First Detection of the [CII] 158 μm Line in the Intermediate Velocity Cloud Draco

E. Keilmann, N. Schneider, V. Ossenkopf-Okada, M. Röllig, S. Kabanovic, L. Bonne, T. Csengeri, B. Klein, R. Simon and F. Comerón

Overview of the Draco Cloud

Draco is a high-latitude (scale height 298 pc) diffuse cloud, originating either from a Galactic fountain process or from infall of extragalactic gas (Fig.1). It contains gas at local, intermediate, and high velocities (LVC,IVC,HVC). The distance to the IVC and LVC is 481±50 pc. The radiation field is very low since it does not have any OB stars in its immediate vicinity.

First detection of ionised carbon

We detected the 158 μm [CII] line, using the upGREAT receiver on SOFIA, at 4 out of 5 positions (Fig. 2). However, [CII] was not discovered in other diffuse clouds, i.e. **Spider**, **Polaris** and **Musca**, also exposed to a weak UV-field (Schneider et al. 2024).

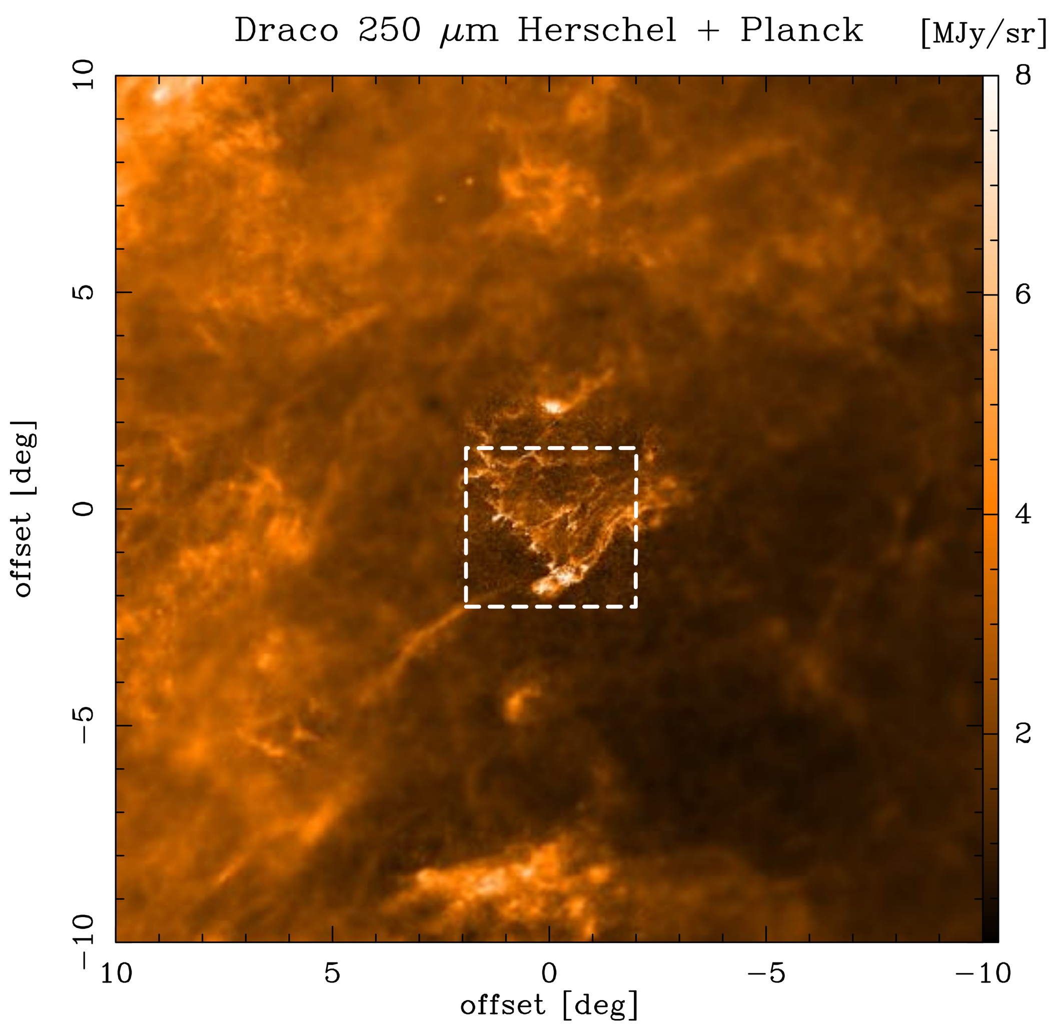

Figure 1: Herschel 250 μm map of Draco, outlined within a larger scale Planck map, provides an overview of the cloud and its environment.

PDR Modeling

Modelling the [CII] and CO emission in Draco (Fig. 3) with the KOSMA-τ photodissociation model (Röllig & Ossenkopf-Okada 2022), using the PDR toolbox (Pound & Wolfire 2023) requires a very low FUV field (< 0.35 G_0) for all positions, which contradicts the FUV field determined from the 160 μm flux (a few G_0) or the census of the stars.

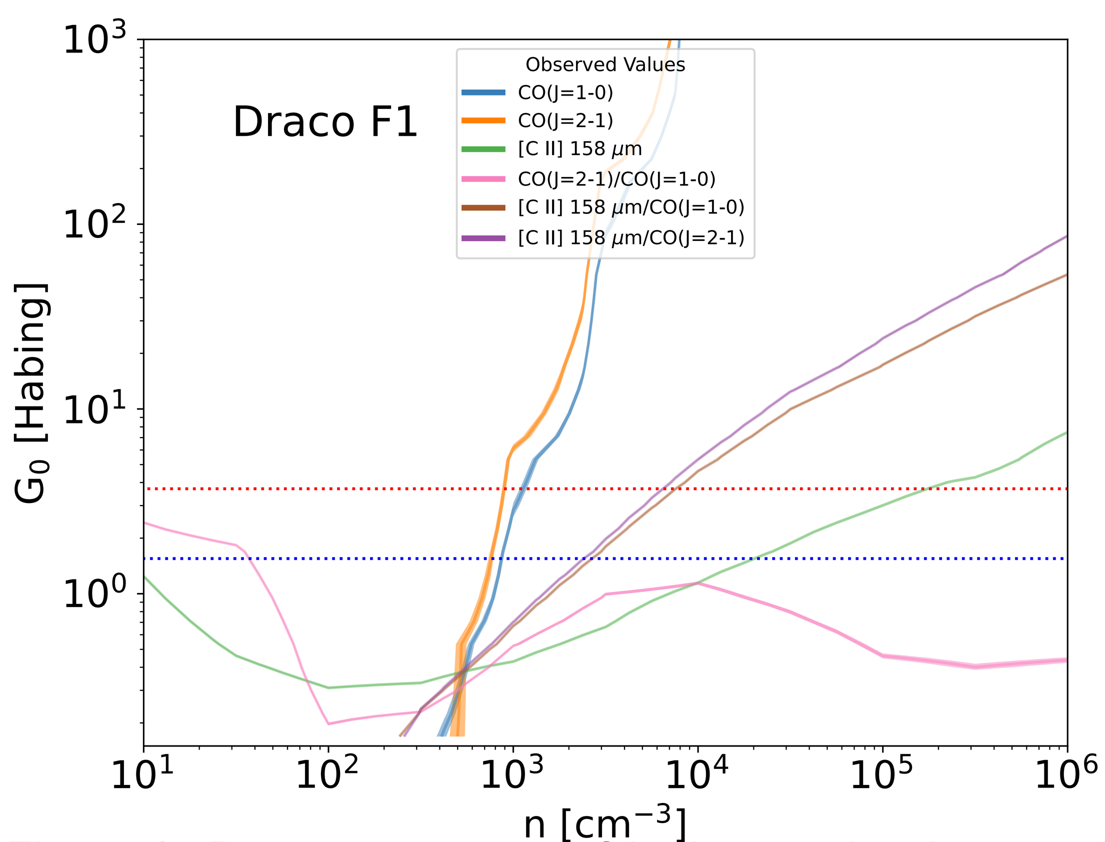

Figure 3: Parameter space of hydrogen density n and FUV field calculated from the KOSMA-τ model for 0.1 $M_\odot$ clumps for the Draco Front1 position. The isocontours at different colours show the observed line integrated intensities or ratios. The estimated FUV field from the 160 μm flux is indicated by a red dashed line and from the census of the stars as a dashed blue line.

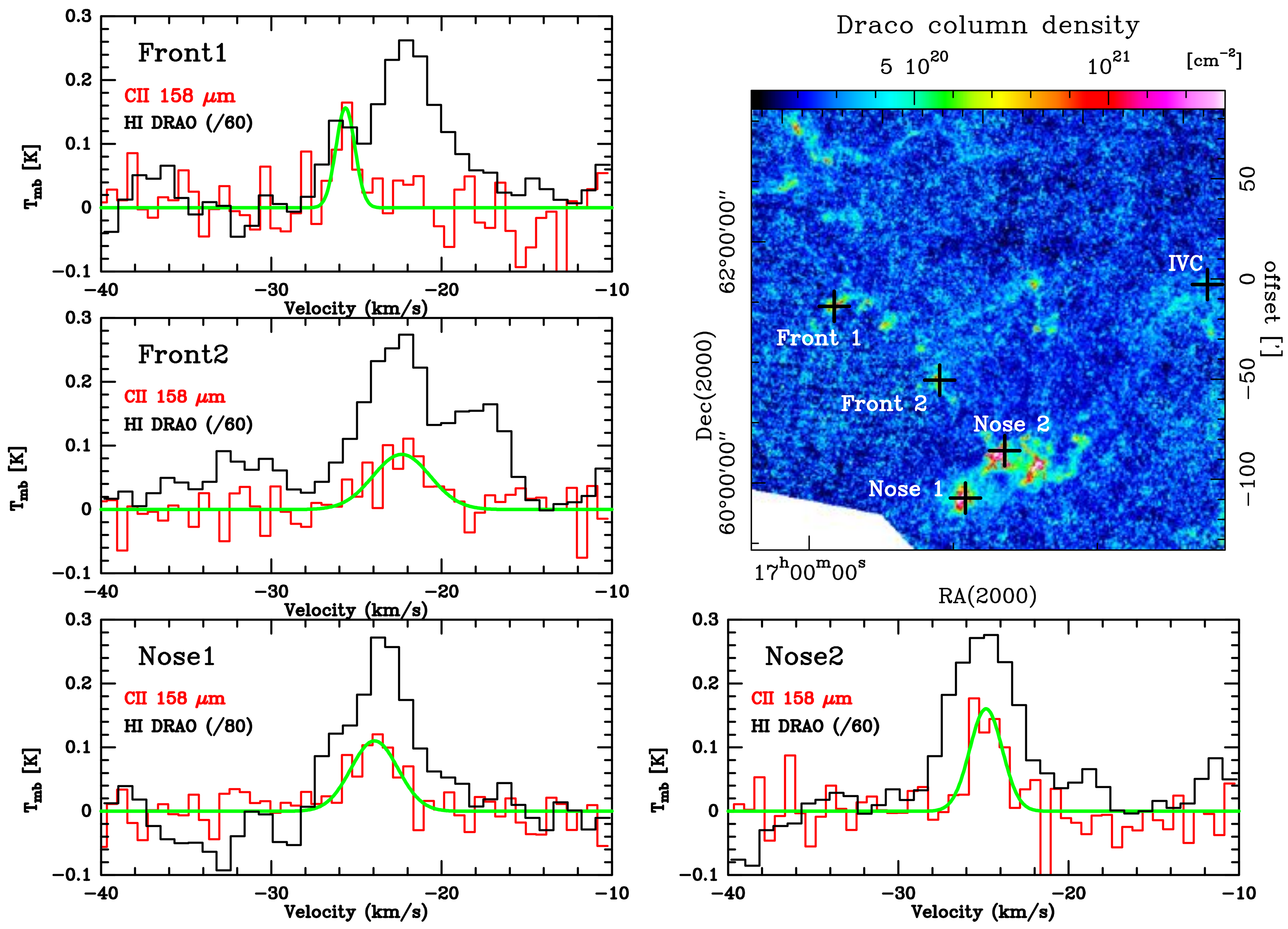

Figure 2: The upper right panel displays a Herschel map of hydrogen column density obtained from dust, with the locations of the observed [CII] positions marked by black crosses. In the surrounding panels, spectra of the [CII] 158 μm line and the HI 21 cm line (DRAO) at a resolution of $\sim 1'$ are presented. Note that the HI line was adjusted for improved clarity. The green curve represents a Gaussian fit to the [CII] line.

We conclude that (sub)-thermal excitation of the [CII] line can not account for the observed emission in Draco.

RADEX Modeling

RADEX (van der Tak et al. 2007), a non-LTE radiative transfer code, is utilised to model the cooler molecular gas component of Draco and to estimate the physical conditions such as temperature, density, and column density based on CO and ^{13}CO line observations. From RADEX modelling the density must be at least $3 \times 10^3\,\mathrm{cm}^{-3}$ at a temperature of around 10 K to fit the observed ratios for Draco. The model suggests that the observed CO line ratios in Draco determine gas at higher densities than estimated from the PDR modelling.

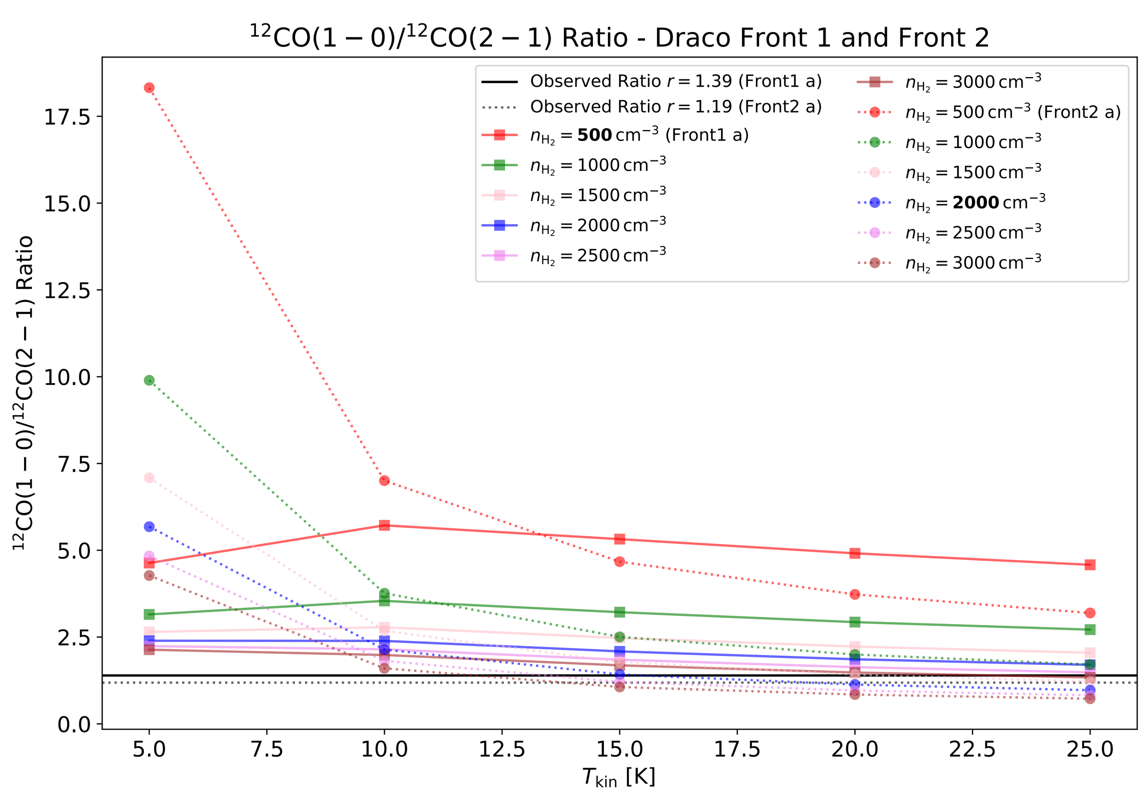

Figure 4: RADEX results for the ^{13}CO 1→0/2→1 and ^{12}CO 1→0/2→1 brightness ratios as a function of density and temperature for the Draco Front 1 and 2 positions. The observed ratios are shown as a solid and dashed black line. The density obtained with PDR modelling is marked in bold.

The discrepancies between the PDR and RADEX models and the inability to explain the [CII] emission by the PDR model suggests that an additional mechanism must be at play.

[CII] emission as a signpost of shock excitation

The only differences between **Draco** on one hand, and **Spider, Polaris**, and **Musca** on the other hand, is the higher dynamics of Draco. The cloud descents toward the Galactic plane and interacts with HI clouds (Fig. 1).

Shock waves can compress and heat the gas, leading to enhanced [CII] emission without a corresponding increase in CO emission, especially in a low-FUV environment like Draco.

This proposal is supported by a shock model (Gusdorf et al. 2008) with a pre-shock density of 100 cm^{-3} and a C-shock velocity of 20 km/s.

Conclusions

Neither PDR modelling of the [CII] and CO lines nor RADEX modelling of CO lines can consistently explain the observed emissions. The PDR model requires a UV field much lower than 1 G_0, which is not provided by the different methods of our UV field determinations. For Draco, heating by collisions of HI clouds could explain the high level of the 160 μm flux and the [CII] emission which is reproduced by a shock model with a C-shock. Non-detections of the [CII] line in other low-density clouds support the necessity of highly dynamic processes for [CII] excitation in UV-faint regions.

References

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