Growth Process of a Protostellar Binary Revealed with ALMA

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We report results of our ALMA Cycle 0 observation of a protostellar binary L1551 NE, which show that the protostellar binary is growing through the mass accumulation from the surrounding circumbinary material [1].

More than half of stars with masses similar to the Sun are known to be binaries [2,3]. Studies of formation and growth processes of binaries are thus essential for comprehensive understanding of star formation. Protostellar binaries are surrounded by disks of molecular gas and dusts, "circumbinary disks" (hereafter CBDs), and are considered to grow through accumulation of the materials from the CBDs. Resolutions and sensitivities of previous observations are, however, not high enough to investigate the structures and gas motion in the CBDs, and to discuss the feeding process of the materials to the central protostellar binaries. The spatial resolution and sensitivity of our ALMA Cycle 0 observation of L1551 NE are ~1.6 times and ~6 times higher than those attained in our previous SMA observations [4,5], respectively, and thus we are able to investigate internal structures and gas motions in the circumbinary disk of L1551 NE in detail.

Figure 1 (*left*) shows the observed L1551 NE image of the dust-continuum emission at a 0.9-mm wavelength. There are compact components associated with the individual binary stars (cross marks), "circumstellar disks". The circumstellar disks are surrounded by a larger (r ~300 AU) CBD, which exhibits *U*-shaped feature to the south of the protostellar binary, emission protrusions to the northwest which curls to the northeast, and emission minima between these features and the protostellar binary. Gas motions in the CBD as revealed in the $C^{18}O$ ($J = 3–2$) line show faster rotations than the local Keplerian rotation and expanding motions in these continuum features, and slower rotations and infalling motions in the regions of the continuum emission minima.

To interpret physics of these observed structures and gas motions in the CBD around L1551 NE, we conducted numerical simulations of the CBD using the supercomputer ATERUI in National Astronomical Observatory of Japan (NAOJ) (Figure 1 *right*) [6]. The theoretical image shows two spiral arms stemming from the individual binary stars, which constitute the CBD. In those spiral arms the gas rotates with the velocity faster than the local Keplerian rotation velocity, and exhibits expanding motion. On the other hand, in the inter-arm regions the gas rotates slower, and exhibits infalling motion toward the central protostellar binary. This is because of the exchange of the angular momenta inside the CBD, caused by the non-axisymmetric gravitational torques from the central binary. These simulation results reproduce the observed structures and gas motions in the CBD around L1551 NE quantitatively; that is, our ALMA observation unveiled the growth process of the protostellar binary by removing the angular momenta of the surrounding material and capturing those materials.

Our ALMA Cycle 2 proposal to observe L1551 NE at a ~0″.1 angular resolution has been approved, and the observation will be made in the summer 2015. We anticipate that the observation will reveal the spiral arm features and gas motions in the CBD unambiguously, and that we will be able to discuss physical mechanism to set final masses and mass ratios of binary stars.

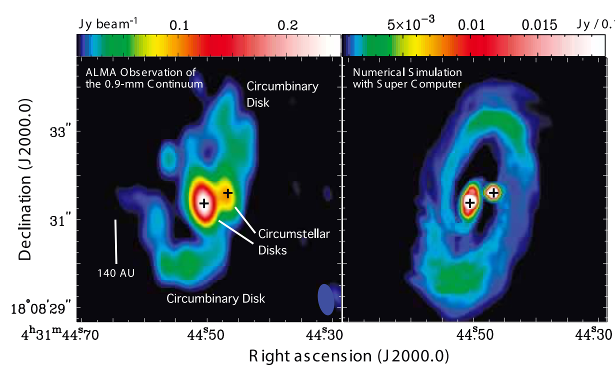

Figure 1: (*Left*) ALMA image of L1551 NE in the 0.9-mm dust-continuum emission. Crosses denote the positions of the protostellar binary, and a filled ellipse at the bottom-right corner the synthesized beam (0″.72×0″.36; P.A.=9.1°). (*Right*) Theoretically-predicted 0.9-mm dust-continuum image of L1551 NE obtained from our numerical simulation using the NAOJ supercomputer ATERUI.

References

[1] Takakuwa, S., et al.: 2014, *ApJ*, **796**, 1.
[2] Raghavan, D., et al.: 2010, *ApJS*, **190**, 1.
[3] Reipurth, B., et al.: 2014, *Protostars and Planets VI*, 267.
[4] Takakuwa, S., et al.: 2012, *ApJ*, **754**, 52.
[5] Takakuwa, S., et al.: 2013, *ApJ*, **776**, 51.
[6] Matsumoto, T.: 2007, *PASJ*, **59**, 905.