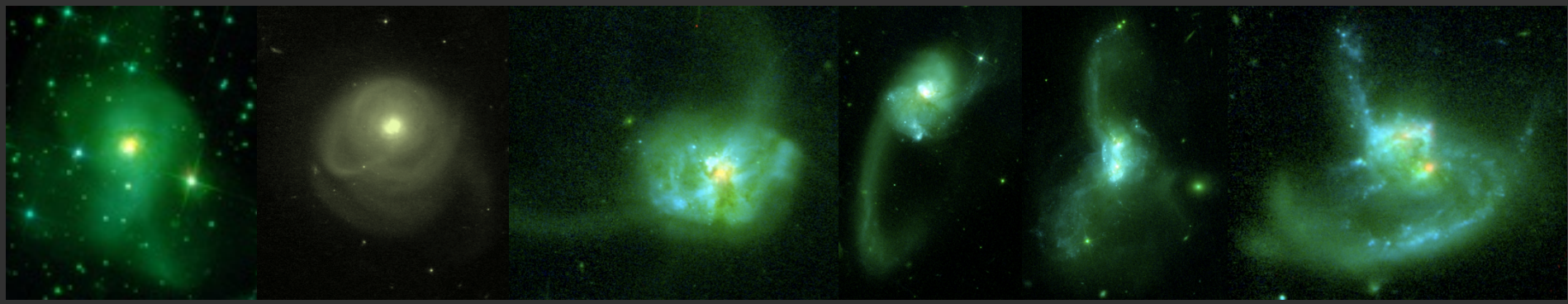
ALMA observation of ^{12}CO/^{13}CO(3-2) molecular gas in merging ULIRGs



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Galaxy Merger

Galaxy Interaction

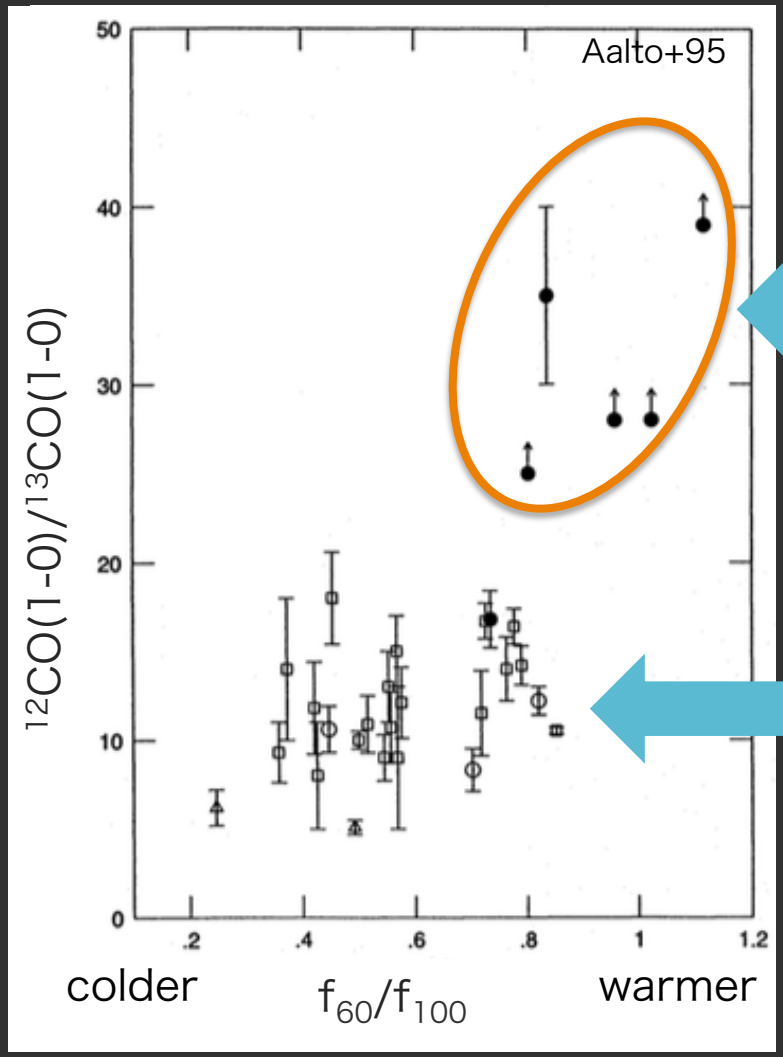
↓

Change
- ✓ morphology
- ✓ physics
- ✓ chemistry

→ Galaxy merger is key to understand galaxy evolution

Global $^{12}CO/^{13}CO$ line ratio

The global $^{12}CO/^{13}CO$ ratio is know to be higher in luminous merging galaxies



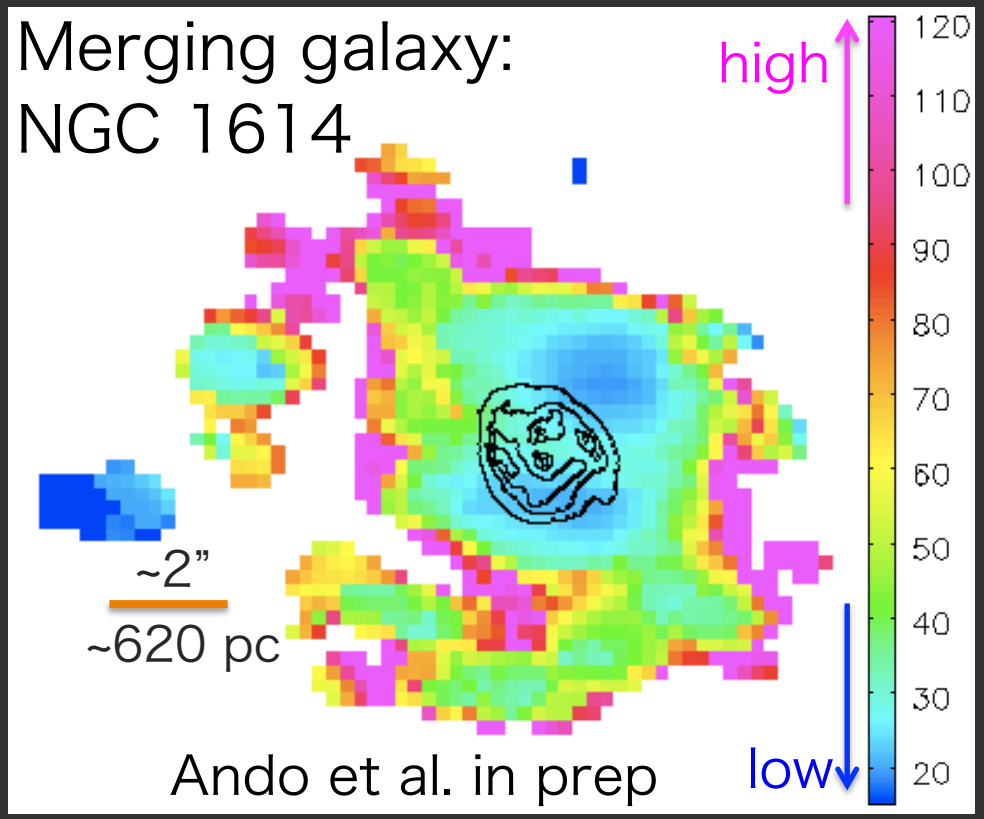
~ 30:
luminous merging galaxies

~ 10: normal spirals

Exact reason unknown
ALMA can offer a clue

Case study: NGC 1614

ALMA observation of $^{12}CO/^{13}CO$ line ratio



Contrary to expectations, the $^{12}CO/^{13}CO$ ratio is low at the central region

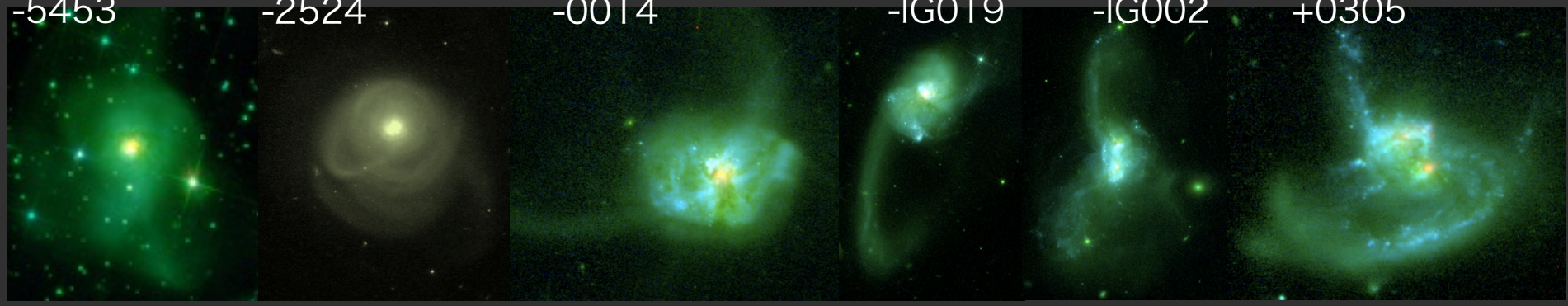
Possibly due to gas inflow to the central star forming region

Next step is to increase the sample

Target Sources & Observations

Sample

Six mergers of the brightest ULIRGs ($L_{IR} > 10^{12}\ L_{\odot}$) in the local universe

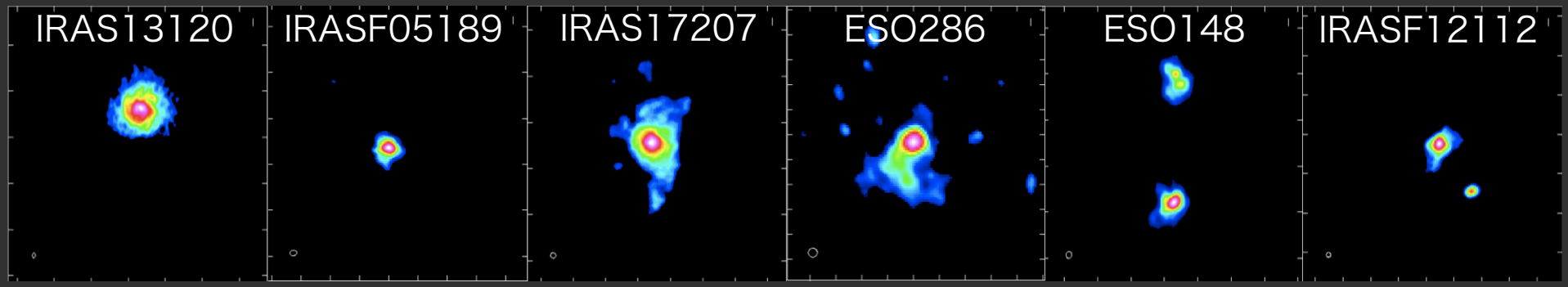


- ✓ ALMA cycle 3-4
- ✓ Band 7
- ✓ Spatial resolution: ~ 200pc

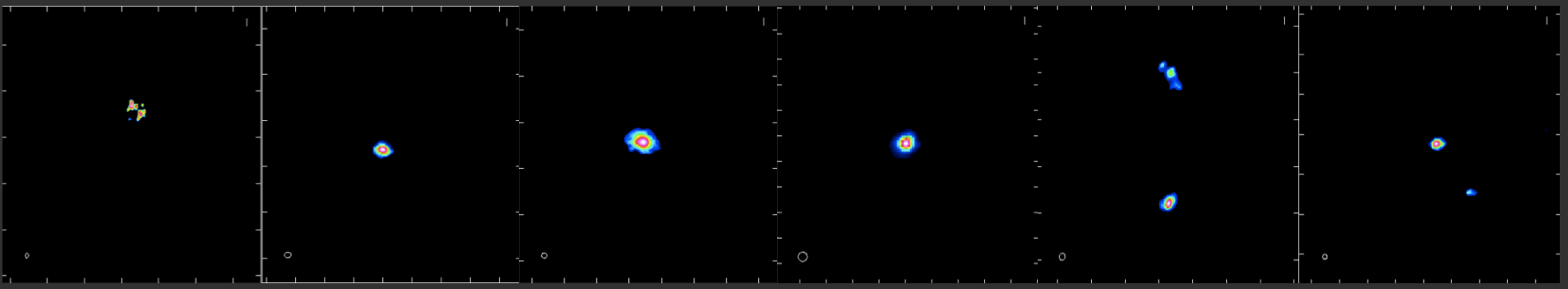
^{12}CO(3-2), ^{13}CO(3-2) and dust continuum

^{12}CO(3-2) & ^{13}CO(3-2) Intensity maps

^{12}CO(3-2)

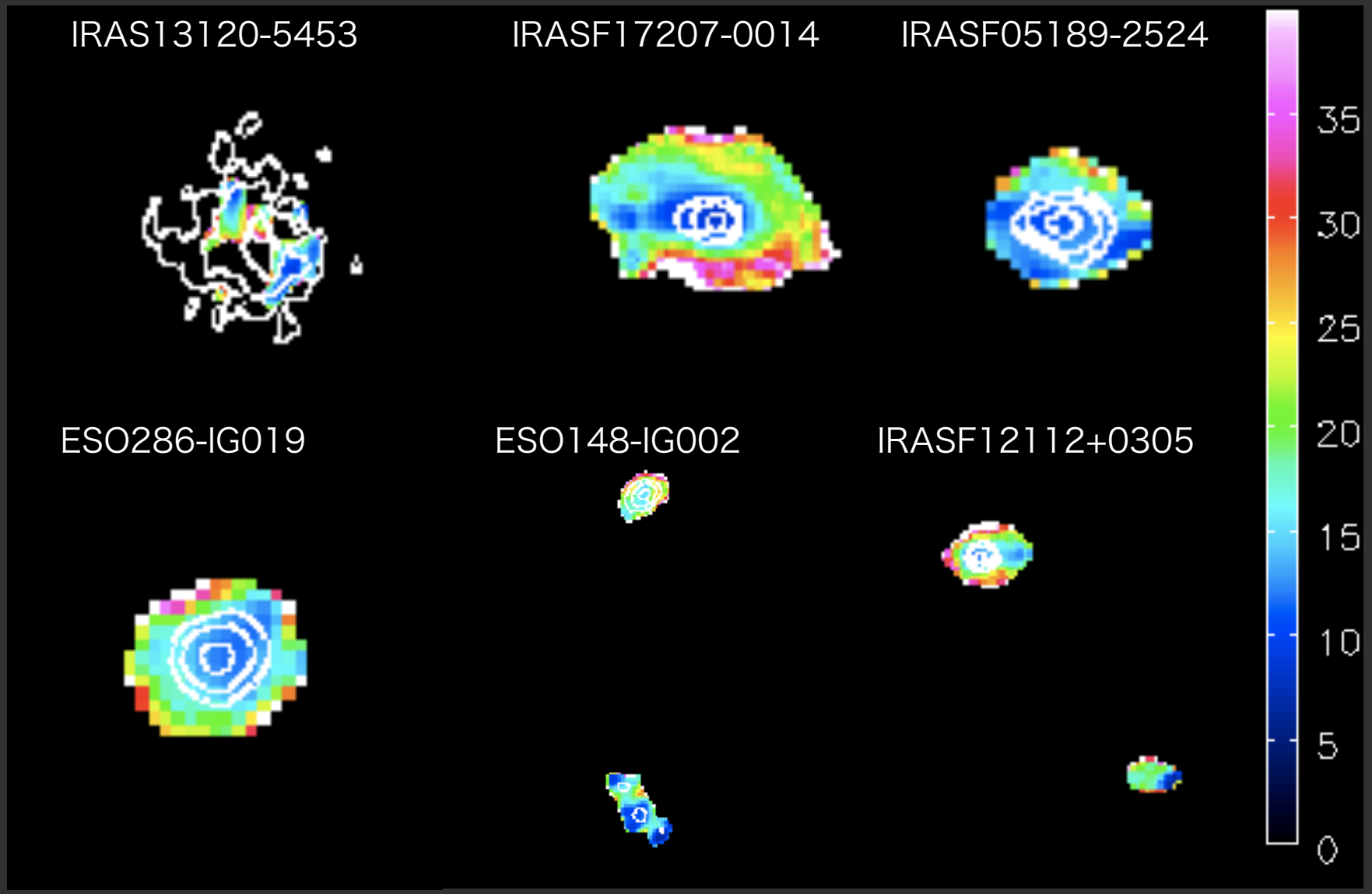


^{13}CO(3-2)



- ^{12}CO is much more extended than ^{13}CO

Spatially resolved $^{12}CO/^{13}CO(3\text{-}2)$ ratio map



Contour
- 320GHz dust continuum
- Star formation tracer

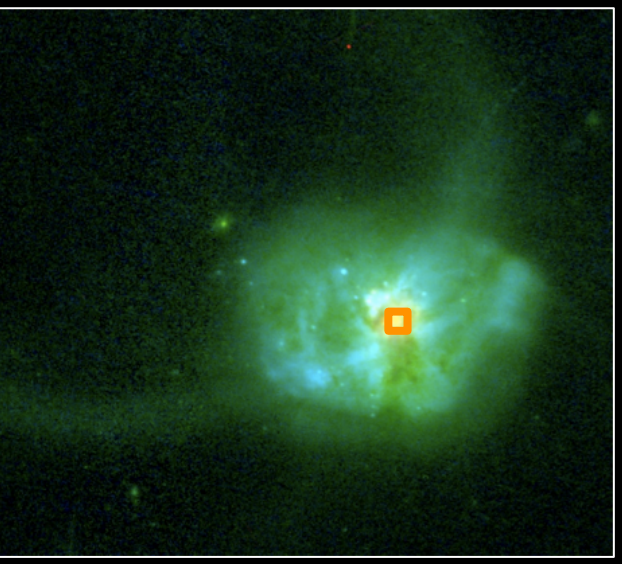
Spatially resolved $^{12}CO/^{13}CO(3-2)$ ratio map

	IRAS 13120	IRAS 17207	IRASF 05189	ESO 286	ESO 148	IRASF 12112	Spiral galaxies
Average	21	17	14	22	22	21	~11
Ratio at the SF peak	22	8	11	12	15	13	

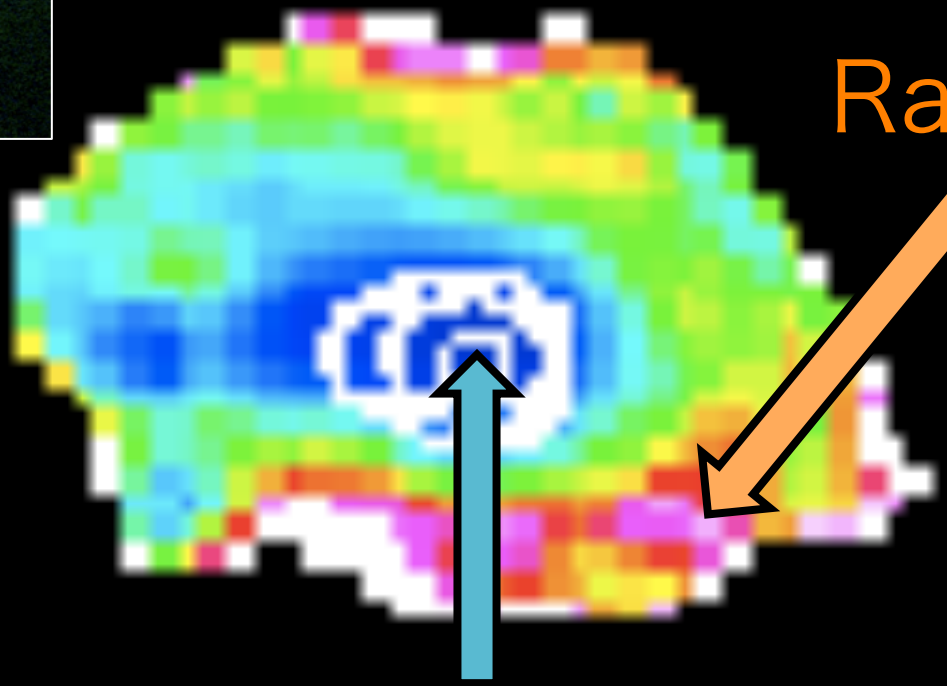
General Trends:

1. The global ratio is higher (~20) than normal spiral galaxies (~10)
2. Ratio at the strong dust continuum region is lower than outskirts (i.e. outskirts are higher)

Spatially resolved $^{12}CO/^{13}CO(3\text{-}2)$ ratio map



One of examples: IRASF17207-0014

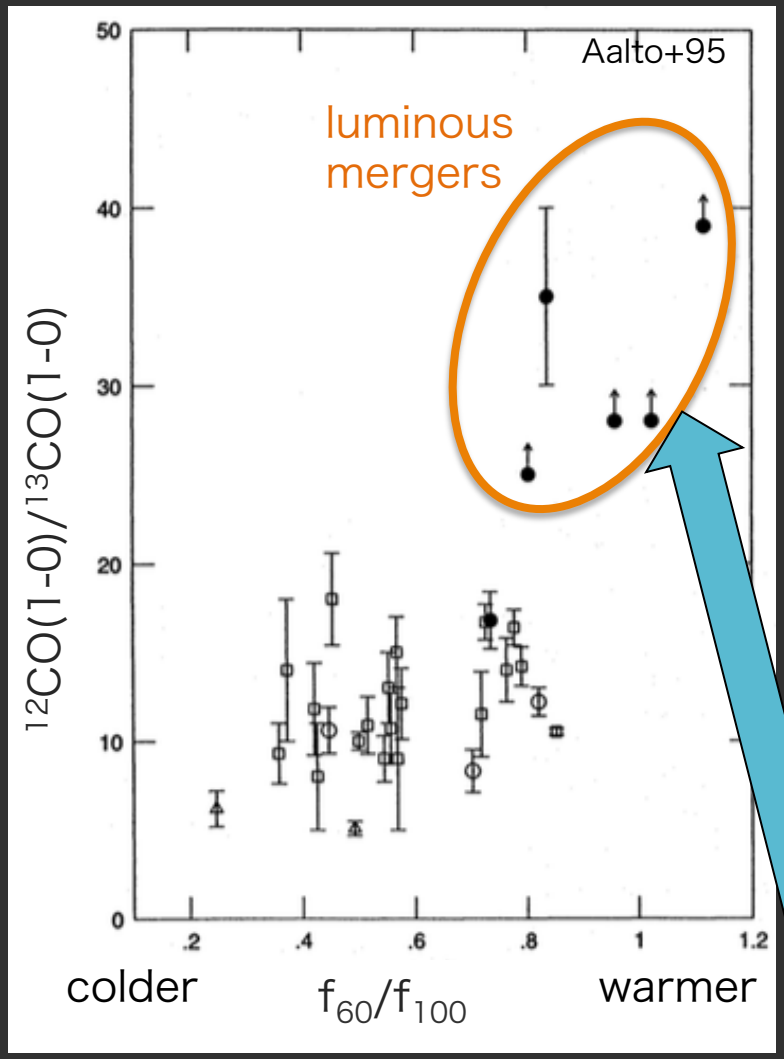


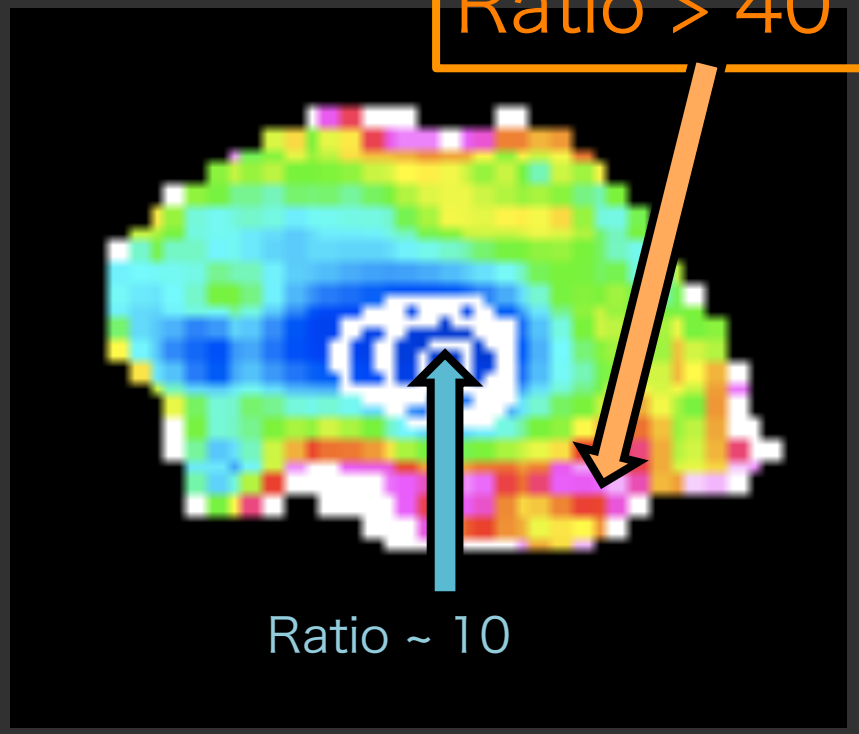
Ratio > 40

Ratio ~ 10

500pc

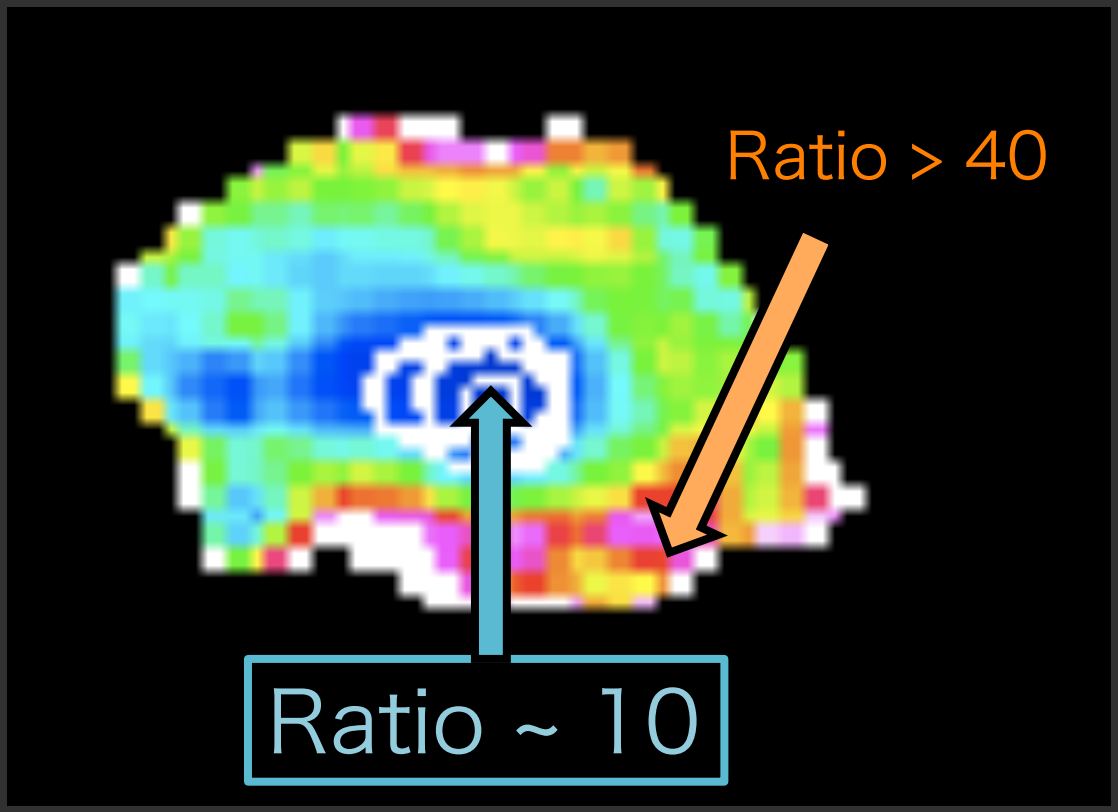
Spatially resolved $^{12}CO/^{13}CO(3-2)$ ratio map





High global ratio is due to extended (~kpc) gas

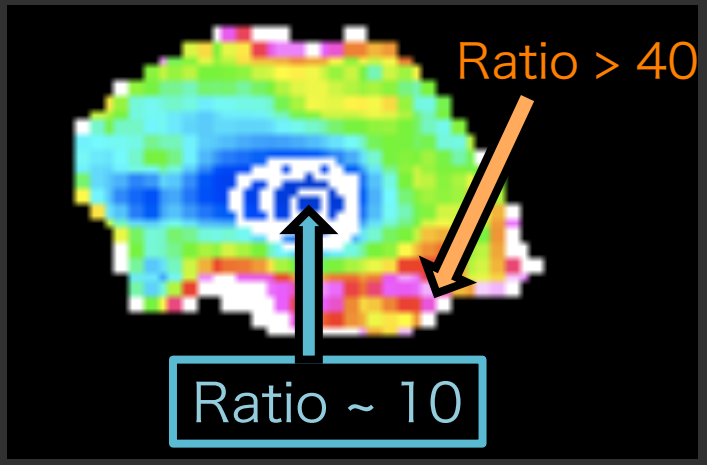
Exact reason still to be investigated



^{12}CO/^{13}CO(3-2) ratio is low at the dust continuum peak

Why?

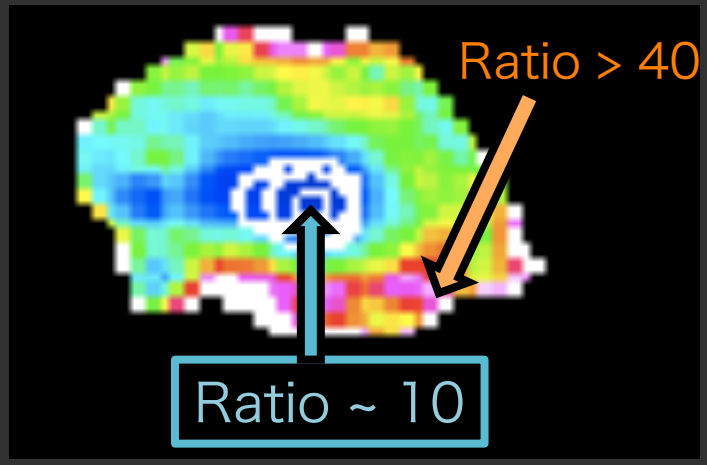
The lower $^{12}CO/^{13}CO(3\text{-}2)$ ratio at the dust continuum peak



Possible reasons

1. Opacity (low ^{12}CO or high ^{13}CO opacity)
2. Gradients in relative abundance

The lower ^{12}CO/^{13}CO(3-2) ratio at the dust continuum peak



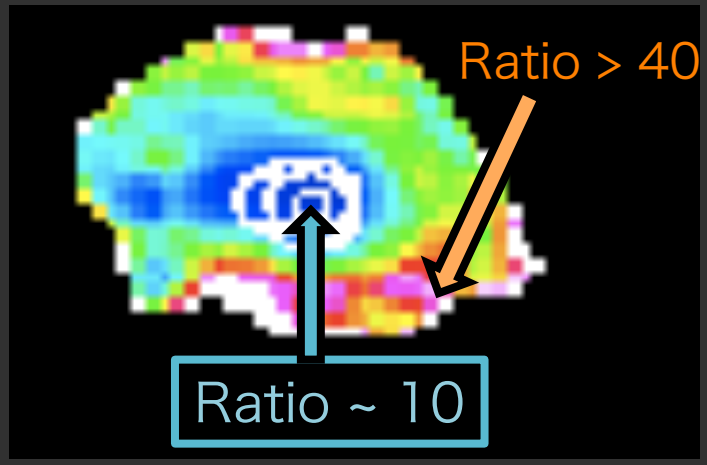
Possible reasons

1. Opacity (low ^{12}CO or high ^{13}CO opacity)
2. Gradients in relative abundance

- Turbulent dominated gas?
- Depopulated low-J gas to higher excitation?
- .
- .

e.g. Aalto et al. 1991

The lower $^{12}CO/^{13}CO(3\text{-}2)$ ratio at the dust continuum peak



Possible reasons

1. Opacity (low ^{12}CO or high ^{13}CO opacity)
2. Gradients in relative abundance

Example: Arp 220

$[^{12}CO]/[^{13}CO]$ abundance ratio differ between the center and the outer regions

- ✓ Center: 90
- ✓ East: 159
- ✓ West: 142

Sliwa et al. 2017

Summary

- ✓ ^{12}CO(3-2) and ^{13}CO(3-2)
  in six merging ULIRGs with ALMA

- ✓ ^{12}CO(3-2)/^{13}CO(3-2) ratio maps
  - ➢ The global higher ratio is due to the extended gas rather than the center
  - ➢ Ratio at the strong dust continuum (star forming) region is lower than outskirts

- ✓ Possible reasons
  - Opacity
  - Abundance variation

  => additional analysis is needed!

Future Work

- ✓ ^{12}CO(1-0), HCN(4-3), HCO+(4-3), CS(7-6) etc...
- ✓ Solve the radiative transfer model to investigate more detailed physical conditions