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Aperture Synthesis Observations of Low-mass Protostars: Formation Processe of Protoplanetary Disk in Protostellar Envelope

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Aperture synthesis observations of 13CO(J=1-0/J=2-1) line emission toward the protostellar binary L1551 IRS 5, made with the Nobeyama Millimeter Array, are presented. 13CO(J=1-0) observations with a spatial resolution of 5arcsec have revealed a centrally condensed component associated with IRS 5 whose size of 2000 AU in diameter and extended X-shaped components around IRS 5. The X-shaped components have symmetrical structures centered on IRS 5 and trace the swept-up gases along the outer shell of the blue- and red-shifted outflow. On the contrary, the central component shows infall and rotational motion. The infall velocity of the envelope is consistent to the free-fall velocity around a centarl mass of 0.5 Modot, whereas the rotational velocity is 0.5 km/s at 700 AU in radius with radial dependence of 1/r, suggesting the specific angular momentum of the gases has conversed during the contraction of the protostellar envelope.

13CO(J=2-1) observations with a spatial resolution of about 2arcsec have performed in order to reveal the most central part of the infalling envelope. 13CO(J=2-1) emission shows a disklike structure in the central part of the envelope. A distinct velocity gradient is seen along the major axis of the disklike structure or perpendicular to the outflow axis, while no prominent gradient can be found along the minor axis, suggesting the disklike structure is purely rotating. The velocity gradient along the major axis agrees with the Keplerian rotation and the rotating disk radius which derived from the analysis based on the iso-velocity map of 13CO(J=2-1) is 490 +- 50 AU, and required the enclosed mass of the binary system is 0.6 +- 0.2 Modot. The disk radius is, however, significantly larger than the centrifugal radius of 30 - 300 AU which expected from the local specific angular momentum of the infalling envelope deduced from the past C18O(J=1-0) observations. The inconsistency of both the disk radii indicates the following posibilities about the disk formation processes in the protostellar envelopes: 1) Torque from gravitational interaction between the inner disk and the binary has converted to the disk, and as a result, the disk has extended. 2) The turbulent viscosity of the disk has made the disk extended. Neither the gravitational interaction nor the turbulent viscosity, however, seems probable mechanisms for making such a large disk. On the other hand, another posiiblility is the under estimation of the specific angular momentum. Because the rotational motion detected in 13CO(J=1-0) emission is faster

than that in C18O(J=1-0) as a factor of 2, suggesting the surface of the envelope have a large specific angular momentum compared to the mid-plane of the envelope. We also reports the recent results of the single protostar of HL Tau.