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FLUX MONITORING OF 6.7 GHz METHANOL MASER TO SYSTEMATICALLY RESEARCH PERIODIC VARIATIONS USING THE HITACHI 32-m

Koichiro Sugiyama[1], Yoshinori Yonekura[1], Kazuhito Motogi[2], Yu Saito[3], Kenta Fujisawa[2], Shota Ishii[3], Munetake Momose[3], Mareki Honma[4], Fumie Tazaki[4], Kei E. I. Tanaka[5], Takashi Hosokawa[6], Mizuho Uchiyama[7], and Kohei Inayoshi[8]

[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]College of Science, Ibaraki University, 2-1-1 Bunkyo, Mito, Ibaraki 310-8512, Japan
[4]Mizusawa VLBI Observatory, NAOJ, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
[5]Department of Astronomy, University of Florida, 211 Bryant Space Science Center, PO Box 112055, Gainesville, FL 32611, USA
[6]Department of Physics and Research Center for the Early Universe, The University of Tokyo, Tokyo 113-0033, Japan
[7]Institute of Astronomy, Graduate School of Science, The University of Tokyo, Tokyo 113-0033, Japan
[8]Department of Astronomy, Columbia University, 550 West 120th Street, New York, NY 10027, USA

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

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ABSTRACT

We have initiated single-dish monitoring observations of ∼400 methanol maser sources at 6.7 GHz using the Hitachi 32-m radio telescope from December 2012 to systematically research periodic flux variations, which are observed in some methanol maser sources associated with high-mass (proto-)stars. In our monitoring, we have made daily monitoring, so that each source has been observed every nine days with an integration time of 5 min (typical 3 σ detection sensitivities of 0.9 Jy). The monitoring observations help us statistically understand periodic flux variations with a period longer than 50 days. As an initial result, we present a new detection of periodic flux variations in the 6.7 GHz methanol maser source G 036.70+00.09. The period of the flux variations is ∼53 days (∼0.019 cycles day^{-1}), and seems to be stable over 9 cycles, at least until the middle of August 2014.

Key words: Masers: methanol — Stars: formation — Stars: massive — Stars: variables

1. INTRODUCTION

6.7 GHz methanol masers show a characteristic "periodic" flux variation, discovered by Goedhart et al. (2003). The periodic variations have been detected in thirteen methanol maser sources so far, for which the observed period ranges between 30 and 668 days (Goedhart et al. (2004), 2009; Araya et al. (2010); Szymczak et al. (2011); Fujisawa et al. (2014); Maswanganye et al. (2014)). It is suggested that there are some possible mechanisms which could cause periodic variations around high-mass (proto-)stars, such as colliding-wind binaries (van der Walt , 2011) and periodic accretion onto binary systems (Araya et al. , 2010). Of the various mechanisms, we note the stellar pulsation model of high-mass protostars suggested by Inayoshi et al. (2013), because of its occurrence at the pre-main sequence phase, easy explanation of sinusoidal continuous variations, and expected periods of the order of 10–100 days. This model also predicts that the period-luminosity (P-L) relation can be described with a power law. It is predicted that the P-L relation indicates a correlation among the periodicity, the luminosity, and the accretion rate during the pulsational instability phase. If the relation can be verified by observations, we can estimate the accretion rate onto the surface of the protostar as well as its mass and radius solely from the periodicity of the pulsation. The estimation of these physical parameters is quite difficult even using Atacama Large Millimeter/submillimeter Array. 6.7 GHz methanol masers with periodic flux variations are suitable targets to observationally verify the P-L relation. The number of such sources detected so far, however, is rather limited. To increase the number of sources, we have initiated daily monitoring observations using Hitachi 32-m telescope, since Dec. 2012.

2. OBSERVATIONS

As target sources, we selected ∼400 methanol masers at 6.7 GHz, which are all the ones observable from Hitachi station (declination > −30 deg) allowing us to verify the P-L relation systematically. Daily monitor was performed from Dec. 2012 to Jan. 2014 and from

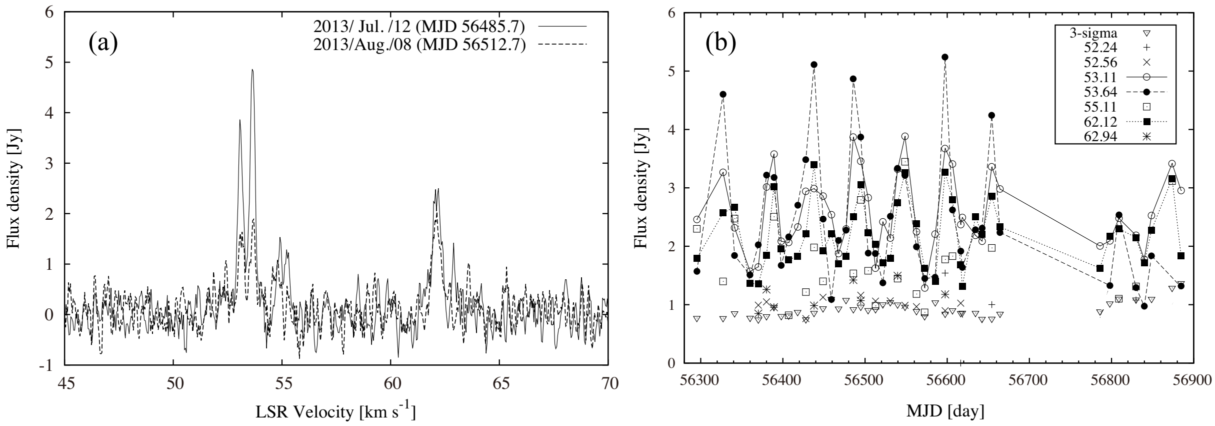

Figure 1. The 6.7 GHz methanol masers in G 036.70+00.09 observed in our monitoring observations. (a) Spectra observed on Jul. 12th 2013 (MJD = 56485) and Aug. 08th 2013 (MJD = 56512) respectively, corresponding to the maximum and minimum states of the spectral component at $V_{\rm lsr} = 53.64$ km s^{-1} during the expected 4th period. (b) Flux variations of each spectral component from Jan. 3rd 2013 (MJD = 56295) to Aug. 15th 2014 (MJD = 56884). Spectral components are distinguished by symbols, as shown in the legend box at the top-right. The detection limits of 3 σ in each observation are shown by inverted triangles. The top three bright components at $V_{\rm lsr} = 53.64, 53.11, 62.12$ km s^{-1} are connected with dashed, solid, and dotted lines, respectively.

May 2014 to Aug. 2014, while the monitoring was interrupted by maintenance from Feb. 2014 to Apr. 2014. Daily monitor allows us to ensure that each source is observed every nine days, and statistically understand periodic flux variations with a period longer than 50 days. We recorded the left-hand circular polarization signals, and set an observing bandwidth of 8 MHz divided into 8192 channels, yielding a channel spacing of 0.044 km s^{-1}. The typical rms noise level 1 σ was 0.3 Jy with an integration time of 5 min.

3. RESULTS AND CONCLUSIONS

Here, as an initial result, we present the new detection of periodic flux variations in the 6.7 GHz methanol maser source G 036.70+00.09. In this source, we have made monitoring observations from Jan. 3rd 2013 (MJD = 56295) to Aug. 15th 2014 (MJD = 56884), and identified seven spectral components. A part of the spectra and flux variations of each spectral component during the observed period are shown in Figure 1. In panel (b), the top three bright components at $V_{\rm lsr} = 53.64, 53.11, 62.12$ km s^{-1} are indicated with dashed, solid, and dotted lines, respectively. It seems that the top three bright components showed synchronized and periodic flux variations, which seem to be stable over 9 cycles during the observed period. We made periodic analyses of the monitoring data by using both compressive sensing (e.g., Honma et al. (2014)) and LASSO (e.g., Kato & Uemura (2012)), which are methods in the field of sparse modeling. The period of the flux variations was calculated to be ∼53 days (∼0.019 cycles day^{-1}) with both methods. Time delays of ∼9 days (the interval of each observation) at maximum were seen among the top three components, i.e., during the expected 1st, 4th, and 9th periods as shown in Figure 1(b). It is hard to confirm the delays in our monitoring observations, however, which are not sufficient to detect time delays of a few days. We will perform follow up monitoring observations of this source with intervals of 1–3 days.

We will continue monitoring observations of ∼400 methanol masers at 6.7 GHz using the Hitachi 32-m after Sep. 2014. We will show new detections of the periodic flux variation sources with a period longer than 50 days and updated P-L relation with newly detected sources in the forthcoming papers.

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