円盤・惑星相互作用によるギャップ生成の定量的モデル
Quantitative Modeling of the Gap Induced by a Planet in a Protoplanetary Disk

金川 和弘[2]、*武藤 恭之[1]、田中 秀和[3]
Kazuhiro Kanagawa[2], *Takayuki Muto[1], Hidekazu Tanaka[3]

1.工学院大学基礎・教養教育部門、2.シュチェチン大学、3.東北大学・天文
1.Division of Liberal Arts, Kogakuin University, 2.University of Szczecin, 3.Astronomical Institute, Tohoku University

Recent high resolution observations have revealed that protoplanetary disks are rich in structures. Especially, multiple ring-like structures are discovered in the disk around HL Tau by the long baseline campaign observations of ALMA.

Such structures may be connected to the dynamical processes that occur in the disks. One interesting processes that occur in protoplanetary disks is the gravitational interaction between a (already formed) planet and the disk. As a result of disk-planet interaction, planets induce gap and spirals in the disk. If such structures are found in real observations, they strongly indicate the existence of a planet embedded in the disk. The shape of the gaps and spirals can be used to infer the physical properties of the disk and the planet. The physical parameters of disks and planets that are derived based on the disk morphology are independent from those derived from other methods. It is therefore important to understand and model the disk-planet interaction quantitatively.

In this poster, we present a series of numerical simulations and analytical theory of the gap formation by a single planet embedded in a protoplanetary disk. We quantify the shape of the gap structures in terms of the planet mass, disk scale height and disk viscosity. We first present the depth and the width of the gap can be determined by these three quantities. We have found that the gap depth is determined by a single parameter $K = q^2 / (h^5 * alpha)$, where q is the mass ratio between the planet and the central star, h is the disk aspect ratio, and alpha is the disk viscosity parameter. We have also found that the gap width is determined by $K' = q^2 / (h^3 * alpha)$. We have derived a simple formula that describes the gap depth and width in terms of K and K'. We apply our results to the ALMA long baseline campaign observations of the disk around HL Tau, and suggest that the planet mass is <~ 1 MJ, if the observed gap is induced by (unseen) planets in the disk. We also present the model for the detailed profiles of the gap induced by a planet, which can be compared to observations if detailed gas structures are revealed in the near future.

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