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Absolute proper motions of water masers in NGC 281 measured with VERA

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Abstract. We report on absolute proper-motion measurements of H_2O maser features in the NGC 281 West molecular cloud, located ∼320 pc above the Galactic plane and associated with an HI loop extending from the Galactic plane. We conducted six-epoch phase-referencing observations of the maser source with VERA (VLBI Exploration of Radio Astrometry) over six months since May 2006. The H_2O maser features are found to be systematically moving toward the southwest and further away from the Galactic plane with a vertical velocity of ∼20–30 km s $^{-1}$ at its estimated distance of 2.2–3.5 kpc. Our new results provide the most direct evidence that the gas in the NGC 281 region was blown out from the Galactic plane, most likely in a superbubble driven by multiple or sequential supernova explosions in the Galactic plane.

Keywords. astrometry, Galaxy: kinematics and dynamics, ISM: bubbles, masers

Introduction and results

NGC 281 (α_{2000} =00^h52^m, δ_{2000} = +56°34' or l =123°.07, b = −6.°31) is an HII region situated z ∼320 pc above the midplane of the Perseus arm of the Galaxy at a heliocentric distance of 2.9 kpc (Guetter & Turner 1997), surrounded by a giant molecular cloud complex. Megeath *et al.* (2002) identified this region on a large-scale HI loop extending from the Galactic plane, and found a 270-pc ring of the clouds of the region, expanding at a velocity of 22 km s^{-1} parallel to the plane. They suggested that the clouds have been formed in a fragmenting superbubble shell. In order to investigate the systemic motion of the region, we have conducted six-epoch phase-referencing observations of an H_2O maser source in the NGC 281 West cloud with VERA over six months since May 2006.

Figure 1 shows the results of relative and absolute proper-motion measurements of the H_2O maser features in NGC 281 West. We detected 10 maser features persistent for more than two epochs, with radial velocities V_{LSR} of −39 to −22 km s^{-1}. These include eight features in C3 and 2 features in C1, corresponding to the VLA observations by Tofani *et al.* (1995). We first examined the internal motions of the maser features in C3, relative to the brightest maser, feature 4 with V_{LSR} = −31.8 km s^{-1}, and they showed expanding motions with velocities from 10 to 20 km s^{-1} (1 mas yr^{-1} corresponds to 13.7 km s^{-1} at a distance of 2.9 kpc). We then measured the absolute proper motions of the maser features 4 (in C3), 9 and 10 (in C1), assuming the distance to NGC 281 to be 2.9 kpc and subtracting the expected parallax from the observed motions. Adopting a different distance of 2.2−3.5 kpc instead of 2.9 kpc in the parallax subtraction yields a difference of 10−15% in the resultant proper motions. As shown in Figure 1, the mean absolute proper motions of the features in C3 and C1 show a systematic motion toward the southwest. This direction, southwestward, agrees well with that of the proper motion of HD 5005 (the ionizing source of NGC 281), measured with *Hipparcos* (Perryman *et al.* 1997). Figure 2 shows a plot of the mean motion of the maser features relative to the

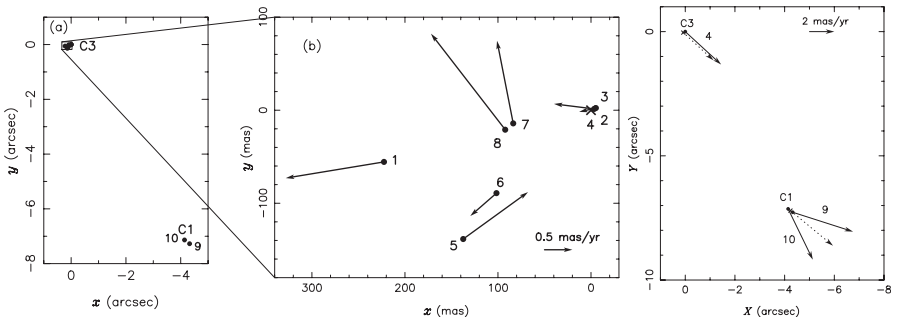

Figure 1. (*left*)(*a*) The maser feature distribution; (*b*) the internal motions of features in C3 relative to feature 4 (denoted by X). (*right*) A map of the absolute proper motions of features 4, 9 and 10 (solid arrows) and the mean proper motions in C3 and C1 (dotted arrows). The map origin is set at RA(J2000.0)=$00^{\rm h}52^{\rm m}24.^{\rm s}70086$ and DEC(J2000.0)= $+56°33'\ 50.''5270$. From Sato *et al.* (2007), ©2007 Astronomical Society of Japan.

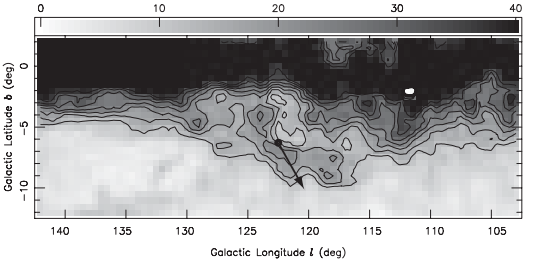

Figure 2. A plot of the mean motion of H_2O maser features in NGC 281 West relative to the simulated Galactic rotation, superimposed on gray-scale and contour maps of the HI data from Hartmann & Burton (1997), integrated over $V_{\rm LSR} = -65$ to -25 km s^{-1}. From Sato *et al.* (2007), ©2007 Astronomical Society of Japan.

simulated Galactic rotation, obtained by subtracting the expected apparent motion of NGC 281 due to the Galactic rotation (assumed to be a flat rotation) and the solar motion from the detected proper motion. This mean motion is considered to trace the systemic motion of the region away from the Galactic plane at a transverse velocity of 20-30 km s^{-1} perpendicular to the plane, which is comparable to the ring expansion velocity of 22 km s^{-1} parallel to the plane (Megeath *et al.* 2002), thus yielding a comparable kinetic energy ($\sim 4 - 8 \times 10^{51}$ ergs) of the clouds for motions perpendicular to the plane as well as parallel. Our measurements provide the most direct evidence that the gas in the NGC 281 region was blown out from the Galactic plane, most likely in a superbubble driven by multiple or sequential supernova explosions in the Galactic plane.

This work is based on Sato *et al.* (2007) and reproduced with authorization from Astronomical Society of Japan. See Sato *et al.* (2007) for more details on the measurements and discussions.

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