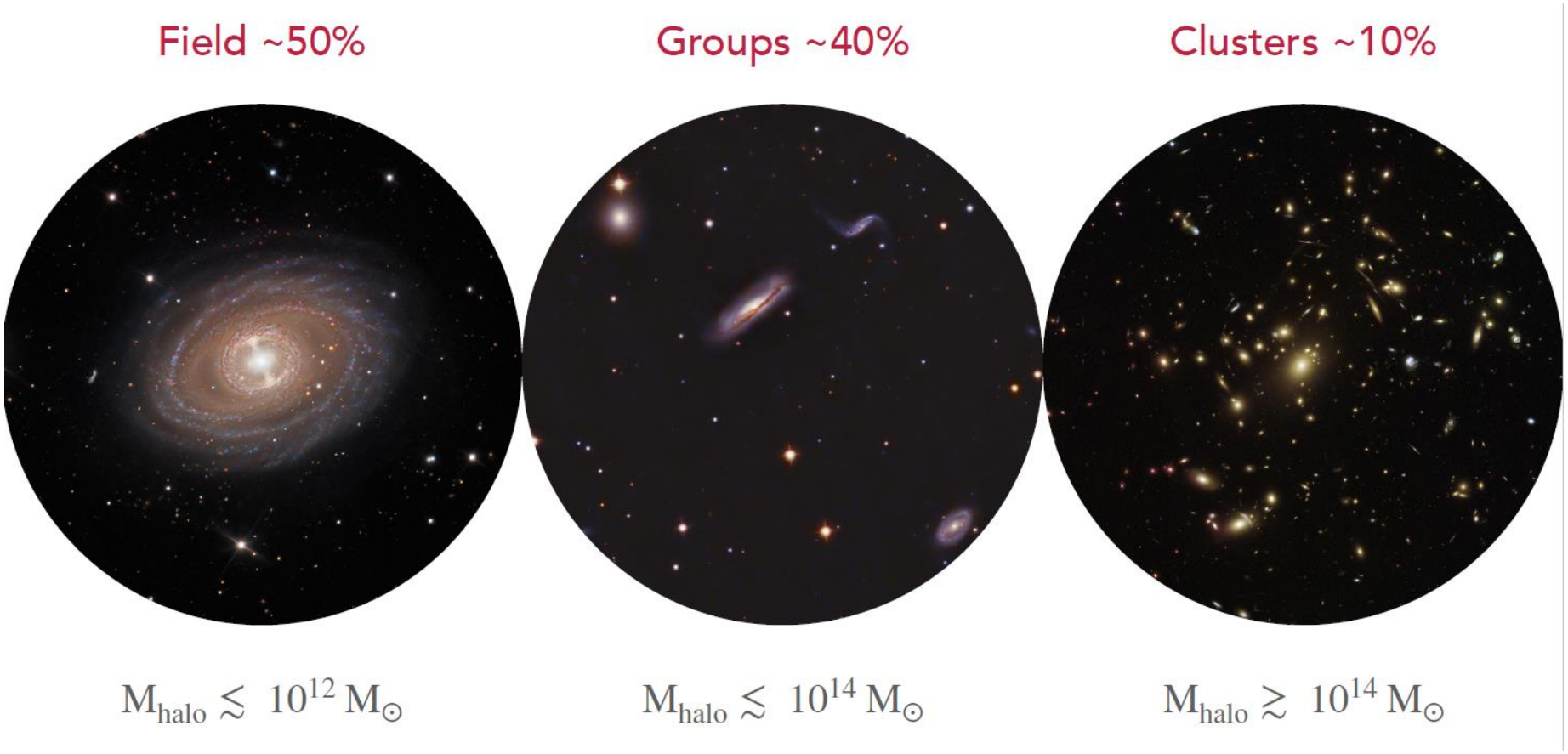
# The impact of the group environment on molecular gas of group galaxies

이범현 (Bumhyun Lee) (KIAA-PKU)

Environment workshop 2021

2021.02.09

# *Galaxy in different environment*




**Half of galaxies → galaxy groups**

e.g., Eke et al. (2004)

Figures adapted from Toby Brown's talk

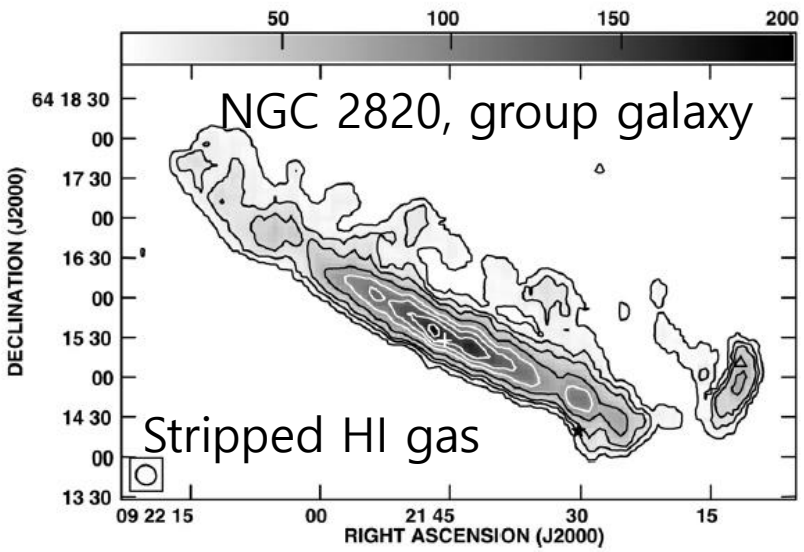
# *Environmental effects on group galaxies*

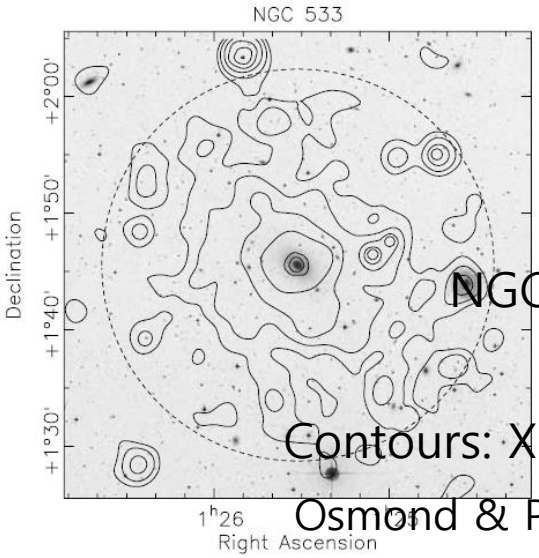
- **Gravitational interactions:**
  **Tidal interactions**, merging, etc
  low velocity dispersion: 200 – 300 km/s
  (e.g., Mihos 2004; Moore et al. 1999; Duc et al. 2018)

- **Hydrodynamic (IGM and ISM) interactions:**
  Ram pressure stripping, etc
  (e.g., Gunn & Gott 1972; Kantharia et al. 2005; Rasmussen et al.2006)


Environmental processes in galaxy groups: change physical properties of group galaxies (e.g., morphology, star formation activity, gas content)

Seth et al. 2020, Kleiner et al. 2021, Castignani et al. 2021




NGC 533 group

Contours: X-ray (ROSAT)

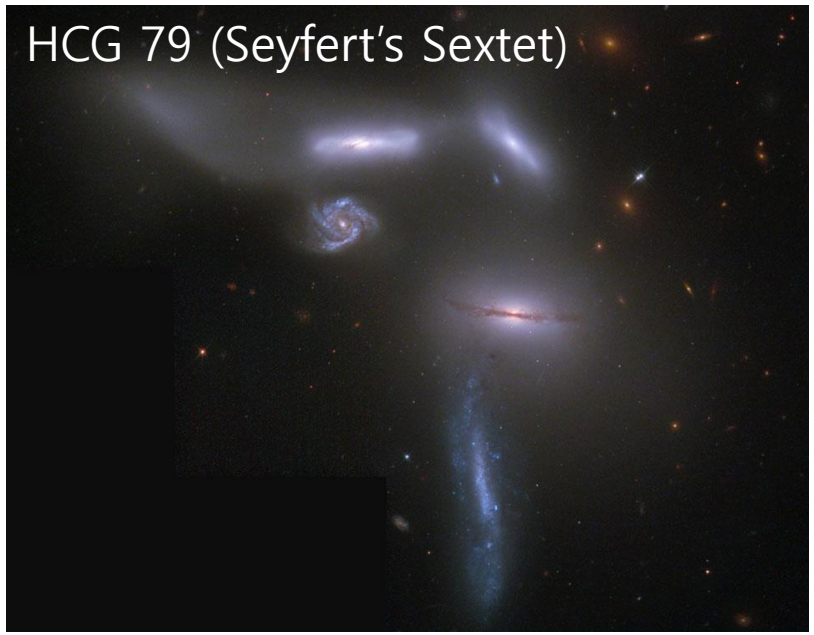
Osmond & Ponman 2004

# *Galaxy evolution in the group environment*

✓ Half of all galaxies in the local universe → galaxy groups (e.g., Eke et al. 2004)

but, not many studies on galaxy groups, compared to galaxy clusters
especially, not many studies on molecular gas of group galaxies.

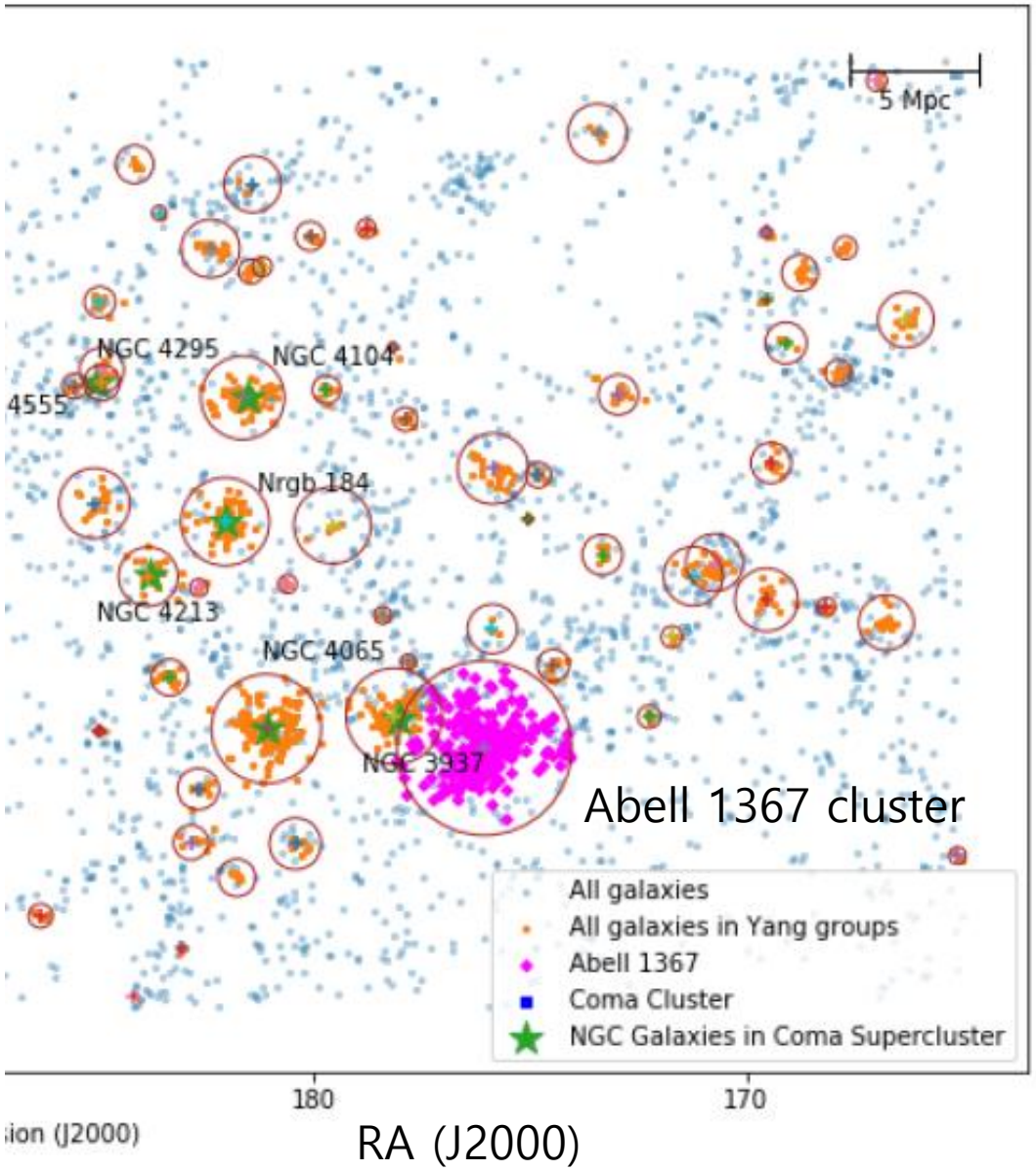
Historically, studies on galaxy groups → compact groups (e.g,. Hickson compact groups)


However, there are different types of galaxy groups:

1) Compact groups
2) Loose groups
3) Fossil groups

# *Galaxy evolution in the group environment*



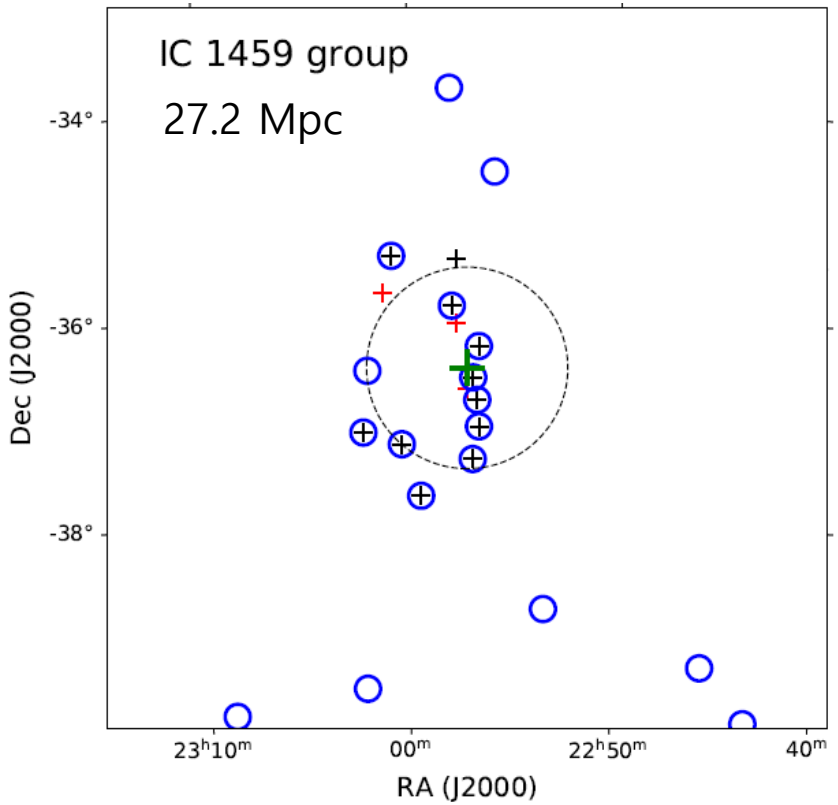

✓ Pre-processing: a high fraction of group galaxies is quenched before entering galaxy clusters, the enhanced transformation of galaxies

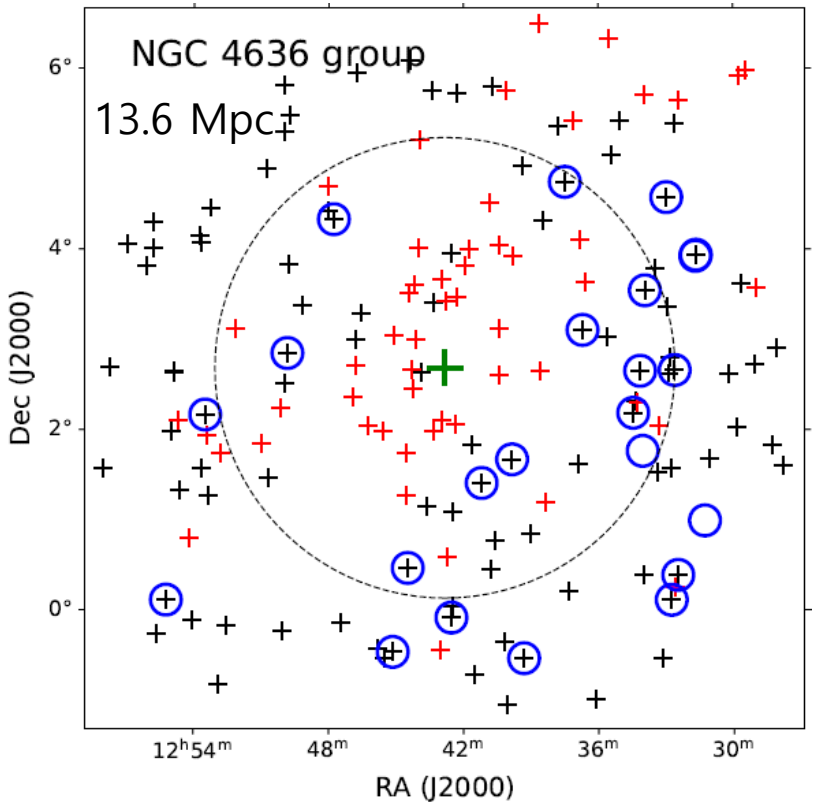
(e.g., Cybulski et al. 2014; Jaffe et al. 2016; Jung et al. 2018; Seth et al. 2020, Kleiner et al. 2021, Castignani et al. 2021).

→ The importance of studying galaxy evolution in the group environment is increasing.

**Obtaining a deeper understanding of how group environmental processes affect the molecular gas of group galaxies and hence their star formation activity**

# *Sample selection & ACA CO observations*




Crosses:
- black: late type galaxies
- red: early type galaxies
- green: brightest group galaxy

Galaxies are within $1.5 \times R_{200}$ and $\pm 3 \times \sigma_{group}$ (IC 1459: 222 km/s, NGC4636: 248 km/s).

Open circles: target galaxies

Dashed circle: 1.5 x R200

- IC 1459 group (isolated group, 27 Mpc): 18 galaxies
- NGC 4636 group (near the Virgo cluster, 13.6 Mpc): 22 galaxies
- HI detection (spiral & dwarf galaxies) in the GEMS-HI survey (Parkes telescope)
- Stellar mass of samples: $\sim 10^7 - \sim 10^{10}\, M_\odot$

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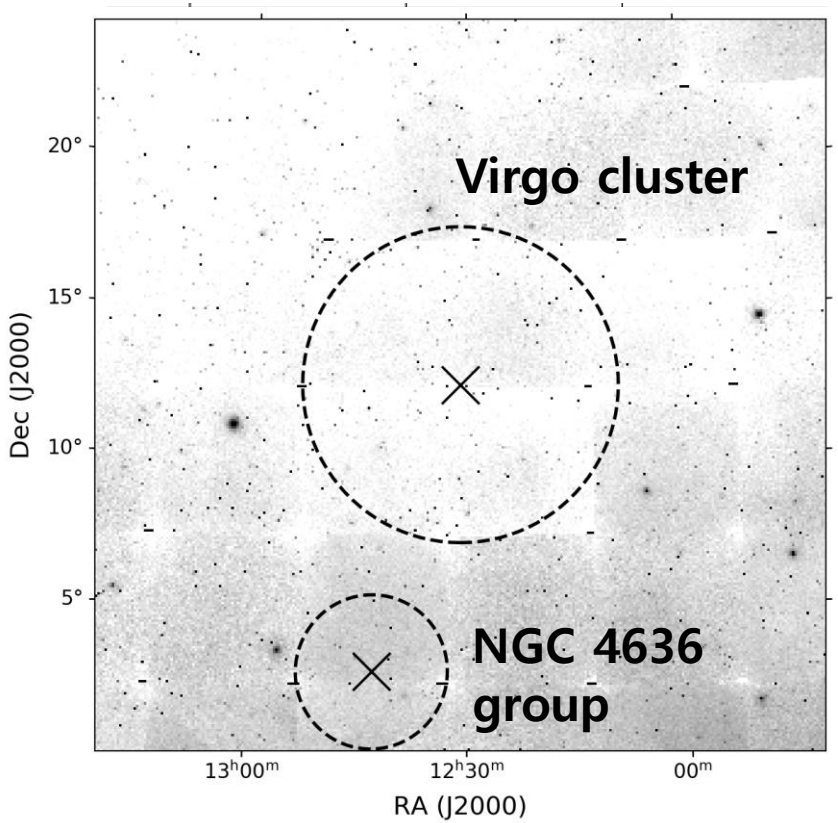


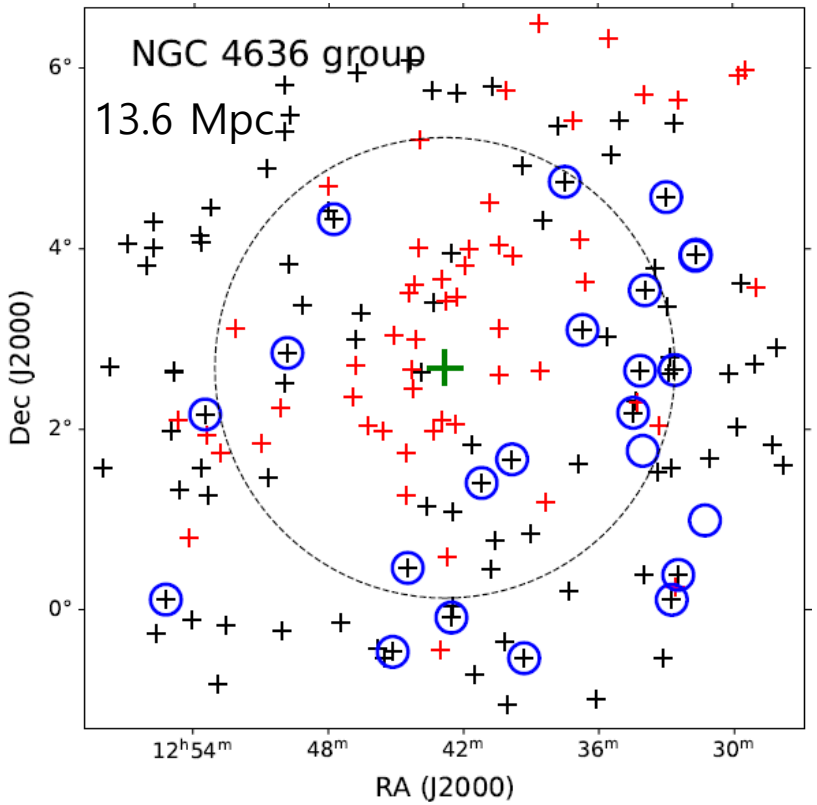


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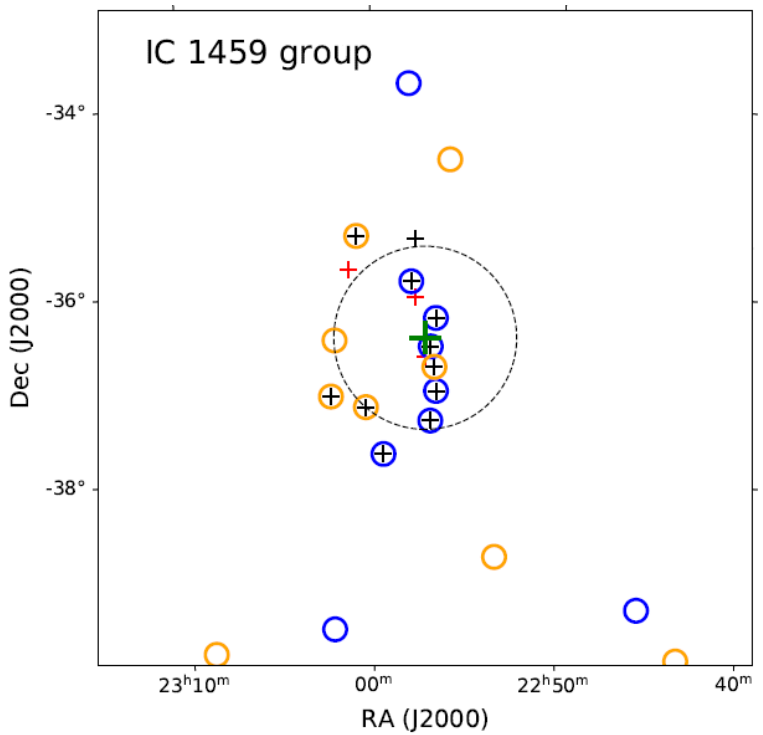
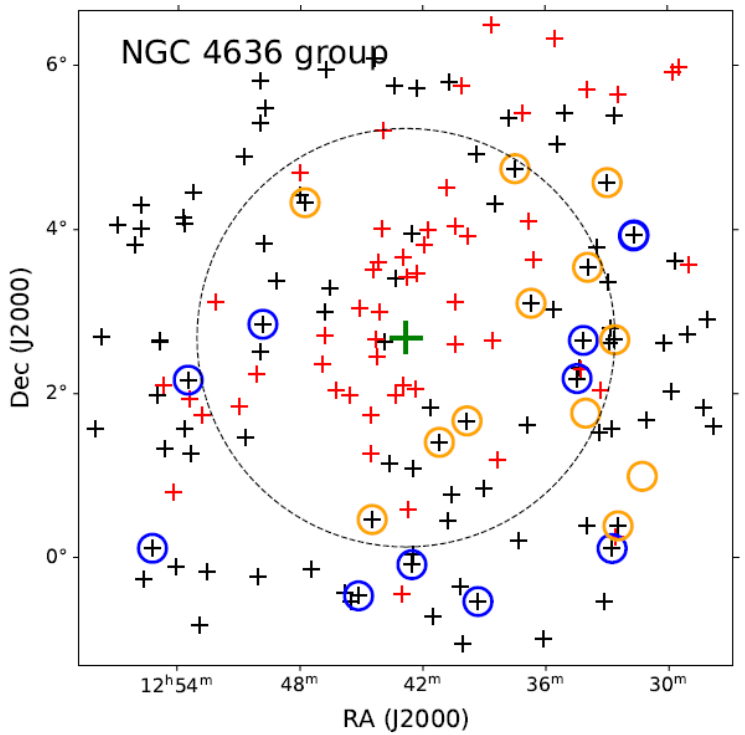



Open circles: target galaxies
- Blue: CO detection
- Orange: CO non-detection

The first CO imaging survey for IC 1459 and NGC 4636 groups (ALMA cycle 7, PI: B. Lee)

- Configuration: 7m array (ALMA/ACA), 9 - 11 antennas
- Observing line: 12CO (J=1-0) (main), CN (N=1-0; J=3/2-1/2), 3mm continuum
- Beam size: ~11 arcsec (~1.5 kpc (IC 1459 group) and ~0.7 kpc (NGC 4636 group))

✓ IC 1459 group - 12CO detection: 9 / 18 galaxies

✓ NGC 4636 group - i) 12CO detection: 10 / 22 galaxies, ii) CN (1-0) detection: 3 galaxies, iii) 3mm continuum detection: 4 galaxies

# *Scientific goals*

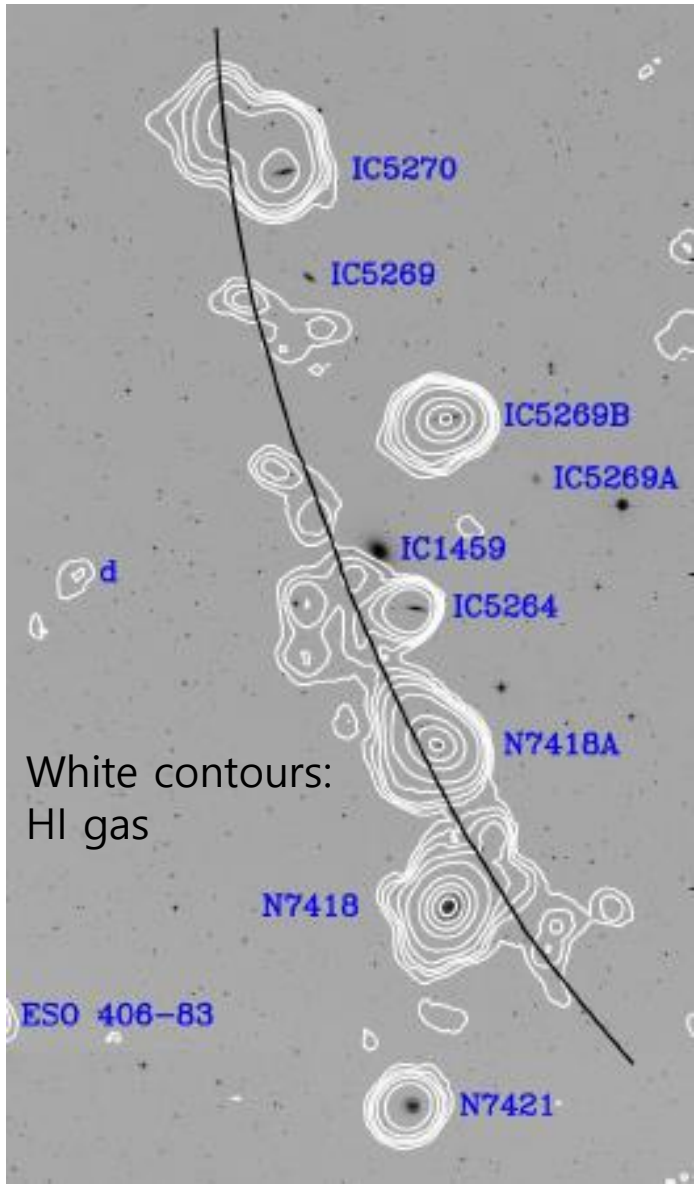
Combined with multiwavelength data (e.g., CO + HI, IR, and UV), obtaining a comprehensive understanding of molecular gas, star formation activity, and galaxy evolution in a group environment

**Goal 1:** Probe the morphological and kinematical characteristics of the molecular gas in the group environment, and compare CO gas with HI gas

**Goal 2:** Investigate the relationship among physical parameters (SFR, stellar mass, SFE, sSFR, gas fraction) at sub-kpc and kpc scales

**Goal 3:** Compare the properties of group galaxies with that of field galaxies, as well as with those of cluster members (e.g., Fornax and Virgo – ALMA CO observations)

# *HI gas in IC 1459 group*




White contours:
HI gas

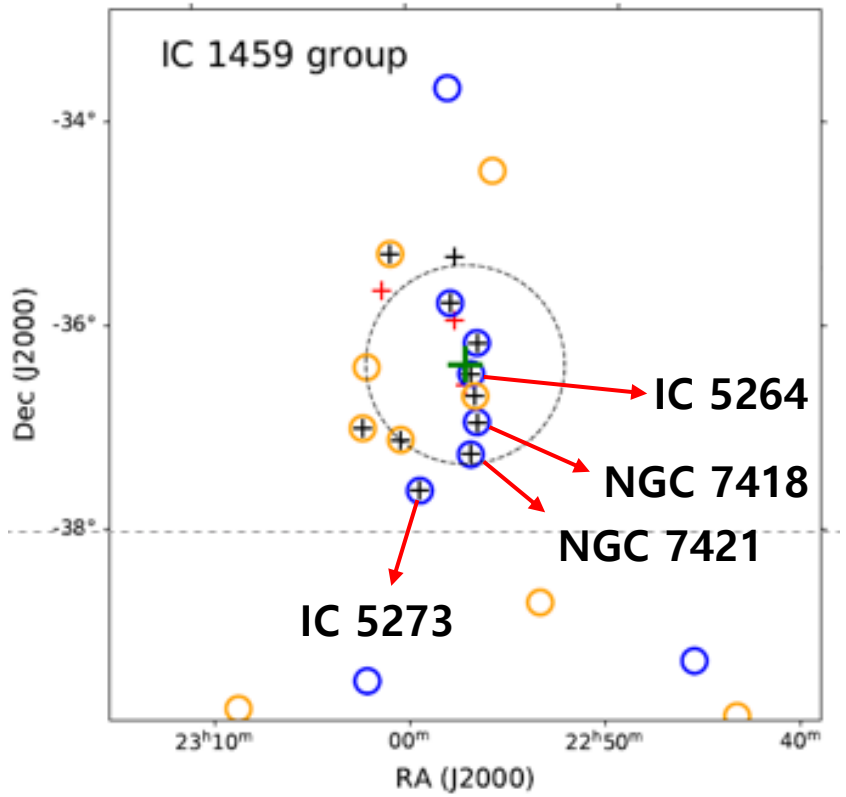
HI gas observations using the Karoo Array Telescope (KAT-7: the South African SKA pathfinder)

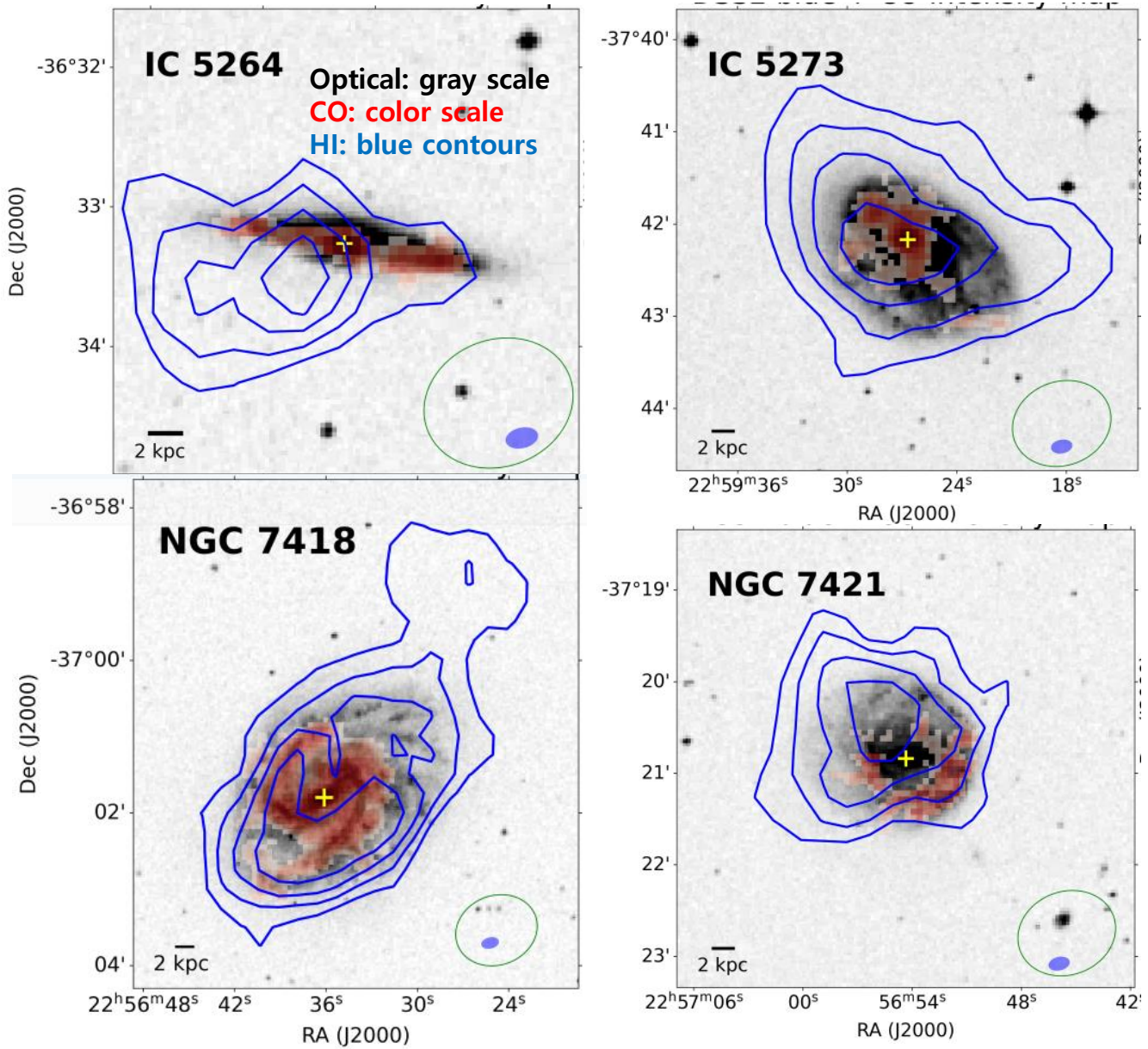
**Distorted HI distribution & Stripped HI gas**
**→ Many interactions in IC 1459 group**

Contour levels: 5,10,..., $\times 10^{18} cm^{-2}$

Oosterloo et al. 2018

# *Asymmetric HI & CO distributions*




**Both CO & HI distributions are highly asymmetric.**

Lee et al. 2021, in prep.

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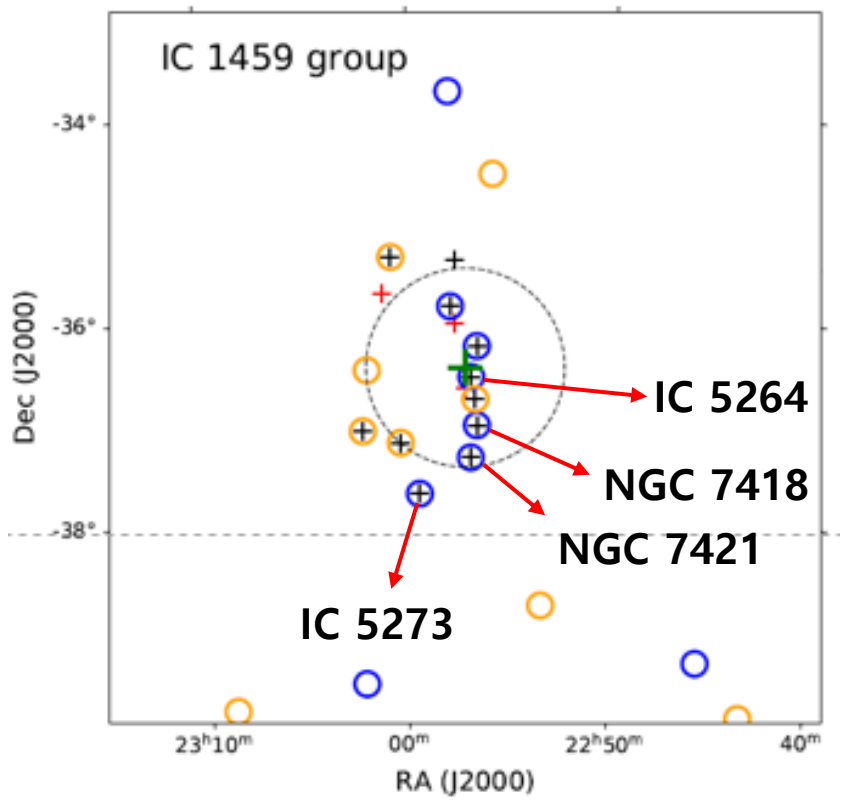


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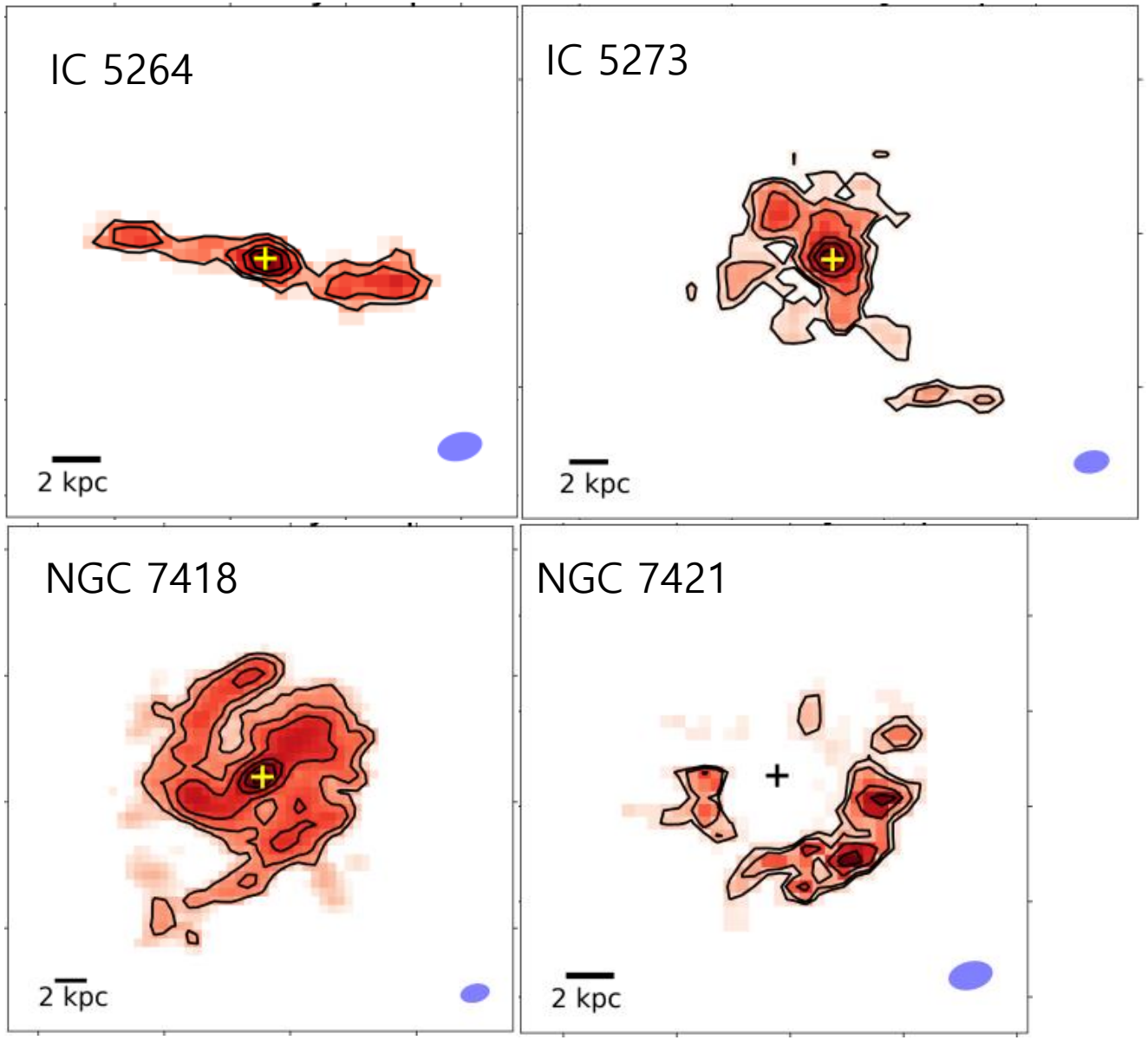
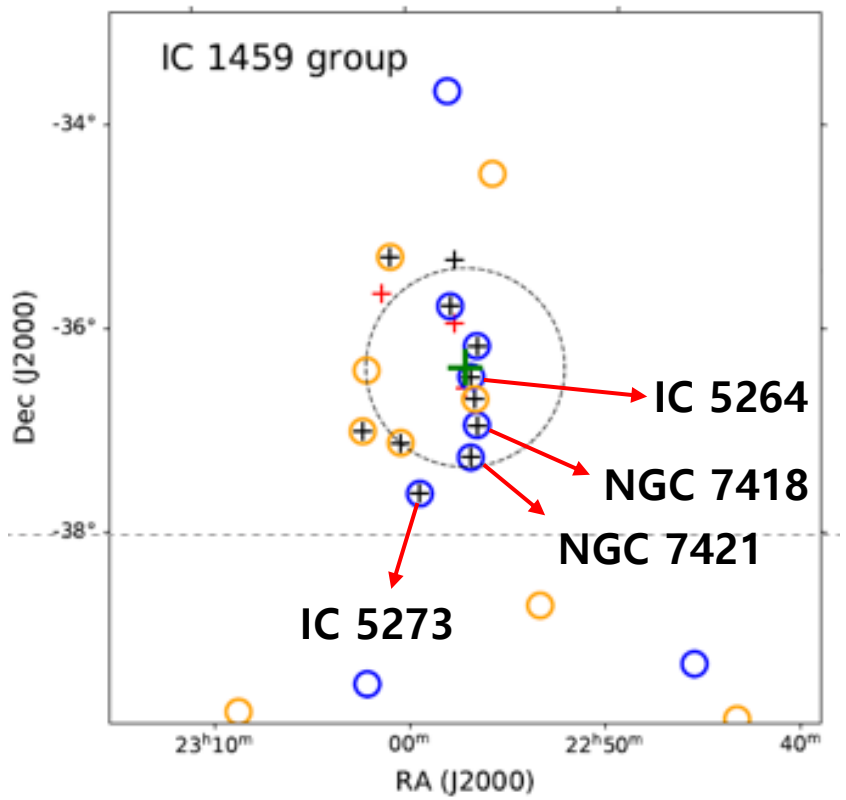


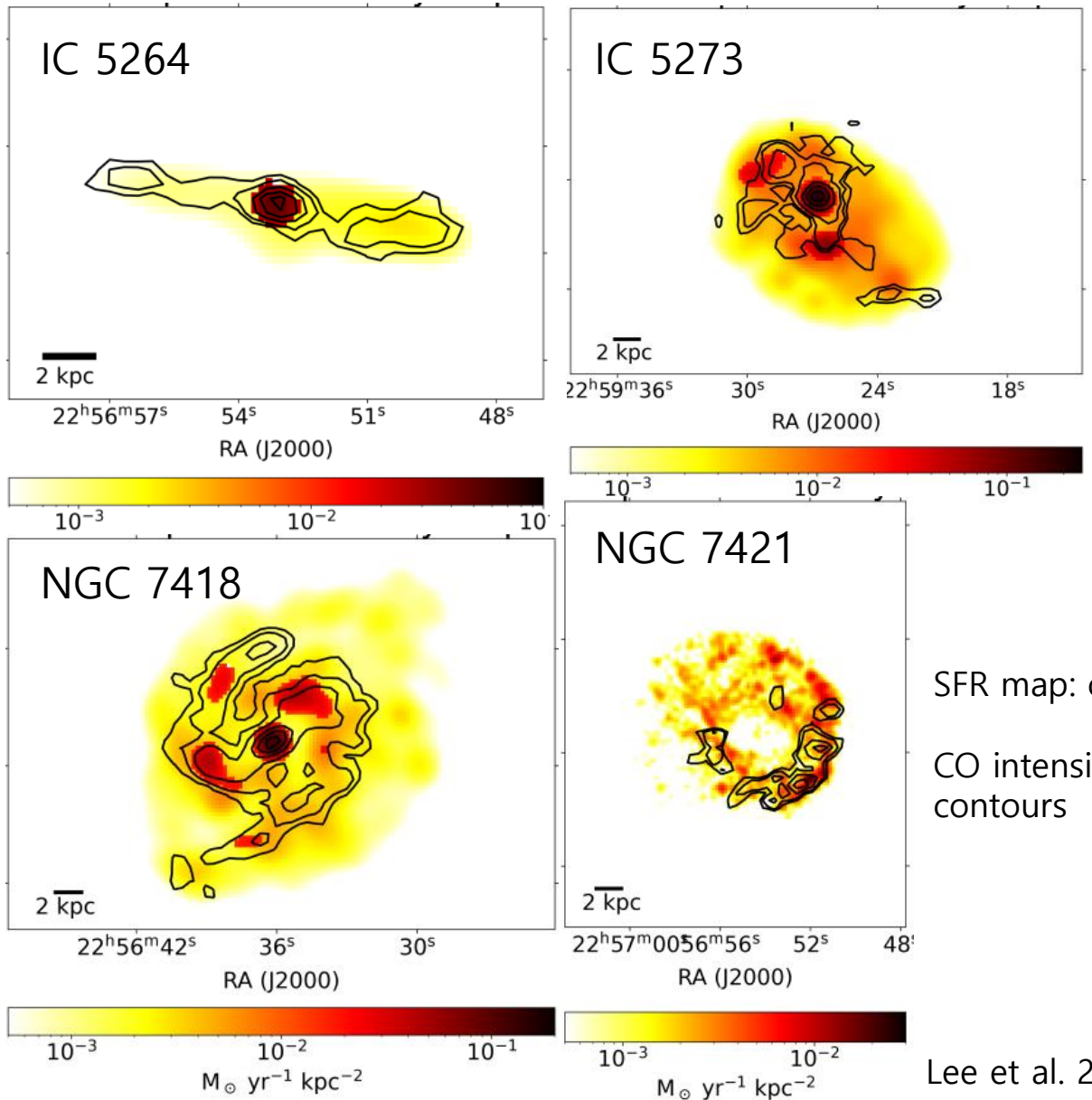

ACA CO intensity map

Lee et al. 2021, in prep.

# *Change of star formation activity*




**physical properties (cold gas & star formation) of group galaxies are affected by group environmental processes** (e.g., tidal interaction)

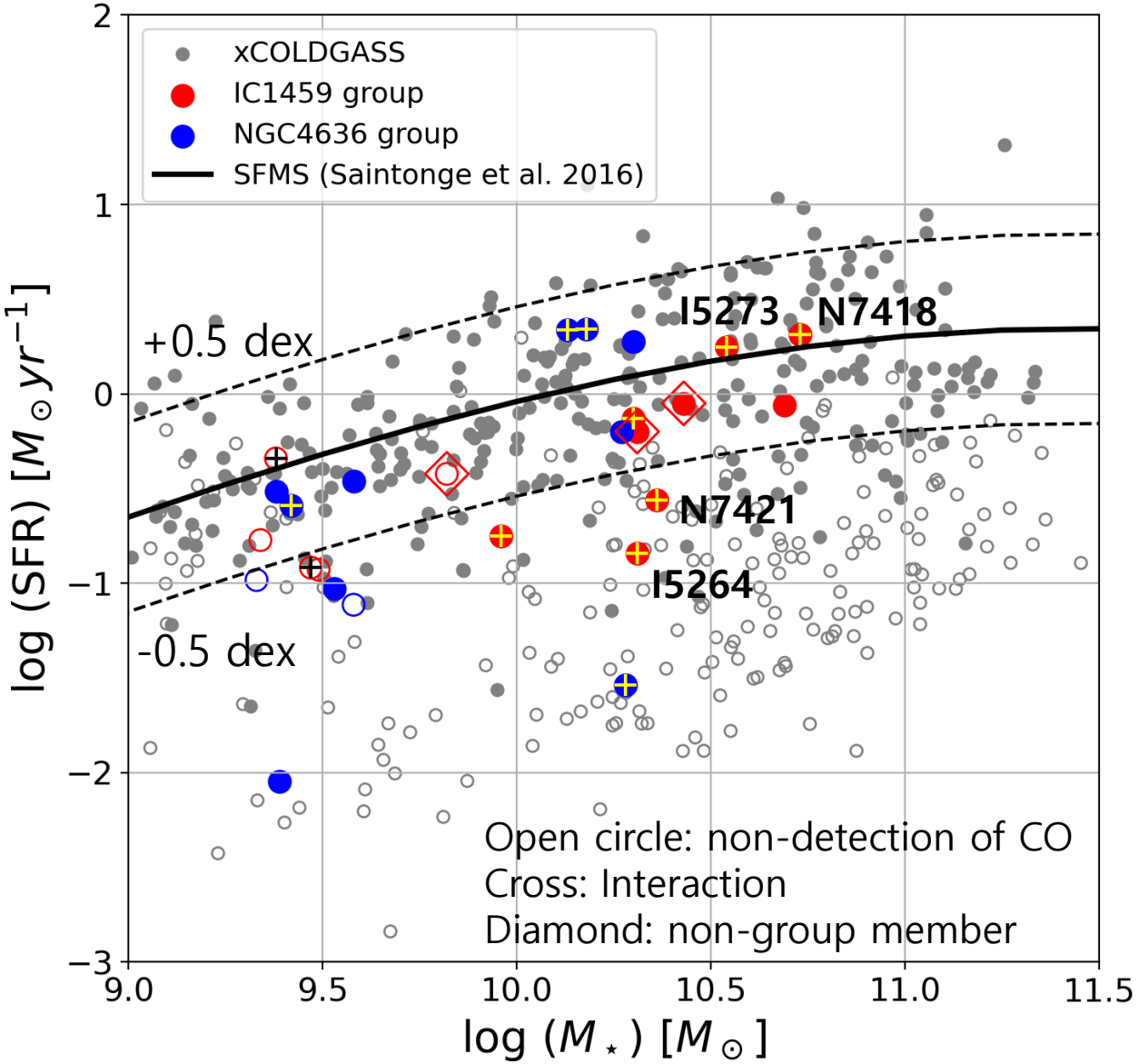



SFR map: color scale

CO intensity map: contours

Lee et al. 2021, in prep.

# *Global properties of group galaxies*




23 group members
+ 3 non-group members

**10 out of 23 galaxies (~43%): lower star formation rate at given stellar mass → group environmental effects?**

✓ IC 5273, NGC 7418: star-forming galaxies

✓ 2) NGC7421, IC5264: suppression of star formation

# *Summary*

- ✓ 12CO observations for 40 group galaxies using the ACA → 19 group galaxies have CO detection.
- ✓ Group galaxies show asymmetric ISM (CO & HI) and SFR distributions.
- ✓ Half of group sample have lower star formation rate.
- ✓ Physical properties of group galaxies can be affected by group environmental processes.