Invitation to ALMA and exciting research with it

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ALMA telescope (Atacama Large Millimeter/submillimeter Array) is an international facility built and operated by Europe (ESO with its 16 member countries), North America (USA and Canada) and East Asia (Japan, Taiwan and Korea), in cooperation with Chile. It is located at the 5000-m site in the Atacama altiplano in the Andes in northern Chile, and has an extremely high performance in observing millimeter and submillimeter waves (wavelengths from 3.5 mm down to 0.32 mm). It is an aperture synthesis telescope consisting of 54 12-m parabolic antennas and 12 7-m parabolic antennas, and can adjust its spatial resolution by changing the antenna array configuration.
In the long baseline campaign in 2014, ALMA demonstrated its maximum baseline of 15 km to reveal multiple ring/gap structure in the protoplanetary disk around HL Tau by the spatial resolution as high as 0.025" (3.5 AU) at the observing wavelength of 0.87 mm (ALMA Partnership et al. 2015, ApJL 808, L3). By observing protoplanetary disks around young stars with various characters and various stages, ALMA is revolutionalizing our understanding of the earlier stages of planetary formation.
East Asia, who contributes 25% of the construction and operation of ALMA, has a 22.5% share of the observing time (= 25% x 0.9, because 10% goes to Chile). This presents a great opportunity for researchers in Japan, Taiwan and Korea to join and drive the exciting research.
ALMA Regional Centers (ARCs) have been established in Europe, North America and East Asia as interface points between ALMA and research community. The East Asian ALMA Regional Center (EA-ARC) is located in the Mitaka headquarter of National Astronomical Observatory of Japan. ARCs take care of the call for proposal, preparation of the observing script for accepted proposal, quality assurance and delivery of observed data, and updates and maintenance of the data archive. ARCs are answering users' consultations on, e.g., proposal preparation and data analysis through a helpdesk and support astronomers.
In the present paper, I introduce how the observations with ALMA are made and how we support the researchers. I hope more and more researchers join in the exciting and revolutionary science using ALMA and its archival data.
National Astronomical Observatory of Japan/ALMA
http://alma.mtk.nao.ac.jp
East Asian ALMA Regional Center
http://alma.mtk.nao.ac.jp/e/forresearchers/ea-arc/
ALMA Observatory
http://www.almaobservatory.org

Keywords: Planet formation, Protoplanetary disks, Radio astronomy observations, Millimeter and submillimeter waves

Sintering-induced dust ring formation in protoplanetary disks

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The latest ALMA observation of HL Tau revealed spectacular concentric dust rings in its circumstellar disk. We propose the hypothesis that the multiple rings resulted from the sintering of icy aggregates in the disk. Sintering is the process that fuses particles consisting of an aggregate at temperatures slightly below the melting temperature of the particles. Sintering makes aggregates harder but less sticky (Sirono 1999; Sirono & Ueno 2008), thereby suppressing their growth through coagulation. In a protoplanetary disk, icy aggregates are thought to contain various volatiles such as CO and CH_4, each of which may cause the sintering of the aggregates in the vicinity of its snow line (Sirono 2011). We construct a simple model that takes into accout sintering, coagulation, and radial drift (Adachi et el. 1976; Weidenschilling 1977) of composite ice aggregates in a protoplanetary disk. We find that the aggregates pile up in the sintering zones near the snow lines because smaller aggregates drift toward the central star more slowly. At millimeter wavelengths, the sintering zones are seen as bright, optically thick rings with a spectral slope of 2, whereas the non-sintering zones are seen as as dark, optically thin rings of a spectral slope of 2.3-2.5. The observational features of the sintering and non-sintering zones are consistent with those of the major bright and dark rings found in the HL Tau disk, respectively. We also apply our model to the protoplanetary disk of TW Hya, for which latest ALMA observations suggest the presence of a pileup of dust near the CO snow line (Nomura et al. 2016).

Keywords: HL Tau, TW Hya, sintering, ALMA

Modeling of Dust Emission from Disk Surrounding HD 142527

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We model the 870 μm dust continuum emission from the azimuthally-asymmetric disk around HD 142527 based on ALMA Cycle 0 observation. The disk is inflated, inclined by 27° to the line of sight, and its major axis is along PA = 341°. High resolution images in NIR scattered light (Fukagawa et al. (2006)) and MIR thermal radiation (Fujiwara et al. (2006)) indicate that the eastern side (PA = 341° −161°) of the disk is farther whereas the western side (PA = 161° −341°) is closer to us. In our model, we assume the radial surface density distribution of the dust disk to be gaussian, and the dust size distribution follows $a^{-3.5}$, where a_{max} = 1 mm. At the observation wavelength, scattering opacity is 10 times larger than absorption opacity in our model (Aikawa & Nomura (2006)). Dust density, temperature, and radiative energy density of the disk are determined by M1 approximation method (Kanno, Harada, Hanawa (2013)).
The peak surface densities of dust, Σ_0, at PA = 21° (the brightest region) and PA = 221° (the faintest region) are 0.8 g cm^{-2} and 0.008 g cm^{-2}, which are consistent with Muto et al. (2015). We cannot reproduce, however, the observed surface brightness in the northwestern region (PA = 291° − 351°), i.e., the near side with about 80% brightness of PA = 21°, even with Σ_0 = 1.25 g cm^{-2}. This is due to: (i) the heavy scattering; (ii) the dependence of the disk surface brightness on the veiwing angle. We solve the problem by reducing the scattering opacity to 10% of its original value. Subsequently, the Σ_0 values for the brighter lopsided region (PA = 291° −71°) become about 50% lower than their original values, while for the remaining optically thin regions Σ_0 values do not change significantly. We will also discuss how such a scattering opacity can be realized.

Keywords: HD 142527, Dust emission, Modeling

Quantitative Modeling of the Gap Induced by a Planet in a Protoplanetary Disk

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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.

Keywords: Protoplanetary Disks, Disk-planet Interaction, Direct Imaging Observations of Disks

ALMA Observation of Gas and Dust in Debris Disks

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The evolution from protoplanetary disks to debris disks is very important for understanding planet formation. Infrared emissions from debris disks observed by AKARI imply that the debris disks have gas components. The archive data of ALMA cycle1 include the samples of the debris disks found by AKARI. Therefore, we analysed the data and then found CO detections in 5 of 10 samples.

Keywords: protoplanetary disk, debris disk, gas/dust

The Spatially-resolved HCN(*J* = 4-3) Interferometric Observation on Neptune's Stratosphere with ALMA Array

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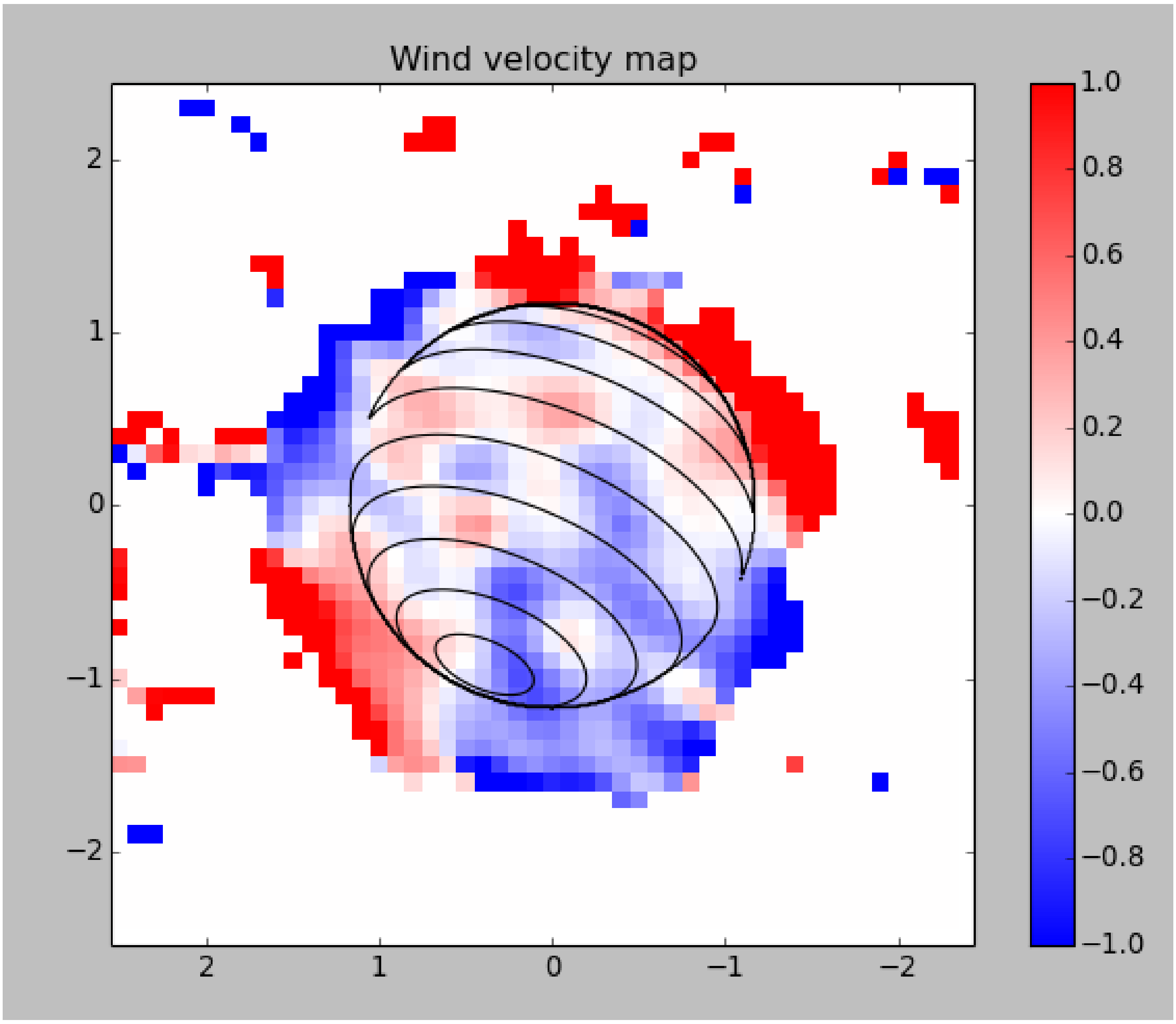
ALMA array is a powerful tool to illustrate both the photochemistry and dynamics of gas giants' stratosphere thanks to its high spatial resolution and sensitivity. We have constructed the spatially-resolved HCN(J=4-3) map of Neptune with archived ALMA data obtained during Cycle-0 season. From the doppler-shift analysis, stratospheric dynamics of Neptune's stratosphere showing the spatial difference is illustrated clearly. In this presentation, obtained result and possible driving mechanism of the dynamics will be discussed.

Keywords: ALMA array, Planetary atmosphere, Radio astronomy


Wind velocity map
2
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