Detailed Density and Velocity Structures of the Protostellar Core B335

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In order to understand physical processes of low-mass star formation, it is important to investigate the properties of dense ($\sim10^5$ cm^{-3}) cores in molecular clouds. Such compact (~0.1 pc) cores supply material to newly forming stars through dynamical gravitational collapse, nevertheless detailed physical processes are still uncertain. One of the investigative approaches is to derive the detailed density and velocity structures from observations of protostellar cores which are expected to retain information on the initial conditions of collapse.

The Bok Globule B335 is an isolated low-mass star-forming region harboring a low-mass Class 0 source, which is a suitable target for the study of low-mass star formation. We carried out the observations with the Nobeyama 45 m telescope and the Nobeyama Millimeter Array (NMA) in the $H^{13}CO^+(J=1-0)$ line emission. We performed combined imaging of interferometer and single-dish data in the Fourier domain (u–v domain), and applied the data optimizations to sensitivities and relative weights between 45 m and NMA data [1]. We finally obtained a combined image of B335 in the $H^{13}CO^+$ line emission with a synthesized beam size of $5''.6\times4''.4$.

Our analysis using a combining technique of singledish and interferometer data revealed the structure of the inner dense envelope within the core with a high spatial resolution of ~750 AU. Using the 45 m and combined data, we determined the radial column density profile of the B335 core. We found a reliable difference in the power-law indices of density profile between the outer and inner regions of the core; $n(r) \propto r^{-2}$ for $r \geq$ 4000 AU and $n(r) \propto r^{-1.5}$ for $r \leq$ 4000 AU. Our derived density profile is better explained, both qualitatively and quantitatively, in the picture of Shu's self-similar solution than in that of the Larson–Penston solution. Moreover, we performed simple model calculations of position–velocity diagrams to investigate the kinematics in the core. The model calculations successfully reproduce observational results, while suggesting a central stellar mass of $\sim0.1\,M_\odot$ and a small inward velocity of ~0 km s^{-1} in the outer region of the core $\geq$ 4000 AU.

From quantitative comparisons of density and velocity structures from the observational results with theoretical models, we concluded that a picture of Shu's solution or an isothermal collapse of a marginally stable Bonnor–Ebert sphere is suitable for the gravitational collapse of the B335 core. This result is published in [2].

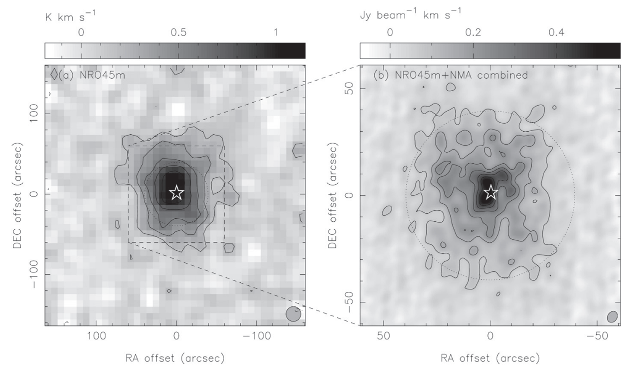

Figure 1: Total integrated intensity maps of B335 in the $H^{13}CO^+(J = 1-0)$ line emission obtained with the 45 m telescope (left) and by combining the 45 m telescope and NMA data (right). The open star in each map is the peak position of the 87 GHz continuum emission observed with the NMA. The beam size for each map is shown as a filled circle or filled ellipse at the bottom right corner. Dotted circle in the combined image indicates the field of view, i.e., FWHM primary beam size of the NMA observations.

References

[1] Kurono, Y., Morita, K.-I., Kamazaki, T.: 2009, *PASJ*, **61**, 873.
[2] Kurono, Y., Saito, M., Kamazaki, T., et al.: 2013, *ApJ*, **765**, 85.