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Warp and shadows in transitional disks

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Recent high-resolution observations using the Atacama Large Millimeter/submillimeter Array (ALMA) have deepened our understanding of protoplanetary disks. Protoplanetary disks are objects composed of dust and gas that rotate around a young star and are thought to be the birthplace of planets. In fact, structures (gap, cavity, spiral, etc.) have been observed in these disks and could have been created by the gravitational interaction between the planet and the disk. Among these, a disk in which a cavity with a radius of several tens of au is observed in the innermost region of the dust disk is called a transitional disk. The causes of this evolution are not yet clear, but gravitational interaction between planet and disk, disk wind, photoevaporation, and early dust evolution in the inner region are considered.

Recent high-resolution observations have detected several transitional disks associated with a compact dust disk of radius a few au. In a typical viscous accretion disk, the frequency of detection of this phenomenon should be very low because this compact disk would accrete to the star immediately if there is no supply of materials from the outer region. Therefore, it is thought that there is some mechanism to maintain the compact dust disk.

Moreover, a centroid velocity map obtained from molecular emission lines shows velocity distortion in the innermost region of the disk, as shown in the figure1(a). One of the causes is warp. Warp is a structure in which the inclination of the disk changes radially, which is thought to be caused by gravitational interaction between the disk and a planet with an inclined orbit, or by accretion of materials with different angular momentum. If the compact disk is misaligned, this can cast a shadow on the outer disk and create non-axisymmetric temperature. As shown in figure1(b), this signature has been observed in several transitional disks.

We performed radiative transfer calculations using RADMC-3D to investigate a radiation field made by the warped disk. We calculated the temperature distribution of a transitional disk with a radius of 100 au, which has a compact dust disk with a radius of 4 au which is misaligned 10 deg from mid-plane, using the Thermal Monte Carlo method and found that there is a temperature difference of 3-4 K in the outer dust ring. This is consistent with the temperature asymmetry of the transitional disk associated with SY Cha observed by ALMA Band 6[1]. The intensity model calculated for the radiative transfer of this disk model at a wavelength of 1.3 mm (figure1(c)) is consistent with the observed asymmetric pattern of the dust continuum, as shown in figure1(b).

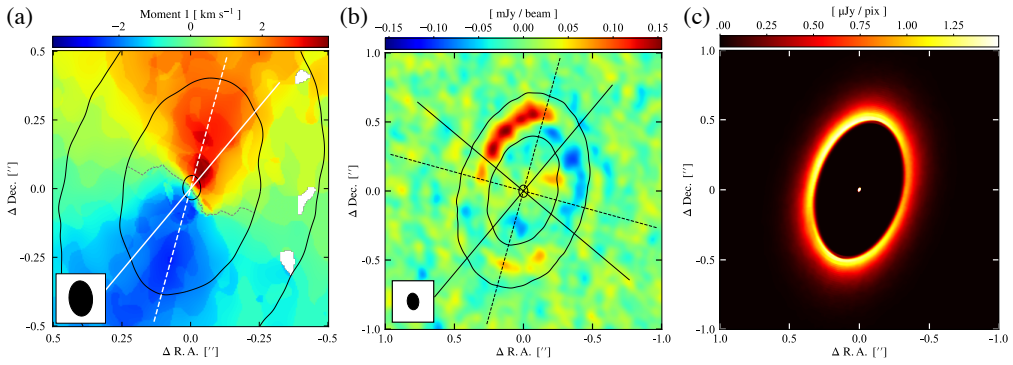

Figure 1. (a): Centroid velocity map made from the ^{12}CO(2-1) line emission from SY Cha. (b): Residual map obtained by subtracting the axisymmetric intensity model from the dust continuum emission from SY Cha. (c): Result of the radiative transfer calculation at a wavelength of 1.3 mm.

References

[1] Orihara, R., et al., "ALMA Band 6 high-resolution observations of the transitional disk around SY Cha" *PASJ*, accepted.