SOFIA/FIFI-LS spectroscopy of Gy 3-7 cluster in the outer Galaxy

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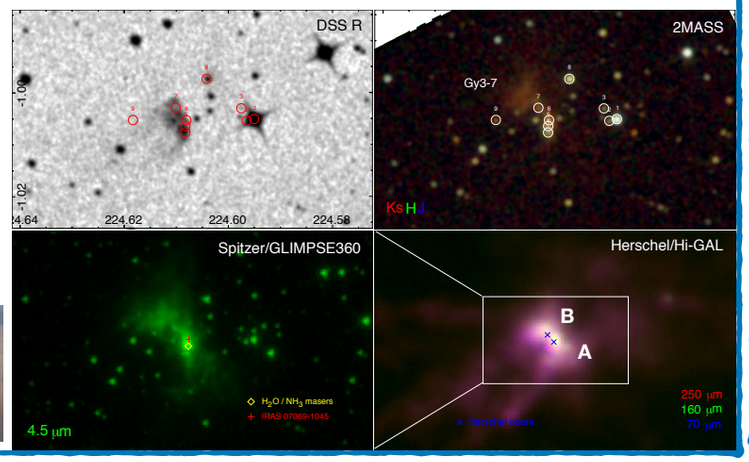
Abstract

Star formation is ubiquitous in the Galaxy, but the physical and chemical conditions in star-forming sites might differ as a function of Galactocentric radius. For example, due to the negative metallicity gradient, the efficiency of gas cooling and dust shielding is expected to decrease in the outer Galaxy.

Here, we present the SOFIA/FIFI-LS mapping observations toward the Gy 3-7 cluster in the Canis Major star-forming region covering highly excited CO lines from J=14-13 up to 30-29, [CII] at 158 μm, and [OI] at 63 and 145 μm. The CO rotational temperature of ~300 K toward two dense cores are similar to other Galactic star-forming regions of similar masses. On the other hand, the ratio of total line emission in CO versus [O I], a tracer of metallicity, is comparable to star-forming regions in the Magellanic Clouds. Thus, Gy 3-7 is a suitable target to quantify the impact of low metallicity on star formation.

Observations

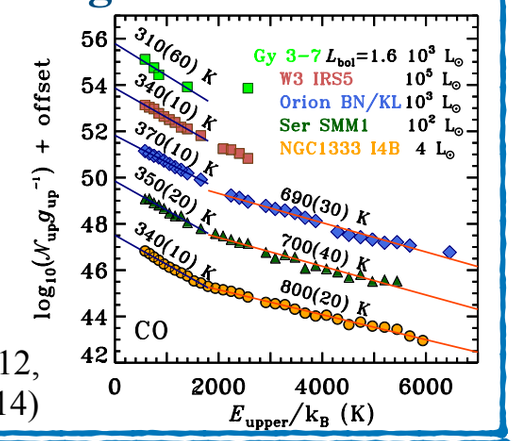
- FIFI-LS integral field spectrometer (Fischer et al. 2018)
- 5x5 array with 2 independent channels and optimized pixel sizes:
  - 6″x6″ for 50 to 120 μm
  - 12″x12″ for 100 to 200 μm



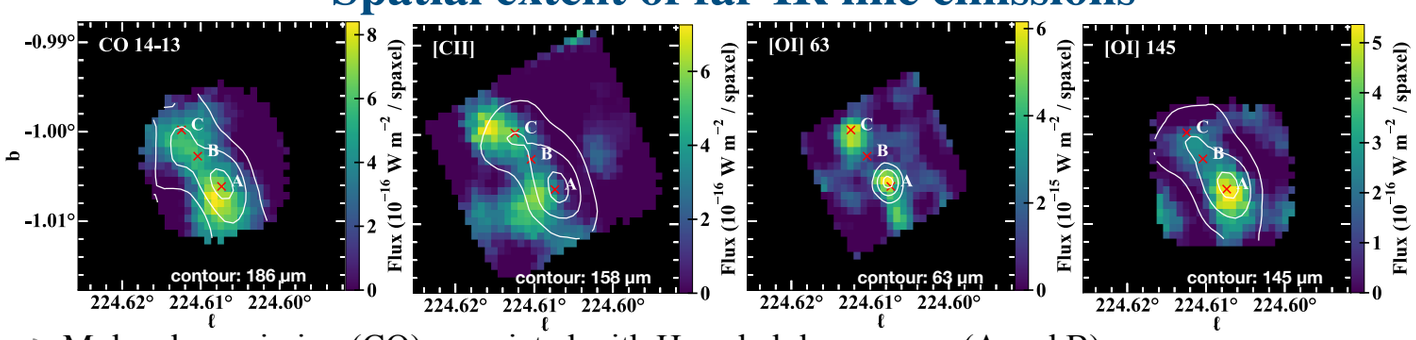
CO excitation diagram

- $T_{rot\,(CO)}$ ~ 300K at position of dense core A, assuming LTE conditions.
- $T_{rot\,(CO)}$ is similar to other low- and high-mass protostars in the Milky Way.

(Data were taken from Herczeg et al. 2012, Goicoechea et al. 2012, Karska et al. 2014)

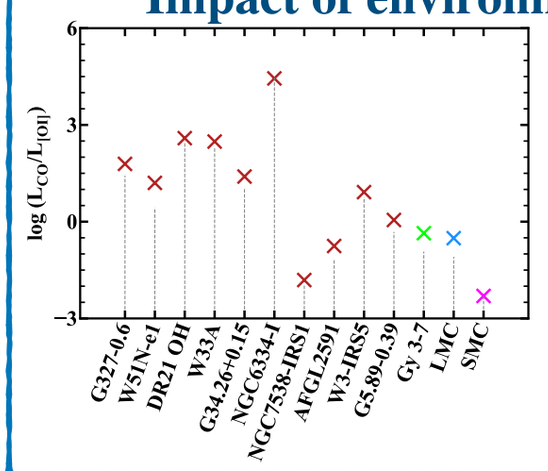


Spatial extent of far-IR line emissions



- Molecular emission (CO) associated with Herschel dense cores (A and B)
- [CII] peaks away from dense cores, esp. at the position of the N-E nebulosity (C)
- [OI] emission peaks both at the vicinity of the IR sources (jets) and in the nebulosity (PDR)

Impact of environment on line cooling



- $L_{CO}/L_{[OI]}$ in the far-IR range in Gy 3-7 (green) is lower than in many high-mass YSOs (brown, Karska et al. 2014), but similar to such sources in the Magellanic Clouds (blue & pink, Oliveira et al. 2019).
- A likely effect of lower metallicity in Gy 3-7 due to the location in the outer Galaxy.

Conclusions and next steps

- Far-IR line emission from Gy 3-7 resembles some of the massive YSOs in the Milky Way.
- The ratio of molecular-to-atomic cooling suggests the impact of low-metallicity on line cooling in Gy 3-7.
- On-going analysis of APEX/PI230 observations will reveal gas kinematics in the region.

Mass-loss rate ($\dot{M}_{out}$)

- $\dot{M}_{out}$ from dense core A ~ 7×10^{-6} $M_\odot yr^{-1}$(calculated from $L_{[OI]63\mu m}$, Mottram et al. 2017) .
- Adopting the $\dot{M}_{acc}$ calculated from $F_{HBr\gamma}$ (Calvet et al. 2004) in the RMS survey (Cooper et al. 2013), the ratio of ejection and accretion is ~ 0.1.

The detail of references can be found here: *https://github.com/nganle191919/list-of-ref.git*

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