

# Internal proper motion of 6.7 GHz methanol maser in high mass star forming regions

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## Abstract

We have observed the spatial distributions of the 6.7 GHz methanol maser in 38 high mass star forming regions (HMSFRs) using VLBI to study the gas motion around high mass young stellar objects. The morphologies of the maser distribution were divided into five types (Linear, Arched, Elliptical, Paired, Complex). The next step of this study is to derive the proper motions of these

sources. One of Elliptical sources have shown rotation and infall (Cep A; Sugiyama et al. 2014). However, proper motion is reported in few sources at present. In this work, we report on the proper motions of the maser spots of four morphological types (Linear, Elliptical, Paired, Complex).

## Introduction

### 1. Previous study of high mass star formation

High mass star formation is poorly understood because of far distance ( $\sim 1$  kpc) and high opacity. In recent years, high-resolution interferometric observation at submillimeter and near-infrared wavelengths have suggested existence of the rotating structure, which is traced by hot core molecules (e.g.,  $\text{CH}_3\text{CN}$ ), and compact dusty disk ( $\sim 20$  AU), elongating perpendicular to the outflow [1][2].

### 2. 6.7 GHz methanol maser

6.7 GHz methanol masers have been observed only HMSFRs. The maser is compact and bright enough to measure proper motions using VLBI. In fact, proper motion tracing rotation and infall have been reported on an Elliptical source, Cep A HW2 [3]. However, Proper motion of the maser have been reported in only  $\sim 10$  sources, in spite of the maser have been detected  $\sim 900$  sources by single-dish observation, and the distribution have already been imaged for 60 sources by VLBI observation (Figure 1).

### 3. Project of measuring proper motion

We have been conducted VLBI monitoring project of

the maser sources with East Asian VLBI Network (EAVN) to systemically investigate their internal proper motions of 6.7 GHz methanol maser. Fujisawa et al. (2014) [4] presented the results of the first epoch observation for 36 sources. Observed sources are divided into five morphologies (Linear, Arched, Elliptical, Paired, Complex). In present, we have started proper motion measurements of these sources to study the circumstellar gas motion for each morphological types. In this work, we report on the proper motion of four types (linear, Elliptical, Paired, Complex).

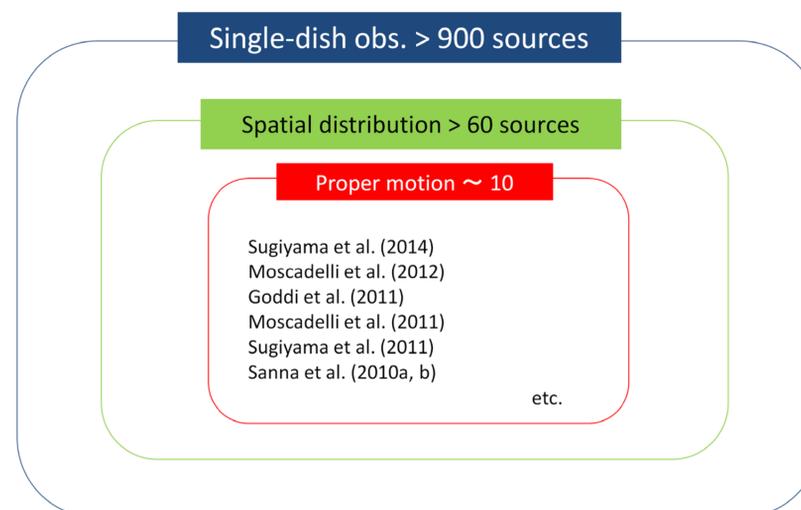


Figure 1. previous study of 6.7 GHz methanol maser sources. Proper motion is very few !!

## Observation

VLBI observations of 6.7 GHz methanol maser sources were conducted with EAVN (Figure 2) [5] in 2010 to 2013. The typical size of the major axis of the synthesized beam was about 5 mas ( $\sim 10$  mas in southern sources).

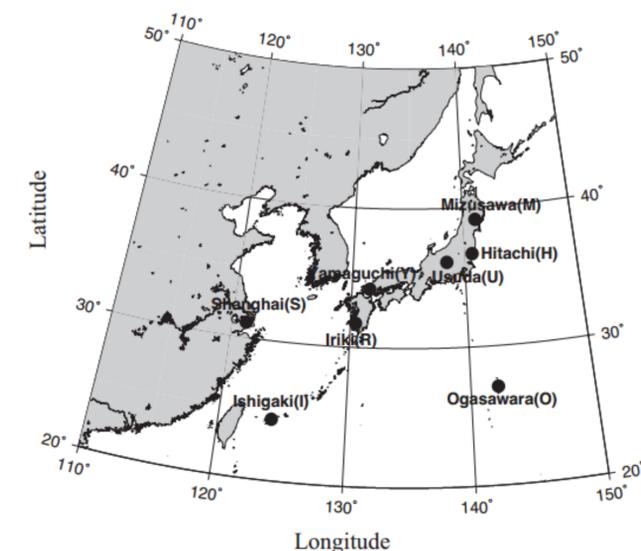


figure 2. East Asian VLBI Network

Table 1. Position and distance of Target sources

Sources	R.A.	Dec.	Distance
011.49-01.48	18h16m22.13s	-19d41m27.1s	1.6 kpc
232.62+00.99	07h32m09.79s	-16d58m12.4s	1.68 kpc
351.77-00.53	17h26m42.57s	-36d09m17.6s	1 kpc
352.63-01.06	17h31m13.91s	-35d44m08.7s	0.9 kpc

# Results

## <Spatial Distribution & Proper motion>

Table 2. Parameter of spatial distribution

	Number of spots	Radial Velocity [km/s]	Spatial Scale [AU × AU]	Spatial Morphology
011.49-01.48	62	4.67 – 17.14	261 × 703	Complex
232.62+00.99	9	22.20 – 23.43	23 × 102	Paired
351.77-00.53	18	-2.66 – 2.08	103 × 105	Elliptical
352.63-01.06	24	-4.31 – -2.73	221 × 186	Linear

Table 2. Proper motion of each sources

	011.49-01.48	232.62+00.99	351.77-00.53	352.63-01.06
Max of proper motion [km/s]	21.47	0.72	0.81	0.13
Min of proper motion [km/s]	0.87	6.15	7.75	8.00

## <Characteristics of Proper Motion>

- 11.4-1.4... Overall, it seems to be moving to the south. But, origin of this motion has been not yet known ( helical outflow? rotating? structure? etc. ).
- 232.6+09... Spots in each cluster move apart from each other. It is difficult to discuss this motion because of limited feature.
- 351.7-05... Elliptical morphology and velocity gradient suggest that this sources is associated with rotating structure. But, the motion seems to be expanding. This motion can be explained by disk wind (ref: poster in VLBI social hour, D.Hirano, 2013).
- 352.6-10... EW cluster and NE cluster move towards each other. This motion maybe show infalling motion.

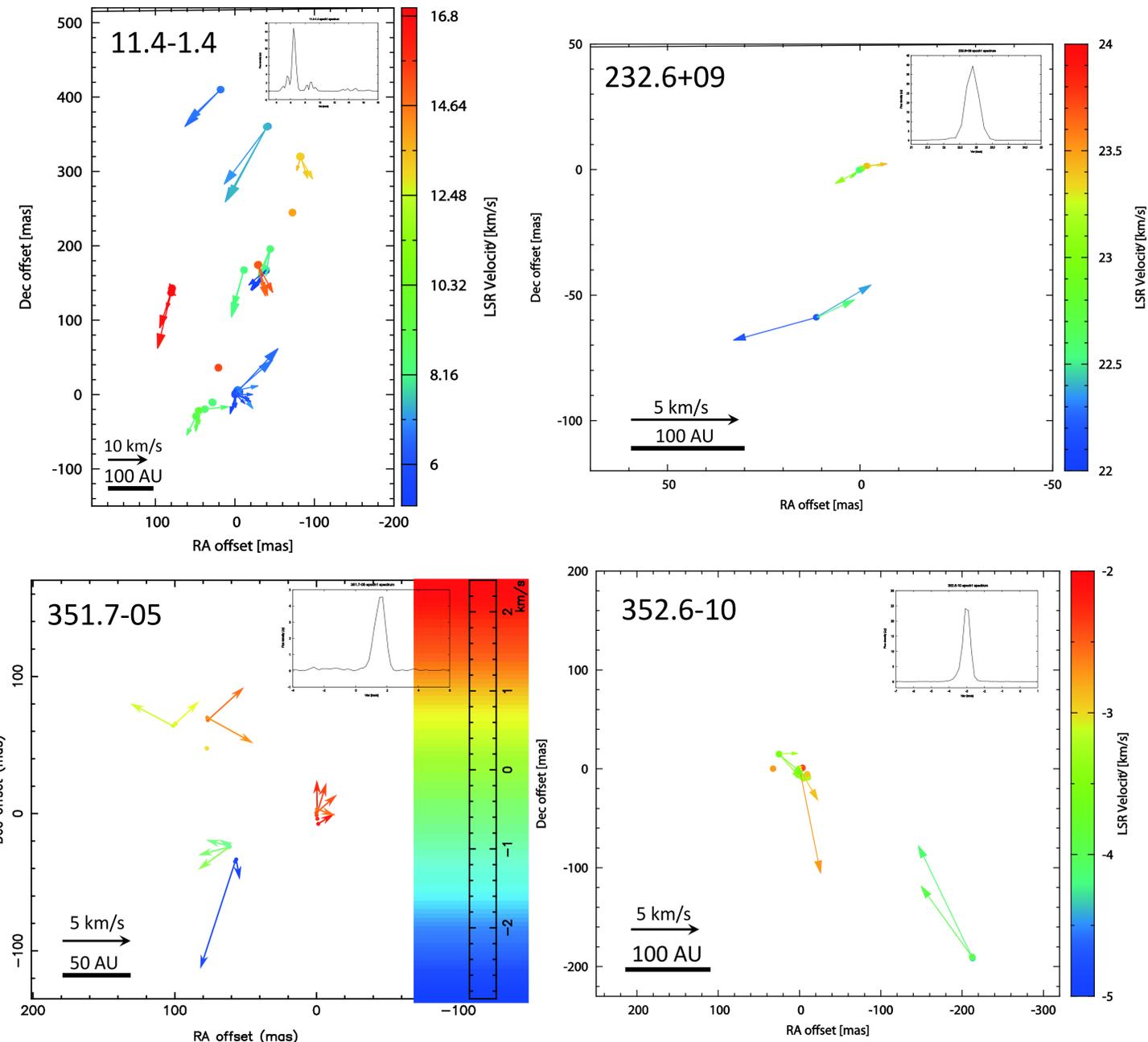


Figure 3. Proper motion and spectrum of each sources. Circle: spot position, color-bar: radial velocity, Vector: proper motion, length of Vector: Flux intensity(logarithm proportionality)

# Future

- Proper motion of each sources
  - Proper motion of 6.7 GHz methanol maser can not be understood only by VLBI data. Therefore, we must know information such as infrared, molecular line, radio continuum in the future to understand positional relation between central star, circumstellar disk, outflow and this maser etc.
- Proper motion VS spatial morphology
  - We will investigate systemic studies about a relation between the kinematics and the morphology by deriving proper motion of sources other than that reported in this work

# Reference

- [1] Patel, N. A., et al. 2005, Nature, 437, 109
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- [5] Shen, Z., Yang, J., Hirabayashi, H., Inoue, M., Kim, H.-G. & Han, S.-T. 2004, Asia-Pacific Radio Science Conference Proceedings (eds. Tang Keyun and Liu Dayong), p401-402.