論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	ALMA observational studies on the origins of the axisymmetric ring-gap structures in the protoplanetary disks
著者(和文)	KIM Seongjoong
Author(English)	Seongjoong Kim
出典(和文)	学位:博士(理学), 学位授与機関:東京工業大学, 報告番号:甲第11384号, 授与年月日:2020年3月26日, 学位の種別:課程博士, 審査員:奥住 聡,野村 英子,井田 茂,中本 泰史,佐藤 文衛,中島 淳一,武藤 恭之
Citation(English)	Degree:Doctor (Science), Conferring organization: Tokyo Institute of Technology, Report number:甲第11384号, Conferred date:2020/3/26, Degree Type:Course doctor, Examiner:,,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	Earh and Planetary Sciences	系 コース	
学生氏名： Student's Name	Seongjoong Kim		

申請学位（専攻分野）： Academic Degree Requested	博士 (Science) Doctor of
指導教員（主）： Academic Supervisor(main)	Satoshi Okuzumi
指導教員（副）： Academic Supervisor(sub)	Hideko Nomura

要旨（和文 2000 字程度）
Thesis Summary（approx.2000 Japanese Characters ）

Disk substructures in protoplanetary disks (PPDs), such as rings, gaps, and spiral arms, are considered as a possible signpost of forming planets. Recent high-resolution (sub-)millimeter observations done by Atacama Large Millimeter and Sub-millimeter Array (ALMA) have revealed that these disk substructures are very common in PPDs. To understand the origins of these disk substructures, especially focusing on the axisymmetric dust gap-ring structures, I study the dust and gas properties using ALMA data.

First, I detect the axisymmetric dust gap-ring structure around a T Tauri star CR Cha by the recent high-resolution ALMA observation at Band 6. It is the first time resolving the disk substructure in the CR Cha disk with the beam size of ~0.09" (~16 au in physical scale at the distance of ~187.5 pc). The CO isotopologue (12CO, 13CO, and C18O) lines are also observed with ~0.2" resolution for obtaining gas properties. There is a bump-like structure in the peak brightness temperature radial profile of the 13CO line at the location of the dust ring. To explain these observed features in the CR Cha disk, I suggested two possible mechanisms.

The first scenario is the gap opening by a planet. By adopting an empirical relation between the planet mass and the gap structure, a Jupiter mass planet is required to reproduce the observed gap structure. Once the dust gap is opened by a planet, the stellar radiations easily reach the outer wall of the gap directly making a temperature bump beyond the dust gap.

Another possible scenario is dust trapping at a gas pressure bump. When the dust disk becomes more compact than the gas disk due to radial drifts of dust grains, the gas temperature bump is formed at the outer edge of the dust disk. Due to the rapid drop of the optical depth at the disk outer edge, the radiation of the hot disk surface layer penetrates the disk vertically to the midplane. The radiative transfer calculation reproduces the observed bump structure of gas temperature at the outside of the dense dust disk. This temperature bump creates the gas pressure bump at the same location. Then, the dust grains are trapped at the gas pressure bump during their radial drifts from the outer disk, eventually making a dust ring structure.

For examining the reliability of two scenarios I suggested, I need more constraints on the physical properties of dust grains like dust temperature and size distribution. The multiwavelength analysis of the observational data is one of the powerful tools to constrain the dust properties more accurately than the single wavelength. With this motivation, I study the synthetic ALMA multiband analysis to find the best combination of three ALMA bands for deriving the accurate dust temperature Td, dust optical depth τ_ν, and dust opacity power-law index β (β is the power-law index of dust opacity, $\kappa_\nu \propto \nu^\beta$). By this analysis, I can directly derive the three unknowns (Td, τ_ν, β) without any assumptions on dust temperature and optical depth.

The TW Hya disk is the best object to examine the synthetic ALMA multiband analysis because its proximity (d ~ 59.5 pc) gives a chance to resolve very small-scale disk substructures and it has nearly all ALMA band observations in the archive. The synthetic multiband analysis results show that the Band [10,6,3] set is the best combination for

minimizing the constraint ranges of the dust properties in the TW Hya disk corresponding to the observational uncertainties. The band combinations with Band 9 or 10 and with the large frequency intervals between the bands in the set give us narrow constraint ranges, that is, the better constraints of the dust properties. These are related to the conditions which give accurate constraint ranges on the dust properties: the combination of optically thick and thin bands, large β, and low dust temperature.

To examine the consistency of the synthetic analysis results, I apply the multiband analysis to ALMA archival data of the TW Hya disk at Band 4, 6, 7, and 9. Band [9,6,4] set provides the dust properties close to the model profile, while Band [7,6,4] set gives the dust properties deviating from the model at all radii with very broad constraint ranges to specify the accurate values of dust temperature, optical depth, and dust opacity power-law index β. These features are well consistent with the synthetic ALMA multiband analysis results.

Also, the synthetic ALMA multiband analysis model shows that I can constrain the accurate dust properties by applying this multiband analysis to a proper combination of observational data for various protoplanetary disks having different disk conditions. It indicates that this multiband analysis can be widely applied to many protoplanetary disks for deriving their dust properties and establishing the statistical studies in the future.