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 (Rodrıguez 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$_2$O 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$_2$O 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 ~10 km/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$_2$O 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.

Comparing the VLA 1.3 cm 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.

Table of model fitting results

<table>
<thead>
<tr>
<th>Properties</th>
<th>HW2</th>
<th>HW3d</th>
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</thead>
<tbody>
<tr>
<td>H$_2$O dyn. time-scale</td>
<td>3500 yrs</td>
<td>100 yrs</td>
</tr>
<tr>
<td>Protostars</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Continuum emission size</td>
<td>800 mas</td>
<td>400 mas</td>
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</tbody>
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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