Molecular Outflows From the Protocluster, Serpens South

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Most stars form in clusters. Therefore, understanding the formation process of star clusters is a key step towards a full understanding of how stars form. Recent observations have revealed that star clusters form in turbulent, magnetized, parsec-scale dense clumps of molecular clouds. These clumps contain masses of 10^2–$10^3\,M_\odot$, fragmenting into an assembly of cores that collapse to produce stars. In cluster-forming clumps, stellar feedback such as protostellar outflows, stellar winds, and radiation rapidly start to shape the surroundings. Because of the short separations between forming stars and cores, these feedback mechanisms are expected to control subsequent star formation. However, the roles of the stellar feedback on cluster formation remain poorly understood observationally.

In this study, we carried out molecular outflow survey toward a young embedded cluster, Serpens South, in CO (3–2) using the ASTE 10 m telescope, and attemped to reveal the role of molecular outflows in star formation in this cluster-forming region. Serpens South is a nearby embedded cluster, recently discovered by Guthermuth et al. (2008) using the Spitzer Space telescope.

An interesting characteristic of the cluster is its extremely-high fraction of protostars. In the central region, the number fraction of protostars (Class I) relative to the YSOs detected by the Spitzer telescope (Class I/II) reaches about 80 %. This fraction is largest among the cluster-forming regions known within the nearest 400 pc. This suggests that Serpens South is in the very early phase of cluster formation.

The main results are summarized as follows.

1. We found that many outflow components concentrate in the dense part where the protocluster resides. Most of these outflow components appear to move away from the dense part.

2. We estimated the global physical quantities of the outflows. The total outflow mass, momentum, and energy seem smaller than those of the Serpens Cloud Core, a nearby typical parsec-scale cluster-forming clump, located about 3° north of Serpens South. However, the characteristic outflow speed appears somewhat larger than that of the Serpens Cloud Core. This may imply that the YSO populations of Serpens South are younger than those of the Serpens Cloud Core.

3. The outflow energy injection rate is likely to be somewhat larger than the energy dissipation rate of the supersonic turbulence, suggesting that the outflow feedback can significantly contribute to the generation of the supersonic turbulence in the dense clump. Assuming the median stellar mass of $0.5\,M_\odot$, the mean outflow momentum per unit stellar mass is estimated to be about $4\,\mathrm{km\,s^{-1}}$, under the assumption of optically-thin gas.

4. The total outflow energy appears significantly smaller than the global gravitational energy of the dense part where the protocluster is located. In other words, it may be difficult to destroy the cluster-forming clump by the current outflow activity. This may be inconsistent with the dynamical model of cluster formation, for which the outflow feedback due to the initial star burst is envisioned to disperse the dense gas from the cluster-forming clump [1].

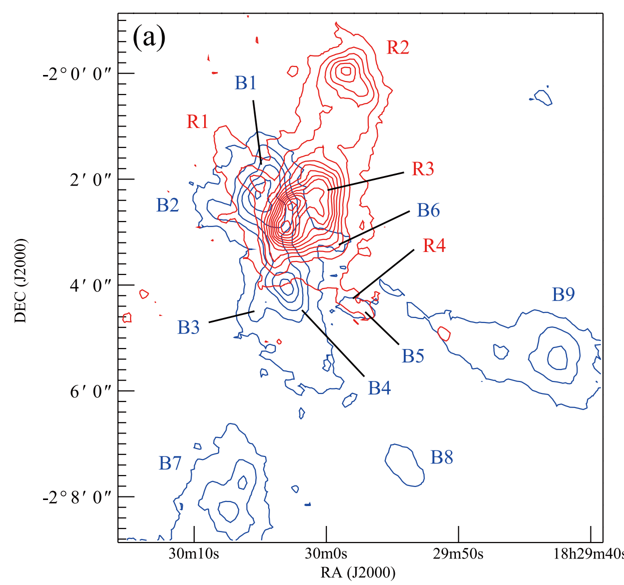

Figure 1: Molecular outflow lobes identified from CO (J = 3–2) emission toward the Serpens South protocluster. The blue contours represent blueshifted ^{12}CO gas and red contours represent redshifted ^{12}CO gas. The blue and red contour levels go up in $6\,\mathrm{K\,km\,s^{-1}}$ step, starting from $3\,\mathrm{K\,km\,s^{-1}}$. The integration ranges are −9.75 to 3.75 km $\mathrm{s^{-1}}$ for blueshifted gas and 11.25 to 29.25 $\mathrm{km\,s^{-1}}$ for redshifted gas.

Reference

[1] Nakamura, F., Sugitani, K., Shimajiri, Y., et al.: 2011, *ApJ*, **737**, 56.