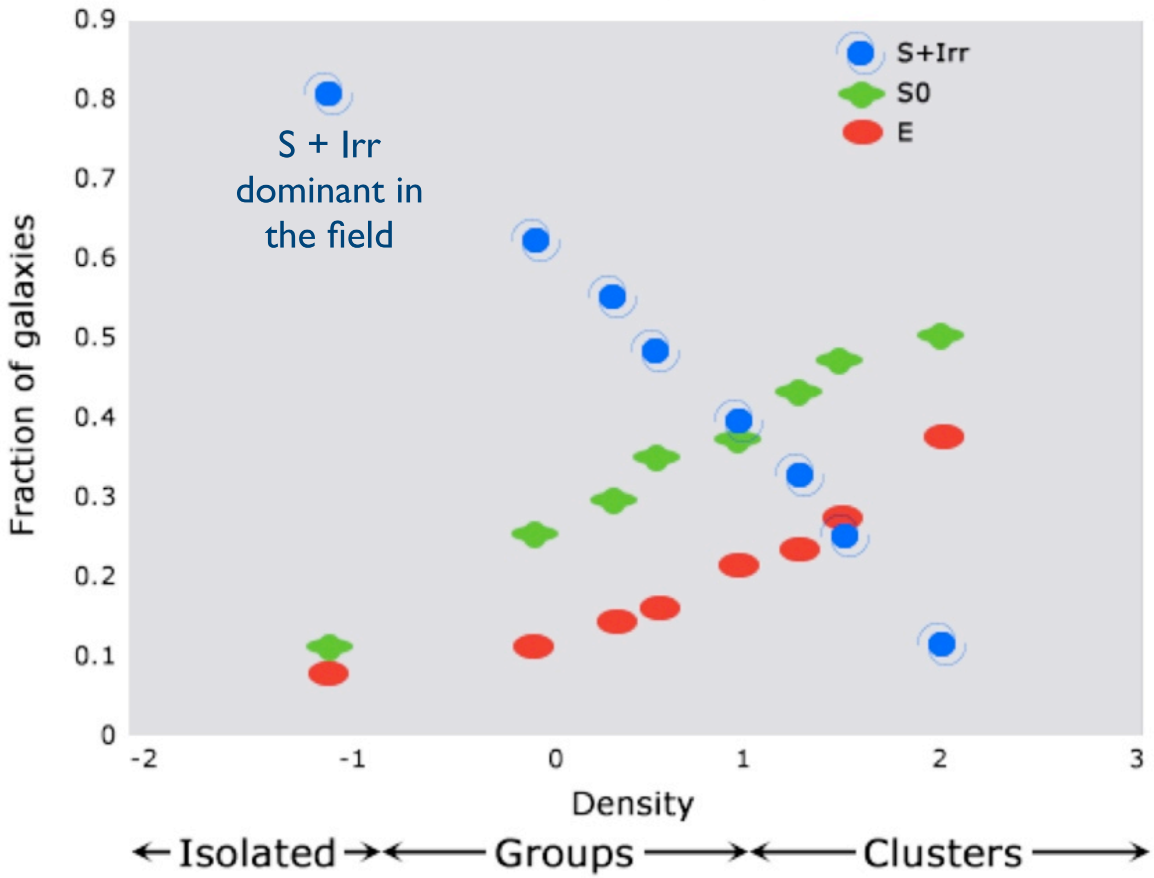
Evolutionary Paths in Galaxy Morphology, 2013 Sep 23-26, Sydney Australia

Environmentally Galaxy Evolution: From a Gas Perspective

Aeree Chung Yonsei University



Morphology-density relation
(Dressler 1980)
A study of ~50 nearby clusters

~90% E + S0
in cluster cores

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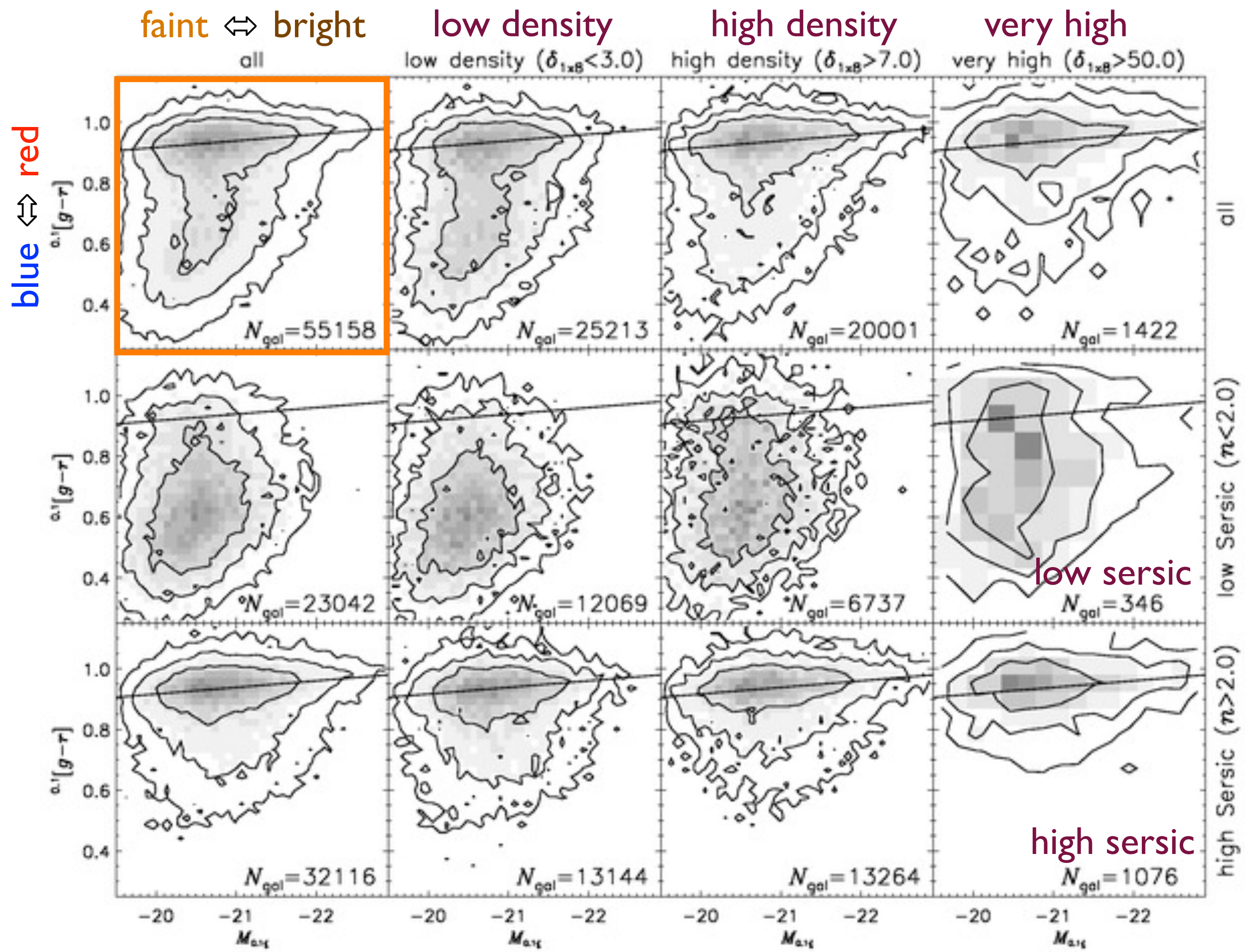

Color-Magnitude diagram (SDSS galaxies; Hogg et al. 2004)

In higher density environments, the fraction of disky, blue galaxies dramatically decreases

Environment matters in galaxy evolution!

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Environmentally Galaxy Evolution: From a Gas Perspective

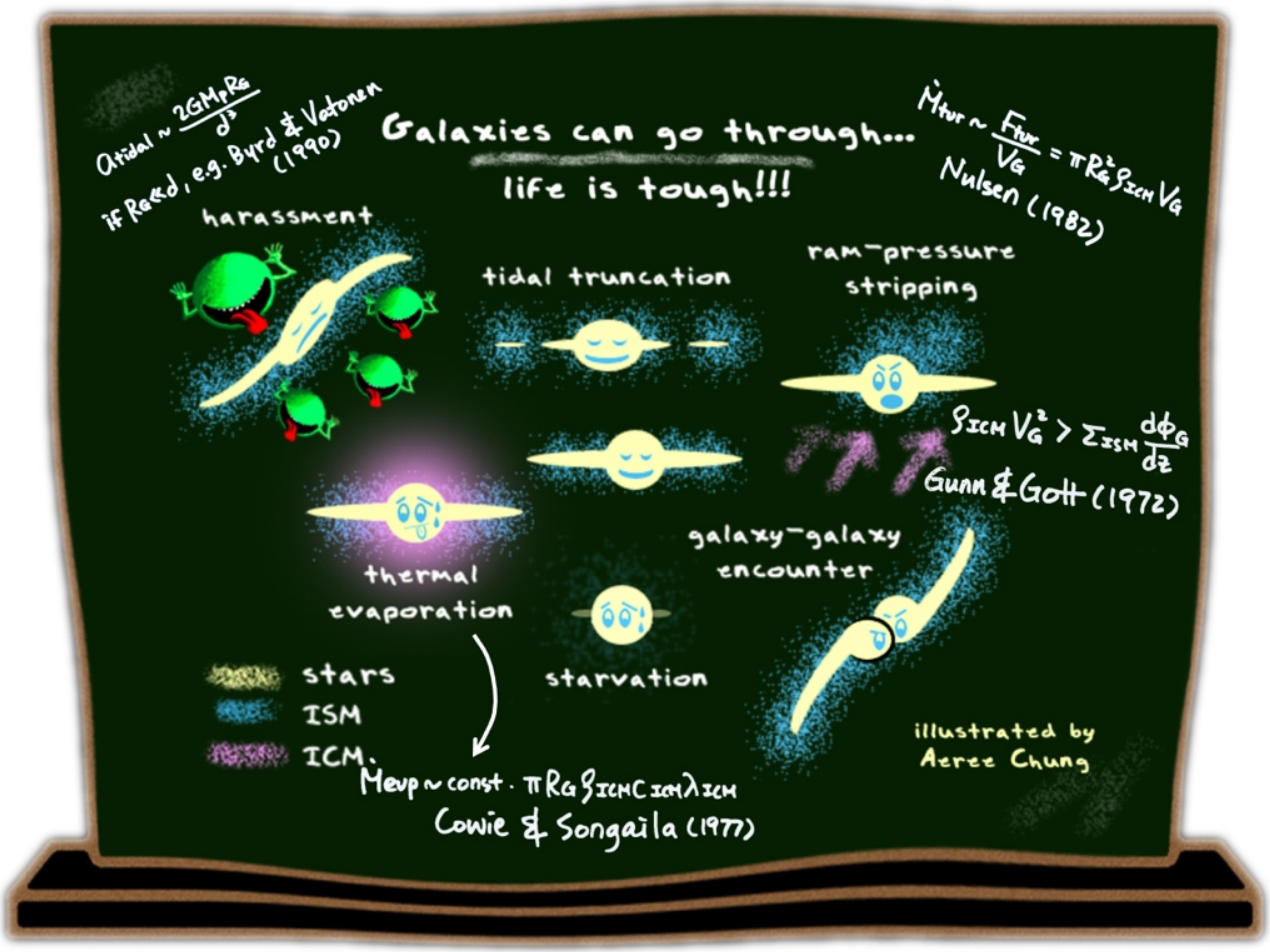
Aeree Chung Yonsei University

1. Environmental processes
2. HI as a probe of environmental effects
3. VIVA, an HI study of late type Virgo galaxies
4. HI Stripping and color evolution of galaxies
5. Environmental effects on molecular gas & star formation

Environmental effects

- Tidal interaction
  - Slow interaction between galaxies (galaxy merging)
  - Fast & repetitive encounters between galaxies (harassment)
  - Tidal truncation due to the cluster potential
- Gas-gas interaction interstellar medium vs. intra cluster/galactic medium
  - Ram-pressure stripping
  - Turbulent-viscous stripping
  - Thermal evaporation (conduction)
- Starvation, stripping of hot halo

Environmental effects

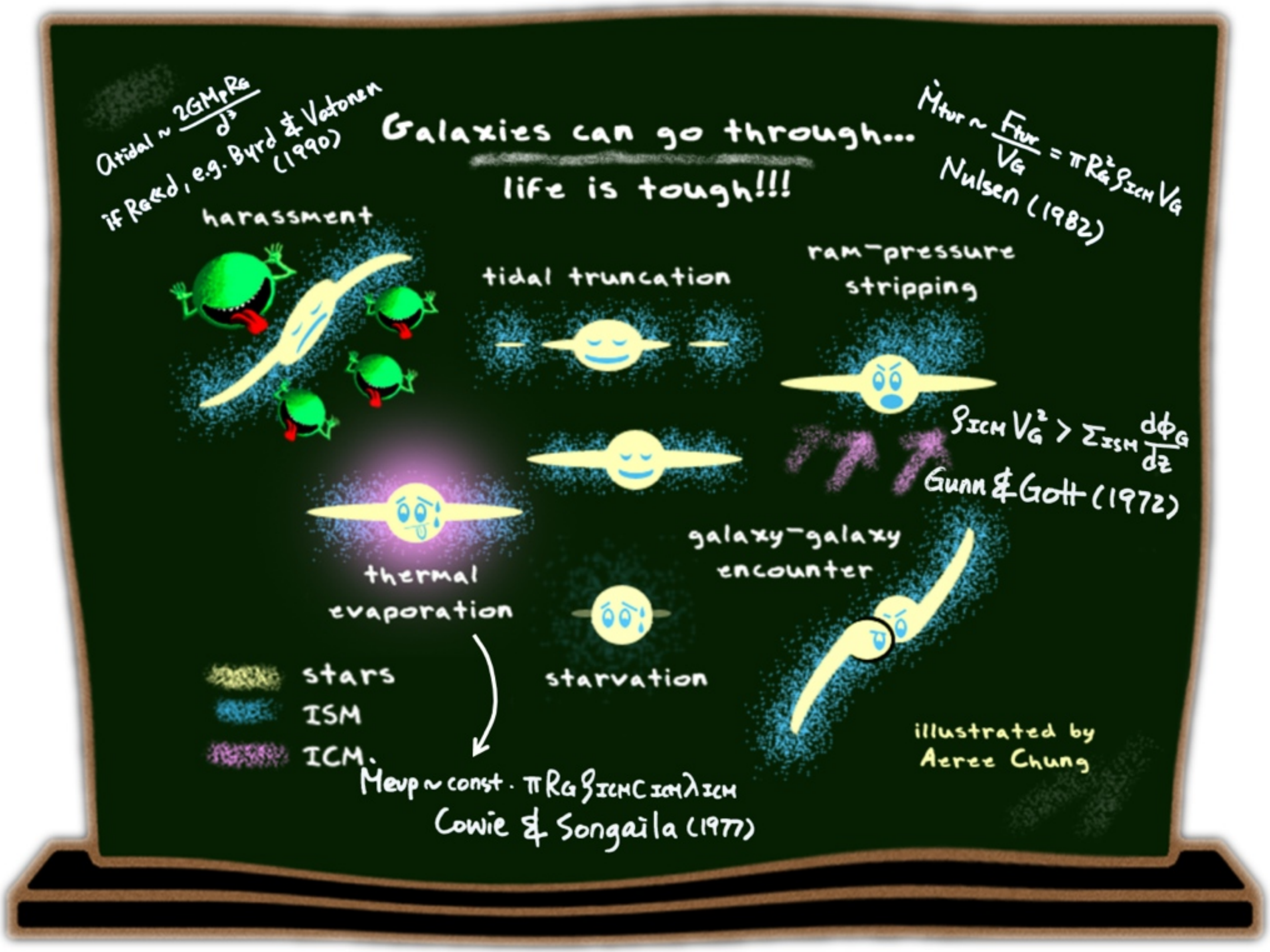


Tidal interactions

vs.

Gas-gas interactions

HI as a probe of environmental effects



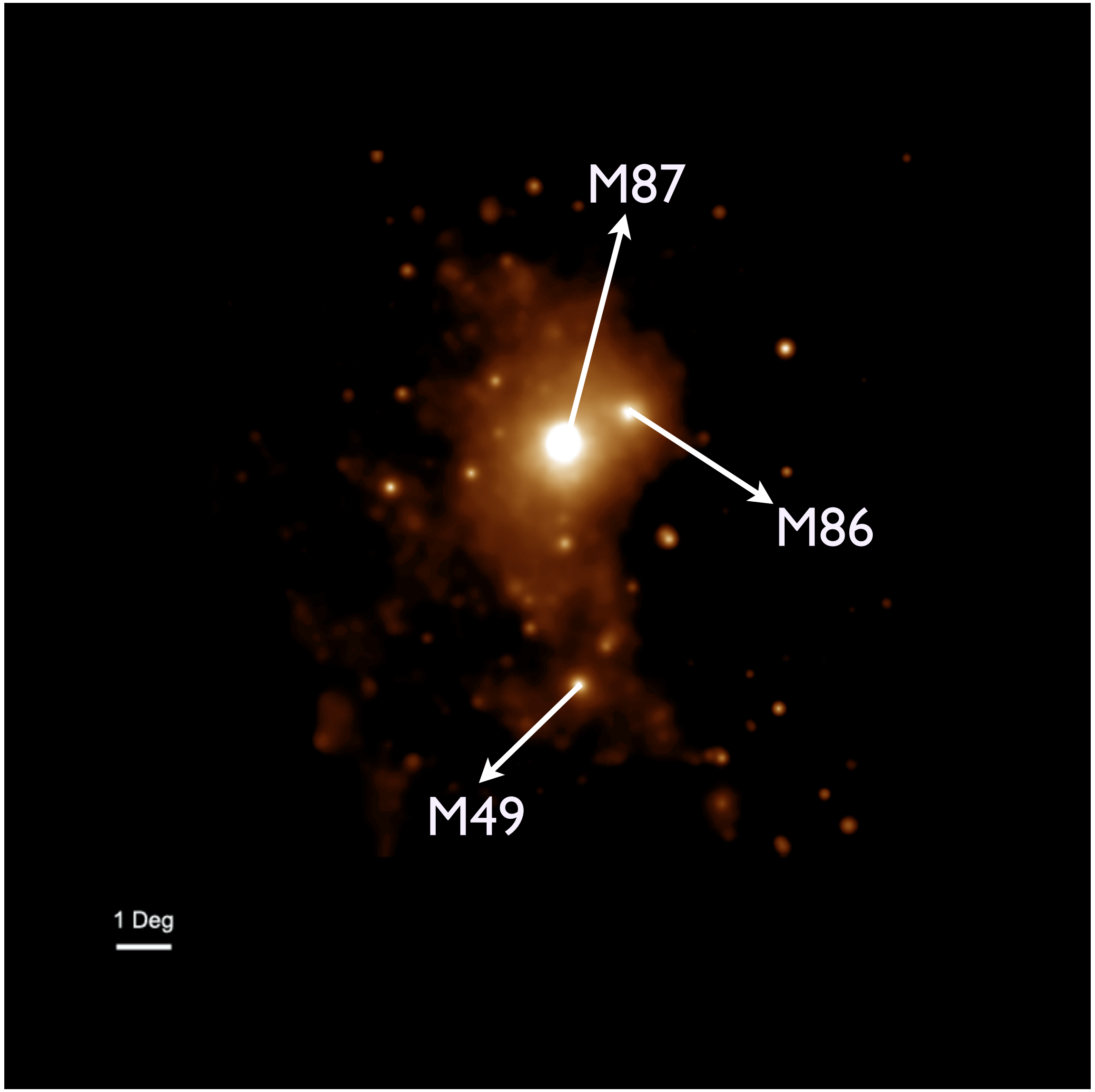
Vulnerable to surroundings

Morphology & kinematics

Gas reservoir - evolution

Virgo cluster of galaxies

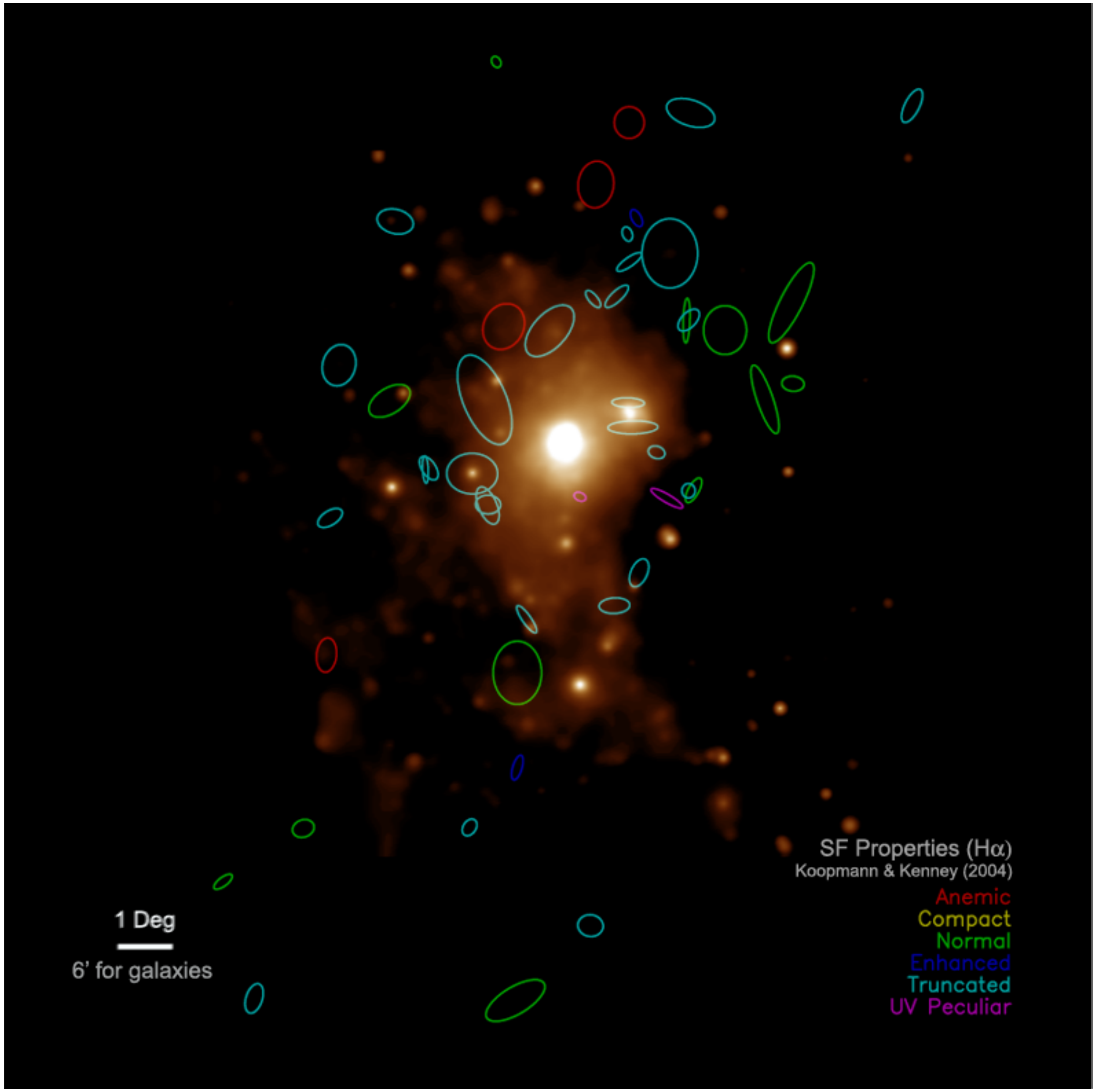
- ROSAT X-ray image
  (Böhringer et al. 1994)
- Nearest rich cluster
  (d~16.5 Mpc, Mei et al. 2007)
- Kinematically young
  (many candidates for galaxies undergoing various processes)



VIVA VLA Imaging of Virgo galaxies in Atomic gas

VIVA

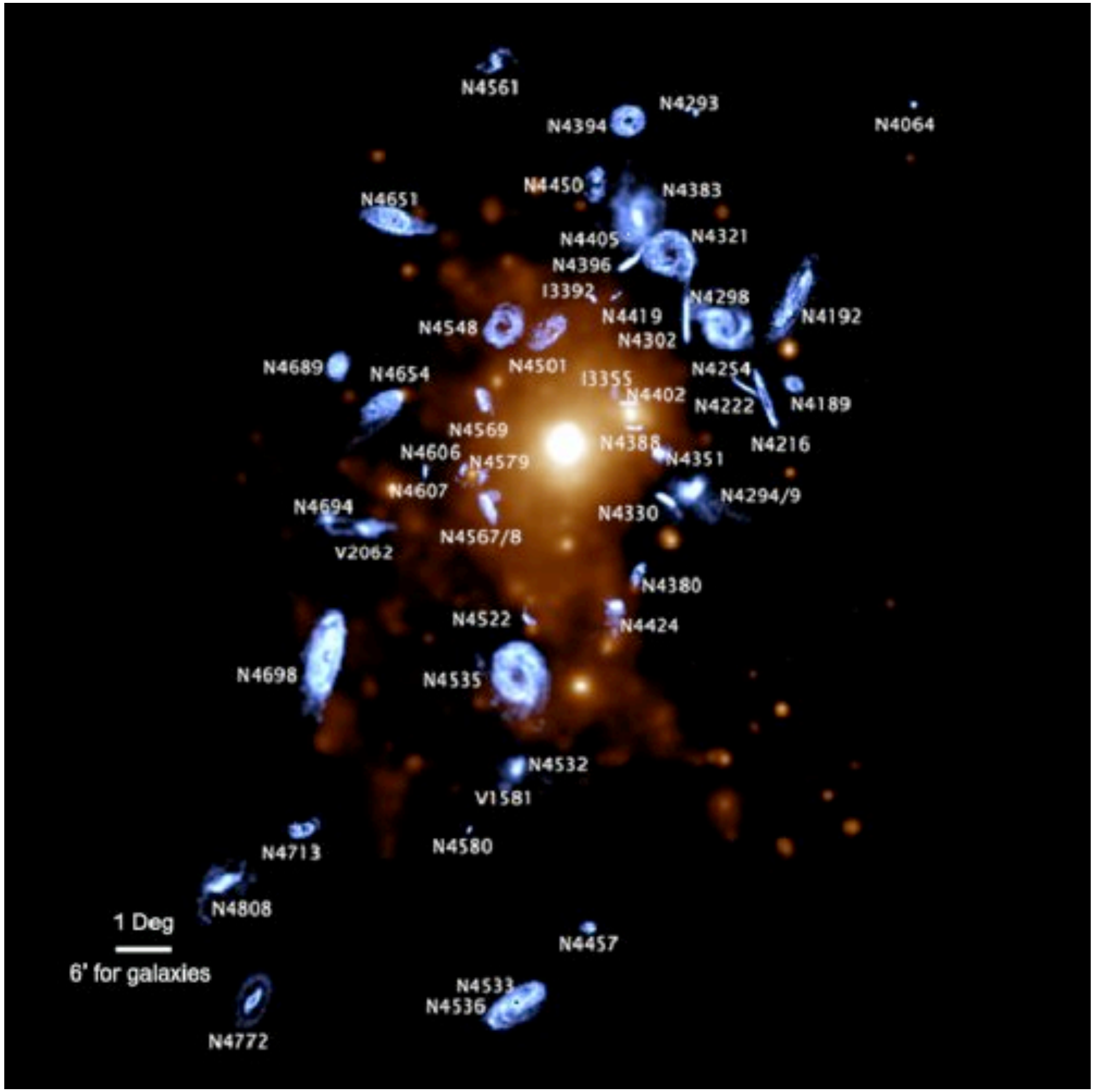
- VLA HI imaging study of 53 late type galaxies selected in a range of density regions; observations were done mostly in C or CS, and complemented by D-array data



VIVA VLA Imaging of Virgo galaxies in Atomic gas

VIVA HI Atlas

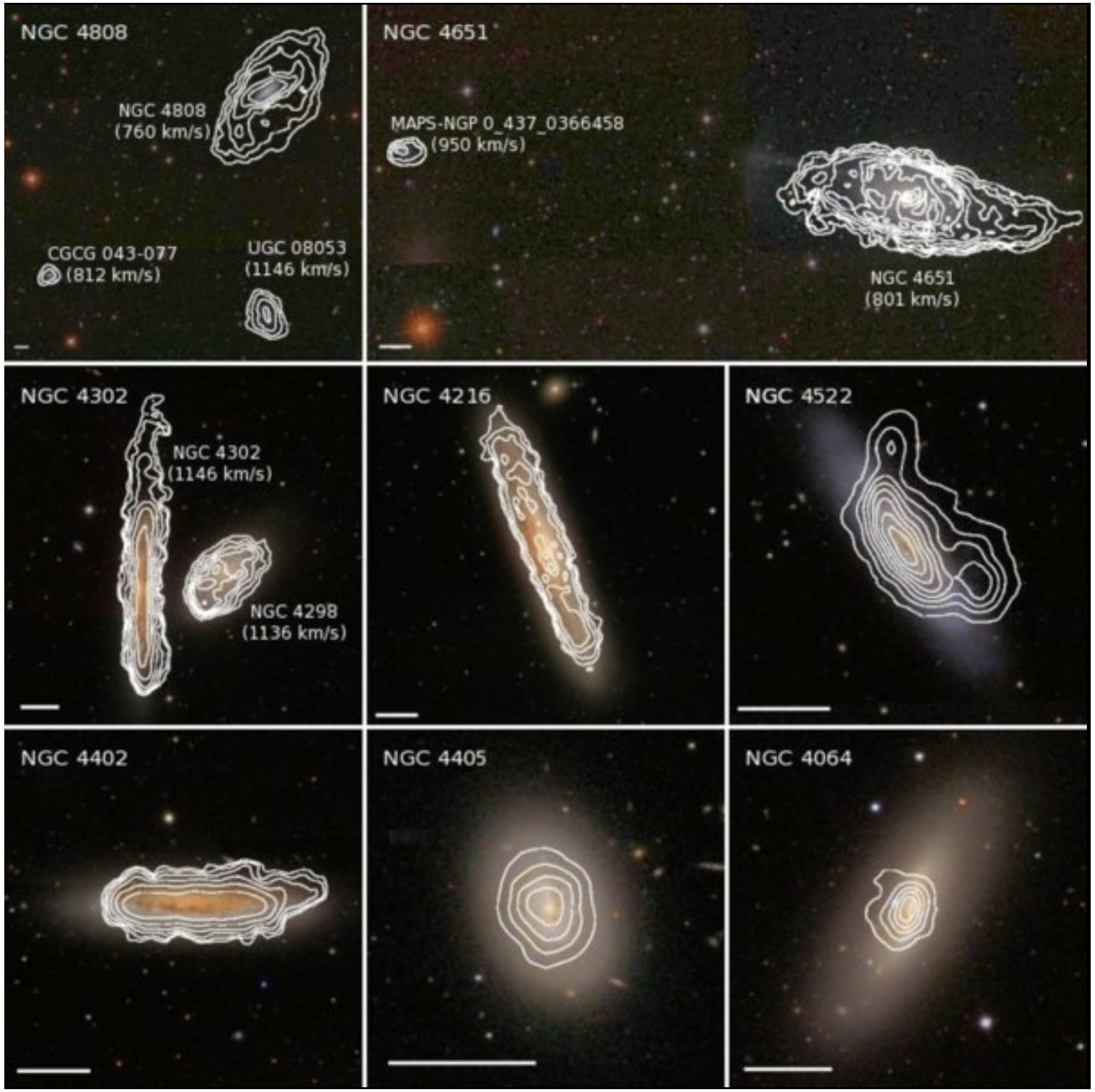
- HI in blue, magnified by a factor of 10+X-ray in orange (Chung et al. 2009)



VIVA VLA Imaging of Virgo galaxies in Atomic gas

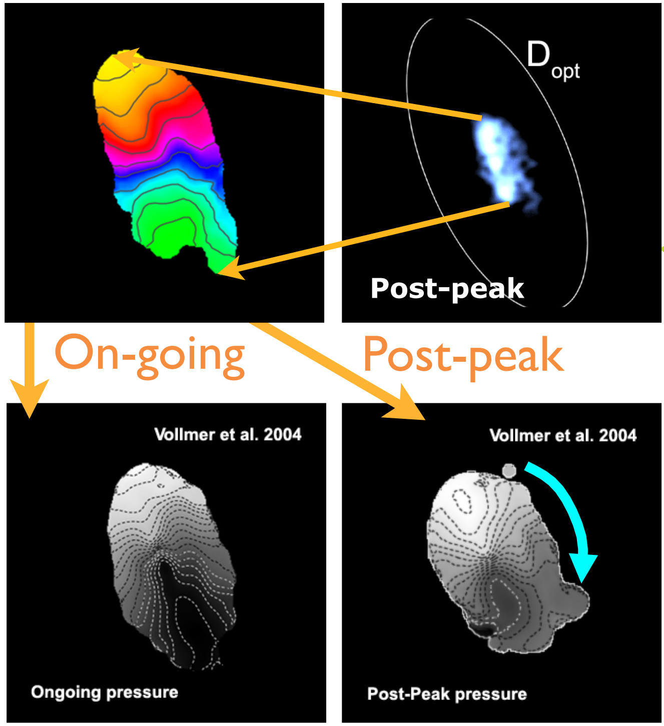
VIVA Examples
(Chung et al. 2009)

- ☑ Gas-gas interaction
- Undisturbed stellar disk + truncated HI disk within the stellar disk
- ☑ Tidal interaction
- Morphological peculiarities in gas and stellar distributions

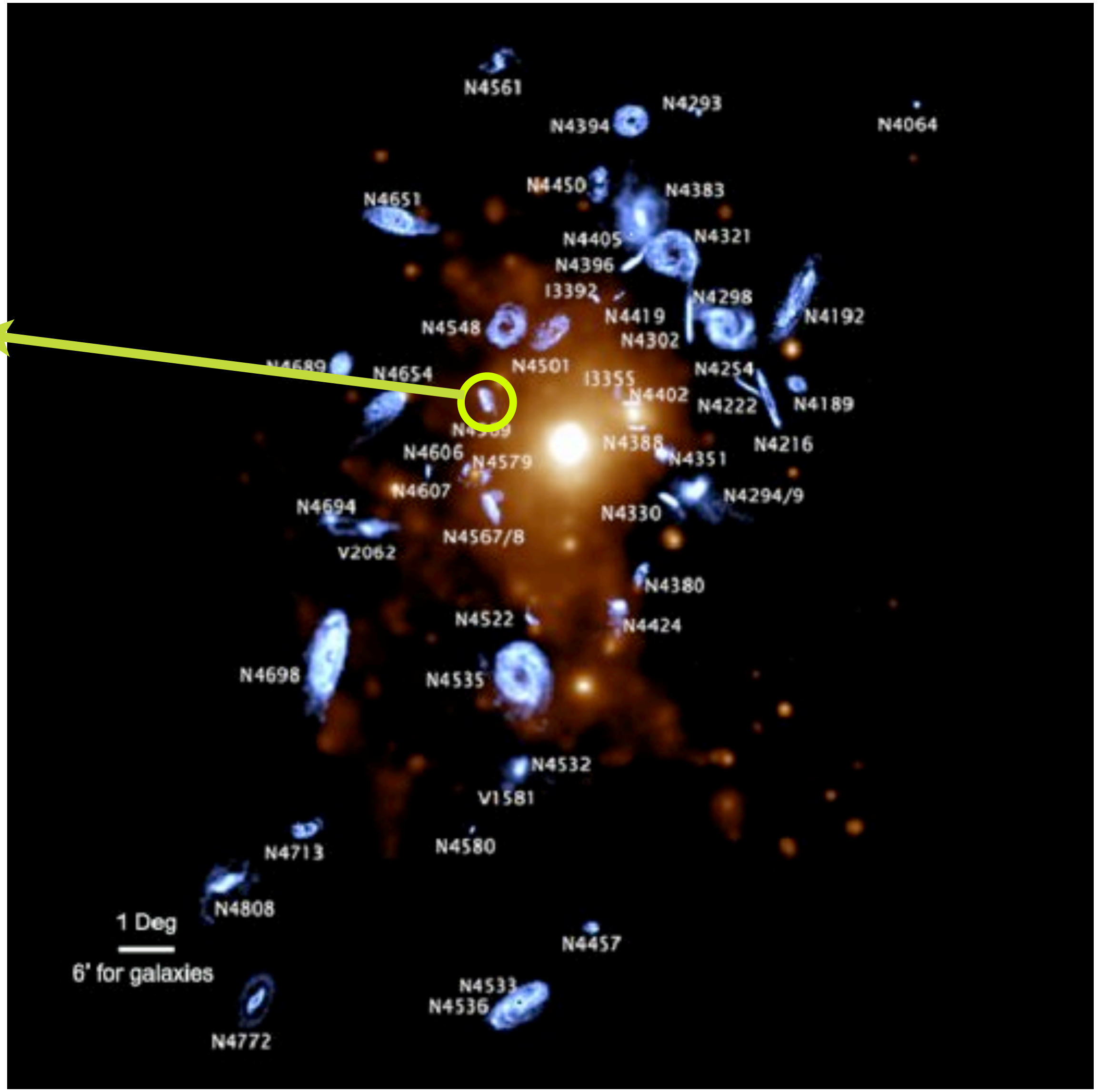


History by comparison of model and HI

- Vollmer et al. (2004)



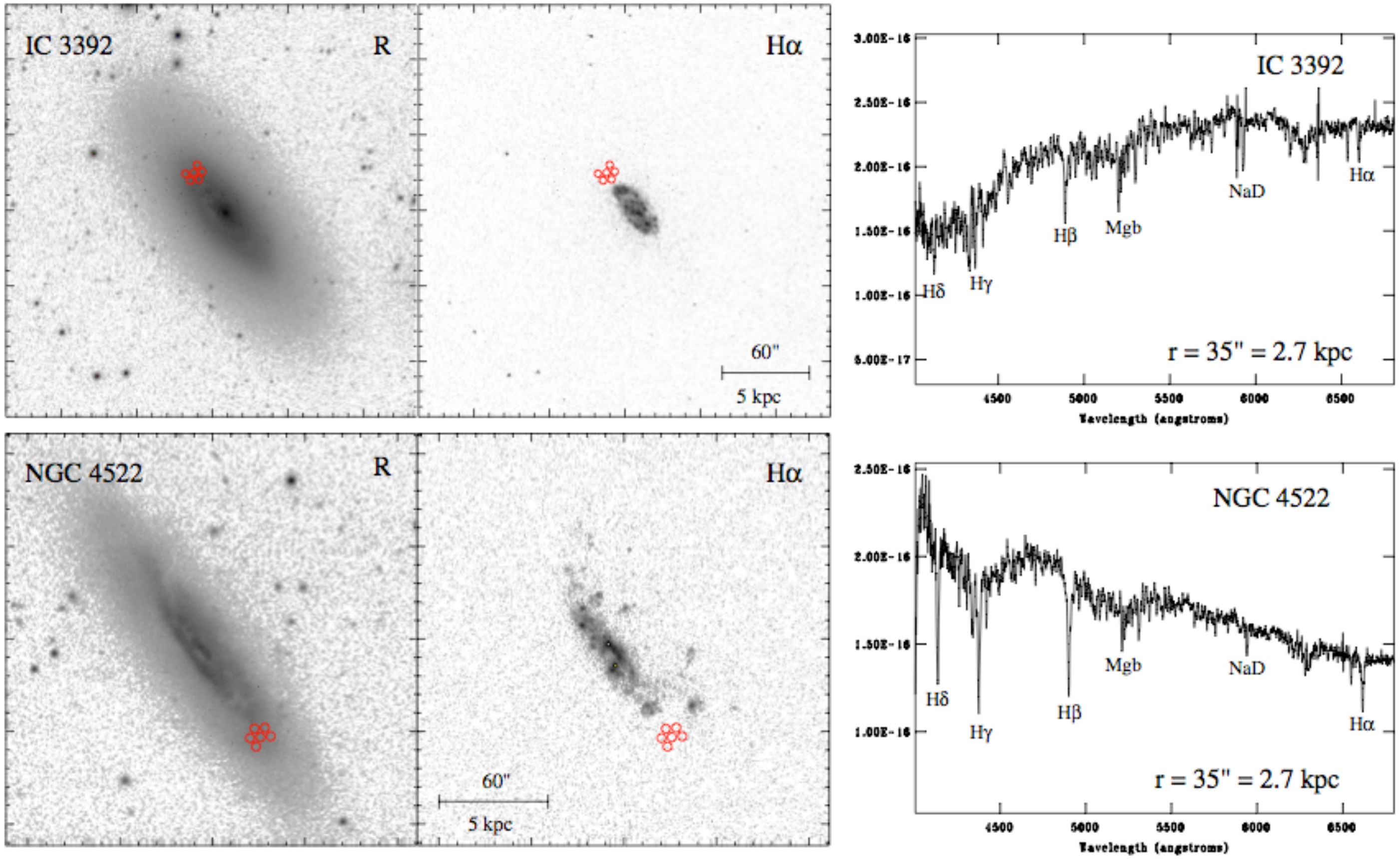
- The gas kinematics along its single-sided arm suggests gas falling back



SF quenching epoch at HI truncation radius

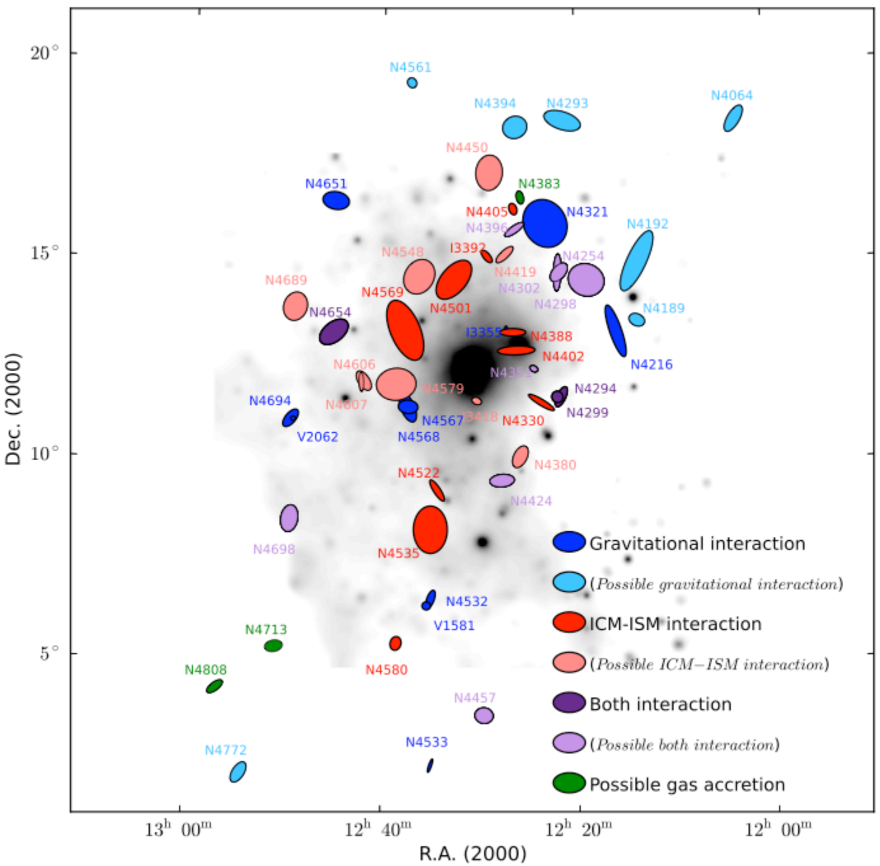
- Crowl & Kenney (2008)

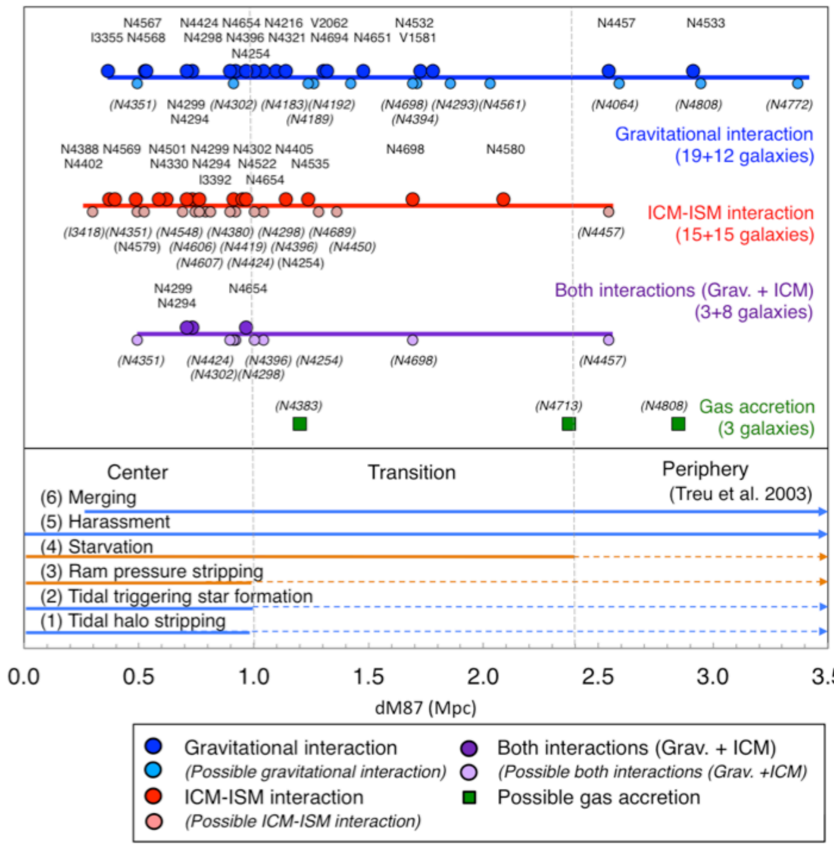
- SparsePak on WIYN 3.5m at HI truncation radii - stellar population synthesis model (starburst99) to measure the age of stars: t_q →Gas stripping timescale



VIVA galaxies & environmental effects

- Diagnosed by multi-wavelength data including HI (Hyein Yoon et al., in prep)

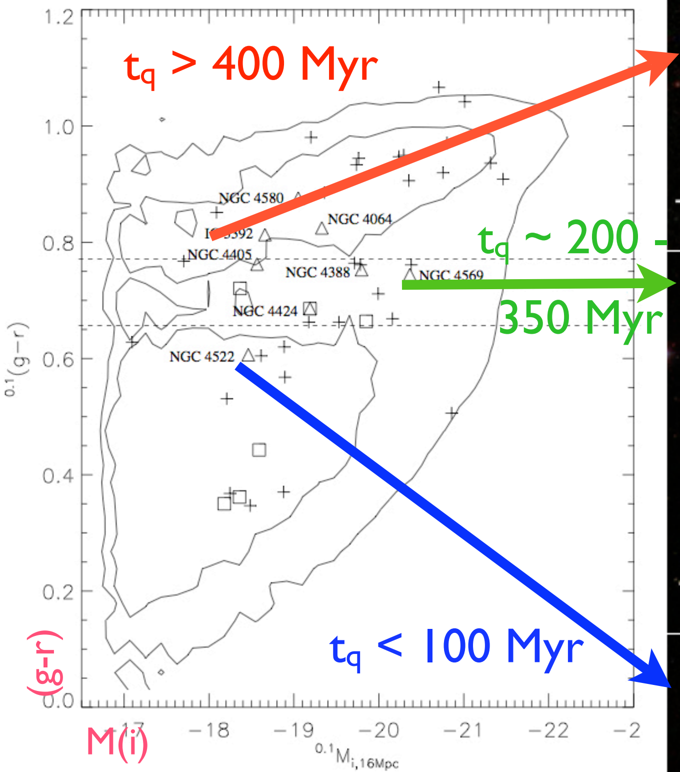


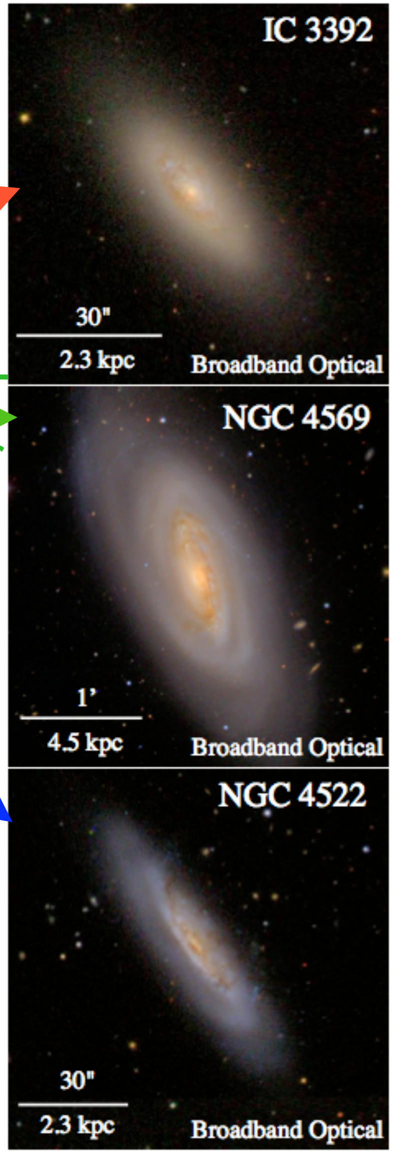


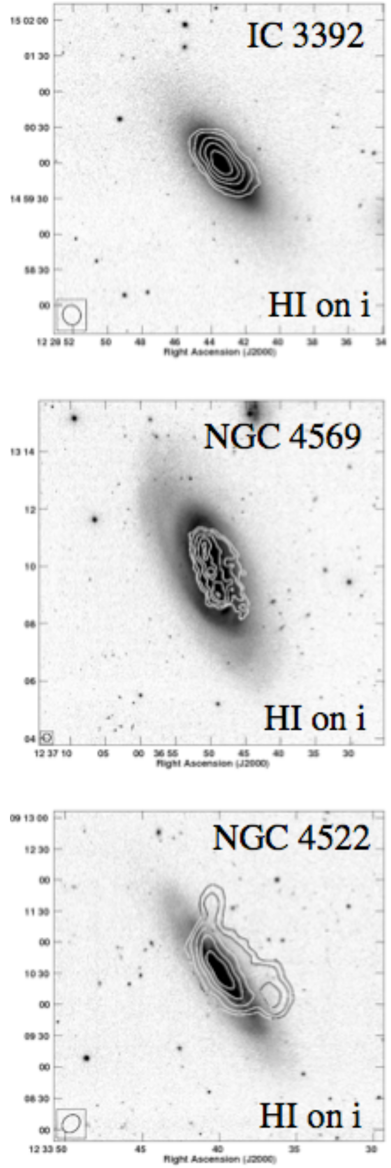
- Optical image + spectra (WIYN +), UV (GALEX), IR (Spitzer), etc. (J. H. van Gorkom, J. Kenney, H. Crowl, E. Murphy, D. Schiminovich, A. Abramson, S. Tonnesen, B. Vollmer, I. Wong +)

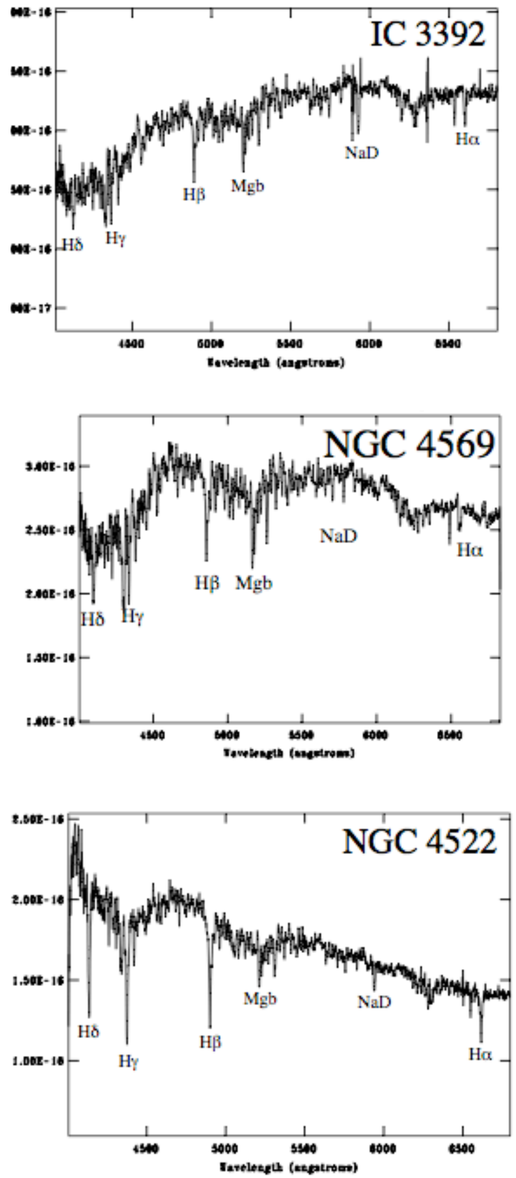
Color evolution of VIVA galaxies

CMD of VIVA on SDSS





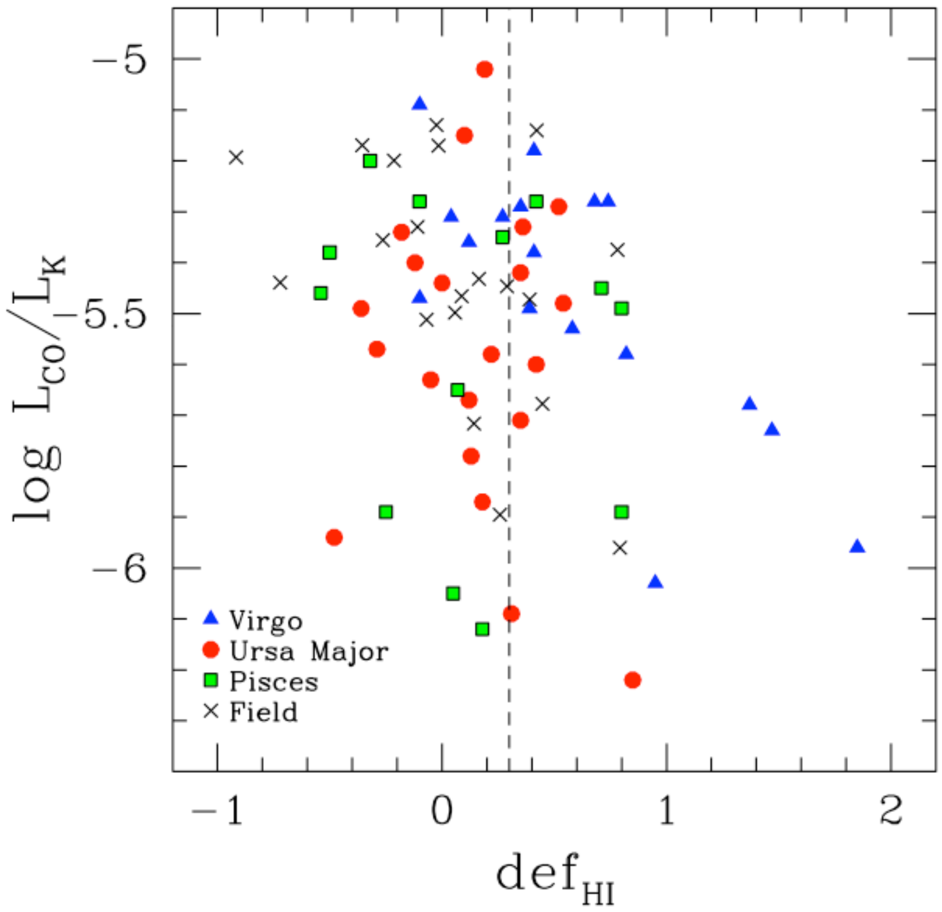




Contours: 140K+ SDSS (Blanton et al. 2003)
+ Cross: VIVA sample

HI stripping does everything?

- HI properties are found to be correlated with global color. However, molecular gas plays more important role in SF. Any signs of molecular gas stripping?

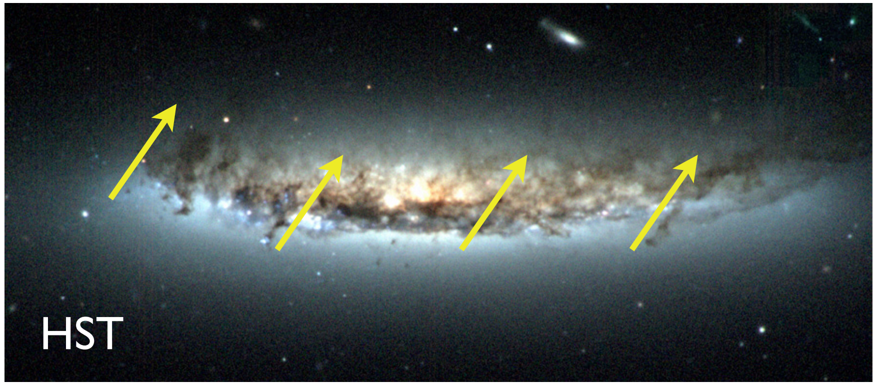


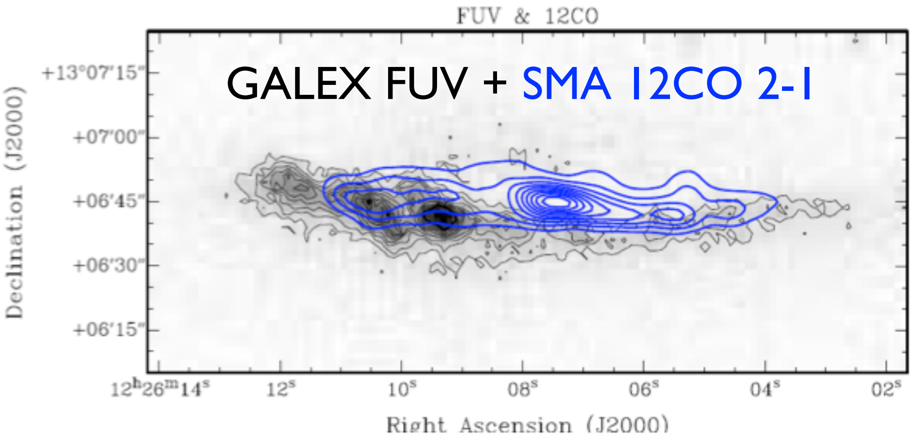
- Still under debate; we do not find any convincing evidence
- A range of L_{CO}/L_K for both HI deficient and HI normal galaxies (Eun-Jung Chung 2012, PhD Th)
- Hard to define how deficient galaxies are in CO in the same way as atomic hydrogen
- Then how HI stripped galaxies suppress forming stars?

Molecular gas properties in HI stripped disk

- NGC 4402

- Excess of CO emission along enhanced UV (and H-alpha)





- Molecular gas (and dust) distinct from normal Sp's

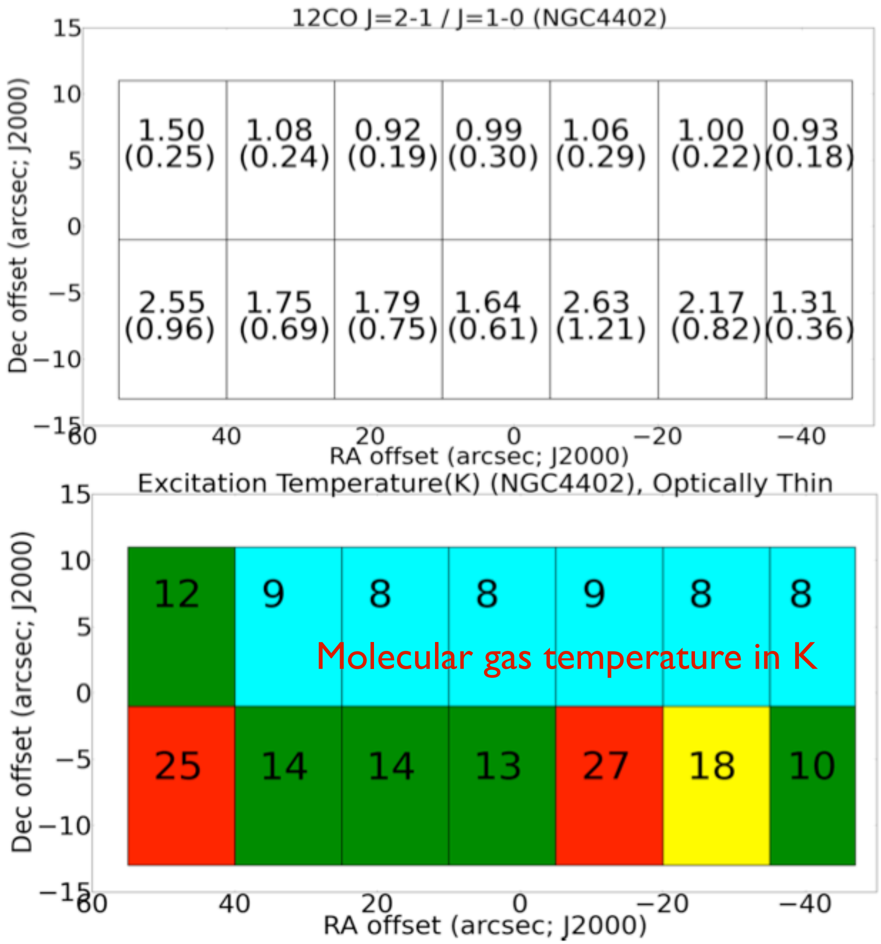
- SF enhanced along the HI compression (wind side)

- Even if the molecular gas does not get stripped, its properties may well be affected by the ICM.

Molecular gas properties in HI stripped disk

- NGC 4402

- Preliminary result by Bumhyun Lee (SMA CO 2-1 + Kuno's NRO 1-0 data)



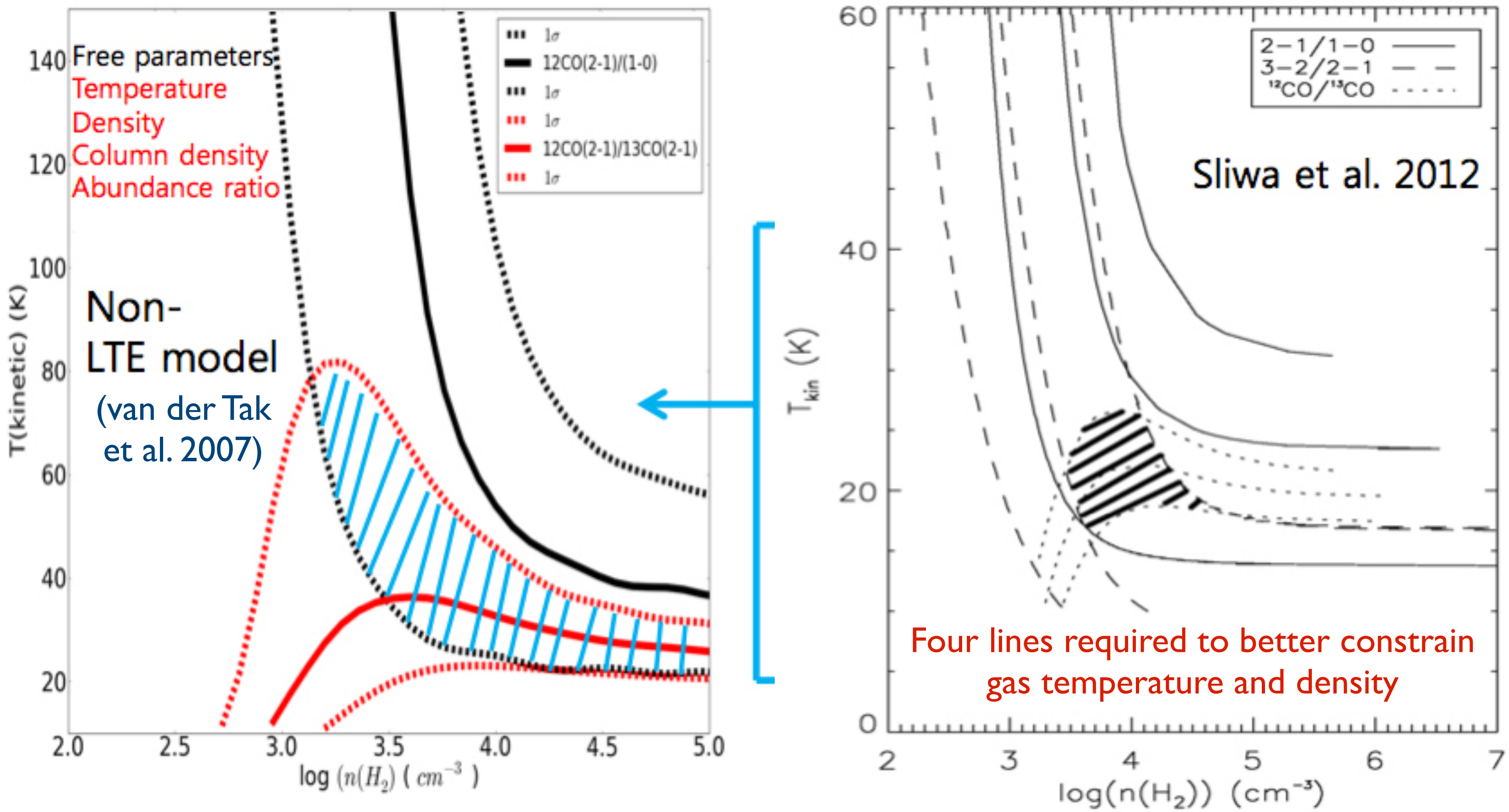
- LTE solution based on 12CO (1-0) & (2-1) line intensity

- What happens after enhanced star formation on wind side?

- Using line diagnostics, we will probe molecular gas temperature distribution and kinematics (ok to form stars?)

Molecular gas properties in HI stripped disk

- NGC 4402
  - Preliminary result by Bumhyun Lee (12CO 1-0, 2-1 & 13CO 2-1)



Molecular gas properties in HI stripped disk

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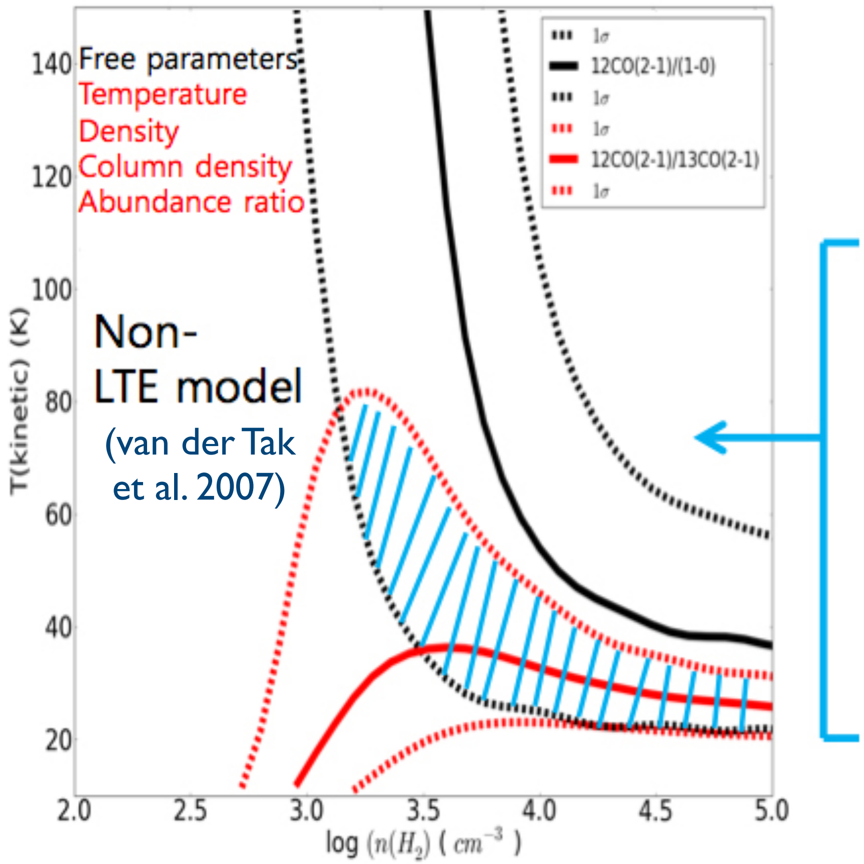
  - Preliminary result by Bumhyun Lee (NRO 12CO 1-0, SMA 2-1 & 13CO 2-1)



  - Non-LTE solution, work in prog.
  - IRAM 13CO 1-0 mapping data, recently obtained.

Summary

Environmentally Driven Galaxy Evolution: From a Gas Perspective

1. HI is a powerful tool to probe environmentally galaxy evolution.

2. HI gas properties are well correlated with global color of galaxies although it is less likely to be directly relevant to star formation activities.

3. No clear evidence for molecular gas stripping is found but molecular gas properties in galaxies undergoing strong ICM pressure are distinct from those of field galaxies, which is expected to affect star formation activities.

4. Cool/cold gas is important in galaxy evolution!

Thank you!

Any Questions?