

The FIFI-LS view of the Galactic Centre

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Introduction

The Milky Way's Galactic Centre serves as a rich laboratory for the study of star formation in extreme environments. Among the most pressing issues is the "Paradox of Youth" – the existence of a dense nuclear cluster of massive stars around Sgr A* that formed within the last 10 Myr. If these stars formed *in-situ*, then the closest gas reservoir would be the Circumnuclear Disk (CND). We used SOFIA's field imaging spectrometer FIFI-LS to obtain **spatially resolved maps of 11 far-infrared emission lines** with an angular resolution approximately 4 times higher than previous published data. From these, we derive measurements of the physical state of the CND, and make inferences on its **role in the formation of a nuclear cluster**.



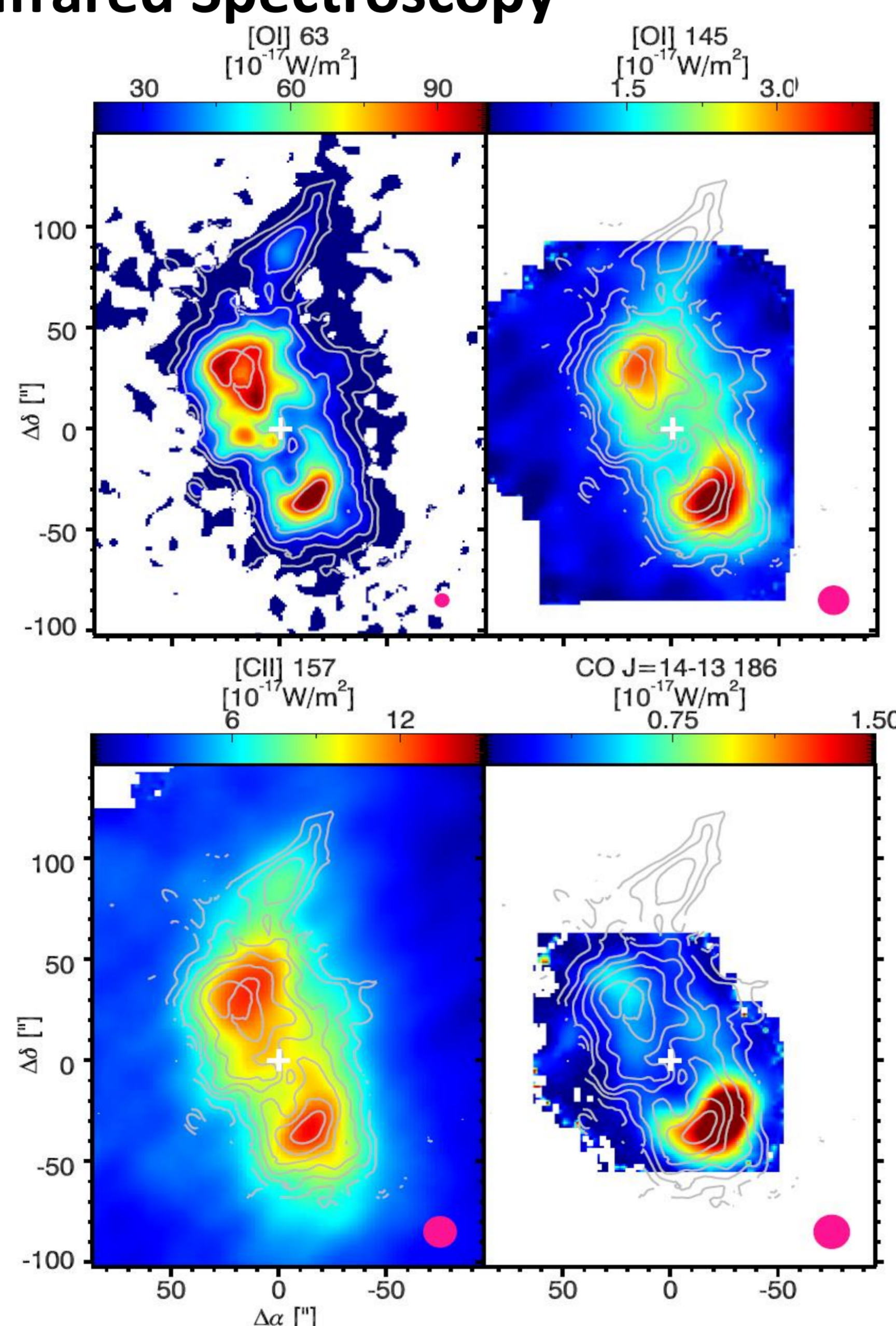
Far-Infrared Spectroscopy

Observation data:

- 8 flights during OC2C, OC4F & OC5I
- Line flux + continuum at 11 wavelength bands 40 – 200 μm
- [CII] 158, [OI] 63 & 145, [OIII] 52 & 88, [NIII] 57, 5 high- J CO lines

Observed features:

- Most lines trace GREAT **dual lobes + streamers** w/ strong clumpiness
- Projection of FORCAST **inclined dusty torus** (Lau et al. 2012)
- Illuminated inner edge of **photodissociation region (PDR)**
- CO stronger in south
 - Local heating?
- [OIII], [NIII] trace **ionised mini-spiral**

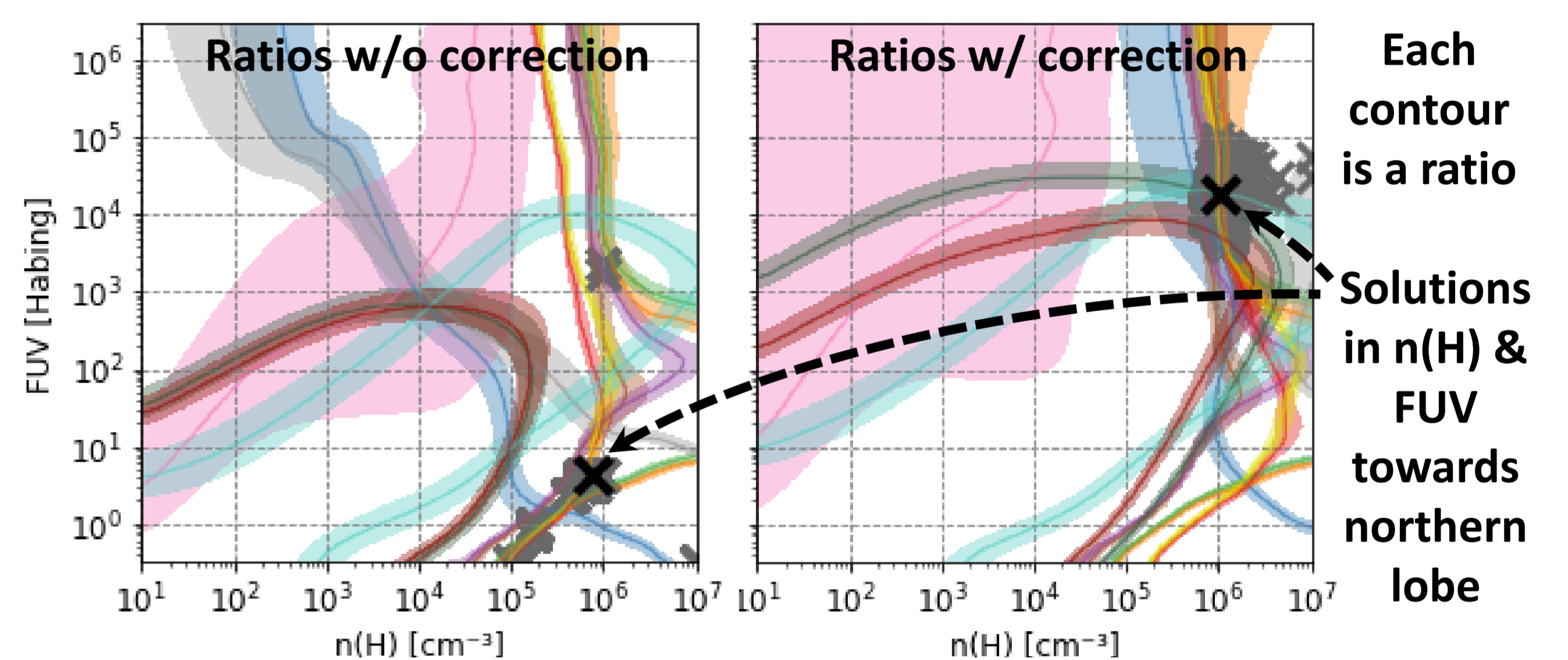


FIFI-LS enabled multidagnostic mapping with high spatial resolution and fast speed

Dense ISM Characterisation

PDR modelling:

- Model dense gas as 1D slab illuminated by nuclear stars
- Wolfire-Kaufman 2020 PDR model in pdrtpy toolbox by Marc Pound
- Fit observed **line ratios** to obtain **gas density** and **FUV field hardness**
- Need to correct for [OI] self-absorption, [CII] non-PDR contributions



Results:

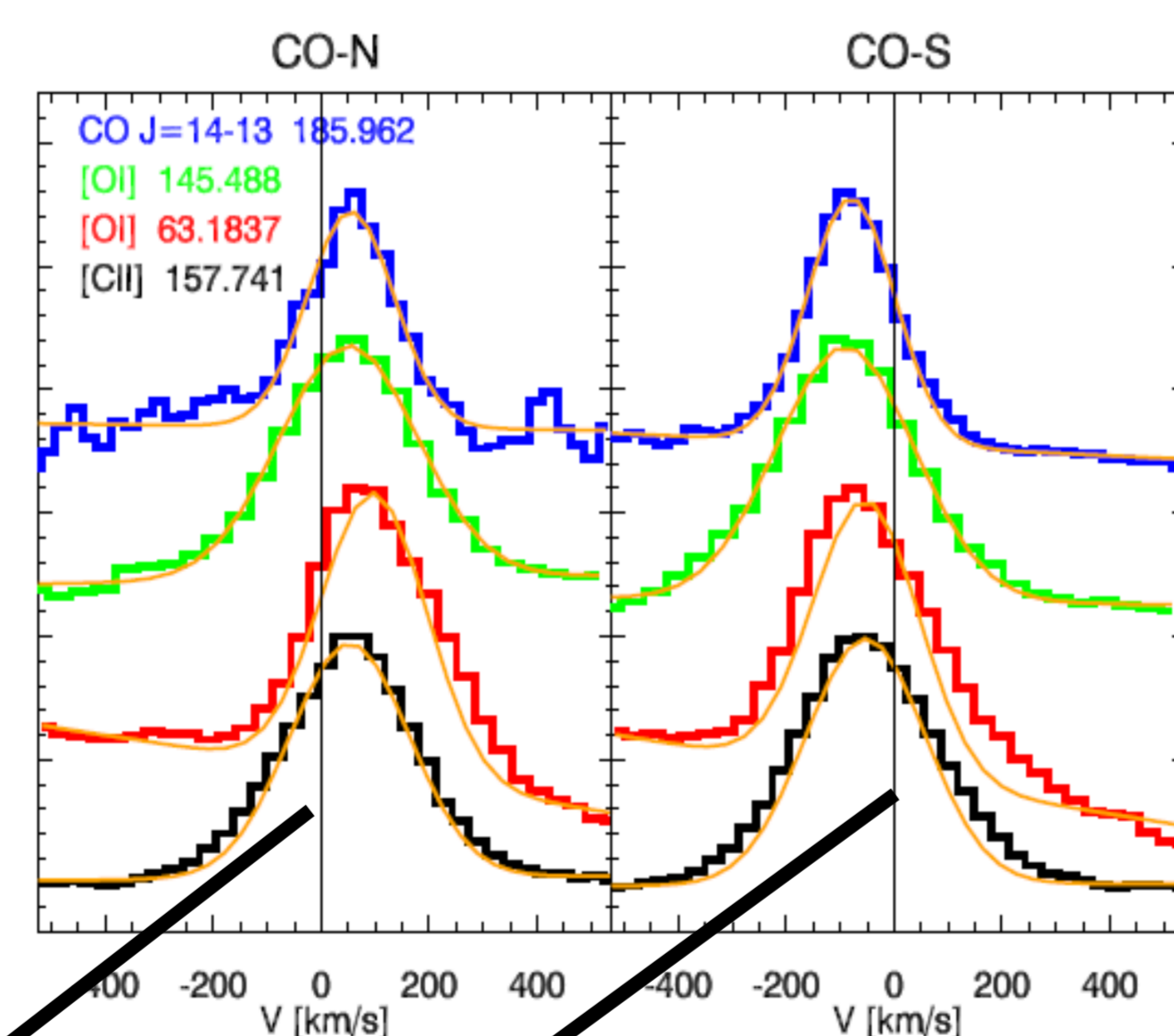
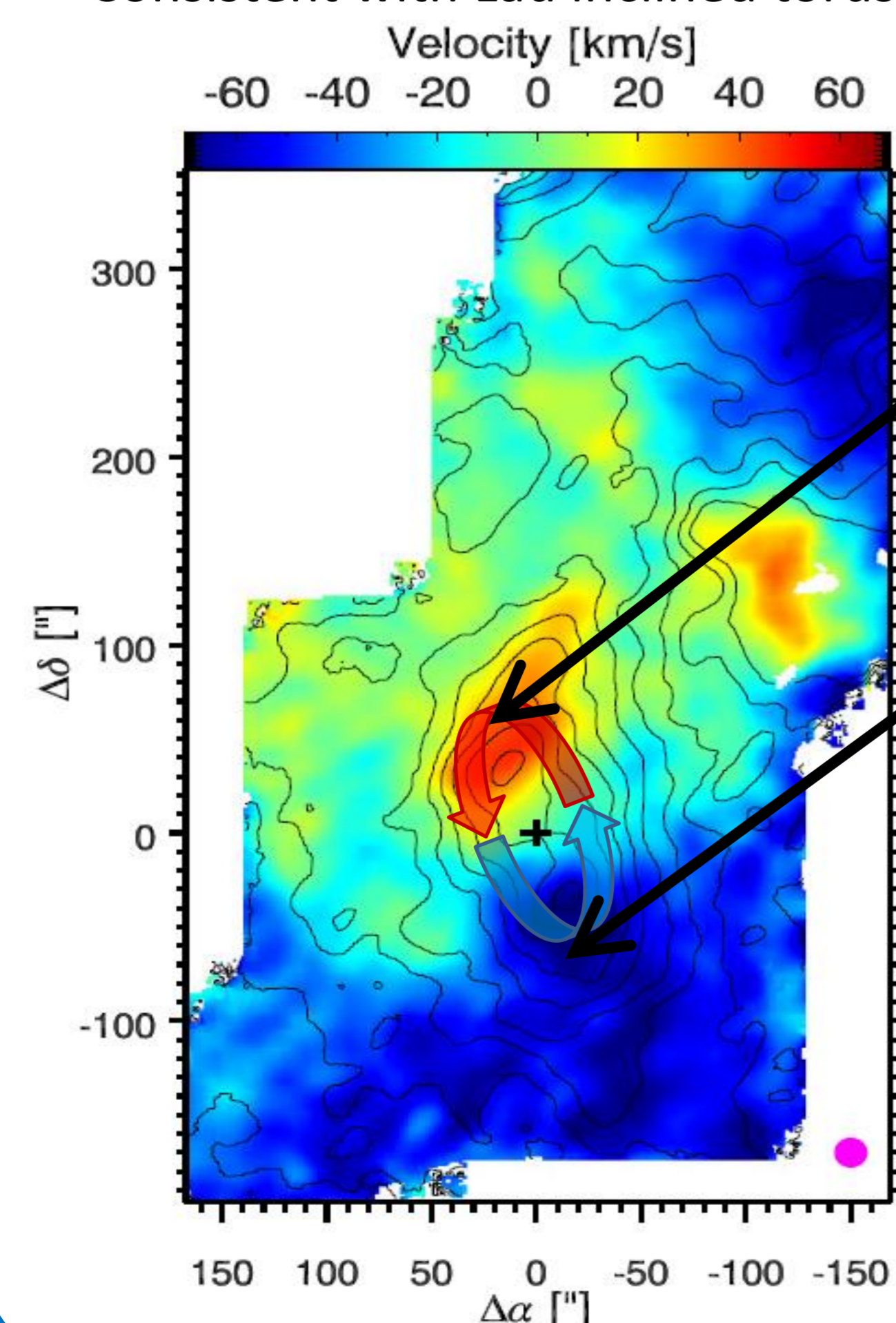
- Models very sensitive to ensemble of line ratios and far-IR continuum
 - **Using only fine structure lines is insufficient!**
- 85% of [CII] not from warm PDR, [OI] 63 self-absorption up to 60%
- Huge impact on model results, cannot take [CII], [OI] at face value
- Density peaks in southern lobe at $10^{6.2} \text{ cm}^{-3}$ – lower than Roche limit
 - All of CND is **susceptible to tidal forces** and may be **transient**

*CND not a stable reservoir for in-situ star formation
Can infalling gas improve the situation?*

Dynamics & Infall

Velocity maps:

- Doppler shifts observed for all species via gaussian fits to profiles
- Positive velocity in north lobe, negative in south lobe
- Consistent with Lau inclined torus



Streamers:

- Streamer feature north-west of Sgr A* at $+30 \text{ km s}^{-1}$
- Dynamics at lobes agree with VLA model (Zhao et al. 2010)
 - CND may be a **collection of Keplerian orbits**, not a torus
 - Infall via ionised mini-spiral

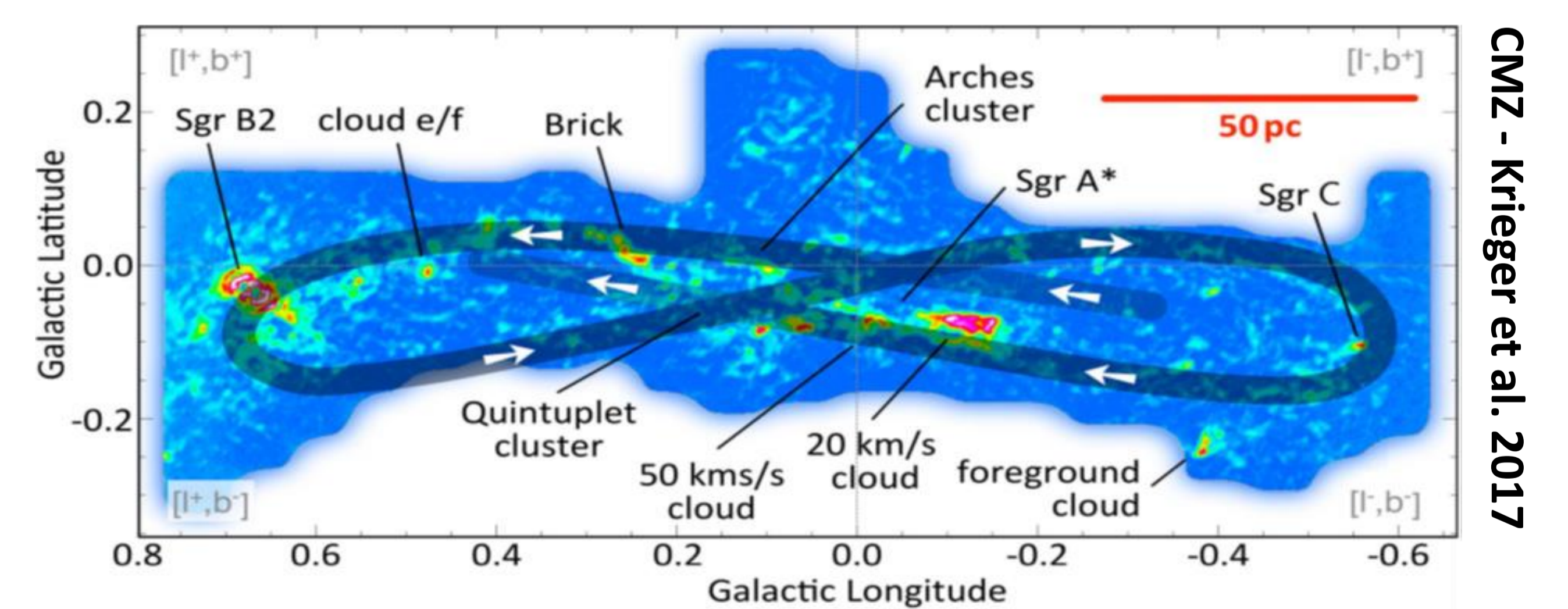
Promising infall routes for future star formation

Are we observing a snapshot of a longer formation sequence?

The Bigger Picture

Central Molecular Zone:

- CND and central cluster embedded within larger 100 pc-scale region
- Apparent evolutionary chain of objects in diverse star-forming states
- Following stable closed orbits, gas periodically injected by galactic bars
- **Episodic creation of stellar populations on ~10 Myr cycle**



Next generation FIFI-LS observations:

- Cycle 9 GO project targeted Sgr B2, Sgr C, „Dust Ridge“ & „The Brick“
 - Multidagnostic mapping to determine physical characteristics and **relative evolutionary states**
- Extended CND region observed with On-The-Fly mapping
 - Linking CND to the larger scale cycle of SF and ISM infall

*CND and central cluster lie within a multiscale episodic system
New FIFI-LS data aims to link spatial & temporal scales*

FULL PAPER: Iserlohe, C., Bryant, A., Krabbe, A., Fischer, C., et al. 2019, "FIFI-LS Observations of the Circumnuclear Ring" *ApJ* 885, 169



- References:**
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