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Letter to the Editor

A New Main Line OH Maser with a Probable Zeeman Pattern

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Summary. We have detected strong, highly circularly polarized emission in the 1665 and 1667 MHz lines of OH arising from a region of star formation in the molecular cloud that produced the Cepheus OB3 association. The two strongest peaks in both the 1665 MHz and the 1667 MHz lines display one single Zeeman pattern indicative of a magnetic field of 3.5 mG.

Keywords: OH maser - Zeeman splitting - Cepheus OB3

I. Introduction and observations

During a survey of large molecular clouds in the 1667 MHz line of OH with the Dwingeloo telescope, one of us (J.G.A. W.) detected a narrow peak coinciding with the bright area "Cepheus A", discovered by Sargent (1977, 1979) in the molecular cloud that produced the Cep OB3 association. The narrowness of the OH peak suggested main line maser emission. On 1979, May 25, 28 and 29, new OH ground state observations have been obtained with the 100 m Effelsberg telescope of the Max-Planck-Institut für Radioastronomie at Bonn. The beamwidth of this telescope at 18 cm is 7.7 arcmin; we used a spectral resolution of 0.07 km s^{-1}, while the receiver system temperature was 40 K. The 384-channel autocorrelator was divided in two equal parts; one measured left circular (LC) polarization, the other right circular (RC) polarization. For the Effelsberg telescope at 18 cm the ratio between S and T is S/T = 0.35 Jy/K. (polarized flux density).

In the main lines (1665 and 1667 MHz) we received strong signals, but in the satellite lines (1612 and 1720 MHz) we found no signals stronger than 0.2 Jy. The best position of all peaks was $\alpha = 22^h54^m21\overset{s}{.}7 \pm 2\overset{s}{.}0$ and $\delta = +61^\circ45'28'' \pm 15''$ (1950.0), or $\ell = 109\overset{\circ}{.}87$, $b = +2\overset{\circ}{.}11$. This position can be compared with that of the H_2O maser recently discovered by Blitz and Lada (1978) for which the best position is (Downes, private communication) $\alpha = 22^h54^m19\overset{s}{.}9 \pm 2\overset{s}{.}0$, $\delta = +61^\circ45'45'' \pm 10''$. Exact positional coincidence between H_2O and OH maser is possible, although in other objects such a coincidence is not common.

The observed 1665 and 1667 MHz line profiles are shown in figure 1. Pashchenko and Rudnitskij (1979) reported a detection in the 1665 and 1667 MHz lines during October 1978. In a recent preprint Rodriguez, Morgan, Ho and Gottlieb report a detection in April 1979. They also found a broad, weak feature at $V_{LSR} = -10$ km s^{-1} in emission at 1612 MHz and in absorption at 1720 MHz. Probably the weak features must be attributed to the molecular cloud containing Cep A and not to the maser source.

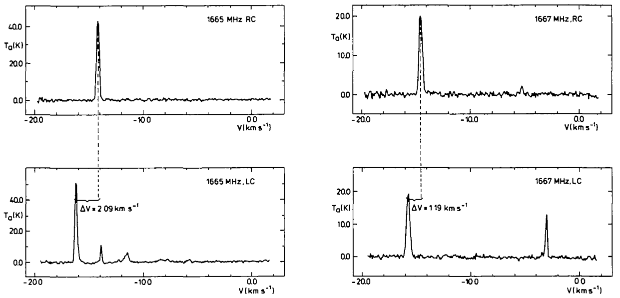

Fig. 1. 1665 and 1667 MHz OH line profiles in the direction of Cep A, observed May 1979 with the 100 m telescope at Effelsberg. "LC": Left Circular Polarization; "RC": Right Circular Polarization. Velocity is with respect to LSR; resolution is 0.07 km s^{-1}. 1 K antenna temperature corresponds to 0.35 Jy of polarized flux density.

II. Interpretation and discussion

We have fitted Gaussian line profiles to the individual peaks in figure 1. Characterizing each Gaussian component by its central (peak) velocity V_{LSR}, its peak brightness temperature T_A or its (polarized) peak flux density S and by the line width at half maximum, LW, we obtain the results shown in Table 1.

Table 1

Freq.	Pol.	V_{LSR}	T_A	S	LW
MHz		km s^{-1}	K	Jy	km s^{-1}
1612	L,R	-	< 0.6	< 0.2	-
1665	L	-16.23	51.6	18.1	0.24
		-13.91	12.2	4.3	0.16
		-12.30	2.2	0.8	0.15
		-11.50	8.0	2.8	0.37*
		- 8.52	1.4	0.5	0.65*
		- 7.88	1.6	0.6	0.33
		- 5.83	1.6	0.6	0.30
1665	R	-14.14	42.4	14.8	0.29
1667	L	-15.76	19.4	6.8	0.38
		- 3.43	1.6	0.6	0.38
		- 3.06	13.2	4.6	0.17
1667	R	-14.57	19.8	6.9	0.35
		- 5.26	3.4	1.2	0.24
1720	L,R	-	< 0.6	< 0.2	-

*Probably a blend of several components

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In both lines the component velocities have an average around -10 km s^{-1}, close to the average velocity of the molecular cloud of -10.3 km s^{-1} as measured in CO by Sargent (1977). The maser source is therefore probably associated with the cloud. The four strongest, completely circularly polarized components have the following properties: (a) The average velocity $\overline{V}$ of the strongest LC and RC peaks in 1665 MHz line is -15.19 ± .02 km s^{-1}, which is practically identical to the value $\overline{V} = -15.17 \pm .02$ in the 1667 MHz line. The uncertainty in the rest frequencies of the two lines is about 100 Hz or 0.02 km s^{-1} (ter Meulen and Dymanus, 1972). (b) The velocity difference ΔV between the strongest LC and RC peaks is 2.09 km s^{-1} in the 1665 MHz line and 1.19 km s^{-1} in the 1667 MHz line. The ratio between these two values is 1.76 ± .04, very close to the value of 5/3 expected for a Zeeman pattern (Cook, 1973). (c) In both lines the strongest LC component has the most negative velocity. (d) In each line the strongest LC and RC components have almost the same flux densities. (e) The line widths, LW, of the strongest RC and LC components are similar in the 1665 MHz line (.24 and .29 km s^{-1}); the same is true for the 1667 MHz line (.38 and .35 km s^{-1}). The difference between these two sets is probably significant.

Most of these properties agree nicely with the prediction by Goldreich, Keeley and Kwan (1973, GKK) based on considerations of radiative line transfer through an active region with a considerable magnetic field. Three components should be observed in each line; a red shifted σ-component, ($\Delta m = \pm 1$), an unshifted π-component ($\Delta m = 0$), and a blue shifted σ-component ($\Delta m = \pm 1$) about as strong as the red shifted one but with opposite polarization. According to GKK the absence of the linearly polarized π-component can be explained by large Faraday rotation. A field of 3.5 mG gives a velocity separation $\Delta V = 2.06$ km s^{-1} in the 1665 MHz line and $\Delta V = 1.24$ km s^{-1} in the 1667 MHz line; and the two 1665 MHz and the two 1667 MHz components have the same average velocity, as is observed. Large Faraday rotation implies that the rotation measure RM > $1/\lambda^2$, where RM $\equiv 2.6 \times 10^{-17} \int n_e B\, dR$. Setting all quantities constant along the maser-gain path and taking $R \leq 10^{15}$ cm we find: $n_e \gtrsim 10^2$ cm^{-3}. This number is to be compared with the molecular density $n(H_2) \gtrsim 10^6$ cm^{-3}. While the observed properties (a) through (d) are easily explained by the GKK model, this is not true for property (e). We find it difficult to understand why the 1667 MHz components are systematically broader than the 1665 MHz components. In principle, the anomalous Zeeman effect works in the right direction, but it is far too small (Cook, 1975).

Zeeman patterns such as predicted by GKK have been recognized before in other main line OH masers (for a summary of such studies see Habing and Israel, 1979). However, to our knowledge the present object is the first where four components in two different lines appear to come from the same region. We therefore predict that VLBI experiments will show such a coincidence.

Cook (1975) has pointed out that a relatively small radial velocity gradient along the line of sight will prevent the growth of oppositely circularly polarized components in one region. Therefore our observations lead to the following alternative conclusions: (1) the variation of radial velocity through the maser is << 0.3 km s^{-1} (2) the masering region has a symmetrical structure and the LC and RC components arise in two different, but similar layers. Such layers may be realized in MHD instabilities in the dense neutral shell surrounding an expanding H II region.

If the H II region expands with a velocity of 5 km s^{-1}, and if it has a density $n \gtrsim 10^6$ cm^{-3} the ram pressure $\rho v^2 = 4 \times 10^{-7}$ erg cm^{-3}. This is equal to the magnetic energy density $B^2/8\pi = 5 \times 10^{-7}$ erg cm^{-3}. The magnetic field in the neutral shell will thus influence the expansion of the H II region.

The presence of main line OH maser in Cepheus A is an indication that star formation takes place there. Other indications are the presence of a reversal in the CO line profiles ("self absorption", Sargent, 1977), of an H_2O maser (Blitz and Lada, 1978), of near IR sources and ultra compact H II regions (Beichman et al., 1979) and of a far IR source (Koppenaal et al., 1979).

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