CIRCULAR POLARIZATION OF ASTROPHYSICAL MASERS

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ABSTRACT

Results of further calculations are presented to explore the non-linear, Zeeman overlap effect as the cause for the circular polarization of astrophysical masers. Emphasis is placed on the regime in which the Zeeman splitting is small and on the variation of the polarization with maser saturation.

Strong net circular polarization has long been recognized as a striking characteristic of astrophysical OH masers. It is especially prominent for OH masers in molecular clouds (star-forming regions) for which the measured, fractional circular polarization exceeds fifty percent in perhaps half of the masers (e.g., Reid and Moran 1981). Linear polarization is also common. More recently, high resolution studies of the other general class of OH masers--those associated with circumstellar environments--have found significant, net circular polarization in these as well (Mutel et al. 1979; Cohen et al. 1987). In a very few of both classes of OH masers, Zeeman pairs can be identified and tend to indicate magnetic fields of a few milligauss or so. Very recently, circular polarization (up to about ten percent, fractionally) has been detected in the radiation of the circumstellar SiO masers (Barvainis, McIntosh and Predmore 1987). Because of the much smaller magnetic moment of SiO (in comparison with OH), the occurence of this circular polarization is of special, potential significance.

Here, we emphasize some additional points and present some further calculations beyond our basic paper (Deguchi and Watson 1986) on the previously unrecognized non-linear, Zeeman overlap mechanism as a cause for the circular polarization of astrophysical masers. Our calculations treat the case of an angular momentum J=1-0 transition and utilize the Sobolev approximation. The velocity gradients are cylindrically symmetric with the gradient in the axial direction being much smaller than the gradient in the other directions so that the maser is essentially one-dimensional in the axial direction.

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Our previous results were directed toward the regime in which (Zeeman splitting/local Doppler breadth) > 1. Here, we show how the polarization characteristics vary with this ratio as it approaches zero. Ten percent circular polarization remains at a value of about 0.1 for this ratio. Note also that the linear polarization (unlike the circular) is non-zero (as it should be) when there is no Zeeman splitting. This is most likely to be the relevant regime for species such as SiO with small magnetic moments.

We also consider in more detail how the circular polarization varies with the degree of saturation (R_3/Γ) of the maser. It rapidly reaches to near its asymptotic value when (R_3/Γ) is only a few. For (Zeeman splitting/local Doppler breadth) $\gtrsim$ 1 and at least partly saturated masing the sign of the circular polarization tends to be that of the Zeeman transition of the highest frequency when the masing region is expanding (and vice-versa).

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