Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS21-P01 Room:Convention Hall Time:May 25 18:15-19:30

Fracture process inferred from fragment shape in impact disruption

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The results of the previous impact experiments show that the shape of the fragments, characterized by the triaxial dimensions a, b, and c, (a ? b ? c), behaves in a very regular way (e.g., Fujiwara et al. 1989). In widely different experimental conditions, the axial ratios, b/a and c/a, have distributions peaked at about each mean value, ˜0.7 and ˜0.5, respectively, and flattened (i.e., small c/a) fragments are almost absence.

We find that, if the distribution of the shape parameters, (b/a, c/a), is homogeneous, and there is no fragment at c?? <k, where k is a constant (0 <k <1; in Fujiwara et al. (1978) k was ˜0.2), the averages of the shape parameters, (0.7, 0.5) can be realized. Then, we discuss the fracture processes to represent the homogeneous distribution in the shape parameters. The expected dominant fracture process in impact fragmentation is reported.

Fujiwara, A., et al., Nature 272, 602-603, 1978.

Fujiwara, A., et al., in Asteroids II, pp. 240-265, 1989.

Keywords: impact, disruption, fragment shape, fracture process

PPS21-P02 Room:Convention Hall Time:May 25 18:15-19:30

Experimental study on collisional destruction of iron bodies: Temperature dependence

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Introduction: Iron meteorites are composed of iron-nickel alloys and most of them have unique crystalline structures known as Widmanstatten patterns. They undergo a transition from ductile to brittle behavior as the temperature is lowered. It is thought that they may have been derived originally from the cores of their parent bodies and so they may tell us the history of planetary formation.If the collisional destruction of cores of parent bodies occurred, fragments of them should be scattered as iron asteroids, but they have not been discovered yet. M-type asteroids may be iron asteroids but it is found that some of them have low density, and might be rubble-piles.We performed impact experiments and examined the temperature dependence of degree of disruption and fragment velocity in order to collect basic data for studying the possibility of formation of iron-rubble-pile asteroids.

Experimental method: We performed impact experiments using two different guns. Impact experiments with velocities of 0.6-1.2 km/s were performed using a powder gun at Kobe University and with velocities of 6.8-7.3 km/s were performed using a two-stage light-gas gun at the Institute of Space and Astronautical Science (ISAS). The projectiles were cylinders 15 mm in diameter machined from stainless steel or nylon spheres 7 mm in diameter. The targets were blocks of Gibeon iron meteorite or cylinders 25 mm and 35 mm in diameter machined from SS400 steel.We used room-temperature targets in the experiments using the two-stage light-gas gun, while we used room-temperature (298K) and low temperature (170-150K) targets in the powder gun-experiments.We compared the velocity distribution of fragments, fragment mass distribution and relationship between energy density and largest fragment mass fraction in low temperature and room temperature to examine the temperature dependence. We measured velocities of fragments using a high-speed camera. Additionally, we performed impact experiments using two targets with different aspect ratios (0.37 and 1) to examine the effect of target shape.

Results: We measured fragments with velocity 20-900 m/s and found that most fragments have velocities lower than the escape velocity of Psyche, i.e., 130 m/s. Temperature dependence is seen in the fragment mass distribution and the relationship between energy density and largest fragment mass fraction. The total mass fraction of SS400 steel fragments with mass less than 1 % of the initial mass accounted for 2.4-25 % of the initial mass at low temperature, whereas 0.12-18 % of the initial mass at room temperature. Energy density for destruction of targets with aspect ratio 0.37 is lower at low temperature than room temperature, which is not seen in previous studies.

Keywords: iron meteorites, impact, rubble-pile

PPS21-P03 Room:Convention Hall Time:May 25 18:15-19:30

Porosity of Granular Surface of Small Bodies - Relationship between Pressure and Porosity

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The Moon and many asteroids have regolith on the surface. Regolith can have various porosities and if we compress powder bed that has porosity, porosity is expected to decrease. Revealing the relationship between pressure and change in porosity makes it possible to estimate penetration depth of interplanetary dust particles or meteorites, and lander on asteroids. Porosity of planetesimals formed of dust aggregates is theoretically expected to 90 % (Kataoka et al., 2013). On the other hand, laboratory experiments show that surface of target constructed by such fluffy dust aggregates is compressed when impacted by sieved dust aggregates (Meisner et al., 2012). It is possible that porosity of planetesimals can be changed by impacts between planetesimals. Revealing their relationship is useful to estimate aggregate's porosity during the evolutional process toward planets.

First, it is necessary to determine porosity before compression. In this work, we focus on regolith on asteroids, i.e. granular bed accumulated under microgravity conditions. Porosity is determined by configuration of particles. Factors affecting regolith porosity are particle diameter, particle shape, interparticle force, and gravity. An empirical formula that include force ratio between interparticle force and gravity is presented (Yu et al., 2003; Kiuchi and Nakamura, 2014). However, this empirical formula is obtained by measurements under 1 G, so it is necessary to check if this formula can work under microgravity. Additionally, particle size distribution is not included in this formula. Regolith particle is not monodisperse because regolith is made up of impact fragments. So it is necessary to take effect of particle size distribution into account. Size distribution of impact fragments is usually represented as power-law. A geometric model has been proposed to estimate the porosity of granular bed that has close packing state (e.g. made by tapping) constructed by particles having power-law size distribution (Suzuki et al., 2001). However, porosity of loose packing state doesn't agree with the value predicted by the model. More studies for relationship between porosity of loose packing state and particle size distribution are needed to estimate initial porosity of regolith after deposition.

Second, we consider cases of impact or landing, i.e., when pressure is applied to regolith.

In this study, we conduct compression experiment of silica sand 1-3, of similar shape and different size distributions (median diameter is 13 μm, 24 μm, and 73 μm, respectively) fly ash (4.5 μm), fused alumina particles (5.3 μm), and basalt fragments smaller than 210 μm prepared by an impact experiment (29 μm) (hereafter called "basalt") using a centrifuge and compression testing machine.

We sieved them into a cylindrical container of diameter 5.8 cm and depth 3.3 cm (for basalt, diameter 2.7 cm and depth 1.4 cm) and the top part of the bed over the height of the container was leveled off. Silica sand 2 and basalt samples are resemble in median diameter, but porosities before compression are different, 58 % and 52 %, respectively. That means basalt has lower porosity. Power indices of cumulative volume fraction versus particle size are 0.53 and 0.78, respectively, so we obtained similar result with Suzuki et al. (2001): in the cases of loose packing state, porosity decreases with increase of the power index. We applied 1-18 G by the centrifuge or up to 106 Pa by the compression testing machine on the sample and determined porosity after compression from the sample volume obtained by bed height or displacement by compression.

In this presentation, we make a comparison between our result and existing powder compaction equations. In addition, we discuss about change in porosity by pressure and change in compressive strength by porosity in relation with particle size distribution.

Keywords: planetesimals, asteroids, porosity, powder and granular material

PPS21-P04 Room:Convention Hall Time:May 25 18:15-19:30

Impact experiments in viscous fluid: Implications to crater formation and viscous relaxation on cometary nuclei

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Introduction: A cometary nucleus is supposed to be composed of rocks, ices and organic matters, and comets could be one of the most primordial bodies in the solar system because cometary nuclei would have never experienced high thermal metamorphism to evaporate water ice from the interior since their formation. Thus, it is very interesting to explore the internal structure, but the direct observation of the interior is quite difficult. While the morphology of the impact craters on the surface of cometary nucleus is expected to reflect the internal structure, therefore, it is important to study the formation process of impact craters on the surface simulating the comet nuclei in order to clarify the internal structure of cometary nuclei. Several circular depressions on the surface of cometary nuclei were found by the space craft such as Stardust and Rosetta, but their morphology was quite different from those on the rocky bodies such as the Moon because of the viscosity of refractory organic matters constructing the surface layer. In this study, we carried out impact experiments on viscous fluids and examined the effect of viscosity on the crater volume.

Experimental methods: We did impact experiments by using the one-stage vertical He-gas gun at Kobe University. We prepared a target by mixing glucose syrup with water, and the viscosity was controlled from 10^{-3} to 47 Pas. A projectile was a disk-shaped agar with the diameter of 10 mm and the thickness of 5 mm. We chose the agar as a projectile material because we'd like to study the effect of projectile destruction at impact. The projectile velocity was a constant of 65$\pm$15 m/s, and the impact experiments were carried out under the air pressure. The cratering phenomena were observed by a high-speed camera, and we analyzed the crater depth changing with the time and the crater maximum diameter.

Result: We measured the time change of the crater depth and diameter by using the video images, and examined the effect of viscosity on these sizes. First, we found that the crater depth increased with the increase of time, and it became the maximum at a certain time. So we calculated the crater volume by using the maximum depth and the diameter measured at this time. In this study, we examined the relationship between the non-dimensional crater volume, π^{1*}=(Vρ/m)$\cdot$(1.61gD$_p$/u^2)^a (V: crater volume, ρ: target density, g: gravity, D$_p$: target diameter, u:velocity, a: constant), and the non-dimensional viscosity, π^{2*}=(η/(ρD$_p$u))$\cdot$(1.61gD$_p$/u^2)$^{(a-1)/2}$ (η: viscosity). As a result, the π^{1*} became constant, irrespective of the viscosity at small π^{2*} (gravity regime), while the π^{1*} decreased with the increase of viscosity at large π^{2*} (viscous regime). Fink et al. (1984) showed the similar behavior, so we can say that this trend did not depend on the impact velocity. But our π^{1*} was relatively smaller than that of previous works and the power of the fitting line by using the power equation in viscous regime was larger than that of previous work.

Next, we calculated the relaxation time as the duration from the time when the crater depth became the maximum to the time when the depth becomes 1/e times as large as the maximum. As the result, the relaxation time was larger with the increase of the viscosity. We calculated the theoretical relaxation time by using the equation of t$_R$$\cong$8$\eta$/($\rho$gD$_c$) (D$_c$: crater maximum diameter), and compared this theoretical values with our results. As a result, our experimental results were larger than the theoretical values as the viscosity became larger.

Keywords: impact crater, cometary nuclei, viscosity, relaxation time

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Tensile, crushing, and impact strength and their relationships for chondrules and other rock samples

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There are different scenarios for chondrule formation. Chondrules are thought to be captured into chondrites after their formation, then underwent collisional and thermal evolutions. Beitz et al. (2013) studied the relationship between pressure and porosity based on impact compression experiments of simulated chondrite samples. They showed that the maximum pressure which chondrite parent bodies experienced can be estimated from the tensile strength of chondrules and the fraction of intact chondrules. However, the tensile strength of chondrules is not known. Therefore we started to estimate the tensile strength of chondrules in order to discuss the maximum pressure chondrite parent bodies experienced.

The strength measurable for chondrules is crushing strength of spherical samples. Generally, tensile strength is measured using shaped samples, while it is difficult to shape chondrules. In stead, we estimate the tensile strength from the crushing strength of chondrules assuming that the relationship between these strengths of other samples can be applied to those of chondrules.

Static compression experiments of about 30 chondrules showed that the crushing strength of chondrules is around 8 MPa (Shigaki & Nakamura, Fall meeting of The Japanese Society for Planetary Sciences 2014). It is shown from the measurement of the strength of dunite samples that crushing strength and tensile strength are almost equivalent. Furthermore, we tried to estimate the crushing strength from impact strength. Using the results of impact disruption experiments of chondrules (Ueda et al., 2001), we found that the crushing strength of chondrules might possibly be stronger (~30MPa). The inconsistency of the values of crushing strength can be due to different relationships between these strengths for different silicate materials.

In this study, we employed more variety of rock samples to examine their tensile, crushing, and impact strengths and their relationships, in order to obtain more reliable tensile strength of chondrules. We prepared disk and spherical samples of dunite, basalt, Berea sandstone, and tuffaceous sandstone. While chondrules were removed from Allende (CV3) specimens in the previous experiment using tweezers and files, we separated them from matrix by means of Freeze-thaw method. We will perform impact experiments of chondrules onto a stainless steel plate to obtain the impact strength of chondrules.

In this presentation, we will introduce our results of all samples used so far and discuss the tensile strength of chondrules estimated from the relationships of these strengths for the different silicate samples.

Keywords: chondrites, chondrules

PPS21-P06 Room:Convention Hall Time:May 25 18:15-19:30

The inclination evolutions of protoplanets through giant impacts

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The Kepler mission has reported over 3500 planetary candidates (e.g., Batalha et al., 2014).

There are 899 transiting planet candidates in 365 multiple-planet systems, and 333 systems are only composed by 818 ungiant candidates, whose radii are smaller than 6 Earth radius, and which are composed by Neptunes and super-Earth.

When multiple planets are detected by the transit method, the mutual inclinations can be estimated by the ratio of transit duration times.

Fabrycky et al. (2014) suggested that the typical mutual inclination between Kepler candidates in multiple-planet systems lies in 1.0 degree - 2.2 degree.

Inclinations of protoplanets are excited by the mutual scatterings between them.

It is expected that protoplanets can excite the inclinations up to the half values given by their escape velocities.

The excited inclination is estimated as i_{esc} = 5.4 degree for a 10 Earth mass planet at 0.1 AU.

The small inclinations of observed ungiants suggest that if they are formed in-situ accretion, some inclination damping mechanism is working.

Since the eccentricities of the merged protoplanets are damped through giant impacts between protoplanets, as pointed out by our previous study, the inclinations is expected to be damped by the giant impacts.

On the other hand, for a Earth mass planet at 1 AU, i_{esc} = 8.6 degree.

The resultant planets from N-body simulations in the giant impact stage normally have i = 3 degree without any damping forces (e.g., Kokubo et al. 2006).

Ths smaller inclinations of calculated planets also suggest that inclinations are damped through the giant impact.

We investigate inclination evolutions through the collisions in the giant impact stage by N-body simulations.

We find that the inclination of the merger body is smaller than the larger inclination of the colliding two protoplanets.

The inclination after a collision is expressed as the function of the mutual inclination and the angular momenta.

Our N-body simulations suggest that the inclinations of observed ungiant planets can be reproduced by the in-situ accretion of planets in the gas-free environment.

Keywords: planetary accretion, giant impact phase, inclination

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The formation probability of the binary planet

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Binary planet is a system in which two planets revolve around a central star while rotating around each other. In the case of gaseous planets, a planet can capture the other planet by the tidal force when they closely approach during the planet scattering process. We study the closest distance between the planets during the scattering phase and determine the probability of binary planets formation.

It is known that the amount of energy dissipated by dynamical tides significantly depends on the distance between the planets. For two planets to be captured as a binary planet, it is necessary that the planets approach within several times of their physical radii. How multiple planets approach can be calculated only by mutual gravitational interactions, regardless of the details of the tidal model. In addition, the encounters of planets do not occur continuously unlike the encounter of the central star and the planet. Previous studies suggest that the formation of binary planets takes place immediately after the start of the orbital instabilities. We stop our calculations by 10000 Keplerian orbits, but perform 10000 simulations, which allow the statistical discussion. We compare Jacobi integral and the tidal energy to be dissipated at their closest encounter.

Results of our simple approach are almost consistent with the previous study, which performed orbital calculations including tidal dissipations (Ochiai et al. 2014). We find that the probability of binary planet formation was about 10%, independent of the semi-major axis. We vary the strength of tides as a parameter. We find that when the tidal dissipation is four times stronger, the formation probability of the binary planet becomes approximately two times larger. The probability of formation becomes 1/4 when the tides are 1/4.

Keywords: binary planet, N-body simulation

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Transmission spectrum models of exoplanet atmospheres with haze: Effects of growth and settling of haze particles

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Since the first discovery of an exoplanet in 1995, detection of more than 1500 exoplanets has been reported. Recently, in addition to detection, multi-wavelength transit observations have been done to characterize detected exoplanets. From a decline in apparent stellar brightness due to a planetary transit, we can measure the planetary radius. Also, the observed wavelength-dependent radius (which is often called the transmission spectrum) provides the information of absorption and scattering of stellar light by molecules in the planetary atmosphere. Thus, the composition of the planetary atmosphere can be constrained by comparison between the observational and theoretical transmission spectra. The constraint on atmospheric composition is expected to give an important clue to the origin of the planet.

Until today, transmission spectra of 20 exoplanets have been obtained. Some of the recent observations detected flat or featureless spectra, inferring the existence of particles such as hazes floating in the atmosphere. This means the existence of hazes would obscure the predicted spectral features of molecular absorption, making it difficult to prove its atmospheric composition. Also, the transmission spectra seem to be somewhat diverse. Some contain the Rayleigh-slope feature in the visible, some show molecular and atomic features in the near-IR. These observational facts raise questions such as how common hazy atmospheres are beyond the solar system, how diverse transmission spectra of hazy atmospheres are, and how much information of atmospheric composition one can obtain from hazy atmospheres.

There are a few theoretical studies of transmission spectra of exoplanet atmospheres that consider the effect of haze in the atmosphere (e.g., Howe & Burrows 2012; Morley et al. 2013). However, the models of haze are ad hoc; they treated the size, number density, and vertical distribution of haze particles as parameters. While they found parameter ranges in which the theoretical transmission spectra match the corresponding observations, they did not discuss if the viability of those haze properties is physically supported.

In this study, to derive realistic properties of hazes in the atmospheres of transiting exoplanets, we have developed a new theoretical model that considers the creation, collisional growth, and settling of haze particles. Also, with obtained properties of hazes, we have modeled transmission spectra of the atmospheres, using the numerical code that we developed previously. We have found that the haze particles tend to distribute in a wider region than previously thought and that haze particles of various sizes are formed in the atmosphere, which in general yield flat spectra. Simulating the transmission spectra for wide ranges of parameters concerning haze such as atmospheric composition, temperature, and UV irradiation from the host star, we constrain the parameter ranges that result in observed features in the transmission spectra. We also find the parameter ranges that show features of molecular absorptions in the spectra without being obscured by haze, making it possible to derive the information of the atmospheric composition from the observation of the transmission spectra.

Keywords: exoplanets, transits, transmission spectrum models, atmospheric composition, haze

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The possibility of the homogeneization of the isotopic ratio in the primordial solar nebula

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Introduction:
Star and planetary systems are formed through gravitational collapse of molecular cloud cores. Since molecular clouds consist of materials from various super novae and red giant stars, it is naturally considered that dust particles in molecular cloud cores have various isotopic ratios. On the other hand, it is known that solid materials in our solar system, especially materials of the Earth, moon, mars, and meteorites, have almost identical isotopic ratios. To homogenize isotopic ratios in solid materials, it seems that the material should be evaporated completely once, mixed well, and re-solidified. So, the homogeneous isotopic ratio in the current solar system suggests that our solar system experienced some massive evaporation events in its formation phase. However, it is not well understood which process can be responsible for such a high temperature event in the solar nebula.

Goal of this study:
We clarify if the homogenization of the isotopic ratio among all the solid materials in the solar nebula can be realized in the course of the formation and evolution of the solar nebula.

Model:
We suppose a molecular cloud core whose mass is one solar mass. The core is assumed to rotate rigidly and to consist of gas and dust particles. Dust particles have various isotopic ratios, but they are mechanically well mixed in the core.The collapse of the molecular cloud core, and the following formation and evolution of the solar nebula are modeled based on Cassen & Moosman (1981). Landing places of infalling materials from the core is estimated depending on the angular momentum. Turbulence is present in the solar nebula and the viscous torque due to the turbulence works. Also, the gravitational torque produced by the self-gravity of the solar nebula is taken into account (Nakamoto & Nakagawa 1995). The motion of dust particles relative to the gas is calculated using the turbulence diffusion model (Wherstedt & Gail 2002). The temperature of the solar nebula is obtained based on the balance between the viscous heating and the radiative cooling. The model parameters are the initial temperature and the angular velocity of the molecular cloud core.We assume that dust particles evaporate completely at the temperature of 2,000 K, and when the gas temperature becomes less than that, isotopically homogeneous dust particles are produced.

Results:
The temperature of the solar nebula becomes a decreasing function of the distance from the Sun. So, when the initial temperature of the core is high, and the initial rotation velocity of the core is low, the radius of the solar nebula becomes small and the fraction of isotopically homogeneous dust particles becomes high. For example, almost all the solid materials in the solar nebula becomes isotopically identical, when the initial temperature of the core is 15 K and the angular velocity is (2-3)x10ˆ14 sˆ-1.

Discussion:
According to observations, angular velocities of molecular cloud cores are around from 10ˆ-14 sˆ-1 to 10ˆ-13 sˆ-1 (Goodman et al. 1993). So, it is implied that the molecular cloud core that formed our solar system might have a smaller angular velocity compared to typical values. This may be consistent with a fact that our Sun is a single star: it is shown that molecular cloud cores having higher angular momentum tend to form binary systems, while those having lower angular momentum tend to form single star (Matsumoto & Hanawa 2003).

Conclusions:
We investigated the formation and evolution of our solar nebula following the gravitational collapse of the molecular cloud using numerical simulations. And we found that isotopic ratio of solid materials in the solar nebula can be completely homogenized, if the radius of the solar nebula is small enough due to the high temperature or the low angular velocity of the initial molecular cloud core.

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Origin of the Great Red Spot and Formation of Moon and Earth's deep ocean-floor caused by Collision of mantle asteroid

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1. Multi-impact hypothesis: MI is a new hypothesis to the moon and the planet Earth evolution is the answer to the unified understanding of the ***"Earth and Moon and Solarsystem of Mystery"***

(1). "Origin hypothesis of the moon and the deep Ocean-floor bottom by a multi-impact" was proposed

a new collision mechanism to Earth's mantle piece. The differentiated Mars size of primitive planetichiusu Bourdais'law that has not been proven, was formed in the asteroid belt position.

Why was broken by perturbing tidal forces of Jupiter and flattening of the orbit of primitive planet CERRA by whether? = Jupiter perturbation **protoplanetary CERR**A was desripted.

(2). "Giant planet collision hypothesis: GI (Cameron etc.)" Problems me was discussed below.

The differentiated Mars size of primitive planet, due to the collision (**on chance of good luck**) from the revolution surface obliquely backward. = Impossible.

In hypothesis that forms the moon of only mantle component, it is not possible to explain the Earth's evolution and current status. = **Just only** a hypothesis for the origin of the moon.

2. Comparison of the two hypotheses ∗∗∗∗MI Multi-Impact collision ∗∗∗∗vs ∗∗∗∗GI Giant Impact collision ∗∗∗∗

(1). The impact velocity at the time of moon formation

∗∗∗∗MI. ***(12.4km/s , 36.5 degrees)*** ∗∗∗∗vs ∗∗∗∗GI. (**0~8km/s**: the most die about 30 degrees) ∗∗∗∗

(2). In Collision energy ∗∗∗∗MI (8.01 $*10^{30}$J). ∗∗∗∗vs ∗∗∗∗GI (2.05 $*10^{31}$J) = **about 2.56 times as MI** ∗∗∗∗

(3). Collision probability ∗∗∗∗New Mechanism by nature ∗∗∗∗vs ∗∗∗∗Non-Mechanism by Extremely small chance ∗∗∗∗

(4). time mechanisms ∗∗∗∗***about 4 billion years ago*** ∗∗∗∗vs ∗∗∗∗**about 4.6 billion years ago** ∗∗∗∗

3. It is possible unified understanding of ***the effect of multi-impact hypothesis*** ∗∗∗∗to **"Earth and moon of mystery."** ∗∗∗∗

(1). Whether **the five times biological large extinctions** have occurred in the earth ?

It is caused by the multiple of debris has collided to Earth.

(2).Why **large extinctions** of five degrees or more of the organism species occurs at the Earth?

Due to ***the collision of the multi-impact hypothesis.***

(3). Why undifferentiated chondrite and stony achondrites, stony-iron meteorites and Iron meteorite are ***mixed in the meteorite***?

The cause is the Multi-Impact the cause.

(4). Why asteroid belt was not accustomed to planet(formerly theory)?

Itokawa than crustal fragments that was differentiated?

(5). Platetectonics of ***Plate boundary formation***, I suggested

"The origin hypothesis of ***crust flaking*** and ***deep ocean-floor formation***.".

(6). Why, Earthquake belt of the Pacific Rim is formed, whether the back-arc and trench has been formed?

(7). The origin of continental drift and the deep ocean floor,

I was elucidated the mystery of the driving force. ***Driving force = eccentric moment of inertia.***

(8). ***Why diamond pipe has been formed*** in the South African Premier and Russian Mirunu˜i district?

Continental drift and after collisions of Hawaii position,

collided with the opposite side of the Drake Passage of Mirunu˜i mine, Antarctica is I was stabilized to move.

(9). Why earth's axis is **tilted even 23.5 degree** from the revolution surface ?

The reason for this, it was estimated that ***the collision of the Drake (high latitude) CERRA division piece to the position.***

(10). ***Why the Earth's core eccentricity (about 10%) has occurred?***

Earth's mantle by CERRA debris collision to the Pacific Ocean position ***is missing***, is due to ***Isostasy to complement it***.

(11). The new hypothesis to ***the origin of the Jupiter's Great Red Spot*** , Why is it ? How is it ?

∗∗∗The world's first the new hypothesis ∗∗∗

(12). Although other outer planets are made of gas and ice. Why Pluto is or silicate dwarf planets?

In this way, the origin of Moon and the Earth evolution according to the multi-impact hypothesis,

serves the interpretation the future of **unified** understanding.

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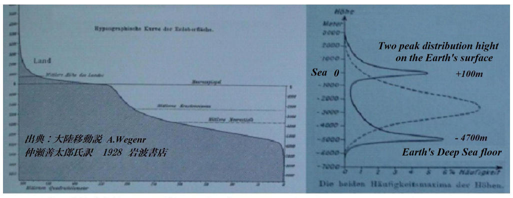
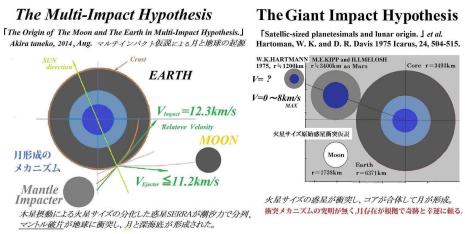
Keywords: The CERRA tide division by Jupiter perturbation, Collision of the Earth, Moon formation, Formation of Earth's Deep Oceanflooor, Origin of the Great Red Spot, Origin of the asteroid belt and the meteorite





PPS21-P11 Room:Convention Hall Time:May 25 18:15-19:30

A one-dimensional cloud model for Earth-like exoplanets and its stationary solution

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Exoplanets which have flat transmission spectrum are observed in recent years. It is thought that there are two possibility of reasons with flat spectrum. First, it is the case that the exoplanet has an atmosphere which is high average molecular mass. In this case, there are no absorption lines because atmospheres are concentrated at low levels. Second, optical thick clouds cause flat spectrum because clouds disturb starlight. It is difficult to distinguish these two cases, so it is important to predict optical properties of clouds on exoplanets.

There is a prior model of exoplanet's clouds Zsom et al.2012. This model considers microphysics of condensation, on the other hand location of cloud top and sweeping process by rain droplets are free parameters. However, this model has a problem that optical properties of clouds strongly depend on these free parameters.

The main goal of this research is to develop a self-consistent microphysical cloud model for 1D which contains not only microphysics of condensation but also microphysics of coalescence by cloud droplets and rain droplets. We present a self-consistent microphysical cloud model for 1D atmosphere calculating revolution of cloud droplets and rain droplets to consider coalescence process. Furthermore, our cloud model introduces a physical parameter which is updraft velosity, on the other hand location of cloud top and sweeping process by rain droplets are automatically determined.

We apply this model to Earth and obtain the following results. Quiet atmospheres (updraft velocity is less than0.1m/s) and clean atmospheres (number density of cloud condensation nuclei is less than10cm^{-3}) can make optical thin cloud. These results are caused by decreasing cloud droplets by downturn of cloud top, coalescence process and sweeping process by rain droplets. Furthermore, we reveal that rain droplets sweep 70% cloud droplets. These results which argue the possibility of forming optical thin clouds on exoplanets are new results which we can get by considering location of cloud top and coalescence process.

Our cloud model enables to determine the vertical distribution and optical propertiesof exoplanetary clouds as a function of physical atmospheric parameters. The development of this research is to estimate an impact of exoplanet's cloud on transmission spectrum.

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PPS21-P12 Room:Convention Hall Time:May 25 18:15-19:30

Semi-analytical estimation of the ocean tide on the early Earth

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We have investigated the ocean tide on the early Earth using semi-analytical method. The tidal force of the Moon exerted on the Earth is considered to have been an order of magnitude larger at the early time than at present, since the Earth-Moon distance was smaller (Goldreich, 1966). Abe et al (1997) and Abe and Ooe (2001) performed numerical simulation of the early Earth's ocean tide, estimating amplitudes of $\sim$0.1 m for three uniform depths of the ocean (1000 m, 2600 m and 4200 m). They pointed out that such small amplitudes are caused by the difference of periods between the early Earth's rotation and the free oscillation of the ocean. This result is important to study the ancient surface environment on the Earth. However the accurate ocean depth on the early Earth has not been established yet, although it could be several times as large as the current. The free oscillation of a thin layer of the ocean with a certain constant depth over the Earth can be described with Laplace's tidal equations. Longuet-Higgins (1968) numerically solved the Laplace's tidal equations, showing the relation between the eigenfrequency and Lamb's parameter. Based on his results, we have derived semi-analytical expression for the relationship between the ocean depth and the Earth's rotation period as possible resonance of various oscillation modes. If the Earth's angular velocity have changed in a range of 1 — 4.8 times relative to the present value, the ocean depth for the resonance is estimated to be 17 — 420 km for P_2^2 mode, 0.5 — 13 km for P_3^1 mode, and 18 — 480 km for P_3^3 mode. These results indicate that semidiurnal mode (P_2^2) would have been very small as shown by previous studies, unless depth of the early ocean was more than six times greater than the current. However P_3^1 mode could be larger than P_2^2 mode due to resonance during the orbital evolution of the Moon, although the amplitude depends on attenuation due to eddy viscosity of the ocean.

Keywords: Ocean tide, Dynamical evolution of earth-moon system, primitive Earth, eigenfrequency, eigenfunction, tidal force

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The attenuation behavior of shockwaves induced by hypervelocity impacts investigated using the iSALE shock physics code

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The dominant geographical features on airless planets and/or satellites are impact craters. Such craters are an evidence that planets and satellites suffered a numerous number of hypervelocity impacts during their histories. The kinetic energy of an impactor is transferred into a target body as a strong shockwave, leading to phase changes, including vaporization, melting, and the transition into a high-pressure phase, and characteristic feature by fracture, i.e., shutter cones. Quenched high-pressure minerals and the impact-induced geological features in strata on the Earth provide us useful information to investigate the surface history of the Earth. Recently, such high-pressure minerals have found from the Apollo rock samples and meteorites by new techniques for analyses. A physical model, which describes shockwave attenuation after a hypervelocity impact under a wide range of impact conditions, is necessary to investigate the impact history on such small bodies based on such shock indicators. However, the impact outcomes on such small bodies have not been fully understood because the effects of surface gravity, porosity, strength, and temperature profile on the shock propagation into a target body have not been studied well.

In this study, we conducted a series of numerical calculations using the iSALE shock physics code to investigate the shock attenuation under a various impact conditions. We are able to numerically solve the attenuation behavior of an impact-generated shockwave due to an interaction between the shockwave and a rarefaction wave from a free surface by using the iSALE. In addition, iSALE includes various material models, including granular materials, rocks, and metals, and a porosity compaction model. Thus, iSALE is highly suitable for our purpose. We obtained preliminary results as described following; (1) the target porosity significantly enhances the degree of the shock attenuation, (2) the degree of the shock attenuation for visco-elast-plastic bodies is larger than that for an inviscid fluid, (3) the internal friction of the target material changes the wave profile of the shockwave, (4) a higher target temperature leads to a higher degree of the shock attenuation. We are planning to construct the physical model based on a number of numerical results under a wide range of impact conditions.

We gratefully acknowledge the developers of iSALE, including Gareth Collins, Kai Wūnnemann, Boris Ivanov, Jay Melosh, and Dirk Elbeshausen.

Keywords: Hypervelocity impacts, Shock propagation, High-pressure minerals, Shutter cones, Shock physics code

PPS21-P14 Room:Convention Hall Time:May 25 18:15-19:30

Development of Compressible and Non-Expanding Fluid Solver for Simulation of Impact and Penetration Dynamics

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An impact probe called penetrator is expected to play an important role in the exploration of the interior of an object in the solar system, especially at a low-cost small mission. To realize the penetrator mission, the analysis model of the penetration dynamics must be established. The fact that the force model based on the Newtonian theory for the aerodynamic prediction of hypersonic flying objects is still effective not only for a penetrator into the regolith (Suzuki, et al., 20th ISTS, 96-i-02V, 1996) but also for that into ice (Suzuki, et al., 30th ISTS, 2015, to be presented) implies that the motion of soil particles or fragmented ice pieces can be macroscopically described in a framework of fluid dynamics. Unlike well-known compressible gas, expansion does not occur at unloaded state or exposure to the vacuum. In the present study, for the purpose of the numerical simulation of impact and penetration dynamics, we consider the compressible but non-expanding fluid (hereinafter referred to as CNEF) model, and the Riemann solver is developed for it.

For the numerical analysis of impact problems, the SPH (Smoothed Particle Hydrodynamics) method is often used with some appropriate fluid dynamics model. Though numerical instability of the SPH method can be overcome by applying Godunov scheme (Namba, et al., CFD symposium, D02-2, 2014), particle-based methods still have problems in computational efficiency and description of rigid surfaces. Consequently, we use the finite volume method with the Godunov scheme for numerical simulation of CNEF flows.

To avoid the appearance of expansion waves in a CNEF flow, we assume that the pressure increases with the density only at loading and it instantaneously becomes zero without changing the density at unloading. By using such pressure model, the CNEF only allows the formation of shock waves. Expansion waves are not formed at all. Instead, it allows for the void (or vacuum) to be formed in a flow. Neglecting the effects of viscosity and diffusivity for simplicity of analysis, the dynamics of a CNEF flow is described by the inviscid Euler equations combined with the above pressure model. It should be noted that the pressure is not a quantity of state any more, because it depends on the path of the process. To consider the presence of a void in a flow, the VOF method (Hirt, C. W. and Nichols, B. D., J. Comp. Phys., 39, 1981) is used.

For the numerical simulation of a CNEF flow with the finite volume method and the Godunov scheme, the Riemann solver is necessary. At present, we have found four types of the fundamental solutions: a) translational motion of the fluid in vacuum, b) a pair of running shock waves formed at the collision between two lumps of fluid, c) formation of unloaded zone at a rear-end collision, and d) separation between a quicker front runner and a slower second runner. We have analytically obtained the fundamental solutions assuming that the pressure linearly increases with the density at loading. The numerical results for the test problems on the one-dimensional collision show that after the collision, two lumps of fluid are combined into a single lump without formation of expansion waves as expected for the CNEF model. For the future works, all the fundamental solutions for the Riemann problem of CNEF should be mathematically confirmed, and the CNEF model should be improved to be suitable for actual impact dynamics problems.

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Keywords: impact, numerical simulation, fluid dynamics, Riemann solver

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1-D Plane Parallel Shock Waves of Dust-Gas Mixed Fluid: For Simulations of Chondrule Forming Planetesimal Bow Shocks

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Chondrules are millimeter sized silicate composition spheres that are the dominant component in most chondritic meteorites. It is considered from experiments and measurements that chondrules experienced flash heating events and melting/re-solidification in the early solar nebula. The shock wave heating model is one of the most viable models for chondrule formation. And we think that eccentric planetesimals are the source of shock waves in the solar nebula.

Planetesimal bow shocks for chondrule formation have been studied by some work (e.g., Boley et al. 2013, Ciesla et al. 2004). In those works, the dust-to-gas mass ratio was considered to be around the standard solar value, which is about 1:100. On the other hand, based on petrological studies, it is considered that the partial pressure of oxygen in the gas around the molten chondrules was considerably higher than the canonical value. If the oxygen in the gas is supplied from evaporated dust particles, the initial dust-to-gas mass ratio is estimated to be 1:1 or 10:1 (Jones et al. 2000). When the dust-to-gas mass ratio in the fluid is high enough, physical and chemical effects of dust on the flow would not be negligible. So, in order to investigate the chondule formation by shock waves in the dusty condition, we need to carry out hydrodynamical simulations with high dust/gas mass ratio.

In this study, first, we examine 1-D plane parallel shock waves of dust/gas mixed fluid with high dust/gas mass ratio. Especially, we clarify a relation between physical quantities behind the shock waves and the dust/gas mass ratio. Then, for our future study, we develop a numerical code to simulate the dust rich fluid. We assume that the size of dust particles is small enough so the motion and the temperature of dust particles are the same with those of the gas. We also assume that the dust particles evaporate completely when their temperature exceeds 2,000 K.

First, we analytically obtain the relation of the temperature, density, velocity, and the pressure between before and behind the shock wave, when the energy transfer is not taken into consideration (adiabatic case). When the dust particle is not incorporated in the fluid at all, this relation is known as the Rankine-Hugoniot relation. And we extend the relation so that the effects of dust particles are taken into account. According to the relation obtained here, we found that the density, pressure, and the velocity behind the shock do not depend on the dust/gas mass ratio, the temperature rises as the dust/gas mass ratio increases. These dependences can be understood based on the mass and the momentum conservation. The temperature behind the shock is an increasing function of the dust/gas mass ratio, because the gas number density behind the shock becomes lower as the dust/gas mass ratio increases, but the pressure should be the same, so the temperature should be higher.

Second, we carried out numerical simulations of 1-D plane parallel shock waves using the numerical code developed for this study. We found that numerical results are in a good agreement with analytical solutions. Thus, we think that the developed numerical code is applicable for for future simulations that include 2-D geometry and radiative energy transfer.

Keywords: chondrule, shock wave, hydrodynamics simulation

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A numerical simulation on diurnal thermal waves of an asteroid surface with detailed topographical model

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The numerical-shape model of asteroid Itokawa is available to perform the combined calculation of thermo physical state of a planetary surface in surface topography and thermal inertia. The spatial resolution of numerical shape model for a thermal observation in a future exploration will require the appropriate scale of the surface topography to explain the observed data in physically meaningful manner, which will determine the issue of understanding of the thermo physical state of asteroids. The thermo physical modelings for spherical planet including lunar and mercury are successful for explaining observational results with spatial resolutions. However the classical thermal models for ground based observation to explain the light curve of point of light asteroid fails to explain the spatially-resolved monitoring images that contains the distribution of surface temperature in thermal infrared wave length. The new thermo physical modeling style needs constructing to adequately simulate the thermal state of a planet with specially resolved none-spherical topographical perspective. The thermal state of NEA is explained in black body approximation in terms of albedo and thermal emissivity. The additional features will be expected when we consider the topographical effect in thermo physical modeling of an asteroid, which contains self-shadowing effect, thermal re-radiation heating and scattering of direct solar flux of the surface. When we take the black body approximation into account, the former two effects becomes more important to calculate the temperature of an asteroid with spatially-resolved numerical shape models which will be different from spherical models with no such secondary effects.

The thermo physical state of an asteoroid surface is well described in thermal inertia of surface materials of the planet. The degree of thermal inertia can be estimated by reproducing diurnal thermal profiles of surface temperature, whose difference from spherical thermal models is necessary to be evaluated as well as the accuracy and feasibility of the estimation. The accuracy depends upon imaging frequency of an on-board imaging device, which in turn is supposed to be used for the purpose of deciding the imaging operation for investigating the accuracies of thermal inertia, conversely. The effect of local topography (several m) as well as the global shape (several hundred m) is considered at the same time in this study.

Keywords: asteroid, surface temperature, spatial resolution, thermal modeling, topography, thermal inertia

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Thermal evolution simulation of asteroid Vesta

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Vesta has been regarded as the parent body of the HED meteorites. From the observation of DAWN spacecraft, the uppermost layer of Vesta is composed from howardite ranging from 50km to 80km (Jutzi et al. 2013). It is known that the ratio of the number of eucrites to diogenites is around two. Based on these facts, rapidly cooled magma layer on Vesta should be more than 10km in thickness.

In this work, I studied the evolution of internal thermal evolution of Vesta due to heating of decay of 26Al. I calculate the temperature distribution by solving numerically heat conduction equation. According to Formisano et al.(2013), if Vesta completed its formation within 1.4Ma from the injections of 26Al into the solar nebula, the degree of silicate melting of inside Vesta exceeds 50 vol%. But in that work, convection and melt migration were not taken into account. These two mechanisms contribute to cool Vesta. So it is expected that the formation of Vesta is completed more early if these are taken into account. By the way, it is known that it takes about a few hundreds year for Vesta-size planet to complete its formation in planetary formation standard model.

As a convection model, I adopted the simple model of Kaula (1979). It was assumed that generated melt migrates the surface instantaneously, and the migrating melt to the surface was accounted as the rapidly cooled magma. There are two parameters in this study, including a (the percentage of melt migration) and t0 (formation time of Vesta), and perform simulation taking into account the convection and melt migration.

As a result, convection and melt migration substantially change the evolution of internal thermal structure, and total eruptive volume of melt considerably depends on a and t0. The magma volume increases as a increases. On the other hand, the magma volume decreases as t0 increases.

When t0=0, corresponding to no decay of 26Al at the beginning, and $a>0.3$, the erupting magma layer of 10km in thickness is formed. When a=1, that is all melt is erupted, the erupting magma layer of 10km is formed if $t0<0.9$Ma. According to these results, Vesta should be completed its formation within 0.9Ma after CAI formation, and more than 30% of generated melt should migrate the surface. But all generated melts aren't necessarily erupted, and if $a<1$, Vesta has to be completed more early.

Therefore, it is suggested that the formation time of Vesta should be more early than the estimate by Formisano et al.(2013), and that planetary formation standard model might have to be reviewed.

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PPS21-P18 Room:Convention Hall Time:May 25 18:15-19:30

Jovian core formation at the boundaries of dead zone: dependence on the gas surface density ditribution

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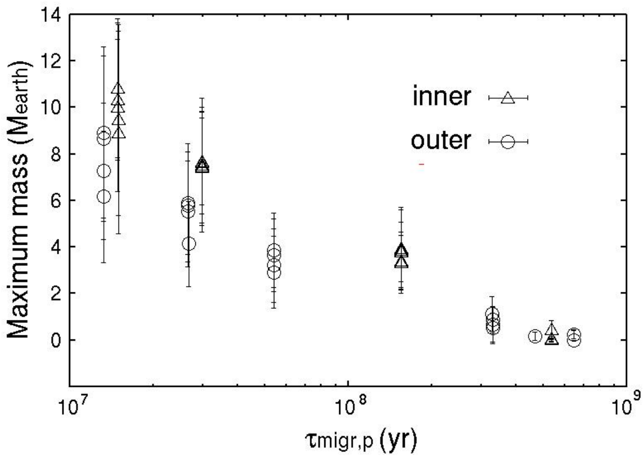
In a protoplanetary nebula, dead zone is formed where the viscosity is low because of low ionization fraction. There is a large variation in viscosity at the boundary of dead zone. This variation leads to the formation of vortices which can trap dust aggregates. A protoplanet can be formed in short timescales in a vortex. Sandor et al. (2011) showed that a core of Jovian planet is formed within a few Myr at the boundaries of dead zone.

In this simulation, a gas surface density distribution obtained from Lyla et al.(2009) is adopted. We changed the heights of two peaks in the distribution and checked the dependence of the largest mass on the height. We confirmed that the migration timescale of a planet inversely proportional to the peak height. It has been shown that the largest mass depends on the migration timescale logarithmically. This result indicates that the time evolution of the gas surface density cannot be neglected in the formation of a core. We will present the simulation results taking account of the time evolution of gas surface density distribution.

Fig 1: Maximum mass at the inner (triangles) and outer (circles) boundary of dead zone. Error bars show the standard deviation for 100 simulation runs.

Keywords: jovian planet, core, dead zone, gas surface density distribution



PPS21-P19 Room:Convention Hall Time:May 25 18:15-19:30

Measurements of the density, permittivity, and crack distribution in basalt targets based on the impact experiment

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The many meteorites have impacted the lunar surface during ˜4.6 Ga, in which the crater terrain is formed. In lunar nearside, the lunar lava (basalt) covers the inside of the basins (mare region), formed by large meteorites. The Lunar radar sounder (LRS) onboard the Japanese lunar orbiter SELENE (KAGUYA) radiated the electromagnetic wave in the Moon and succeeded in detecting the lunar surface and subsurface reflectors in the mare region [Ono et al., 2009]. Using the LRS data, Ishiyama et al. [2013] estimated the bulk permittivity of the lunar uppermost basalt layer and suggested a high porosity (more than ˜20%) of mare basalts. This estimated porosity is higher than the porosity of the Apollo basalt samples, so that the impact-induced macro cracks, which are not included in the Apollo basalt samples, are probably introduced in the lunar uppermost basalt layer. However, we cannot evaluate the subsurface distribution of the impact-induced macro cracks and the effect of the cracks on the permittivity estimated from the LRS data. Therefore, we produce the artificial impact crater on the basalt target based on the impact experiment, and measure the density, permittivity, and crack distribution in the basalt target.

We performed the impact experiment by using the two-stage light-gas (hydrogen) gun at JAXA on December 2014. The spherical stainless projectiles (0.32 cm in diameter and 0.133 g in mass) were launched at the velocities of 3.5, 4.5, 5.5, 6.5 km/s to investigate the impact velocity dependency and impacted on the basalt targets of 20 cm$\times$20 cm$\times$10 cm. We repeated the impact experiment twice for each impact velocity in order to confirm the repeatability. Next, we drilled core samples (2.5 cm in diameter and 8-10 cm in length) from the basalt targets along a horizontal and depth directions in order to investigate the effect of anisotropic crack on the permittivity. This investigation gives us the opportunity of the verification based on the effective medium theory [e,g., Sihvola, 1988], which supposes the effect of anisotropic crack on the permittivity. Finally, we sliced the core sample each of ˜4 mm in thickness and polished the surface of sliced samples to measure permittivity and surface crack distribution.

We estimated the density of the sliced sample from the measurements of its mass and volume, and investigated the crack fraction by scanning the surface of the sliced thick sample. The permittivity of the sliced thick sample was measured at 5 MHz by using the permittivity measurement system (TOYO Technica Corporation: Type-1260 impedance analyzer and Type-12962A interface) for measuring the permittivity. In the presentation, we will report the initial analysis result of the sliced samples.

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Structure of the accretion disk around a protostar and the planetesimal formation (II)

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We constructed steady-state protoplanetary disk models that can explain the local concentration of the solid materials in the disk. The enhancement of the particle to gas ratio in the disk is favorable for the planetesimal formation scenario through the gravitational instability (Youdin and Shu 2002).

We considered one dimensional viscous accretion disk in steady-state as the disk model. The disk structure is determined by the balance of the angular momentum flux and the viscous torque, the balance of the viscous heating, the irradiative heating, and the radiative cooling as the function of mass accretion rate. The viscous process is determined by the Magnetorotational Instability (MRI). Whether MRI is active or inactive is determined by the ionization degree. In addition to the galactic cosmic rays and the radioactive nuclei, we take into account the thermal ionization as the ionization source in this study, which brings the inner disk becomes MRI active. The previous works (Balbus and Hawley 2000) showed that this thermal ionization boundary was located very close to the central star (0.1AU or less). We, however, found that the viscous heating of the disk sifts the front location outward to nearly 1 AU for the case of mass accretion rate, 10^{-7} Ms/yr.

In this transition region (inner MRI front), the drift velocity of the solid particles turns out to be outward because of the positive pressure gradient at the mid-plain of the disk. This change in drift direction leads the concentration of solid particles around the boundary. Since the drift velocity is size dependent, this concentration mechanism is also size dependent. Small particles larger than 1cm can be trapped, but less than 1mm pass this front. The temperature of this region is around 1000K-1300K. The planetesimals are likely to be almost volatile free, if they formed in such a high temperature. We discuss our disk model and the implications to the planetesimal formation and the chemical compositions of meteorites in more detail in the presentation.

Keywords: protoplanetary disk, planetesimal formation, magnetorotational instability

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The effect of the condensation of ice components on the theoretical estimate of the thermal evolution of ice giants

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Though Uranus and Neptune are similar in mass and radius, the former is significantly fainter than the latter. Most of previous theoretical studies of thermal evolution of ice giants assumed three-layer models composed of a hydrogen-helium envelope, an ice mantle and a rocky core. According to them, the observed effective temperature of Uranus is lower than theoretically predicted (e.g., Fortney et al., 2011; Nettelmann et al., 2013). Previous studies did not consider the condensation of ice components in the atmosphere.

The difference between Uranus and Neptune might be whether they experienced a giant impact event or not. Uranus is believed to have experienced a giant impact, since the axis of rotation of Uranus is tilted to the orbital plane (Slattery et al., 1992). The giant impact may have mixed Uranus's hydrogen and helium in the envelope with ice components and the planet has a significant amount of ice components in its atmosphere. If this is true, the initial compositional distribution is expected to be different between Uranus and Neptune. Especially, the effect of condensation is not negligible for Uranus.

In this study, we consider the thermal evolution of ice giants considering the condensation of ice components in the atmosphere. During the thermal cooling of the planet, the ice components in the atmosphere condense and then moist convection occurs. Then, the cooling of the planet is controlled by the radiation limit. The radiation limit appears when the optical depth and temperature structure of the entire atmosphere approach a fixed profile. Consequently, the effect of the condensation makes short the timescale of the thermal evolution of the planet. That effect is important to understand the difference of the thermal evolution between Uranus and Neptune.

Keywords: ice giants, thermal evolution