Cosmic Masers: Proper Motion toward the Next-Generation Large Projects
Proceedings IAU Symposium No. 380, 2024
T. Hirota, H. Imai, K. Menten, & Y. Pihlström, eds.
doi:10.1017/S1743921323002363

Yamaguchi interferometer survey of protostellar outflows embedded in 70-μm dark infrared dark cloud

Keita Kitaguchi[1], Kazuhito Motogi[1,2], Kenta Fujisawa[2], Kotaro Niinuma[1,2] and Ryotaro Fujiwara[1]

[1]Graduate School of Sciences and Technology for Innovation, Yamaguchi University, Yamaguchi, Yamaguchi 753-8512, Japan. email: kmotogi@yamaguchi-u.ac.jp

[2]The Research Institute of Time Studies, Yamaguchi University, Yamaguchi, Yamaguchi 753-8511, Japan

Abstract. Recent ALMA observations detected protostellar outflows in 70-μm dark infrared dark clouds (IRDCs). These sources are candidates for the initial stages of high-mass star formation. We launched a new survey for free-free emission from outflow shocks using the Yamaguchi Interferometer (YI) at 8 GHz. We aim to catalog proto-high-mass protostar candidates that are still in the low to intermediate-mass phase. We selected starless-like clumps without any 70-μm point source from Traficante et al. (2015). We currently detected 82 sources from 167 clumps. 37 of them are fainter than 20 mJy (down to a few mJy). They tend to associate with colder and denser clumps that are suitable for star formation. This fact suggests that, at least, some of them trace star-formation activities. The highest-density clumps are, in fact, associated with several masers and molecular outflows. Furthermore, some of them have already shown a signature of ongoing cluster formation.

Keywords. ISM:jets and outflows, accretion disks, stars: massive, stars: protostars

1. Introduction

A number of evolved accretion disks in high-mass protostellar phase (*e.g.,* Motogi *et al.* 2019; Maud *et al.* 2019, etc) has been found in the last decade, indicating that high-mass stars are formed by disk mediated accretion similar to that of lower mass stars. The star-formation efficiency of a molecular core (i.e., total stellar mass over the natal core mass) is known to be 50 % (*e.g.,* Machida & Hosokawa 2013). Typical mass of high-mass starless cores is 10–30 $M_{\odot}$. This is too small to form O-type stars implying additional accretion from natal clamps and/or filaments (*e.g.,* Kong *et al.* 2021). How massive initial virialized core can become depends on pre-collapse condition of natal massive clump (e.g., temperature, density, and virial parameter, etc). It is essential to study a practical environment of natal clump and core just before gravitational collapse for quantitatively understanding high-mass star formation.

70-μm dark infrared dark clouds (IRDCs) are starless-like and considered to include the earliest stage of high-mass star formation. Recent ALMA observations detected protostellar outflows in such 70-μm dark IRDCs (*e.g.,* Feng *et al.* 2016; Pillai *et al.* 2019). These outflow sources are the best candidates of "Proto-high-mass protostars" (PHPs), which are still in low–intermediate mass stage but with high accretion rate. They could be extremely young seeds of high-mass protostars and still hold initial environment without significant feedback.

Table 1. Categories of surrounding environment of faint sources.

Category	Signs of star-formation	Clump numbers
1	Only the continuum detected by YI	14
2	Outflow and/or maser within the clump	3
3	Signature of cluster formation around the clump	4
Uncategorized	No other observation	16*

*One maser source associated with a foreground AGB star is included.

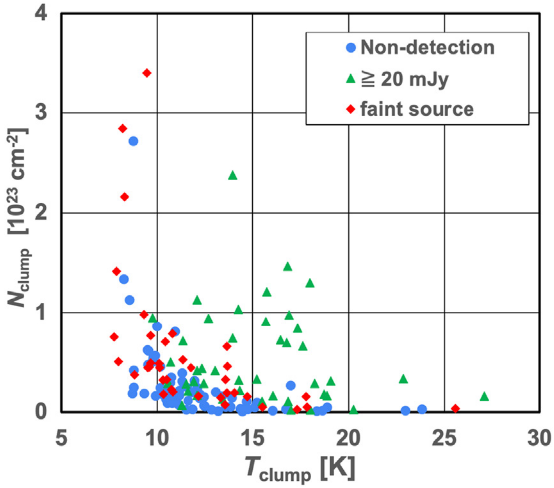

Figure 1. Dust temperatures versus H_2 surface densities for all the targeted clumps. Blue, green, and red markers show non-detection clumps, bright sources, and faint sources (< 20 mJy), respectively.

2. YI survey of protostellar outflows in 70-μm dark IRDCs

We conducted new 8 GHz continuum survey towards 70-μm dark IRDC clumps by using the Yamaguchi Interferometer (YI) (Fujisawa *et al.* 2022). We aimed to search for outflow shocks associated with PHPs. We observed 167 starless-like IRDC clumps cataloged by Traficante *et al.* (2015).

We detected 81 continuum sources and 37 of them are fainter than 20 mJy with the minimum flux density of 1.9 mJy. Figure 1 shows comparison of dust temperatures and H_2 surface densities of natal IRDC clumps. These faint sources tend to associate with relatively colder and higher surface density clumps, i.e., suitable condition for star formation. This fact suggests that some of them do trace star-formation actives such as young, deeply embedded outflow shock. We then searched for evidences of star-formation activity for these faint sources. We found that 7 clumps were associated with masers and/or molecular outflows, 14 clumps were only detected by YI, and there were no maser or outflow observation for other 16 clumps. Table 1 summarizes the environment of the faint clumps. These categories possibly reflect different evolutionary stages at 70-μm dark phase.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1743921323002363

https://doi.org/10.1017/S1743921323002363 Published online by Cambridge University Press

References

Feng, S., Beuther, H., Zhang, Q., *et al.* 2016, *ApJ*, 828, 100
Fujisawa, K., Aoki, T., Kanazawa, S., *et al.* 2022, *PASJ*, 74, 1415
Kong, S., Arce, H. G., Shirley, Y., *et al.* 2021, *ApJ*, 912, 156
Machida, M. N. & Hosokawa, T. 2013, *MNRAS*, 431, 1719
Maud, L. T., Cesaroni, R., Kumar, M. S. N., *et al.* 2019, *A&A*, 627, L6
Motogi, K., Hirota, T., Machida, M. N., *et al.* 2019, *ApJ*(Letters), 877, L25
Pillai, T., Kauffmann, J., Zhang, Q., *et al.* 2019, *A&A*, 622, A54
Traficante, A., Fuller, G. A., Peretto, N., *et al.* 2015, *MNRAS*, 451, 3089 Brown, S. F., Semel, M., *et al.* 1992, *A&A*, 265, 682

https://doi.org/10.1017/S1743921323002363 Published online by Cambridge University Press