Unveiling Star Formation in the Milky Way: *The Diamond Ring in Cygnus X*

Credit: NASA/JPL-Caltech/CfA

Simon Dannhauer, Robert Simon, Nicola Schneider, Lars Bonne, Timea Csengeri and the *FEEDBACK* team

Overview: Cygnus X, DR21 and the "Diamond Ring"

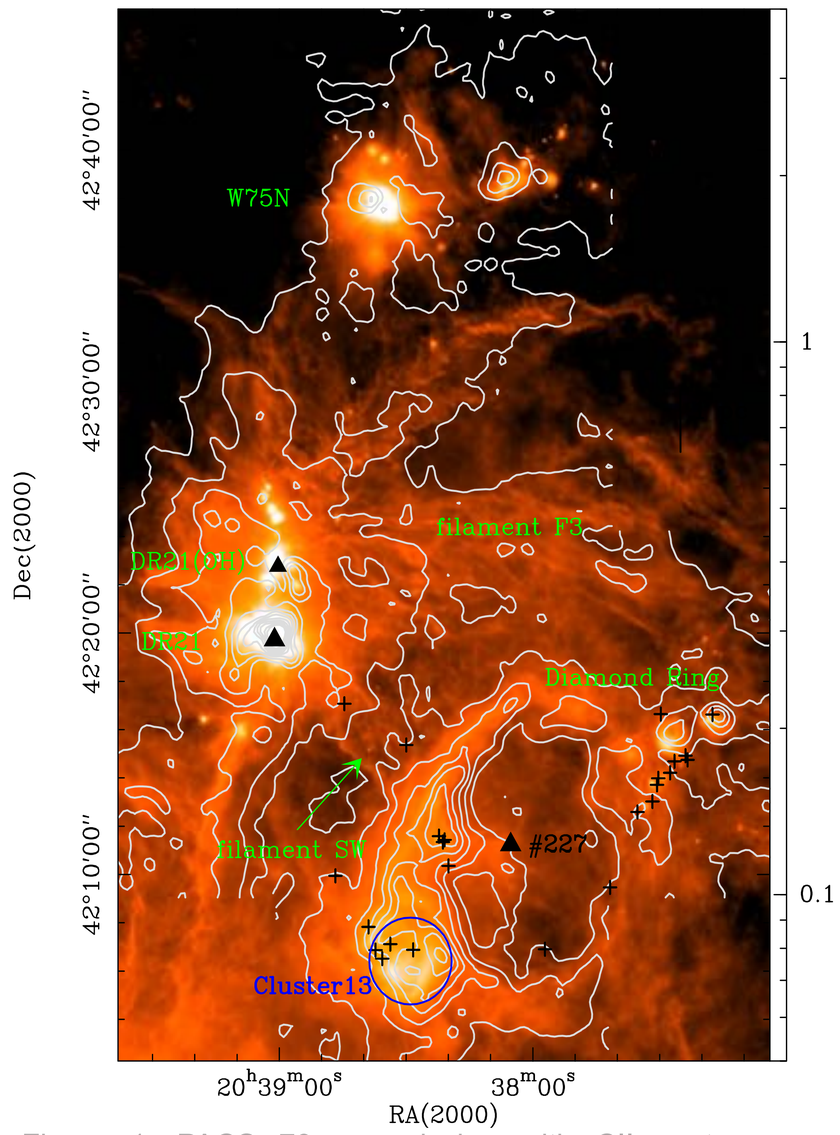

Figure 1: PACS 70μm emission with CII contours overlaid. The filaments F3 and SW (Hennemann et al., 2012) are indicated. The star #227 is indicated. Black crosses are protostars from Kryukova et al., 2014). The B-star cluster Cl13 is shown by a circle.

Young OB stars ionize their surrounding medium via FUV radiation and stellar winds, creating a HII region bubble around them. For the first time we observe a true ring - all other bubbles showed expanding shells (e.g., RCW120, Luisi et al. 2021; RCW36, Bonne et al., 2022) - in the Cygnus X complex. Cygnus X is a massive, nearby (1.4 kpc) star forming region (see, e.g., Schneider et al., 2006, Motte et al., 2007). There are several prominent sources (see Fig. 1):

- the well-studied DR21 ridge (Schneider et al., 2010, Hennemann et al., 2012) with the massive outflow DR21, and the proto-cluster DR21(OH) in the north of it, which itself is fed by infall from filaments to the west.
- Southwest of the DR21 ridge lies the "Diamond Ring", a bright ring-like structure in dust-continuum emission (Beerer et al. 2010, Kryukova et al., 2014), also traced in CO transitions and in the ionized carbon CII 158 μm line (SOFIA Legacy Project FEEDBACK [1]). Channel maps (see Fig. 4) reveal a filamentary connection to the DR21 ridge.

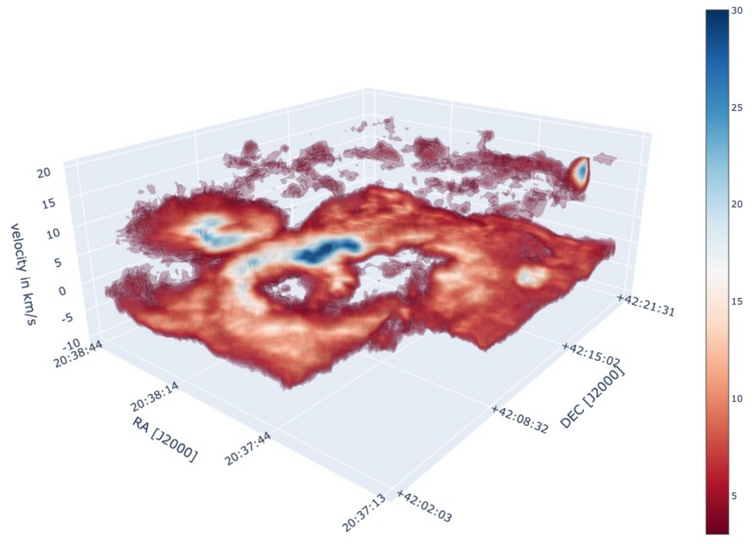

Figure 2: 3D-CII cut-out of the ”Diamond Ring” region, the z-axis corresponds to velocity, the colour scheme to integrated intensity in K km/s. The cluster of B-stars (Cl13) shows signature of a bubble-like expansion while the ring does not.

The *riddle* of the ring

- The ring is associated with an HII region.
- The CII data shows no hints of bubble-like gas expansion, indicating this is a real ring (see Fig. 2).
- Small velocity difference between the eastern and western part.

What is the ionizing source and what is driving the expansion?

How could such a structure form in the context of the larger region?

What is its evolutionary stage?

Preliminary Results

- Southeast peak contains a cluster of B-stars (Cl13, Le Duigou et al., 2002) and is detached in velocity space from the ring, CO data indicate that Cl13 is part of the molecular cloud complex at around +8 km/s.
- Massive star close to the centre of the ring (#227 in Comeron et al., 2008). PDR-modelling, using the *WK2020* model of the *PDR Toolbox* of the FUV field gives 60 G0 at the star's position (see Fig. 3), which is too low for an OB-star, a possible run-away star could so far not be identified.
- Assuming a tilted ring and fitting an ellipse to determine the tilt, we find the ring is rotated ~40° against the viewing plane. The velocity gradient between east and west then corresponds to a **low expansion velocity** of ~2.5 km/s.

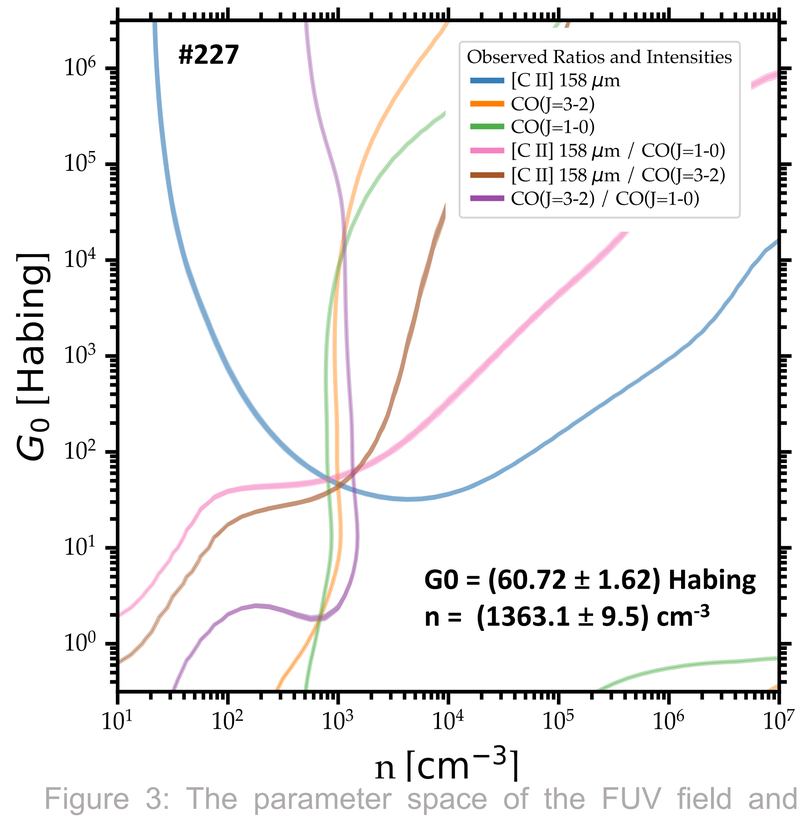

Figure 3: The parameter space of the FUV field and density obtained from PDR (Photodissociation Region) modelling using the WK2020 model of the PDR Toolbox (Pound et al., 2023) and line ratios and intensities obtained with SOFIA and archival data within a beam of 60” around the position of star #227. The velocity range corresponds to -4 to 4 K km/s, associated with the ring.

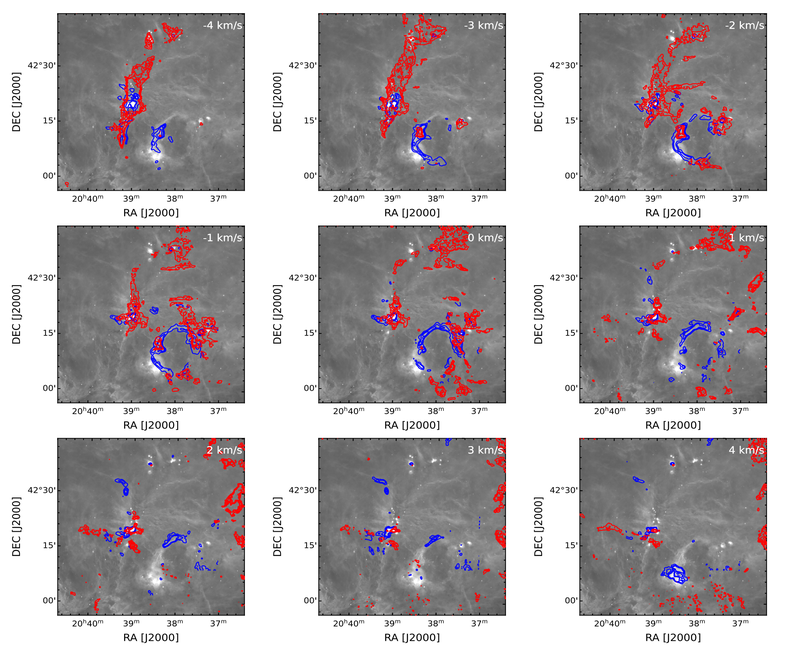

Figure 4: Channel map of Spitzer 8μm emission overlaid with Nobeyama CO (1-0) (red) and CII. The ring is clearly visible, also a molecular connection towards the ridge and the detachment of Cl13 in velocity space.

Conclusions & Outlook

1. The “Diamond Ring“ is a Diamond (Cluster 13) and a ring.
2. #227 is most-likely not the ionizing star.
3. Comparisons to synthetic simulations will give important constraint on the formation of sheet-like ISM and stellar feedback.
4. The NOEMA Large Program NASCENT-stars (PI: T. Csengeri) will cover dense protostellar cores in the region, bridging the spatial scale gap for stellar feedback.

Also beyond it‘s lifetime, SOFIA observations of star forming regions are an invaluable assets in disentangling the intricate processes governing the birth of stars!

REFERENCES

[1] feedback.astro.umd.edu

IMPRS for Astronomy & Astrophysics Bonn and Cologne
INTERNATIONAL MAX PLANCK RESEARCH SCHOOL

SFB 1601

UNIVERSITÄT ZU KÖLN