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EXPECTED WATER LINE SPECTRUM OF THE PROTOSTAR OMC2-FIR4

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Abstract. We present the expected water line spectrum of the protostar OMC2-FIR4. Dust continuum maps obtained at 350, 450 and 850 μm have been used to constrain the density and dust temperature profiles of the FIR4 envelope. We then compute the gas temperature accordingly by solving the gas thermal balance at each radius. Since previous studies (Jørgensen et al. 2005) have suggested the presence of a strong external illuminating FUV field, we considered this possibility in addition to the standard IS FUV illumination case. Specifically, we computed the water line spectrum for both G_0=1 and G_0=1000 case and for different water abundances. We show that the two spectra are very different and their observation will therefore allow us to constrain water abundance in the protostar envelope and discriminate between the two possibilities, G_0=1 and G_0=1000.

1 Introduction

Intermediate mass (IM) stars are crucial in studies of star formation because they constitute the link between low- and high- mass stars. In addition, IM stars are the dominant source of the Inter-Stellar (IS) FUV field, which regulates the phases of the ISM in the Galaxy, and, in turn, the overall Galaxy star formation process and history. In this context and in preparation of the HIFI/Herschel Key Program "Spectral Surveys of Star Forming Regions", we have studied in detail the IM protostar OMC2-FIR4, which will be targeted in that program. OMC2-FIR4 is the brightest submillimeter source of the Orion Molecular Cloud 2 (Mezger et al. 1990), and with a 1000 $L_\odot$, represents a rare case of nearby IM Class 0 candidate protostar. Here we present the expected water line specturm of OMC2-FIR4.

2 Dust modeling

The first step to obtain predictions on the gas emission is to derive the dust physical structure, namely the density and temperature profiles of the protostar envelope. In order to constrain them, we used the Spectral Energy Distribution (SED) points and continuum flux profiles otained from the maps at 350 (Lis et al. 1998), 450 and 850 μm (Johnstone & Bally 1999). We assumed a power low density profile, $n(r) = n_0\ (r/r_0)^{-\alpha}$, for an envelope of radius R_{max}. The parameters, n_0, α, R_{max} are constrained by the SED and the maps using the 1D radiative transfer code DUSTY (Ivezic & Elitzur 1999).

Jørgensen et al. 2005 sugested an Inter-Stellar Radiation Field (ISRF) with $G_0 = 10^4$. We tried, thus, several G_0. The different values of G_0 give rise to differences in the best model parameters but not so in the resulting SED and flux profiles. The dust density and temperature profiles obtained in two cases $G_0 = 1$ and 10^3 are shown figure 1.

As shown in figure 1, a large G_0 has three main effects on the dust temperature and density profiles: 1) The dust temperature increases at the edge of the envelope, 2) The envelope has to be smaller in order to fit the flux profiles, 3) The density is accordingly increased to counter balance the reduced sizes.

As mentioned before different values of G_0 do not change the resulting SED and flux profiles, thus it is not possible to constrain G_0 value with the dust continuum. Therefore, in the following we use the two dust physical structure models obtained with $G_0 = 1$ and 10^3.

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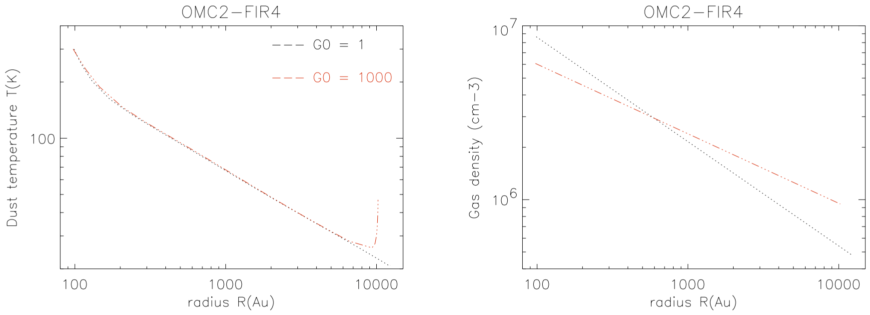

Fig. 1. Dust temperature and density profiles of the FIR4 envelope, on the left and right panel, respectively. The black and red curves represent the profiles obtained in the case G_0 = 1 and G_0 = 1000, respectively.

3 Gas modeling

To derive the theoretical water line spectrum, one needs the gas temperature profile obtained by solving the energy balance at each radius, computing the cooling and heating rates as in Ceccarelli et al. (1996) and, using the new collisional coefficients by Faure et al. (2007). Therefore, we derived in the two cases $G_0 = 1$ and 10^3, the ortho and para expected water line spectrum, for different H_2O abundances in the inner part, $\chi(H_2O)_{in}$, and outer part of the envelope, $\chi(H_2O)_{out}$ (figure 2).

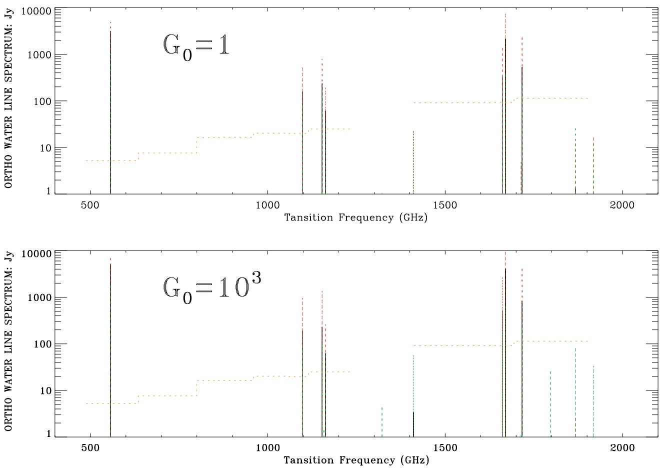

Fig. 2. Expected water ortho line spectrum of the protostar OMC2-FIR4. The two cases $G_0 = 1$ and 10^3 are shown on the upper and lower panel respectively.The red dashed line represents the case $\chi(H_2O)_{in}=10^{-4}$ and $\chi(H_2O)_{out}=10^{-6}$, the black solid line represents the case $\chi(H_2O)_{in}=10^{-5}$ and $\chi(H_2O)_{out}=10^{-7}$, and the green dashed line represents the case $\chi(H_2O)_{in}=10^{-6}$ and $\chi(H_2O)_{out}=10^{-8}$. The orange dashed line represents the HIFI/Herschel sensitivity.

The dust and gas are thermally decoupled in the inner region ($T_{dust} > 100$ K), because of the sublimation of the water ices. Since the cooling in this part is mainly due to H_2O, the difference between the strength of the lines depend on $\chi(H_2O)_{in}$. $\chi(H_2O)_{out}$ only affects the strength of lines from the lower energy transitions. Furthermore, the intensity of some lines depend also on G_0, making it possible to constrain its value.

4 Conclusion

We have shown that the water line spectra mainly depends on the χ(H2O). Therefore it will certainly be possible to constrain it from the future HIFI/Herschel water line spectra. Furthermore, due to the dependence of some lines in G_0, it will also be possible to constrain its value.

5 The bibliography

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