

The Flared Gas Structure of the Transitional Disk around Sz 91

*Takashi Tsukagoshi¹, Munetake Momose¹, Yoshimi Kitamura², Ryohei Kawabe^{3,4,5}, Masao Saito³, Sean Andrews⁶, David Wilner⁶, Tomoyuki Kudo³, Jun Hashimoto⁷, Nagayoshi Ohashi³, Motohide Tamura^{7,5}

1. Ibaraki University, 2. Japan Aerospace Exploration Agency, 3. National Astronomical Observatory Japan, 4. The Graduate University for Advanced Studies, 5. University of Tokyo, 6. Harvard-Smithsonian Center for Astrophysics, 7. Astrobiology Center

Transitional disks are believed to be a good laboratory for the investigation of the planet formation process because of its inner hole structure. Sz 91 is a nearby young low-mass star surrounded by the transitional disk. Previous ALMA observations have resolved the inner hole structure and have revealed the symmetrical ring-like distribution of the remaining dust materials. The gas disk structure, however, has not been understood well because of the lack of sensitivity and resolution. Therefore, the improvement of the image quality is essential to determine the overall structure of the Sz 91 disk in detail.

Thus, we have conducted 0.14 arcsec resolution high-sensitivity observations of the dust continuum at band 7, and the CO(3-2) and HCO⁺(4-3) line emissions toward the transitional disk around Sz 91 with ALMA. The dust disk appears to be an axisymmetric ring, concentrated within a radius of ~120 au, as found by the previous study with ALMA. The widths of the dust ring from the Gaussian fitting of the radial profile are 31.2 and 30.0 au for the major and the minor axes, respectively.

The similar values of the widths along the major and minor axes indicate that the dust ring is not geometrically thin, while it is difficult to estimate about the actual height of the dust ring with the spatial resolution of this study. Keplerian rotation is found in both the CO and HCO⁺ images. The gas disk extends out to ~400 au and is also detected in the inner hole of the dust ring. A twin-line pattern is found in the channel maps of CO, which can be interpreted as the emission from the front and rear of the flared gas disk. This is the first direct imaging of the two-layered velocity pattern of the gas emission towards a transitional disk around a low-mass star. We perform the radiative transfer calculations using RADMC-3D, to check whether the twin-line pattern can be reproduced under the assumption that the flared gas disk has a power-law form for the column density and $T_{\text{gas}} = T_{\text{dust}}$. The thermal Monte Carlo calculation in RADMC-3D shows that the disk temperature has a gradient along the vertical direction beyond the dust ring, as it blocks the stellar radiation. We conclude that the twin-line pattern can be naturally explained by the flared gas disk in combination with the dust ring. In addition, no significant depletion of the CO molecules in the cold midplane achieves a reasonable agreement with the observed twin-line pattern. This result indicates that the CO emission from the warm surface layer on the rear side of the Sz 91 disk must be heavily absorbed in the cold midplane.

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