Reassessing the [CII]-Deficit in RCW79

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Bubble in the Bubble

Recent studies have shown that the ionized carbon 158 µm line (C^+, [CII]) is a key tracer of **gas cooling** and **dynamics** in photo-dissociation regions. Observations in Orion (Pabst, et al. 2019) and FEEDBACK (Schneider, et al. 2020) Galactic regions using SOFIA data have revealed **expanding shells** with significant velocities (~10-15 km/s). These shell expansions are primarily **driven by stellar winds** from massive stars rather than thermal expansion.

In a recent A&A Letter (Keilmann, et al. 2025, 697:L2), we report the first detection of a bubble-shaped source (S144 in RCW79), associated with a **compact H II** region, excited by a single O7.5-9.5V/III star, consistent with a bubble still mostly **„filled“ with** C^+. This indicates most likely an **early evolutionary stage** before significant wind–blown cavities form.

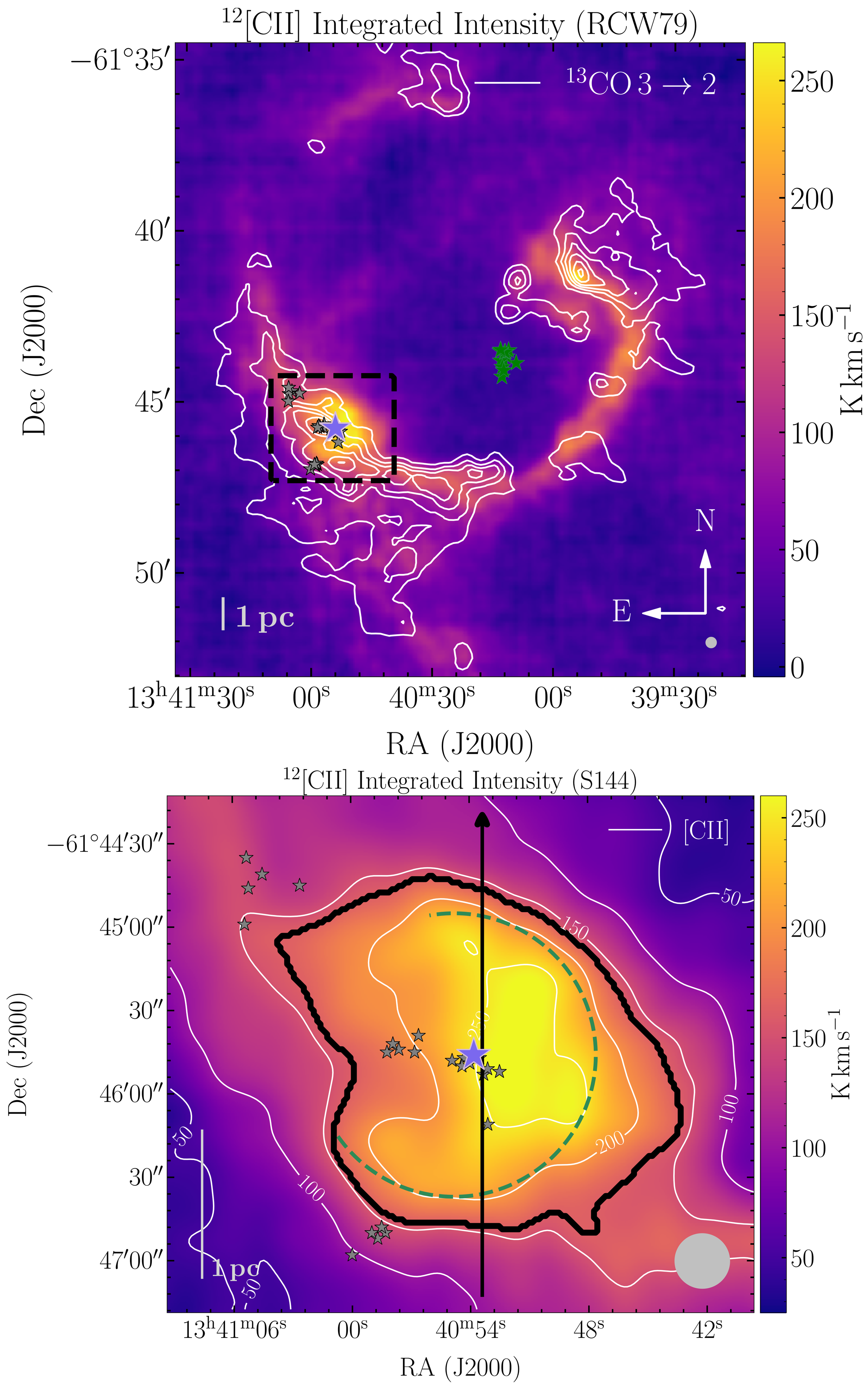

Figure 2: Line-integrated (-70 to -20 km/s) [C II] intensity maps of RCW79. Top: RCW79 in [CII] with its ionizing source of twelve O-type stars marked in green. The black rectangle outlines S144 (the bubble in the bubble). Bottom: The black contour outlines S144 as detected with dendrograms. The black arrow indicates the PV-cut shown in Fig. 3. The dotted green ring shows the extent of the Spitzer 8 µm ring.

[CII]-deficit

In RCW79, we observe a so-called **[CII]-deficit**, which has lowered [CII] emission compared to Far-Infrared (FIR) emission. Considering the moderate density and radiation fields in S144, we exclude possible explanations, such as high dust optical depth or reduced photo-electric heating efficiency. Instead, we explain the [C II]-deficit as caused by **[C II] self-absorption**.

Dynamics of S144

Fitting ellipses to PV cuts yields a **low expansion velocity** of ~2.6 km/s (Fig. 3) of the [C II] bubble. Modeling the [C II] emission with SimLine non–LTE radiative transfer code (Ossenkopf, et al. 2001), the scenario is consistent with a combination of expansion and [CII] self-absorption.

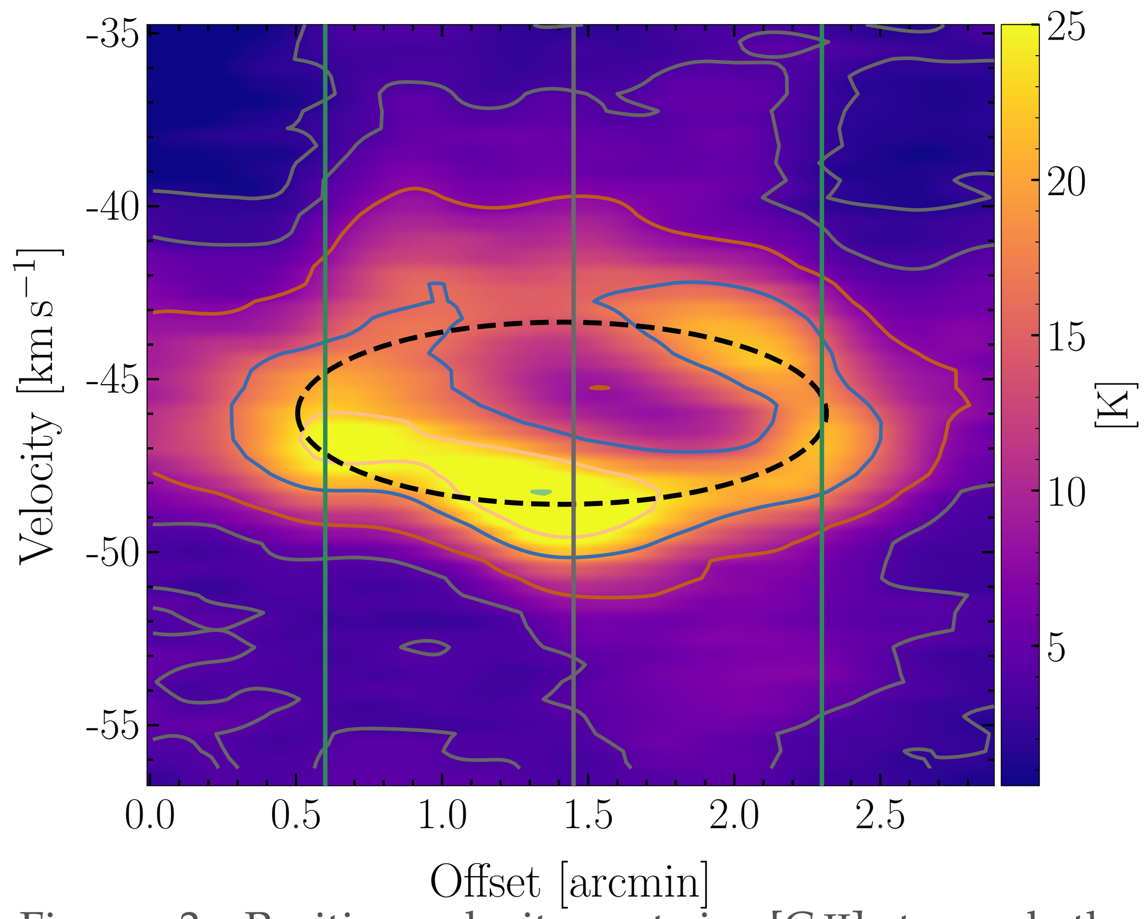

Figure 3: Position-velocity cut in [C II] toward the ionizing O star. Offset 0 arcmin marks the lower declination in Fig. 2 (bottom). The dashed ellipse results from fitting the emission in various PV cuts. The vertical gray line marks the position of the O star, and the green lines the extent of the Spitzer IR ring.

Reconstructing Missing [CII] Emission

A **two-layer model** (Kabanovic et al. 2022) reveals an optical depth of ~4-5, consistent with a single-layer analysis shown in Fig. 4 (top).

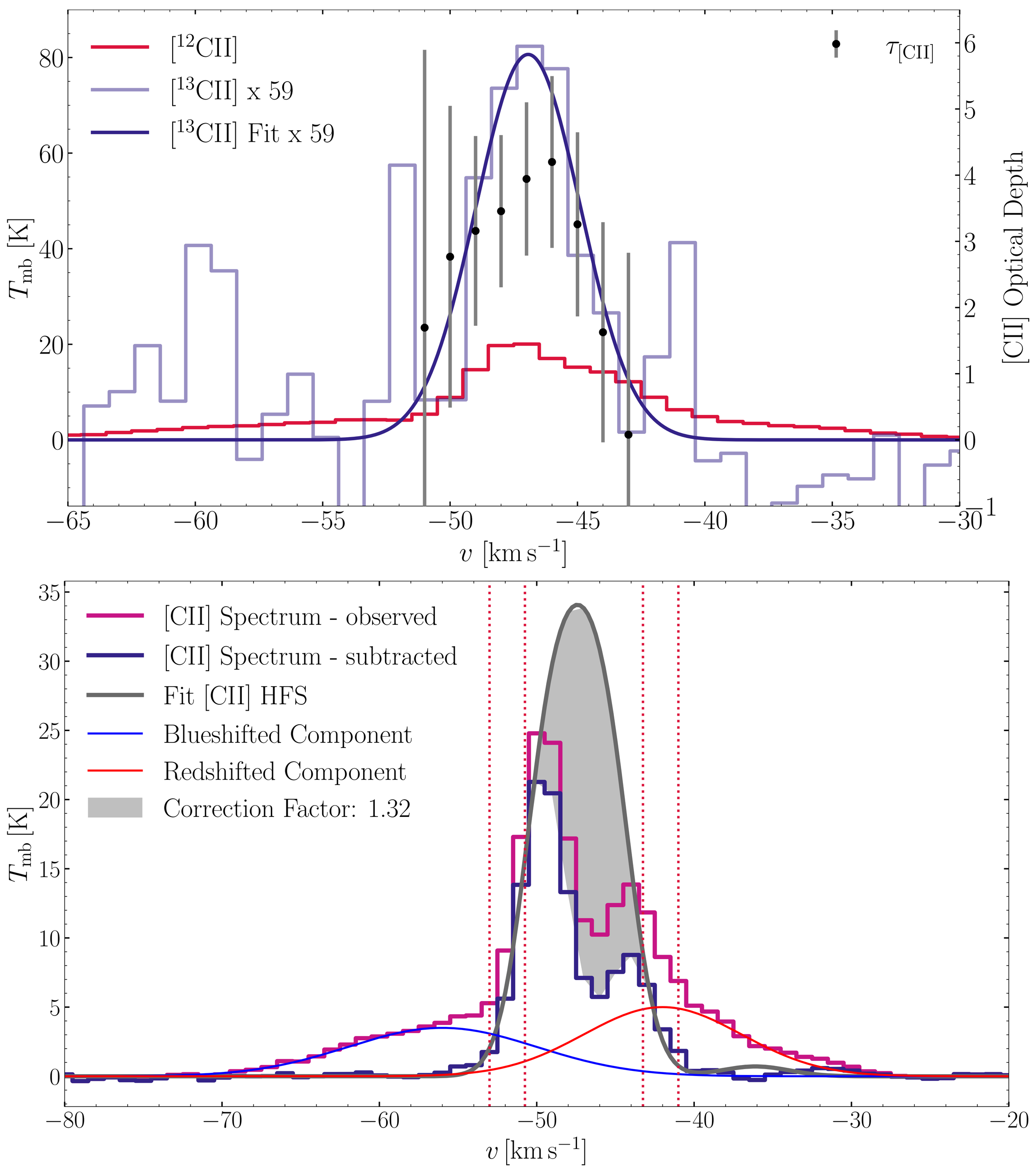

Figure 4: [C II] line spectra. Top: Average [^{13}C II] emission overshoots average [^{12}C II] emission, showing optical depth around 4-5. Bottom: Reconstructing missing [^{12}C II] flux by fitting line wings.

Fitting the line wings under consideration of the excitation temperature and optical depth and by incorporating [^{13}C II] emission and assuming [^{12}C II] self-absorption, we can **reconstruct** the missing [^{12}C II] flux (correction factor) as shown in Fig. 4 (bottom). This correction factor ranges from 1.1 to 1.4, and is able to **recover the missing [CII] flux**. Note, this method is not trying to simply fit some Gaussian shape, but rather takes physical information into account.

Prior to actual wing-fitting, emission from the large shell of RCW79 is fitted and subtracted (blue and red components). Only the region around the ionizing O star is corrected, since double-peak spectra are first detected automatically, which are evident only around the O star.

Resolving the [CII]-deficit

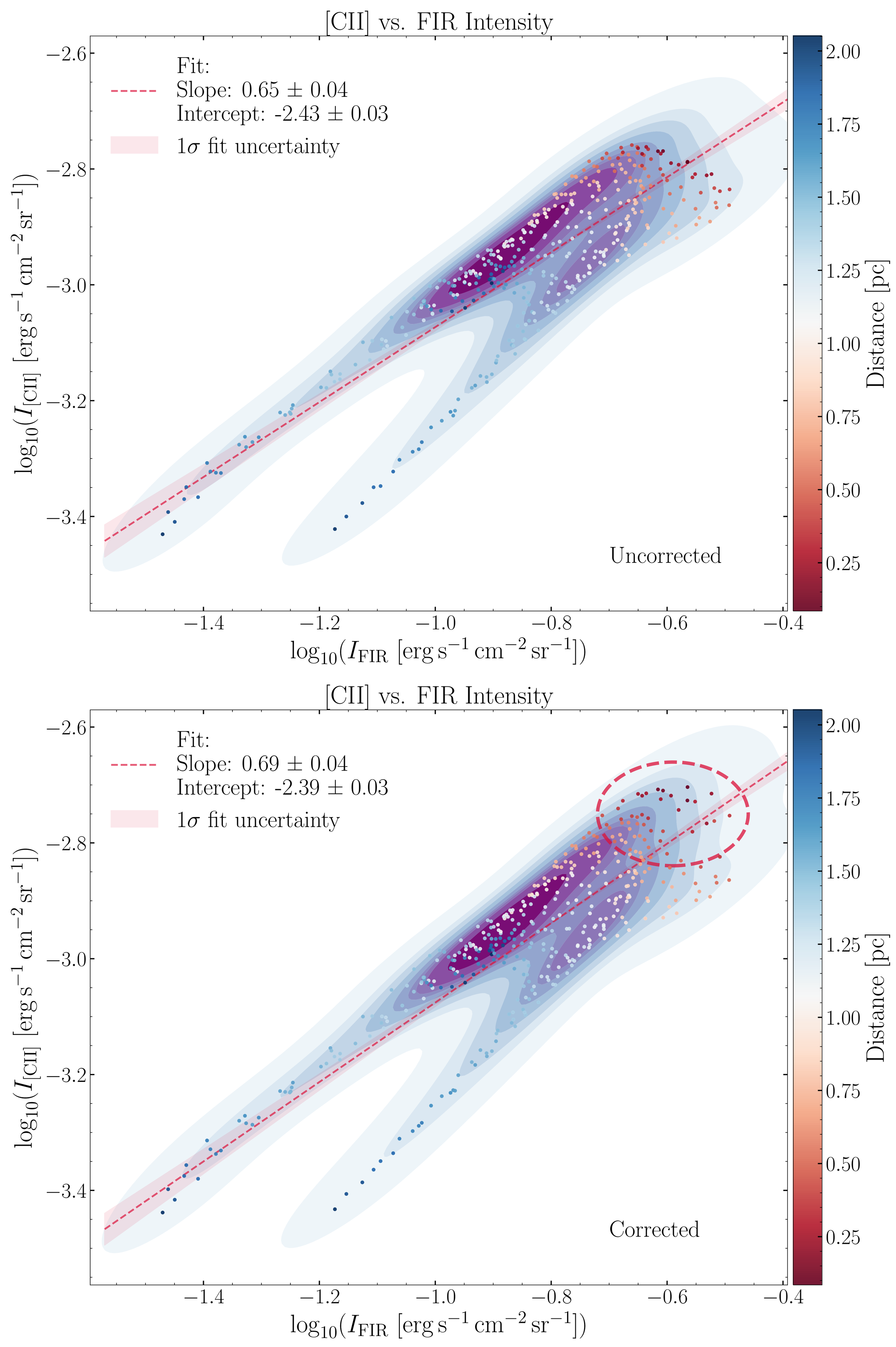

Figure 5: [C II] to FIR correlation. Top: The uncorrected [C II] emission clearly shows a [C II]-deficit for high values of [C II] and FIR emission. Bottom: The reconstructed and corrected [C II] emission is shifted upwards, encircled by a dashed red ellipse, recovering a linear correlation.

Figure 5 (top) shows the apparent [C II]-deficit. After reconstructing under assumption of self-absorption, the corrected [C II] emission **restores a linear relation** to the FIR emission (Fig. 5, bottom), without invoking extreme densities, metallicities, or ionization parameters.

Conclusions

In S144, we see for the first time a bubble „filled“ with [C II] emission, indicating an early evolutionary state of a [CII] bubble.

Our method reveals **[CII] self-absorption** as the most likely **explanation** for the apparent [C II]-deficit in not-so-extreme Galactic regions like RCW79.

[CII] self-absorption must be accounted for when interpreting [CII]-deficits in Galactic H II bubbles, and broader surveys are needed to quantify the prevalence of this effect.

References

Pabst, et al. 2019, Nature, 565, 618, Schneider, et al. 2020, PASP, 132, 104301, Keilmann, et al. 2025, A&A, 697:L2, Ossenkopf, et al. 2001, A&A, 378, 608, Kabanovic, et al. 2022, A&A, 659:A36

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