FORMATION OF ROCKY PLANETESIMALS VIA RECONDENSATION OF NANOGRAINS.

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Introduction: Terrestrial planets in our solar system are formed from rocky planetesimals, whereas the way of rocky planetesimal formation is still unrevealed. If the building blocks of rocky planetesimals are submicron-sized interstellar dust grains [1], then there are two difficulties for silicate dust grains to aggregate into kilometer-sized planetesimal, viz., fragmentation barrier [2] and radial drift barrier [3]. It is because dust aggregates of silicate grains are easy to disrupt and to compress. However, these difficulties would be removed if the building blocks are not submicron-sized interstellar grains but nanometer-sized condensates in the early solar system. This is because the critical velocity for catastrophic disruption increases when the radius of monomers is small [4], and the porosity of dust aggregates also increases [5]. Therefore, nanometer-sized monomers can form rocky planetesimals via fluffy aggregates in a similar way of icy planetesimals [6].

Model: In this study, we assume the initial condition of all the silicate dust grains in the solar nebula as nanometer-sized monomers, for simplicity. We adopt the minimum mass solar nebula [7] with a solar-mass central star. We consider that Brownian motion, radial drift, azimuthal motion, and turbulence induce the motion of dust aggregates. We use an analytic formula of Kolmogorov turbulence [8]. We assume that the radius of monomer a_0 is $a_0 = 2.5$ nm, and the rolling energy is 1.1×10^{-11} erg in this study. The density evolution of dust aggregates is obtained by (i) hit-and-stick growth [9], (ii) static compression by ram pressure of the disk gas [10], and (iii) static compression by self-gravity [10].

Results: First, we confirm whether the maximum collision velocity satisfies the growth condition. The maximum collision velocity Δv_{max} is $\Delta v_{\mathrm{max}} = \alpha^{1/2}\, c_{\mathrm{s}}$, where α is a dimensionless parameter associated with the strength of turbulence, and c_{s} is the sound velocity [8]. We assume $\alpha = 10^{-3}$ or $\alpha = 10^{-4}$ as realistic values. Meanwhile, the critical velocity for catastrophic disruption Δv_{cr} is $\Delta v_{\mathrm{cr}} = 6 \times 10^{2}\, (a_0 / 0.1\ \mu\mathrm{m})^{-5/6}$ cm s^{-1} [4, 11]. Therefore, dust aggregates can grow without serious disruption when the monomers are nanometer-sized grains.

Then, we also reveal whether dust aggregates can overcome the radial drift barrier or not. Figure 1 shows the evolutionary tracks of the dust aggregates at 1.5 au from the sun. We show that the revealed tracks overcome the radial drift problem for the cases of strong turbulence (Figure 1a) and weak turbulence (Figure 1b).

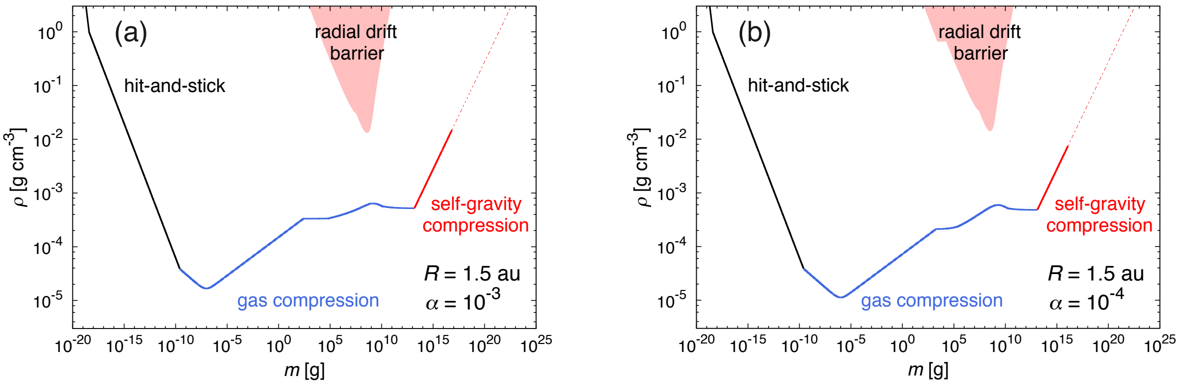

Figure 1. Evolutionary tracks of rocky planetesimal formation in the minimum mass solar nebula at 1.5 au from the sun.

Discussion: There are several evidences suggesting that building blocks of rocky planetesimals have experience of recondensation; for example, almost all dust grains among our solar system are isotopically homogeneous for most elements such as iron [12]. In addition, these condensates might be initially formed as nanometer-sized grains because observed size distribution of matrix grains in Allende CV3.2 chondrite [13] has a peak at 5 nm in diameter. The peak of the size-frequency distribution strongly depends on the degree of the thermal metamorphism [14]. We will discuss how to obtain the initial size distribution of the building blocks of rocky planetesimals by back calculating of grain growth process in future, and we should also measure the size distribution of matrix grains in a chondrite whose petrologic type is 3.00 such as Semarkona.

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