SiO maser observations towards Orion-KL with VERA

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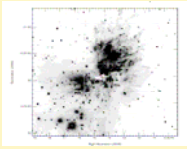
Abstract

We present results of phase-referencing VLBI observations of SiO masers in the Orion KL region made with VERA. The goal of our study is to investigate the dynamics of the gas surrounding Source I, as well as to determine the distance to Orion-KL.We imaged SiO v=1, J=1-0 and v=2, J=1-0 maser emissions in Orion-KL and compared the absolute positions of maser spots with that of Source I. The 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 and proper motions of the maser spots indicate that the gas around Source I is rotating and expanding.

In addition, we present the preliminary result of measurement of the annual parallax using the SiO v=2 emission. The annual parallax of Orion-KL is derived to be 2.49±0.07mas, corresponding to the distance of 401±11pc.

Introduction

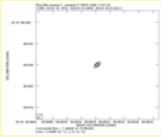
•Orion-KL : The nearest region of ongoing high-mass star formation
-There are many infrared sources, but Source I is outstanding among them due to the association with strong SiO and water masers.
-Previous studies suggest the models of :
◦ an outflow oriented southeast-northwest and an orthogonal torus :e.g Bally & Zinnecker (2005)
◦ a disk of which axis oriented northeast-southwest and an outflow :e.g Greenhill et al.(2003), Reid & Menten,. et al. (2007)
•Our observation aims to:
-measure the absolute positions and proper motions of SiO masers.
→constrain the model of structures and dynamics of gas surrounding Source I
-measure the annual parallax using SiO maser emissions



2.12μm H_2 image(subaru)+OH maser (Cohen et al. 2006)

Observations

•Multi-epoch observations using VERA dual-beam system : 2006.84, 2006.92, 2007.02, 2007.12, 2007.21, 2007.32, 2007.41
•Target : v=1, J=1-0 and v=2, J=1-0 SiO masers in Orion-KL
reference source : J0541-0541
•Recorded with 16 x 16 MHz IF channels :
Two 16MHz IF channels were assigned for each SiO transition, others for reference source.
•Correlation with the Mitaka FX correlator yielded 512 spectral channels in each IF, resulting in velocity resolution of 0.21km/s.
•All data reduction were performed with AIPS software.



The image of reference source, J0541-0541

Results

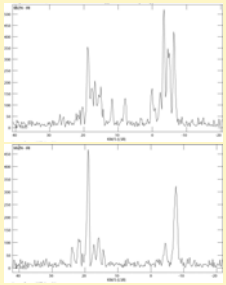


Fig 1. Cross power spectra of SiO J=1-0 v=1(top) and SiO J=1-0 v=2(bottom) observed with the mizusawa-iriki baseline. (2007.32)

1. The distance to Orion-KL

:We measured the trigonometric parallax of Orion-KL by multi-epoch VLBI astrometry.
• Fig 2 : Parallax fit for one of the maser spots detected at 6 epochs (2006.84, 2006.92, 2007.02, 2007.12, 2007.21, 2007.32).
We used one of the SiO v=2 maser spots of which the V_{lsr} is –9kms^{-1}.
→best fit for RA: 2.49±0.07mas, corresponding to a distance of 401±11pc.
best fit for Dec : 2.39±0.22mas, corresponding to a distance of 419±39pc.
best fit for RA and Dec: 2.48±0.63mas, corresponding to a distance of 402±10pc.
:This result is consistent with other parallactic distances to Orion nebula
- Hirota et al. (2007): 437±19pc, Sandstrom et al. (2007) : 389^{+24}_{-21}pc, Menten et al. (2007) : 414±7pc

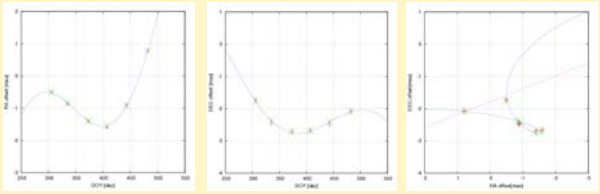


Fig 2. (left) The positions of the reference spot in RA during 6 epochs. (center) The positions of the reference spot in Dec during 6 epochs. (right) The locus of the reference spot. The red line represents the direction of the proper motion of the spot.

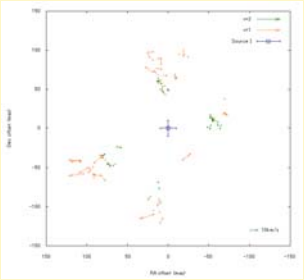


Fig 3. The absolute positions and proper motions of two transitions. The positions are taken from the data of 2006.84. The origin is the position of Source I.

2. The distribution of the SiO masers

•Fig 3 : The absolute positions of SiO v=1,2 J=1-0 masers with precision ~1 mas.
◦ X-shaped distribution centered at Source I, spreading over a region 200 x 200 mas for v=1 and 150 x 150 mas for v=2.
(The position of Source I is taken from Rodriguez et al. 2005)
→agrees with that of other observations using VLBA (e.g Greenhill et al. 2004, Doeleman et al. 2004).
◦ SiO v=2 emissions tend to lie closer to Source I than SiO v=1 emissions.
:SiO v=1 emissions are distributed in the region of radius 33±8AU while that of SiO v=2 emissions is 25±5AU at 401pc.
→Two transitions are overlapped within the mutual errors, but considerably separated.
→It suggests that the maser emissions would be pumped by not only collision, but radiation from Source I.

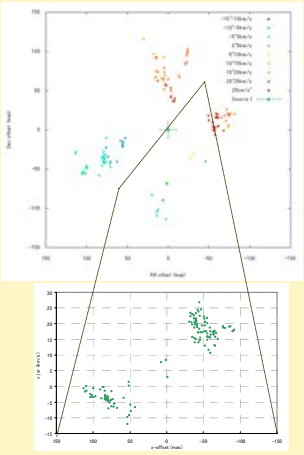


Fig 4. (top) The radial velocities of SiO maser emissions (2007.32). The origin is the position of Source I (Rodriguez et al.2005).
(bottom) P-V diagram of SiO v=1,2 emissions

3. The kinematics of the SiO masers

•Fig 3 : The proper motions of SiO emissions based on our VLBI astrometry. The proper motion of Source I(Rodriguez et al. 2005) is subtracted from that of each maser spot.
◦ The proper motions of SiO emissions are ~13kms^{-1} on average and mainly outward along the arms of X.
• Fig 4: The radial velocities of the SiO maser emissions, ranging from –10kms^{-1} to 25kms^{-1}
◦ The emissions to the north-west are red-shifted, while those to the south-east are blue-shifted.
◦ P-V diagram indicative of Keplerian rotation.
: On the assumption of a simple edge-on Keplerian disk, the dynamical mass of the YSO is 6$M_{\odot}$. This is consistent with the estimation that Source I is ZAMS B0-B1 star (Reid et al. 2007).
→The simplest interpretation for the 3-D motions of the SiO masers is that the masers trace the disk wind from the upper and lower side of the thick, edge-on disk of which an axis is northeast-southwest orientation.
:This hypothesis cannot explain what the powering source of large-scale high-velocity CO outflow oriented southeast-northwest is.
→There is another possibility that P-V diagram and proper motions of masers would be the decelerating outflow along a southeast-northwest direction.

Future works

• Additional phase-referencing observations
→more accurate value of annual parallax of Orion-KL and proper motions of individual SiO masers
• Detailed modeling of the gas surrounding Source I
◦ considering the spatial distribution and velocity field of the maser emissions, along with their pumping and amplification mechanisms
◦ link to the larger scale structure in the Orion-KL region

References

Bally & Zinnecker, 2005, AJ,129, 2281
Cohen et al. 2006, MNRAS, 367, 541
Doeleman,.et al. 2004, ApJ, 607, 361
Greenhill,.et al. 2004, IAUS, 221, 155
Hirota,.et al. 2007, PASJ, in press
Menten & Reid,.et al. 2007, to appear in A&A
Reid & Menten,.et al. 2007, ApJ, 664, 950
Rodriguez,.et al. 2005, ApJ, 627, 65
Sandstrom,.et al. 2007, accepted to ApJ