Late Stage Capture of Solids by Growing Gas Giant Planets

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Recent studies of internal structure of gas giants Jupiter and Saturn suggest that their envelopes are enriched with heavier elements than hydrogen and helium, relative to the solar composition.The estimated amounts of heavy elements in the envelopes are 18-39M⊕ for Jupiter and 1-8M⊕ for Saturn.Such overabundance of heavy elements cannot be explained by simple formation models in which a solid core forms first through accretion of planetesimals composed of heavy elements and, then, collect the surrounding gas with solar or subsolar abundances from the protoplanetary disk (or the solar nebula), predicting that the amounts of heavy elements in the envelopes of Jupiter and Saturn are as small as or less than 3M⊕ and 1M⊕, respectively.Previous studies examined the possibility of additional increase of heavy elements through the capture of planetesimals during the gas accretion phase by performing orbital integration of planetesimals in the vicinity of a growing protoplanet.
They revealed that much more planetesimals than Hayashi Disk are needed to be consistent with the enriched heavy elements in Jupiter's envelope and Saturn tends to capture much more planetesimals than Jupiter.The latter result is inconsistent with the estimations.
Then in our study, the effects of supply limit of gas from protoplanetary disk, gap opening in the protoplanetary disk, and formation of circumplanetary disk on the capture of planetesimals are evaluated by the orbital integration of planetesimals in the model of gas structure around planet.We revealed that the opening of gap in protoplanetary disk doesn't affect the capture of planetesimals, but the formation of circumplanetary disk increase the mass of captured planetesimals.And the difference of the growth rate between Jupiter and Saturn makes the mass of captured planetesimals by Jupiter increase as much as Saturn.These results alleviate the contradiction between internal structure theory and planet formation theory.

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