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Quenching of expanding outflow in massive star-forming region W75N(B)-VLA 2

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Abstract. VLBI observation of masers is a powerful mean to understand the early evolutionary phase of massive star formation. A few different scenarios of outflow evolution in the massive protostars have been proposed, and cannot be readily examined because the precise timing of appropriate maser phenomena is difficult. In particular, it has been a matter of debate whether a well-collimated or a less-collimated outflow comes first in the very early phase of the massive protostellar evolution. Long-term, multi-epoch VLBI monitoring is probably the most important method to trace the outflow evolution. Such a monitoring of a massive star-forming region W75N(B) has been very successful. Since the first detection of the expanding water maser shell associated with the star-forming region VLA 2 of W75N(B) in 1999, the observations in 2005 and 2007 displayed that the expanding water maser shell has been evolved to well-collimated from a less collimated morphology. Observations in 2012 also confirmed such a transition. It would be a major breakthrough in our knowledge of the formation and evolution of the first stages of massive protostars. We performed multi-epoch VLBI observations in mid-2014. On the contrary to its expansion for 13 years, the maser shell at VLA 2 observed in 2014 is comparable to the size observed in 2012. The quenching of the maser shell size indicates that the previously expanding outflow has been decelerated plausibly due to the interaction with surrounding interstellar medium.

Keywords. ISM: individual objects (W75N), ISM: jets and outflows, ISM: kinematics and dynamics, stars: formation

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1. Introduction: Expanding Outflow in W75N(B)-VLA 2

The active star-forming region (SFR) W75N(B) is located at a distance of 1.32 kpc, and contains three massive young stellar objects within an area of $1.5'' \times 1.5''$ ($\sim$2000 AU$\times$2000 AU): VLA 1, VLA 2 and VLA 3 (after Torrelles *et al.* 2003). VLA 1 and VLA 3 display elongated radio continuum emission, consistent with a thermal radio jet. On the contrary, VLA 2, located between VLA 1 and VLA 3, shows unresolved continuum of unknown nature. The three sources are conjectured to be at different evolutionary stages. VLA 1 and VLA 2 are probably the most and least evolved, respectively. The water maser observations show that VLA 1 traces a collimated thermal radio jet, whereas VLA 2 traces an expanding shell (Torrelles *et al.* 2003 and Surcis *et al.* 2011).

There are two typical types of outflows in massive SFRs: wind-like and bipolar. It has been only conjectured which comes first by comparing two or more SFRs. Based on 1999, 2005 and 2007 VLBI observations of 22 GHz water masers, we first provide a strong evidence of transition from a wind-like to a bipolar-like outflow in a single SFR, VLA 2 (Kim *et al.* 2013; also see Kim & Kim 2014). Only a wind-like feature was detected with an expanding velocity of 40 km s^{-1} during 1999-2005. On the contrary, during 2005-2007, the velocity became 100 km s^{-1}, and the outflow in VLA 2 appeared more collimated. Further observation in 2012 (Surcis *et al.* 2014) show that the water maser distribution

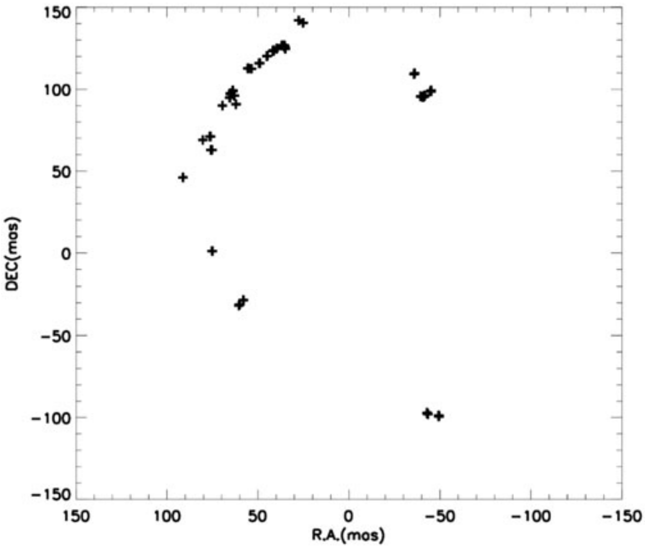

Figure 1. The water maser features around W75N(B)-VLA 2 observed with KaVA in 2014.

around VLA 1 is unchanged from the previous VLBI observations. On the contrary, the shell-like structure in VLA 2 is expanding along the direction parallel to the thermal radio jet of VLA 1. JVLA observations in early 2014 show that the elongation of the continuum emission at 4−48 GHz is in good agreement with that of the water maser distribution in VLA 2 (Carrasco-González *et al.* 2015).

2. Quenching of expanding outflow during 2012−2014

In April to June 2014, we performed three-epoch KaVA observations of the water masers in VLA 2 (Fig. 1). The elliptical fits show that the sizes of semi-major and semi-minor axes are ∼130 and ∼70 mas, respectively. The maser shell distribution in 2014 is comparable to the values estimated in the 2012 observations within a few percent (e.g., Kim *et al.* 2013, Surcis *et al.* 2014, and Carrasco-Gonzalez *et al.* 2015). The quenching of the maser shell size in 2012−2014 indicates that the previously expanding outflow has been decelerated plausibly due to interaction with surrounding interstellar medium (Kim *et al.*, in preparation).

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