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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 $v=0$ $J=5\rightarrow4$.

	Red lobe:	**Blue lobe:**
Velocity Interval ($\mathrm{km\,s^{-1}}$):	$[+10.0:+74.7]$	$[-54.7:+8.6]$
N_{SiO} ($10^{14}\mathrm{cm^{-2}}$):	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
$\dot{M}_{\mathrm{out}}$ ($10^{-4}M_{\odot}\mathrm{yr^{-1}}$):	39.5±4.6	7.0±1.0
P ($M_{\odot}\mathrm{km\,s^{-1}}$):	2180±308	884±125
V_{char} ($\mathrm{km\,s^{-1}}$):	52.6	17.3
$\dot{P}$ ($M_{\odot}\mathrm{km\,s^{-1}yr^{-1}}$):	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^{3}au):	12.2	9.2
t_{dyn} (yr):	1104±9	2532±28

of diameter (1.5×0.5) arcsec^2 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'ong *et al.* (2013) and Liu *et al.* (2015) and computed the physical properties of the SiO $v=0$ $J=5\rightarrow4$ line emission (see Table 1) as follows. (1) The column densities within a main beam $N_{\mathrm{SiO}}=1.6\times10^{11}\mathrm{cm^{-2}}\times\frac{(T_{\mathrm{ex}}+0.35)\exp\{31.26/T_{\mathrm{ex}}\}}{\exp\{10.4/T_{\mathrm{ex}}\}-1}\times\frac{1}{J_{\nu}(T_{\mathrm{ex}})-J_{\nu}(T_{\mathrm{bg}})}\int T_{\mathrm{mb}}\mathrm{d}\nu$ 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 $L_{\mathrm{SiO}}\simeq2.3\times10^{-4}\mathrm{L}_{\odot}\times\left(\frac{\mathrm{d}}{6\,\mathrm{kpc}}\right)^2\frac{\int T_{\mathrm{mb}}\mathrm{d}\nu}{1\,\mathrm{K\,km\,s^{-1}}}$, where d is the distance of W49 N, $L_{\odot}$ the luminosity of the sun and $\int T_{\mathrm{mb}}\mathrm{d}\nu$ the velocity integrated intensity inside the main beam; (3) the gas mass in the outflow $M_{\mathrm{out}}=N_{\mathrm{SiO}}\left[\frac{\mathrm{H_2}}{\mathrm{SiO}}\right]\mu_{\mathrm{g}}m_{\mathrm{H}}d^2\Omega_{\mathrm{A}}$, where $\Omega_{\mathrm{A}}=\frac{\pi}{4\ln(2)}\theta^2_{\mathrm{FWHM}}$, $\mu_{\mathrm{g}}=1.36$ is the mean molecular mass per hydrogen atom, m_{H} is the hydrogen atom mass, and the ratio $\left[\frac{\mathrm{H_2}}{\mathrm{SiO}}\right]$ 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 $\dot{M}_{\mathrm{out}}=\frac{\mathrm{P}}{t_{\mathrm{dyn}}V_{\mathrm{wind}}}$ where V_{wind} is the wind velocity; (5) the momentum $P=M_{\mathrm{out}}\times V_{\mathrm{char}}$ where the characteristic outflow velocity (V_{char}) is defined as $V_{\mathrm{char}}=V_{\mathrm{flow}}-V_{\mathrm{sys}}$, 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 $\dot{P}=\frac{P}{t_{\mathrm{dyn}}}$; (7) the kinetic energy $E=\frac{1}{2}M_{\mathrm{out}}\times V^2_{\mathrm{char}}$; (8) the mechanical luminosity $L_{\mathrm{mech}}=E/t_{\mathrm{dyn}}$; 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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