Water Delivery to Terrestrial Planets by Pebble Accretion

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The Earth would contain water of 0.023wt%-1wt% on the surface(ocean) and in the interior. It is observationally suggested that early Mars and early Venus had water. In particular, the water fraction of the early Mars may be comparable to that of the current Earth. Based on this information, we have investigated the water fraction of the Earth, Mars, Venus, and Mercury delivered by pebble accretion which is actively discussed today, numerically calculating the growth and inward migration of icy pebbles.
It is suggested that the snow line once migrated down to ~0.7AU. Then, the terrestrial embryo gained water components from capturing migrating icy pebbles from outer parts of the protoplanetary disk. Because icy components have been subtracted in the outer disk, the gas in the terrestrial planet region should have been 'dry '.
Using this model, Sato et al. (2016) calculated the amount of water delivered to the Earth by icy pebble accretion and showed that a relatively small disk, strong turbulence, late passage of the snow line at 1AU are required to be consistent with the inferred water content of the current Earth. We have generalized their simulation to a system of multiple planets (Earth, Mars, Venus and Mercury). While we used the same model of migration and formation of dust grains as Sato et al. (2016), we included decrease in pebble mass flux due to accretion by each planet. We found that the final water fraction of individual planets is directly determined by total amount of solid materials remaining in the disk. As long as the snow line passage timing at the individual planetary orbits is the same for all the planets, the final water fraction of individual planets should be similar to one another, while the amount of the water fraction depends on disk size, strength of turbulence, the timing of the snow line passage.

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