Water Maser Bipolar Outflow in the Cepheus A HW3d Star-forming Region

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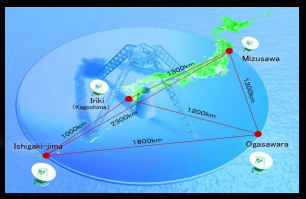


Abstract/Summary

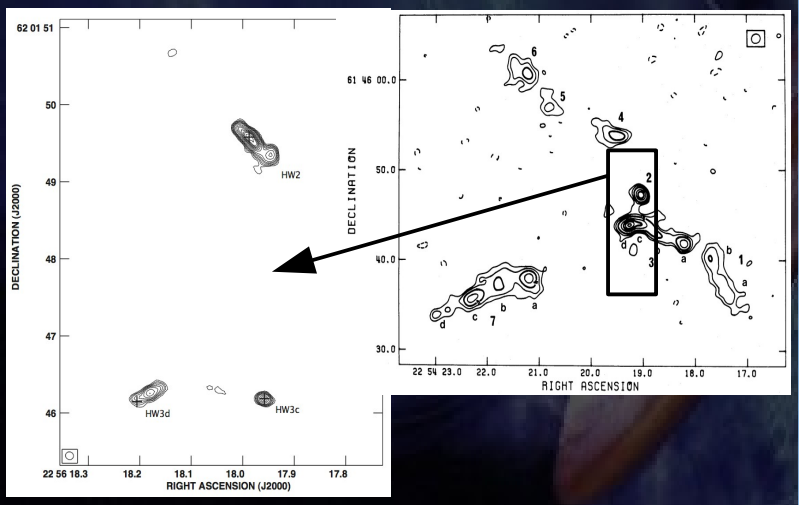
Cepheus A (Cep A) is a massive star-forming region at the distance of ~700 pc (Dzib et al. 2011). It is clear that HW2 harbors a massive young star (Rodŕiguez et al. 1994; Patel et al. 2005), but unclear in the case of other HW objects. In fact, Garay et al. (1996), through multifrequency Very Large Array (VLA) radio continuum observations, argue that some of the HW objects are internally excited by a young stellar object (YSO), while others are externally shock-excited at the interface between winds of other YSOs and molecular clumps in the region. We present the results of multi-epoch H_2O maser observations carried out with the VERA toward Cep A. We focused on the HW3d objects in Cep A. We measured for the first time the relative proper motions of 30 H_2O maser features, whose spatio-kinematics trace (one or more) compact bipolar outflow. This outflow is highly collimated, expanding through ~290 AU (400 mas) , and having a mean expansion velocity of ~10km/s (~3 mas/yr). The dynamical time-scale of the outflow is estimated to be ~100 years, indicating that this object is in a very early phase of star formation. We also have analyzed VLA archive data of 1.3 cm continuum emission in 1995 and 2006 obtained towards Cepheus A. These results indicate possible distinct protostars around HW3d and/or strong variability in its radio continuum emission.

Observations

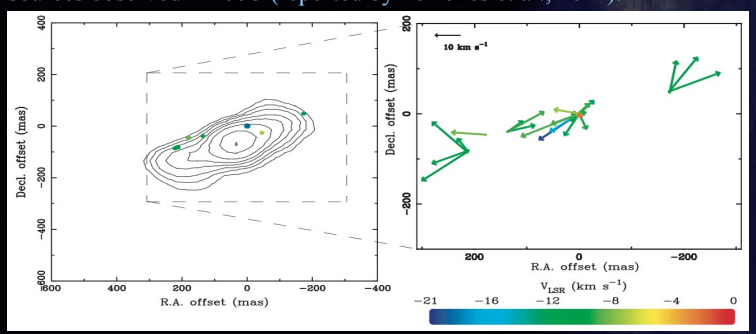
The observations of the Cepheus A H_2O masers at ~22 GHz with VERA were carried out in 9 epochs from May, 2006 to August, 2007. A position-reference source, J2302+6405 was simultaneously observed with Cep A.

Results & HW3d Internal Exciting Source Evidence

We obtained 30 maser proper motions, tracing a bipolar outflow in HW3d of Cep A.



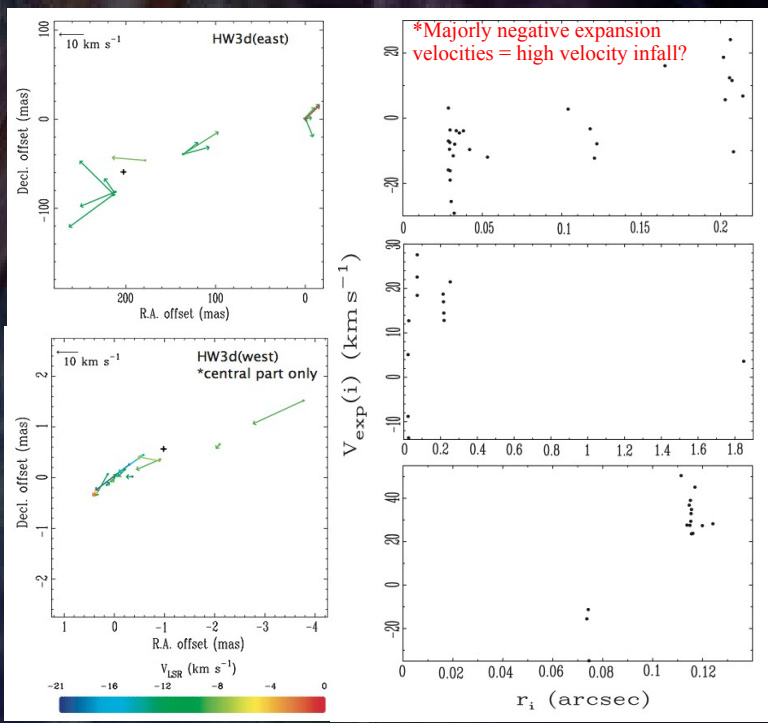
1.3cm continuum contour map of Cepheus A made from the 2006 observation. The beam size is 0.11 × 0.1 arcsec at the position angle of 73.8°. Contour levels are 5, 5, 7, 9, 12, 15, 20, 30, 40, 50, 60, 70, 80, 100, and 120 times the RMS noise (5.182×10^{-5}Jy/beam) of the map. HW2, HW3d and HWc are shown in the map according to the naming system by Hughes & Wouterloot (1984) (left panel). The plus signs on the HW2, HW3c, and HW3d objects indicate the peak position of the continuum sources observed in 1995 (reported by Torrelles et al., 2011).



Left The distribution of the H_2O masers aligned with the HW3d 1.3cm continuum map. *Right* The proper motions of these maser features. Astrometric analysis of the r07049 observation epoch enabled us to determine the absolute position of a maser spot (-6.67 km/s component) at RA(J2000) = $22^h56^m17.97745^s$ & DEC(J2000)= +62°01′49.3784″, which made the alignment of the maps possible.

Comparing the VLA 1.3cm continuum map of 1995 and 2006, there is an unexpected shift in the peak position of the HW3d continuum source relative to the HW2 source. Our estimation of the proper motion yielded ~65 km/s. Is this possible?

We carried out a radial expansion model fitting analysis.



Left Maser distribution of *HW3d(east)* (top) and *HW3d(west)(bottom).* *Right* Distributions of the expansion velocities of the individual maser features that were derived from the model fitting in *HW3d* (top panel), *HW3d(east)* (middle panel) and *HW3d(west)* (bottom panel), respectively.

Properties	HW2	HW3d
H_2O dyn. time-scale	3500yrs	100yrs
Protostars	4	2
Continuum emission size	800 mas	400 mas

	HW3d	*HW3d(east)*	*HW3d(west)*
$N_{feature}$	30	13	17
Systemic proper motion:			
V_{0x} (km s^{-1})	−2.5±3.0	11.9±0.1	−21.8±3.6
V_{0y} (km s^{-1})	5.4±2.2	−1.2±0.1	12.7±2.0
Position offset:			
x_0 (mas) …	20.000±10.500	205.743±3.374	−99.733±13.500
y_0 (mas) ….	−17.000±9.000	−59.868±4.045	57.698±9.000
$\sqrt{S^2}$ * …….	3.3	2.2	1.4

* Mean of the root-mean-square residual of the model fitting.

Table of model fitting results

We concluded the following;
* HW3d is internally excited by a young protostar
* There is high possibility of more than one exciting source in HW3d
* HW3d compared to HW2 is in an earlier phase of evolution