論文内容の要旨

論文題名：「 Outflows in Orion-KL : 3-Dimensional Kinematics of H_2O and SiO Masers」

「 Orion-KL領域のH_2O, SiOメーザー観測によるアウトフローの3次元運動構造解明」

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Results of multi-epoch VLBI observations toward H_2O vapor masers and SiO masers in Orion-KL are reported. After the explosive outflows In Orion-KL are detected with H_2 and CO, the origins of outflows have been studied by a number of observations (Genzel and Stutzki 1989). However, the origins of outflows and the properties of the driving sources are remain debated until now.

It is known that there are two kind of outflows in Orion-KL: wide-angle, northwest-southeast high-velocity outflow, and northeast-southwest low-velocity outflow. Source I, a radio source, has been a possible candidate for the driving source of both high-velocity and low-velocity outflow since it is located at the center of the outflows. However, recent high-angular resolution observations toward Source I suggest that Source I drives only low-velocity outflow, thus what drives high-velocity outflow remains as one of the unsolved problems.

To explain the origin and nature of the wide-angle outflow, some authors proposed that the Source I, BN and n had a close encounter about 500 years ago, and the energy ejected in this process may power the high-velocity outflow in Orion-KL(Gómez et al. 2008; Rodríguez et al. 2005). Still, there are alternate scenario that the close passage between Source I and BN trigger a accretion on Source I and outburst of outflow, or that the interaction changes the direction of outflow from Source I (Tan 2004; Plambeck et al. 2009).

To investigate the nature of Source I and the kinematics in outflow, 3-dimensional motion of gas will be essential. Strong masers in Orion-KL is useful to trace the outflows and stellar matters surrounding Source I. Thus, high-resolution VLBI observations of masers can be used to probe the structure and kinematics of the disk/outflow surrounding the protostars.

Here, We present the results of VLBI observation toward SiO v=1, J=1-0 and v=2, J=1-0 maser emission and H_2O maser emission in Orion-KL. The SiO maser emissions show an X-shaped distribution centered at Source I, and the SiO v=2 emissions lie closer to Source I than the SiO v=1emissions. The radial velocities of maser features are divided into two radial velocity ranges: -10 to 1kms^{-1} and 5 to 25 km s^{-1} (Fig. 2). Relative to the systemic velocity of 5 km s^{-1}, red-shifted emission is located in western arms, while blue-shifted emission is located in eastern arms. The radial velocities tend to decrease with the velocity gradient of $\sim$0.4 km s^{-1}AU^{-1} along the distance from Source I in both red-shifted and blue-shifted arm.The proper motions of SiO emissions range from 2 to 26km s^{-1} and are mainly outward along the arms of X, and are independent to the distance from Source I. Our observations indicate that the SiO masers trace the rotating and expanding gas around Source I.

3-D kinematics shows SiO masers are in rotating, expanding material, possibly on the surface of accretion disk. Its rotating velocity is $\sim$24 km S^{-1} and central mass $M_* \sim 14\ M_\odot$, which is consistent with the mass estimation by the radio emission observation or the dynamical scenario.

We imaged the H_2O maser associated with low-velocity outflow and measured the proper motions of individual water maser features using the phase-referencing observation data taken in 2005, 2006 with VERA. H_2O masers with line-of-sight velocity range of -5-32 km s^{-1} are spread over the region of 45$\times$50 arcsec and centered on the vicinity of IRc 2 (Fig. 1). The distribution shows an elongated pattern in direction of low-velocity outflow, and most of maser emission is located in southwestern region from Source I. Moreover, the positions of maser features show good match with the limb of SiO $v = 0$ emission observed with CARMA, suggesting that H_2O masers arise in the dense interstellar material heated by the low-velocity outflow from Source I.

The motions of H_2O masers shows that the center of expansion is consistent with Source I, while the systemic motion of H_2O masers are close to the ambient cloud. It suggests that the maser emissions arise between the dense ambient clouds and the outflow from Source I.

With the result of SiO maser observations, our result shows that the Source I is a massive YSO with accretion disk and collimated outflow. This study provides an evidence of a massive protostar with disk-mediated accretion.

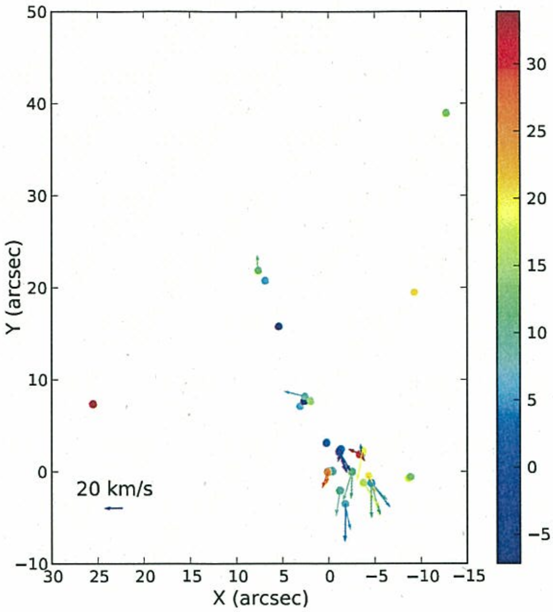

Figure 1: Measured absolute proper motions of H_2O maser features. (0,0) is the position of reference spot. Color represents the line-of-sight velocity of each feature.

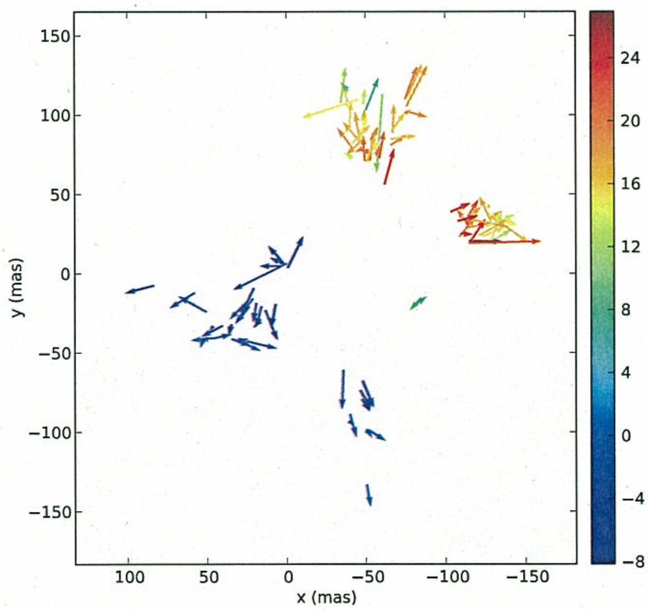

Figure 2: Proper motions of SiO v=1,2 maser emission. Color corresponds to its line-of-sight velocity of a feature. The length of each arrow is proportional to the (absolute proper motion - proper motion of Source I(Goddi et al. 2010), thus, corresponding to the proper motion relative to the Source I.