Environmental Dependence of [CII] Emission in Ringed Galaxy NGC 7331

Sutter & Fadda, ApJ, 926:82 2022

Why study [CII]?

- Often the brightest observed emission line
- Detectable at high-*z* by ALMA
- Important PDR cooling line
- Potential SFR tracer, ISM Diagnostic

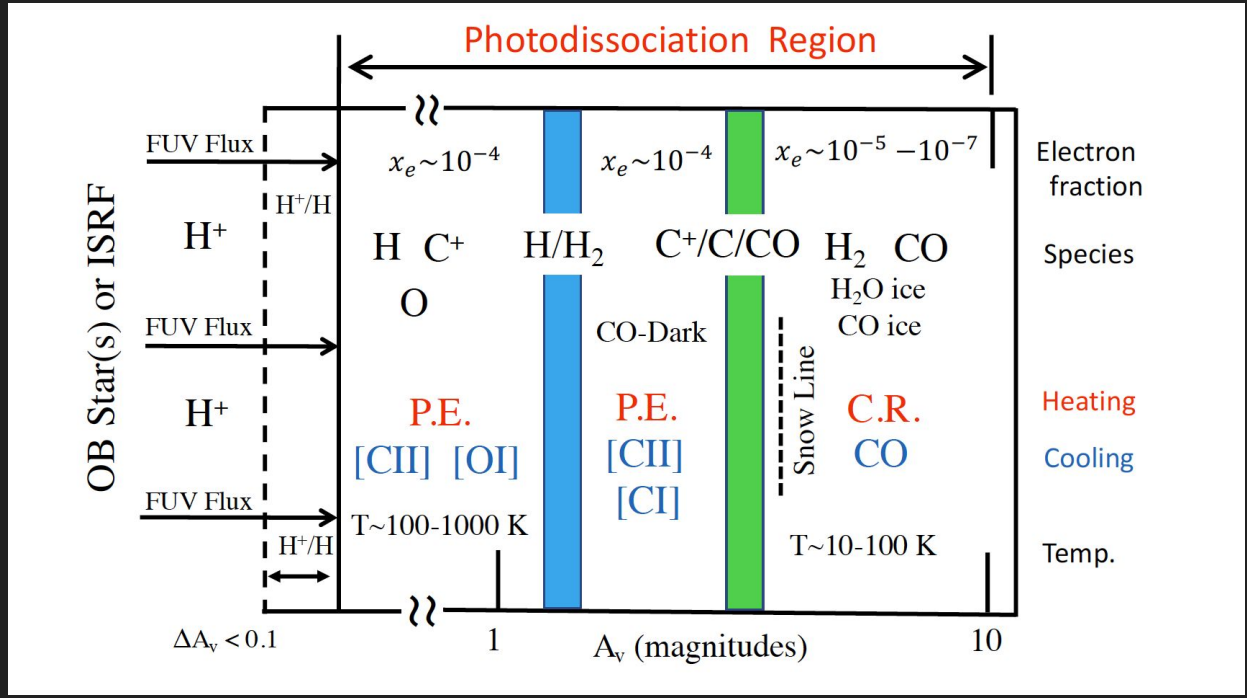


Image Credit: Wolfire, Vallini, & Chevance 2022

Unanswered questions surrounding [CII]

- Multiphase origins complicates [CII] observations
- [CII] deficit is observed in a variety of sources
  - Problematic for future use of [CII] as a SFR indicator, especially in high-z galaxies

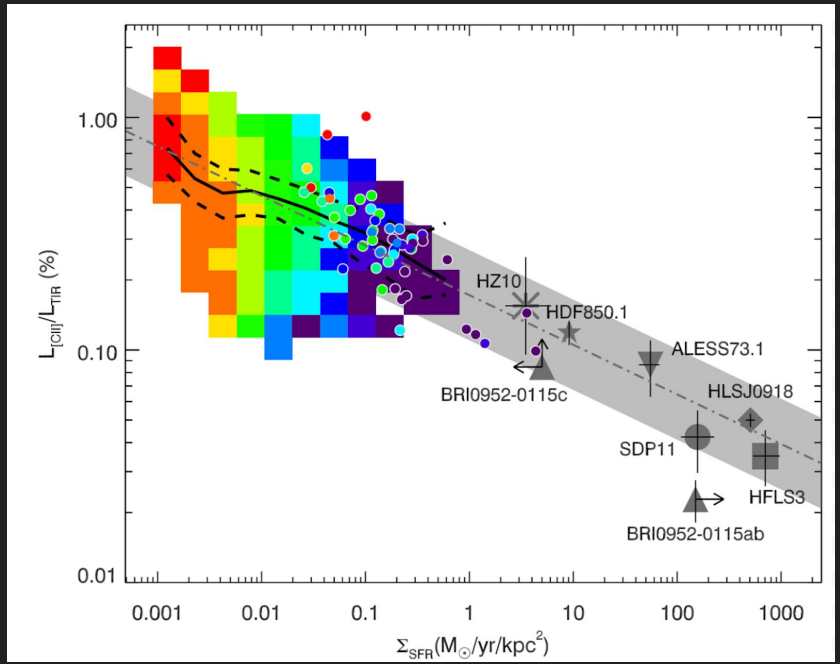


Image Credit: Smith+2017

Why NGC 7331?

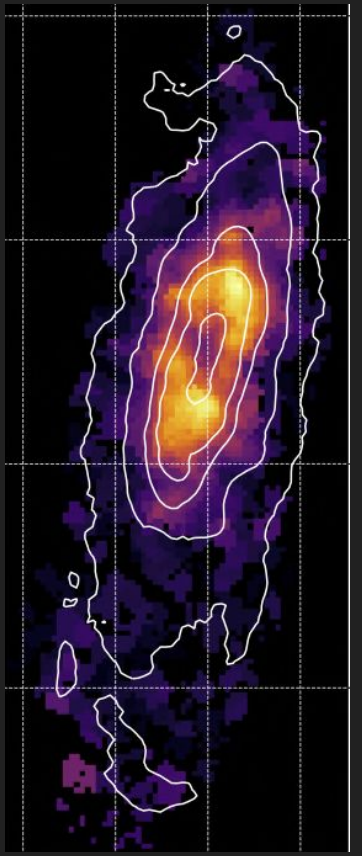
- Nearby (D ~ 14 Mpc), highly-inclined (*i* ~ 72°) galaxy
- Milky Way analog
- Molecular ring
- Wide range of archival data

New FIFI-LS [CII] Map

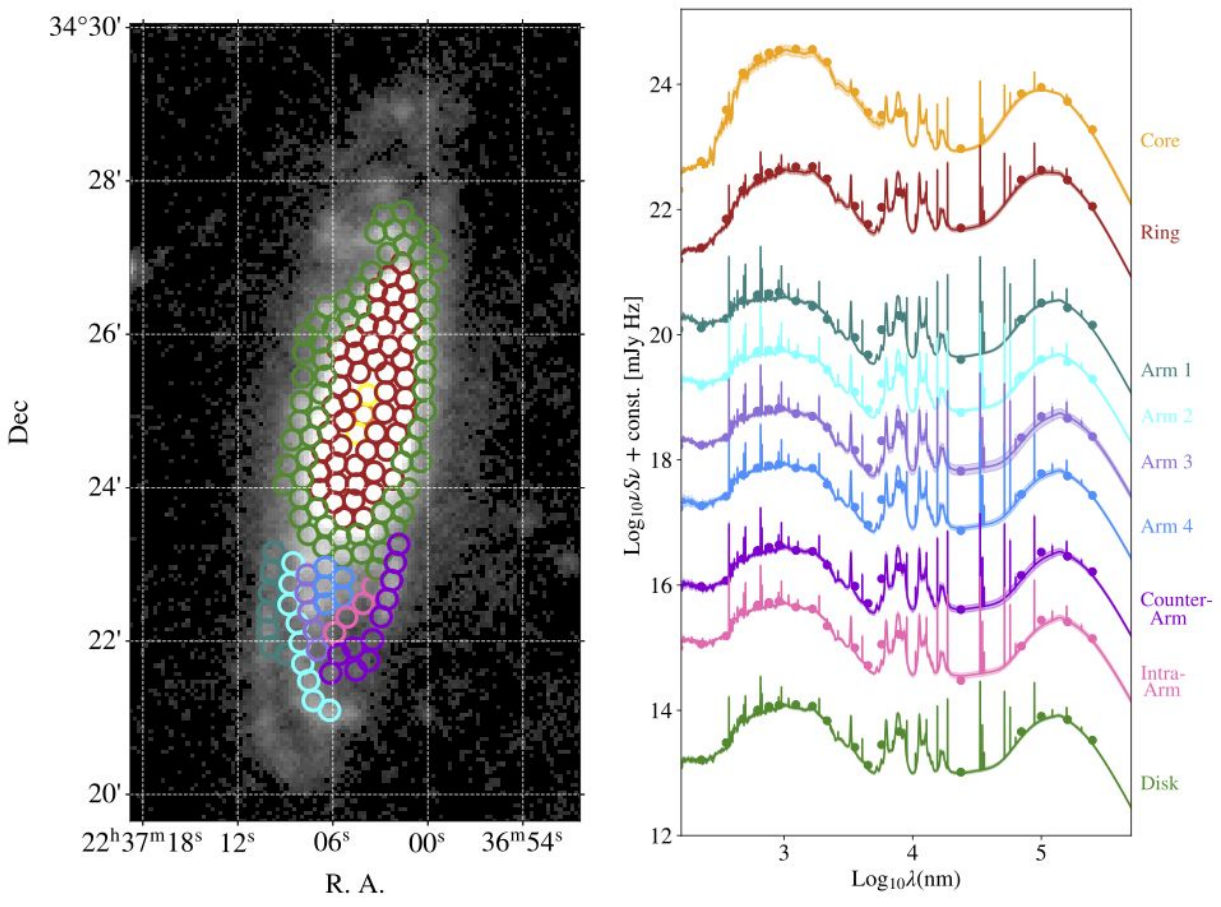
- Obtained during Cycle 7
- 13 AORs, covering much of the disk
- Molecular ring is clearly visible

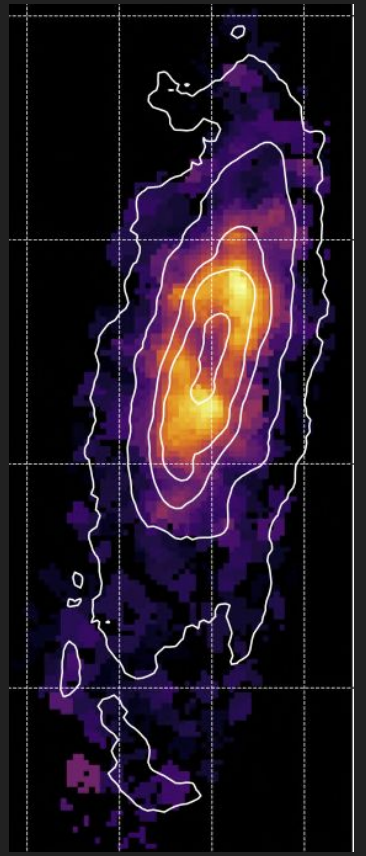
Optical
(SDSS)

Infrared
Spitzer
3.6 μm



FIFI-LS
[CII] 158

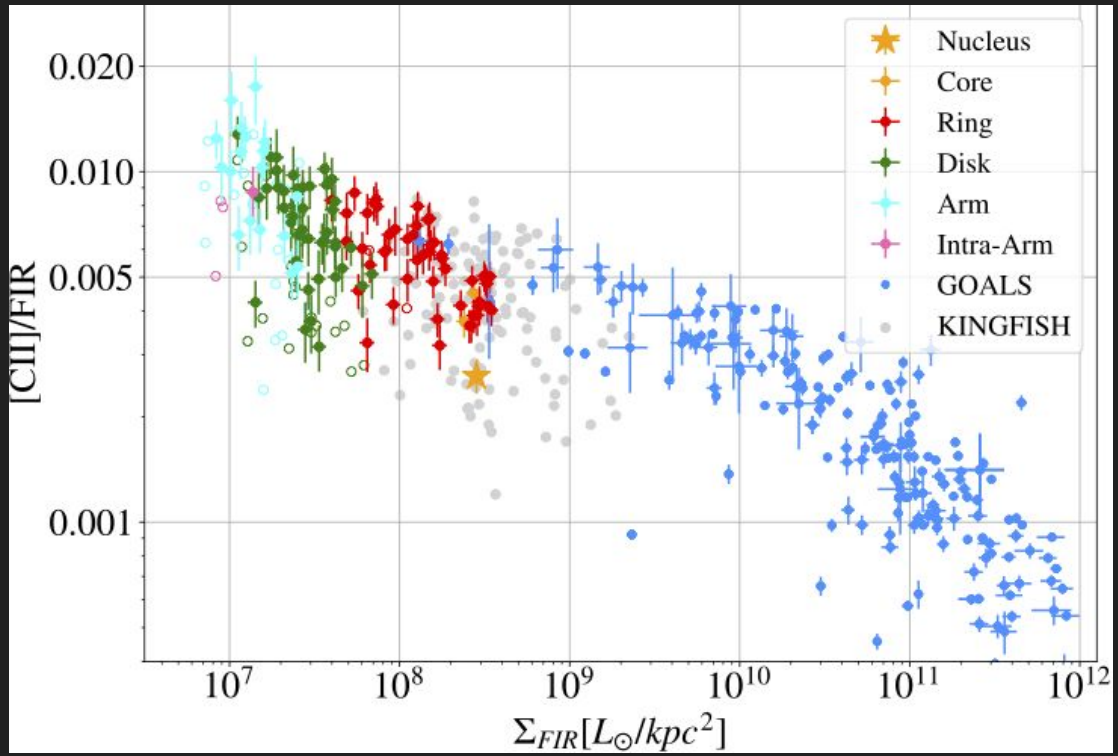




FIFI-LS
[CII] 158

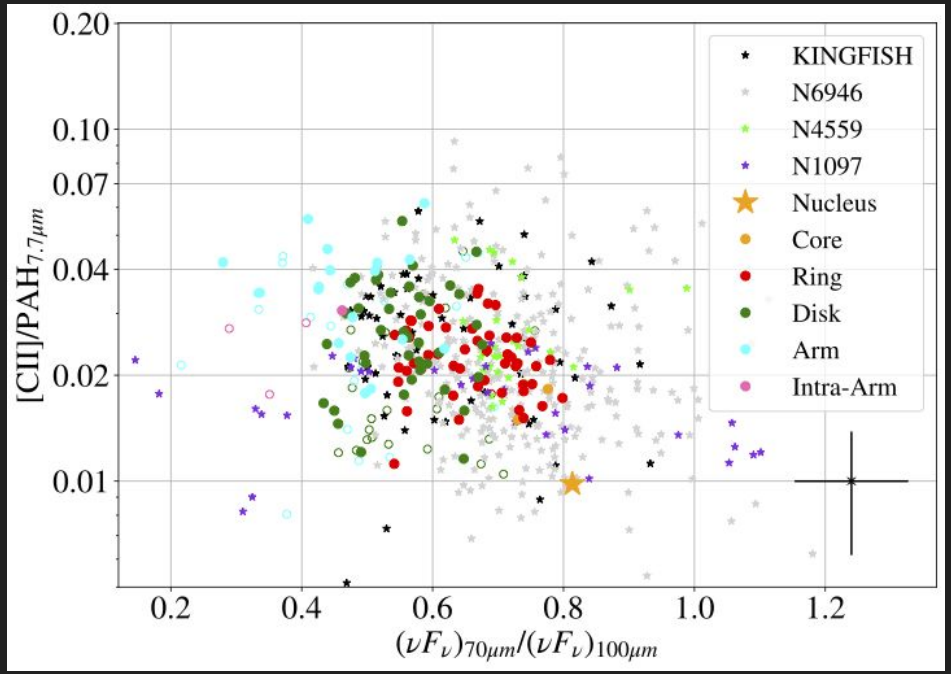
Local extension of the [CII] deficit

- [CII] deficit is a frequently cited issue with using [CII] as SFR indicator
- Adding data from NGC 7331 to plots of [CII]/FIR shows clear extension from ULIRGS to NGC 7331's quiescent disk



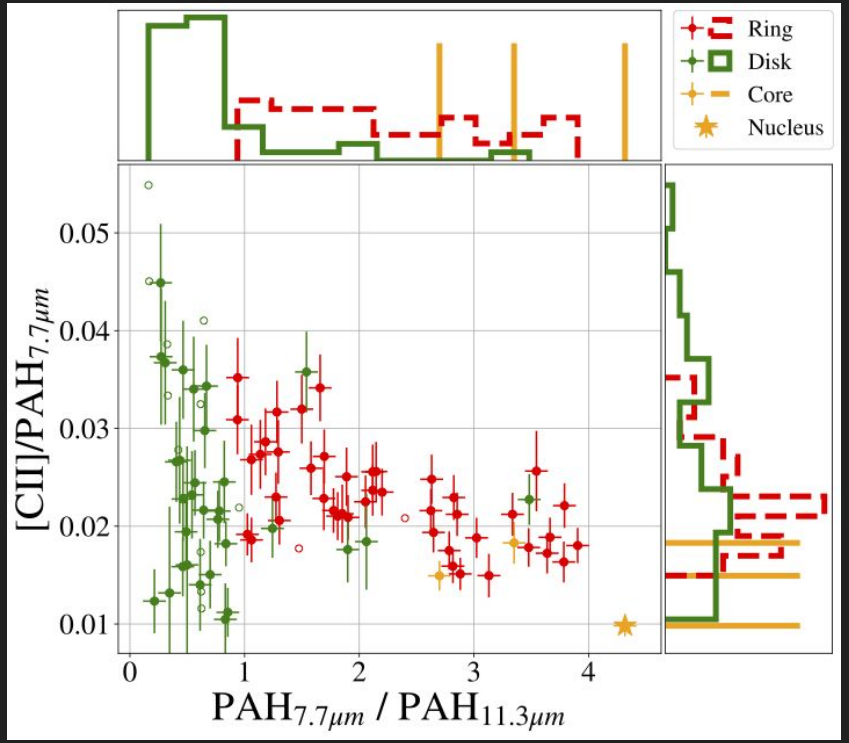
[CII] and PAH emissions

- Potential measurement of photoelectric heating efficiency
- PAH measured by subtracting SED modelled stellar continuum from IRAC 8.0 micron photometry
- See slight deficit, but less than observed in [CII]/FIR



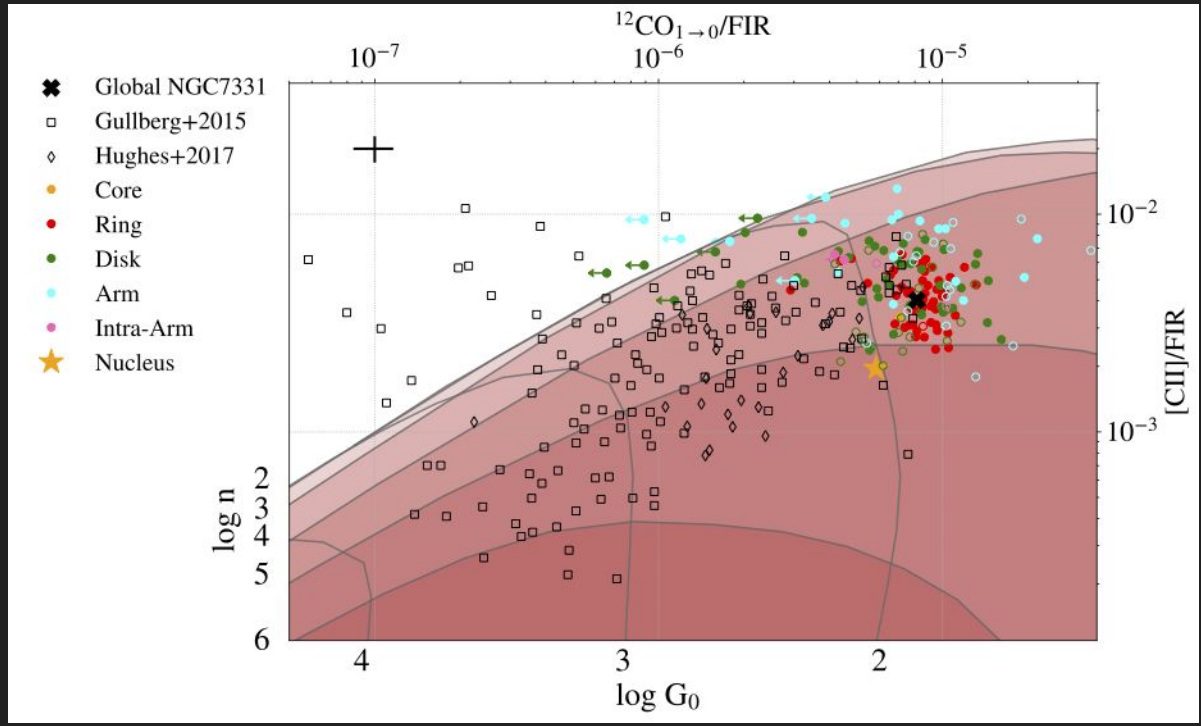
[CII] and PAH emissions

- Also compare to PAH charge
- 7.7/11.3 micron feature ratio is considered an indicator of grain charge
- Increased grain charge shows slight decrease trend in [CII]/PAH
- Clear differences in environments



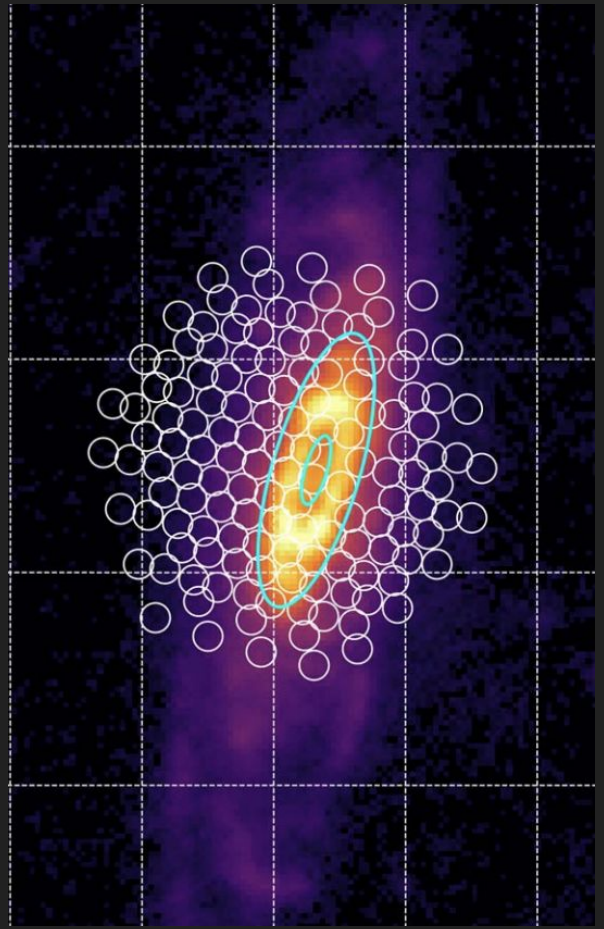
Comparisons to CO

- Use HERACLES CO map to compare [CII] and CO
- See areas with [CII] emission but no CO emission
  - Potentially CO-dark molecular gas?



Origin of the [CII] Emission

- Use archival [NII] 205 data to determine the fraction of [CII] emission from neutral ISM
- Azimuthal and radial dependencies suggest environmental differences in [CII] origin location



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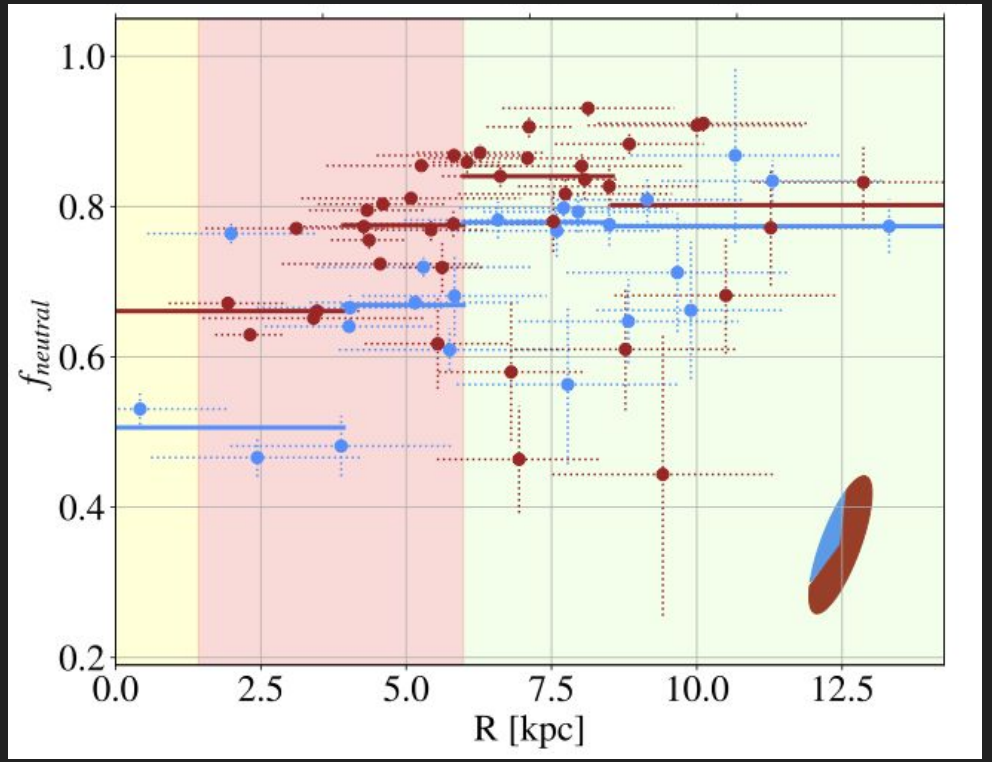

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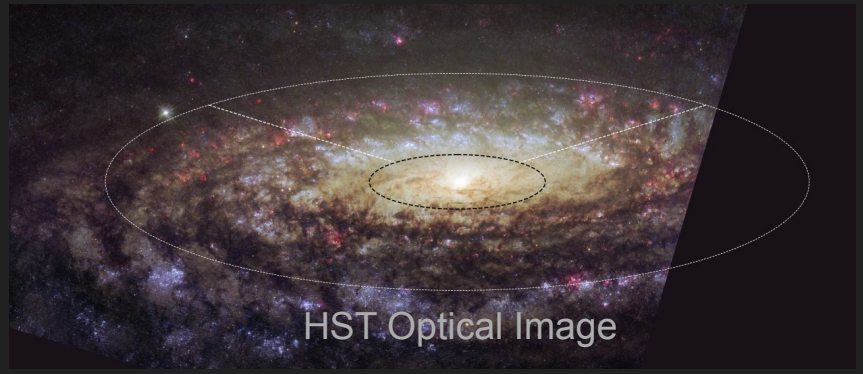

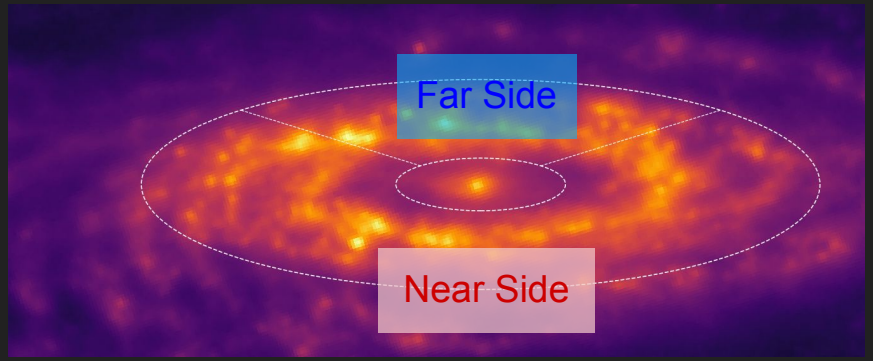

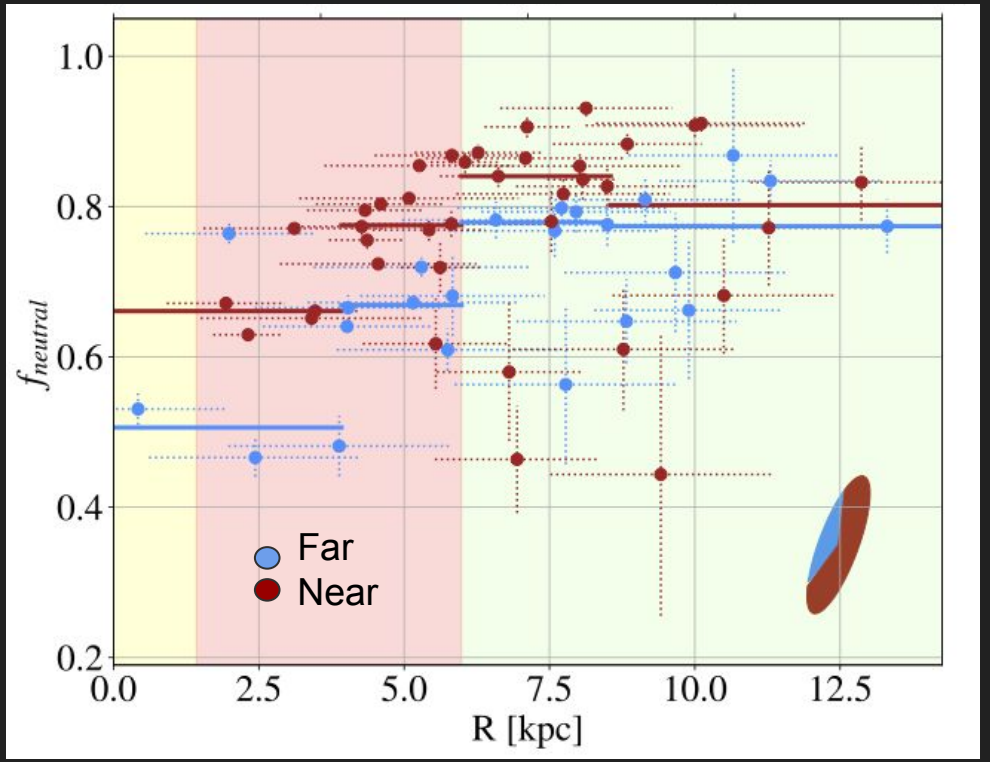

Conclusions and future work

- The origin of the [CII] emission in NGC 7331 varies both radially and azimuthally
- The [CII] deficit trend extends from the global measurements from the GOALS U/LIRGS to local measurements
- We plan to extend this work through comparisons to archival [CII] maps from PACS and FIFI-LS

NGC 4736, Image Credit: R. Jay GaBany

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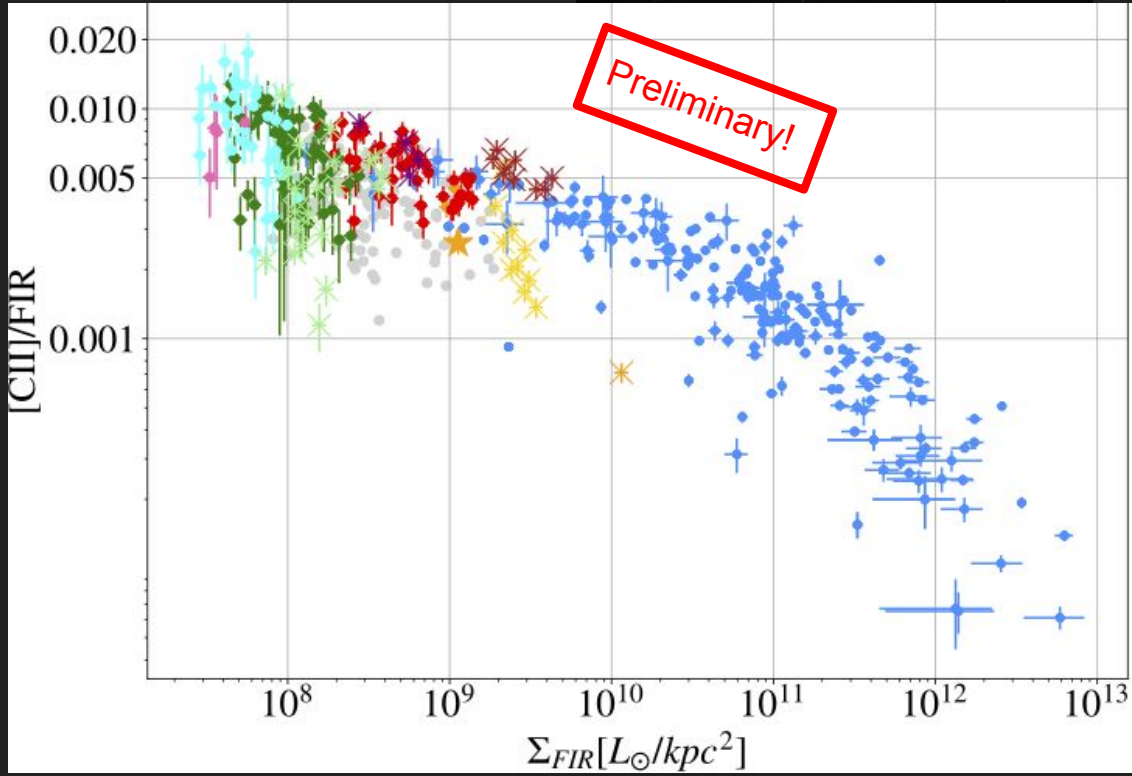
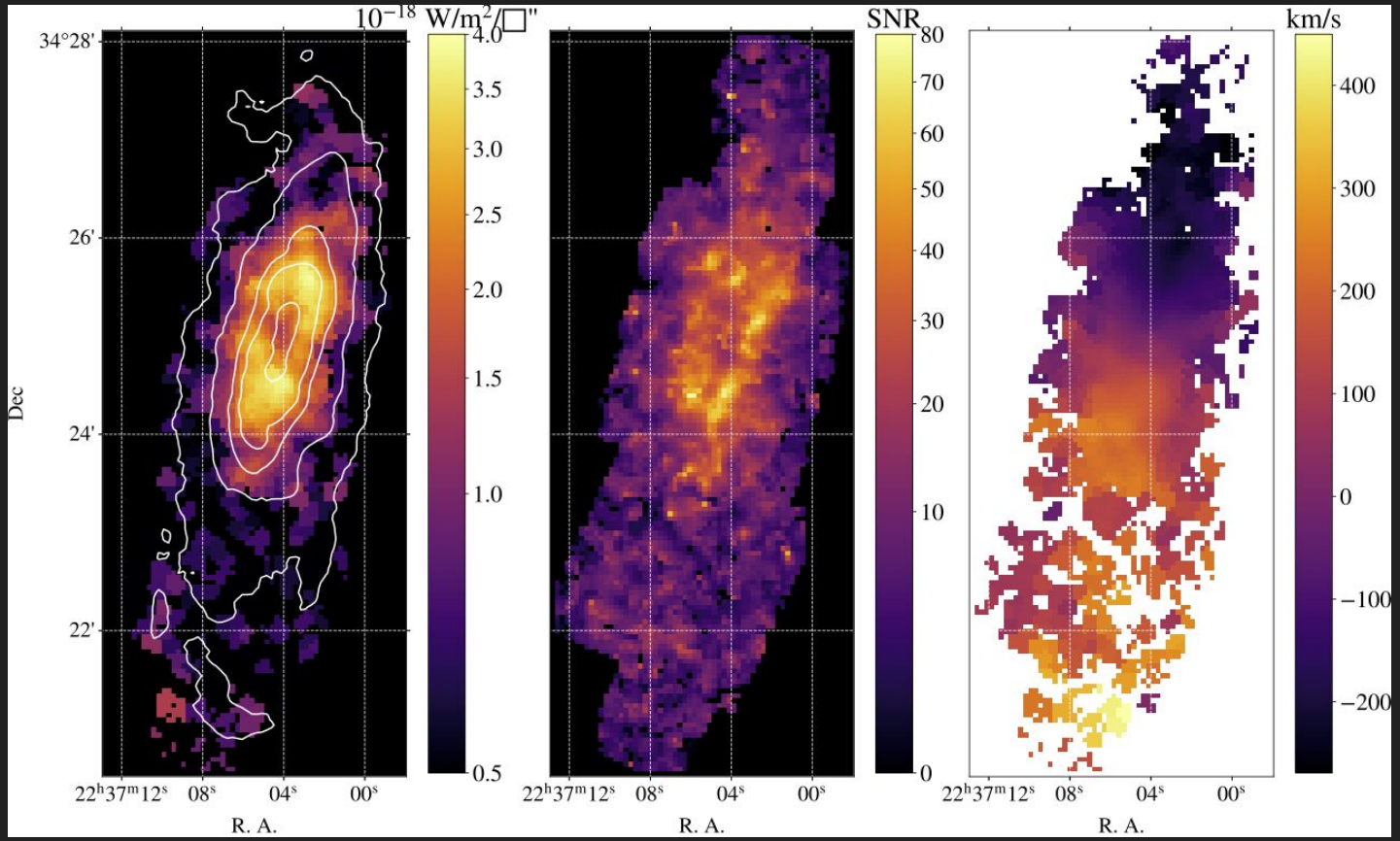
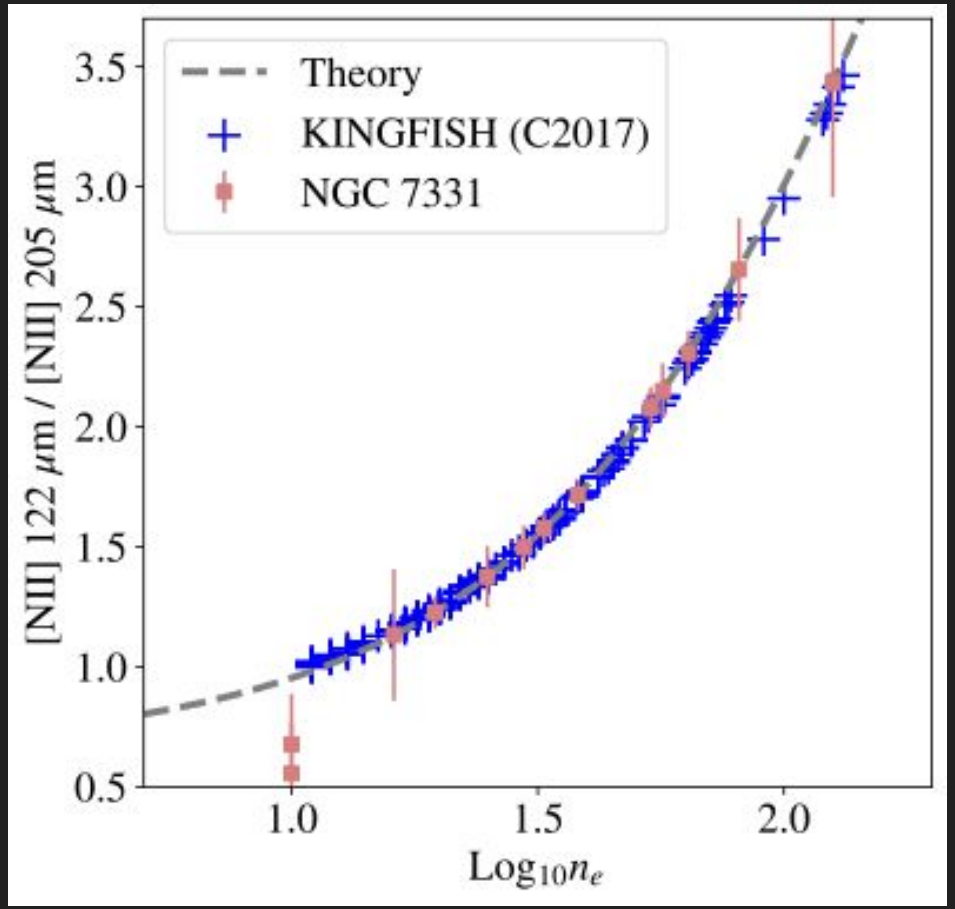
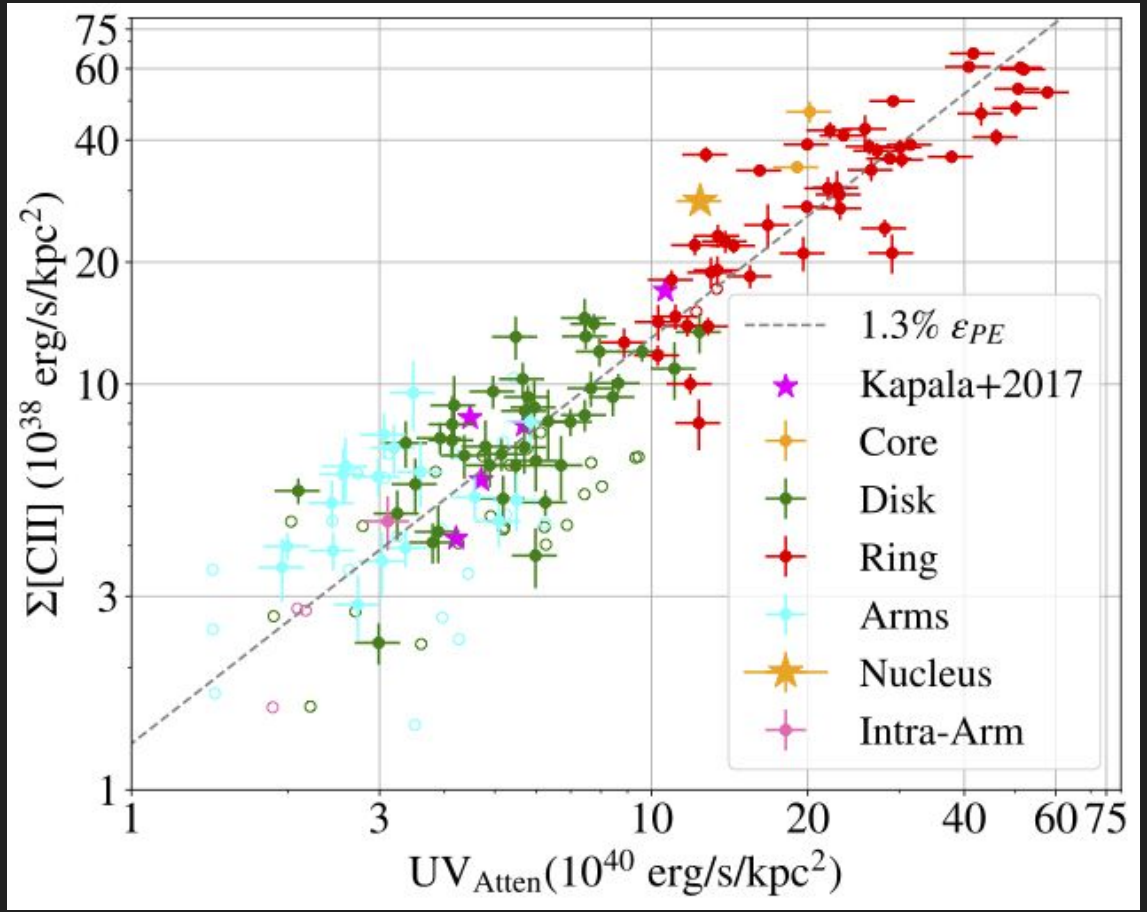


ADDITIONAL SLIDES

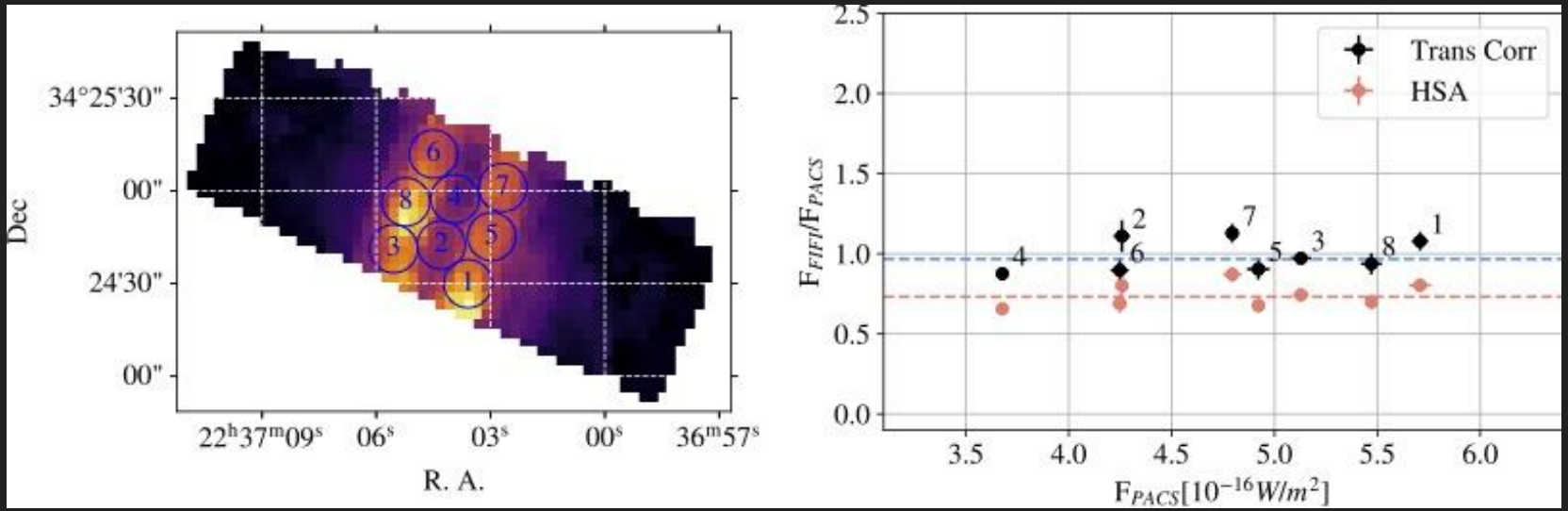

10^{-18} W/m^2/□"
34°28'
26'
24'
22'
Dec
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
22^{h}37^{m}12^s
08^s
04^s
00^s
R. A.
SNR
80
70
60
50
40
30
20
10
0
km/s
400
300
200
100
0
−100
−200

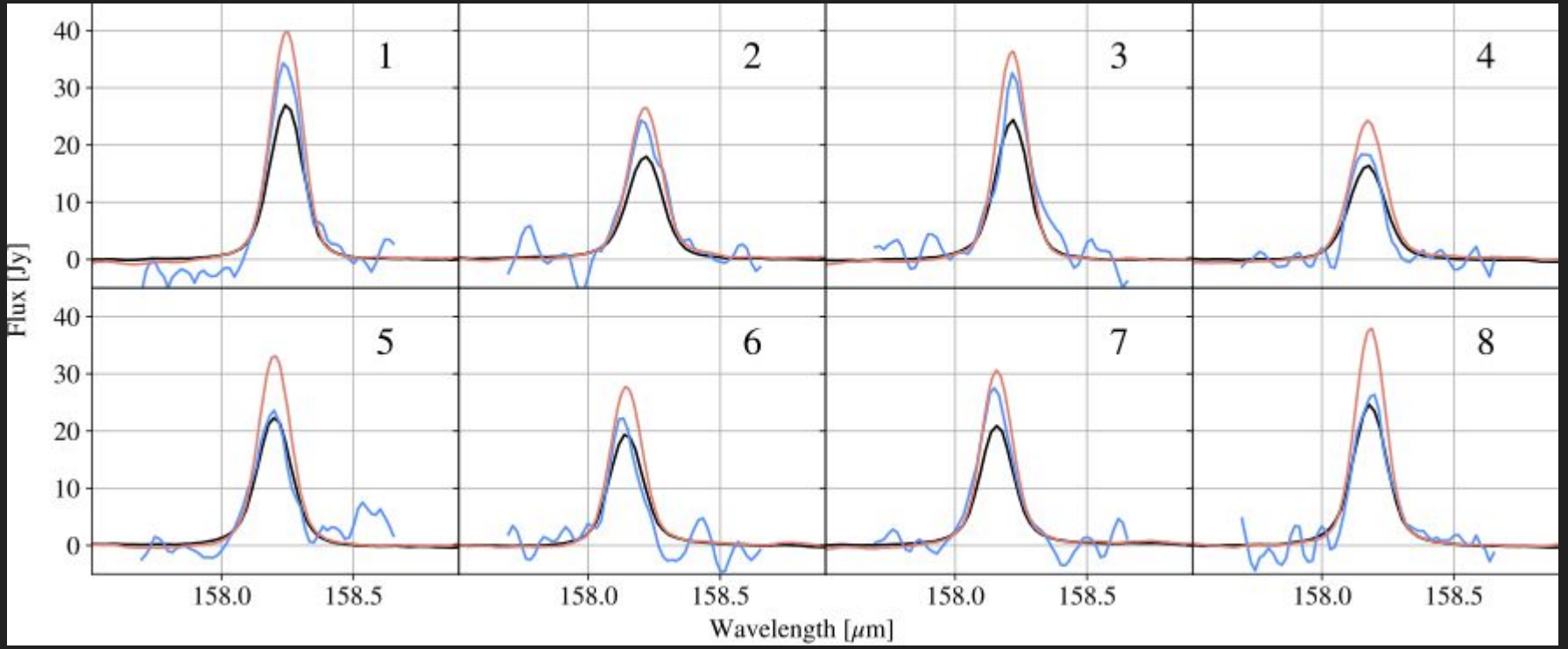

Theory
KINGFISH (C2017)
NGC 7331
[NII] 122 μm / [NII] 205 μm
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1.0
1.5
2.0
Log10ne


75
60
40
20
10
3
1
1
3
10
20
40
60
75
Σ[CII] (10^{38} erg/s/kpc^2)
UV$_{\rm Atten}$(10^{40} erg/s/kpc^2)
1.3% ε_{PE}
Kapala+2017
Core
Disk
Ring
Arms
Nucleus
Intra-Arm

Comparison with PACS data

- A strip of NGC 7331 has been previously observed by PACS




1
2
3
4
5
6
7
8
40
30
20
10
0
Flux [Jy]
158.0
158.5
Wavelength [μm]