Simulation of CH_3OH Masers

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A model of CH_3OH maser is presented. Two techniques are used for the calculation of molecule level populations: the accelerated lambda iteration (ALI) method and large velocity gradient (LVG), or Sobolev, approximation. The methods are found to give similar results, provided the gas velocity change across the cloud due to the velocity gradient is much larger than the Doppler line width.

1 Introduction

Intense maser transitions of the CH_3OH molecule are observed towards high-mass star-forming regions. The high brightness temperature of the maser emission permits us to observe them with the very long baseline interferometry (VLBI) technique, achieving both very high angular and velocity resolutions. Modeling of the maser pumping can provide estimates of the physical conditions in the maser regions [1]. The current study is aimed at modeling of the pumping mechanism of methanol masers. The zone of validity of the LVG approximation is discussed.

2 Results

We consider the one-dimensional model of a flat gas-dust cloud. The cloud consists of a mixture of H_2 and CH_3OH molecules, He atoms, and dust particles. The physical parameters of the cloud are the following: number density of H_2 molecules $N_{\mathrm{H2}} = 5 \times 10^6$ cm^{-3}, number density of CH_3OH (A- and E-species) $N_{\mathrm{m}} = 100$ cm^{-3}, gas temperature $T_{\mathrm{g}} = 150$ K, dust temperature $T_{\mathrm{d}} = 150$ K, micro-turbulent speed $v_{\mathrm{turb}} = 0.5$ km s^{-1}, velocity gradient $\mathrm{d}v/\mathrm{d}z = 0.05$ km s^{-1} AU^{-1}. Let us define the resonance region length $\Delta z_{\mathrm{D}} = v_{\mathrm{D}}\, \mathrm{d}v/\mathrm{d}z$, where v_{D} is the velocity width of the spectral line profile. The LVG approximation with the full treatment of continuum effects [2] and the ALI method [3] were used in the calculations of methanol level populations and line intensities. The detailed description of the model is given in our paper [4].

Fig. 1 shows the dependence of the gain of the maser line at 6.7 GHz at the line center on the cloud depth calculated by means of the ALI method and the LVG approximation. There is a significant discrepancy in the results of two methods at the cloud height $H = 30$ AU. The gain has negative values at almost all cloud depths according to accurate calculations, while the LVG approximation provides

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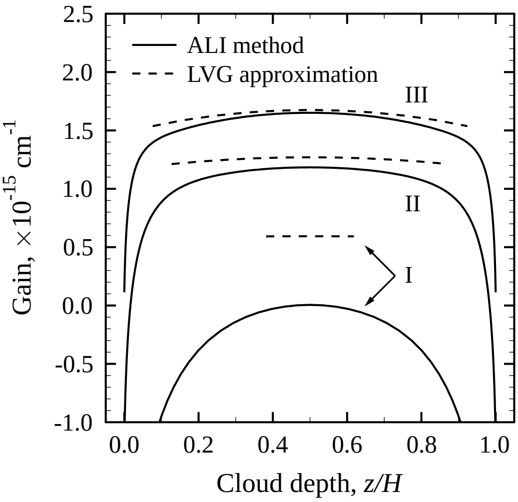

Figure 1: The gain of the 6.7 GHz $5_1 \rightarrow 6_0$ A^+ maser line as a function of the cloud depth. The results are presented for three values of the cloud height: (I) 30 AU; (II) 90 AU; (III) 150 AU. At the parameters in question, $\Delta z_{\rm D} = 11.5$ AU.

high positive values of the maser gain. There is an agreement between the results of two techniques at large cloud height – the difference between the gain values at the cloud centre is about 10 per cent at $H = 90$ AU and about 2 per cent at $H = 150$ AU. The LVG approximation reproduces the results of accurate radiative transfer calculations at large cloud heights and high velocity gradients: the cloud height has to be of the order of or greater than 5–10 lengths of the resonance region.

References

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