Unusual Classical T Tauri Star, PDS 66
P.04	M. Doi	Origin of Cavities in Cosmic Spherules
P.05	D. Fujiwara	Numerical Simulations of Dust Circulation in Protoplanetary Disks
P.06	M. Fukagawa	AKARI Pointed Detections of Circumstellar Material around Main Sequence Stars
P.07	K. Heng	Long-Lived Planetesimal Disks
P.08	K. Hodapp	Sigma Orionis IRS B: An evaporating proplyd containing a sub-stellar object
P.10	D. Ishihara	AKARI Mid-Infrared All-Sky Survey
P.11	C. Kaito	Laboratory experiments on the evaporation of amorphous and crystalline grains
P.12	E. Kato	Subaru Near-Infrared Coronagraphic Images of LkHa 234
P.13	E. Kawamura	Size distribution of dust grains in vortices in the protoplanetary disk
P.14	M. Kitamura	Direct imaging of the FU Ori pre-outburst candidate V1331 Cyg
P.15	K. Kretke	Migration barriers in protostellar disks and preferred location for gas giant formation
P.16	A. Kumamoto	Silicon oxide formation in hydrogen or carbon monoxide gases
P.17	I. Matsuyama	Dispersal of Protoplanetary Disks by Central Wind Stripping
P.18	F. Meru	Self-gravitating discs with radiative transfer: their role in giant planet formation
P.19	M. Momose	Wide-field Imaging Survey of Dust Continuum Emissions at lambda = 1.1mm toward Chameleon and Lupus Regions with AzTEC on ASTE
P.20	J.-L. Monin	Disks around brown dwarfs : formation and diversity
P.21	T. Muranushi	Does Lightning Strike Protoplanetary Disks?: Charge Separation Study of Ice Dust Grains and Its Effect on Dust Growth
P.22	T. Muto	Orbital Evolution of Particles Embedded in a Protoplanetary Disk and the Possibility to Observe Low-Mass Planets in a Protoplanetary/Debris Disk
P.23	T. Nakamoto	Crystallization of Silicate Particles in Circumstellar Disks by Shock Waves
P.24	S. Okuzumi	Electric charging of dust aggregates
P.25	T.-S. Pyo	Transition Disks — Key of Disk Evolution and Planet Formation
P.26	E. Saito	Planetesimal formation by sublimation of icy dust aggregates : effect of H2O vapor pressure
P.27	I. Sakon	Evolution of circumstellar PAHs in soft and hard radiation environment
P.28	T. Shimonishi	AKARI 2–5μm Spectroscopic Observations of Ices around Extragalactic Young Stellar Objects
P.29	S. Skinner	X-rays and Protoplanetary Disks
P.30	T. Suyama	Numerical Simulation of Structure Evolution of Dust Aggregates Growing in Protoplanetary Disks
P.31	T. Suzuki	Dispersal of protoplanetary disks by MHD turbulence-driven disk winds
P.32	T. Takeuchi	Growth of settling dust particles in turbulent disks
P.33	S. Takita	AKARI All-Sky Survey of T Tauri Stars: the Taurus-Auriga region
P.34	K. Tanaka	OMOSHI Effect : A New Mechanism for Mass Accretion under the Radiation Pressure in Massive Star Formation
P.35	I. Yamamura	The first release of the AKARI-FIS Bright Source Catalogue
P.36	C. Yasui	Disk fraction in low-metallicity environment
P.62	A. Seifahrt	Radiative transfer in circumstellar disks - 1D models for GQ Lup

Planet session

P.09	Y. Hori	Gas accretion rate onto a proto-gas giant planet during the stage of runaway gas accretion
P.37	E. Griv	Rapid Formation of the Solar System by Gravitational Instability
P.38	H. Genda	Giant impacts and terrestrial planet formation
P.39	H. Harakawa	The detection of a new large mass planet orbiting around a K0 type star
P.40	R. Kandori	Selection of Nearby Star Targets for the Subaru Strategic Exploration of Exoplanets and Disks (SEEDS project)
P.41	M. Kuzuhara	A substellar companion with a very wide separation to a binary T Tauri Star
P.42	M. Nakajima	A numerical study of collisions of icy bodies using SPH method
P.43	M. Ogihara	N-body Simulations of Planetary Accretion around M Dwarf Stars
P.44	T. Sasaki	Origin of a difference between Jovian and Saturnian satellite systems
P.45	K. Sugitani	A search for T Tauri stars toward dense cores
P.46	C. Tachinami	Thermal evolution and magnetic field of Hot Super Earths
P.47	T. Tanigawa	Satellite Formation: Supply of Solid Material to Circum-Planetary Disk
P.48	C. Thalmann	SPOTS: Search for Planets Of Two Stars — a direct imaging survey for exoplanets in binary systems
P.49	K. Yamamoto	SEEDS: Target selection for open clusters and moving groups
P.56	D. Matsukura	Planetary Spins Acquired from Planetesimal Accretions in Runaway/Oligarchic Stage

Instrumentation and Future Mission session

P.50	H. Canovas	First Results from the Extreme Polarimeter (ExPo)
P.51	V. Garrel	Enabling new high contrast imaging science on Subaru Telescope with Electron Multiplying CCDs
P.52	T. Kamizuka	Image stabilized balloon-borne telescope developed for 'Tera-GATE'
P.53	T. Kanoh	Development of Far-Infrared Interferometric Telescope Experiment
P.54	N. J. Kasdin	Advances in wavefront correction and estimation at the Princeton University High-Contrast Testbed
P.55	F. Martinache	Aperture Masking Interferometry for Subaru's Extreme AO
P.57	T. Miyata	MAX38: A mid-infrared camera for ground-based observations at 8 to 38 micron.
P.58	N. Murakami	Development of 4th-Order Nulling Coronagraphs for Partially Resolved Stars
P.60	K. Watanabe	Development of the GaAs based THz photoconductor and balloon-borne experiment module 'TG-ZERO'
P.61	Y. Hayano	Progress of the laser guide star AO at Subaru Telescope

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[Invited Speakers]

Daniel Aapai, Charles Beichman, Jean-Luc Beuzit, Gael Chauvin,
Christine Chen, Markus Feldt, Malcolm Fridlund,
Miwa Goto, James Graham, Olivier Guyon, Phil Hinz,
Paul Kalas, Michael Liu, Eric E. Mamajek, Amaya Moro-Martin,
Norio Narita, Nagayoshi Ohashi, Marshall Perrin, Bun'ei Sato,
Eugene Serabyn, Ryuji Suzuki, Hidekazu Tanaka, Eric Tatulli, Edward Thommes,
Wesley Traub, Sebastian Wolf, Mark Wyatt

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Subaru Telescope,
National Astronomical Observatory of Japan

Abstract

Abstract for Oral Presentations

Disk Session

Structure and Evolution of Circumstellar Disks Around Young Stars: The Initial Conditions of Planet Formation

Eric E. Mamajek

We review the statistical properties of circumstellar disks around young stars emphasizing recent results from the Spitzer Space Telescope. We will focus on aspects that influence the initial conditions of planet formation including orbital radii, total mass, and gas/dust composition, as a function of stellar mass and age.

Subaru Strategic Exploration of Exoplanets and Disks with HiCIAO/AO188 (SEEDS)

Motohide Tamura (NAOJ)*, and the SEEDS team*

Since the first detection of exoplanets orbiting normal stars in 1995, many exciting discoveries have been made, but our understanding of planetary systems and their formation is far from complete. Armed with a much better performance than that of the Subaru-CIAO-AO36 combination, our main purpose is to conduct the Subaru-HiCIAO-AO188 imaging survey as a Subaru Strategic Observation, searching for giant planets (1 MJ $<$ mass $<$13 MJ) as well as protoplanetary/debris disks at a few to a few tens of AU region around $\sim$500 nearby solar-type or more massive young stars after performance certification. As demonstrated with recent successes of direct imaging of planetary mass objects around Vega-type A stars, direct imaging is indispensable for the detection of such "young" planets, especially planets beyond the snowline (4–40AU), which is complementary to radial velocity searches. We have conducted a thorough target selection during the last half year.

In this talk, we will first overview the Subaru results with the previous coronagraph CIAO. Then we will outline the SEEDS goal, target selection processes, and expected results. A full list of the current SEEDS member ($\sim$90 people from 24 institutes) can be found on our web site.

Investigating Disk Geometries and Dust Properties with Coronagraphic Polarimetry

Marshall Perrin

High-angular resolution coronagraphy and imaging polarimetry have both proven to be valuable tools for studying the properties of circumstellar disks around young stars, but only recently has it become possible to apply these techniques together. Coronagraphic polarimetry observations, obtainable with ACS and NICMOS on Hubble, and some adaptive-optics-corrected telescopes on the ground, are now providing new constraints on light scattering processes on subarcsecond scales within disks. When combined with multiwavelength numerical radiative transfer models, these data can yield insight into both the overall disk geometry as well as the size distribution and other properties of their constituent dust grains. I will present initial results from several recent HST programs studying disks around young stars, summarize ongoing modeling efforts, and discuss future prospects in this area using next-generation high-contrast AO systems.

Protoplanetary disk formation in molecular cloud cores

Masahiro Machida, Shu-ichiro Inutsuka, Tomoaki Matsumoto

Using three dimensional nested grid method, we investigated the formation process of the protoplanetary disk. We adopted the Bonner-Ebert sphere with the number density of 10^6 cm^{-3} as the initial state, and calculated the evolution of the collapsing cloud core parameterizing the rotation rate. Adopting the sink cells, we could calculate the gas accretion onto the protostar for about 10^6 yr. After the protostar formation, the circumstellar (or protoplanetary) disk with a size of about 100 AU appears at the center of the cloud. The size and mass of disks depend on the angular momentum of the host cloud. When the molecular cloud has a large amount of the angular momentum, the disk becomes gravitationally unstable and fragments into several clumps. We expect that gaseous planets are possible to form in such disk for a short duration. On the other hand, when the initial cloud has a small amount of the angular momentum, a stable disk is formed around the protostar. The property of disks and condition for the planet formation are also discussed.

Thermally induced waves in protoplanetary disks and its implication for planetary formation

Sei-ichiro Watanabe

We calculate the quasi-static thermal evolution of irradiated protoplanetary disks by directly integrating the radial optical depth to determine the optical surface and find that in disks with modest mass accretion rates, thermal waves are spon-taneously excited in the outer disk, propagate inward, and dissipate at small radii. The disks evolve to a quasi-periodic state where thermal waves continuously propagate from 100 AU to 0.25 AU in about 100 years. The mechanism driving this thermal instability is a shadowing effect in which the surface where most of the stellar radiation is intercepted at any given radial location may be affected by the vertical structure in the disk regions interior to that radius. This quasi-periodic state is stabilized by viscous dissipation associated with the mass accretion through the disk. For the cases of the mass accretion rate to be 10^{-7} solar mass per year, wave excitation and propagation are suppressed an d the disk reaches approximately steady states. The result that quasi-periodic wave-propagating states exist in disks with modest disk accretion rates is robust to variation in the disks structural parameters, such as their surface density profile, opacity law, and vertical dust distribution. In passive protoplanetary disks, especially transitional disks, these waves induce significant episodic changes in SED, on timescales of decades, because the midplane temperature can vary by a factor of 2 between the exposed and shadowed regions. The transitory peaks and troughs in the potential vorticity distribution can lead to baroclinic instabilities, which may excite turbulence in the planet-forming regions.

Multi-Scale modelling of protoplanetary disks

Francois Menard (LAOG), *Christophe Pinte* (Exeter), *Gaspard Duchene* (LAOG & UC Berkeley)

A wide range of high quality data is becoming available for several protoplanetary disks. The data sets include broadband SED from UV/optical to radio range, images in both scattered light and thermal emission, polarisation maps, etc... In this presentation we will discuss three exemples where we managed to fit several data sets with a single set of disk parameters.

To reach these results, several hundred thousand models were calculated, allowing for bayesian analyses to be performed and error bars and/or validity range to be estimated on the best fit model parameters.

We will discuss these results in the context of disk structure, disk evolution, and planet formation.

A Hybrid Scenario for Planet Formation

Shu-ichiro Inutsuka

The standard scenario for the formation of planets has two critical problems: (1) Turbulence in the disk stirs up dust particles and prevents the dust sedimentation onto the disk mid-plane that is required for the fragmentation of the dusty layer prior to planetesimal formation. (2) The gravitational interaction of (proto)planets and the disk tends to result in their migration onto the central star within a short timescale. These problems have stimulated extensive theoretical work but still remain to be solved. In contrast, the recent increase of our understanding the star formation process enables us to depict the long term evolution of protoplanetary disks and the resultant gravitational fragmentation and the formation of gaseous planetary mass objects in the disks. We critically review recent progress in our understanding of these processes and propose a possible hybrid scenario for the formation of variety of planetary mass objects.

Modeling and observations of (mostly unresolved) debris disks

Amaya Moro-Martin

The dust disks commonly observed around mature main sequence stars (generally A to K2 type) are evidence that plantesimals are present in these systems on spatial scales that are similar to that of the asteroids and the Kuiper Belt obejects in the Solar system. It is inferred that their dust mass declines with time as the dust-producing planetesimals get depleted, and that this decline can be punctuated by large spikes that might be due to individual collisional events. Debris disks present a wide range of sizes and structural features (inner cavities, warps, offsets, rings, clumps...) and there is growing evidence that, in some cases, they might be the result of the dynamical perturbations of a massive planet. Our Solar System also harbors a debris disk and some of its properties resemble those of extra-solar debris disks. Debris disks can shed light on the diversity of planetary systems helping us place our Solar system into context. This talk will review the debris disk phenomenon, the results from past surveys, the modeling efforts and the prospects for the future.

Modeling of Debris Disks Resolved with Spitzer and HST

Karl Stapelfeldt

Signatures of Planets In Debris Disks

Marc Kuchner

An extrasolar planet sculpts Fomalhaut's debris disk; probably many other debris disks contain planets that we could locate if only we could better recognize their signatures in the dust that surrounds them. But the interaction between planets and debris disks involves both orbital resonances and collisions among grains and rocks in the disks — difficult processes to model simultaneously. I will review the different kinds of planet signatures in debris disks and describe new 3-D models of debris disk dynamics that incorporate both collisions and resonant trapping for the first time. I will discuss the implications of these models for coronagraphic imaging with Subaru and other telescopes.

On the formation of multi-planetary systems in turbulent disks

Hanno Rein, John C. B. Papaloizou

Of the recently discovered 334 extrasolar planets, at least 75 are in a multiple planet systems. About 10% of these are in or very close to a resonant configuration where two planets show a mean motion commensurability, with four systems in or near a 2:1 resonance. Resonant configurations can be established by dissipative forces acting on the planets which lead to convergent migration.

We clarify the response of those systems in a 2:1 mean motion commensurability to stochastic forcing, with planet masses ranging from the super Jovian range to the terrestrial range. The stochastic forces could result from MRI (magneto rotational instability) driven turbulence within the protoplanetary disk but our treatment is equally applicable to any other source. Although we cannot observe turbulent disks directly, stochastic forcing may have played an important role in shaping the configurations of observed systems in mean motion resonance.

We develop an analytic model of stochastically forced planets in mean motion resonance and verify it with numerical simulations. We show that stochastic forcing readily produces systems in mean motion resonance with broken apsidal corotation. As one example, we show that turbulence naturally provides an explanation of the configuration of the HD128311 system.

With the presented framework, further observations of extrasolar planetary systems with better statistics and accuracy may lead to an improved situation for assessing the role of turbulence in the early stages of planet formation.

Planetesimal formation induced by sintering

Sin-iti Sirono

Planetesimal formation is still a big problem unresolved in planetary formation theory. Here I show a new scenario of planetesimal formation induced by sintering of grain aggregates. Icy dust aggregates infall to the central star due to gas drag. The temperature of the aggregates increases and sintering proceeds. The porous structure of the grain aggregate is unstable, and they break to small fragments. Because the infalling velocity of the fragments is substantially smaller than the original aggregates, the fragments stagnate and the surface density of the dust component increases. Eventually the surface density exceeds the critical density of gravitational instability. I show the results of the following numerical simulations; 1) fragmentation induced by sintering and 2) evolution of the surface density distribution of the dust component. I found the fragmentation efficiently proceeds by sintering via both surface diffusion and vapor transport, which are the two main mechanisms in the protoplanetary nebula environment.

Dynamical theory for debris disks: planets, planetesimals and dust

Mark Wyatt

Planet formation processes produce both planets and debris (planetesimals and dust). The structure and evolution of debris disks is strongly affected by the architecture of the planetary system. Thus observations of debris disks, both detailed studies of individual objects and statistical studies of populations of debris disks, provide vital clues as to the nature of any underlying planetary system. Interpretation of these observations requires a theoretical model for the dynamics of dust production in debris disks, and for how debris material interacts with the planets, as well as an understanding of the consequences of the processes involved in planetary system formation and evolution. This talk will review recent progress on the various components of such a dynamical model, and the implications for our understanding of how planetary systems form and evolve.

Imaging debris disks: A path to finding exosolar planets

Paul Kalas

Advances in high-contrast imaging have produced a new sample spatially resolved debris disks with morphologies that are attributed to the dynamical effects of exosolar planets tens of AU's from the host stars. Debris disks therefore flag nearby systems where it may be possible to accomplish the direct detection of planets analogous to Neptune. To illustrate this science path, I will review the steps behind our recent discovery of planet candidate orbiting the nearby star A star Fomalhaut. By modeling exoplanet atmospheres and the dynamics of disk-planet interactions, we constrain the mass of Fomalhaut b to less than three Jupiter masses. I will discuss the puzzling aspects of this detection, and explore future prospects for elucidating its physical properties.

Multi-wavelength observations and modeling of circumstellar disks

Sebastian Wolf

Observations of circumstellar disks at various wavelengths trace different physical processes and regions in circumstellar disks. I will review modeling approaches based on observations in different wavelength ranges at low to high spatial resolutions. Exemplary case studies will be presented which illustrate state-of-the-art observations and subequent radiative transfer modeling of circumstellar disks as well as predictions for future observations.

How outer disk communicates to inner disk

Miwa Goto

We will try to answer how/if the evolution in the outer disk has influence on the inner disk. The two-layer models have established the paradigm of how to understand the evolution of outer protoplanetary disks (>10 AU). How good the knowledge applies to inner disks (< 1AU) is still to be seen. The outer- and inner- disks have been believed to dissipate on the same timescale according to the sub-mm survey of nearby T Tauri systems. However, there are hints slowly accumulating that the evolution of an inner disk goes rather independent way, controlled by the physical processes different from that is relevant to the outer disks.

We will test the statement using CO vibrational band of Herbig Ae/Be stars observed by CRIRES at VLT. The line flux of CO v=1-0 P(30), which falls in the clean part of the atmospheric transmission, shows marked correlation with the near-infrared excess over the stellar photosphere. The CO vibrational band is a secure probe of the inner disk, for its high density, high temperature, but above all, its kinematics. The link between CO and the near-infrared excess safely locates the excess source at the inner-rim of the disk as opposed to the circumstellar envelope. On the other hand, the line flux of P(30) does not show any clear trend either with FIR-color, NIR/FIR-color, or the type of the SED (I/II). Apparently the inner disk (<1 AU) is little influenced by what is taking place in the outer disks.

Characterizing the Dust and Gas Around Main Sequence Stars

Christine H. Chen

Debris Disks are dusty, gas-poor disks, whose circumstellar material is generated via secondary processes such as collisions between parent bodies. Spitzer IRS spectroscopy has discovered central clearings in the majority of these systems, suggesting that planets may be forming or may have already formed. Although the majority of debris disks possess cold dust (Tgr < 100 K), analogous to that believed to exist in our Kuiper Belt, $\sim$5% of systems are known to possess warm grains, analogous to zodiacal dust. The most extreme of these systems may indicate recent large collisions, similar to either the Moon-forming event or the period of Late Heavy Bombardment which occured when our solar system had an age of 30–100 Myr and 700 Myr, repectively. High resolution visual and optical spectroscopy has detected absorption due to tenuous circumstellar, atomic gas in a handful of debris disk systems. Although challenging to detect, this material may provide additional insight into the chemistry and evolution of the circumstellar environment.

AKARI/IRC Survey of Hot Debris Disks

Hideaki Fujiwara, Daisuke Ishihara, Takuya Yamashita, Takashi Onaka, Misato Fukagawa, Hiroshi Murakami, Hirokazu Kataza, Takanori Hirao, Takafumi Ootsubo, Takao Nakagawa, and Keigo Enya

After the IRAS observations, main-sequence stars that have circumstellar debris disks and thus show infrared excess have been discovered. Since debris disks are thought to be the final stage of planet formation, it is very important to investigate property and evolution of debris disks statistically. Especially, mid-infrared observations become a key method for planet formation study because mid-infrared excess traces the thermal emission from debris dust in planet forming region. We are carrying on an unbiased survey of debris disk candidates that show mid-infrared excess by using the AKARI/IRC mid-infrared all-sky survey data. So far, we have identified some new debris disk candidates that show large 18 micron excess. In this presentation, we will show the initial results of the debris disk survey with the AKARI/IRC.

Physical processes of dust aggregates in protoplanetary disks

Tetsuo Yamamoto

We discuss topics on the physics of dust aggregates in protoplanetary disks, that is, structural evolution of dust aggregates by their collisions, a nonthermal crystallization mechanism of amorphous silicate dust, and infrared emission spectra of the aggregates.

We demonstrate that collisions of dust aggregates lead to very low density planetesimals and show that dust can grow even in high velocity collisions without disruption. We also show low density dust aggregates formed by collisions exhibit infrared spectra similar to those of small particles. This result indicates that the disappearance of the infrared features such as that of the 10 micron silicate emssion does not implies growth of dust but implies compaction of dust aggregates. We propose a new mechanism of crystallization of amorphous silicate dust, which works at temperatures well below the temperatures of the crystallization due to annealing.

Dust Growth in Protoplanetary DIsks

Hidekazu Tanaka

Numerical Simulation of Dust Aggregate Collisions: Growth and Disruption of Dust Aggregates

Koji Wada, Hidekazu Tanaka, Toru Suyama, Hiroshi Kimura, Tetsuo Yamamoto

Growth and disruption process of dust aggregates by their mutual collisions is important for understanding planetesimal formation in protoplanetary disks. The collision velocity of dust aggregates could reach up to several tens of m/s in protoplanetary disks. To examine the feasibility of dust growth through such high-velocity collisions, we carry out 3D numerical simulations of collisions between not only ballistic cluster-cluster aggregation (BCCA) clusters but also ballistic particle-cluster aggregation (BPCA) clusters, including offset collisions with various impact parameters. BCCA clusters have a fluffy structure with a fractal dimension less than about 2 and should be a typical structure of dust in their early growth stage. Our recent studies reveal that BCCA clusters are compressed by their mutual collisions and result in structures with a fractal dimension about 2.5. On the other hand, BPCA clusters have a fractal dimension about 3 and thus compact st ructures. Therefore, it is possible to discuss the criteria about the growth and disruption of BCCA clusters and BPCA clusters as extreme cases of collisions between fluffy aggregates and between compact aggregates, respectively. The results of our numerical simulations show that the critical collision velocity at which dust can grow or not is given by approximately 40–60 m/s for icy dust aggregates, even if offset collisions are taken into account. This supports a scenario of planetesimal formation through collisions of dust aggregates in protoplanetary disks.

Gas Accretion from a Circumbinary Disk to Protoplanetary Disks

Tomoyuki Hanawa

Young circumbinary disks are expected to supply gas onto protoplanetary disks through accretion. Such mass supply has been studied based on new 2D numerical simulations in which a circular binary is surrounded by an isothermal Keplerian disk at the initial stage.

The simulations show that the gas supply is variable due to oscillation of spiral waves in the circumbinary disk. The amplitude of the oscillation varies on the timescale of several tens rotation period. The gas supply rate is positively correlated with the amplitude of the oscillation. The gas is supplied through L2 point to protoplanetary disks associated with the primary and secondary. The mass accretion rate tends to be higher for the primary disk although the secondary disk has a higher accretion rate in certain periods. The primary disk is perturbed so intensely by the impact of gas flow that the outer part is removed. The secondary disk is always quiet on the contrary. Both the primary an d secondary disks have travelling spiral waves which transfer angular momentum inside them. The mass supply from the circumbinary disk is higher when the temperature is higher. The inner edge of the circumbinary disk retreats gradually.

Polarimetry for the Disks around Young Brown Dwarfs

Jun Hashimoto, M. Tamura, R. Kandori, Y. Nakajima, N. Kusakabe, Y. Sato

We report the near-infrared (NIR) polarimetry of 29 young brown dwarfs (YBDs). This is the first NIR linear polarization survey YBDs in the Taurus, rho Ophiuchi, and Chamaeleon dark clouds. The observations were conducted with SIRPOL on the IRSF 1.4-m telescope in South Africa. SIRPOL is a polarimeter which has the capability to conduct the JHKs-simultaneous imaging polarimetry. Our targets are inferred to have circumstellar disks based on optical and NIR spectroscopy and their spectral energy distribution (SED). The spectral types of these targets range from M6.25 to M9.5 and the masses range from about 80 to 10 $M_{Jupiter}$. We have detected significant linear polarization from three YBDs. In previous studies for YBD disks, the observed SEDs have been well fit by the flat or flared disk models (e.g., Natta et al. 2002), thus we consider significant polarization of three YBDs is due to photon scattering by the dust in circumstellar disks rather than in envelopes. Highly polarized sources serve as "direct" evidence for possible disk systems, and thus, YBDs with significant intrinsic polarization are the best targets for future high-resolution telescopes.

Planet session

Doppler Planet Searches around Intermediate-Mass Stars

Bun'ei Sato

Precise Doppler surveys of intermediate-mass stars (G–K giants and subgiants, A–F dwarfs) have become one of the major subjects in the field of extrasolar planets during the past several years. To date, about 20 substellar companions have been detected around stars with 1.5–4 $M_\odot$ and they begin to show different properties from those around low-mass stars. We here review the recent progress on planet searches around intermediate-mass stars mainly based on the results from the planet search program at Okayama Astrophysical Observatory.

Exoplanet imaging

Gael Chauvin

Exoplanet thermal imaging

Daniel Apai

Gas disks to gas giants: Simulating the birth of planetary systems

Edward Thommes

The now more than 300 discovered planetary systems display a wide range of masses, orbits and, in multiple systems, dynamical interactions. These represent the end point of a complex sequence of events, wherein an entire protostellar disk converts itself into a small number of planetary bodies. Here, we present new simulations of this process (Thommes, Matsumura & Rasio, Science 2008), for the first time evolving fully interacting ensembles of growing planets over the entire gas disk lifetime. We obtain results in agreement with some of the key trends observed in the properties of the exoplanets, and find that interaction among the planets — not just gravitational, but also competition for gas — plays a very important role. Analogs to our own Solar System appear to be a less common outcome, originating from disks near the boundary between barren and (giant) planet-forming.

Past and Future Studies of Transiting Extrasolar Planets

Norio Narita

The discovery of transiting extrasolar planets has enabled a number of fascinating stduies that have been of great importance to exoplanetary science. Photometry of a transit yields the radius of the planet and its orbital inclination, which reveals the true mass and mean density of the planet when combined with radial-velocity measurements. In addition, follow-up observations of transiting planets such as secondary eclipse, transmission spectroscopy, and the Rossiter effect provide us the information of surface temperature, planetary atmosphere, and orientation of planetary orbits. Such observational information, which will provide a greater understanding of extrasolar planets, is available only for transiting planets. In this talk, I will summarize what we can learn from transiting exoplanets and introduce near and far future prospects in this field.

Binarity among Transit Host Stars

Thomas Henning, S. Daemgen, F. Hormuth, C. Bergfors, M. Janson, W. Brandner, S. Hippler

The binarity of stars may play an important role in the process of planet formation and the subsequent dynamical evolution of planetary systems. We report the detection of new binaries among transit host stars, using high-resolution 'Lucky Imaging'. We will discuss binarity as a factor in planetary system evolution.

Radial velocity studies and their limits - the need for synergy

Thomas Dall

I will briefly review the results of the ongoing extrasolar planet searches using radial velocities derived by high-accuracy high resolution optical spectroscopy. I will discuss the limitations caused by stellar magnetic activity, granulation, or surrounding dust and debris disks. I will present some case studies and discuss how further studies in other wavelength regimes are required and how a suite of specialized instrumentation would have a positive impact on the field.

THEIA: Telescope for Habitable Exoplanets and Interstellar/Intergalactic Astronomy

N. Jeremy Kasdin, David N. Spergel, Sara Seager, Paul Scowen, Ken Sembach, Robert J. Vanderbei, Stuart Shaklan, Doug Lisman, Sally Heap, Eric Cady, Dmitry Savransky, Rob Egermen, Roger Linfield, Domenick Tenerelli

In Spring 2008 the US National Aeronautics and Space Administration (NASA) began funding a collection of Astrophysics Strategic Mission Concept Studies. These are intended to provide architectures to NASA and the US National Academy of Science for a variety of science missions that might be initiated in the next decade. One of those missions is THEIA, the Telescope for Habitable Exoplanets and Interstellar/Intergalactic Astronomy. THEIA is a multi-instrument space-telescope concept employing a 4-m diffraction-limited telescope operating at UV and Visible wavelengths. THEIA includes a wide-field high-resolution camera (SFC) operating from 190 to 1075 nm to study the astrophysical processes and environments relevant for the births and life cycles of stars and their planetary systems and a far-UV high-resolution spectrograph (UVS) to examine the cosmic web (IGM), its interactions with galaxies, and its enrichment with the products of stellar and galactic evolut ion. THEIA will also have a hybrid combination of an internal coronagraph and an external occulter for direct imaging and characterization of Earth-like planets orbiting sun-like stars.

Called the eXtrasolar Planet Characterizer (XPC), this part of THEIA consists of three baseline instruments each covering part of the 0.25 to 1.1 micron wavelength range. The overall planet-star contrast level achieved is about 10^{-12}, with the internal coronagraph and external occulter each contributing part of the starlight suppression. This hybrid combination allows for a smaller, closer occulter and a more robust overall design that is easier to engineer. The wide band of wavelengths allows for the broadest possible science, including ozone detection in the UV, oxygen absorption, and water vapor in the near-IR. This talk will present an overview of THEIA, its range of science, and the architecture allowing high contrast over a broad band.

Formation of short-period terrestrial planets

Shigeru Ida, D. N. C. Lin

In a series of the papers (Ida & Lin 2004a, b, 2005, 2008a, 2008b), we have constructed a numerical scheme to simulate the anticipated mass and semimajor axis distributions of planets based on a comprehensive treatment of the sequential planet formation scenario. In the scheme, we first generate a set of protoplanetary disk models. Assuming that planetesimals have been formed in the disks, we integrate growth of protoplanetary seeds due to planetesimal accretion. If planetary masses become large enough, gas accretion onto the planets is also added. The planets' orbits evolve through type I and type II migrations due to tidal interaction with disk gas.

We have newly incorporated resonant trapping between migrating planets and giant impacts after disk gas depletion into our scheme to study distributions of orbital eccentricity, semimajor axis, and mass of close-in terrestrial planets around solar-type stars. We discuss comparison with observational data.

Gas accretion onto planetary cores: three-dimensional self-gravitating radiation hydrodynamical calculations

Ben A. Ayliffe, Matthew R. Bate

We have investigated gas accretion by planetary cores using three-dimensional self-gravitating radiation hydrodynamical calculations able to resolve the accretion process down to the surface of the solid core. Past calculations of this process can be separated into one of two categories. There have been one-dimensional quasi-static models that ignore the three-dimensional structure of the protoplanetary disc in which the core is embedded and neglect the complex three-dimensional hydrodynamical interaction of the core with the disc. Alternately, there have been three-dimensional hydrodynamical calculations of the process which typically neglect self-gravity, radiative transfer, and/or do not resolve the flow far inside the Hill sphere of the planetary core. Our calculations are the first to model this process self-consistently and not make any of the above approximations. Observers are now using direct imaging techniques to search for exoplanets, primarily t argeting young systems where planets are thought to be brightest as they radiate their formative heat. However, Marley et al. (2007) showed that the luminosity obtained from models for young planets (up to 100Myrs) is highly dependent upon the assumed initial conditions. This could make theoretical models inaccurate when applied to the young planets being targeted. We are therefore endeavoring to produce the most realistic early stage conditions we can by including more of the relevant physics.

Formation of super earths

Doug Lin

4 micron direct imaging search for the dynamically implied planet or brown dwarf companion to Eps Ind

Markus Janson

At distances of only 3.3 and 3.6 pc respectively, Eps Eri and Eps Ind are two of the most nearby solar-type stars. In addition, they both exhibit long-term radial velocity trends indicative of planetary companions at relatively large separations, making them interesting for the purpose of direct imaging. Previously, we have reported the results of a deep imaging campaign of Eps Eri at 4 micron, which in combination with dynamical data led to the exclusion of any planets more massive than 3 Mjup anywhere in the system. Here, we will briefly review those results, and subsequently present new results using the same method for Eps Ind A, where the massive planet or low-mass brown dwarf implied by the RV trend is undetected. The combination of radial velocity and imaging data places strong constraints on the system parameters, to the extent that a consistent picture can only be attained if the system is significantly older than the most commonly quoted age estimates of around 1 Gyr.

A Spitzer IRAC Substellar Companion Search Around 88 MLT Dwarfs: Observational Results and Monte Carlo Population Analyses

Joseph Carson, Massimo Marengo, Brian Patten, Giovanni Fazio

I report observational techniques, results, and Monte Carlo population analyses for a Spitzer IRAC substellar companion search around 88 M, L, and T dwarfs. For the typical target star distance, the survey is sensitive to companions with temperatures $\sim$500K and warmer. This survey therefore represents the most sensitive population survey of mid to wide-separation (greater than $\sim$40 projected AU) substellar companions to low mass stars and brown dwarfs. Based on IRAC color-magnitude identification, and ground-based near-infrared spectroscopic follow-up, we find that no system shows positive evidence of a substellar companion (searchable separation $\sim$3-arcsec to $\sim$3-arcmin; projected separation $\sim$40–2000 AU at the median target distance). The presented Monte Carlo simulations report which companion fractions are consistent with this observational result.

Mass determination and homogeneous comparison of planet candidates imaged directly

Tobias Schmidt and Ralph Neuhaeuser (AIU, University Jena, Germany)

Between April 2005 and November 2008, 12 planet candidates detected by direct imaging have been published. The first few planet candidates were found around very young stars; most recently, planets were found around stars with debris disks. For companions imaged directly, i.e. in wide long orbits, it is difficult to constrain the mass well. Hence, it remains often unclear whether the companion is a planet or a brown dwarf. This may also depend on the exact definition of planet, in particular its upper mass limit. We will present VLT/SINFONI and other spectra of some of the objects and a comparison with Drift-Phoenix model atmospheres as well as young free-floating comparison objects. Then, we will compare these detected objects and determine their mass ranges in a homogeneous way. Based on that we will shortly discuss their formation and nature.

Instrumentation and Future Mission session

Adaptive Optics for Exo-Planet Observations

Markus Feldt

Many programmes and projects are underway to finally achieve the goal of directly observing planets outside of our solar system. All such observations will rely on the support of adaptive optics. I will review the basic properties, benefits and parameters of such systems with respect to exoplanet observations. AO systems to support direct imaging will be the prime focus, but I will also provide insight into the (potential) role of AO in other methods, such as astrometry and radial velocity observations.

The critical role of AO in exoplanet observations is three-fold: AO has to enable the utilization of the telescope's full theoretical resolution. It also has to concentrate as much light as possible into the star's and planet's image cores and remove it from the corresponding halos in order to enhance the achievable contrast limit. And last not least, the wavefront as such needs to be as flat as possible in order to enable devices like coronagraphs to efficiently remove the primary star's light. The latter two items combined result in a enormous dependence of finally achievable contrast from the so-called "Strehl Ratio", the measure for wavefront flatness.

Coronagraph (review)

Olivier Guyon

Direct imaging of exoplanets and disks requires very good rejection of the light from the central star. I will show how recent advances in coronagraphy and wavefront control are opening new science oportunities, both from space and ground. Ground-based Extreme-AO systems currently under construction are incorporating some of these new coronagraphic technologies and will allow direct detection of a scientifically meaningful sample of giant planets. Higher performance coronagraphs are currently being developed in laboratories, and will almost certainly allow direct visible (reflected light) imaging of exoplanets with ground-based telescopes. Ongoing designs of space-based coronagraphs show that direct imaging of Earth-like planets may be within the reach of medium-sized ($\sim$1.5m) telescopes. Larger space telescopes ($\sim$4m diameter) could obtain the high signal-to-noise ratio spectra needed to detect life.

The Gemini NICI Planet-Finding Campaign

Michael C. Liu

Our team is currently carrying out a major two-year, 50-night observing program to directly image and characterize young ($\lesssim$1 Gyr) extrasolar planets using the Near-Infrared Coronagraphic Imager (NICI) on the Gemini-South 8.1-meter telescope. NICI is the first instrument on a large telescope designed from the start for high-contrast imaging, comprising a high-performance adaptive optics (AO) system with a simultaneous dual-channel coronagraphic imager. In combination with state-of-the-art AO observing and data analysis methods, NICI currently achieves about an order of magnitude better contrast than any previous ground-based or space-based instrument at separations inside of $\sim$2 arcseconds. The Campaign Team has also carried out significant preparatory efforts to identify previously unrecognized young stars as targets and to develop a rigorous quantitative methodology to constructing the observing strategy. The Planet-Finding Campaign began in December 2008 and is in full operation, with deep imaging of several dozen stars already obtained. We describe the Campaign's goals, design, target selection, on-sky performance to date, and early science results. The Planet-Finding Campaign represents the largest and most sensitive imaging survey to date for massive ($\sim$1 Mjup) planets around other stars.

HiCIAO: High Contrast Instrument for the Subaru Next Generation Adaptive Optics

Ryuji Suzuki, M. Tamura, H. Suto, J. Morino, R. Kandori, T. Kudo, J. Nishikawa, N. Ukita, J. Murakami, H. Izumiura, J. Hashimoto, L. Abe, H. Takami, O. Guyon, T. Nishimura, M.

Hayashi, A. Tavrov, V. Stahlberger, H. Yamada, S. Jacobson, K. Hodapp

HiCIAO is a high contrast instrument for the 8.2 m Subaru Telescope on Mauna Kea. The instrument is a near-infrared camera which benefits from a new Adaptive Optics system of the Subaru Telescope (AO188). The instrument realizes the high contrast with a help of AO188, a classical Lyot coronagraph, and three differential imaging techniques (polarimetric, spectral, and angular). Besides the differential imaging modes, HiCIAO also offers a direct imaging mode which covers $20'' \times 20''$ FOV with $0.01''$/pixel resolution, and a pupil viewing mode for a precise alignment of Lyot stop on the pupil image. The expected contrasts are $10^{5.5}$ at $1.0''$ separation and $10^{3.8}$ at $0.1''$ separation from a central bright object in the spectral differential imaging mode. The instrument will be used in a SEEDS project which is approved as a strategic observation program of the Subaru Telescope regarding direct detection of gaseous planets around young stars and detail study of proto-planetary and debris disks. Hundred twenty nights will be allocated to the project in five years starting from summer 2009.

After extensive characterization tests in a laboratory, HiCIAO received the first light with AO188 in December 2008. Basic performances as an infrared camera as well as coronagraphic capability have been (will be) investigated in the past (coming) commissioning observations. In this talk, I will provide an introduction to the instrument and the performances verified so far in the laboratory and commissioning observations.

Direct planet detection with the Gemini Planet Imager

James Graham

The Gemini Planet imager is an "extreme" adaptive optics system being designed and built for the Gemini Observatory. GPI combines precise and accurate wavefront control, diffraction suppression, and a speckle-suppressing science camera with integral field and polarimetry capabilities. GPI's primary science goal is the direct detection and characterization of young, Jovian-mass exoplanets. For systems younger than 2 Gyr exoplanets more massive than 6 Jupiter masses and semimajor axes beyond 10 AU are detected with completeness greater than 50%. GPI will also discover faint debris disks, explore icy moons and minor planets in the solar system, reveal high dynamic range main-sequence binaries, and study mass loss from evolved stars.

SPHERE, a "Planet Finder" instrument for the VLT

Jean-Luc Beuzit

Interferometer review

Eric Tatulli

In this presentation, I will review how optical spectro-interferometry has become a particularly well suited technique to study the close environment of young stars, by spatially resolving both their IR continuum and line emission regions. I will summarize in which ways optical interferometers have brought major insights about our understanding of the inner part of circumstellar disks, a region in which the first stages of planet formation are thought to occur. In particular, I will emphasize how new methods are now enabling to probe the hot gas emission, in addition to the circumstellar dust. Finally, I will discuss the impact of on-going and future interferometric developments on stellar and planetary formation issues.

The Stratospheric Observatory for Infrared Astronomy (SOFIA)

Robert Joseph

SOFIA comprises a 2.5 m telescope built into a Boeing 747 airplane. Its focal plane instrumentation includes an array of 9 of imagers and spectrometers covering the spectral region from 0.5μm to 1.6 mm. It will fly at altitudes between 39 and 45 kft (12-14 km) above 99.8% of the obscuring water vapor. SOFIA has been under joint development by the U.S.A. (80%) and Germany (20%) for the past decade. SOFIA will be operated as a Guest Observer facility similar to any space astronomy mission. The first science flights are scheduled for next May, the next call for observing proposals will be in November 09, and the next call for proposals for new instruments will be in 2010.

I will describe the expected telescope performance and the measurement capabilities of the SOFIA instrumentation, the support offered for proposal preparation and data analysis, and give examples of the kinds of science that might be done using SOFIA instrumentation.

Nulling at the Keck Interferometer and Palomar

Eugene Serabyn

One of the new modes of the Keck Interferometer is mid-infrared nulling, which is designed to detect faint emission from the immediate vicinity of bright stars. This mode is now fully operational and has just completed a one-year "key science project" phase. This talk will describe this novel observational mode, and some of the types of initial results. A few recent related developments at Palomar, such as the fiber nuller, will also be briefly touched upon.

Detecting debris disks and wode-orbit planets with the Large Binocular Telescope Interferometer

Phil Hinz

The Large Binocular Telescope Interferometer (LBTI) provides a unique combination of resolution and sensitivity in the thermal infrared. This is particularly helpful in detecting faint emission from debris material around nearby stars, as well as giant planets in wide-orbits. Both of these programs will provide important insights for developing into the architecture for other planetary systems. I will discuss the discovery space of the LBTI and present observational results from prototype instruments now being carried out at the MMT observatory.

The ALMA Project

Nagayoshi Ohashi

The Atacama Millimeter and Submillimeter Array (ALMA) is the largest ground-based telescope we have ever built. The array is now under construction in the Chajnantor area in the Atacama desert (5000m in elevation) in northern Chile. The ALMA project has three major international partners: North America (NA), Europe (EU), and Japan. The NA and EU partners are responsible for the construction of the 12m Array (ALMA-baseline project), while Japan is responsible for the construction of the Atacama Compact Array (ACA; ALMA-Japan project). ALMA will be 10–100 times more sensitive and will provide 10–100 times better angular resolutions than existing mm and submm telescopes. Such a tremendously powerful array will allow us to study protoplanetary disks and debris disks in detail where planet formation is considered to take place. We expect ALMA to play crucial roles to understand these disks. ALMA will be completed in 2012, and its expected lifetime is at least 50 years.

The ALMA construction is moving forward: as of January 2009, there are thirteen 12 m antennas (nine from ALMA-NA and four from ALMA-Japan) are under construction and testing at the ALMA Operation Support Facility (OSF) in Chile. There are two Front-End subsystems at OSF, and one of them has been installed into one of the 12 m antennas to evaluate the antenna performance. A part of the correlator systems has been also installed at the Array Operation Site (AOS), and is under testing. First fringe is planed to be obtained in 2009, followed by the commissioning and science verification with three antennas. In my talk, the latest status of the ALMA project and its expected science on protoplanetary disks and debris disks will be presented.

Imaging disks using a small, well-corrected telescope subaperture and a phase-mask coronagraph

Dimitri Mawet, Gene Serabyn

We present the first images of the scattered light from HD 32297's debris disk obtained in the H and Ks band using phase-mask coronagraphy on the 1.6-meter well-corrected subaperture at the 200-inch Palomar Hale telescope. HD 32297 is an A0 star known to possess a nearly edge-on disk with a high fractional luminosity Ld /Ls $\sim$ 0.003 in the infrared. Our H and Ks-band images bring new constraints for this system: spatial scales, color information, asymmetry characteristics. Our observations also demonstrate the advantage of using a well-corrected subaperture to reach extreme adaptive optics regime, along with a phase-mask coronagraph providing a very small inner working distance (∼2 lambda/d).

ALADDIN: a nulling interferometer dedicated to the characterization of faint circumstellar material

Vincent Coude du Forest

Exozodiacal dust play an important role for the feasibility and dimensioning of future space missions dedicated the spectroscopic analysis of the atmosphere of earth-like planets. This calls for a survey of dust clouds around potential targets, in order to retire risk on the space mission and not waste time on sources where exoearths cannot be detected. ALADDIN is an infrared (L-band) nulling interferometer optimized for this objective. Although relatively modest in size (two 1-meter class telescopes on a maximum baseline of 32m), it takes advantage from the privileged atmospheric conditions on the Antarctic plateau to achieve a sensitivity better than what can be obtained with a pair of 8m class telescopes on a temperate site. Beyond its main mission, the science potential of ALADDIN extends to the study of all kinds of faint circumstellar material (dust and/or molecules) around young, old or main sequence stars.

An interferometric survey of hot dust around debris disk and solar type stars

Vincent Coude du Forest, O. Absil, E. di Folco, D. Defrere, J.-C. Augereau

High-precision interferometric observations (using the FLUOR instrument at the CHARA array) have been obtained in the near-infrared K band around a sample of A to G-type stars. They aim at directly detecting the presence of optically thin circumstellar dust emission within the terrestrial planetary zone around main sequence stars known to harbour cold debris discs, and solar-type stars. The measured squared visibilities are compared to the expected visibility of the stellar photospheres based on theoretical photospheric models taking into account rotational distortion. We search for potential visibility reduction at short baselines, a direct piece of evidence for resolved circumstellar emission. Our detections, combined with Spitzer observations around 10 microns, put strong constrains on the properties and distribution of hot grains in these inner planetary systems.

The Subaru Coronagraphic Extreme AO Project (SCExAO)

Frantz Martinache, Olivier Guyon, Julien Lozi, Motohide Tamura, Klaus Hodapp, Ryuji Suzuki, Yutaka Hayano, Michael. W. McElwain

While the existence of large numbers of extrasolar planets around solar type stars has been unambiguously demonstrated by RV, transit and microlensing surveys, attempts at direct imaging with AO-equipped large telescopes remain unsuccessful.

Current surveys are limited by modest AO performance which limits inner working angle

to 0.2", and only reach maximum sensitivity outside 1". This translates into orbital distances greater than 10 AU even on most nearby systems, while only 5 % of the known exoplanets have a semimajor axis greater than 10 AU.

This calls for a major change of approach in the techniques used for direct imaging of the direct vicinity of stars. A sensible way to do the job is to combine coronagraphy and Extreme AO. Only accurate and fast control of the wavefront will permit the detection of high contrast planetary companions within 10 AU.

The SCExAO system, currently under assembly, is an upgrade of the HiCIAO coronagraphic differential imaging camera, mounted behind the 188-actuator curvature AO system on Subaru Telescope. This platform includes a 1000-actuator MEMS deformable mirror for high accuracy wavefront correction and a PIAA coronagraph which delivers high contrast at 0.05" from the star (5 AU at 100 pc). Key technologies have been validated in the laboratory: high performance wavefront sensing schemes, spider vanes and central obstruction removal, and lossless beam apodization.

The project is designed to be highly flexible to continuously integrate new technologies with high scientific payoff. Planned upgrades include an integral field unit for spectral characterization of planets/disks and a non-redundant aperture mask to push the performance of the system toward separations less than lambda/D.

Characterization of Exoplanets and Protoplanetary Disks with the proposed E-ELT instrument METIS.

Stefan Hippler, Wolfgang Brandner, et al.

METIS (Mid-infrared Thermal Imager and Spectrograph) is a 3 to 20 micron multimode instrument for the 42m European Extremely Large Telescope (E-ELT). The instrument modes currently under study include direct and coronagraphic imaging, long-slit spectroscopy, integral field spectroscopy and polarimetry. METIS will be interfaced with the E-ELT adaptive optics system, and incorporate its own on-axis natural guide star wavefront sensor, and thus achieve Strehl ratios of $\geqq$90% in the N-band. I will outline two of the main science goals of this instrument, direct imaging of exoplanets as well as characterization of protoplanetary disks. Because of the superior angular resolution and high contrast METIS at the E-ELT will be able to image exoplanets at considerably closer orbits than JWST/MIRI.

Measuring radial velocities in the near Infrared

Andreas Seifahrt (IAG Goettingen), *Jacob Bean* (IAG Goettingen)

High-resoluton near-infrared spectrographs offer the potential to achieve radial velocity (RV) precisions of $<$ 10 m/s. Such measurements open the door to uncharted land, like planets around extremely low mass stars ($>$ M4) and even around brown dwarfs. It will also facilitate RV measurements of young and active stars in a spectral domain where the intensity contrast between the stellar surface and spots is significantly reduced or where high extinction prevents RV measurements in the optical. However, measuring radial velocities with high precission in the near infrared requires a careful assessment of the necessary calibration procedures and expected error sources. I will review the design of current instruments, such as CRIRES at the VLT and its implications for RV measurements. I will give an overview about the different kinds of calibration options (lamps, gascells, telluric lines, frequency comb), incl. first results from on-sky RV stability measurements.

SIM/TPF

Wesley Traub

The ideal way to discover and characterize all exoplanets around nearby stars is to discover the planets with astrometry, then characterize them with direct imaging. To be specific, the Space Interferometer Mission (SIM-Lite) could do the astrometry, and the Terrestrial Planet Finder (TPF) could do the characterization. If TPF is an internal coronagraph it is TPF-C, if an occulter it is TPF-O, or if an interferometer TPF-I. I will discuss the advantage of using SIM-Lite, in combination with radial velocity observations, to detect nearby exoplanets, and to estimate their orbital parameters. SIM Lite will tell us that the planet exists, that it has an estimated mass, and that we can estimate when and where it will re-appear. With this information, a coronagraph can find the planet again, measure its visible spectrum, and characterize it. Additional observations with an interferometer can fill out the full picture. Then, many properties of the planet can be estimated, including a search for signs of life, using the orbit, mass, and visible and infrared spectra.

The European Space Agency's plans for studies of exoplanets and their formation

Malcolm Fridlund

The aim of ESA's Cosmic Vision plan is to adress specific questions within 4 main themes, the first of which is: "What are the conditions for planet formation and the emergence of life" Central within this context is the issue of so-called Exo-planets, i.e. worlds orbiting stars other than our own Sun, and how they relate to the planets in our Solar System, the conditions in and history of. The EP-RAT is asked to consider a strategy for how we can progress in the area of exo-planets, including specifically the identification of Earth-like planets, and their habitability with a special emphasis of such worlds that are nearby. Such a strategy, although primarily contained within the Cosmic vision 2015–2025 plan may include preliminary preparation and planning even beyond those dates. Th elements of the strategy may include ground based and space based facilities and applications, as well as an estimate of their capabilities in the near- and far time frame. It is important that the framework of the strategy is realistic as what concerns funding, and therefore take into account that parts of the strategy may have to be taken in a step wise approach, rather than with major and high risk space applications. That being said, a certain amount of boldness in the plan should be included as an alternative.

The activity will commence with a call for white papers on technologies, projects and specific missions, which will be issued by ESA and which will be open to scientists affiliated with any institution in an ESA member country. The EP-RAT shall perform an evaluation of these and take them into account when preparing the strategy. The EP-RAT will also be free to consult the community as it sees fit and to invite experts to its meeting if necessary.

The EP-RAT is being asked to specifically address the following:
1. Key scientific areas, issues and problems, taking into account the most recent developments in exo-planetary and star/planet formation research
2. Technologies relevant to progress: Current status and future capabilities and problems. Identification of key technologies
3. Evaluation of current space missions and ground based experiments: Current status and future capabilities
4. The potential and problems of addressing the issues at different wavelengths.
5. Major events in the progress towards the ultimate goals: The role of theory. Preparation of a timeline of scientific steps
6. Complimentarity of ground based and space based applications
7. Preparation of a timeline for the R & D, and development of technology for required steps.
8. Identification of opportunities of cooperation and synergy with national programs and those of space agencies exterior to European Space Agency
9. Prepare a summary report of the evaluation of the responses to the call for white papers
10. Prepare an end report over the suggested strategy that will be made available to the broad community by ESA in electronic form.

This report should contain a broad road-map for exoplanetary science that can be implemented as a strategy by ESA

Formation of Terrestrial Planets from Protoplanets

Eiichiro Kokubo

The final stage of terrestrial planet formation is known as the giant impact stage where lunar-to-Mars-sized protoplanets collide with one another to form planets. We investigate this final assemblage of terrestrial planets from protoplanets using N-body simulations. As initial conditions, we adopt the oligarchic growth model of protoplanets. We systematically change the initial protoplanet system parameters. For each initial condition, we perform many runs, and from their results we derive the statistical properties of the assembled planets. For the standard disk model, typically two Earth-sized planets form in the terrestrial planet region. We show the dependences of the mass and orbital elements of planets on the initial protoplanet system parameters. The number of planets slowly decreases as the surface density of the initial protoplanets increases, while the mass of individual planets increases almost linearly. We also find that the spin angular velocity of the planets is well expressed by a Gaussian distribution and their obliquity is well expressed by an isotropic distribution. The typical spin angular velocity is given by the critical spin angular velocity for rotational breakup under the assumption of perfect accretion in collisions.

Coronagraph methods on precise wavefront compensation (UNI-PAC) and deep achromatic nulling

Jun Nishikawa, K. Yokochi, N. Murakami, L. Abe, T. Kotani, M. Tamura, T. Kurokawa, A.V. Tavrov, M. Takeda

We will present novel coronagraph methods on precise wavefront compensation and achromatic nulling which could be candidates of TPF optics. One is a pre-optics setup which we call UNI-PAC that behaves partly as a low-efficiency nulling coronagraph, and partly as a high-sensitivity wavefront aberration compensator (phase and amplitude). We used an (intensity-) unbalanced nulling interferometer (UNI) which performs a rejection of part of the wavefront electric field and then the recombined output wavefront has its input aberrations magnified. Because of the unbalanced recombination scheme, aberrations can be free of phase singular points (zeros) and can therefore be compensated by a downstream phase and amplitude correction (PAC) adaptive optics system, using two deformable mirrors. In the image plane, the central star's peak intensity and the noise level of its speckled halo are reduced by the UNI-PAC combination: the output-corrected wavefront aberrations can be interpreted as an improved compensation of the initial (eventually already corrected) incident wavefront aberrations. The important and unique characteristic is that not all the elements in the optical setup using UNI-PAC need to reach the lambda/10000 rms surface error quality. We will present recent progress of the experiments proving its principle. The second is 3-D Sagnac interferometric coronagraph which can achieve achromatic nulling by use of geometrical lambda/2 phase shift. We observed nulling depth of 1E-5 $\sim$ 1E-7 at 0$\sim$15 lambda/D region at 532nm and 633nm. We developed a tandem configuration of the Sagnac interferometer for deep nulling of resolved stars. The third is an eight octant phase mask coronagraph which can also obtain the achromatic deep nulling of 1E-10 for resolved stars. We confirmed its performance by numerical simulations and started experiments.

International collaboration on exoplanet missions

Chas Beichman

Search for life on exoplanets: toward a coordinating international institution

Jean Schneider, Vincent Coude du Foresto, Marc Ollivier

Searching for life in the Universe will make use of several large space missions in the visible and thermal infrared, with increaing spectral and angular resolution. They will require plans for many coming decades. We present the necessity for building an international structure to coordinate activities for the next decades and sketch the structure and role of a dedicated international institution.

Exoplanet search via Gravitational Microlensing

Takahiro Sumi

We review the recent results of the exoplanet search via Gravitational Microlensing. The microlensing technique is unique and complementary to other methods because it dose not rely on the light from the primary. The microlensing is sensitive to the small planets down to Earth mass around dim M-dwarfs. Planets with large semi-major axis, farther than the snow line, can also be detected instantaneously without waiting for one orbital period. Most significantly, distant planetary systems up to the galactic bulge can be probed, by which we can understand the galactic distribution of the planetary systems. We present the current status of the observations focusing on the survey by Microlensing Observation in Astrophysics (MOA) collaboration and summarize the features of the detected planetary systems.

Abstract for Poster Presentations

Disk Session

P. 01

Experimental study on the sticking velocity of rimmed chondrules: implication for the formation of planetesimal precursor

Masahiko Arakawa, Yo-ichiro Uchiyama, and Chisato Okamoto (Nagoya University)

Chondrite parent body is one of the most realistic models of planetesimlas in the solar nebula, and chondrites are well known to be composed of chondrules, which are spherical glass balls with the size of sub-mm. It could be necessary to coagulate these glass balls in order to form the precursor aggregates of planetesimals. Recent theoretical study on the chondrule coagulation shows that the chondrule covered with porous silicate rim can stick together to coagulate at the impact velocity less than 1 m/s. We then conducted the impact experiments of simulated rimmed chondrules at the impact velocity from 10cm/s to 80 m/s to obtain the sticking velocity and the restitution coefficients. We changed the porosity of the rim from 70 % to 90 % and the thickness from 2 mm to 10 mm, while the rim was composed of sub-micron silica dusts, and a glass ball with the size of 10 mm was used as a chondrule analogue. As a result, we found that the upper limit of the sticking velocity, Vc, varied with the thickness of silica layer (rim) and the porosity. Vc changes from 40 cm/s to 70cm/s with the increase of the thickness of the silica layer having the porosity of 90 %. The restitution coefficient monotonically decreases with the velocity beyond 1 m/s for the silica layer with the porosity of 70 % and 80 %, and shows the minimum less than 0.1 at the impact velocity of 52 m/s and 9 m/s for each porous layer of 70 % and 80 %, respectively. These results suggest that the porous rim of the chondrule could help the coagulation of the chondrules to form the precursor of planetesimals at the wide range of the impact velocity beyond 10 m/s.

P. 02

Protostellar Accretion Disks of the NGC 1333 IRAS 4A Binary System

Minho Choi and Ken'ichi Tatematsu

We present the results of radio imaging observations of the NGC 1333 IRAS 4A protobinary in the ammonia (2, 2) and (3, 3) lines and in the 1.3 cm continuum. Both ammonia and continuum maps show two compact sources, accretion disks of A1 and A2. Interestingly, the A2 disk is brighter in the ammonia lines but dimmer in the dust continuum than its sibling disk. This difference suggests that the disks have surprisingly dissimilar characters, one gas-rich and the other dusty. If such a condition can persist until the planet-forming phase of the disk evolution, planetary systems produced in such disks may look very different

from each other.

P. 03

Grain Growth and Global Structure in Protoplanetary Disks: The Case of the Unusual Classical T Tauri Star, PDS 66

Stephanie Cortes

We present ATCA interferometric observations of the old (13 Myr), nearby (86pc) classical T Tauri star, PDS 66. Unresolved 3 and 12 mm continuum emission is detected towards PDS 66, and upper limits are derived for the 3 and 6 cm flux densities. We also present HST/NICMOS 1.1 micron PSF-subtracted coronagraphic imaging observations of the circumstellar environment of PDS 66. These data are combined with published optical and longer wavelength observations to make qualitative comparisons between the median Taurus and PDS 66 spectral energy distributions (SEDs). The HST observations reveal a bilaterally symmetric circumstellar region of dust scattering $\sim$0.32% of the central starlight, declining in surface brightness as $r^{-4.2}$. The light-scattering disk of material appears to be inclined 32$\pm$5 degrees from a face-on viewing geometry, and extend to a radius of 170 AU. The mm-wave data show a spectral slope flatter than that expected from ISM-sized dust particles, which is evidence of grain growth. By comparing the near-infrared emission to a simple model, we determine that the location of the inner disk radius is consistent with the dust sublimation radius (0.1 AU). We place constrains the surface density at 5 AU using a flat-disk model. Despite that PDS 66 is much older than a typical classical T Tauri star ($\leq$5 Myr), its physical properties are not much different.

P. 04

Origin of Cavities in Cosmic Spherules

Masao Doi, Taishi Nakamoto

Cosmic spherules are extraterrestrial-origin round shaped dust particles. When the extraterrestrial dust particles enter the Earth's atmosphere, they are heated by the gas friction and melted. Because of the surface tension, the molten particles become spherical and form cosmic spherules when they solidify. Some cosmic spherules seem to bubble inside the particle, because there are some cavities in those cosmic spherules. On the other hand, chondrules, which are spherical silicate particles in meteorites and thought to be formed by the gas frictional heating in the solar nebula, do not contain cavities usually. It is not known well how cavities formed in the cosmic spherules. And the origin of cavities in cosmic spherules may privide a hint for the origin of chondrules. Thus, we study the origin of cavities in cosmic spherules; specifically, we examine whether a bubble in a forsterite particle entering the Earth's atmosphere grows or not. If the dust particle re-solidifies before the bubble disappears, the bubble may remain inside the particle. In this study, assuming that the inside of the dust particle is isothermal and isobaric, we examined the bubble size by simulating the temperature and the pressure in the dust particle for a wide variety of entry parameters. We have found that the bubble does not remain in the particle even if a bubble forms and grows, because the bubble shrinks earlier than the particle solidifies. Thus, it seems likely that cavities are originated from volatile elements, which evaporate and remain in the particle.

P. 05

Numerical Simulations of Dust Circulation in Protoplanetary Disks

Daisuke Fujiwara and Sei-ichiro Watanabe

In the standard scenario, the formation of planetesimal occurs through coagulation of the dust particles in the protoplanetary disks. However, the meter-sized particles rapidly fall into the central star due to the gas drag force before planetesimal formation. Thus, some outow mechanisms are required for planetesimal formation. We perform numerical simulations of the radial circulation of the dust particles in weak turbulent protoplanetary disks, taking the stellar radiation pressure induced the dust outow and a pued-up inner rim with shadowed region (Dullemond et al. 2001) into account. Our main objective is to conrm that the following dust circulation mechanism will be realized in the protoplanetary disk: at the inner rim, falling dust particles partially evaporate and break up into ne grains, which are stirred up to the irradiated surface layer by magnetorotational instability (MRI) and blown outward by radiation pressure. The blowing particles reenter into the disk interior and settle toward the midplane. In this presentation, we report the details of the dust circulation ow.

P. 06

AKARI Pointed Detections of Circumstellar Material around Main Sequence Stars

Misato Fukagawa (Osaka University), *H. Murakami, T. Hirao, K. Enya, T. Ootsubo, T. Nakagawa, D. Ishihara* (ISAS/JAXA), *T. Yamashita* (Hiroshima University), *H. Fujiwara, M. Ueno, T. Onaka* (University of Tokyo), *J. Marshall, G. J. White* (Open University), *H. Kataza, T. Wada, I. Yamamura* (ISAS/JAXA), *and AKARI/MP-VEGAD team*

A significant fraction of bright main sequence stars are known to possess circumstellar disks, established primarily through far-infrared photometry with IRAS, ISO and Spitzer. The existence of infrared excesses indicate the presence of substantial reservoirs of solid dusty material in circumstellar disks, which could be signposts of planetary systems since the observed grains have short lifetimes against radiation pressure and PR drag, and must be replenished by collisions of unseen parent bodies (planetesimals). These far-infrared observations are most efficient to find the excess sources, but sensitive to the Kuiper-belt type disks, not the warmer disks suggesting asteroid-belt analogs. We report AKARI detections of mid-infrared excesses toward a sample of Hipparcos stars, discussing the implications for understanding circumstellar dust emission, and the planet formation and dispersal process.

The AKARI/IRC observations were supplemented by pointed observations with the far infrared surveyor (FIS) designed to search for evidence of colder dust grains. Forty one stars were observed using the MIR-S (7, 11 micron) and MIR-L (15, 24 micron) filters, and in the four FIS bands at 65, 90, 140, and 160 microns. A further 48 stars were observed only with the IRC, and 3 brightest stars only with FIS. The IRC colours reveal that 6 of the stars show excess emission at 24 microns about 10% greater than the expected photospheric emission, and several of the other stars show hints of excess emission at lower levels. Our detection limit at 24 microns corresponds to a fractional dust luminosity approximately 50 times larger that of the Asteroid belt in our own solar system, and the present detections will be discussed in the context of planet formation and disk evolution.

P. 07

Long-Lived Planetesimal Disks

Kevin Heng & Scott Tremaine

Debris disks tend to be discovered at semimajor axes of ∼10 to 100 AU and beyond, and are the progeny of invisible planetesimals, analogous to extrasolar Kuiper Belts. However, they are but one manifestation of these disks. In an upcoming paper, we show that other detection techniques may uncover both dynamically hot and cold disks with a wide range of semimajor axes. Synergy between these techniques and future debris disk surveys may enhance the scientific benefits and returns of both subfields. Further calculations are in progress.

P. 08

Sigma Orionis IRS B: An evaporating proplyd containing a substellar object

Klaus W. Hodapp, Christof Iserlohe, Bringfried Stecklum

We present Keck OSIRIS integral field spectroscopy of the Sigma Orionis IRS binary system. This young system consists of a brighter component of early M spectral type and a fainter component with a complex spectrum, being composed of a late M photosphere, a continuum, presumably from hot dust emission, and a strong emission spectrum of atomic hydrogen and helium lines. We interpret this object as a proplyd in the late stages of destruction by the UV radiation from the nearby primary component of the Sigma Orionis system, the O9.5 star Sigma Ori A.

P. 10

AKARI Mid-Infrared All-Sky Survey

Daisuke Ishihara, Takashi Onaka, Hirokazu Kataza, Hideaki Fujiwara, Satoshi Takita, Carlos Alfageme, Martin Cohen, Naofumi Fujishiro, Pedro Garcia-Lario, Sunao Hasegawa, Hideo Matsuhara, Yoshifusa Ita, Woojung Kim, Takao Nakagawa, Toshio Matsumotob, Hiroshi

Murakami, Youichi Ohyama, Shinki Oyabu, Jeonghyun Pyo, Itsuki Sakon, Alberto Salama, Craig Stephenson, Hiroshi Shibai, Toshihiko Tanabe, Kazunori Uemizu, Munetaka Ueno, Fumihiko Usui, Takehiko Wada, Hidenori Watarai, Chisato Yamauchi, and Issei Yamamura

AKARI All-Sky Survey observations were carried out in the mid to far-infrared spectral region with six photometric bands, during the cryogenic mission phase of AKARI from May 8, 2006 to August 26, 2007.

The mid-infrared part of the AKARI all-sky survey was carried out with two mid-infrared broad bands centered at 9 and 18 μm. More than 90 percent of entire sky was observed by both bands during this period. The 5-sigma sensitivities for point sources are about 50 and 120 mJy, respectively. The spatial resolution is better than 10 arcsecond at both bands. The AKARI mid-infrared survey achieved a deeper sensitivity and a finer spatial resolution than the previous IRAS survey.

AKARI mid-infrared survey has a sensitivity to detect a debris disk of beta Pic at a distance of 100pc and several new debris disk candidates have already been discovered at 18μm in a prelimiary study, separately discussed by Fujiwara et al.

More debris disk candidates are expected to be found in further investigations, which will make a significant impact on the statistical study of debris disks.

P. 11

Laboratory experiments on the evaporation of amorphous and crystalline grains

Chihiro Kaito and Akihito Kumamoto

Amorphous and crystalline grains with the size of 100 nm order produced in laboratory using coalescence and growth in smoke have been used as the sample of crystallization, low energy He ion spattering and sublimation of grains. SiO grains produced by the evaporation of SiO powder in inert gas showed that produced grains were amorphous composed of microcrystallites of Si and beta-cristobalite. The SiO grains altered by heating 500C in air to the quartz microcrystallites, which were transformed by the oxidation of Si crystallites. The oxidation energy of Si crystallites accelerated the transformation of SiO2 quartz structure. The IR spectral difference of these amorphous grains due to beta-crystallite and quartz has been clearly observed. Amorphous Mg-bearing silicate grains were crystallized at 800C via the stall state at 750C. If we covered the thin carbon layer on these amorphous grains, the crystallization temperature became 600C via the graphitization of a morphous surface carbon layer. If we covered the surface with the thin carbon layer produced in CH4 gas atmosphere, exothermic chemical reaction on the carbon layer to the graphitization by exposing in air at room temperature introduced the crystallization of amorphous silicate grains which was clearly supported the low temperature crystallization. The amorphous Mg-bearing silicate grains absorbed CH4 molecule crystallized by electron beam irradiation (low-temperature crystallization). The electron energy dependence on the size of the amorphous grains has been elucidated. If amorphous layer (SiO) was covered with crystallite grains (Fe), the oxidation energy in Si at Low temperature introduced the epitaxial growth of SiO2 (beta-cristobalite). The diffusion of ion hardly took place at 100C. Crystal forsterite grains altered to the MgO fine crystal and SiO2 amorphous from the surface of the grain by low energy He ion sputtering. The sublimation of forsterite grains will be al so presented in this meeting.

P. 12

Subaru Near-Infrared Coronagraphic Images of LkHa 234

Eri Kato, Misato Fukagawa, Hiroshi Shibai (Osaka Univ)

We present high resolution (0.2") near-infrared images of the Herbig Ae/Be star LkHa 234 taken with the stellar coronagraphic camera CIAO (Coronagraphic Imager with Adaptive Optics) on the Subaru Telescope. Herbig Ae/Be stars are intermediate-mass pre-main-sequence stars. It is important to spatially resolve their circumstellar structures for understanding star and possible planet formation mechanisms, but their circumstellar environments remain less understood than those of lower-mass stars mostly due to their large distances. We have observed LkHa 234, located in the NGC 7129 star formation region at 1.25 kpc, using the adaptive optics and the coronagraph. Obtained near-infrared (J, H and K bands) images reveal detailed circumstellar structures around LkHa 234. Six young stellar objects (YSO) candidates are detected at 2"–10" from LkHa 234, and 4 out of 6 candidates are identified for the first time. Our high resolution imaging reveals the complex morphology of the reflection nebula which is located at approximately 3" from LkHa 234 and extended more than 5" toward the west. We will discuss the nature of the YSO candidates based primarily on the color-color and color-magnitude diagrams and the source of the reflection nebula.

P. 13

Size distribution of dust grains in vortices in the protoplanetary disk

Eri Kawamura, Sei-ichiro Watanabe

Planetesimal formation in vortices in the protoplanetary disk is one of the planetesimal forming scenarios. The vortices are considered that long-lived, elliptic, coherent anticyclonic ones in a Keplerian shear. Formation mechanism and long-term maintenance of such vortex in disk is being researched (Inaba & Barge 2006*1, Barranco & Marcus 2005*2, etc.) and considered that dust is concentrated in the central part of vortices and planetesimals or planets will be formed there. We also research this scenario. We consider that this scenario can be divided into the following three stages. 1: Captureing dust particles or aggregates by a vortex. 2: Concentrating dust particles or aggregates into the center of a vortex. 3: Making planetesimals within the central part of a vortex. In the first stage, falling dust to the sun will be captured. And in the second stage, the dust surface density will increase near the center of a vortex. Then the self-gravitational instability or enhanced collision will occur. This is the third stage. In our research, we solved the equation of dust motion in a steady vortex (here, we refered Johansen et al. 2004*3 for vortex gas flow). The result is that dust surface density increases in proportion to the minus square of the distance from the center of a vortex. We determine arbitrary the gas stream which couple elliptic vortex and Keplerian shear, and we estimate total mass and size distribution of concentrated dust which is namely planetesimal.

*1 Inaba, S. & Barge, P. 2006, ApJ 649, 415. *2 Barranco, J. A., & Marcus, P. S. 2005, ApJ 623, 1157. *3 Johansen, A., Andersen, A. C., & Brandenburg, A. 2004, A&A 417, 361.

P. 14

Direct imaging of the FU Ori pre-outburst candidate V1331 Cyg

Misae Kitamura, Toru Yamada, Motohide Tamura, Tomoyuki Kudo

V1331 Cyg is a young stellar object at about 550 pc. It was classified as a pre-outburst FU Orionis candidate by the previously observations. It is important to study the disks before and after the outburst of FU Ori-type stars in order to understand mass accretion and evolution of the disks around young stars. Based on the observation with the Hubble Space Telescope in optical, V1331 Cyg is known to have the structure of an outer ring (15″–20″ (8000-11000AU) in diameter) and an inner ring (5.5″–6.5″ (3000AU)). The outer ring is thought as an envelope connected to an adjacent dark cloud LDN981. The inner ring is thought as the gas reservoir of the further inner accretion disk but its nature is still uncertain. On the other hand, existence of a protoplanetary disk (0.5 solar mass) lying at the region inner than the inner ring is revealed by the observations of sub-millimeter continuum and CO molecular gas. We therefore carried out a direct imaging of V1331 Cyg in H band with CIAO (Coronagraphic Imager with Adaptive Optics) on the Subaru telescope to investigate the inner structures of V1331 Cyg to directly detect the disk and get new knowledge about the nature of the inner ring. Spatial structures revealed by direct imaging may describe the physical conditions of the disk and can restrict the theories of planetary formation. In our preliminary results, we clearly detected a bright arc inner than the known inner ring, which is likely to be the scattered light from the disk. In the conference, we will discuss more detailed nature of the structure including the detailed comparison with the HST images.

P. 15

Migration barriers in protostellar disks and preferred location for gas giant formation

Katherine Kretke

P. 16

Silicon oxide formation in hydrogen or carbon monoxide gases

Akihito Kumamoto and Chihiro Kaito

On the laboratory experiments for the production of metals, oxides and carbide, the smoke experiments due to the condensation from gas phase have been extensively done. Coalescence and growth in smoke can be produced the crystalline silicates. Experiments based on gas-solid direct condensation from Mg-Fe-SiO-H2-O2 vapor yielded various metastable phases. We recently noticed that the smoke experiments in H2 gas was different growth mode in inert gas. In this paper, the grain formation of H2 and CO gases that were also important gases in our universe have been indicated by focusing the silicate grain formation. SiO grains of 50 nm order can be produced by evaporation SiO powder in inert gases. Similar results can be obtained by evaporation in H2 gas. The rapid cooling in H2 gas introduced the characteristic fine convex and concave surface particle. If the Si powder were evaporated in CO gas atmosphere, the produced particles were also amorphous SiO grains witch is composed of Si and beta-cristobalite. The size of Si crystallites was large in SiO particle produced in CO gas atmosphere by evaporating Si powder than any other methods. Therefore Si gas and fine particle produced near the evaporation source was oxidized in CO gas atmosphere. The advanced flush evaporation method which can be produced Mg2SiO4 grains was used in H2 gas atmosphere with the mixture powder of Mg:SiO=1:1. We can get the MgSi2 crystal grains and amorphous MgSiO3 grains. The identification of MgSiO3 grain has been done by the IR spectrum of the produced grains.

P. 17

DISPERSAL OF PROTOPLANETARY DISKS BY CENTRAL WIND STRIPPING

Isamu Matsuyama, Doug Johnstone, and David Hollenbach

We present a model for the dispersal of protoplanetary disks by winds from either the central star or the inner disk. These winds obliquely strike the flaring disk surface and strip away disk material by entraining it in an outward radial-moving flow at the wind-disk interface which lies several disk scale heights above the mid-plane. The disk dispersal time depends on the entrainment velocity, $v_d = \epsilon c_s$, at which disk material flows into this turbulent shear layer interface, where ϵ is a scale factor and c_s is the local sound speed in the disk surface just below the entrainment layer. If $\epsilon \sim 0.1$, a likely upper limit, the dispersal time at 1 AU is $\sim$ 6 Myr for a disk with a surface density of 10^3 g cm^{-2}, a solar mass central star, and a wind with an outflow rate $\dot{M}_w = 10^{-8}$ M$_\odot$ yr^{-1} and terminal velocity $v_w = 200$ km s^{-1}. When compared to photoevaporation and viscous evolution, wind stripping can be a dominant mechanism only for the combination of low accretion rates ($\lesssim 10^{-8}$ M$_\odot$ yr^{-1}) and wind outflow rates approaching these accretion rates. This case is unusual since generally outflow rates are $\lesssim 0.1$ of accretion rates.

P. 18

Self-gravitating discs with radiative transfer: their role in giant

planet formation

Farzana Meru, Matthew Bate

We present new results on the fragmentation, spiral structure strength and angular momentum transport in self-gravitating accretion discs. The early evolution of massive self-gravitating discs has been considered using cooling parameters to describe the thermodynamics (e.g. Lodato & Rice 2005) and using grid-based radiative transfer calculations (e.g. Cai et al. 2008; Boss 2004). We present results from simulations using a Smoothed Particle Hydrodynamics code with radiative transfer to follow the evolution of such discs in order to simulate more realistically the physical processes of energy transfer that may occur in such massive discs, with particular focus on whether regions of these discs are able to cool sufficiently enough to fragment and form giant planets. Future observations using Subaru, Keck, VLT, Gemini, ALMA and other telescopes will not only observe extra-solar planets but also young discs undergoing planet formation, perhaps detecting the pres ence and strengths of spiral structures in massive discs as predicted by theory. With this in mind, the need to model these discs as realistically as possible is important in order to marry the theories of giant planet formation and disc evolution with observations.

P. 19

Wide-field Imaging Survey of Dust Continuum Emissions at lambda = 1.1mm toward Chameleon and Lupus Regions with AzTEC on ASTE

Munetake Momose (Ibaraki University), *Masaaki Hiramatsu* (ASIAA), *Takashi Tsukagoshi, Yoshito Shimajiri* (Univ. of Tokyo), *Norio Ikeda, Yoshimi Kitamura, Kazuhisa Kamegai* (ISAS/JAXA), *Hajime Ezawa, Ryohei Kawabe, Masao Saito* (NAOJ) *and AzTEC on ASTE Team*

We present in this poster the results of imaging survey of dust continuum emissions toward Chameleon and Lupus regions. Observations were made with AzTEC, a 144-element bolometer array camera developed at the University of Massachusetts, mounted on ASTE sub-millimeter telescope during 2007–2008. These two regions are nearby (d$\sim$150pc) and contain more than 200 T Tauri stars (TTSs), allowing us to carry out non-bias survey of circumstellar disks. The point-source detection limit of $\sim$15mJy, corresponding to 0.003$M_\odot$ under the assumptions of T = 10K and beta = 1, results in the detection rate of 10% for TTSs in Chameleon and 20% for those in Lupus. It's still unclear what causes the systematic difference in detection rate, but this may be due to systematic difference in disk mass or temperature affected by global environment in each region. We also present the cloud structure of the Lupus 3 regions obtained with AzTEC on ASTE. The distribution of the extended emission at 1.1mm is quite similar to the extinction map derived from infrared observations. Comparisons of these show that the cloud temperature is about 10K and is almost uniform, but also suggest that densest parts that do not contain any young stellar object have slightly lower temperature ($\sim$8K). Point sources associated with young stellar objects (YSOs) are detected, while a filamentary structure with no distinct YSOs but is nearly in gravitationally unstable is also found.

P. 20

Disks around brown dwarfs : formation and diversity

Jean-Louis Monin, S. Guieu, F. Menard, C. Pinte

Disks around Very Low mass stars and brown dwarfs can be used as a clue of their formation process. It has often been argued that the presence of significant disks around brown dwarfs is an evidence that they form like stars (core collapse and disk accretion). However, recent theoretical models have been published (eg. Bate 2009 MNRAS 392, 590) and produce numerous stars and brown dwarfs, with a significant fraction of Very Low Mass objects retaining a large disk even after ejection through dynamical interactions. We will present a recent study of disks around brown dwarfs in the Taurus Cloud together with state of the art disks modeling to determinate the physical parameters of this large variety of disks, from large edge-on disks to possible debris disks.

P. 21

"Does Lightning Strike Protoplanetary Disks?: Charge Separation Study of Ice Dust Grains and Its Effect on Dust Growth"

Takayuki Muranushi & Tatsuya Tomiyasu

Dust growth in protoplanetary disks is a crucial process for understanding both protoplanetary disk evolution and planet formation. Many models are proposed to overcome the difficulties in the standard model of planet formation, such as the turbulence-driven dust formation and increased collisional cross sections by fluffiness of the dust grains. However, we have not yet found a reliable scenario for dust grain growth. In this contribution, we investigate the role of electric charge in dust growth in protoplanetary disks. In the mid-plane of the disk, micrometer-sized dust grains are supposed to be accumulated several electrons in equilibrium, because electron thermal velocity is much larger than that of ions. But if the dust grains are charged much more, the electric field would dramatically affect the dust growth process. We have been studying charge separation for ice particles in the earth's atmosphere, which causes the thunder and lightning.

We modeled ice crystals as Monte-Carlo crystal system where oxygen nuclei are fixed, and protons can move between levels, creating or annihilating H3O and OH- ions. We calculate the degree of charge separation by ensemble average of the simulation runs. We created point-like defects and surfaces in our model ice and their effect on charge separation. Our simulation is the first to model the mesoscale behavior, with creation and annihilation, of ion defects in ice crystal. Our simulation is carried out on general purpose graphic processors (GPGPUs), one of the latest computing hardware famous of high cost performance and efficient implementation massively-parallel computation.

P. 22

Orbital Evolution of Particles Embedded in a Protoplanetary Disk and the Possibility to Observe Low-Mass Planets in a Protoplanetary/Debris Disk

Takayuki Muto and Shu-ichiro Inutsuka

Understanding the distribution of dust particles in the vicinity of the planet embedded in a disk is essentially important in direct imaging observations. For example, recent findings of a low-mass object in Fomalhaut debris disk use the dust distribution to infer the mass of the object. In this paper, we investigate the motion of a particle around a low mass planet embedded in a non-turbulent gaseous disk. We take into account the effect of the gas structure that is modified by the gravitational interaction between the planet. We derive a general analytic formula that describes the change of the semi-major axis of the particle due to the encounter with the planet using local approximation in distant encounter regime. Our final formula includes the effects of steady, axisymmetric radial gas flow, the global gas pressure gradient in the disk, planet gravity, and the structure of the gas flow modified by the planet's gravity. We compare the analytic results with numerical calculations, and indicate that our formula well describes the secular evolution of the dust particles' semi-major axes well, especially for small particles with large drag coefficient. We discuss the conditions for dust gap opening around a low mass planet and radial distribution of dust particles. We also discuss the possibility of observing a low-mass planet embedded in a protoplanetary disk or debris disk by future instruments such as ALMA or SKA.

P. 23

Crystallization of Silicate Particles in Circumstellar Disks by Shock Waves

Taishi Nakamoto, & H. Miura

Crystalline silicate dust particles have been found observationally in some circumstellar disks around Herbig Ae/Be stars and T Tauri stars. Also, crystalline silicates have been detected in some comets. An unsolved problem here is the origin of the crystalline silicates, because progenitors of those dust particles are thought to be amorphous. A plausible theory for the origin of crystalline silicate is the annealing of amorphous particles. Along that line, some annealing mechanisms have been proposed and examined to date. Shock wave heating is one of them, though suitable conditions of shock waves have not been examined generally. In this study, based on the shock-wave heating mechanism, a wide variety of conditions of shock waves, such as the shock velocity and the pre-shock gas density, in which amorphous particles are heated enough to crystallize, were examined using numerical simulations. As a result, conditions of shock waves that are appropriate for anne aling have been clarified and summarized. Next, if some suitable shock waves can be generated at a right place with a right

velocity was discussed. In this discussion, generation mechanisms for shock waves included the gravitational instability of the disk, the mass accretion from the parental molecular cloud core, bow shocks in front of eccentric planetesimals, and the magnetic bubbles from the central star. It was found that some shock waves can be generated and they may be appropriate to anneal amorphous dust particles there. Thus, in a circumstellar disk, it seems possible that amorphous dust particles are annealed and transformed into crystalline particles by shock waves.

P. 24

Electric charging of dust aggregates and its effect on dust coagulation in protoplanetary disks

Satoshi Okuzumi, Hidekazu Tanaka, and Masa-aki Sakagami

Mutual sticking of dust aggregates is the first step toward planetesimal formation in protoplanetary disks. In spite that the electric charging of dust particles is well recognized in some contexts, it has been largely ignored in the current modeling of dust coagulation. In this study, we present a general analysis of the dust charge state in protoplanetary disks, and then demonstrate how the electric charging could dramatically change the currently accepted scenario of dust coagulation. First, we describe a new semianalytical method to calculate the dust charge state and gas ionization state self-consistently. This method is far more efficient than previous numerical methods, and also provides a general and clear description of the charge state of gas-dust mixture. Second, we apply this analysis to compute the collisional cross section of growing aggregates taking their charging into account. As an illustrative example, we focus on early evolutionary stages wh ere the dust has been thought to undergo ballistic cluster-cluster aggregation (BCCA). We find that, for a wide range of model parameters, the BCCA growth is strongly inhibited by the electric repulsion between colliding aggregates and eventually "freezes out". Strong disk turbulence would help the aggregates to overcome this growth barrier, but it would cause the collisional fragmentation in later growth stages. These facts suggest that the combination of electric repulsion and collisional fragmentation would impose a serious limitation on dust growth in protoplanetary disks. We propose a possible scenario of dust evolution after the freeze-out. Finally, we briefly point out the importance of the fluffy nature of dust aggregates for the magnetorotational stability of protoplanetary disks.

P. 25

Transition Disks - Key of Disk Evolution and Planet Formation

Tae-Soo Pyo, Tomoyuki-Kudo, Jun Hashimoto, and Motohide Tamura

Transition disk is one of the most important criteria for SEEDs YSO/Taurus category. Because their properties indicate significant disk evolution from continuous optically thick disk and are related to the plant formation. They show no or weak IR excess shortward of 10 micron and a significant excess at longer wavelengths in SED. Their SED indicate that the stellar disks have an optically thin inner region — hole or gap — is surrounded by an optically thick outer disk. The hole or gap is a result from ”disk clearing” by giant planets or grain growth or phtotoevaporation. In this presentation, we summary the properties of the transition disks selected by SEEDs YSO/Taurus category.

P. 26

Planetesimal formation by sublimation of icy dust aggregates: effect of H2O vapor pressure

Etsuko Saito, Sin-iti Sirono

Planetesimal formation is still one of the most important unresolved problems in planetary science. I propose a scenario of planetesimal formation in this study. Sublimation of H2O ice in an icy dust aggregate leads to concentration of silicate dust core particles at a particular heliocentric distance. I show that the dust column density can reach the critical density required for the self-gravitational instability of the dust layer. The dust surface density locally increases by a factor of 10 in 6000 yr for 10-cmsized aggregates. The timescale is shorten by the sublimated H2O vapor.

P. 27

Evolution of circumstellar PAHs in soft and hard radiation environment

Itsuki Sakon, Takashi Onaka (University of Tokyo), *Hidehiro Kaneda* (Nagoya University), *Yuki Kimura* (Hokkaido University), *Midori Saito* (Institute for Molecular Science), *In-Ok Song* (Seoul National University)

Several Herbig Ae/Be stars are known to exhibit UIR bands in their infrared spectra. They are generally believed to be carried by circumstellar PAHs either in the associated nebulosity and/or on the surface of the circumstellar disk. The relative band strengths, the band shapes and the band peak positions of these features are expected to vary in different physical conditions of the carriers. Actually, recent observational studies report the evidence for the variations in the spectral properties of the UIR bands among sources with different stellar spectral types. We have examined the properties of the UIR bands and their spatial variations in several objects including both the early type (O5-O6) and the late type (K2) based on Subaru/COMICS observations. In this presentation, we plan to discuss the physical and chemical evolution of carbonaceous dust including PAHs in terms of the difference in the strengths and the hardness of the incident radiation fields. The obtained results are useful to utilize UIR band emission as a diagnostic tool of the physical condition of the disk surface once the circumstellar disk is spatially well resolved in the mid-infrared in a future.

P. 28

AKARI 2-5um Spectroscopic Observations of Ices around Extragalactic Young Stellar Objects

Takashi Shimonishi, Takashi Onaka, Daisuke Kato, Itsuki Sakon, Yoshifusa Ita, Akiko Kawamura, and Hidehiro Kaneda

Infrared spectra of young stellar objects (YSOs) embedded in molecular clouds show absorption features of various ices. These ices are important reservoir of heavy elements, and control the chemical evolution of YSOs. Also, they are thought to be an origin of ices in planetary systems (e.g. comets). However, formation, evolution, and diversity of ices in the universe are not understood well. So far, observations of ices around YSOs are limited to Galactic objects. But different galactic environment (e.g. metallicity) should affect the properties of circumstellar material. In this study, we investigated the ices around massive YSOs in the Large Magellanic Cloud (LMC).

In the earlier study (Shimonishi et al. 2008), we performed the 2–5μm low-resolution (R$\sim$20) spectroscopic survey of the LMC with AKARI, and confirmed several massive YSOs in the LMC. Next, we performed follow-up observations toward these objects with AKARI at higher spectral resolution (R$\sim$80). As a result, we detected the absorption features of 3.05um H2O ice, 4.27um CO2 ice, and 4.67um CO ice. H2O is known to be the most abundant ice around Galactic YSOs, and others are also abundant in our Galaxy. Our analysis showed that YSOs in the LMC have higher abundance of CO2 ice and lower abundance of CO ice compared to Galactic YSOs. This result is the important evidence indicating that extragalactic YSOs holds different chemical balance in their circumstellar environments.

In this presentation, we report the results of 2–5μm spectroscopy of extragalactic YSOs, and discuss the difference of chemical balance around extragalactic YSOs.

P. 29

X-rays and Protoplanetary Disks

Stephen Skinner, M. Guedel, K. Briggs, M. Audard, S. Lamzin, and K. Sokal

The X-ray luminosities of solar-mass T Tauri stars (TTS) are typically a thousand times greater than the present-day Sun. Even higher luminosities are reached during brief but powerful X-ray flares, which flash-heat and melt material near the star and irradiate the protoplanetary disk with bursts of high- energy particles. The intense X-ray emission and associated particle radiation will affect the temperature structure, ionization, and chemistry of the protoplanetary disk, and possibly even its dynamics. We summarize recent X-ray observations of young star-disk systems with Chandra and XMM-Newton, including protostars, TTS, and rapidly-accreting FU Ori stars. We will show and discuss interesting X-ray spectral features that likely arise in the disk or accretion stream including fluorescent Fe emission lines and excess low-energy absorption above that expected from optical extinction estimates.

P. 30

Numerical Simulation of Structure Evolution of Dust Aggregates Growing in Protoplanetary Disks

Toru Suyama, Koji Wada and Hidekazu Tanaka

In protoplanetary disks, the internal structure of dust aggregates changes during dust growth. Such evolution of structure affects the cross section, the strength, and the optical property of that. In this study, we performed N body simulation of oblique collision of dust aggregates and examined the evolution of structure. In our simulation, the radius and the cross section do not depend on the impact velocity. The cross section is proportional to the mass and dust has large cross section.

P. 31

Dispersal of protoplanetary disks by MHD turbulence-driven disk winds

Takeru Suzuki (U.Tokyo) *& Shu-ichiro Inutsuka* (Kyoto U.)

We investigate the accretion disk wind driven by magnetorotational instability and its role in the dynamical evaporation of the gas component of protoplanetary disks. We perform local three-dimensional MHD simulations of stratified accretion disks. Initially given weak vertical magnetic fields are effectively amplified by magnetorotational instability and winding due to differential rotation. The breakup of channel flows developed above and below the mid-plane drives structured disk winds by transporting the Poynting flux to the gas. This mechanism of the disk wind is very robust and should play an essential role in the dynamical evaporation of proto-planetary disks. The breakup of channel flows also excites the momentum fluxes associated with Alfvenic and (magneto-)sonic waves toward the mid-plane. We discuss the role of these waves in the sedimentation of small dust grains.

P. 32

Growth of settling dust particles in turbulent disks

Taku Takeuchi

Dust growth and settling in turbulent disks are studied by solving a coagulation equation. We consider dust particles that settle toward the disk midplane, and solved a coagulation equation. We assumed that the disk has weak turbulence (alpha $\sim 10^{-5}$), and that dust collisions always result in coagulation without any fragmentation.

We investigated when the midplane dust layer forms. The formation time of the dust layer depends on what size we pay attention. The first generation of particles grows during their sedimentation. Even after the first generation has settled on the midplane, there remains some dust at high altitudes, and they continue to fall onto the dust layer. Suppose we focus on a specific size of the dust. The formation of the dust layer of that specific size completes when the dust materials above the layer deplete. For the dust particles to grow larger than a

certain size during sedimentation, it is required that an enough amount of the dust remains above the layer. This required amount of the dust is larger for larger particles to grow. After the dust above the layer depletes, the structure of the layer settles to the steady one that determined by the balance between sedimentation and turbulent diffusion, that can be obtained analytically. For particles larger than 1 cm, the dust layer always has the steady structure, even when the first generation appears at the midplane.

We compared the dust growth timescale to that of dust radial drift. For the dust to grow larger than the critical size at that the particles drift fastest, the turbulence must be weak (alpha $< 10^{-7}$) or the initial dust-gas ratio is large (> 0.1).

P. 33

AKARI All-Sky Survey of T Tauri Stars: the Taurus-Auriga region

Satoshi Takita, Yoshimi Kitamura, Hirokazu Kataza, Daisuke Ishihara, Munetaka Ueno, Akiko Kawamura, Misato Fukagawa

We report preliminary results of our protoplanetary disk survey toward T Tauri Stars (TTSs) using the AKARI All-Sky Survey data. AKARI observed more than 90 % of the entire sky in six photometry bands from mid- to far-infrared wavelengths, whose angular resolutions were about one order of magnitude higher than those of the IRAS. The mid-infrared observations at 9 and 18 micron wavelengths were carried out with the Infrared Camera (IRC), and the far-infrared ones at 65, 90, 140, and 160 micron wavelengths with the Far-Infrared Surveyer (FIS). The beta version of the FIS Point Source Catalogue (PSC) has been released to the team members last year, and the IRC PSC is about to be open to them. We searched 285 TTSs over a 2000 square degrees area in the Taurus-Auriga star forming region, in addition to evaluation of the reliability of the two PSCs. We succeeded in detecting 72 TTSs with AKARI. About 60 % of the detected sources have the IRAS counterparts, but most of these flux densities are thought to be overestimated in the IRAS PSC because of the contamination by the nebulosity surrounding them. In this talk, we show the quality of the beta version of the AKARI PSC, and discuss the properties of the detected TTSs with AKARI by comparing the AKARI and IRAS PSCs.

P. 34

OMOSHI Effect : A New Mechanism for Mass Accretion under the Radiation Pressure in Massive Star Formation

Kei Tanaka and Taishi Nakamoto

In a formation process of very massive star, the strong radiation pressure at the dust sublimation front in the accretion flow plays a crucial role in halting the accretion flow. To overcome this strong radiation pressure, it was considered that a large ram pressure produced by a large mass accretion rate of $\sim 10^{-3} M_{\odot}/yr$ or more is needed (Wolfire & Cassinelli 1987, Kurmholz & Bonnell 2007). We have reinvestigated the necessary condition

at the dust sublimation front in the massive star formation process, and propose a new mechanism for overcoming the radiation pressure. The accumulated mass in a stagnant flow near the dust sublimation front helps the mass accretion by its weight. By this new mechanism, the steady accretion can be realized with a low accretion rate. Thus, this mechanism relaxes the condition for the massive star formation. We call this mechanism the "OMOSHI effect", where OMOSHI is an acronym for "One Mechanism for Overcoming Stellar High radiation pressure by weIght". Additionally, in Japanese, OMOSHI is a noun meaning a heavy weight that is put on something to prevent it from moving. To investigate the physics of the OMOSHI effect, we calculated the structure that generates the OMOSHI effect. Additionally, we examined if the accretion flow would be swept up by the stellar radiation or not after a breakup of the structure by some instability. In conclusion, the OMOSHI effect enables the gas flow to accrete on to the massive star with a small accretion rate. And the disk accretion has an advantage for a recreation of the structure generating the OMOSHI effect.

P. 35

The first release of the AKARI-FIS Bright Source Catalogue

Issei Yamamura and AKARI All-Sky Survey team

The Japanese infrared astronomy satellite AKARI have made All-Sky Surveys at six wavelength bands (9, 18 microns with the Infrared Camera (IRC), 65, 90, 140, and 160 microns with the Far-Infrared Surveyor (FIS)), during its cold-mission phase from May 2006 to August 2007. More than 90 per cent of the entire sky were observed more than twice. One of the primary goals of the AKARI survey is to produce the all-sky infrared source catalogues. We here report the release of the first version of the FIS Bright Source Catalogue (beta-1). The catalogue contains about 63,000 sources. The detection limit at the most sensitive band (90 micron) is about 1.3 Jy, approximately corresponding to the 10 sigma of the noise level. The photometric accuracy is 20–50 per cent, depending on the band. The position uncertainty is currently dominated by the FIS data processing to 4–5 arcsec. Much higher spatial resolution (about 1 arcmin) of the AKARI survey surpasses the IRAS in detection and photometry of point source in the crowded area. The better positional accuracy is also useful for identification with other observations. Detailed performance and scope of improvements will be presented. Preliminary scientific results are also displayed. The catalogue is currently only available to the AKARI science team members for the initial scientific researches as well as for the validation. We plan to update the catalogue in the coming months with respect to completeness, reliability, and accuracy.

P. 36

Disk fraction in low-metallicity environment

Chikako Yasui, Naoto Kobayashi, Alan T. Tokunaga, Masao Saito, Chihiro Tokoku

We are investigating star forming clusters in the extreme outer Galaxy (EOG), at a

Galactic radius (Rg) of more than 18 kpc, to study circumstellar disks in a low metallicity environment ($\lesssim -0.5$ dex). Although the circumstellar disks of forming stars in the solar neighborhood (assumed with solar metallicity) are known to dissipate with a timescale of ∼5–10 Myr, there are no observations in other metallicity environments. Using Subaru MOIRCS, we obtained deep near-infrared (NIR) images of two clusters, which are very young (∼0.5 Myr) and one of the most distant embedded clusters ever found in the EOG. For both clusters, we found that the fraction of cluster members with near-infrared excess, which originates from inner dust disk at radii of $\lesssim 0.1$ AU, is significantly lower than those in the solar neighborhood. Our results suggest that stars forming in a low metallicity environment experience disk dispersal in a time scale of < 1 Myr, while it takes as much as ∼5 Myr in the solar metallicity environment. This may give some insight to the planet formation in the low metallicity environment.

Planet Session

P. 09

Gas accretion rate onto a proto-gas giant planet during the stage of runaway gas accretion

Yasunori Hori, Masahiro Ikoma, and Shigeru Ida

In situ measurements by the spacecrafts revealed that the atmosphere of Jupiter and Saturn are enriched by heavy elements such as carbon and nitrogen compared to the solar abundances. The enrichment may have originated from planetesimals accreted onto a proto-gas giant planet during the stage of runaway gas accretion. Shiraishi & Ida (2008) calculated orbital evolutions of planetesimals around a growing protoplanet. They suggest that the accretion rate of planetesimals onto a protoplanet depends strongly on that of gas onto a protoplanet and its radius. However, their evolutionary behaviors during runaway gas accretion are not clear. This leads to the uncertainty in the estimate of the total amount of heavy elements in the envelope of a protoplanet due to planetesimal accretion. In this study, evolutions of a protoplanet have been calculated with one-dimensional quasi-static model. Focusing on the stage of runaway gas accretion, we have investigated the gas acc retion rates onto proto-gas giant planets. We have also examined the effects of changing a critical core mass and grain opacity on the results.

P. 37

Rapid Formation of the Solar System by Gravitational Instabil-

ity

Evgeny Griv

Attempts to find a plausible explanation of the origin of the solar system began very long time ago but have not yet been quantitatively successful. The knowledge of more than 300 planets orbiting other stars has opened new interest for the origin and the dynamics of our own planetary system. In this work, the gas and dust solar nebula of the solar composition is considered. A simultaneous formation of the sun and all the planets around it ($\approx 5 \times 109$ yr ago) through a local Jeans' gravitational instability of small-amplitude gravity perturbations (e.g., those produced by a spontaneous disturbance) in the nebula disk is suggested. We use a largely previously published analysis (Griv & Gedalin 2006; Griv 2007; Griv, Liverts & Mond 2008) of the linear growth of perturbations in a rotating fluid disk to draw conclusions about the formation of the solar system. Particularly, it is shown that a collective process, forming the basis of the disk instability hypothesis, with surprising simplicity solves the two main problems of the dynamical characteristics of the system, which are associated with its observed spacing and orbital momentum distribution.

P. 38

Giant impacts and terrestrial planet formation

Hidenori Genda, Eiichiro Kokubo, and Shigeru Ida

The terrestrial planets in our solar system were formed in two stages: the formation of several tens of Mars-sized protoplanets through accretion of planetesimals (Kokubo and Ida 1998), and collisions among these protoplanets (Chambers & Wetherill 1998). The latter stage is called the giant impact stage. In the extrasolar system, many giant impacts should occur. In order to systematically investigate the phenomena of giant impacts, we perform more than 1000 simulations of giant impacts for various parameter sets by using SPH (smoothed particle hydrodynamic) method. We have investigated the effects of such energetic collisions on the features of the terrestrial planets such as the number, the size, spin state etc. Our main conclusions are as follows: (1) 40% of giant impact events during terrestrial planet formation are not merging events. (2) Such imperfect accretion does not affect the final number and mass of the terrestrial planets, and formation timescale so much. (3) However, it leads to decrease of the final spin velocity, and (4) change of the core/mantle ratio, which makes the high or low density terrestrial planets. (5) The total mass of ejected material by giant impacts during standard terrestrial planet formation is statistically estimated to be about 10% of the total mass of terrestrial planets, which maybe affect the final orbital elements of the terrestrial planets.

P. 39

The detection of a new large mass planet orbiting around a K0 type star

Hiroki Harakawa

We report the detection of a new large mass planet orbiting around a K0 type star(V=8.26) which has a minimum mass Msin i=8.9 Jupiter mass in a 692.9 day orbit by precise radial velocity measurements from Subaru and Keck. The derived orbital parameters based on minimizing chi square by down-hill simplex method suggest that these radial velocity variations are consistent with an almost circular planet orbit and a Mars-like semimajor axis (e=0.04, a=1.6AU). The residuals to a single-Keplerian fit suggest the possible stellar wobbling by another companion which has lower mass and a shorter period than the primary one.

P. 40

Selection of Nearby Star Targets for the Subaru Strategic Exploration of Exoplanets and Disks (SEEDS project)

Ryo Kandori, M. Tamura, J. Morino, M. Ishii, R. Suzuki, J. Hashimoto, N. Kusakabe, N. Narita, (NAOJ)*, B. Sato,* (TiTEC)*, T. Yamada,* (U-Tohoku)*, K. Enya,* (JAXA)*, M. Goto, J. Carson, C. Thalmann,* (MPIA)*, M. McElwain, A. Moro-Martin, J. Knapp, E. Turner,* (Princeton)*, and SEEDS/HiCIAO team*

SEEDS (Subaru Strategic Exploration of Exoplanets and Disks with HiCIAO/AO188) is the first proposal accepted for the Subaru strategic observations program with 120 allocated nights in total for 5 years run. The goals of our survey are to address the following key issues in exoplanet/disk sciences, (1) the detection and census of exoplanets, (2) the evolution of protoplanetary and debris disks, (3) the link between exoplanets and disks. Targets for the SEEDS exoplanet search (more than 300 stars) are composed of four categories including the nearby stars category. We report our scientific motivation, feasibility, and current status of the SEEDS target selection in the nearby star category.

P. 41

A substellar companion with a very wide separation to a binary T Tauri star

Masayuki Kuzuhara, Motohide Tamura, Tomoyuki Kudo, Miki Ishii, Ryo Kandori, Shogo Nishiyama

Direct imaging of extrasolar planets is useful to understand the initial distribution of massive planets in the outer regions around young parent stars. Interestingly, the planetary mass companions detected so far are surprisingly widely distributed in distance around their parent stars, which provides us to understand the origin of those companions. However, the maximum separation of those widely separated planetary mass companions are yet unknown. We have conducted a high-resolution imaging and spectroscopic survey with the Subaru telescope to study if there is a maximum separation and resulted in a detection of a possible planetary mass ($\sim$12 $M_{jupiter}$) companion to a binary T Tauri star. The separation to its parent star is about 1100 AU, the widest separation among similar objects in star forming

regions.

P. 42

A numerical study of collisions of icy bodies using SPH method

Miki Nakajima, Hidenori Genda and Shigeru Ida

We have numerically studied collisions of icy bodies during planet formation and satellite formation. We have focused on the merging criterion of icy bodies and change in ice-rock ratio. The behaviors of collisions of icy bodies have not been known well although these collisions occur frequently in the solar system and extra solar systems. In the solar system, icy satellites could have been formed through impacts, which may cause the difference of ice-rock ratio of Saturnian satellites. In extra solar systems, planets such as ocean planets and hot Neptunes may grow up through giant impacts among icy protoplanets. In our calculation, we used Smoothed Particle Hydrodynamics (SPH) method, which is one of powerful methods to compute fluid dynamics. We have built our code so that it can use gravity pipe computer (GRAPE), which computes the gravitational force of each particle 100 times faster than usual computers. Due to a large number of usable particles, our simula tion has a high resolution and a number of runs, which makes it possible to obtain statistically-warranted results. We used several equations of states and compared their outcomes, including Tillotson equation of state and an data base, SESAME. We also changed the properties of icy bodies, such as its mass and ice-rock ratio, and investigated how these properties affect the outcome.

P. 43

N-body Simulations of Planetary Accretion around M Dwarf Stars

Masahiro Ogihara, Shigeru Ida

We have investigated planetary accretion from planetesimals in terrestrial planet regions around M dwarf stars through N-body simulations including tidal interactions with disk gas. Because of low luminosity of M dwarfs, habitable zones (HZs) are located in inner regions. In the close-in HZ, type-I migration and the orbital decay induced by eccentricity damping are efficient according to the high disk gas density. In the case of full efficiency of type-I migration predicted by the linear theory, we found that protoplanets migrate to the vicinity of the host star, and 3 to 6 planets eventually remain in mutual mean motion resonances and their orbits have small eccentricities and they are stable both before and after disk gas decays. In the case of slow migration, the resonant capture is so efficient that densely-packed small protoplanets remain in mutual mean motion resonances. In this case, they start orbit crossing, after the disk gas decays and eccentricity d amping due to tidal interaction with gas is no more effective. Through merging of the protoplanets, several planets in widely-separated non-resonant orbits with relatively large eccentricities are formed. Thus, the final orbital configurations (separations, resonant or nonresonant, eccentricity, distribution) of the terrestrial planets around M dwarfs sensitively depend on strength of type-I migration. We also found that large amount of water-ice is delivered by type-I migration from outer

regions and final planets near the inner disk edge around M dwarfs are generally abundant in water-ice except for the innermost one that is shielded by the outer planets.

P. 44

Origin of a difference between Jovian and Saturnian satellite systems

Takanori Sasaki, Shigeru Ida, Glen R. Stewart

Jovian satellite system consists of four Galilean satellites with similar masses that are trapped in mutual mean motion resonances with negligibly small other satellites, while Saturnian satellite system has only one big body, Titan, with other satellites of two order of magnitude smaller mass. We explain the origin of the difference following the proto-satellite disk model adopted by Canup & Ward (2006). The model is a steady accretion disk with relatively small mass with uniform infall from the circumstellar proto-planetary disk. Applying the 1D planet formation model developed by Ida & Lin (2008) for the satellite formation problem, we have simulated growth and orbital evolution of proto-satellites. Our hypothesis is that the infall to Jupiter was truncated by a gap opening in the proto-planetary gas disk by Jupiters perturbations while that to Saturn continued until the proto-planetary disk was globally depleted. This difference significantly a ffects the final configuration of satellite systems, because type I migration timescales of proto-satellites are longer than viscous diffusion timescales of the proto-satellite disks but shorter than expected lifetime of the disks. We show that in the case of Jovian system, a few similar-mass satellites are likely to remain in mean-motion resonances in inner regions, the configuration of which is formed by type I migration and temporal stopping of the migration near the disk inner edge. On the other hand, in the case of Saturnian system, one or two dominant body tends to form by orbit crossing and merging of proto-satellites after disk depletion.

P. 45

A search for T Tauri stars toward dense cores

Koji Sugitani (Nagoya City Univ.), *Makoto Watanabe* (Subaru Telescope, NAOJ), *and WFGS2 Team*

T Tauri stars, which are often found around nearby molecular cloud cores, are ideal targets for studying protoplanetary disks and exoplanets. Most of the previous studies of T Tauir stars were conducted only toward nearby, well-known star forming regions such as the Taurus and Ophiuchus molecular clouds, etc. However, there are many not-well-known dense cores with close distances of ∼100–300 pc, and many T Tauri stars are expected to be associated with them. These T Tauri stars would be valuable samples for future studies of the protoplanetary disks and exoplanets. We have been conducting a systematic search for such T Tauri stars toward optically selected dense cores with the Wide Field Grism Spectrograph 2 (WFGS2) on the University of Hawaii 2.2-m telescope. Here we present the preliminary results of our search.

P. 46

Thermal evolution and magnetic field of Hot Super Earths

Chihiro Tachinami, Hiroki Senshu, Shigeru Ida

It is believed that hot Super Earths will be detected in the oncoming space transit surveys such as TESS and Kepler since the closer to host star the planet is, the higher the transiting probability. Thus, we performed numerical simulation on the thermal evolution of Super Earths whose surface temperature is quite high. We model the thermal transfer due to mantle convection and the inner core growth accompanied by the release of both of gravitational energy and latent heat by using mixing length theory.

We focused on the generation of planetary magnetic field via dynamo action that requires vigorous convection within metallic liquid core. We evaluate how long the liquid core convects based on the evolution of core heat flux from the results of the thermal evolution and the duration is assumed to be the lifetime of planetary magnetic field. It is assumed that planetary surface temperature is constant of 1000K and the mantle is wholly convecting in all calculations. We examine some different mantle viscosity model that could vary with mantle composition, especially with water content in the mantle.

We also want to discuss about the observational possibilities for their magnetic fields.

P. 47

Satellite Formation: Supply of Solid Material to Circum-Planetary Disk

Takayuki Tanigawa, Keiji Ohtsuki, Hiroshi Kobayashi

Most of major natural satellites around the giant planets in our solar system are classified into “regular satellites”, which rotate in nearly circular orbits and the equatorial plane of the parent bodies. The satellites are thus thought to form in circum-planetary disks. However, the origin and the properties of circum-planetary disks are not clear. Recently, some hydrodynamic simulations showed that, in the course of gas capturing process to be gas giant planets, gas flow accreting toward the planet forms disk-like structure, thus circum-planetary disks are inevitably formed as a by-product of the formation of gas giant planets. In order to form satellites, however, solid material needs to be supplied to the circum-planetary disks. In this epoch, most of solid material are in the form of planetesimals and the fragments of them, not micron-size dusts, so these large objects need to be captured by the gas drag with the circum-planetary disks. In order t o examine the supply rate of solid material to circum-planetary disks, we calculate the rate of delivered mass of solid materials by using an analytic calculation with some assumptions. We find that the supply of solid materials tend to be concentrated at inner region of circum-planetary disks, which implies that dust-to-gas ratio can change with distance from the planet and larger at inner region.

We discuss this effect on the process of satellite formation.

P. 48

SPOTS: Search for Planets Of Two Stars — a direct imaging survey for exoplanets in binary systems

Christian Thalmann, Miwa Goto, Joseph Carson, Markus Feldt, Thomas Henning, Markus Janson, Ryo Kandori, Jill Knapp, Princeton Michael McElwain, Amaya Moro-Martin, Ryuji Suzuki, Motohide Tamura, Ed Turner, Tomonori Usuda

With the discovery of five extrasolar planets through direct imaging and their publication in November 2008, the field of exoplanet science has entered an exciting new era. The Subaru HiCIAO instrument, representing the current state of the art in exoplanet imaging, is participating in the planet hunt with its strategic survey SEEDS. Binary stars are mostly excluded from SEEDS. However, these systems are expected to harbor a population of planets comparable in number to that of single stars, but differing in many aspects such as the distribution of planet mass, orbital separation, and excentricity. Measuring these deviations would unlock a wealth of information on the processes by which planets form and evolve, providing much-needed constraints to theory. The logical next step is therefore to complement SEEDS with a sister project focusing on binary stars: SPOTS, a "Search for Planets Of Two Stars". We propose a HiCIAO survey of both very tight binaries, the likely hosts of circumbinary planets, and wide binaries, where binary PSF subtraction provides a particularly powerful tool to extract circumstellar planets from the point-spread functions of their parent stars. Only together with SPOTS can SEEDS yield a representative census of the planet population.

P. 49

SEEDS: Target selection for open clusters and moving groups

Kodai Yamamoto (Nagoya Univ), *T. Matsuo* (NASA/JPL), *M. McElwain* (Princeton Univ), *M. Tamura* (NaoJ), *H. Morishita, A. Nakashima* (Nagoya Univ), *H. Shibai, M. Misato, E. Kato, T. Kanoh, Y. Itoh, Y. Kaneko, M. Shimoura* (Osaka Univ), *Y. Itoh, H. Funayama, T. Hashiguchi* (Kobe Univ)

Subaru Strategic Exploration of Exoplanets and Disks with HiCIAO/AO188 (SEEDS) is a strategic project for direct imaging of exoplanets with the Subaru telescope. A new high contrast instrument, HiCIAO is used with a new adaptive optics system, AO188.

We selected target stars for the SEEDS observation from the members of open clusters and moving groups. Because, the uncertainty in ages of the members of open clusters and moving groups is significantly smaller than those of field stars, we can estimate the planet mass from its luminosity, if detected around stars of open clusters and moving groups.

For this selection, we determined the selection criteria for the open clusters and moving groups. Based on the selection criteria, we made a target list for the open clusters and moving groups. The number of target stars selected is 50 and 50 for each category. The

target stars for the open cluster category were selected only from the Pleiades, where those for the moving groups were from 9 moving groups. Furthermore, we calculated the expected number of exoplanets assuming the expected performance of HiCIAO and AO188 on Subaru. The result is that we will detect 2 and 26 exoplanets if the observation is carried out for all 50 targets in the Pleiades and 50 targets in these moving groups, respectively.

We present the selection criteria and the feasibility studies for the open clusters and moving groups.

P. 56

Planetary Spins Acquired from Planetesimal Accretions in Runaway/Oligarchic Stage

Daishi Matsukura (Tokyo Institute of Technology)*, Shigeru Ida* (Tokyo Institute of Technology) *and Eiichiro Kokubo* (National Astronomical Observatory of Japan)

In our planetary system, all planets are rotating with wide varieties of obliquities and spin rates. Especially, spins of terrestrial planets are one of the visible values and give us much useful information to comprehend the planet formation history. It is generally accepted that terrestrial planets have experienced two stages of acquiring spin angular momenta. The first half, (1) accretions of planetesimals in the runaway growth stage. The last half, (2) collisions of protoplanets in the oligarchic growth stage. Here, our research mainly focuses on the former stage.

So far, there are some analytical studies and three-body simulations dealing with planetary spins in the stage. According to these simulations, (1) it is practically hard to duplicate prograding spin values of the Earth-Moon system only by planetesimal accretion. This demands such planetesimals as with low Jacobi energies and distributions around the feeding zones. In addition to this, (2) in some cases, final spin rates of protoplanets can be cancelled, and in other cases, protoplanets may have retrograding spins (Ohtsuki & Ida 1998). Thus, there is a consensus that terrestrial planets mainly acquire their spin angular momentum in the last half stage.

In our research, we perform N-body simulations and compare final protoplanets' spin properties with the ones of three-body simulations. Our study can clarify whether three-body approximation in this stage full of collisions and accretions is valid for analysing the formation process. In our simulations, we adopt a planetesimal system with Hayashi model. Also we set a few thousand numbers of planetesimals distributing randomly with initial eccentricities and inclinations derived from previous studies (Ida & Makino 1992a). We perform simulations over ten thousands years around terrestrial planets regions (1AU) under perfect accretions. Mutual gravitaions are calculated by GRAPE6. In this conference, we show the statistical resuts of planetary spin properties acquired from planetesimal accretions.

Instrumentation and Future Mission session

P. 50

First Results from the Extreme Polarimeter (ExPo)

Hector Canovas

Polarimetry is a powerfull tool for astrophysicist, particularly in for detecting and characterizing exoplanets and protoplanetary disks. We present the first results from ExPo (Extreme Polarimeter), a high sensivity imaging polarimeter that has been built at Utrecht University. ExPo makes use of the double beam-exchange technique, together with a coronograph and a fast-modulating FLC, which allows us to obtain images every 30 millisecs. This instrument can reach the high contrast ratios that are necessary to observe protoplanetary disks, and shows the power of polarimetry for future projects. We will show the very first result from the first light at the William Herschel Telescope, at La Palma, in October 2008, where we observed protoplanetary disks around AB Aur, V1685 Cygni and SU Aur.

P. 51

Enabling new high contrast imaging science on Subaru Telescope with Electron Multiplying CCDs

Vincent Garrel, Olivier Guyon, Frantz Martinache, Sebastian Egner

High contrast imaging of exoplanets and disks with ground based telescopes requires high accuracy wavefront sensing and good calibration of the imaging system. The new generation of Electron Multiplying CCD (EMCCD) visible detectors, now widely available, opens up new exciting possibilities for exoplanet science: - high efficiency wavefront sensing for Extreme-AO can drive Extreme-AO systems for exquisite control of wavefront error, and can also measure residual wavefront errors for PSF halo calibration. EMCCDs could replace Avalanche Photo-Diodes (APDs) currently used on Subaru's AO188 system. - optimal combination of a large number of short exposures (similar to lucky imaging schemes) can greatly improve high contrast imaging performance in the visible, where AO correction by itself is not sufficient.tu

We are now testing a EMCCD camera for use on the Subaru Coronagraphic Extreme AO (SCExAO) system, which is an upgrade of the AO188 + HiCIAO configuration. Results of our laboratory testing of this camera are presented, and the suitability of EMCCD technology for high contrast imaging science is discussed.

P. 52

Image stabilized balloon-borne telescope developed for 'Tera-GATE'

Takafumi Kamizuka, Hirokazu Kataza, Kentaroh Watanabe, Takehiko Wada, Hironobu Makitsubo, Hiroshi Murakami

Astronomical observations in THz band (wavelength: 50-300 microns) give us much information about dust in wide range of protoplanetary disks and debris disks. They are very useful to probe the planet formation process. But such data are still scarce, especially in longer wavelength region. This is because of the lack of high sensitive detectors and heavy telluric absorption. To deal with these problems and observe exozodiacal dust, GaAs photoconductors and balloon-borne telescopes are good tools, and we are developing them in the project named 'Tera-GATE' (Tera-Hz observations with GaAs photoconductors and a balloon-borne TElescope). (About the photoconductors, check Watanabes poster in this conf.)

In contrast to the advantage about atmospheric absorption, balloon-borne telescopes have a problem that they tend to have pointing error, caused by disturbance in the attitude of gondola, and it is difficult to make sensitive observations with long exposure. To improve the image stability, our telescope adopts image stabilization system, which controls the secondary mirror position and corrects the disturbed image position quickly.

The telescope design is as below. Its optics is Cassegrain-like two-mirror system, and the effective aperture is 500 mm. The correctable range of the pointing error is 0.6 degrees (peak to peak value), and the stability of the image, we aim, is a few 0.1 arcminutes. The telescope is under construction and the image stabilization system is being tested with moving light source simulating the image motion in flight. We report about the current status of the development and achievement of the image stability.

P. 53

Development of Far-Infrared Interferometric Telescope Experiment

Tetsuo Kanoh, H. Shibai, M. Fukagawa, T. Matsuo, E. Kato, Y. Itoh (Osaka Univ.), *M. Kawada, T. Watabe, T. Kohyama, Y. Matsumoto, H. Morishita, K. Yamamoto, R. Kanoh, A. Nakashima, M. Tanabe* (Nagoya Univ.), *M. Narita* (JAXA), *and The FITE team*

We have developed the Far-Infrared Interferometric Telescope Experiment (FITE). It will be the first astronomical infrared interferometer working in space. FITE is a balloon-borne telescope, and operated in the stratosphere (the altitude of 35 kilometers). FITE is a Michelson-type stellar interferometer, and has a long base line of 20 meters in maximum. The purpose of the FITE project is to achieve a high spatial resolution of 1 arcsecond at the wavelength of 100 micrometers. At the first flight, FITE has 8 meters base line, and the aim is to measure the interference fringes with a spatial resolution of 2.5 arcseconds. In order to achieve this aim, the two beams must be focused within 2.5 arcseconds accuracy in the imaging quality, within 10 arcseconds accuracy in the beam alignment, and within 30 micrometers accuracy in the optical path length between the two beams. And also the orientation of the telescope must be controlled within 2.5 arcseconds accuracy. In order to achieve these accuracies, the structural parts of the telescope were made of carbon-fiber reinforced plastics, that have very low thermal expansion coefficient and large Young's modulus. During observation, the optical alignment is actively adjusted by the alignment mechanisms. And we adopt three-axis attitude control system to stabilize the orientation of the telescope with high accuracy. FITE is very unique approach, and it serves as a step to further development of infrared interferometer of larger scale in space.

P. 54

Advances in wavefront correction and estimation at the Princeton University High-Contrast Testbed

N. Jeremy Kasdin, Jason Kay, Michael McElwain, Laurent Pueyo, Tyler Groff

The Princeton High-Contrast Testbed has been in operation for over five years and is used to study various concepts in coronography and wavefront control for exoplanet imaging. A particular focus has been on the performance of shaped pupil coronagraphs. In this paper, we review and show experimental results using two sequential deformable mirrors (DMs) for the creation of a symmetric dark hole in the image plane. The stroke minimization algorithm is used to calculate DM settings that will create the dark hole while limiting the stroke required on the DM actuators. In addition, we present a two-camera wavefront estimation scheme that is less dependent on knowledge of the DM surface than traditional estimation via diversity on the DM. This algorithm is used to overcome dependence of the estimate on uncertainties in the DM surface shape. We show both simulation and laboratory results of the two deformable mirror correction using both estimation schemes. This is an essential step toward a comprehensive high-contrast imaging system for planet detection and characterization.

P. 55

Aperture Masking Interferometry for Subaru's Extreme AO

Frantz Martinache, Olivier Guyon and Vincent Garrel

Aperture Masking Interferometry used in combination with Adaptive Optics, is a powerful technique that permits the detection of faint companions at small angular separations.

The precision calibration of the data achieved with this observing mode indeed leads to reliable results up to and beyond the formal diffraction limit, explaining why it has, in just a few years, been ported on most major telescopes.

In this poster, we present its possible implementation on Subaru. We also discuss how the opportunity offered by the planned Extreme-AO upgrade to HiCIAO will push further the performance of this already successful technique, offering Subaru a unique access to a very exciting region of the "contrast-ratio – angular separation" parameter space.

P. 57

MAX38: A mid-infrared camera for ground-based observations at 8 to 38 micron.

Takashi Miyata, Shigeyuki Sako, Tomohiko Nakamura, Takashi Onaka (University of Tokyo), *Hirokazu Kataza* (JAXA/ISAS)

We are developing a new infrared camera MAX38 (Mid-infrared Astronomical eXplorer) for ground-based mid-infrared (8-38 micron) observations. This spectral region will be very important for the study of planetary disks. The MAX38 will be attached on the Univ. of Tokyo Atacama 1.0-meter telescope which is the world highest infrared telescope at the summit of Co. Chajnantor (altitude 5,640m), Atacama, Chile. Thanks to the high altitude and dry weather condition of the site we can access the 30-micron wavelength region from ground-based telescopes for the first time in the world. We employ a Si:Sb 128x128 array detector manufactured by DRS sensor and targeting system, Inc. to cover a wide mid-infrared wavelength range from 8 to 38 micron. A newly developed cold chopping system operated below 10K and metal mesh band-pass filters are installed in the MAX38 optical system. The development of the MAX38 has been almost completed. The first light observation in the N-ban d at the Kanata 1.5 meter telescope (Hiroshima, Japan) was successfully carried out. We will attempt the first 30-micron observation at Atacama in 2009.

P. 58

Development of 4th-Order Nulling Coronagraphs for Partially Resolved Stars

Naoshi Murakami, K. Yokochi, J. Nishikawa, M. Tamura, N. Baba, R. Uemura, N. Hashimoto, L. Abe, A. V. Tavrov, T. Kurokawa, M. Takeda

We present our recent progress in development of novel coronagraphs for extremely suppressing partially resolved stars. We propose two methods; one is an eight-octant phase-mask (EOPM) coronagraph, and the other is a tandem common-path achromatic interfero-coronagraph (TCP-AIC). The EOPM is put on a focal plane to divide a stellar image into eight-octant regions and provide 0/pi phase difference to cause nulling interference. It is possible to design a fully achromatic EOPM by utilizing a polarization interferometry. The TCP-AIC consists of dual 3-D Sagnac interferometers to provide stable and achromatic four-beam nulling interference by using a geometric phase. These novel techniques are advanced versions of previously proposed ones; a four-quadrant phase-mask (FQPM) and a common-path achromatic interfero-coronagraph (CP-AIC). The EOPM and the TCP-AIC are expected to have a 4th-order response to tip-tilt errors, while those of the FQPM and the CP-AIC are expec ted to be 2nd-order. The higher-order behaviors suggest that the EOPM and the TCP-AIC can achieve a deep nulling of 1E-10 for partially resolved stars with large apparent sizes. Our numerical simulations and laboratory experiments of the EOPM coronagraph demonstrate the higher-order behavior successfully. Recently, we have also started to design an optical configuration for constructing the TCP-AIC. The proposed techniques could have an ability to detect extrasolar Earth-like planets within a habitable zone around nearby stars, and could be promising candidates of the coronagraphs for the TPF-C mission. We report the principles, numerical simulations and laboratory demonstrations of the proposed techniques.

P. 60

Development of the GaAs based THz photoconductor and balloon-borne experiment module 'TG-ZERO'

Kentaro Watanabe

A detector technology in far-infrared and submillimeter region (THz region) has been less matured than the other wavelength region. An extrinsic photoconductor is the powerful IR/Submm detector forobservations with low background radiation. N-type gallium arsenide (GaAs) is a good candidate for a photoconductor for use in THz region. Because its photo-excitation energy is smaller than which of Ge:Ga photoconductor, the N-GaAs photoconductor must be able to detect the longer wavelength photons. In order to fabricate a photoconductor with low dark current and high quantum efficiency, the base GaAs material should be much purer than commercially available GaAs single crystal. We applied the liquid phase epitaxy (LPE) which is a suitable crystal growth method for realizing such pure GaAs crystals. As a result, the background impurity density is decreased by several 10^{13} atoms cm^{-3} in the LPE grown GaAs layer. And the test N-GaAs photoconductor device shows spectroscopic response over a wide wavelength range of 150–300 micron. The best sample shows 30 A/W of responsivity and 10^{-16} W/Hz$^{0.5}$ of NEP at 300 micron wavelength at T=1.6 K.

In addition, for the purpose of balloon-borne experiments, we constructed the teraheltz photometer module (TG-ZERO) utilizing our N-GaAs photoconductors. TG-ZERO has 4channel bands with N-GaAs and Ge:Ga photoconductors. The beam of each channel window is individually coupled with Si lens to the detector, covering a different wavelength band in 50–300 micron region. Each beam diameter is 14 mm and focal of view is 2 degrees. Each beam is reflected 90 degrees by plane mirror in front of the cryostat window. The elevation of field of view is changeable over the range of 0–360 degrees by rotating this reflection mirror. The cold chopper is also able to rotate inside the cryostat, chops the optical path to obtain a reference signal.

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Progress of the laser guide star AO at Subaru Telescope

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The curvature-wavefront-based AO system with laser guide star is under commissioning at Subaru Telescope. The AO system is opened since September 2008 using a natural guide star. The test of laser projection to sky resumed on February 13, 2009.

We have obtained around 0.55 of Strehl ratio at K-band under the seeing condition of 0.4 arc second at K-band using a 8th magnitude single star. The Strehl ratio was about 0.2 at

K-band using the faint guide star around 16th magnitude. Even though under the seeing condition of 1 arc second, the obtained almost diffraction limited image at K-band.

The total equivalent magnitude of laser guide star was estimated as 10.7 magnitude. However, the full width half maximum is around 2 are second under the seeing condition of 1 arc second in K-band.

Also the commissioning schedule and milestones for open use observation are introduced in the poster.