

The Dynamics of the Outflow Structure in W49 N

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Abstract. In this current study, we report only the preliminary result of the SiO $v=0$ $J=5 \rightarrow 4$ emission toward W49 N at 230 GHz, observed using the ALMA telescope on September 29, 2018. The position–velocity diagram of the SiO emission shows a structure of a bipolar outflow and has a face-on orientation with an inclination angle of 36.4 ± 0.4 degrees with respect to the line of sight. Here we summarize the calculated physical properties of its outflow.

Keywords. masers – stars: formation, ISM: HII regions, ISM: jets and outflows, ISM: molecules, stars: individual: W49 N

1. The calibrated data of W49 N at 230 GHz taken from JVO portal

We have studied the star-forming region W49 N with the proper motions of 22 GHz water masers found with the KaVA telescope during February to May 2017 (Asanok *et al.* 2023). In the present work, we report the preliminary analysis results of the physical properties of the SiO outflow towards W49 N by using the calibrated data of the ALMA archive. These data were taken in Band 6 and are archived in the Japan Virtual Observatory (JVO) portal service under the project code ALMA#2016.1.00620.S.

2. The SiO $v=0$ $J=5 \rightarrow 4$ outflow

PV diagram: the position–velocity diagram (PV) of the SiO $v=0$ $J=5 \rightarrow 4$ line emission in the W49 N region shows a clear structure of a bipolar outflow with a compact size

Table 1. Physical properties of the outflow derived from the SiO $v = 0 \ J = 5 \rightarrow 4$.

	Red lobe:	Blue lobe:
Velocity Interval (km s^{-1}):	[+10.0 : +74.7]	[-54.7 : +8.6]
N_{SiO} (10^{14}cm^{-2}):	1.4	1.8
L_{SiO} ($10^{-2} L_{\odot}$):	7.4	9.1
M_{out} ($M_{\odot}$):	41.5 ± 5.9	51.1 ± 7.2
$\dot{M}_{\text{out}}$ ($10^{-4} M_{\odot} \text{yr}^{-1}$):	39.5 ± 4.6	7.0 ± 1.0
P ($M_{\odot} \text{km s}^{-1}$):	2180 ± 308	884 ± 125
V_{char} (km s^{-1}):	52.6	17.3
$\dot{P}$ ($M_{\odot} \text{km s}^{-1} \text{yr}^{-1}$):	2.0 ± 0.2	0.4 ± 0.1
E (10^{47}erg):	11.4 ± 1.6	1.5 ± 0.2
L_{mech} ($10^2 L_{\odot}$):	84.0 ± 11.1	4.8 ± 0.6
l_{lobe} (10^3au):	12.2	9.2
t_{dyn} (yr):	1104 ± 9	2532 ± 28

of diameter (1.5×0.5) arcsec² in each lobe. These lobes are formed by gas ejected from the outflow core that subsequently reaches speeds sufficient to generate shocks.

Physical properties of the SiO outflow: we have adapted the equations which were taken from Nguyen-Lu'o'ng *et al.* (2013) and Liu *et al.* (2015) and computed the physical properties of the SiO $v = 0 \ J = 5 \rightarrow 4$ line emission (see Table 1) as follows. (1) The column densities within a main beam $N_{\text{SiO}} = 1.6 \times 10^{11} \text{cm}^{-2} \times \frac{(T_{\text{ex}} + 0.35) \exp\{31.26/T_{\text{ex}}\}}{\exp\{10.4/T_{\text{ex}}\} - 1} \times \frac{1}{J_{\nu}(T_{\text{ex}}) - J_{\nu}(T_{\text{bg}})} \int T_{\text{mb}} d\nu$ where $J_{\nu}(T) = \frac{h\nu/k}{\exp(h\nu/kT) - 1}$, T_{ex} and T_{bg} are the excitation temperature of the gas and background radiation; (2) the luminosity $L_{\text{SiO}} \simeq 2.3 \times 10^{-4} L_{\odot} \times \left(\frac{d}{6 \text{kpc}}\right)^2 \frac{\int T_{\text{mb}} d\nu}{1 \text{K km s}^{-1}}$, where d is the distance of W49N, $L_{\odot}$ the luminosity of the sun and $\int T_{\text{mb}} d\nu$ the velocity integrated intensity inside the main beam; (3) the gas mass in the outflow $M_{\text{out}} = N_{\text{SiO}} \left[\frac{\text{H}_2}{\text{SiO}}\right] \mu_{\text{g}} m_{\text{H}} d^2 \Omega_{\text{A}}$, where $\Omega_{\text{A}} = \frac{\pi}{4 \ln(2)} \theta_{\text{FWHM}}^2$, $\mu_{\text{g}} = 1.36$ is the mean molecular mass per hydrogen atom, m_{H} is the hydrogen atom mass, and the ratio $\left[\frac{\text{H}_2}{\text{SiO}}\right]$ has a large uncertainty which depends on the SiO abundance and types of sources; (4) if we assume the outflow is powered by wind driven therefore the mass lost rate $\dot{M}_{\text{out}} = \frac{P}{t_{\text{dyn}} V_{\text{wind}}}$ where V_{wind} is the wind velocity; (5) the momentum $P = \dot{M}_{\text{out}} \times V_{\text{char}}$ where the characteristic outflow velocity (V_{char}) is defined as $V_{\text{char}} = V_{\text{flow}} - V_{\text{sys}}$, V_{sys} the systemic velocity, and V_{flow} the intensity-weighted velocity of high-velocity emission corrected with the projection effect; (6) the momentum rate $\dot{P} = \frac{P}{t_{\text{dyn}}}$; (7) the kinetic energy $E = \frac{1}{2} \dot{M}_{\text{out}} \times V_{\text{char}}^2$; (8) the mechanical luminosity $L_{\text{mech}} = E/t_{\text{dyn}}$; and (9) the dynamical time scale (t_{dyn}), respectively.

Supplementary material

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/S1743921323003198>

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