

# Water Maser Emission Around Low/Intermediate Mass Evolved Stars

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**Abstract.** We present results of Very Long Baseline Array (VLBA) polarimetric 22 GHz H<sub>2</sub>O maser observations of a number of low/intermediate mass evolved stars. We observed 3 Miras (Ap Lyn, IK Tau and IRC+60370), 1 semi-regular variable (RT Vir) and 1 pPN (OH231.8+4.2). Circular polarization is detected in the H<sub>2</sub>O maser region of OH231.8+4.2 and we infer a magnetic field of  $|B_{||}| = \sim 45$  mG. This implies an extrapolated magnetic field of  $\sim 2.5$  G on the surface of the central star. The preliminary results on RT Vir and IRC+60370 also indicate the first detection of weak H<sub>2</sub>O maser linear polarization.

**Keywords.** masers, magnetic fields, polarization, stars: AGB and post-AGB

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## 1. Introduction

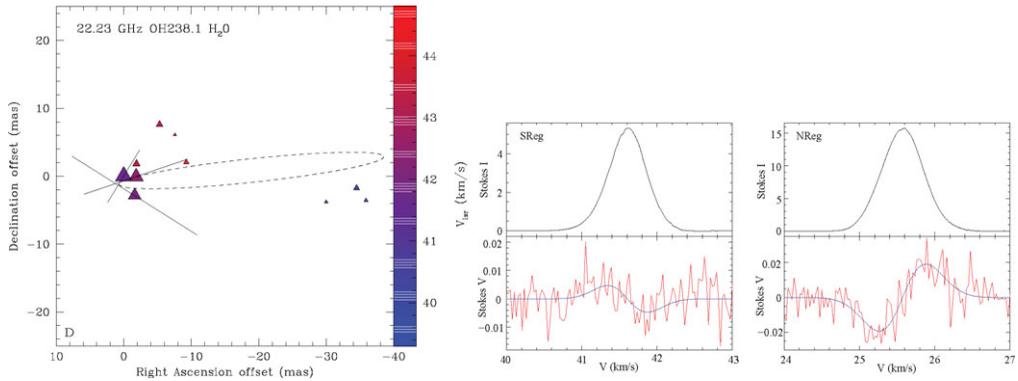
During the transition from an AGB star to a planetary nebula (PN), most low and intermediate mass stars lose their spherical symmetry. Magnetic fields are one of the candidates that can play a role in shaping asymmetrical PNe. However, magnetic field observations around evolved stars are still rare. We observed 22.235080 GHz H<sub>2</sub>O masers around 5 evolved stars with the goal of measuring linear and circular polarization. The results may allow us to infer the magnetic fields properties around these 5 stars.

## 2. Results

### 2.1. OH231.8+4.2 / Rotten Egg Nebula / Calabash Nebula (Leal-Ferreira et al. 2012)

We detected 30 H<sub>2</sub>O masers around OH231.8+4.2. With respect to the central star position, 20 masers are located on the north (NReg), and 10 on the south (SReg). We compared our detections with those of Desmurs *et al.* (2007), and found that the offset between the mean position of the detections of Desmurs *et al.* (2007) and ours is 14.4 mas. Taking a distance  $d = 1540$  pc (Choi *et al.* 2012) and  $i = 36^\circ$  (Kastner *et al.* 1992; Shure *et al.* 1995), the separation velocity between the masers in the 2 regions is  $21 \pm 11$  km/s. The masers appear to be moving in the direction of the nebula jet, albeit at much lower velocity. This could indicate that they arise in a turbulent material entrained by the jet.

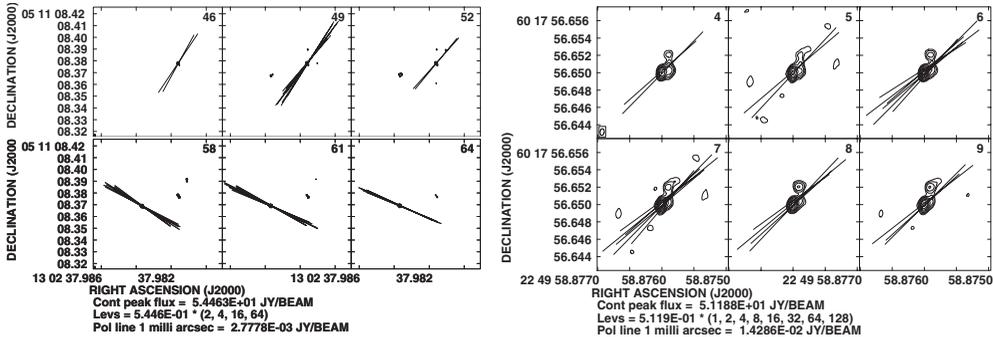
We found linear polarization for 3 features (all in SReg; Fig. 1). The high scatter between the linear polarization vectors can be caused by turbulence or, in case of a toroidal field, it could represent the tangent points of the field lines. We also found circular polarization on the 2 strongest masers; one in each region (Fig. 1). From these results, we inferred  $|B_{||}|_{NReg} = 44 \pm 7$  mG and  $|B_{||}|_{SReg} = -29 \pm 21$  mG. Although the morphology of the field is still not determined, the strength of the field on the surface of the star (with a typical radius of 1 AU) is  $\sim 2.5$  G if we assume a toroidal magnetic field ( $B \propto 1/r$ ).



**Figure 1.** Left: Maser features observed in the region (SReg) around the Southern jet of OH231.8+4.2. The sizes of the triangles are scaled by their fluxes, and the colors follow the velocity scale. The vectors indicate the linear polarization directions, and the detached ellipse is a potential field morphology. Middle and right: I (top) and V (bottom) spectra of the brightest features we detected in the SReg (middle) and in the NReg (right) of OH231.8+4.2. The S-shape solid line is the best fit derivative of the total power spectrum.

2.2. *RT Vir, AP Lyn, IK Tau and IRC+60370*

We did not detect any maser emission around AP Lyn. Several masers were found around RT Vir, IK Tau and IRC+60370. Our preliminary results show that linear polarization between  $\sim 0.5\%$  and  $\sim 0.8\%$  is present around RT Vir and IRC+60370 (Fig 2). This is less than typically found in star forming regions and consistent with the previously found upper limits on the linear polarization in the H<sub>2</sub>O maser envelopes of Mira and supergiant stars (Vlemmings *et al.* 2005).



**Figure 2.** Contour maps of the maser spots of RT Vir (left) and IRC+60370 (right). For RT Vir we show one in every three channels in which linear polarization is present. For IRC+60370 we show 6 consecutive channels. The vectors indicate the linear polarization direction.

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