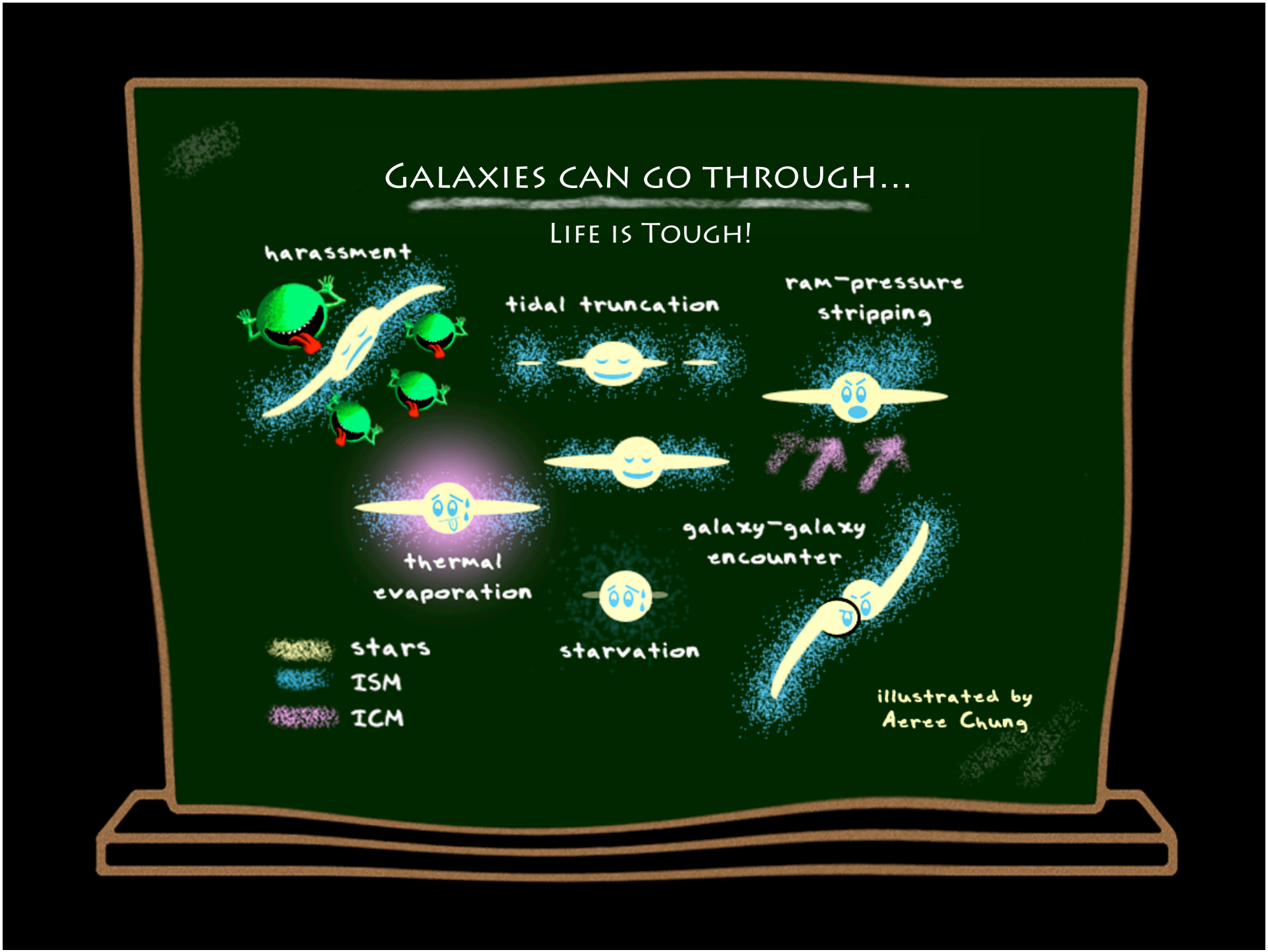
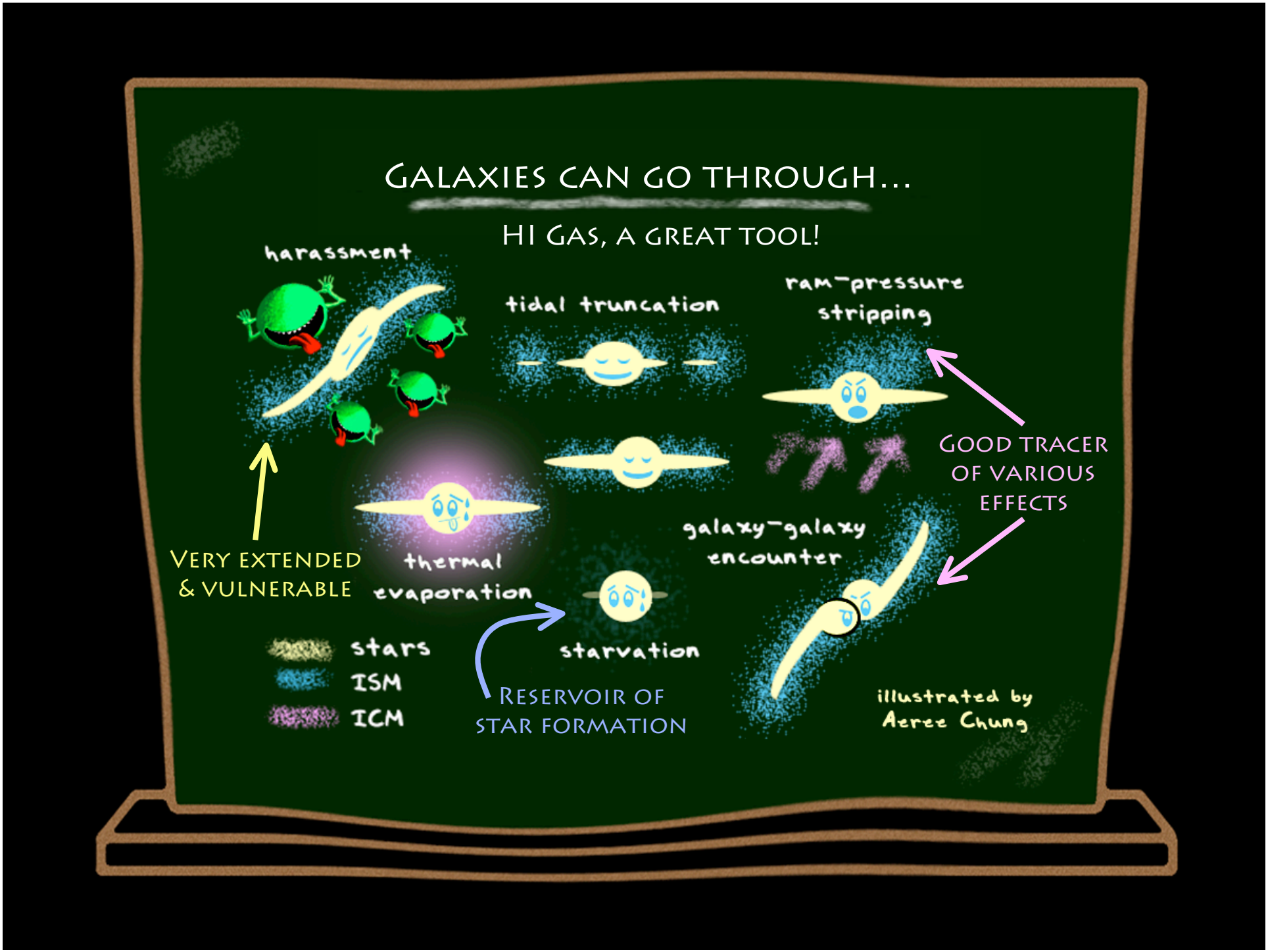
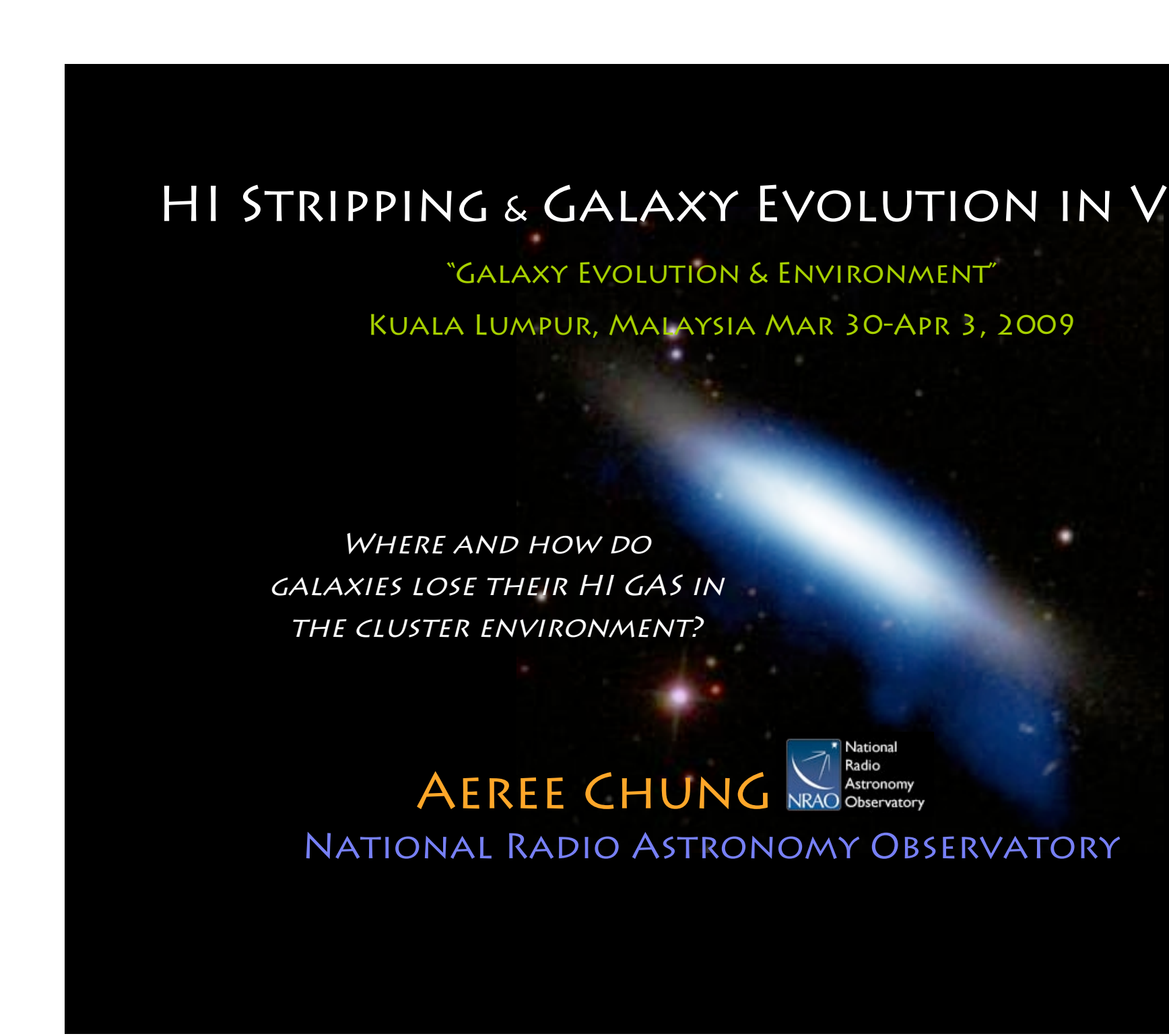

Galaxies can go through...
Life is Tough!
harassment
tidal truncation
ram-pressure stripping
thermal evaporation
galaxy-galaxy encounter
starvation
stars
ISM
ICM
illustrated by Aeree Chung


Galaxies can go through…
HI Gas, a great tool!
harassment
tidal truncation
ram-pressure stripping
Good tracer of various effects
Very extended & vulnerable
thermal evaporation
galaxy-galaxy encounter
starvation
stars
ISM
ICM
Reservoir of star formation
illustrated by Aeree Chung

HI Stripping & Galaxy Evolution in Virgo

"Galaxy Evolution & Environment"

Kuala Lumpur, Malaysia Mar 30-Apr 3, 2009



Where and how do galaxies lose their HI gas in the cluster environment?

Aeree Chung

National Radio Astronomy Observatory

VIVA, VLA Imaging of Virgo galaxies in Atomic gas

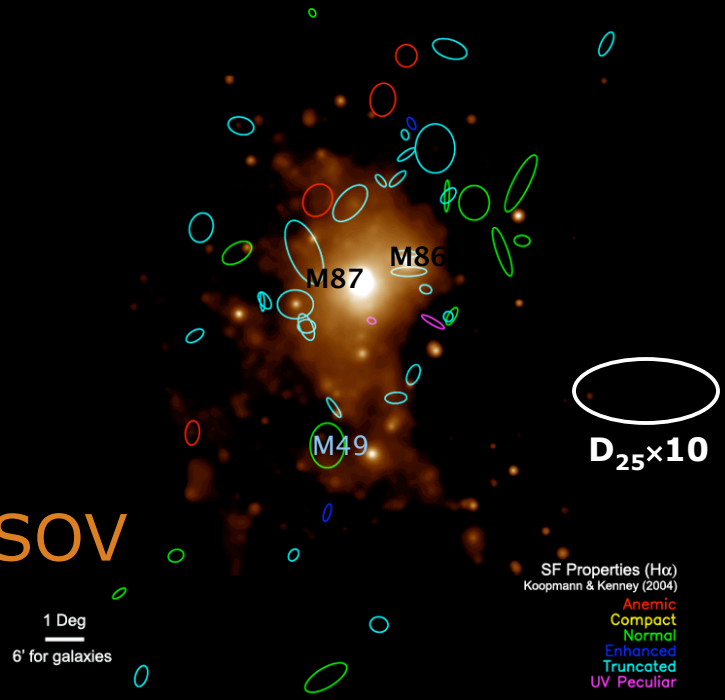
Probe the environmental effects at a range of density regions using the HI morphology and kinematics:
By which effect(s) do galaxies get affected and how far out does the impact of the cluster reach?

VIVA

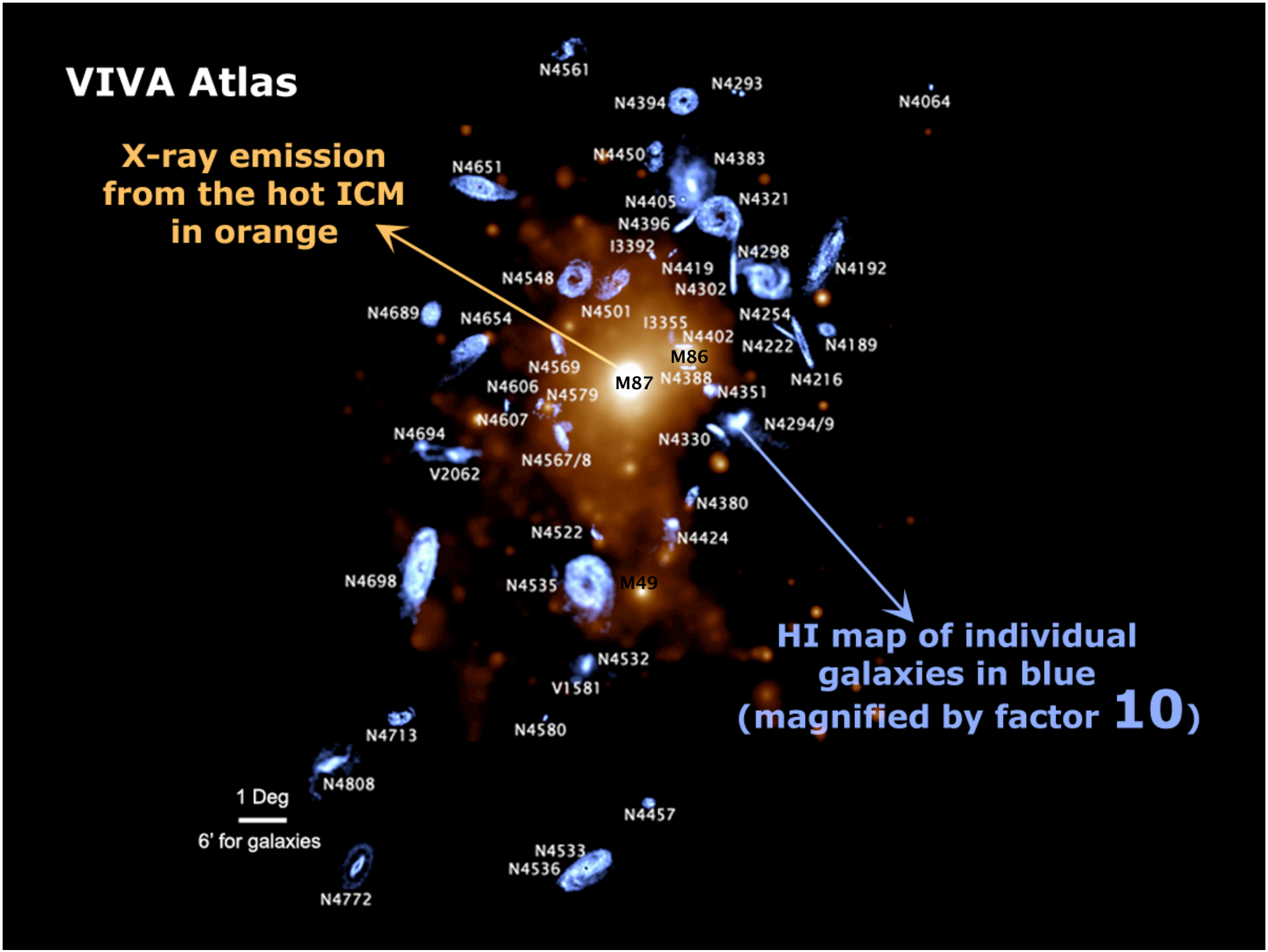
Jacqueline van Gorkom (Columbia)
Jeffrey Kenney (Yale)
Bernd Vollmer (CDS)
Hugh Crowl (UMass)

+ multiwave/follow-up

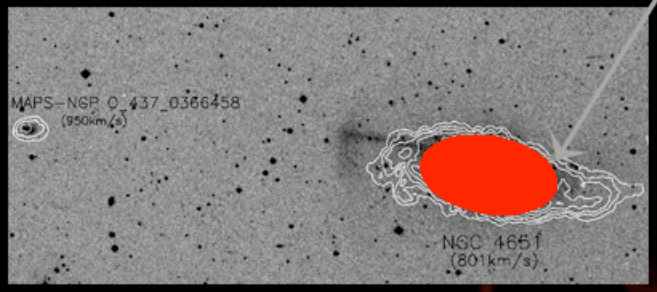
David Schiminovich (Columbia)
Tomer Tal (Yale)
Anne Abramson (Yale)
Eric Murphy (CalTech)
Ivy Wong (Yale) → SPITSOV
Tom Oosterloo (ASTRON)
Juan Cortes(U Chile)

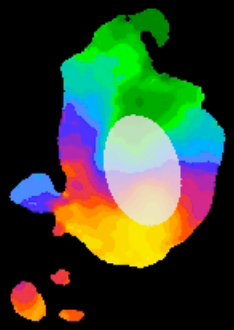


- ✓ 53 Galaxies showing various star formation properties have been selected throughout the cluster from near the dense core to the outskirts
- ✓ Observations were done in CS array, complemented by the archival data (resolution~1.1 kpc, sensitivity: 3-5x10^{19} cm^{-2} in 3s per 10km/s)


VIVA Atlas
X-ray emission from the hot ICM in orange
HI map of individual galaxies in blue (magnified by factor 10)
N4561
N4293
N4394
N4064
N4450
N4383
N4651
N4405
N4321
N4396
I3392
N4298
N4419
N4192
N4548
N4302
N4501
N4254
N4689
N4654
I3355
N4402
N4222
N4189
M86
N4569
M87
N4388
N4216
N4606
N4579
N4351
N4607
N4294/9
N4694
N4330
N4567/8
V2062
N4380
N4522
N4424
N4698
N4535
M49
N4532
V1581
N4713
N4580
N4808
1 Deg
6' for galaxies
N4457
N4533
N4536
N4772

Low Density Outskirts (I)





1 Deg

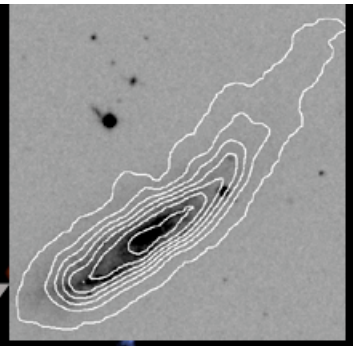
6' for galaxies

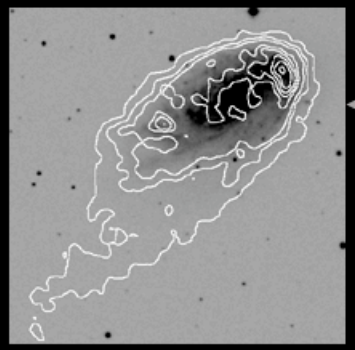
1. Large D_{HI}/D_{opt}
2. Tails, dwarfs, rings
3. Kinematical peculiarities

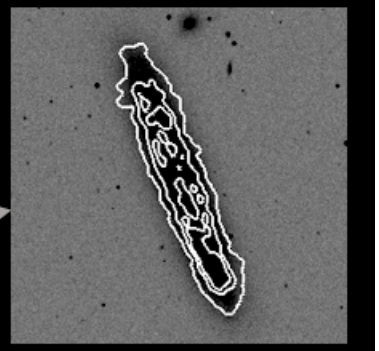
→ **Galaxy-galaxy interactions and gas accretion**

Intermediate Density Regions

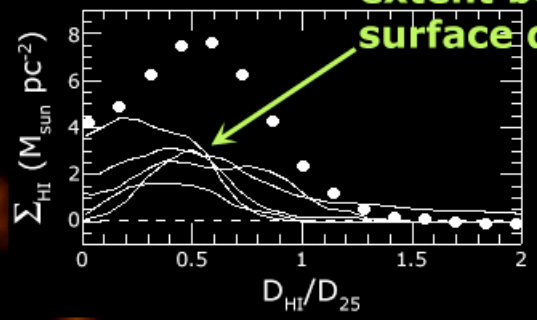
1. Extended one-sided HI tails
   (with/without stellar counterpart)







Similar HI to optical extent but low HI gas surface density



2. Fairly symmetric HI disks with a similar extent as stellar disks and low HI gas surface density

→ Radially falling galaxies start loosing their HI gas through ram-pressure stripping. The tidal field due to neighboring galaxies can accelerate this process in the outer disk.

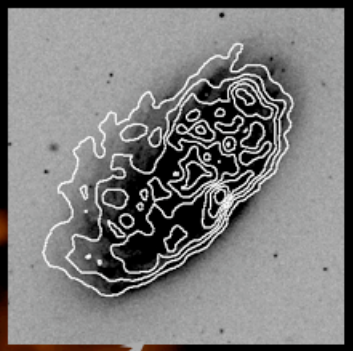
1 Deg

6' for galaxies

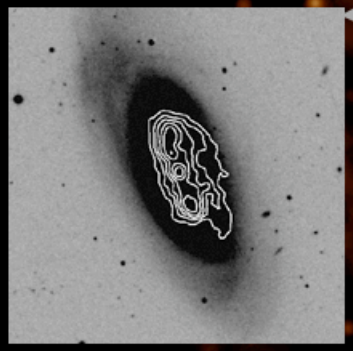
→ More circularly orbiting ones loose their HI gas through slower ICM-ISM interactions e.g. thermal evaporation.

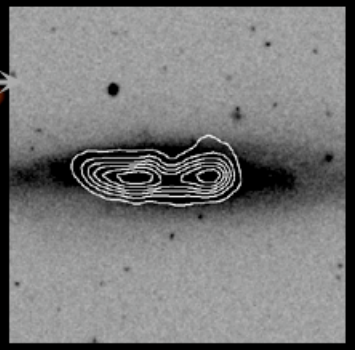
High Density Regions & its Boundary

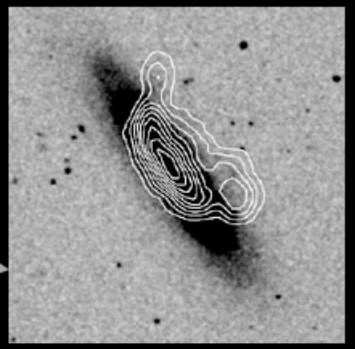
1. Entering: extended HI tails disappear and HI truncation starts more globally within the steller disk.



2. Near the dense core: HI is severly stripped and highly asymmetric as the galaxy is undergoing peak ICM pressure.







4. After core crossing: most of the HI has been stripped but some of the stripped HI gas can be falling back onto the galaxy moves out to the lower density environment.

3. Active ram-pressure stripping at a large distance from M87?
: dynamic ICM (kenney et al. 2004)

1 Deg

6' for galaxies

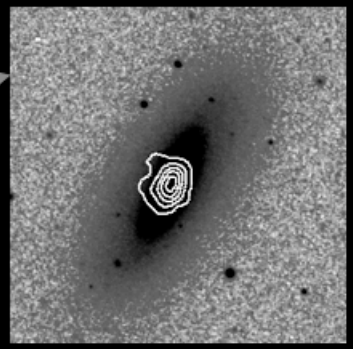
→ **HI disks are highly asymmetric and much smaller than the stellar disks: the impact of ICM-ISM interactions peaks near the cluster center**

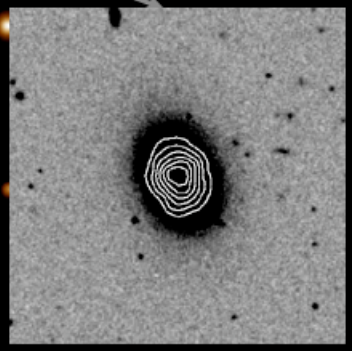
Low Density Outskirts (II)

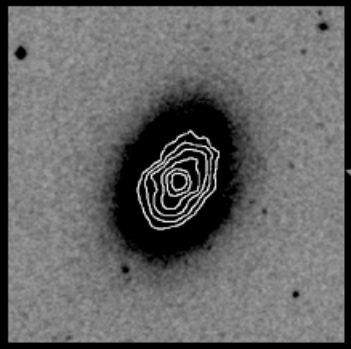
Severely HI stipped with minor asymmetries

1. HI stripping in the center during the core crossing

BUT some of these galaxies are likely to contain enough gas for star formation till RECENTLY! (H. Crowl)





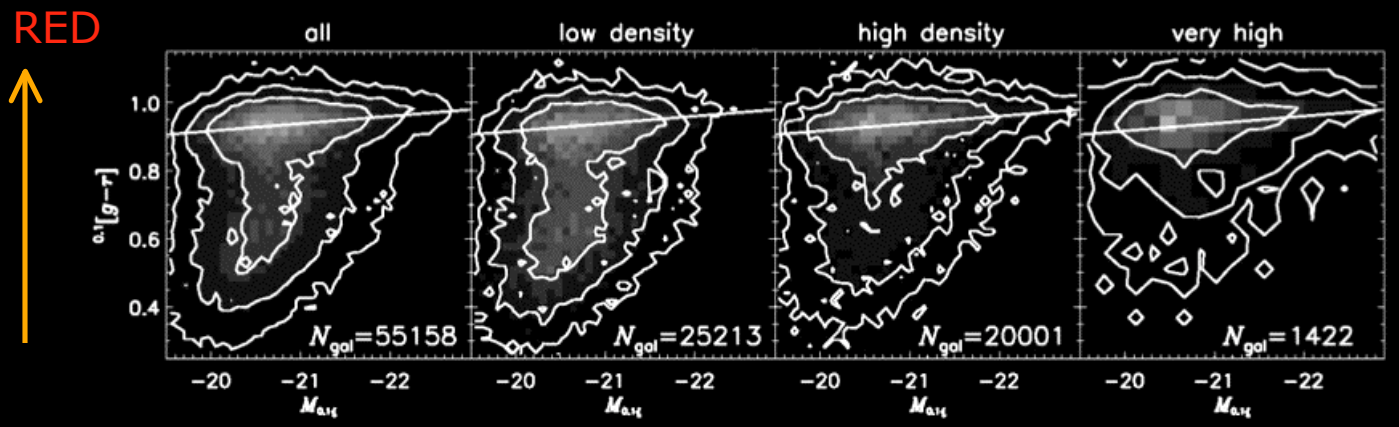


2. Ram-pressure stripping may occur with various strength, affecting galaxies far in the cluster periphery (Tonnesen et al. 2007).

1 Deg

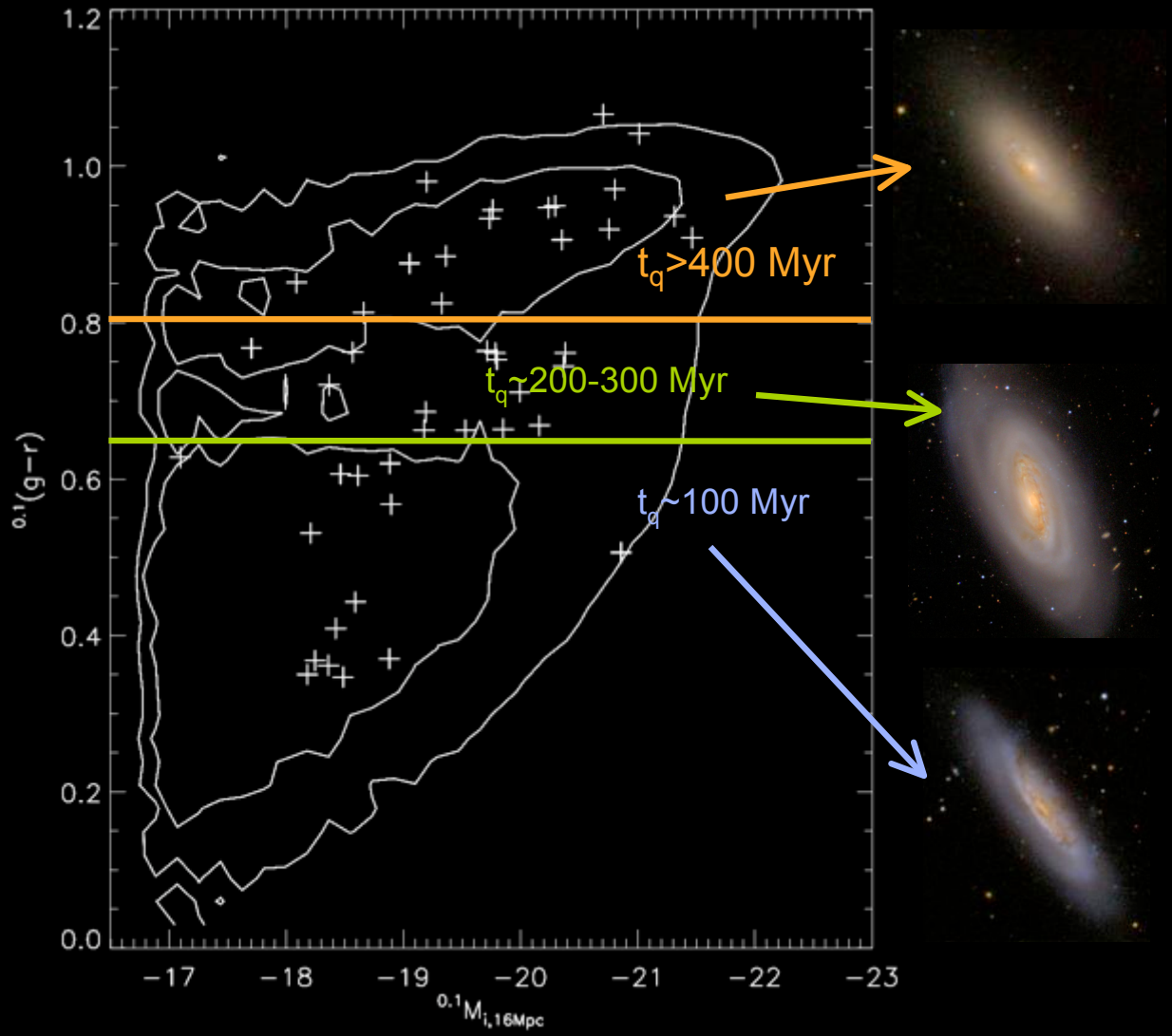
6' for galaxies

ISM Stripping & Color Evolution



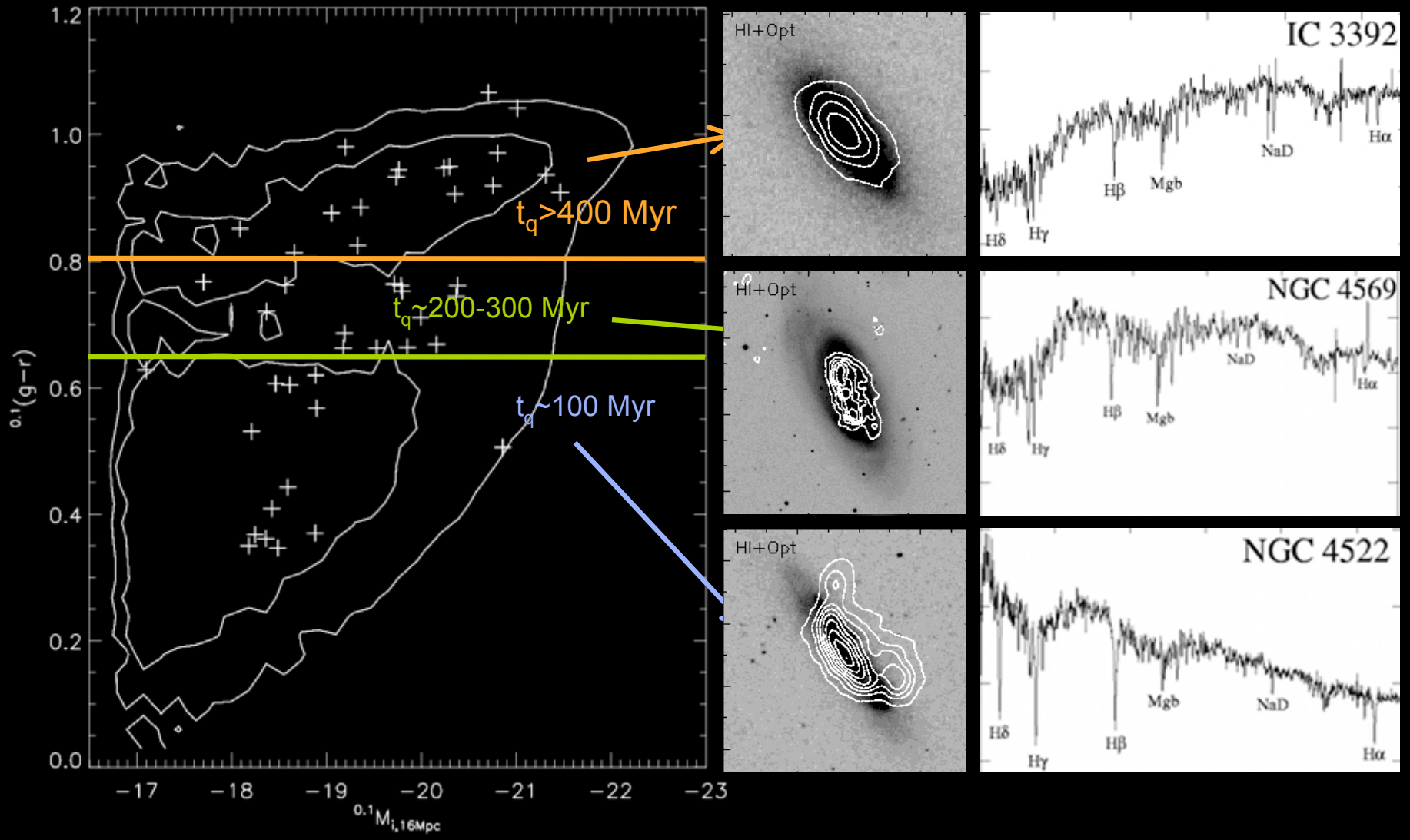
- ✓ Higher fraction of red galaxies in high density regions (Hogg et al. 2004): AGN? Mergers? ISM stripping?
- ✓ The VIVA sample is a good sample to inspect the impact of gas stripping on the color evolution of galaxies in clusters
- ✓ Any correlation between the HI properties and the color?

Color-Magnitude Diagram of VIVA Sample



Contour: 140K+ SDSS Galaxies (Blanton et al. 2003) / Cross: VIVA sample (Crowl, Chung, Schiminovich, et al. 2009 in preparation)

Color-Magnitude Diagram of VIVA Sample



Contour: 140K+ SDSS Galaxies (Blanton et al. 2003) / Cross: VIVA sample (Crowl, Chung, Schiminovich, et al. 2009 in preparation)

Summary

1. HI rich (extended) galaxies are always found in the cluster outskirts
2. HI disk is always truncated within stellar disk in the cluster center
3. At intermediate distances, we find a range of HI stripping stages and we do see the GAS LEAVING the disk

   - ✓ Some are at the right distance where the ICM pressure is just high enough to strip the HI in the outer disk
   - ✓ Even at the distance where the estimated ICM pressure (based on the smooth ICM distribution) is too low to strip the HI gas, a) the tidal field due to neighboring galaxies or b) non static ICM can accelerate the HI stripping

4. We find star formation quenching time scale to be correlated with HI deficiency and morphology: evidence that gas stripping affects color evolution in the cluster environment

The End


N4561
N4293
N4394
N4064
N4450
N4383
N4651
N4405
N4321
N4396
I3392
N4298
N4419
N4192
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N4689
N4654
N4501
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N4402
N4222
N4189
N4569
N4606
N4579
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N4694
N4330
N4567/8
V2062
N4380
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N4698
N4535
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1 Deg
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N4457
N4533
N4536
N4772