ABSTRACT

Day 1

9:40 - 10:20 Eugene Chiang (UC Berkeley)

Title:	Genesis of the Super-Earths
Abstract:	Close-in super-Earths abound in the universe. Super-Earths form late in their parent disk's life, in gas-poor but not gas-empty disks. The final doublings of their rocky core masses occur in-situ by giant impacts unimpeded by gas dynamical friction. Once cores fully assemble, they accrete gas from the residual nebula. We explain how super-Earths/sub-Neptunes acquire their ~1%-by-mass envelopes over an enormous range of nebular depletion histories requiring no fine tuning and in which atmospheric heating by planetesimal accretion is unimportant. Whereas super-Earths/sub-Neptunes form in-situ in disks truncated by stellar magnetospheres --- this is supported by detailed occurrence rate profiles measured by Kepler --- super-puffs/sub-Saturns accreted their ~20%-by-mass envelopes farther out in their disks and migrated inward. We close by placing our work on atmospheric accretion into context with others on atmospheric loss.

10:20 - 10:40 Eiichiro Kokubo (NAOJ)

Title:	Orbital Architecture of Close-in Planetary Systems Formed by Giant Impacts
Abstract:	We investigate the in-situ formation of close-in terrestrial planets including super-Earths by giant impacts using N-body simulations. The goal of this study is to obtain the basic scaling laws of close-in terrestrial planet formation as a function of properties of protoplanet systems. We systematically change the system parameters of initial protoplanet systems and investigate their effects on final planetary systems. We find that in general non-resonant dynamically cold compact systems are formed. The orbits of planets are less eccentric and inclined and the orbital separations of adjacent planets are smaller, compared with those formed in the outer disk. These properties are natural outcomes of giant impacts in the inner disk. In the inner disk the ratio of the physical radius to the Hill radius is large, in other words, gravitational scattering is relatively less effective compared with that in the outer disk. Thus protoplanets are less mobile and accretion proceeds relatively locally, which leads to formation of dynamically cold compact systems. On average the system angular momentum deficit increases with the total system mass, while the mean orbital separation of adjacent planets decreases.

11:00 - 11:20 Masahiro Ogihara (NAOJ)

Title:	Formation of close-in super-Earths in a disk evolving via disk winds
Abstract:	We have investigated formation of close-in super-Earths from planetary embryos in a disk evolving via magnetically-driven disk winds by performing N-body simulations. It is recently revealed that the disk surface density obtains a positive profile in the close-in region ($r < 1$ au) with effects of disk winds. In this region, type I migration can be significantly suppressed. We demonstrate by N-body simulations that planetary embryos do not undergo significant migration and observed properties of close-in super-Earths (e.g., period-ratio distribution) can be reproduced. We also discuss effects of global gas flows on gas-envelope accretion onto super-Earth cores.

11:20 - 11:40 Shigeru Ida (ELSI)

Title:	Dependence of predicted exoplanet distributions on theoretical models
Abstract:	Orbital migration is one of the most important ingredients of planet formation theory. The conventional theoretical models are now being revised for both type I and II migrations. I will discuss how the exoplanet distributions predicted by population synthesis simulations depend on orbital migration models and how the observed exoplanet distributions are reproduced by the theoretical modeling.

14:00 - 14:20 Michiel Lambrechts (Lund Univ.)

Title:	Accretion of gas onto giant planets
Abstract:	Planets larger than about 5 Earth masses can acquire massive gaseous envelopes. For Super-Earths and ice giants envelopes are a 10%-fraction of the core mass, but for gas giants, like Jupiter, envelopes exceed 100 Earth masses. Despite this difference in envelope mass, it is generally accepted that all these giant planets form in approximately the same way. First the planet accretes a solid core, larger than several Earth masses.Subsequently, the core attracts a gaseous envelope. Here, we aim to improve our understanding of the gas accretion phase. In Lambrechts and Lega, 2017, we presented 3D radiative hydrodynamical simulations of the gaseous atmospheres around planets in the 5 to 15 Earth mass regime. These simulations show that gas from the disc is pushed through the outer envelope in less than a 100 orbital timescales. Such a steady-state gas flow implies that the rain out of opacity-providing dust can be prevented, pollution of the envelope may be hindered and the cooling efficiency of the interior envelop may be reduced. We estimate that gas giants require cores larger than about 15 Earth masses and disc opacities that are below 1 cm^2/g, at Jupiter-like orbits, in order to complete their growth in time. New, ongoing work, indicates that the rapid gas accretion gas giants experience, proceeds through quasi-static contraction of the interior envelope, not through dynamic infall. We will conclude with the implications or our work on formation scenarios for giant planets, paying specific attention to envelope pollution by sublimation of accreted solids.

14:40 - 15:00 Yasunori Hori (ABC/NAOJ)

Title:	Gas Accretion onto a Protoplanet During Planetary Migration
Abstract:	Close-in super-Earths are common among over 3,700 exoplanets. Most of them have low mean-densities, which means the existence of an atmosphere onto a core; if some of them possess hydrogen-rich, namely, primordial atmospheres, their atmospheres likely originated from a disk gas. Two ideas for the origin of short-period low-mass planets having atmospheres have been proposed so far: in-situ formation, including giant impacts, and Type I migration. Based on both scenarios, we have investigated a theoretical relationship between planetary mass/semi-major axis and the final mass fraction of a H2/He atmosphere accreted from a prtoplanetary disk. In this talk, we discuss whether observed super-Earths can have/retain the primordial atmospheres.

15:20 - 15:40 Hiroyuki Kurokawa (ELSI)

Title:	Suppression of atmospheric recycling of protoplanets in a protoplanetary disk by buoyancy barrier: implications for the formation super-Earths
Abstract:	Atmospheric recycling of super-Earths embedded in a protoplanetary disk has been proposed to avoid the runaway gas accretion. We conducted a detailed comparison between isothermal and non-isothermal 3D hydrodynamical simulations of the gas flow past a planet. We found that the recycling was suppressed in the non-isothemal case. We discuss the implication for the formation scenario of super-Earths.

Day 2

9:00 - 9:40 Jack Lissauer (NASA Ames)

Title:	Super-Earths & Sub-Neptunes in Multiple Planet Systems
Abstract:	Several hundred multi-planet systems are known, and the majority of the planets that have been found in these systems are larger than Earth yet smaller than Neptune. Studying these systems as a group has shown that most close-in systems of non-giant planets are nearly co-planar. Transit timing variations (TTVs) in many multi-planet systems have been used to derive masses of many planets in this size range, and suggests that for short-period orbits, the boundary between super-Earths and mini-Neptunes is ~ 1.6 Earth radii. The characteristics of several of the most interesting confirmed Kepler & K2 multi-planet systems will also be discussed.

9:40 - 10:00 Jiwei Xie (Nanjing Univ.)

Title:	Orbital Spacing Patterns of Kepler's Multiple Planet Systems: Constraints On Planet Formation
Abstract:	The Kepler space telescope has detected many exoplanets and revealed that multi-planet systems are common. In this work, we investigate the orbital configurations of multi-planet systems statistically. Our work focuses on the orbital spacing (quantified as the orbital period ratio) of adjacent planets in the same systems. Special attention is paid to special period ratios, ie., period ratios near Mean Motion Resonances (hereafter MMR). We find that MMRs and period ratios are not randomly distributed but reveal some intriguing patterns, providing constraints on the formation of Kepler planets (mostly Super-Earth and Neptune size planets).

10:20 - 10:40 Hui-Gen Liu (Nanjing Univ.)

Title:	Searching for the Transit of the Earth-mass Exoplanet Proxima Centauri b in Antarctica
Abstract:	Proxima Centauri is known as the closest star to the Sun. Recently, radial velocity (RV) observations revealed the existence of an Earth-mass planet around it. With an orbital period of ~11 days, Proxima Centauri b is probably in the habitable zone of its host star. We undertook a photometric monitoring campaign to search for its transit, using the Bright Star Survey Telescope at the Zhongshan Station in Antarctica. A transit-like signal appearing on 2016 September 8 has been tentatively identified. Its midtime, TC= 2,457,640.1990 ± 0.0017 HJD, is consistent with the predicted ephemeris based on the RV orbit in a 1σ confidence interval. Time-correlated noise is pronounced in the light curve of Proxima Centauri, affecting the detection of transits. We develop a technique, in a Gaussian process framework, to gauge the statistical significance of a potential transit detection. The tentative transit signal reported here has a confidence level of 2.5σ. Further detection of its periodic signals is necessary to confirm the planetary transit of Proxima Centauri b. We plan to monitor Proxima Centauri in the next polar night at Dome A in Antarctica, taking advantage of continuous darkness. Kipping et al. reported two tentative transit-like signals of Proxima Centauri b observed by the Microvariability and Oscillation of Stars space telescope in 2014 and 2015. The midtransit time of our detection is 138 minutes later than that predicted by their transit ephemeris. If all of the signals are real transits, the misalignment of the epochs plausibly suggests transit timing variations of Proxima Centauri b induced by an outer planet in this system.

10:40 - 11:00 Masashi Omiya (ABC/NAOJ)

Title:	Search for super-Earths and Earth-mass planets around low-mass stars using IRD/Subaru
Abstract:	We are planning to conduct a precise Doppler survey of late-M dwarf stars to search for super-Earths and Earth-mass planets. The survey aims detecting many super-Earths and Earth-mass planets around low-mass stars and understanding configurations of planetary systems with low-mass planets around low-mass stars. The targets of the survey, late-M dwarfs, are low-mass stars suitable to detect low-mass planets by the Doppler technique due to their low stellar masses and then relatively large amplitude of the stellar motion caused by the planets. However, the targets are faint in the optical band and relatively bright in the infrared wavelength. For the large survey of late-M dwarfs, we are commissioning a new instrument optimized to infrared precise radial velocity measurements for the Subaru telescope (InfraRed Doppler instrument, IRD) and we will start the large survey from 2019. According to a survey simulation based on a result of a population synthesis simulation and an observing strategy, we expect to detect more than 30 super-Earths and Earth-mass planets during the survey for five years. In this poster, we describe current status of the IRD project, strategy and simulated results of IRD/Subaru planet search program.

11:20 - 11:40 Elizabeth Tasker (JAXA)

Title:	Finding Patterns in Planets: A neural network approach to the exoplanet dataset
Abstract:	We now know of over 3,500 exoplanets; an explosion in growth since the 1990s that shows no sign of abating. More than 90% of these new worlds have been discovered by either the radial velocity or transit technique. Both provide only a single measurement of the planet's bulk properties: either its minimum mass or its radius. As we step into a new era of exoplanet observations, where instruments such as the JWST aim to probe the atmosphere of these worlds, we are left with using this scant information to select the best candidates for these time-intensive observations. However, while the information per planet is small, the number of discoveries allows the potential for meaningful statistical analysis. Correlations between the planet's bulk property measurements and characteristics of its star and orbit can be used to infer extra information. Although some relationships are obvious (for example, orbital period correlates with stellar irradiation), others may be missed due to a high dimensional dependence on multiple factors, or being outside current expectations of planet formation. Neural networks are a powerful tool to uncover correlations in multi-dimensional datasets, avoid pre-conceived biases and discover more complex trends. This research looks at one example of a neural network (namely a Boltzmann machine structure) for estimating the probability density of missing planetary properties using the available measurements. We present mass and radius estimates for planetary bodies observed by either the radial velocity or transit techniques and discuss how this tool can help guide target selection for future observations.

14:00 - 14:40 Ian Crossfield (MIT)

Title:	Toward an Observationally-motivated Unified Theory of Super-Earth Atmospheres
Abstract:	Planets smaller than Neptune are the most common exoplanets in the Galaxy, but beyond that fact we still know frustratingly little of their atmospheric compositions, chemistry, dynamics, and aerosols properties. I will review the current state of observations of this sub-class of planets, describe some initial hints at possible underlying trends in the population, and sketch the future prospects for studying these objects.

14:40 - 15:10 Norio Narita (Univ. of Tokyo)

Title:	Detections and Characterizations of Super-Earths in the TESS era with Japanese New Instruments
Abstract:	Super-Earths are very interesting targets for detailed studies in the upcoming TESS era. To discover new interesting super-Earths efficiently from TESS candidate planets, we have developed 2 multi-color simultaneous cameras, named MuSCAT and MuSCAT2. MuSCAT (Multi-color Simultaneous Camera for studying Atmospheres of Transiting exoplanets) is a 3-color simultaneous camera installed on the 1.88m telescope at Okayama Astrophysical Observatory in Japan, while MuSCAT2 is a 4-color simultaneous camera on the TCS 1.52m telescope in the Teide Observatory, Canaries, Spain. We will introduce the specifications of the instruments and initial results of MuSCAT and MuSCAT2 for super-Earths. We will also introduce a follow-up plan for super-Earths from TESS using MuSCAT/MuSCAT2 and a new precise RV instrument named IRD on the Subaru 8.2m telescope.

15:10 - 15:40 Akihiko Fukui (NAOJ)

Title:	Challenge in atmospheric observations of M-dwarf planets in optical wavelengths
Abstract:	Ongoing and planned surveys for nearby transiting planets, such as K2 and TESS, will increase the number of small planets that allow us to probe their atmospheres via transmission spectroscopy. In particular, the planets orbiting M dwarfs will be of interest because they show relatively large transit depths compared to those orbiting Sun-like stars. On the other hand, planned atmospheric observations will more focus on infrared rather than optical wavelengths, because M dwarfs are generally active and show large photometric variabilities in optical, which will make it difficult to extract the atmospheric information from optical observations. However, transmission spectra in optical region can provide rich information about the planetary atmosphere, particularly the effective atmospheric scale height through the effect of Rayleigh scattering. To extract the optical spectra of a planet, it is important to monitor the activity level of the host star in addition to the transmission observations of the planet. In this talk, I will introduce our planned multi-band monitoring + transmission observations of several known planets around nearby M dwarfs by using MuSCAT and MuSCAT2, the optical multi-band imagers recently developed for the 1.88 m and 1.52 m telescopes, respectively.

16:00 - 16:20 Yayati Chachan (Caltech)

Title:	On the Role of Dissolved Gases in the Atmosphere Retention of Super Earths
Abstract:	Low-mass low-density planets discovered by Kepler in the Super-Earth mass regime typically have large radii for their inferred masses, implying the presence of H - He atmospheres. These planets are vulnerable to atmospheric mass loss due to heating by the parent star's XUV flux. Models coupling atmospheric mass loss with thermal evolution predicted a bimodal distribution of planetary radii, which has recently gained some observational support. However, a key component that has been ignored in previous studies is the dissolution of these gases into the molten core of rock and iron that comprise most of their mass. Such planets have high temperatures (> 2000 K) and pressures (~ kbars) at the core-envelope boundary, ensuring a molten surface and a subsurface reservoir of hydrogen that can be 5 - 10 times larger than the atmosphere. We bridge this gap by coupling the thermal evolution of the planet and the mass loss of the atmosphere with the thermodynamic equilibrium between the dissolved hydrogen and the atmospheric hydrogen (Henry's Law). Planet masses, effective temperatures, initial surface temperatures and pressures are varied in the model. This atmosphere-interior coupling reveals that dissolved gases in super-Earths play a pivotal role in the longevity of planetary atmospheres. Dissolution in the interior allows the planet to build a larger hydrogen repository during the planet formation stage. The dissolved hydrogen outgases to buffer atmospheric mass loss. Thermal evolution and cooling of the planet also lead to outgassing because solubility goes down as the interior cools. Dissolution of hydrogen in the interior therefore increases the atmosphere retention ability of Super Earths. The study highlights the importance of including the temperature and pressure dependent solubility of gases in magma oceans and coupling outgassing to planetary evolution models.

16:20 - 16:40 Tatsuya Yoshida (Hokkaido Univ.)

Title:	The effect of radiative cooling on the hydrodynamic escape of a Martian proto-atmosphere
Abstract:	Most of the proto-atmosphere on Mars may have been lost by hydrodynamic escape. Previous numerical studies assumed that all of molecules were dissociated into atoms in the upper atmos- phere supposing that high EUV flux may dissociate molecules. However, it is likely that a significant fraction of molecules stays undissociated at least in the lower part of EUV absorption region. If infrared active molecules were included in the atmosphere, they may reduce the amount of atmospheric loss due to the radiative cooling, but its efficiency remains poorly understood. Here, we develop a 1D radiative hydrocode which includes molecular species, and analyze the effect of radiative cooling on the hydrodynamic escape of a proto-Martian atmosphere. We solve the one-dimensional time dependent inviscid fluid equations for a H2-CO atmosphere and obtain steady state solutions by long time integration. When the mixing ratio of CO is lower than 1%, the escape mass flux is not different from the result for the case neglecting radiative cooling. Under the low CO mixing ratios, the radiative cooling by CO in this region is suppressed because the gas temperature is kept low by adiabatic expansion. Thus, the radiative cooling little affects escape rate in these cases. However, as the mixing ratio of CO increases greater than 1%, the escape mass flux begins to decrease. At the same time, gas temperature increases gradually in the subsonic region with increas- ing CO mixing ratio. Hence, the radiative cooling by CO becomes significant in the subsonic region where gas acquires the energy for escape to space. As the mixing ratio of CO increases, the crossover mass also decreases. The crossover mass may become smaller than the mass of CO when the mixing ratio of CO becomes greater than ~15%. In such a case, only H2 may escape leaving behind CO in the proto-atmosphere.

16:40 - 17:00 Naoki Terada (Tohoku Univ.)

Title:	Atmospheric escape from terrestrial CO2-rich planets inside M-star habitable zones
Abstract:	We have investigated atmospheric erosion from non- or weakly magnetized terrestrial exoplanets with Venus-like CO2-rich atmospheres within close-in habitable zones of M-stars. We applied a magnetohydrodynamic (MHD) model of the solar wind interaction with Venus which was verified with in-situ observations from Venus Express and Pioneer Venus orbiters. The results of our study indicate that Earth- or Venus-mass and size exoplanets may experience high non-thermal stellar plasma induced escape which should have an impact on their habitability if they orbit inside HZs < 0.05 AU around EUV active dwarf stars. At such close distances, non- or weakly magnetized Earth-like exoplanets with CO2-rich atmospheres may lose atmospheres equivalent to several tens to hundreds of bar surface pressure. These values can be regarded as upper limits for the atmospheric erosion from super-Earths, although the stellar wind erosion from more expanded non-CO2-rich atmospheres should be much higher.

Day 3

9:30 - 10:10 Laura Schaefer (Arizona State Univ.)

Title:	Secondary atmospheres: composition and evolution during magma ocean phase
Abstract:	Secondary atmospheres form by outgassing of volatile components from the interior of a rocky planet or by impact degassing from large accreting planetesimals. In this talk, I will discuss previous work on the composition of gases produced from a range of initial planetary materials using proxies from the solar nebula. This gas compositional model is then tied to a model that includes core formation and magma ocean evolution to determine how the composition and oxidation state of the atmosphere evolves with the planet. The magma ocean oxidation state evolves as it crystallizes due to partitioning of redox-active elements between melt and crystal phases. The changing oxidation state of the magma ocean will alter the atmospheric composition due to atmosphere and mantle feedbacks.

10:10 - 10:40 Keiko Hamano (ELSI)

Title:	Temporal variations of thermal emission from a solidifying terrestrial planet
Abstract:	Theoretical studies predict that the final stage of terrestrial planet formation involves giant impacts between protoplanets. Giant impacts would have consequences for global melting of terrestrial planets and formation of a magma ocean. Detecting molten terrestrial planets in extrasolar systems is of great significance in testing the widely accepted view of their hot origins. Formation and evolution of planetary atmosphere greatly affects both thermal evolution and emission spectra of a solidifying planet via its greenhouse and blanketing effects. In this talk, I will discuss a trade-off relationship between spectral intensity and occurrence rate of molten planets, based on evolution of planetary atmosphere coupled with a magma ocean.

11:00 - 11:20 Roxana Lupu (BAER Institute)

Title:	Model Atmospheres for Volatile-Rich Hot Rocky Planets
Abstract:	We are building a versatile set of self-consistent atmospheric models to calculate the structure, composition, and spectra of hot rocky exoplanets in short period orbits. To date, more than 100 such hot rocky exoplanets have been confirmed, and they will form the majority of small planets in close-in orbits to be discovered by the TESS and Kepler K2 missions. These hot worlds offer the best opportunity to characterize rocky exoplanets with current and future instruments. We are using a fully non-grey radiative-convective atmospheric structure code with cloud formation combined with a self-consistent treatment of gas chemistry above the magma ocean. Being in equilibrium with the surface, the vaporized rock material can be a good tracer of the bulk composition of the planet. We are investigating both volatile-poor and volatile-rich compositions, with the volatile poor ranging from completely depleted, to water-free (Venus-like), to containing only sulfur and halogens (Io-like). To properly account for these exotic compositions and thermodynamic regimes, we are working on a self-consistent treatment of vertical mixing, condensation, and non-ideal gas behavior. We present our preliminary results for the atmospheric structure of hot, volatile-rich rocky planets. Our models will inform follow-up observations with JWST and ground-based instruments, aid the interpretation of transit and eclipse spectra, and provide a better understanding of volatile behavior in these atmospheres.

11:20 - 11:40 Yuichi Ito (Univ. of Tokyo)

Title:	Atmospheres of Volatile-free Hot Rocky Exoplanets: Theoretical Thermal Structures and Emission Spectra
Abstract:	Until today, over 1000 exoplanets whose radii are less than 2 Earth radii have been discovered. About 50% of those planets have substellar equilibrium temperatures high enough to melt and vaporize rock. Thus, if rocky like CoRoT-7b, they likely have atmospheres composed of rocky materials. Performing gas-melt equilibrium calculations, Schaefer & Fegley (2009) showed that the main constituents of the atmosphere are Na, O2, O, and SiO gas on magma without highly volatile elements. We call such an atmosphere a mineral atmosphere in this study. In addition, they showed that an atmospheric loss process such as the atmospheric escape and transport from dayside to nightside make the selective depletion of Na and K in the atmosphere and magma. Also, our 1-D hydrodynamic model of the highly UV-irradiated mineral atmosphere (Ito & Ikoma, in prep) suggested that the hydrodynamic escape of the mineral atmosphere is massive enough for the atmosphere to remove completely Na during the early stage of the host star. Thus, detection of a mineral atmosphere would provide definitive evidence that the planet is a rocky planet. Furthermore, identifying the mineral atmosphere composition may give constraints on the planet's bulk composition, evolution track and formation process. In this study, we focus on the temperature-pressure structure and detectability for emission spectra of the mineral atmosphere in hydrostatic equilibrium on a hot rocky super-Earth. Also, we investigate the impact of the selective depletion of Na and K on the thermal structure and emission spectra. In order to investigate it, we use the hydrostatic/radiative/chemical equilibrium atmospheric model for mineral atmospheres (Ito et al. 2015) which calculates the gas-melt equilibrium composition of the mineral atmosphere, vertical thermal structure and secondary eclipse depths. We show that thermal inversion structure is made in the atmosphere with Na and K for higher planetary equilibrium temperature, as also shown in Ito et al. 2015. We find that the thermal inversion structure for the mineral atmosphere without Na and K is hotter than that for the atmosphere with Na and K. And then, we find the atmosphere without Na and K has relatively strong spectral feature by SiO and non-spectral-feature by Na and K in the emission spectra. Our feasibility assessment demonstrates that identification of mineral atmospheres with and without Na and K on hot rocky super-Earths in secondary transit is possible via observation from space telescopes.

11:40 - 12:00 Renyu Hu (JPL)

Title:	A Thick Atmosphere on Super-Earth 55 Cancri e
Abstract:	One of the primary questions when characterizing Earth-sized and super-Earth-sized exoplanets is whether they have a substantial atmosphere like Earth and Venus, or a bare-rock surface that may come with a tenuous atmosphere like Mercury. Phase curves of the planets in thermal emission provide clues to this question, because a substantial atmosphere would transport heat more efficiently than a bare-rock surface. Analyzing phase curve photometric data around secondary eclipse has previously been used to study energy transport in the atmospheres of hot Jupiters. Here we use phase curve, Spitzer time-series photometry to study the thermal emission properties of the super-Earth exoplanet 55 Cancri e. We utilize a previously developed semi-analytical framework to fit a physical model to infrared photometric data of host star 55 Cancri from the Spitzer telescope IRAC 2 band at 4.5 µm. The model uses various parameters of planetary properties including Bond albedo, heat redistribution efficiency (i.e., the ratio between the radiative timescale and advective timescale of the photosphere), and atmospheric greenhouse factor. The phase curve of 55 Cancri e is dominated by thermal emission with an eastward-shifted hot spot located on the planet surface. We determine the heat redistribution efficiency to be ~1.47, which implies that the advective timescale is on the same order as the radiative timescale. This requirement from the phase curve cannot be met by the bare-rock planet scenario, because heat transport by currents of molten lava would be too slow. The phase curve thus favors the scenario with a substantial atmosphere. Our constraints on the heat redistribution efficiency translate to a photosphere pressure of ~1.4 bar. The Spitzer IRAC 2 band is thus a window into the deep atmosphere of the planet 55 Cancri e.

13:30 - 13:50 Yui Kawashima (Univ. of Tokyo)

Title:	Possible origin of diverse transmission spectra of warm transiting exoplanets: Growth and settling of atmospheric haze produced via UV irradiation
Abstract:	Recently, transmission spectra of several transiting exoplanets have been obtained. Transmission spectrum provides information of absorption and scattering by molecules and small particles such as hazes and clouds in the planetary atmosphere. Thus, comparison between the observational and theoretical transmission spectra can constrain the composition of the planetary atmosphere. Some of the recent observations, detected steep Rayleigh slope features in the visible and/or featureless spectra in the near-infrared, inferring the existence of haze in the atmospheres, which prevents us from probing the atmospheric molecular composition. Also, the transmission spectra are somewhat diverse: Some contain the Rayleigh slope features in the visible, some show molecular and atomic features. While a few studies addressed theoretical modeling of transmission spectra of hydrogen/helium-dominated atmospheres with the effect of hydrocarbon haze, they did not necessarily use physically-based values of the haze layer parameters (namely, the size and number density of haze particles and the altitude and thickness of the haze layer). In this study, to derive the physically-based distribution of haze particles, we develop a first self-consistent theoretical model for the creation, growth, and settling of hydrocarbon haze particles in hydrogen/helium-dominated atmospheres of close-in warm (< 1000 K) exoplanets. Also, with obtained properties of hazes, we model transmission spectra of the atmospheres to explore whether the recently-observed diversity of transmission spectra can be explained by the variation in the production rate of haze monomers. We find that the haze tends to spread in a wider region than previously thought and consists of particles of various sizes. We also find that the observed diversity of transmission spectra can be explained by the difference in the production rate of haze monomers, which may relate to the strength of UV irradiation from the host stars.

13:50 - 14:10 Kazumawa Ohno (Tokyo Tech.)

Title:	Microphysical Modeling of Mineral Clouds in Warm Super Earths
Abstract:	Recent observations of transmission spectra for super-Earths have revealed that many of them exhibit featureless spectra implying the presence of clouds and/or haze in high altitudes. The information about cloud vertical structure is necessary to interpret the observed spectra correctly. In this study, we investigate the vertical profiles of mineral clouds in super-Earths using a microphysical model that takes into account the vertical transport and growth of cloud particles in a self-consistent manner. We demonstrate that the vertical profiles of mineral clouds significantly vary with the concentration of cloud condensation nuclei and atmospheric metallicity. The cloud-top height increases with increasing metallicity as long as the metallicity is lower than a threshold. If the metallicity is larger than the threshold, the cloud-top height no longer increases appreciably with metallicity because coalescence yields larger particles of higher settling velocities. We apply our cloud model to super-Earth GJ1214 b that exhibits flat transmission spectrum. We find that the height of mineral clouds is too low to explain its flat transmission spectrum even if extremely high metallicity is assumed. This indicates that the presence of photochemical haze is a more natural explanation for GJ1214 b's flat spectrum; alternatively, the porous structure of cloud particle aggregates might help the mineral clouds ascent to higher altitudes.

14:30 - 15:00 Yuka Fujii (ELSI)

Title:	Climate of temperate rocky planets and their observational consequences
Abstract:	Terrestrial planets with surface liquid water attract attention for its relevance to the potential of life. Initial characterization of their atmospheres, especially for those around low-mass stars, are considered as one of the prime science goals of the upcoming James Webb Space Telescope and 30 meter-class ground-based telescopes. Many of such planets are likely to be synchronously rotating, and 3-dimensional climate modeling provides essential insights into the processes that may be important for interpreting future observational data. We discuss the climate of the planets with surface liquid water around low-mass stars based on our recent 3D modeling of atmospheres with GCM ROCKE3D. Special attention is paid to the water vapor profiles, since it affects the detectability of molecular signatures as well as the timescale of water loss, hence the evolution of habitable conditions. While the surface temperature of synchronously rotating planets tend to be stabilized by the substellar clouds, they are found to develop moist and warmer stratosphere while the surface temperature remains moderate, due to the interaction between water vapor transport and the near-infrared portion of the incident spectra. We discuss the implications for the observable features in transmission, thermal emission, and reflectance spectra. We also explore the dependence on the basic planetary parameters including mass and atmospheric pressure.

15:00 - 15:20 Ramses Ramirez (ELSI)

Title:	A Circumstellar Region for Rapidly-Rotating Super-Earth Ocean Worlds
Abstract:	Traditional definitions of the habitable zone assume that habitable planets contain a carbonate-silicate cycle that regulates CO2 between the atmosphere, surface, and the interior. Such theories have been used to cast doubt on the habitability of ocean worlds. However, Levi et al. 2017 have recently proposed a mechanism by which CO2 is mobilized between the atmosphere and the interior of Earth- to super-Earth-sized ocean worlds. At high enough CO2 pressures, sea ice can become enriched in CO2 clathrates and sink after a threshold density is achieved. The presence of subpolar sea ice is of great importance for habitability in ocean worlds. It may moderate the climate and is fundamental in current theories of life formation in diluted environments. Here, we test the Levi et al. 2017 mechanism and use latitudinally-dependent non-grey energy balance and single-column radiative-convective models to find that this mechanism can be sustained on ocean worlds that rotate at least 3 times faster than the Earth. We calculate the circumstellar region in which this cycle may operate for early - mid-M-stars and for our solar system. Our M-star planets have thick enough atmospheres and may be located far enough away from their host stars to avoid synchronous rotation. We predict C/O ratios for our atmospheres that can be verified by the JWST mission.