Astrophysical Masers and their Environments
Proceedings IAU Symposium No. 242, 2007
J.M. Chapman & W.A. Baan, eds.

doi:10.1017/S1743921307013324

A collimated jet and an infalling-rotating disk in G192.16−3.84 traced by H_2O maser emission

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Abstract. We present H_2O masers associated with the massive-star forming region G192.16−3.84 observed with the Japan VLBI network since the year 2005, The spatio-kinematical structure of the maser feature clusters has well persisted since previous observations, in which the masers are associated with two young stellar objects (YSOs) separated by ∼1200 AU and expected to be associated with a highly-collimated bipolar jet and an infalling-rotating disk in the northern and southern YSOs, respectively. We estimated a jet speed of ∼100 km s^{-1} and re-estimated a dynamical age of the whole jet to be 5.6×10^4 years. The spatial distribution of maser Doppler velocities found during the previous and present observations, relative proper motions of H_2O maser features in the southern cluster found in the present observations, a relative bulk motion between the two maser clusters are well explained by a model of an infalling–rotating disk with a radius of ∼1000 AU and a central stellar mass of ∼8 $M_\odot$.

Keywords. masers, stars:mass accretion; individual (G192.16−3.84), ISM:jets and outflows

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The massive-star forming region G192.16−3.84 (hereafter G192) has massive YSO candidates, one of which is a B2-type star with a giant Herbig-Haro bipolar outflow and a possible circumstellar disk (e.g., Shepherd, & Kurtz 1999, Shepherd*et al.* 2004). H_2O masers are associated with both YSOs. The northern and southern H_2O maser clusters exhibit alignments of maser features, respectively, parallel and perpendicular to the bipolar outflow, which is traced by ^{12}CO emission and projected roughly in the east–west direction, parallel to the Herbig-Haro objects. On the basis of the spatial distributions of H_2O masers and $C^{18}O$ emission tracing high density gas, it is suggested that the southern H_2O maser features are associated with a flattened rotating gas torus around the B2-type star, in which the maser velocities are roughly consistent with those in a Keplerian disk.

The VLBI observations for G192.16−3.84 were made at three epochs during 2005 March–June using five or six telescopes of the Japanese VLBI Network, four 20 m telescopes of the VLBI Exploration of Radio Astrometry (VERA), the 45 m telescope of Nobeyama Radio Observatory (NRO), and the 34 m telescope of the National Institute of Information and Communication Technology (NiCT). These observations aimed to elucidate the 3D velocity field of H_2O masers in term of *relative* proper motions of the masers. The astrometric VLBI observations have been made using only the VERA

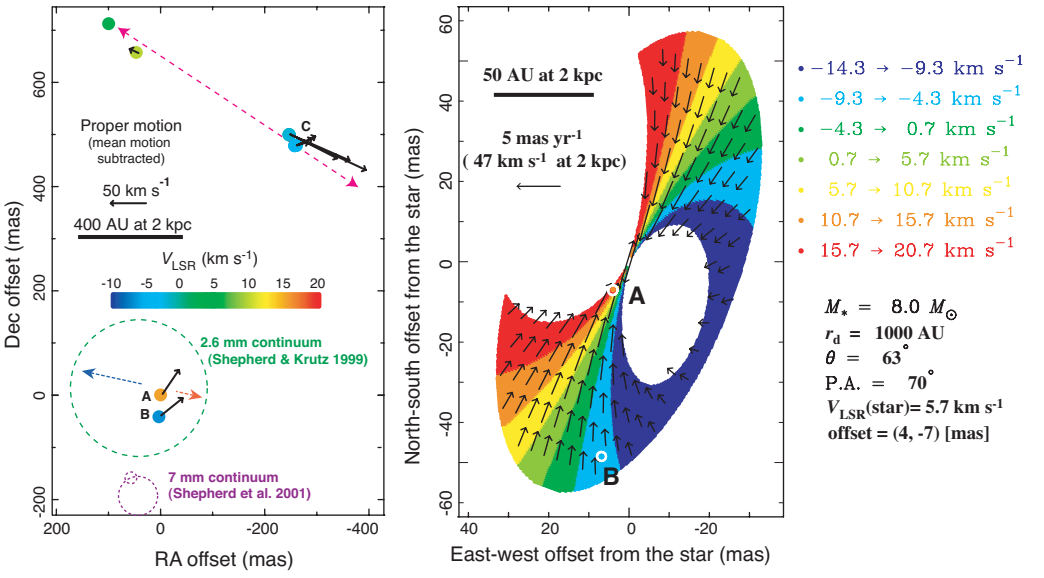

Figure 1. *Left*: Doppler velocity distribution (colored filled circle) and relative proper motions (black arrow) of the H_2O masers in G192.16−3.84. The displayed proper motion vector is the original vector subtracted by a velocity bias (see Imai*et al.* 2006 in detail). Axes of the northern jet and the outer outflow proposed by Shepherd*et al.* 2004 are indicated by dashed arrows. *Right*: Calculated LSR-velocity distribution for masing gas clumps in the modelled thin disk. The H_2O maser features A and B (filled circles, see also the left panel) are indicated after shifting the offset coordinates by the value shown in the panel. Arrows indicate the proper motion of a gas clump located at the root of the arrow.

telescopes equipped with the dual beam system since 2006 October to find an annual parallax and absolute proper motions of the masers. Figure 1 shows the spatial distribution and relative proper motions of maser features. The VERA astrometry enables us to put maser features in the absolute coordinate system at every observing epoch since 2005 October. We found that the dynamical center of the northern Herbig-Haro bipolar outflow is located around the feature *C*, where maser proper motions in two opposite directions are found with respect to the extragalactic position reference source J0603+1742. The southern maser features *A* and *B* were moving towards the northern YSO with a speed of ∼40 km s^{-1}. Such fast motions and large Doppler velocity offsets of the southern maser features from the systemic velocity ($V_{\rm LSR}$ =5.7 km s^{-1}) are well explained by a model, in which maser gas clumps are impinging onto a thin gas disk around the southern YSO found in previous molecular line and continuum emission (e.g., Shepherd*et al.* 2004).

Acknowledgements NRO and VERA observatory are branches of the National Astronomical Observatory, an interuniversity research institute operated by the Ministry of Education, Culture, Sports, Science and Technology. H. I./T. H. and H.I. were supported by Grant-in-Aid for Scientific Research from Japan Society for the Promotion of Science (16540224, 18740109, respectively).

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https://doi.org/10.1017/S1743921307013324 Published online by Cambridge University Press