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Absorption against the Cosmic 2.7 K Background

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Observation of an interstellar line in absorption against the cosmic 2.7 K background is an unusual phenomenon. The intensity, I_ν, of a line generated in an interstellar cloud, with homogeneous excitation conditions, is given by

$$I_\nu - I_{\nu,bg} = (S_\nu - I_{\nu,bg})(1 - e^{-\tau_\nu})$$

where $I_{\nu,bg}$ is the intensity of the continuum against which the line is observed, τ_ν the optical depth of the line, and S_ν the source function, which is the Planck's function at the excitation temperature T_{ex}, i.e., $S_\nu = B_\nu(T_{ex})$. Observation of an interstellar line in absorption against the cosmic 2.7 K background, obviously, implies $0 \text{ K} < T_{ex} < 2.7$ K, which requires rather peculiar physical conditions in the molecule, generating the line.

Up to now, only two lines have been reported in absorption against the cosmic 2.7 K background. The first one is the $1_{10} \rightarrow 1_{11}$ transition of formaldehyde at 4.831 GHz, which was found in absorption in several directions (Palmer et al. 1969). However, in some cases, it has been seen in emission, and even as a maser line (Forster et al. 1980; Whiteoak & Gardner 1983). The second line found in absorption against the cosmic 2.7 K background, in a large number of cosmic objects, is the $2_{20} \rightarrow 2_{11}$ transition of cyclopropenylidene at 21.590 GHz (Madden et al. 1989). Cox, Güsten & Henkel (1987), however, reported the observation of this line in emission in the Planetary Nebula NGC 7027.

We have investigated two molecules, cyclopropenylidene (C_3H_2), and ethylene oxide (C_2H_4O). With the aim to determine the physical conditions required for occurring the anomalous absorption against the cosmic 2.7 K background, we performed NLTE radiative transfer calculations, using a large velocity gradient (LVG) code, where the physical model is that of a homogeneous collapsing cloud. As a background radiation field, we accounted for the cosmic 2.7 K background only.

We found anomalous absorption, i.e., $0 \text{ K} < T_{ex} < 2.7$ K, in both the molecules for three lines, $2_{20} \rightarrow 2_{11}$, $3_{30} \rightarrow 3_{21}$, and $3_{31} \rightarrow 3_{22}$ (Figure 1, Table 1). We note that for all the lines, there exists a rather sharp boundary in the H_2 density above which no anomalous absorption occurs. This implies that the observation of a line in absorption against the cosmic 2.7 K background places an upper bound on the density in the absorbing region.

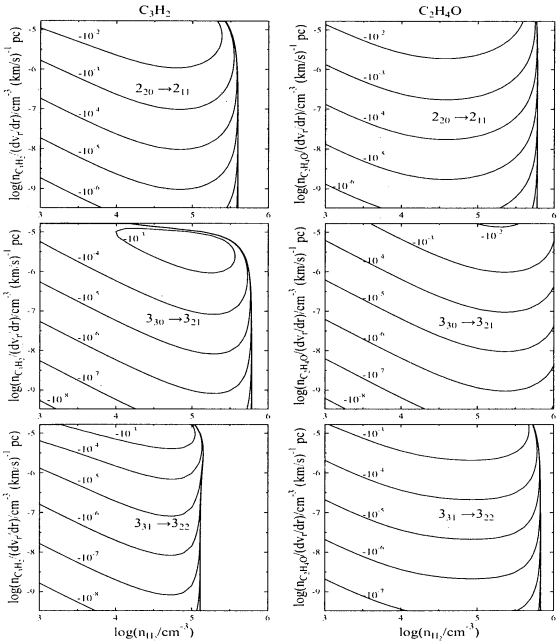

Figure 1. Iso-lines for $(I_\nu - I_{\nu,bg})/B_\nu(30)$ for the spectral lines showing absorption against the cosmic 2.7 K background.

Table 1. Minimum excitation temperature T_{ex}, achieved for the lines, around the molecular hydrogen density n_{H_2}, at the kinetic temperature of 30 K.

Specie	Transition	Frequency (GHz)	T_{ex} (K)	n_{H_2} (cm^{-3})
para-C_3H_2	2_{20} - 2_{11}	21.590	1.1	5 x 10^4
ortho-C_3H_2	3_{30} - 3_{21}	27.100	1.6	5 x 10^4
para-C_3H_2	3_{31} - 3_{22}	59.550	2.1	2 x 10^4
para-C_2H_4O	2_{20} - 2_{11}	15.600	0.8	3 x 10^4
ortho-C_2H_4O	3_{30} - 3_{21}	23.100	1.1	1 x 10^5
para-C_2H_4O	3_{31} - 3_{22}	39.700	1.5	3 x 10^4

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