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# VLA Observations of $H_2O$ Masers in the Class 0 Protostar S106FIR

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**Abstract.** We measured relative positions of the 22 GHz $H_2O$ maser components toward the class 0 protostar S106FIR with the VLA. Two clusters of $H_2O$ masers were found. The separation between these clusters is approximately 50 AU at position angle = 73° and each cluster is spread over about 10–20 AU The size of the S106FIR maser clusters is unusually compact compared with other known $H_2O$ masers associated with outflows of forming stars. The maser emission appears to originate from MHD driven outflow very close to the star.

S106FIR is an intermediate self-luminous protostar ($30L_\odot \leq L_{bol} \leq 1000L_\odot$) which was found as a bright far-infrared point source by Richer et al. (1993). S106FIR is a member of the so-called class 0 sources. We found a compact, dense, optically thin $H^{13}CO^+$(J=1-0) core with a diameter of 9000 AU using the Nobeyama Millimeter Array (NMA) (Furuya et al., in preparation). The $H^{13}CO^+$ map indicates a velocity gradient of 2.16 km sec$^{-1}$ over $\sim$ 2100 AU along an east-west line at p.a. = 79°. Mangum & Wootten (1994) have found an elongated $NH_3$ (2,2) disk-like structure on 4000 AU scales at p.a.= 135° using the VLA. A very compact $H_2O$ maser emission was found toward S106FIR using the NMA. The $H_2O$ masers has a doubly peaked spectrum with a velocity separation of 15 km sec$^{-1}$ and all the maser spots are concentrated within 0.3" (180 AU assuming $D$=600 pc; Kawabe 1987 cited in Richer et al. 1993). No clear outflow activity has been found toward S106FIR with NMA CO (J=1-0) observations (Furuya et al., in preparation). We consider it possible that S106FIR might be too young to generate large-scale outflows.

The $H_2O$ masers at 22 GHz are excellent probes of astrophysical flow motions in the shocked gas, and can be used as very high angular resolution tools for studying velocity fields very close to forming stars. We made higher resolution observations using the VLA in the A and BnA configurations in order to investigate the detailed velocity structure of very close to the protostar. We found that two clusters of $H_2O$ masers are at the center of the $H^{13}CO^+$ core. The separation between these clusters is approximately 50 AU at position angle = 73° and each cluster is spread over about 10-20 AU. The two clusters are well-separated in velocity. The major axis of the $H_2O$ maser cluster is almost parallel to that of the $H^{13}CO^+$ core. The axis of the masers lies roughly perpendicular to the $NH_3$ disk-like distribution. Furthermore, we made synthesis observations with the Japanese VLBI network and the VLBA snapshot observations and confirmed that both the angular and velocity separation was the same as compared with the VLA A configuration observations.

We suggest three possible models for the maser clusters. They could be (1) associated with a MHD driven outflow, (2) arisen in the tangential part of a rotating disk whose radius is 15 $\sim$ 35 AU, or (3) originated near each star of a binary system. The first suggestion is difficult to support by current $H_2O$ maser data because no clear evidence for any outflow activity has been reported (Hayashi et al. 1990; Bachiller 1996; Furuya et al., in preparation). If the second idea is true, then an enclosed mass of $1.5 M_{\odot}$ would be needed to explain the velocity distribution. The difficulty with second idea is that not all of the maser spots are necessarily well-fit by a Keplerian rotation curve, although the mass estimate is reasonable when compared with the observed bolometric luminosity. The third suggestion has a serious problem: there is no evidence for the existence of a binary.

It is obvious that proper motion studies using VLBI can clarify whether the masers arisen in disk, outflow, or both. We are currently analyzing the details of the Japanese VLBI network data as well as the VLA data.

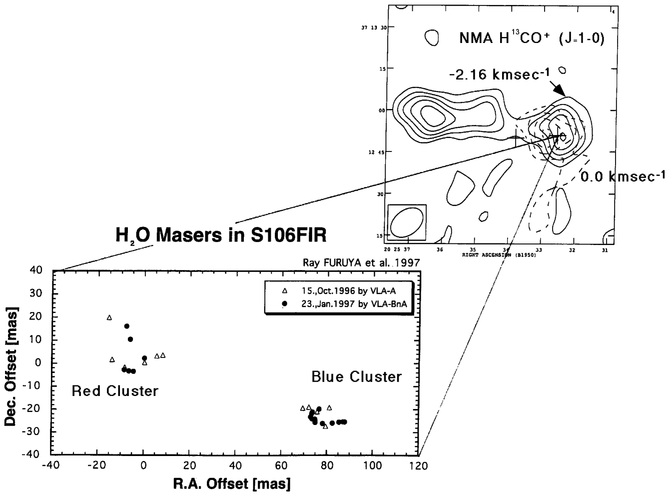


**Figure 1.** The $H_2O$ masers in Class 0 protostar S106FIR by the VLA (*left*), at distance of 600 pc, 20 mas corresponds to 12 AU. The compact optically thin $H^{13}CO^+$ (J=1-0) core with 9000 AU diameter by the NMA (*right*).

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## References

Bachiller, R. 1996. *ARA&A*, **34**, 111–154.
Hayashi, S. S., et al. 1990. *ApJ*, **354**, 242–246.
Mangum, J. G., & Wootten, A. 1994. *BAAS*, **26**, 1454.
Richer, J. S., et al. 1993. *MNRAS*, **262**, 839–851.