Delivery of ammonia ice to Ceres by pebble accretion

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Recent studies with the spectrometer onboard the Dawn spacecraft detected the presence of ammoniated phyllosilicates on the surface of Ceres. It is presumed that ammonia may have reacted with the phyllosilicates on Ceres during differentiation. Ammonia can not exist alone as a solid in the current temperature at the location of Ceres. It has yet to be shown how ammonia is delivered to Ceres.

In this study, by adopting a theory "Ceres formed a protoplanetary core around the current main asteroid belt and accreted ammonia-bearing ice pebbles there", we aim to give constraints on the free parameters of the protosolar nebula. We numerically calculate the growth and radial inward drift of icy dust particles, and the evolution of the surface density of the gas flow and the disk temperature in a viscous disk. We employ a formula of pebble accretion presented by a previous study to quantify the amount of ammonia-bearing ice pebbles delivered to asteroids at 2.8 au.

We find that when the free parameters of the protosolar nebula satisfy certain conditions, Ceres accretes ammonia-bearing ice pebbles with ~ 10 –100 km thickness on its surface by pebble accretion. This result can explain the observations that there is ~ 15km of relief with craters on the surface of Ceres, and the ammoniated phyllosilicates on its surface were formed globally. In our result, we support the disk model with strong turbulence. Moreover, we suggest if ammoniated phyllosilicates come from pebble accretion, the amount of ammoniated phyllosilicates on planets' surface strongly depends on accreting planet masses.

Keywords: pebble accretion, asteroid, protosolar nebula

