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# THE VLBI MONITORING PROJECT FOR 6.7 GHz METHANOL MASERS USING THE JVN/EAVN

Koichiro Sugiyama[1], Kenta Fujisawa[2], Kazuya Hachisuka[3], Yoshinori Yonekura[1], Kazuhito Motogi[2], Satoko Sawada-Satoh[4], Naoko Matsumoto[5], Yu Saito[6], Daiki Hirano[3], Kyonosuke Hayashi[3], Zhiqiang Shen[7], Mareki Honma[5], Tomoya Hirota[5], Yasuhiro Murata[8], Akihiro Doi[8], Kotaro Niinuma[3], Richard Dodson[9], Maria Rioja[9], Simon Ellingsen[10], Xi Chen[7], Kee-Tae Kim[11], and Hideo Ogawa[12]

[1]Center for Astronomy, Ibaraki University, 2-1-1 Bunkyo, Mito, Ibaraki 310-8512, Japan
[2]The Research Institute for Time Studies, Yamaguchi University, 1677-1 Yoshida, Yamaguchi, Yamaguchi 753-8511, Japan
[3]Graduate school of Science and Engineering, Yamaguchi University, 1677-1 Yoshida, Yamaguchi, Yamaguchi 753-8512, Japan
[4]Mizusawa VLBI Observatory, NAOJ, 2-12 Hoshigaoka-cho, Mizusawa-ku, Oshu, Iwate 023-0861, Japan
[5]Mizusawa VLBI Observatory, NAOJ, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[6]College of Science, Ibaraki University, 2-1-1 Bunkyo, Mito, Ibaraki 310-8512, Japan
[7]Key Laboratory of Radio Astronomy, Shanghai Astronomical Observatory, Chinese Academy of Sciences, China
[8]The Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuou-ku, Sagamihara, Kanagawa 229-8510, Japan
[9]International Center for Radio Astronomy Research, M468, The University of Western Australia, 35 Stirling Hwy, Crawley WA6009, Australia
[10]School of Mathematics and Physics, University of Tasmania, Private Bag 37, Hobart TAS7001, Australia
[11]Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, Yuseong-gu, Daejeon 305-348, Republic of Korea
[12]Department of Physical Science, Osaka Prefecture University, 1-1 Gakuen-cho, Naka-ku, Sakai 599-8531, Japan

*E-mail: koichiro@mx.ibaraki.ac.jp, y.yone@mx.ibaraki.ac.jp*

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## ABSTRACT

We have initiated a Very Long Baseline Interferometer (VLBI) monitoring project of 36 methanol maser sources at 6.7 GHz using the Japanese VLBI Network (JVN) and East-Asian VLBI Network (EAVN), starting in August 2010. The purpose of this project is to systematically reveal 3-dimensional (3-D) kinematics of rotating disks around forming high-mass protostars. As an initial result, we present proper motion detections for two methanol maser sources showing an elliptical spatial morphology, G 002.53+00.19 and G 006.79−00.25, which could be the best candidates associated with the disk. The detected proper motions indicate a simple rotation in G 002.53+00.19 and rotation with expansion in G 006.79−00.25, respectively, on the basis of disk model fits with rotating and expanding components. The expanding motions might be caused by the magnetic-centrifugal wind on the disk.

*Key words:* Masers: methanol — Stars: formation — Stars: massive — Instrumentation: high angular resolution

## 1. INTRODUCTION

In the last decade, interferometric observations at submillimeter and infrared wavelengths have demonstrated the existence of a rotating disk around forming high-mass protostars (e.g., Patel et al. 2005; Kraus et al. 2010). The dynamics and the evolution of the disks, however, remain largely unknown. The 6.7 GHz methanol masers are expected to trace the rotating disk on the basis of spatial morphology and line of sight velocity structures (e.g., Minier et al. 2000; Bartkiewicz et al. 2009), and can be a powerful tool to reveal 3-D kinematics of the disk. In fact, rotating proper motions were demonstrated in some methanol sources (e.g., Sanna et al. 2010a, b), one of which was detected with infalling components Sugiyama et al. (2014).

We have initiated a VLBI monitoring project of the 6.7 GHz methanol maser sources using the JVN and EAVN, starting in August 2010, to systematically reveal 3-dimensional (3-D) kinematics of rotating disks around forming high-mass protostars Fujisawa et al. 2014.

## 2. OBSERVATIONS AND RESULTS

As target sources, we selected 36 methanol masers at 6.7 GHz from the previous catalog under the criteria of declination, peak flux density, and no previous VLBI observation. The VLBI observations were conducted with JVN/EAVN in 2010–2013 yr with ∼1 yr gaps, achieving three epoch data for all of the target sources. Details of the source selection, observations, and data reduction are described in the paper by Fujisawa et al. (2014) and

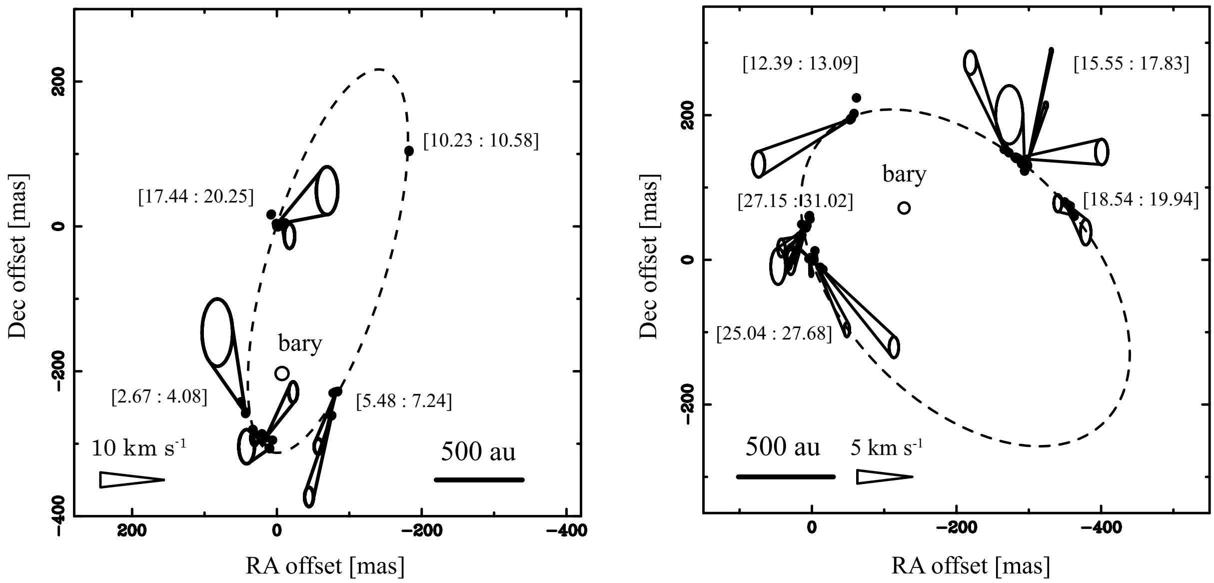


Figure 1. Proper motions of the 6.7 GHz methanol masers in G 002.53+00.19 (*Left*) and G 006.79−00.25 (*Right*) relative to the barycenter (white open circle). Cones show the proper motions in each maser (the aperture of the cone corresponds to the uncertainty). The origin of each cone is located at the relative positional offset of each maser. Attached numerals indicate a range of line of sight velocities for each maser spot (filled circle). The dashed ellipse corresponds to the elliptical structure fitted toward the identified methanol masers.

Sugiyama et al. (submitted).

Here, as an initial result, we present proper motions (relative to the barycenter, which is the averaged position of all of identified masers) of the methanol masers detected in G 002.53+00.19 and G 006.79−00.25, as shown in Figure 1. Spatial distributions of the maser spots of these sources were classified into an elliptical morphology by Fujisawa et al. (2014), which could be the best candidates to be associated with the disk. The amplitude of the detected proper motions ranges from 0.07–0.66 and 0.08–0.60 mas $yr^{-1}$ (corresponding to 1.3–13.1 and 1.3–10.3 km $s^{-1}$ at the source distances), respectively. Through our three epoch observations, most of the detected proper motions seem to entirely move in rotation along the maser ellipse. On the basis of disk model fits with rotating and expanding components to the positions and 3-D velocities including the proper motions Sugiyama et al. 2014, we derived the best-fit parameters of the rotation of $+4.4^{+1.1}_{-1.1}$ and expansion of $-0.2^{+1.1}_{-1.1}$ km $s^{-1}$ in G 002.53+00.19 (simple rotation), and the rotation of $+2.3^{+2.1}_{-1.4}$ and expansion of $+3.4^{+1.8}_{-1.0}$ km $s^{-1}$ in G 006.79−00.25 (rotation with expansion), respectively.

The expanding motions derived in G 006.79−00.25 might be caused by magnetic-centrifugal winds on the disk, which have been observed in the nearest high-mass protostar, Source I in Orion-KL, (e.g., Kim et al. 2008) and was demonstrated through magnetohydrodynamical-driven wind theory Seifried et al. (2012).

To reveal the evolution of disks surrounding high-mass protostars, we will compare disk parameters estimated from hot core molecular tracers and sub-mm dust continuum emissions observed with the high-positional accuracy and the high-spatial resolution array ALMA.

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