

論文 / 著書情報
Article / Book Information

題目(和文)	デッドゾーン内側境界における岩石微惑星形成：円盤表層の影構造と太陽系形成過程への示唆
Title(English)	Planetesimal Formation at the Inner Edge of the Dead Zone: Implications for Disk Observations and Solar System Formation
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種別(和文)	論文要旨
Type(English)	Summary

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論文要旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	地球惑星科学 地球惑星科学	系 コース	申請学位 (専攻分野)： Academic Degree Requested	博士 Doctor of	(理学)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

Planets are thought to form from micron-sized dust particles within a protoplanetary disk rotating around the central star. In the evolution of dust particles, they are thought to form kilometer-sized bodies, so-called planetesimals, which are the building blocks of planets. However, formation of planetesimals, especially rocky ones, is still unclear because dust particles are easy to fragment at a typical collisional velocity in protoplanetary disks and rapidly spiral into the central star.

One preferential site of rocky planetesimal formation is the inner edge of the so-called dead zone. The dead zone is the location where magneto-rotational instability (MRI) is suppressed because of poor gas ionization. The dead zone is likely to have an inner edge where the gas temperature reaches around 1000 K, above which thermal ionization of the gas is effective enough to activate MRI. Across the dead zone inner edge, the turbulent viscosity arising from MRI steeply decreases from inside out, resulting in a local maximum in the radial profile of the gas pressure. The pressure maximum traps solid particles drifting from the outer part of the disk, leading potentially to the formation of rocky planetesimals via the streaming instability followed by the gravitational clumping of the dust layer.

In this thesis, we first analytically investigate the temperature structure of the inner region of protoplanetary disks based on the results obtained from the recent radiation hydro dynamical simulations. The inner part of a disk can be divided into four regions: a dust-free region with a gas temperature in the optically thin limit, an optically thin dust halo, an optically thick condensation front, and the classical optically thick region, in order from the innermost to the outermost. We derive the analytic expressions successfully describing these characteristic structures obtained from the numerical simulations. We find that the radius of the dead zone inner edge predicted from our formulas is 2-3 times larger than that expected from the temperature profile of the classical optically thick disk model.

As a next step, we perform simulations of the dust and gas disk evolution around a Herbig Ae star to investigate the planetesimal formation at the dead-zone inner edge. We show that the total mass of planetesimals is sensitive to the turbulence strength in the dead zone because of the combined effect of turbulence-induced particle fragmentation and turbulent diffusion. For a typical critical fragmentation velocity of silicate dust particles of 1 m/s, the stress to pressure ratio in the dead zone needs to be lower than 0.0003 for dust trapping to operate.

The obtained dust distribution is postprocessed using the radiative transfer code RADMC-3D to investigate the effect of a shadow casted by the dust-pileup. We find that a dust pileup at the dead-zone inner edge, if present, casts a shadow extending out to 10 au. In the shadowed region the temperature significantly drops, which in some cases yields even multiple water snow lines. We also find that even without a dust pileup at the dead-zone inner edge, the disk surface can become thermally unstable, and the excited waves can naturally produce shadows and ring-like structures in observed images. This mechanism might account for the ring-like structures seen in the scattered light images of some disks, such as the TW Hya disk.

Finally, we investigate whether rocky planetesimal formation at the dead-zone inner edge can account for the formation of inner solar system planets by performing simulations of the dust and gas disk evolution around a solar-type star. We show that if the disk is viscously heated, the dust-pileup increases the local temperature at the dead-zone inner edge and rocky planetesimals can form at 0.7-1 au in a disk with a typical gas mass accretion rate. In addition, we also show that the total mass of planetesimals invoked from the current total mass of inner solar system planets can also be reproduced. Although the preferable value of the turbulence strength for the inner solar system formation is strongly limited since the total mass of planetesimals is quite sensitive to it, the value suggested from our simulations is consistent with the value obtained from the recent hydro dynamical simulations. Although the subsequent evolution of the planetesimals has large uncertainty, this scenario would potentially account for the inner solar system formation.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note: Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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