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WATER MASERS FROM THE PROTOSTELLAR DISK AND OUTFLOW IN THE NGC 1333 IRAS 4 REGION

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ABSTRACT

NGC 1333 is a nearby star forming region, and IRAS 4A and IRAS 4BI are low-mass Class 0 protostars. IRAS 4A is a protobinary system. The NGC 1333 IRAS 4 region was observed in the 22 GHz water maser with a high resolution (0.08 ″) using the Very Large Array. Two groups of masers were detected: one near A2 and the other near BI. Most of the masers associated with A2 are located very close (< 100 AU) to the radio continuum source. They may be associated with the circumstellar disk. Since no maser was detected near A1, the A2 disk is relatively more active than the A1 disk. Most of the masers in the BI region are distributed along a straight line, and they are probably related with the outflow. As in many other water maser sources, the IRAS 4 water masers seem to trace selectively either the disk or the outflow. Considering the outflow lifetimes, the disk-outflow dichotomy is probably unrelated with the evolutionary stage of protostars. A possible explanation may be that both the outflow-maser and the disk-maser are rare phenomena and that detecting both kinds of maser around a single protostar may be even rarer.

Key words : Disks — ISM: individual (NGC 1333 IRAS 4) — ISM: jets and outflows — masers — stars: formation

I. INTRODUCTION

NGC 1333 is one of active star forming regions at a distance of 320 pc away from the Sun (Jennings et al. 1987; de Zeeuw et al. 1999). There are at least five young stellar objects in the NGC 1333 IRAS 4 region (Sandell et al. 1991; Rodríguez et al. 1999; Looney et al. 2000). Among them, IRAS 4A is a protobinary system (Lay et al. 1995; Looney et al. 2000; Reipurth et al. 2002). The primary, A1, is brighter than the secondary, A2, in the radio continuum (Looney et al. 2000; Reipurth et al. 2002; Girart et al. 2006; Choi et al. 2007). But, A2 drives stronger and longer outflow than A1 (Choi 2005; Choi et al. 2006). IRAS 4BI is single protostar and have bipolar outflow in the north-south direction (Choi 2001).

Water masers were detected toward the NGC 1333 IRAS 4 region in previous observations (Haschick et al. 1980; Rodríguez et al. 2002; Furuya et al. 2003). While Rodríguez et al. (2002) detected water maser sources near the IRAS 4A region only, Furuya et al. (2003) observed water maser sources in both the IRAS 4A and 4BI region.

We observed the IRAS 4 region with the VLA to understand the relation between water masers and the protostars. Detail of this work can be found in Park & Choi (2007).

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II. OBSERVATION

We observed the NGC 1333 IRAS 4 region in the 22 GHz water maser line in two tracks, March and April in 2006. The Very Large Array in A configuration was used. The synthesized beam size is about 0.08″ and the spectral resolution is about 0.33 km s^{-1}.

III. RESULTS

Totally, twelve maser spots were detected in the NGC 1333 IRAS 4 region: Eight toward IRAS 4A and four toward IRAS 4BI.

IV. DISCUSSION

Most maser spots detected near IRAS 4A are associated with IRAS 4A2. Six maser spots, PC 2–5, 7, 8, are located near the central radio continuum source within 100 AU. Also, the maser velocity are near the systemic velocity of the cloud, within 2 km/s. Therefore, they may be related with the circumstellar disk of IRAS 4A2. On the other hand, no maser spots were detected near IRAS 4A1. Accordingly, A2 disk is more active than A1 disk. This consequence coincides with the facts that A2 drives more powerful outflow than A1 and the A2 disk is brighter in NH_3 line than the A1 disk (Choi 2005; Choi et al. 2007).

In the case of BI maser, maser spots are distributed in a straight line and this direction is similar to the BI

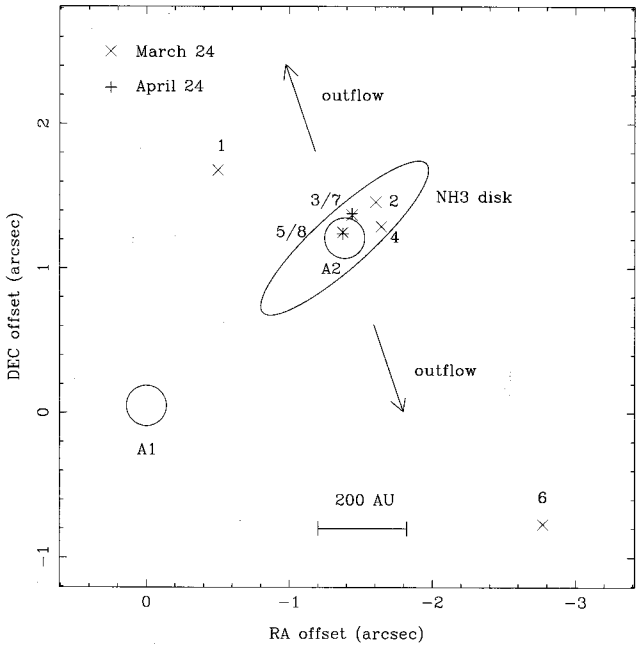

Fig. 1.— The position of the maser spots in the NGC 1333 IRAS 4A region. *Crosses*: Masers detected on March 24. *Plus signs*: Masers detected on April 24. The size of markers corresponds to the synthesized beam ($\approx 0.08''$). *Open circles*: The 3.6 cm radio continuum sources (Reipurth et al. 2002) *Open ellipse*: The NH_3 disk of the IRAS 4A2 (Choi et al. 2007) *Arrows*: The direction of the A2 outflow. (Choi et al. 2005) The straight line at the bottom indicates 200 AU at a distance of 320 pc.

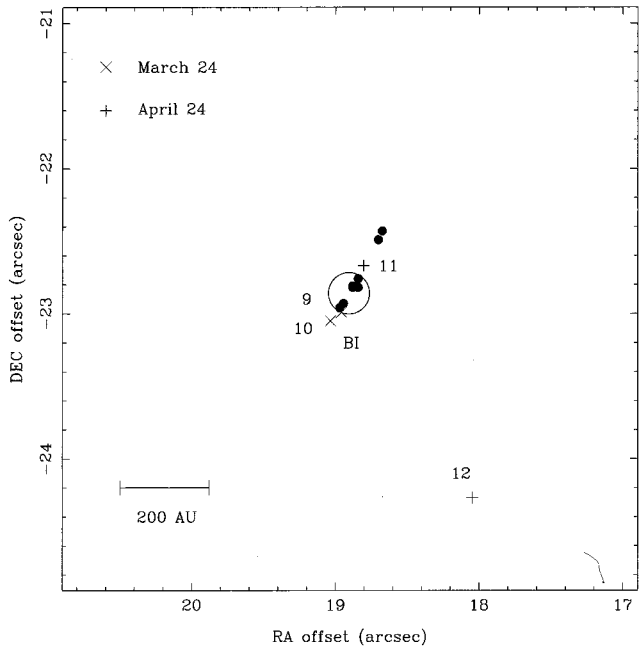

Fig. 2.— The position of the maser spots in the NGC 1333 IRAS 4BI region. *Crosses*: Masers detected on March 24. *Plus signs*: Masers detected on April 24. *Filled circles*: Masers observed by Rodríguez et al. (2002)

outflow. In addition, the maser velocities range from -1.2 to 19.9 km s^{-1} away from the systemic velocity, 6.6 km s^{-1} (Blake et al. 1995).

According to Terrelles et al. (1997, 1998), water masers often prefer to trace selectively either the outflow or disk owing to differences in the evolutionary stage. Disk-masers indicate younger protostars than outflow-masers. Therefore, IRAS 4A2 should be younger than IRAS 4BI. But, IRAS 4A2 seems to be older because of longer outflow. Since water masers are rare phenomenon in protostellar systems, it could be a matter of the probability.

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