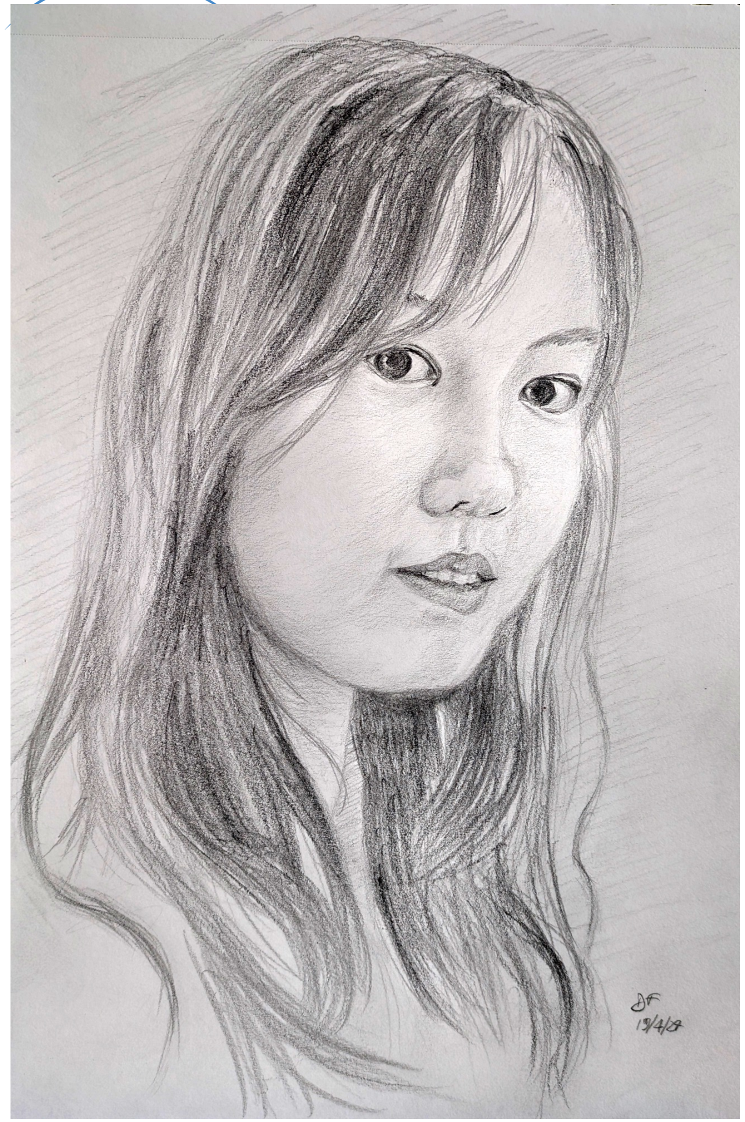
ISM of nearby luminous QSOs through CO and [CII]



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Measuring the ISM Content of Nearby, Luminous, Type 1 and Type 2 QSOs through CO and [C II]

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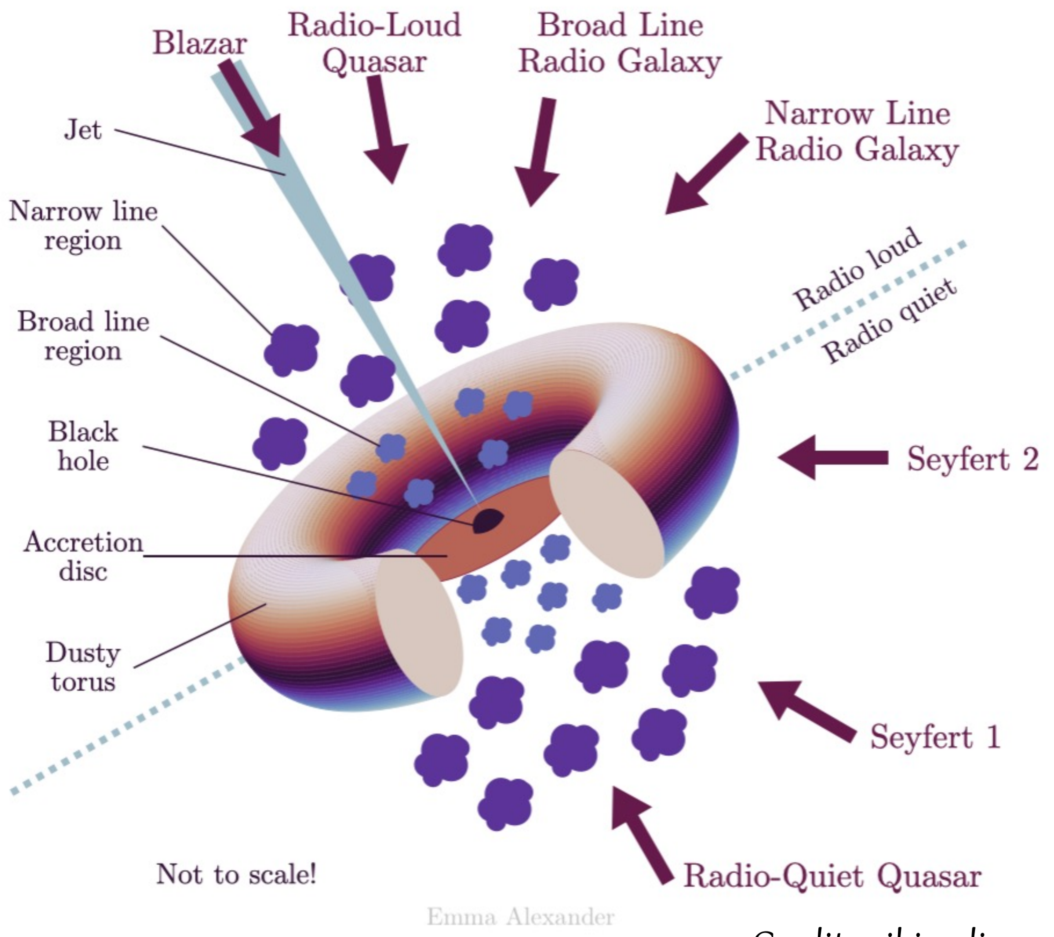
QSO 1 & 2 scenarios



Credit: wikipedia

Orientation scenario

Mergers & starburst

Gas turbulence triggers nuclear activity
QSO2 phase

Winds clears up clouds
QSO1 phase

Evolutionary scenario

ISM in QSO: rationale

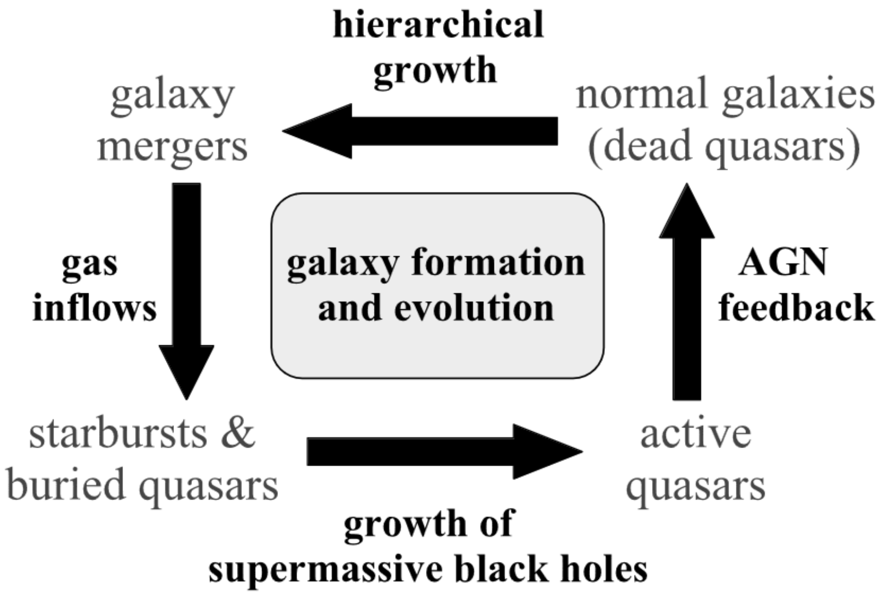
The ISM can be studied via its CO and [CII] emission.

We compare here the emission of QSO (type 1 and 2) whose emission is AGN-dominated with that of LIRGs, whose emission is prevalently due to SF.

In an evolutionary scenario, QSO2 will have a lower gas fraction (M_{H_2}/M_*) and SF efficiency than LIRGs.

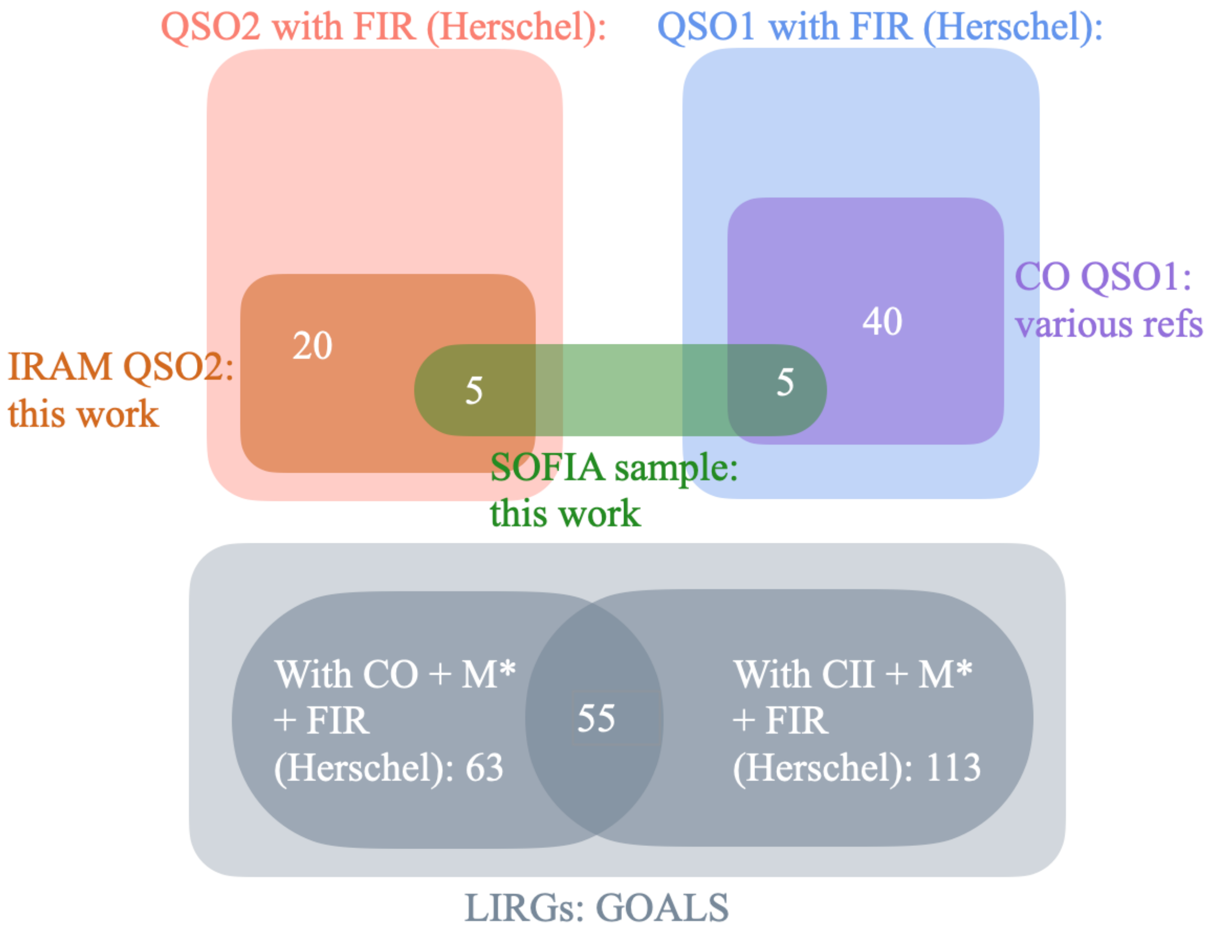
Furthermore, since the feedback from the AGN should impact the ability to form new stars, QSO1 should have lower gas fraction and SF efficiency than QSO2.

Therefore, by comparing tracers of star formation (FIR emission) and of molecular gas (CO and [CII]) we should be able to see if the evolutionary mode is supported by observations.



Cosmic cycle from Hopkins et al (2006)

Samples



QSO sample

LIRG reference sample

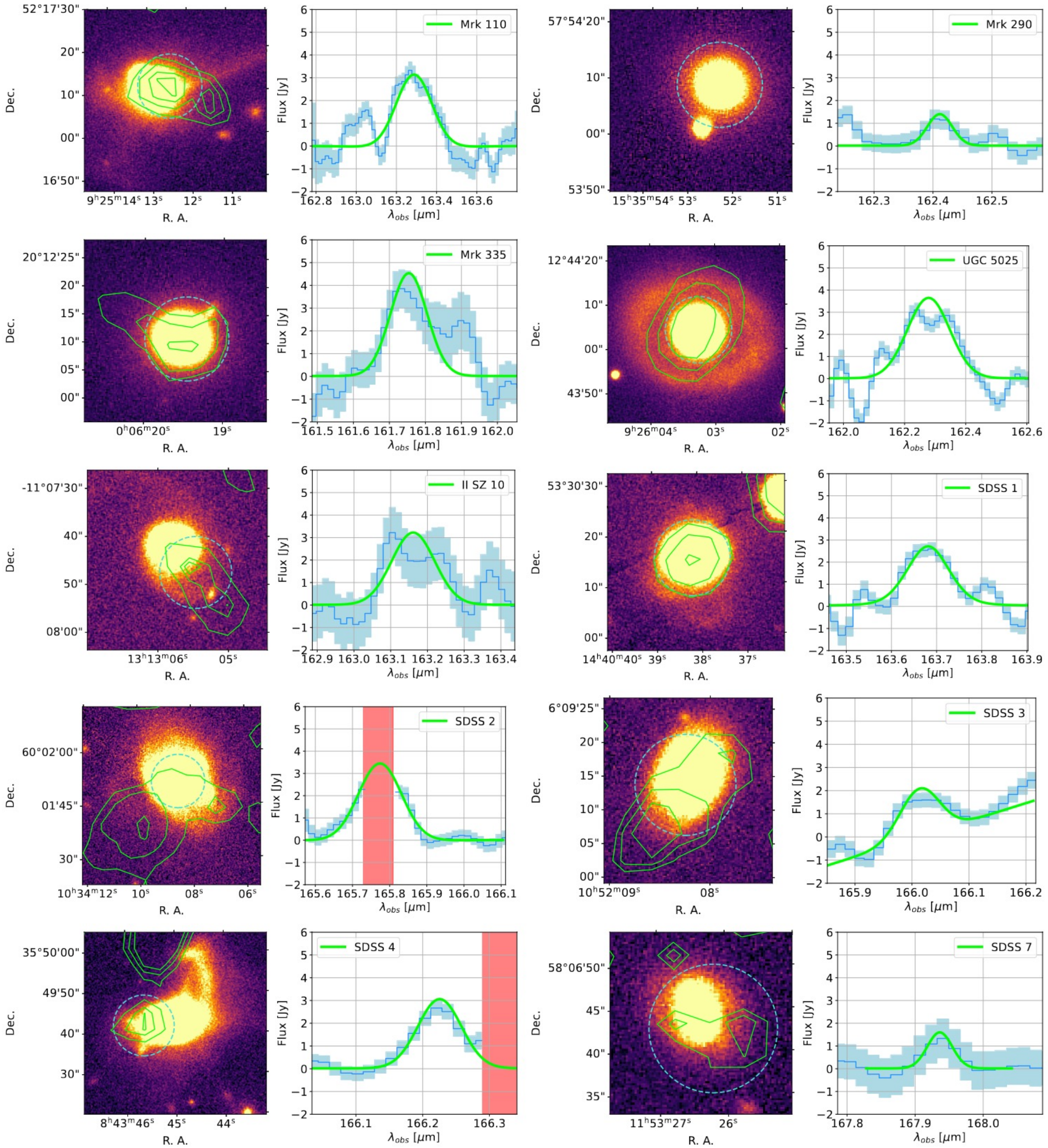
SOFIA sample

- P.I. Andreea Petric
- 5 nearest QSO2s from Shangguan & Ho (2019) [QSO2 from the SDSS survey]
- 5 nearest PG QSO1s observable within the SOFIA atmospheric window for [C II] observations.
- Observations done between August 2020 and February 2023 with 1h on-source integration except for the FIR luminous QSO1 UGC 05025 [30 minutes on source]
- Symmetric chop nodding centered on the red channel of FIFI-LS ([C II] 158μm line).

P.I.: Andreea Petric

FIFI-LS spectra

- 5/5 QSO 2 and 4/5 QSO 1 [CII] is detected
- 3 QSO1 and 3 QSO2 have extended [CII] emission
- Fluxes between 0.8 and 7 x 10^{-17} W/m^2
- Parallel 88um observed for 6 sources, 4 have a detected line.



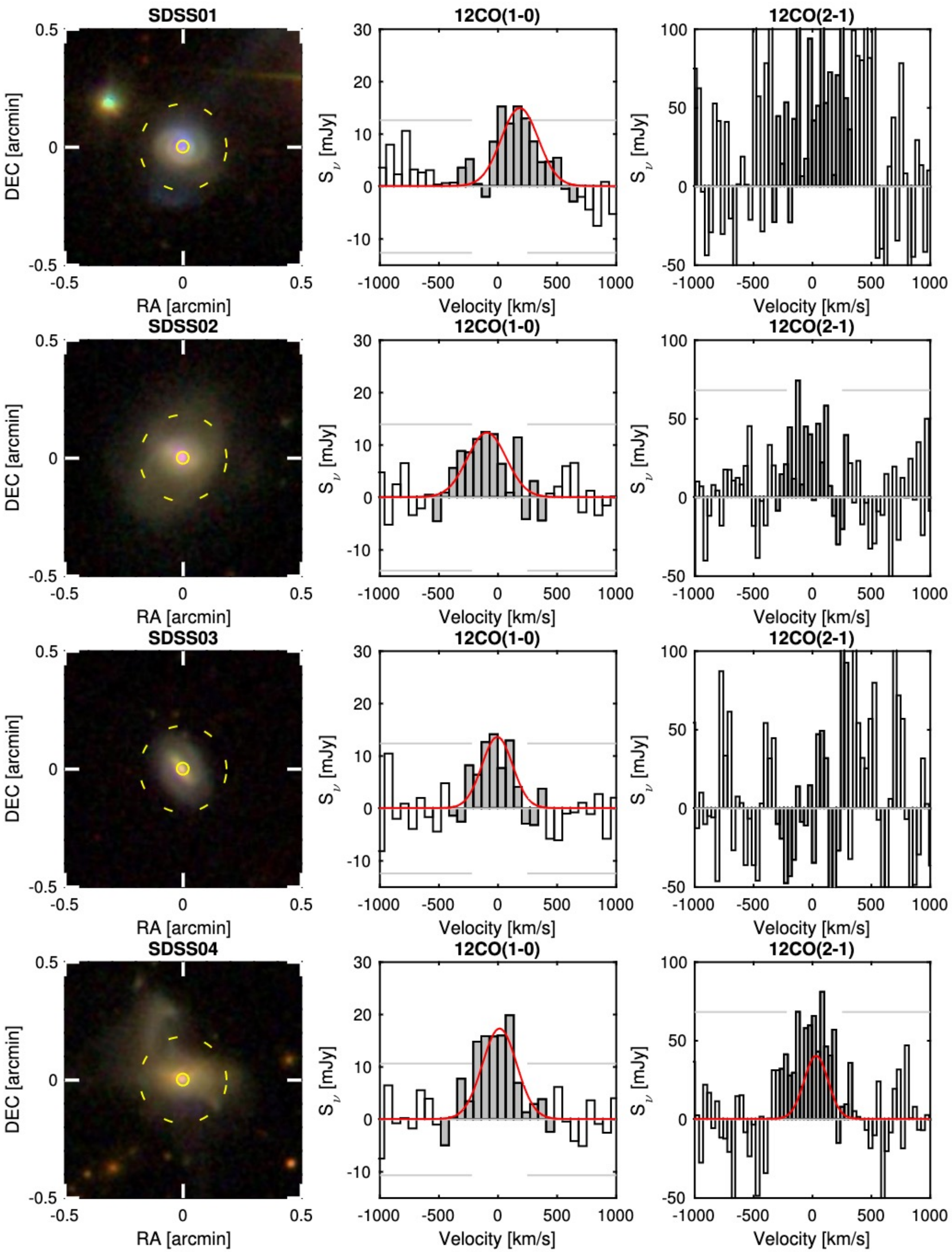
IRAM sample

- IRAM 30m on. 14–20 August 2012 and 8–10 January 2013
- 32 GHz wide available bandwidth to simultaneously observe CO(1–0) and CO(2–1) using the E090 and E230 EMIR band
- 8-minute scans comprised of twelve 30-second long sub-scans
- 20 QSO2 sources observed at CO(1-0)
- 40 QSO1 from literature

P.I.: Andreea Petric

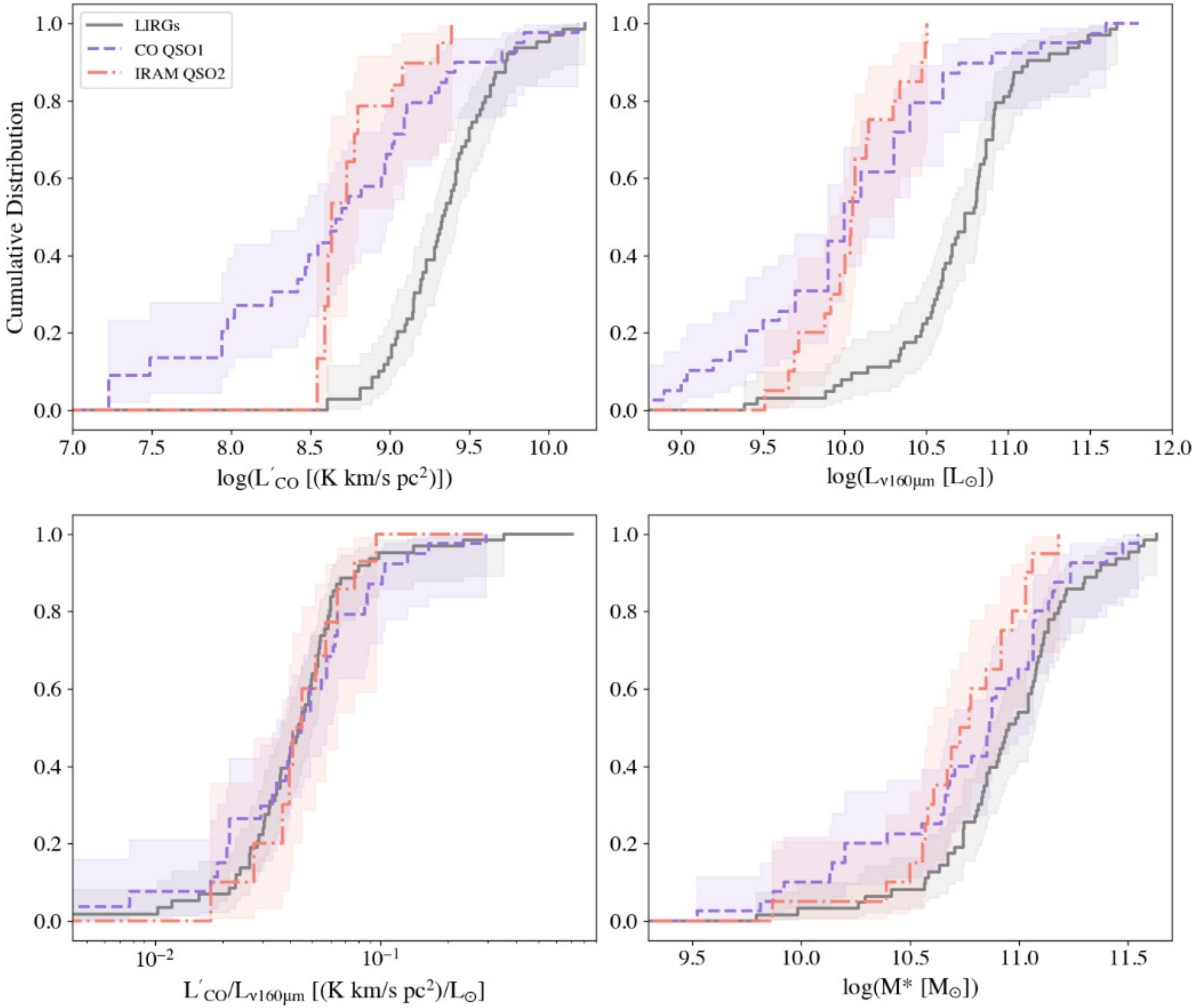
IRAM spectra

- CO(1-0) detected in 10/20 QSO 2 observed
- Fluxes between 0.4 and 1.2 K km/s
- CO(2-1) detected in 40% of 15 QSO2
- 2 sources have CO(2-1) but not CO(1-0)
- 4 sources have the two lines detected with median ratio R_{21} = 0.82



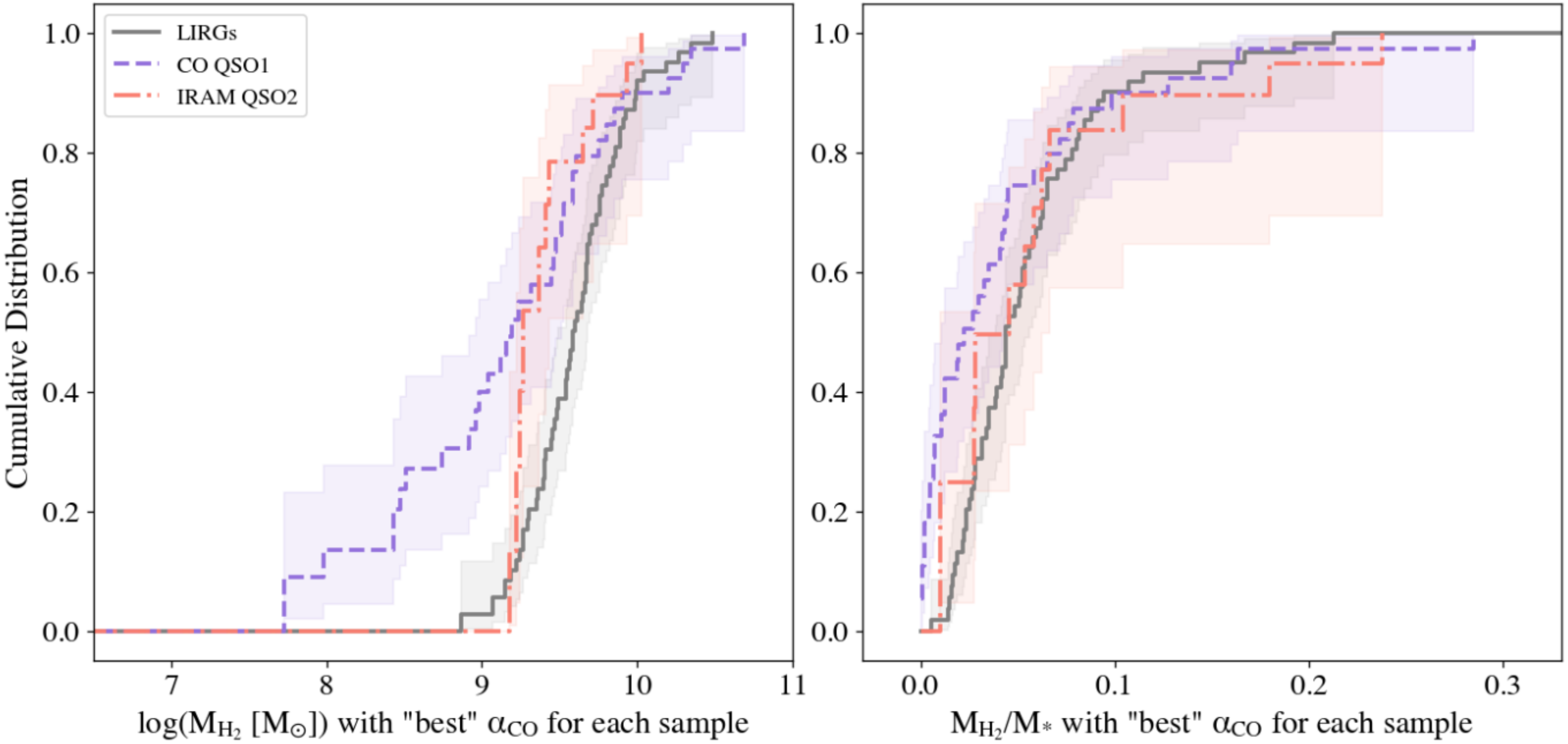
Properties

- LIRG and QSO have different CO and 160um luminosity.
- However their ratios are statistically indistinguishable, meaning that they are equally efficient in converting molecular gas into stars.
- The distribution of stellar masses is similar, although LIRG are slightly more massive.



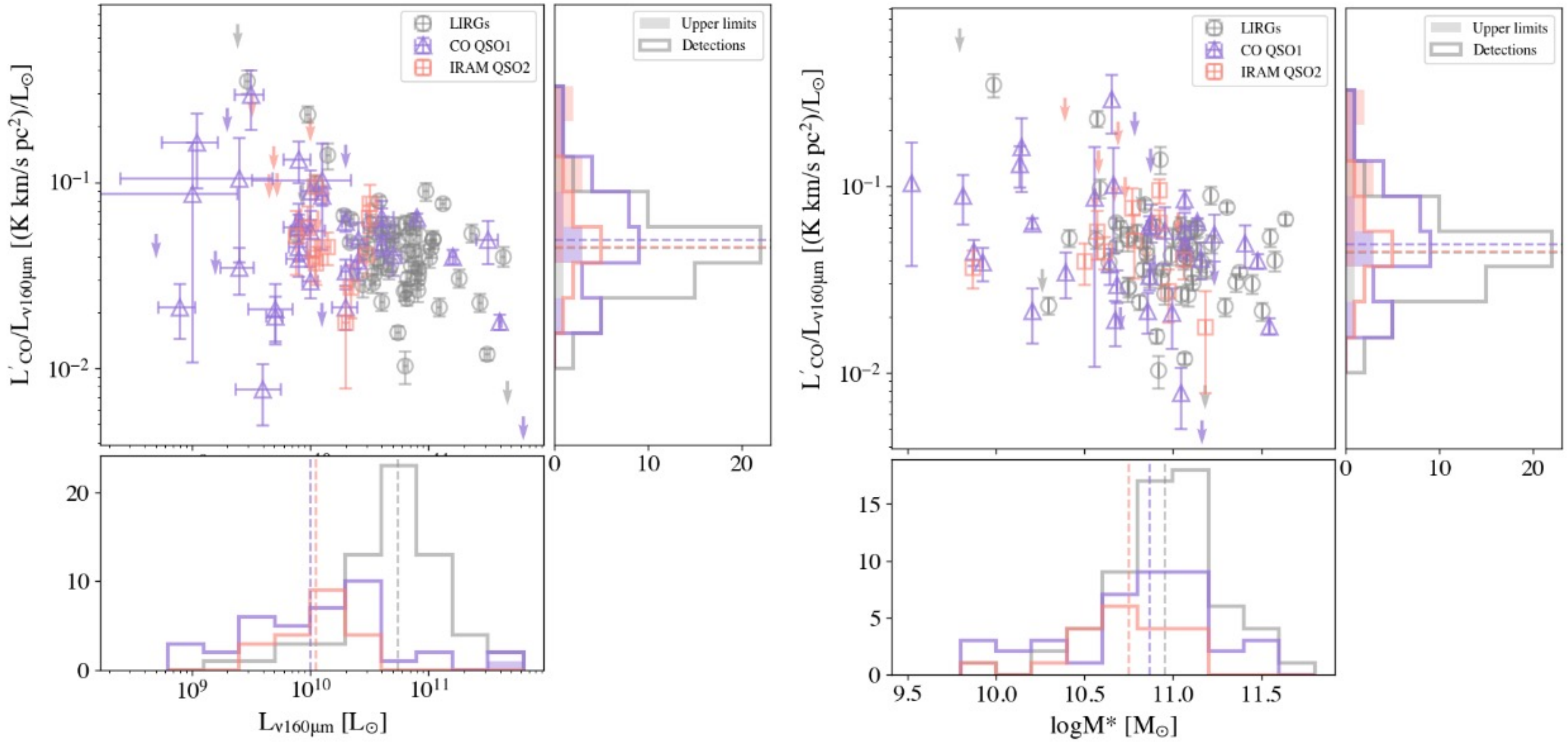
Properties: gas fraction

- QSO1 have lower M_{H_2} than QSO2 and LIRGs. QSO2 have also less H2 than LIRGs.
- QSO 1 have statistically]lower M_{H_2}/M_* ratios than QSO 2 and LIRG which are very similar.



Star formation efficiency using CO

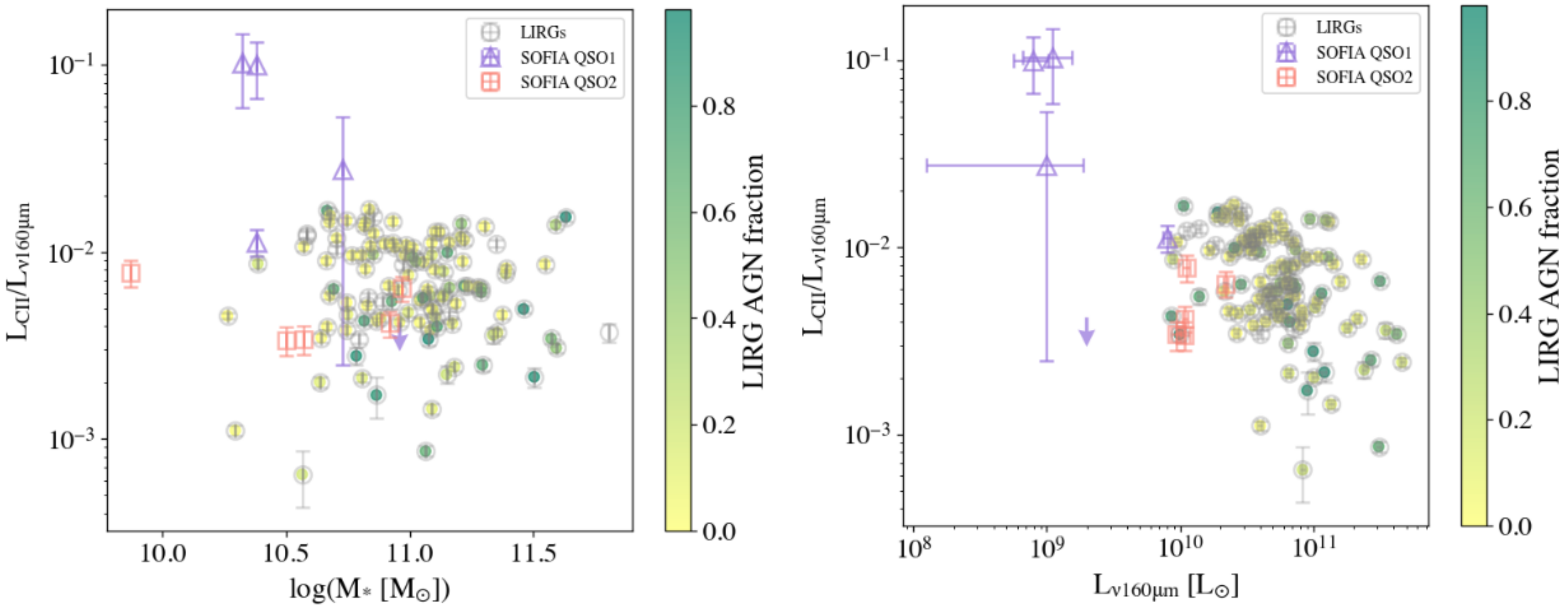
- QSO 1,2 and LIRGs have similar SF efficiencies
- QSO 1 have a larger dispersion



Star formation efficiency using [CII]

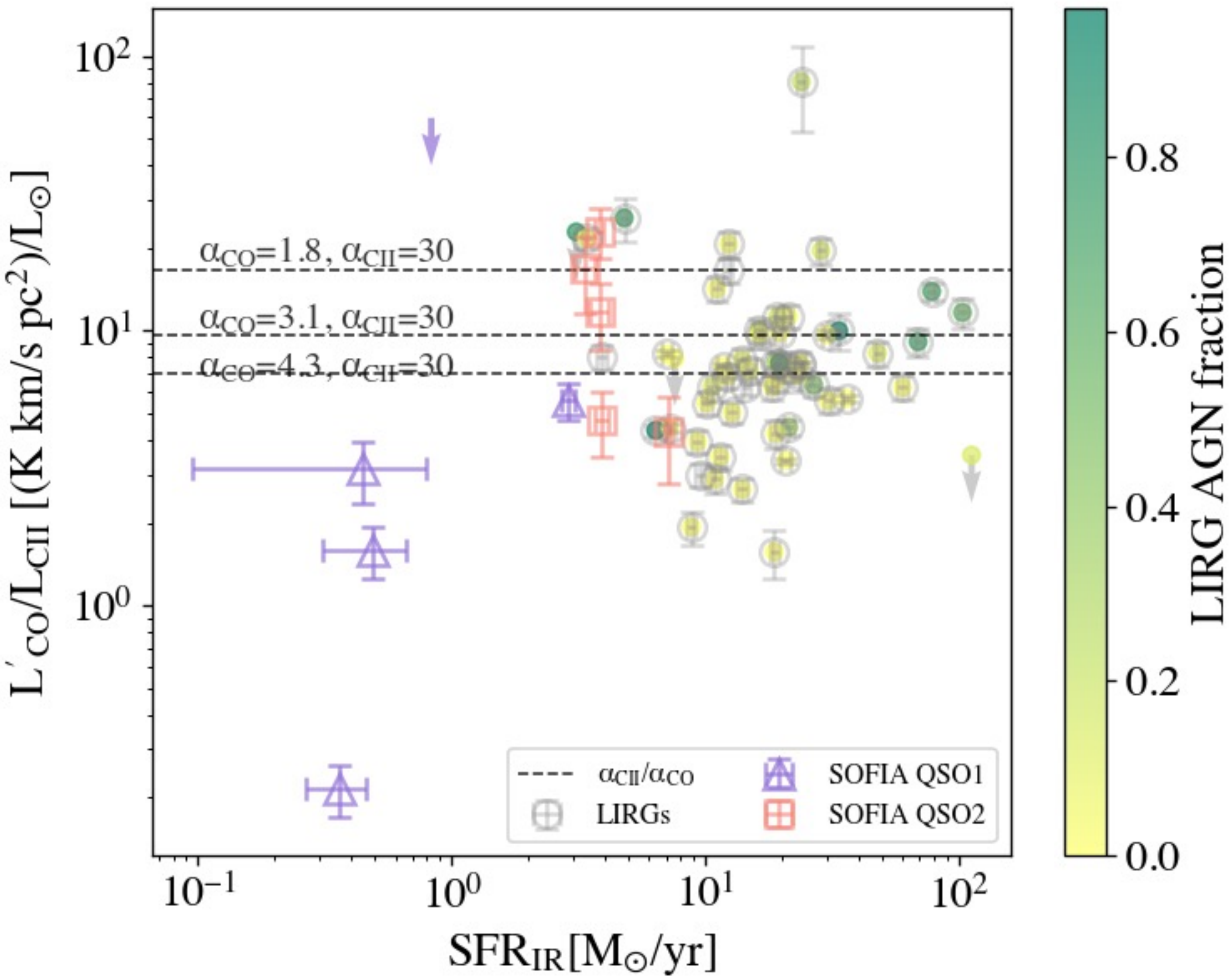
Using [CII] as molecular mass proxy, the situation is different.

The population of QSO1 observed with SOFIA seems to have a lower SFE than LIRGs and QSO2.



[CII] vs CO emission

- 3 out of 4 QSO 1 detected have a low CO/[CII] flux ratio indicating a different than molecular component of [CII] emission, probably more atomic or ionized.
- QSO2 and LIRG have similar ratios.
- All QSO have a narrow relationship between SFR and CO emission, most QSO1 show an excess of [CII] emission



Conclusions

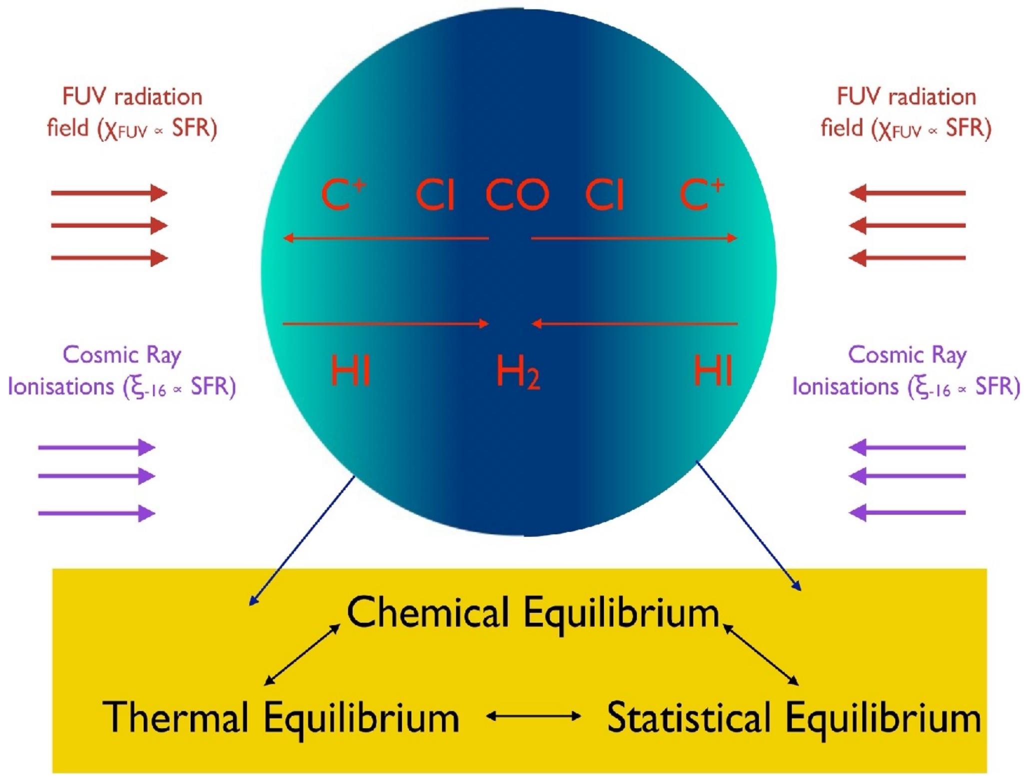
- [CII] can be boosted by shocks, but we do not observe this in the sample of QSO2 galaxies observed with SOFIA

- The extra [CII] observed in the QSO1 sample could arise from different ISM components such as neutral atomic and ionized gas or more diffuse and warm than those emitting CO.

- The evolutionary scenario is not supported by CO and [CII] data in the nearby universe. QSO2 can emerge from LIRGs since they have a similar gas content but they are unlikely precursors of QSO1s.

- Future data of spatially resolved observations are required to further investigate the evolution of QSOs.

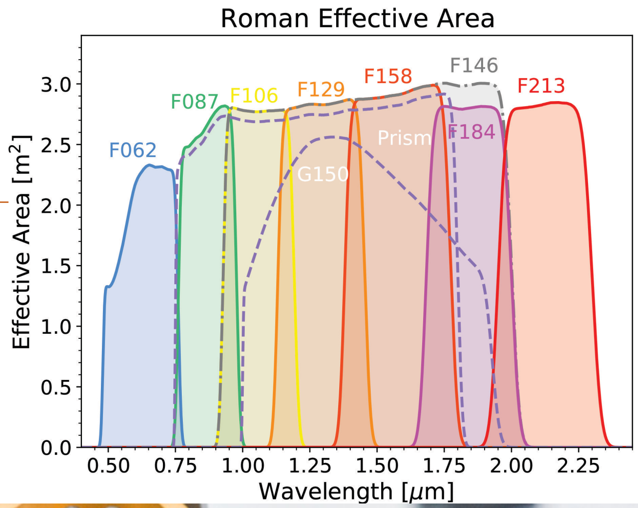
Comparison with theoretical models



Pallavi Patil (JHU)

Currently expanding the study to a sample of ~200 SOFIA and Herschel AGN observed at [CII] and comparing them with simulations to explain the impact of AGN on [CII] emission.

The Nancy Grace Roman telescope

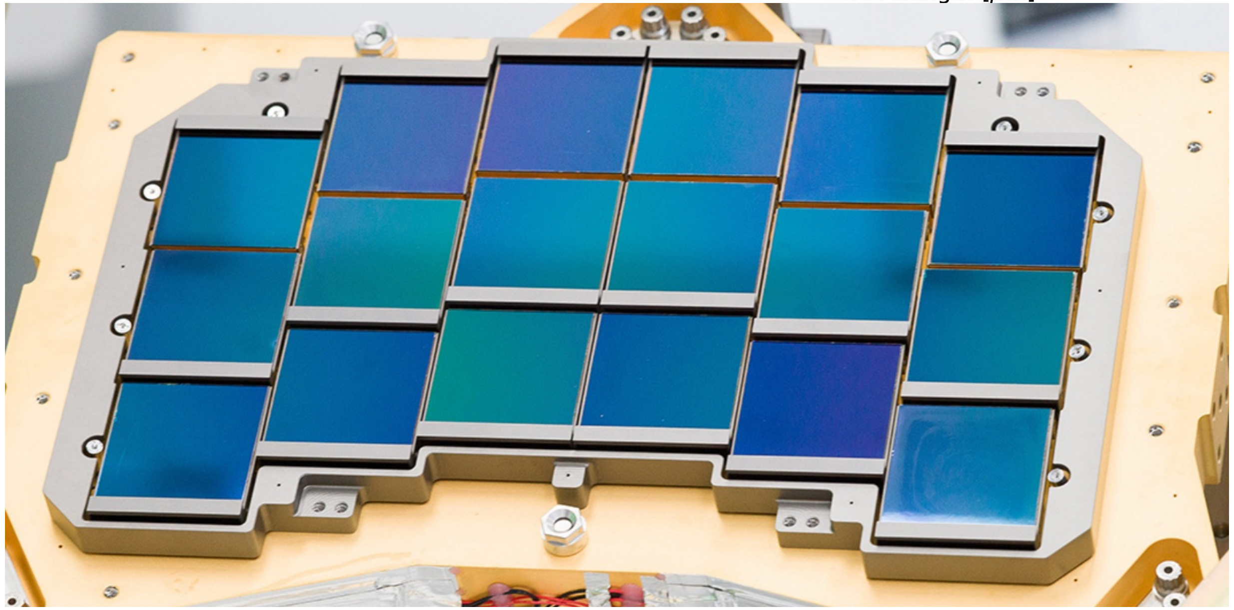


Telescope: *primary mirror 2.4 m diameter*

Optics: 3 mirror anastigmat, to reduce spherical aberration, coma, and anastigmatism on a sq deg field of view.

Launch date: October 26 – May 27, Falcon Heavy

Orbit: L2



WFI: 18 5K x 5K detectors for a total field of view of 0.4 sq degs, pixel of 0.11". Slitless spectroscopy is available. 1000x faster than HST for surveys.

CGI for Technology Demonstration with Community Participation. Several dozen known planetary systems and disks will be observed. Some planets may be targeted for full spectral resolution observations to enable planet characterization.

Roman's community core surveys

High Latitude Wide Area Survey: 2,000 square degrees of the sky with imaging (Y,J,H,F184 down to J=26.7) and low-resolution (grism) spectroscopy (15 million sources z=1.1-2.8) in 2 years. Studies of dark energy and cosmic lensing, high redshift galaxies, galactic halo substructure in nearby galaxies.

High Latitude Time Domain Survey: 0.6 years. Three tiers of imaging: shallow (~27 square degrees), medium (~9 square degrees), and deep (~5 square degrees). Observations would be repeated with a cadence of 5 days in filters Y/J-band for the shallow tier, and J/H-band for the medium and deep tiers. Designed for light-curve characterization of supernovae of redshifts up to 1.7.

Galactic Bulge Time Domain Survey: Observe multiple fields in the Milky Way's bulge for 1 year with high cadence (every ~15 minutes) over six contiguous 72-day seasons. It will create highly sampled light curves of 56 million stars brighter than H = 21.6 (AB) and will discovery over 2000 bound planets in the range 0.1–1,000 Earth masses and orbital major axes from 0.03 to 30 AU through their microlensing signature, and to detect about 20,000 giant planets in short-period orbits from their transit signature.

Galactic Plane Survey: 991 sq degs in 3 filters (F106, F158, F213) spanning latitudes $|b| < 3$ over the longitude range $|l| < 60$ with additional latitude coverage up to $|b| < 10$ in the bulge ($|l| < 10$).