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Large column densities and [^{12}CII] 158 μm self-absorption in Orion B

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Abstract. We present a preliminary analysis of the self-absorbed [CII]-spectra observed with SOFIA/GREAT towards NGC 2024. Together with the detected [^{13}CII] hyperfine satellites, the observed spectra require surprisingly high column densities of C$^+$, both in the warm core and the foreground absorption component. Such high column densities are a challenge to explain with present state-of-the-art PDR models of the UV/molecular cloud interaction.

Keywords. ISM: molecules — ISM: clouds — ISM: individual (Orion B)

As part of the basic science program of SOFIA during 2011 we mapped a $192'' \times 150''$ area in total power on-the-fly mode in the Orion B region (Graf *et al.* 2012), where the first [CII] line detection had been reported in 1980 (Russell *et al.* 1980), more than 30 years ago. The OFF position was confirmed both by former observations (Jaffe *et al.* 1994) and by a comparison measurement to a far-away off-position, to be free of [CII]-emission. For this poster contribution we concentrate on the interpretation of the [^{12}CII] and [^{13}CII] spectrum, obtained by averaging the map over a $60'' \times 15''$ box centered around the position of peak emission (Graf *et al.* 2012).

The fact that the [^{13}CII] profile does not match the double peaked isotopic CO profiles (see Graf *et al.* 1993), but rather shows a single component at a velocity in between the two molecular emission components and a line width slightly larger than either of those, implies, that the double peaked [^{12}CII] profile is self-absorbed. The [^{13}CII] integrated line in the optically thin, high density and high temperature limit requires a total ^{12}C$^+$-column density of about 1.3×10^{19} cm^{-2} (with [^{12}C$^+$]/[^{13}C$^+$]=60), i.e. an equivalent hydrogen column density of 1.6×10^{23} cm^{-2}, or an A_v of about 100 mag.

We fit the total [^{12}CII] and [^{13}CII] profile by a two component model

$$\begin{aligned} T_{mb} &= \left\{ J_\nu(T_{bg}) \left(1 - e^{-\tau(T_{bg}, N_{bg}, v_{bg}, \Delta v_{bg})}\right) \right\} e^{-\tau(T_{fg}, N_{fg}, v_{fg}, \Delta v_{fg})} \\ &\quad + J_\nu(T_{fg}) \left(1 - e^{-\tau(T_{fg}, N_{fg}, v_{fg}, \Delta v_{fg})}\right) \end{aligned}$$

where the optical depth as a function of velocity takes into account both the [^{12}CII] and the three [^{13}CII] hyperfine components (†), Gaussian profiles, and is calculated in the high density limit (Crawford *et al.* 1985). We assume a ^{12}C$^+$/^{13}C$^+$ abundance ratio of 60 and allow T_{ex}, $N(C^+)$, v_{LSR} and Δv_{FWHM} to vary. The foreground T_{ex} is constrained to

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† we use hfs-satellite intensity ratios as quoted in Fig. 1, different from the ones in Cooksy *et al.* 1986, which contains a typo

Table 1. Least-square two component fit results

		parameter	Model 1	Model 2
fixed	**background**	T_{ex} [K]	400	400
	foreground	T_{ex} [K]	80	4
fitted	**background**	$N(C^+)$ [10^{18} cm^{-2}]	9.8(0.2)	11.2(0.2)
		v_{LSR} [km s^{-1}]	10.32(0.02)	10.30(0.03)
		Δv_{FWHM} [km s^{-1}]	3.24(0.03)	3.25(0.03)
	foreground	$N(C^+)$ [10^{18} cm^{-2}]	2.38(0.05)	0.74(0.01)
		v_{LSR} [km s^{-1}]	10.13(0.03)	10.17(0.03)
		Δv_{FWHM} [km s^{-1}]	2.95(0.08)	3.24(0.07)

below about 80 K in order to absorb the background line down to the observed 55 K. The background has to be hotter than 160 K (RJ-corrected peak brightness temperature of the observed [^{12}CII]-profile). The least square fit cannot constrain the back- and foreground temperatures any further. Hence we display a first case (Model 1) with $T_{bg} = 400$ K and $T_{fg} = 80$ K (see Table 1). Another, extreme, case (Model 2) has the same T_{bg}, but $T_{fg} = 4$ K. It demonstrates that very low foreground temperatures are also consistent with the observed spectrum. The total column of C$^+$ stays the same, being fixed by the observed [^{13}CII] line intensity.

On the order of 100 PDR layers would be needed to explain the large total column of C$^+$ observed. In addition, the low temperature, large column of gas required to explain the foreground absorption is difficult to match with any reasonable standard PDR scenario.

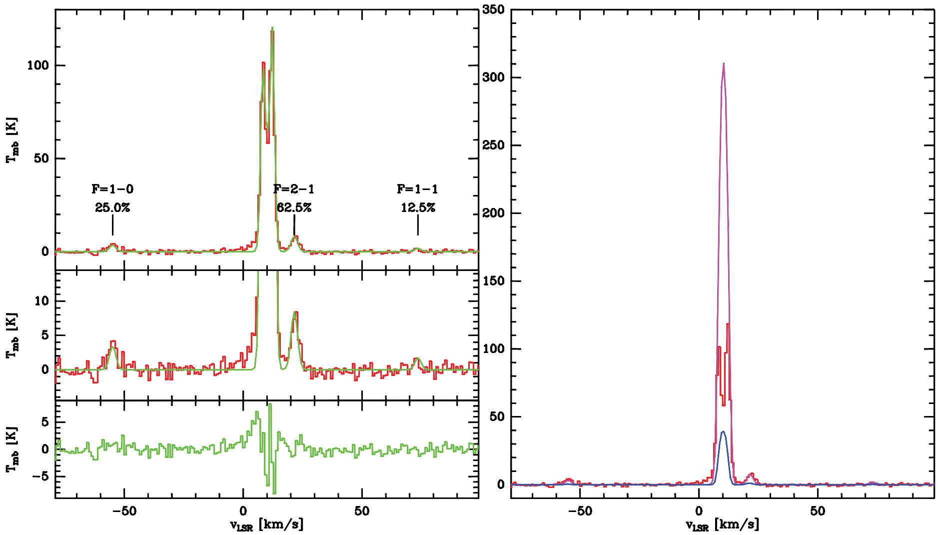

Figure 1. Spectrum and fit of the [^{12}CII] and [^{13}CII] emission (Model 1, Table 1). Left, bottom to top: residual, blow-up showing the [^{13}CII] hyperfines, and complete spectrum (red) and fit (green); right: spectrum (red), background (magenta) and fore-ground (blue).

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