Direct Imaging of a Compact Molecular Outflow from a Very Low Luminosity Object: L1521F-IRS [1]

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Studying the earliest evolutionary phase of protostars is an important topic for understanding the initial conditions of star formation. However, extremely young proto-stars in a very early phase of the accretion process ($\leq 10^4$ yr) are less luminous when compared with well-developed protostars [2]. Unprecedented sensitivity achieved with the *Spitzer* Space Telescope has revealed a large number of low-luminosity candidates, including Very Low Luminosity Objects so called VeLLOs, which has an internal luminosity of $<0.1\,L_\odot$ [3,4,5,6,7]. VeLLOs are known as candidates of extremely young protostars, proto-brown dwarfs, or young stellar objects, which are in a low-state of accretion phase. The nature of VeLLOs are not clear yet since the detailed high-angular resolution observational studies are still limited in number.

We carried out the high-angular resolution interferometric observations using the Submillimeter Array (SMA) toward a well studied VeLLO, L1521F-IRS ($d = 140$ pc). We have spatially resolved a compact and poorly collimated molecular outflow in ^{12}CO(2–1) for the first time (Figure 1). The outflow is aligned along the east-west direction with a lobe size of ≈1000 AU. The estimated outflow mass, maximum outflow velocity, and outflow force are $(9.0–80) \times 10^{-4}\,M_\odot$, $7.2\,\mathrm{km\,s^{-1}}$, and $(7.4–66) \times 10^{-7}\,M_\odot\,\mathrm{km\,s^{-1}\,yr^{-1}}$, respectively. The estimated outflow parameters are similar to values derived for other VeLLOs, and are located at the lower end of values compared to previously studied outflows associated with low- to high-mass star forming regions [8,9]. Low-velocity less collimated ($1.5\,\mathrm{km\,s^{-1}}$/1200 AU) and higher-velocity compact ($4.0\,\mathrm{km\,s^{-1}}$/920 AU) outflow components are suggested from our observation. The low-velocity component is not consistent with those expected in the jet driven or wind driven outflow models, but it could be related to the outflow driven from the first hydrostatic core (FHSC) since they are expected to be of very low-velocity and less collimated as shown by MHD simulations [10]. The high-velocity component likely trace an undeveloped outflow from the protostar. Detection of an infrared source and compact millimeter continuum emission suggest the presence of the protostar, while its low bolometric luminosity ($0.034–0.07\,L_\odot$), and small outflow, suggests that L1521F is in the earliest protostellar stage ($\leq 10^4$ yr) and contains a substellar mass object. The bolometric (or internal) luminosity of L1521F-IRS suggests that the current mass accretion rate is an order-of-magnitude lower than expected in the standard mass accretion model ($\approx 10^{-6}\,M_\odot\,\mathrm{yr^{-1}}$; [11]), which may imply that L1521F-IRS is currently in a low activity phase.

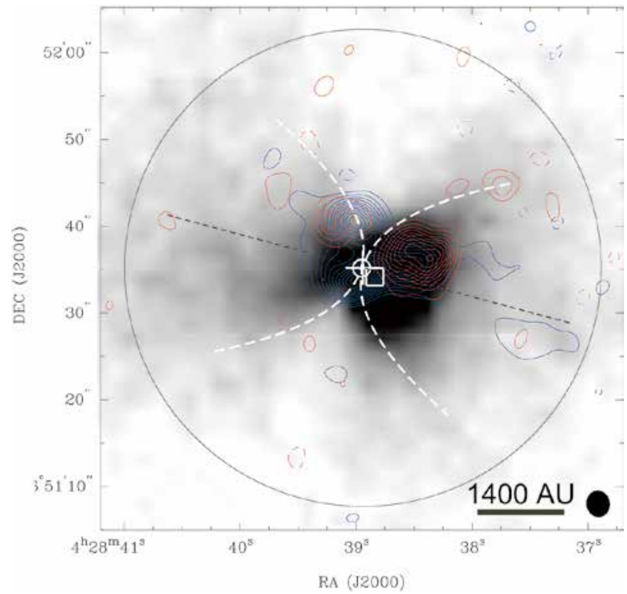

Figure 1: An very compact molecular outflow imaged in CO(2–1) using SMA (contours; This work [1]), superposed on the infrared reflection nebula obtained in the 4.5 μm image with *Spitzer/IRAC* [5].

References

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