Icy pebble accretion onto terrestrial planets: the effect of gas flow

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Earth, the only life-hosting planet we know, is characterized by the small water fraction in the bulk composition: the ocean mass being 0.023% of the Earth mass. Because the abundance of water control the physical and chemical evolution of planets by atmosphere-hydrosphere-lithosphere interactions and by changing the mantle properties, unveiling how water-depleted planets form is crucial for understanding the emergence of habitability on them. Pevious studies have pointed out that icy pebble accretion following the snow line migration in protoplanetary disks typically deliver an excess amount of water to terrestrial planets unless the initial size of the disk is small (30--50 au) or a giant planet in the outer orbit (e.g., Jupiter in our solar system) formed early (Morbidelli et al. 2016; Sato et all. 2016; Ida et al. 2019). In contrast to the previous studies where the accretion rate derived for pebbles moving in (sub-) Keplerian flow, we used the accretion rate derived for pebbles moving in the gas flow perturbed by the gravity of the planet (Kuwahara et al. 2019; Kuwahara et al. in prep.). The presence of horseshoe region and outflow shuts off the accretion of small pebbles. We show that, because migrating icy pebbles at ~1 au are small, the gas flow significantly suppress the accretion onto Earth-sized planets, whereas Mars-sized planets accretes a significant amount of icy pebbles. Our results suggest that Earth-like, water-depleted rocky planets may form in a disk-size range wider than previously considered and in the systems where no giant planet exists.

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