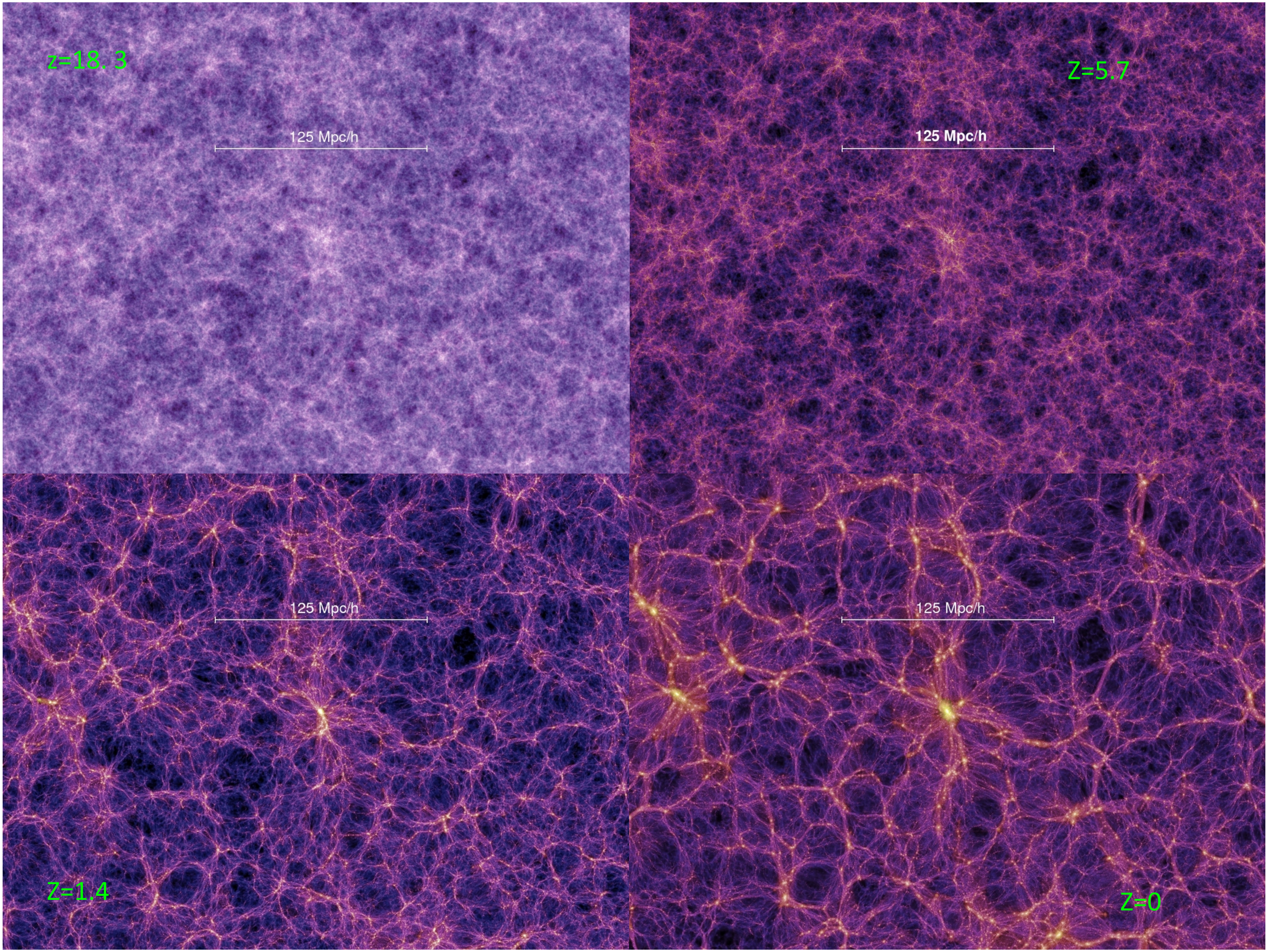
HI Imaging Surveys

Gas and Galaxy Evolution in Different Environments

VLA, WSRT, EVLA, Apertif, ATA, MeerKat, ASKAP, SKA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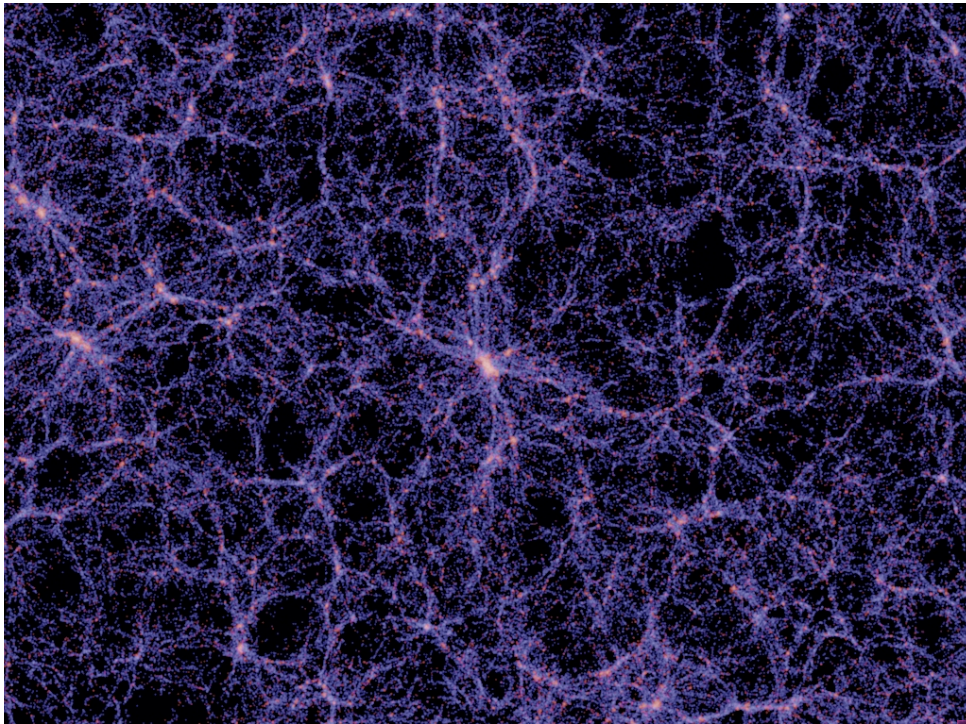
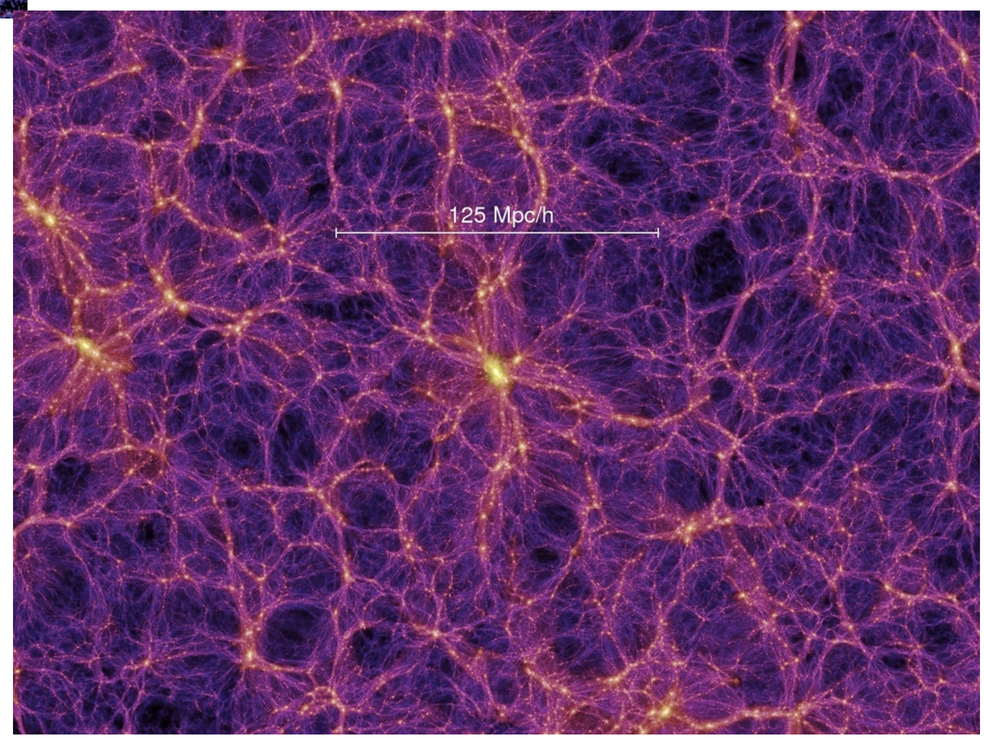
125 Mpc/h
Z=5.7
125 Mpc/h
125 Mpc/h
Z=1.4
125 Mpc/h
Z=0



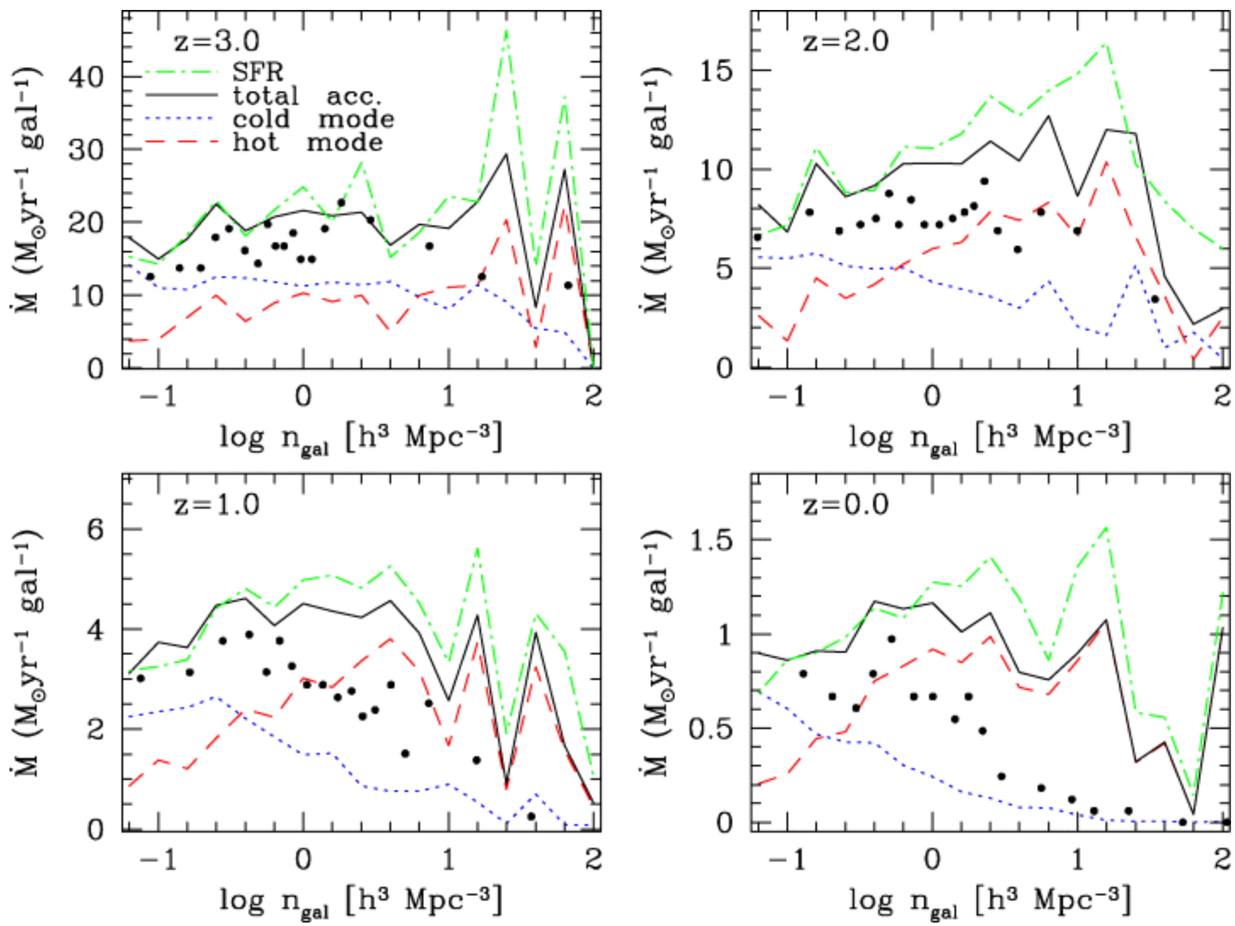
light

Dark matter



Best chance to see ongoing cold gas accretion at z=0 appears to be in low density regions

Keres et al, 2005, MNRAS 363, 2



An HI survey of VOID galaxies

Kathryn Kreckel (Stanonik), Erwin Platen, Burcu Beygu, Miguel Aragon-Calvo

JvG, van de Weygaert, van der Hulst, Peebles, Kovacs, Yip

Select galaxies in the deepest under densities of SDSS selected voids

Use new WSRT backend that probes large instantaneous velocity range

But, how do we find the voids???

Rien van Weygaert, Bernard Jones,

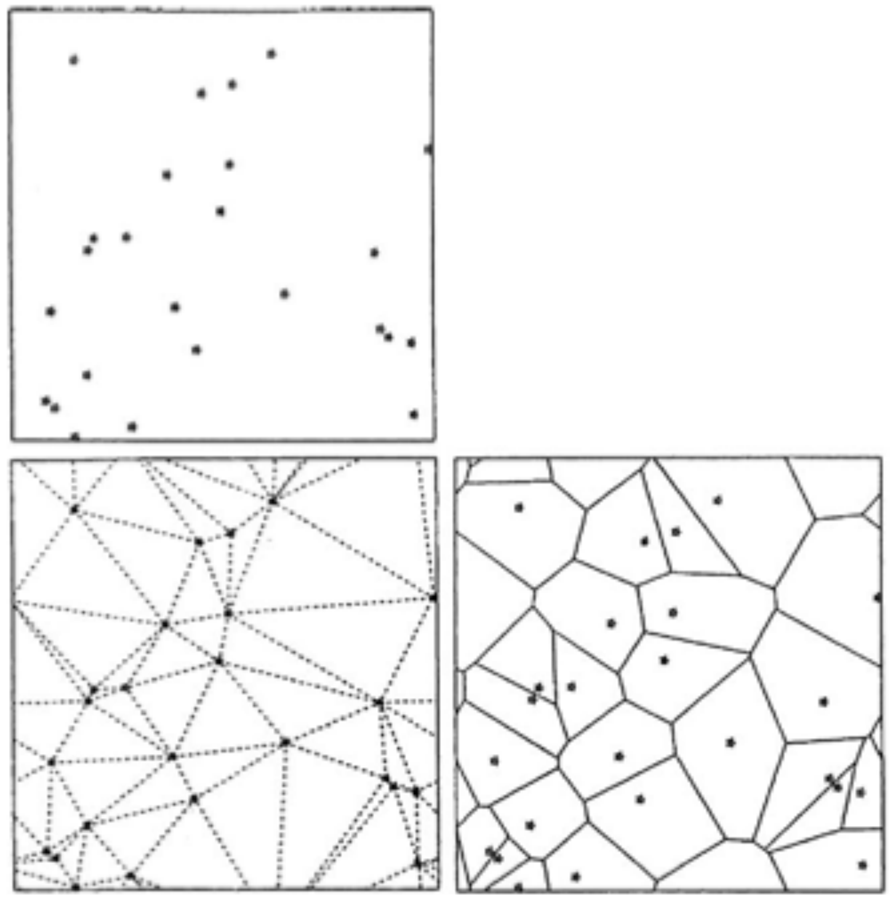
Willem Schaap, Erwin Platen, Miguel Aragon-Calvo

Good reviews in:

Van de Weygaert et al 2009, astroph 0912.3448

van de Weygaert and Schaap 2009,

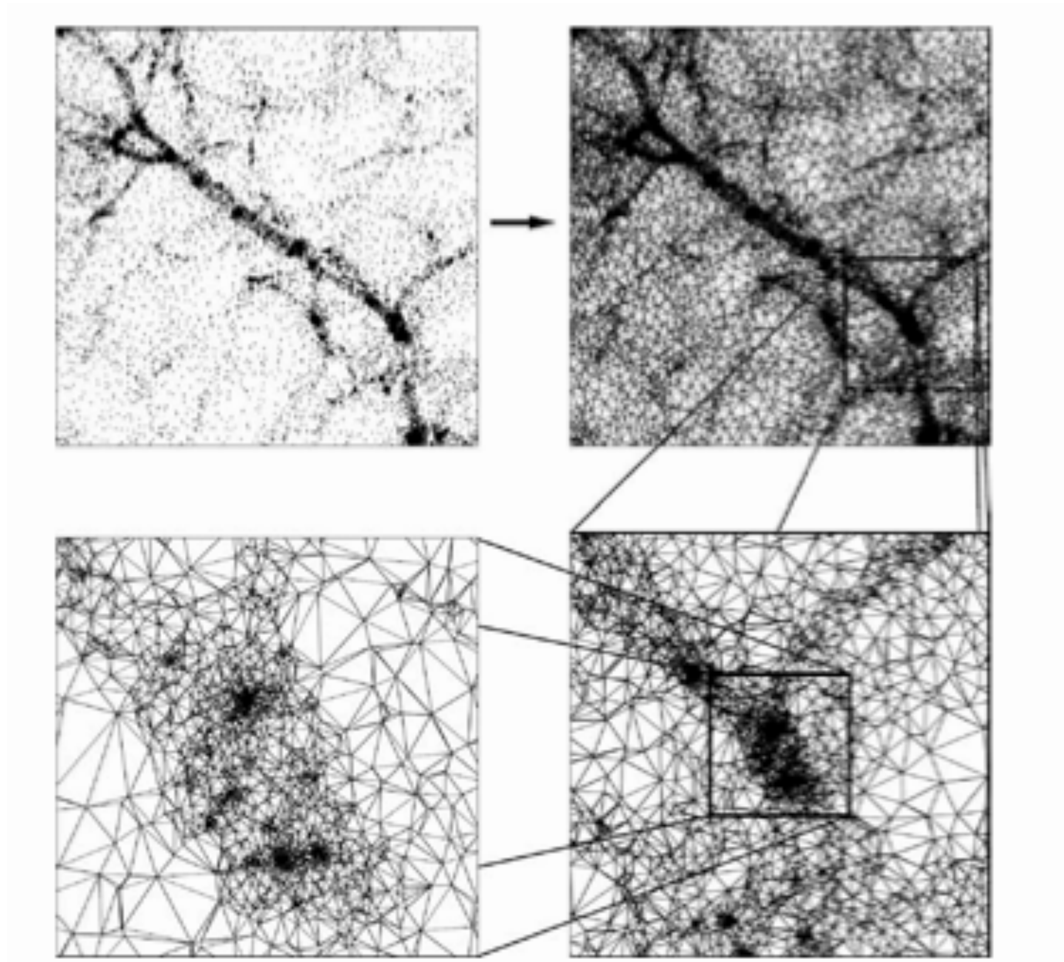
Discretely sampled irregular distribution of point Continuous field



Delaunay triangulation Voronoi tessellation

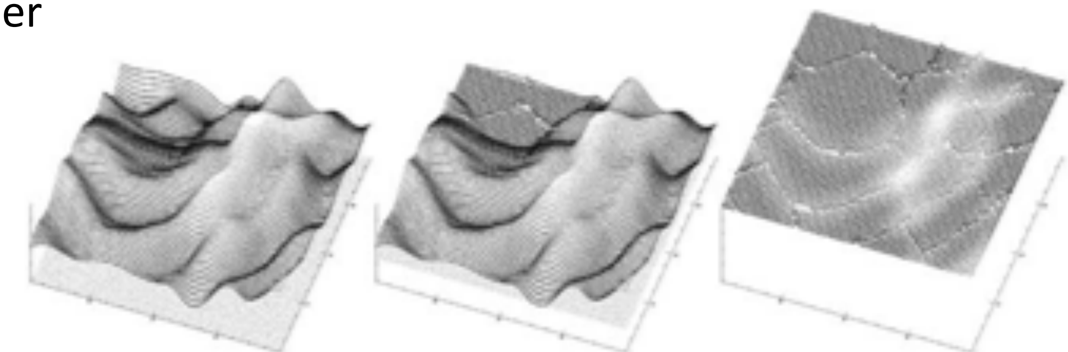
Tesselations as a means of estimating and interpolating discrete point sample into continuous field reconstructions…. Delaunay Tesselation Field Estimator (DTFE)

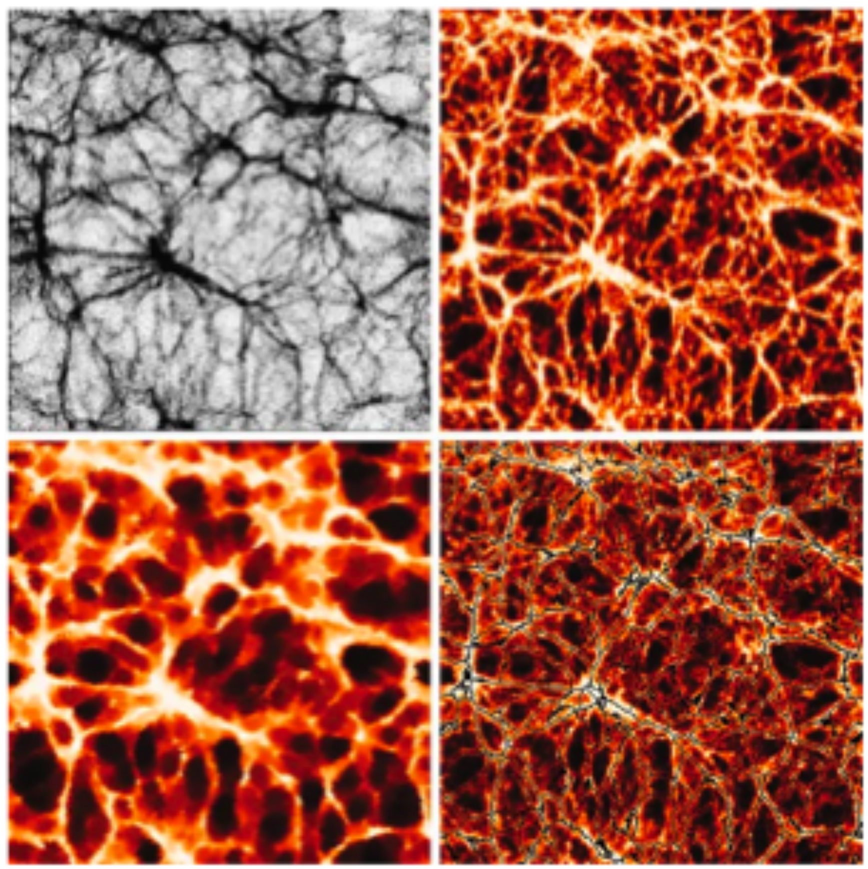
Simulated LSS

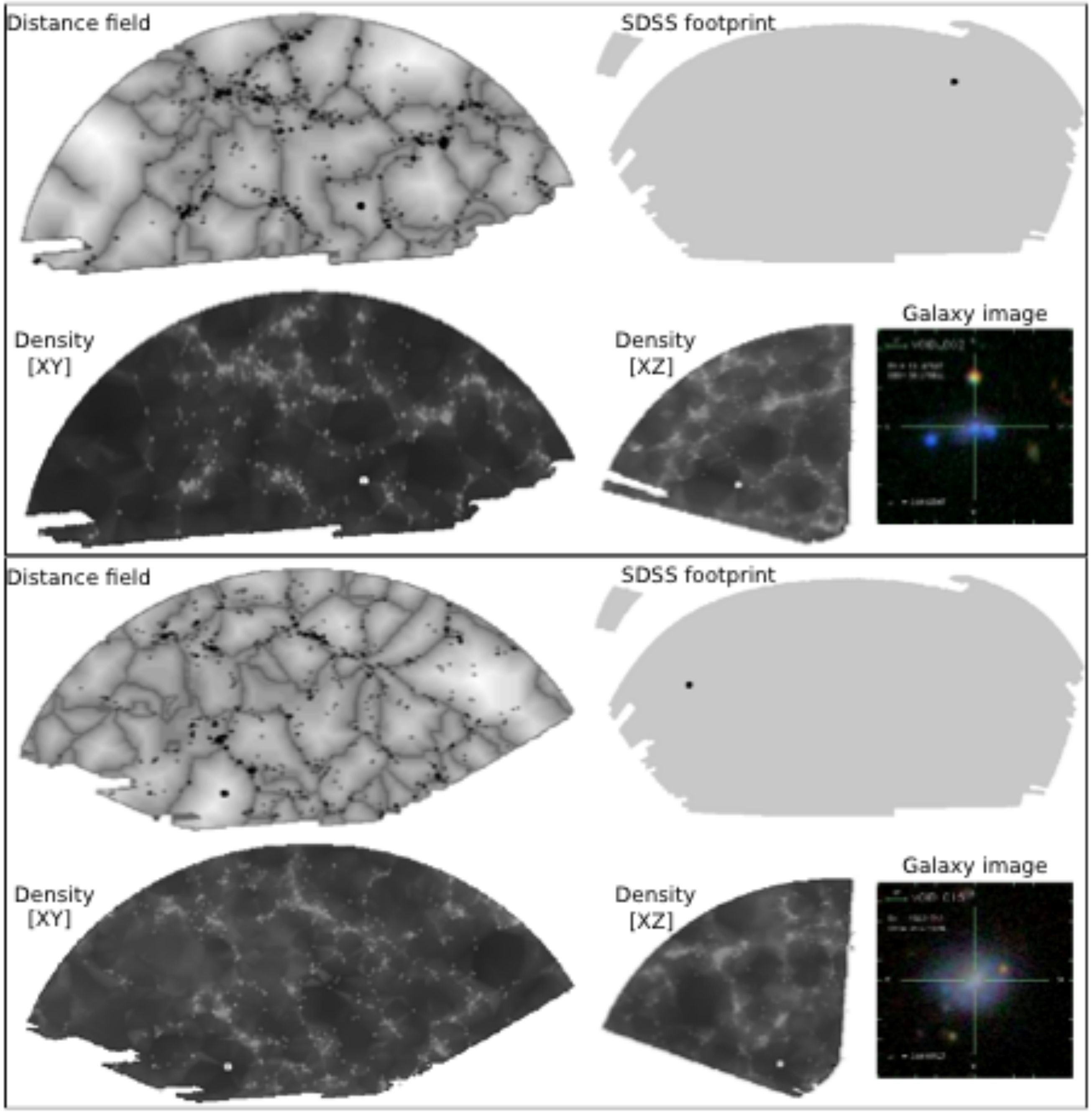


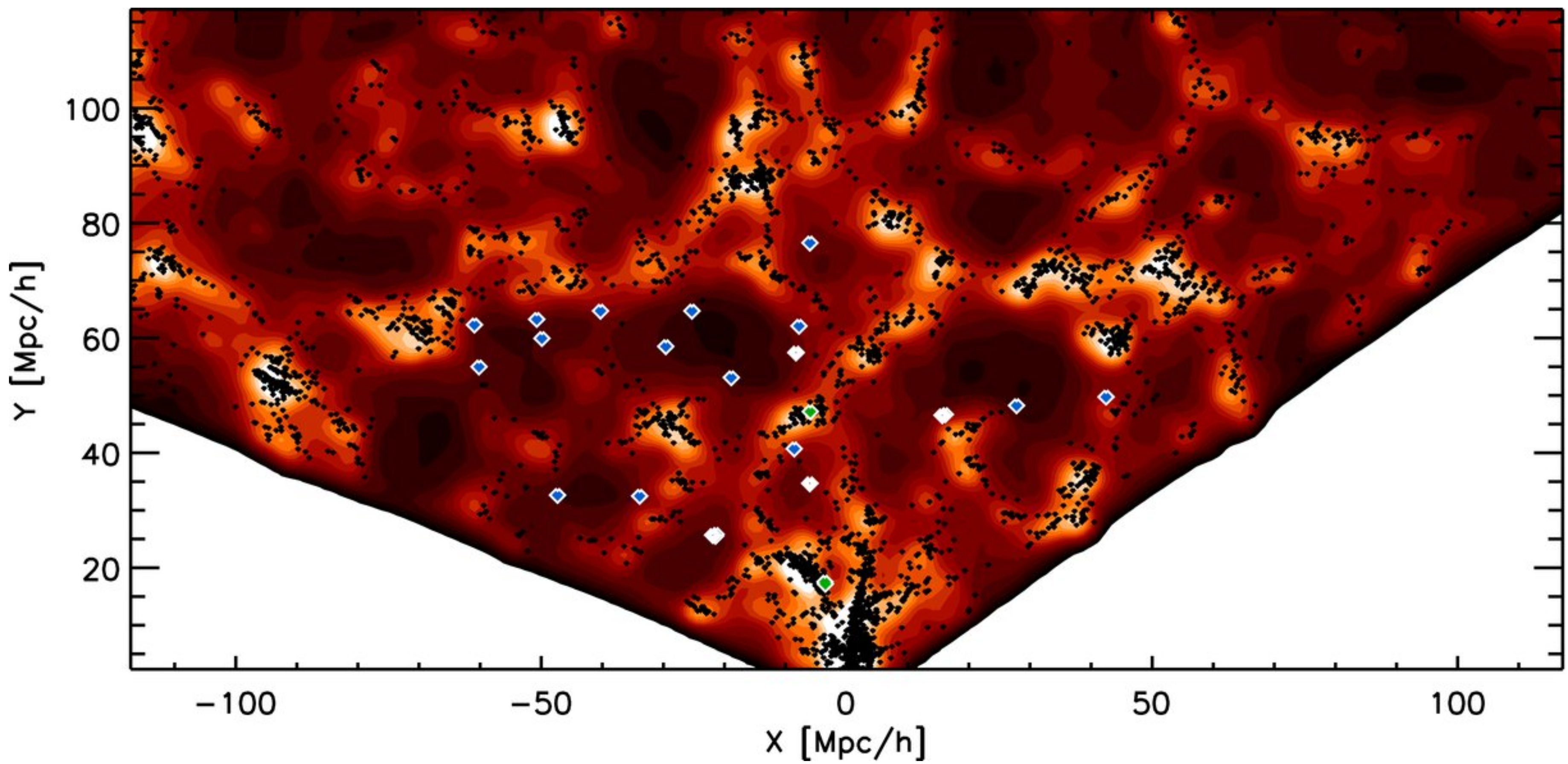
Recovered density field using DTFE

Watershed Void Finder

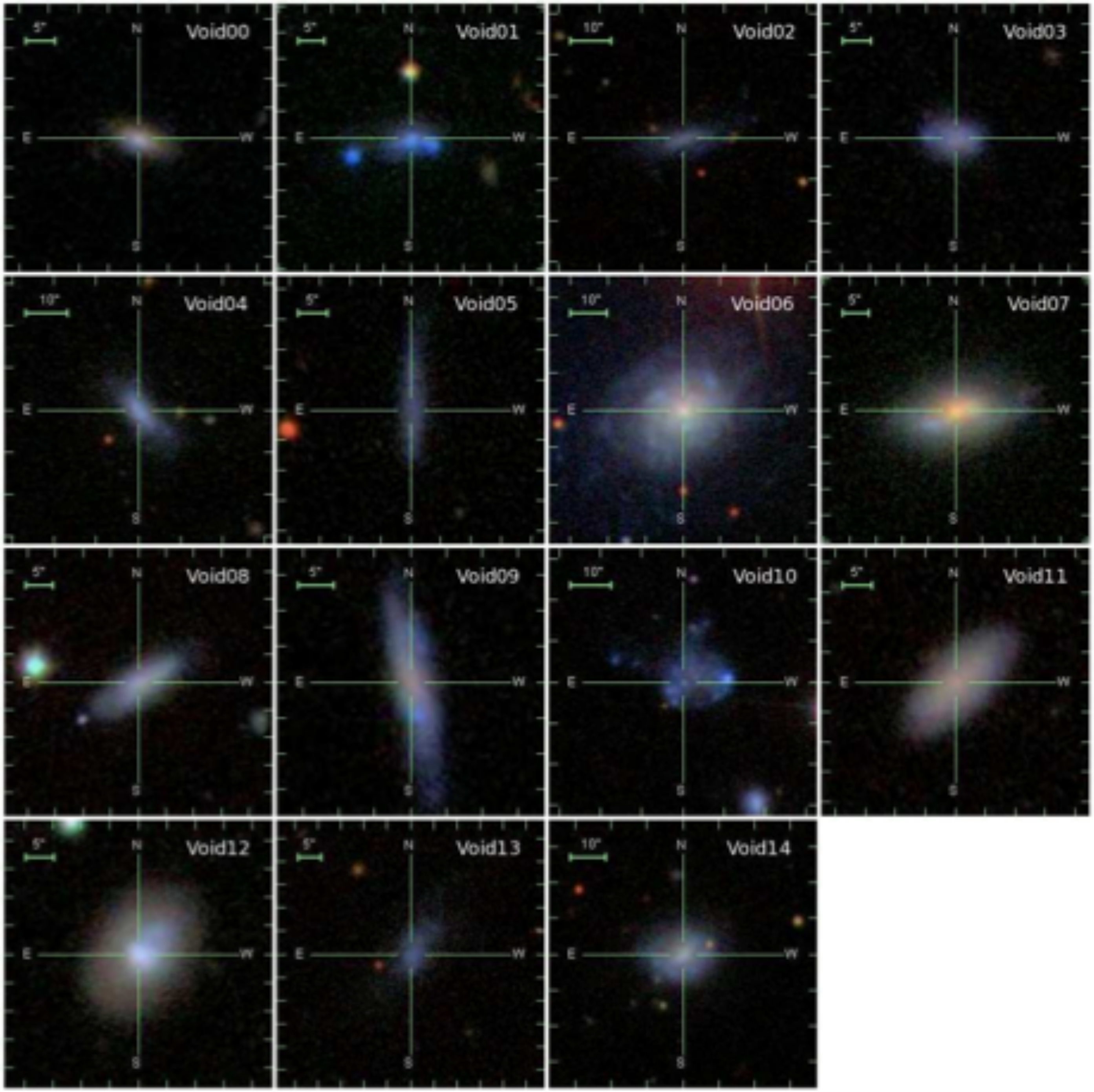


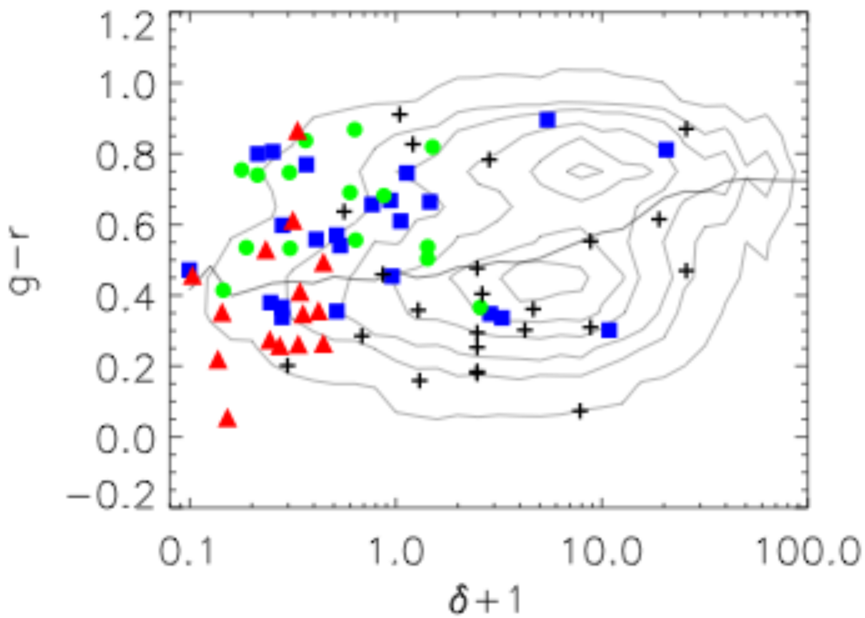



Distance field
SDSS footprint
Density
[XY]
Density
[XZ]
Galaxy image
Distance field
SDSS footprint
Density
[XY]
Density
[XZ]
Galaxy image



Reconstructed density field, black SDSS, diamond void galaxies, green control sample


Void00
Void01
Void02
Void03
Void04
Void05
Void06
Void07
Void08
Void09
Void10
Void11
Void12
Void13
Void14

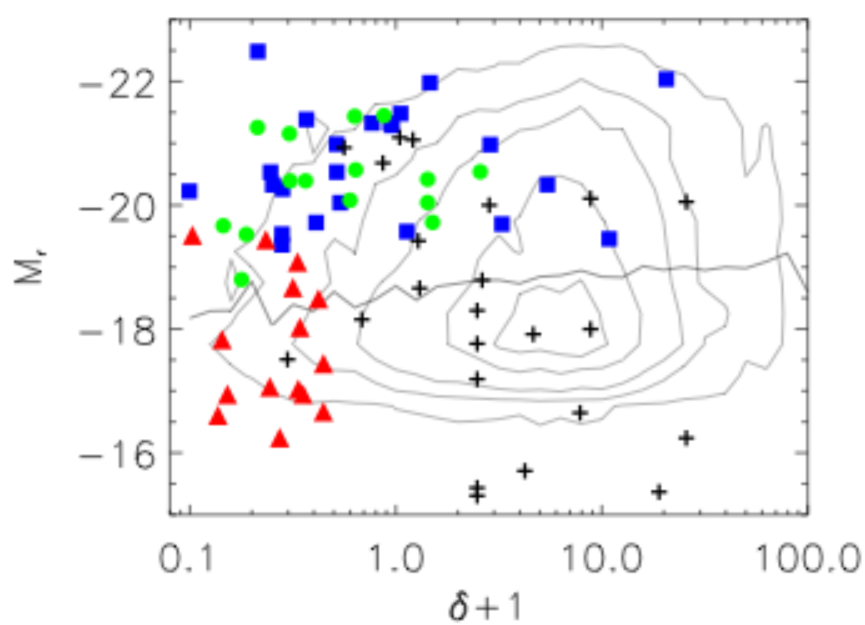


Red triangle void sample

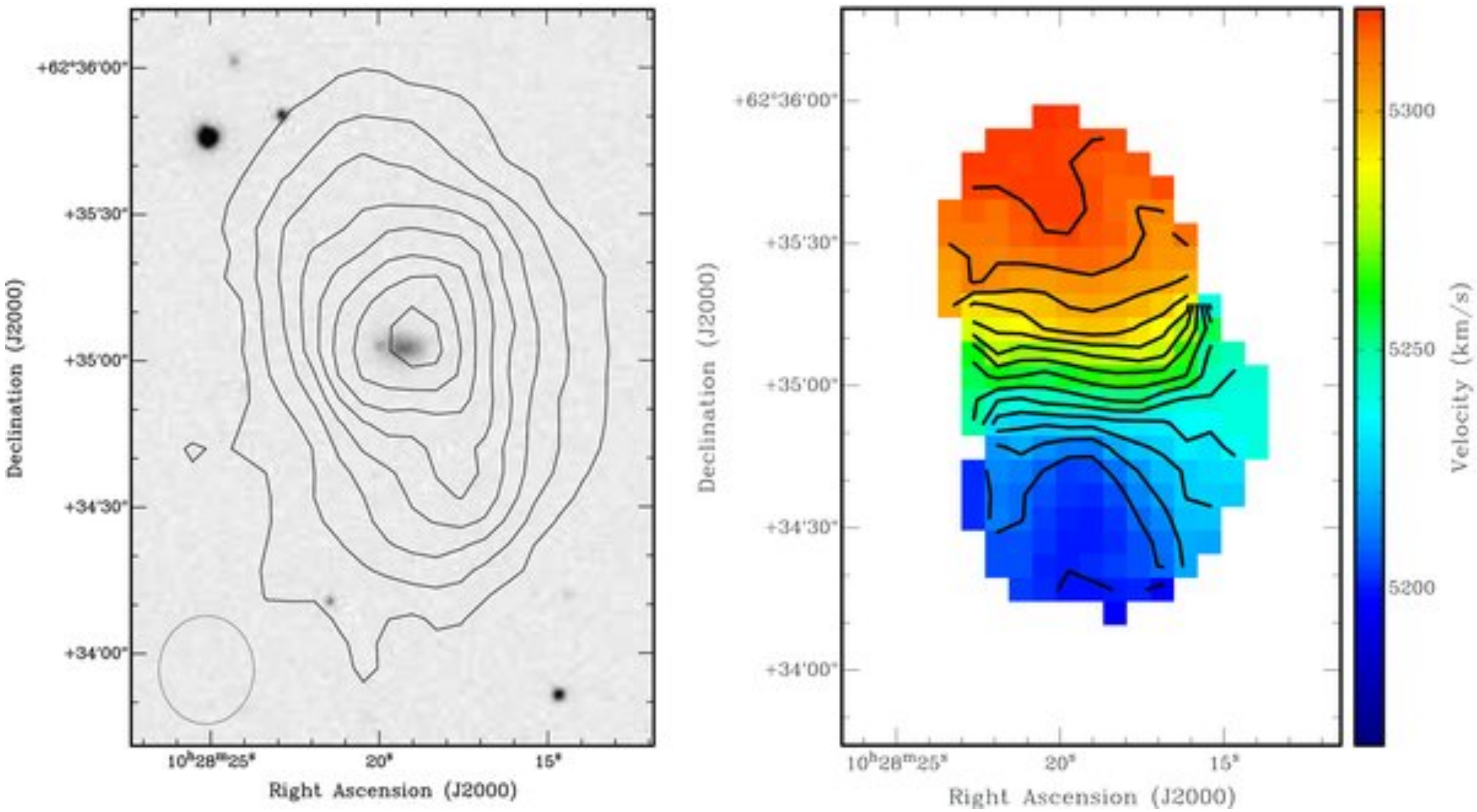
Cross control sample

Blue and green earlier void samples

Our void sample covers full range of colors

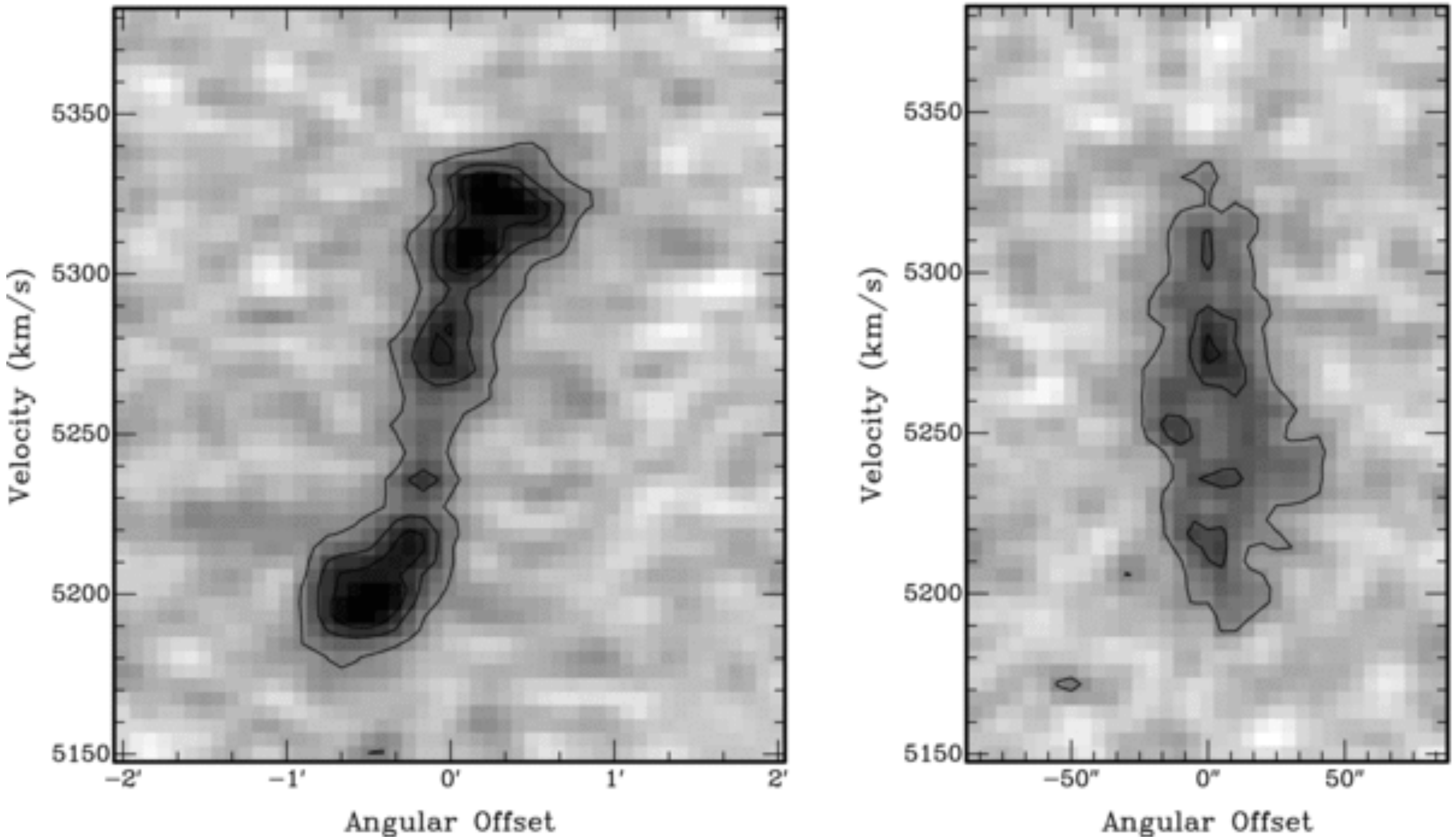


Void galaxies are faint



A polar disk

Stanonik et al 2009

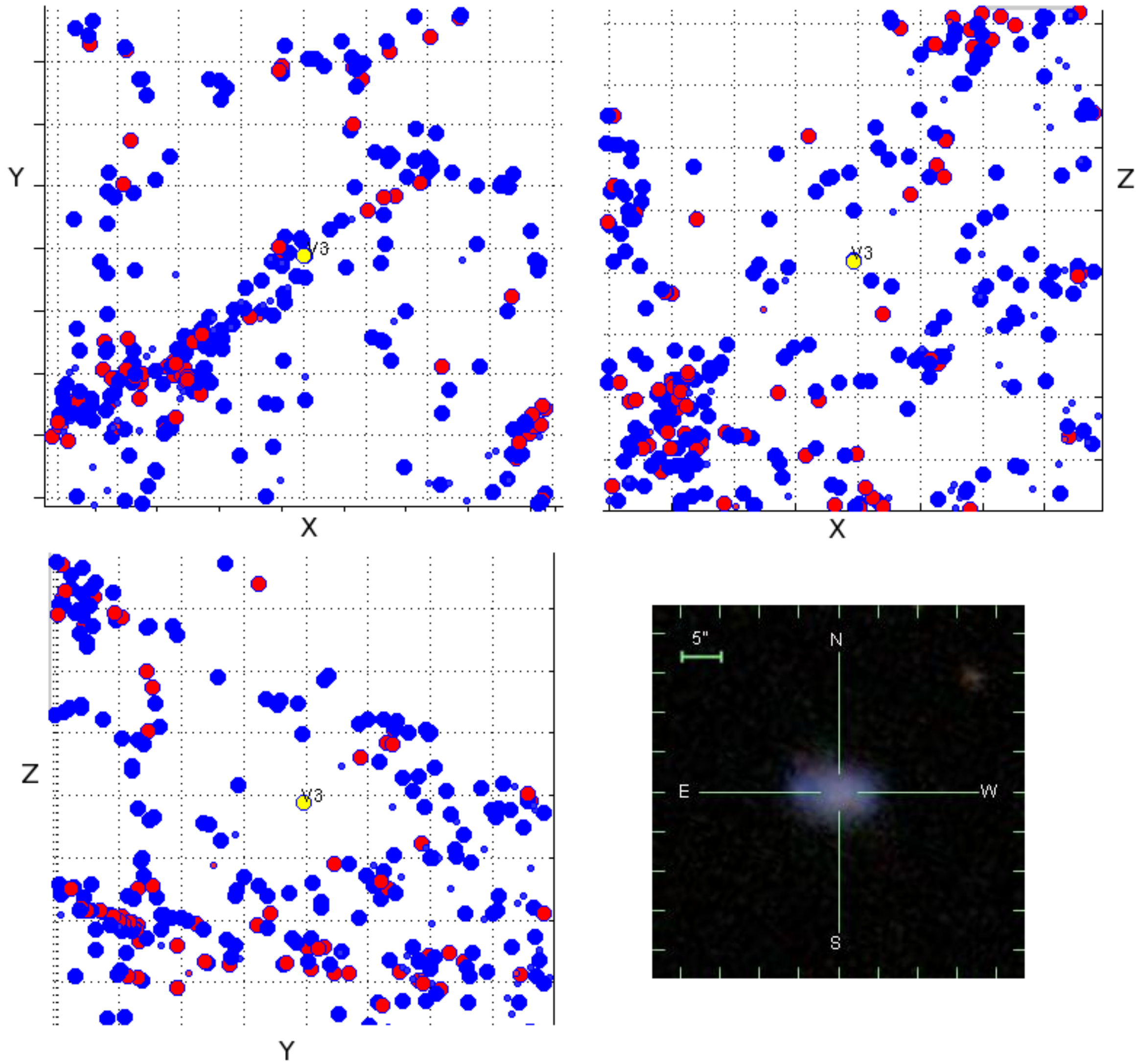


Polar ring.. Mass in HI (3x10^9 Msun) > Mass in stars (1x10^9 Msun)

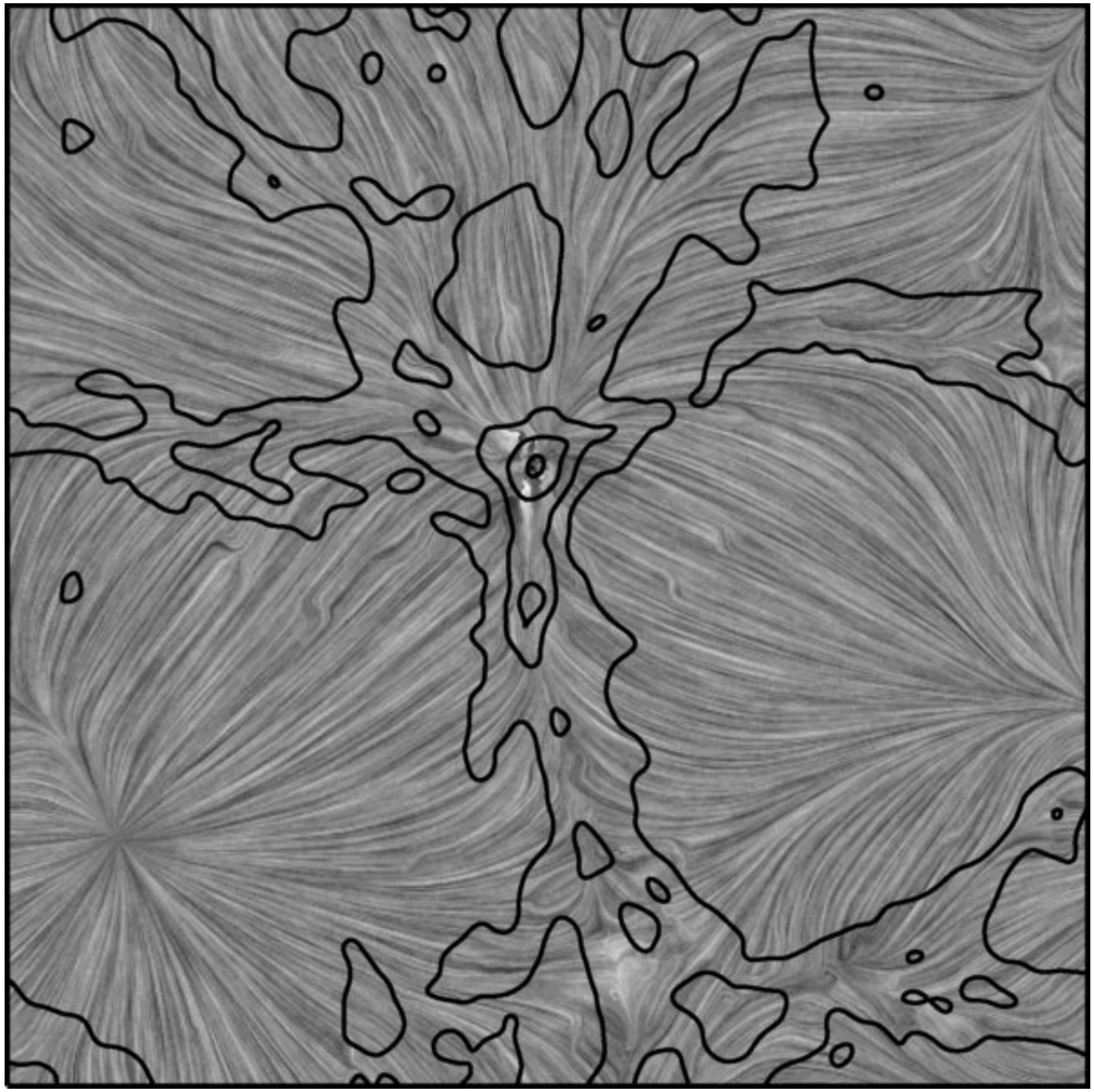
HI much more extended optical.. No optical or UV counterpart to polar ring

Tidal interaction would destroy rotation in disk

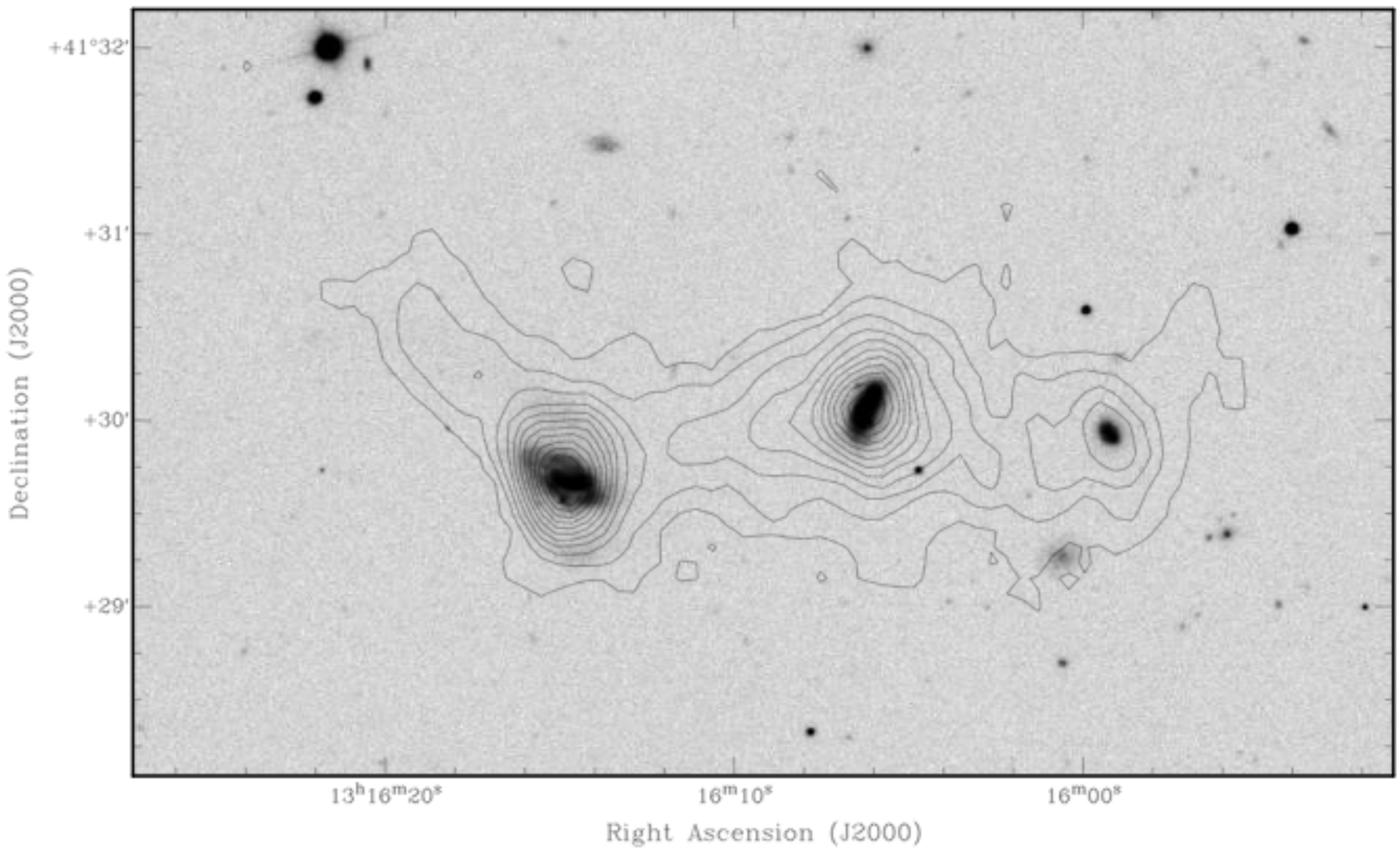
Possible example of cold mode accretion



Polar disk galaxy is in wall



Gas flows out of the void



More polar rings (and filaments? in voids

CONCLUSIONS from the PILOT Void Galaxy Survey

Kreckel et al 2011, AJ 141, 4

Some evidence for increased star formation at lower densities

Structural properties independent of environment, star formation rates do depend on environment.. Evidence for ongoing gas accretion?

Several other studies of void galaxies

Rojas et al 2005, 2006
Pustilnik et al Lynx –Cancer void

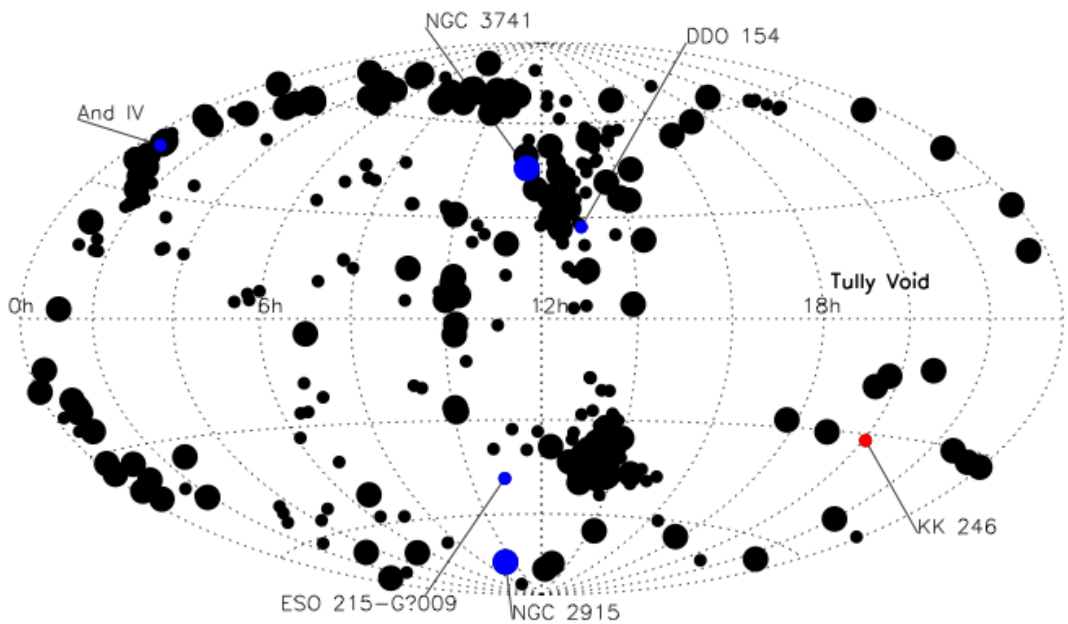


Fig. 5.— All-sky distribution of those galaxies within 4 Mpc (larger dots) and within 8 Mpc (smaller dots). The extended H I disk galaxies discussed in the text, as well as the local void, are marked accordingly.

KK246 a galaxy in the local Tully Void

KK246, a galaxy in the local void, with evidence for accretion

Kreckel, Peebles et al 2011, AJ 141, 204 An EVLA result

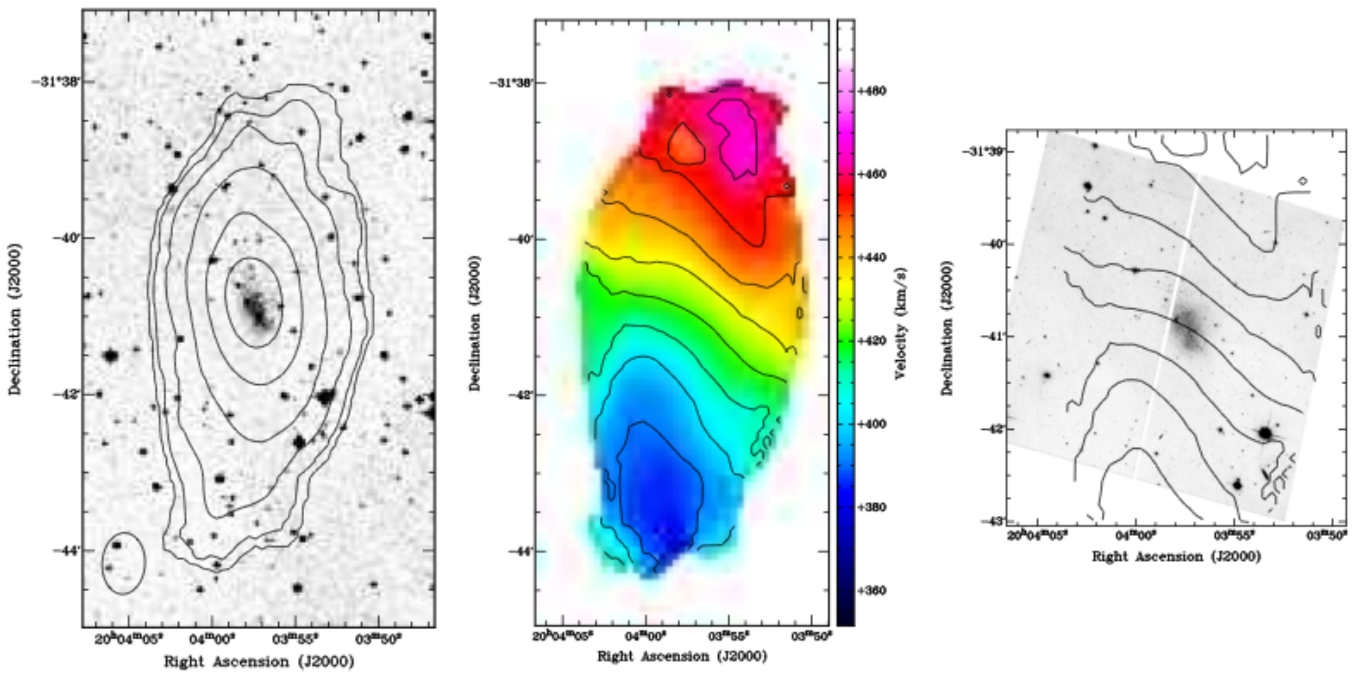


Fig. 1.— Left: KK 246, B-band Second Palomar Observatory Sky Survey Digitized Sky Survey image, overlaid with H I contours. The column density contours are $2(1.8\sigma), 4, 8, 16, 32 \times 10^{19}$ cm^{-2}. Center: the velocity field, with increments of 10.3 km s^{-1} marked. Right: HST ACS F606W image from the Hubble Legacy Archive overlaid with the velocity field.

$D(HI)/D_{opt}$= 5; $M(HI)/L_B$ = 2.3 ; $Mdyn/L_B$= 89 one of the darkest galaxies

Evidence for infall?

gas at anomalous velocities

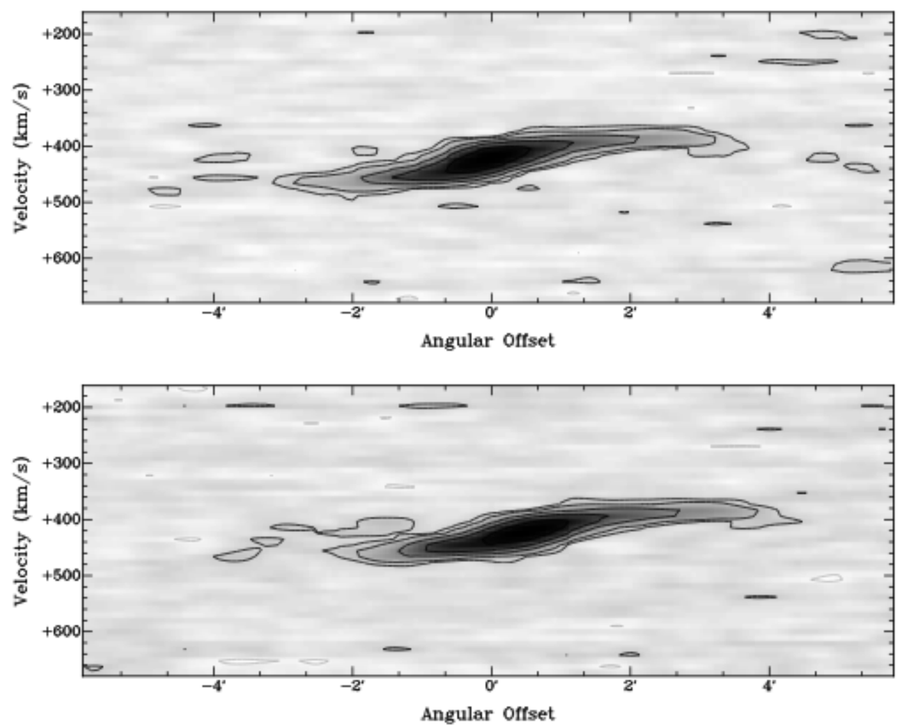


Fig. 2.— KK 246 position-velocity diagrams, aligned with the major axis (top) and annomalous gas (bottom). Contours are at -1, 1 (2.5σ), 2, 5, 10, and 20 mJy Beam^{-1}.

Nearby galaxies as pointers to a better theory of cosmic evolution

P. J. E. Peebles[1] & Adi Nusser[2]

The great advances in the network of cosmological tests show that the relativistic Big Bang theory is a good description of our expanding Universe. However, the properties of nearby galaxies that can be observed in greatest detail suggest that a better theory would describe a mechanism by which matter is more rapidly gathered into galaxies and groups of galaxies. This more rapid growth occurs in some theoretical ideas now under discussion.

NGC 6946
M101
M51

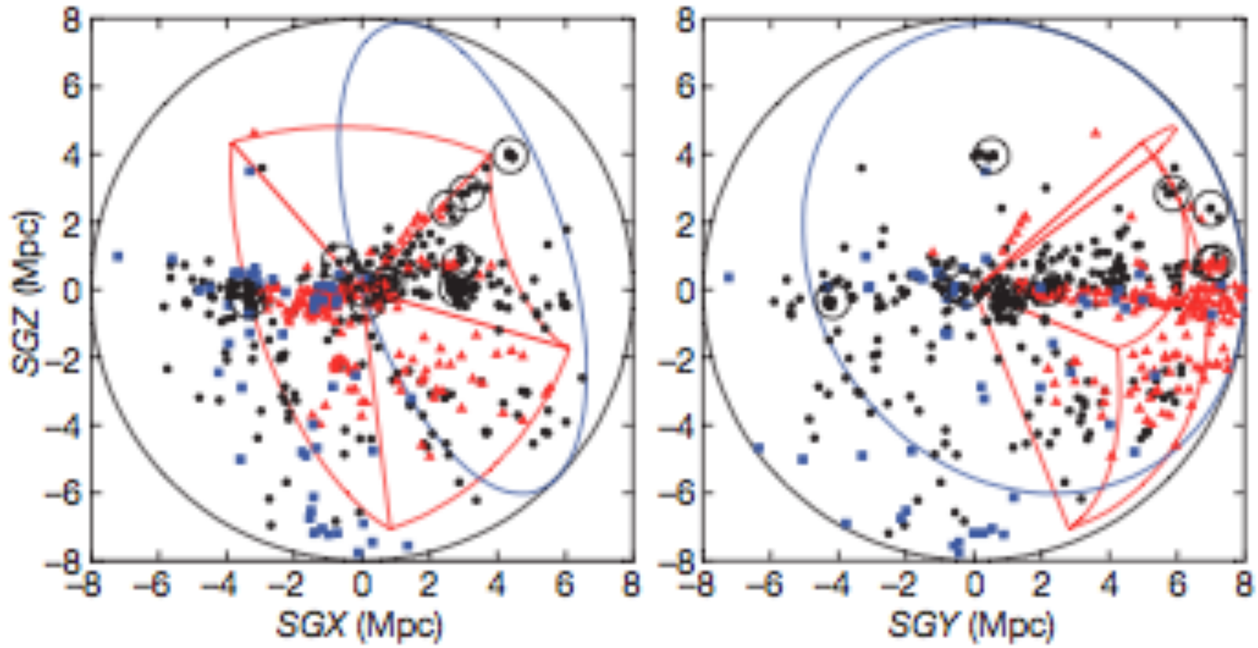


Figure 1 | Galaxies at radial distances 1 < *D* < 8 Mpc from the centre of the Local Group of galaxies. The Local Sheet is the concentration along the centre plane, and the Local Void is the region on the upper left in the left-hand projection. The ten most luminous galaxies (including M31 and the Milky Way at *D* < 1 Mpc) are indicated by the open circles. The orthogonal projections are plotted in supergalactic coordinates[63]. Black filled circles: 337 galaxies largely discovered on photographic plates and with well-measured distances[64]. Red triangles: 172 galaxies added by the Sloan Digital Sky Survey[65] (SDSS), with redshift errors of less than 50 km s^{-1}. Blue squares: 53 galaxies discovered by the H I Parkes All Sky Survey (HIPASS) from 21-cm emission by atomic hydrogen[50]. SDSS and HIPASS have less secure redshift distances and cover only the parts of the sky roughly indicated by the red and blue curves, respectively. There are many more dwarf galaxies to be discovered at this distance.

BULGELESS GIANT GALAXIES CHALLENGE OUR PICTURE OF GALAXY FORMATION BY HIERARCHICAL CLUSTERING*,†

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[2] Universitäts-Sternwarte, Scheinerstrasse 1, München D-81679, Germany

[3] Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse, D-85748 Garching-bei-München, Germany; bender@mpe.mpg.de, drory@mpe.mpg.de

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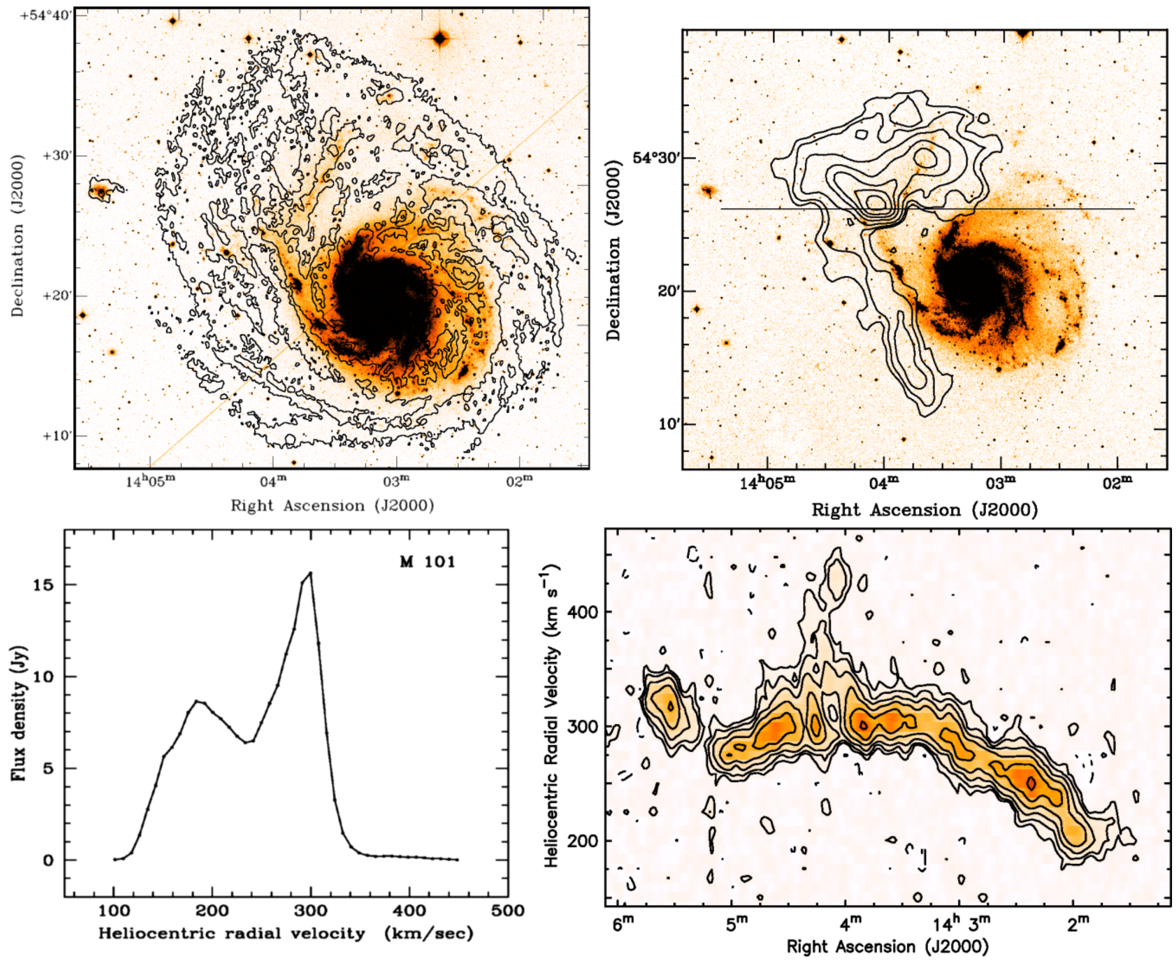
ABSTRACT

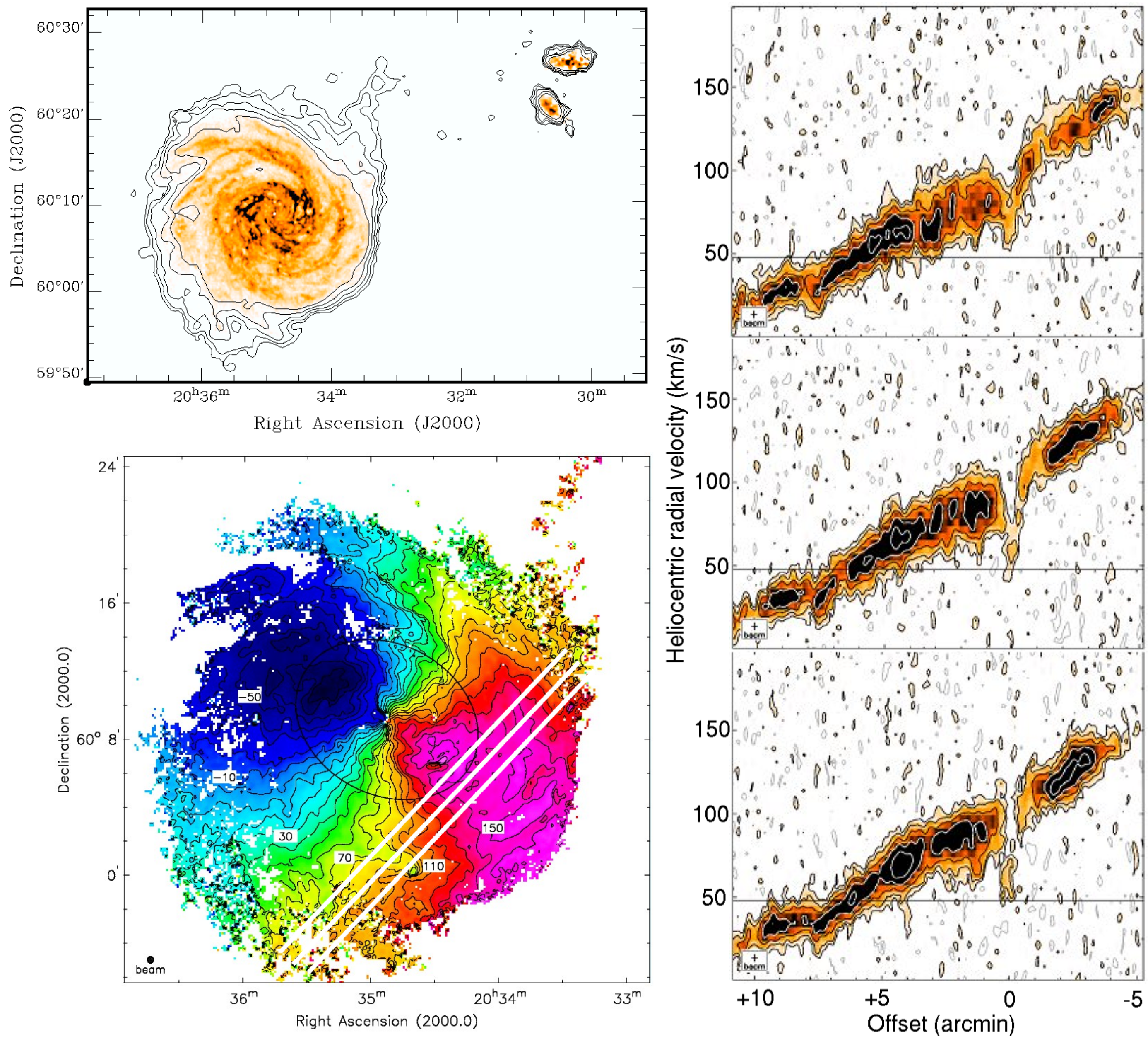
To better understand the prevalence of bulgeless galaxies in the nearby field, we dissect giant Sc-Scd galaxies with *Hubble Space Telescope* (*HST*) photometry and Hobby-Eberly Telescope (HET) spectroscopy. We use the HET High Resolution Spectrograph (resolution $R \equiv \lambda/\mathrm{FWHM} \simeq 15,000$) to measure stellar velocity dispersions in the nuclear star clusters and (pseudo)bulges of the pure-disk galaxies M 33, M 101, NGC 3338, NGC 3810, NGC 6503, and NGC 6946. The dispersions range from 20 ± 1 km s^{-1} in the nucleus of M 33 to 78 ± 2 km s^{-1} in the pseudobulge of NGC 3338. We use *HST* archive images to measure the brightness profiles of the nuclei and (pseudo)bulges in M 101, NGC 6503, and NGC 6946 and hence to estimate their masses. The results imply small mass-to-light ratios consistent with young stellar populations. These observations lead to two conclusions. (1) Upper limits on the masses of any supermassive black holes are $M_\bullet \lesssim (2.6 \pm 0.5) \times 10^6\ M_\odot$ in M 101 and $M_\bullet \lesssim (2.0 \pm 0.6) \times 10^6\ M_\odot$ in NGC 6503. (2) We show that the above galaxies contain only tiny pseudobulges that make up $\lesssim$3% of the stellar mass. This provides the strongest constraints to date on the lack of classical bulges in the biggest pure-disk galaxies. We inventory the galaxies in a sphere of radius 8 Mpc centered on our Galaxy to see whether giant, pure-disk galaxies are common or rare. We find that at least 11 of 19 galaxies with $V_{\mathrm{circ}} > 150$ km s^{-1}, including M 101, NGC 6946, IC 342, and our Galaxy, show no evidence for a classical bulge. Four may contain small classical bulges that contribute 5%-12% of the light of the galaxy. Only four of the 19 giant galaxies are ellipticals or have classical bulges that contribute ~1/3 of the galaxy light. We conclude that pure-disk galaxies are far from rare. It is hard to understand how bulgeless galaxies could form as the quiescent tail of a distribution of merger histories. Recognition of pseudobulges makes the biggest problem with cold dark matter galaxy formation more acute: How can hierarchical clustering make so many giant, pure-disk galaxies with no evidence for merger-built bulges? Finally, we emphasize that this problem is a strong function of environment: the Virgo cluster is not a puzzle, because more than 2/3 of its stellar mass is in merger remnants.

M101, NGC 6946.. The same galaxies that Peebles points out

In this paper we report the discovery of neutral hydrogen moving at high speed perpendicular to the disk of the nearby spiral galaxy M101. This material is found in two locations where the spiral structure itself seems particularly disturbed. The mass involved is 10^7–10^8 $\mathscr{M}_{\odot}$. The velocities appear redshifted by up to about 150 km/s with respect to the "local" H I disk of M101, and yet they seem to connect smoothly to other features seen in that disk. The origin of these high-velocity H I structures is not clear. It is unlikely that they were caused by supernova explosions or even by any spiral dynamics, but they may have resulted from fairly recent collisions of large, extragalactic gas clouds with the disk of M101.



Kamphuis, 1993; van der Hulst and Sancisi, 1988



NGC 4696 (Boomsma 2007) HI holes and velocity wiggles.. Evidence for infall?

VIVA

VLA Imaging of Virgo Galaxies in Atomic Gas

Aeree Chung, Hugh Crowl,

Kenney, van Gorkom, Vollmer

Schiminovich

Select galaxies over wide range of local densities

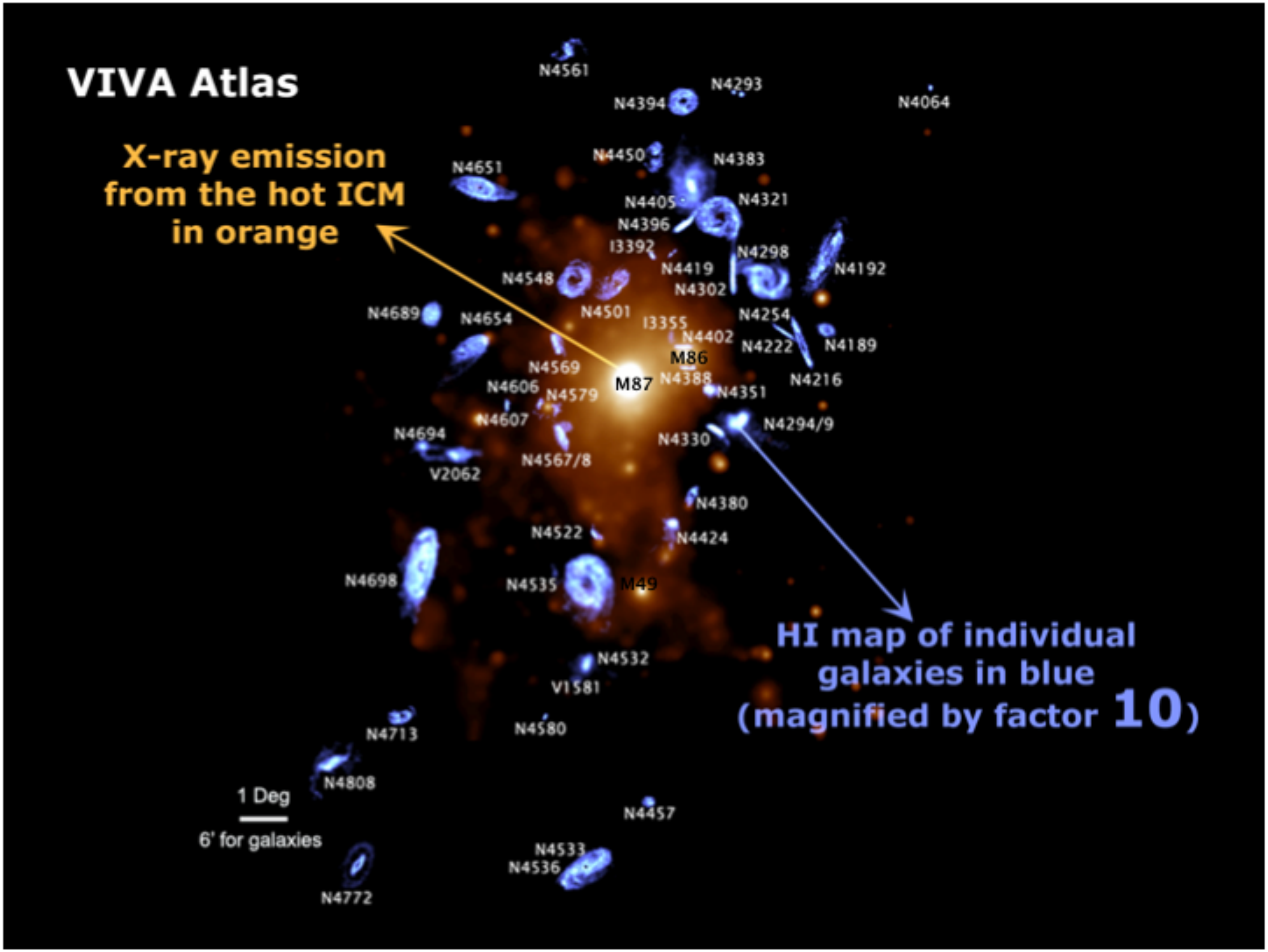
Select galaxies with wide range of star formation properties

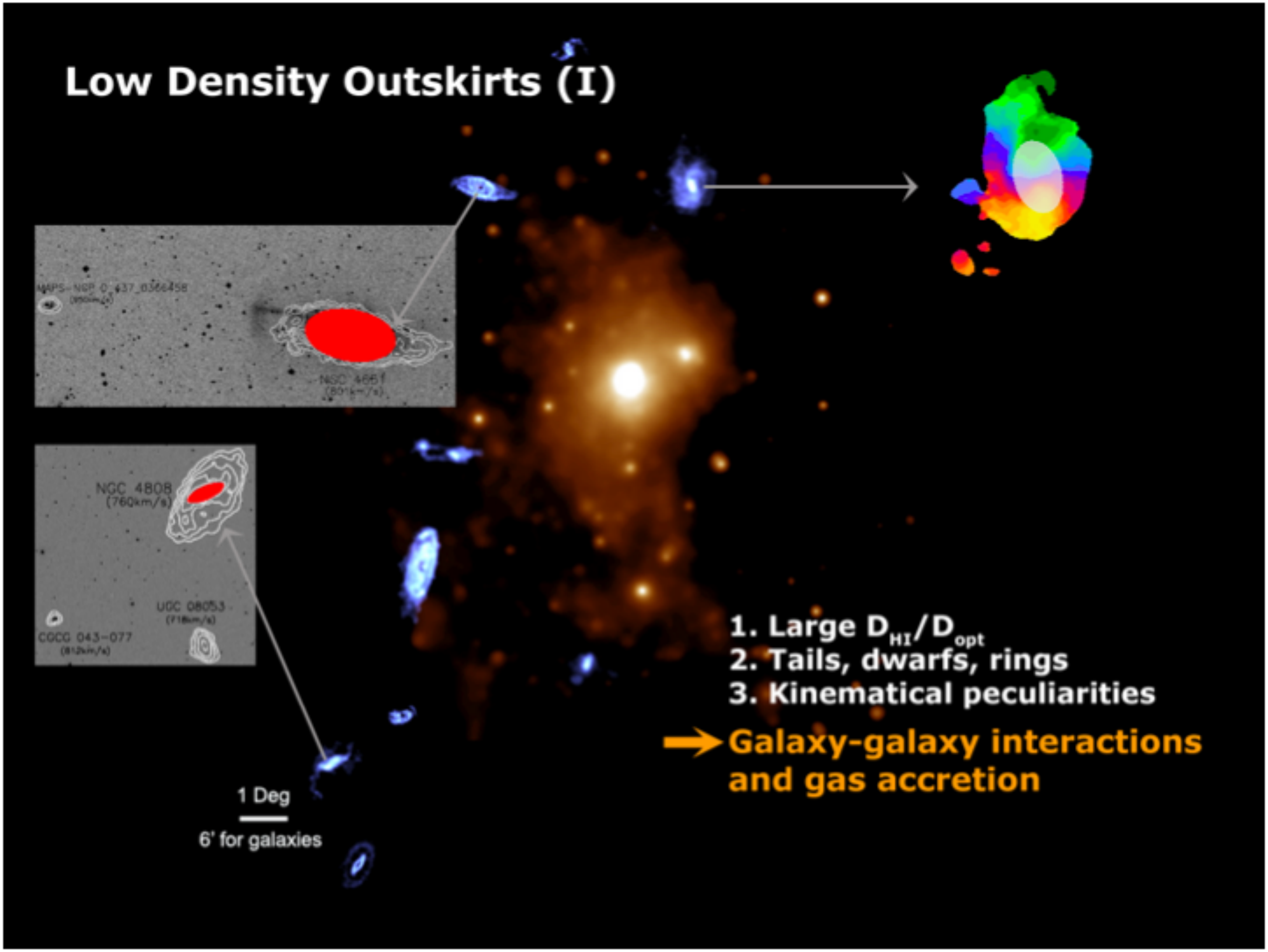
Identify galaxies undergoing trauma

Make sophisticated guess as to what is happening

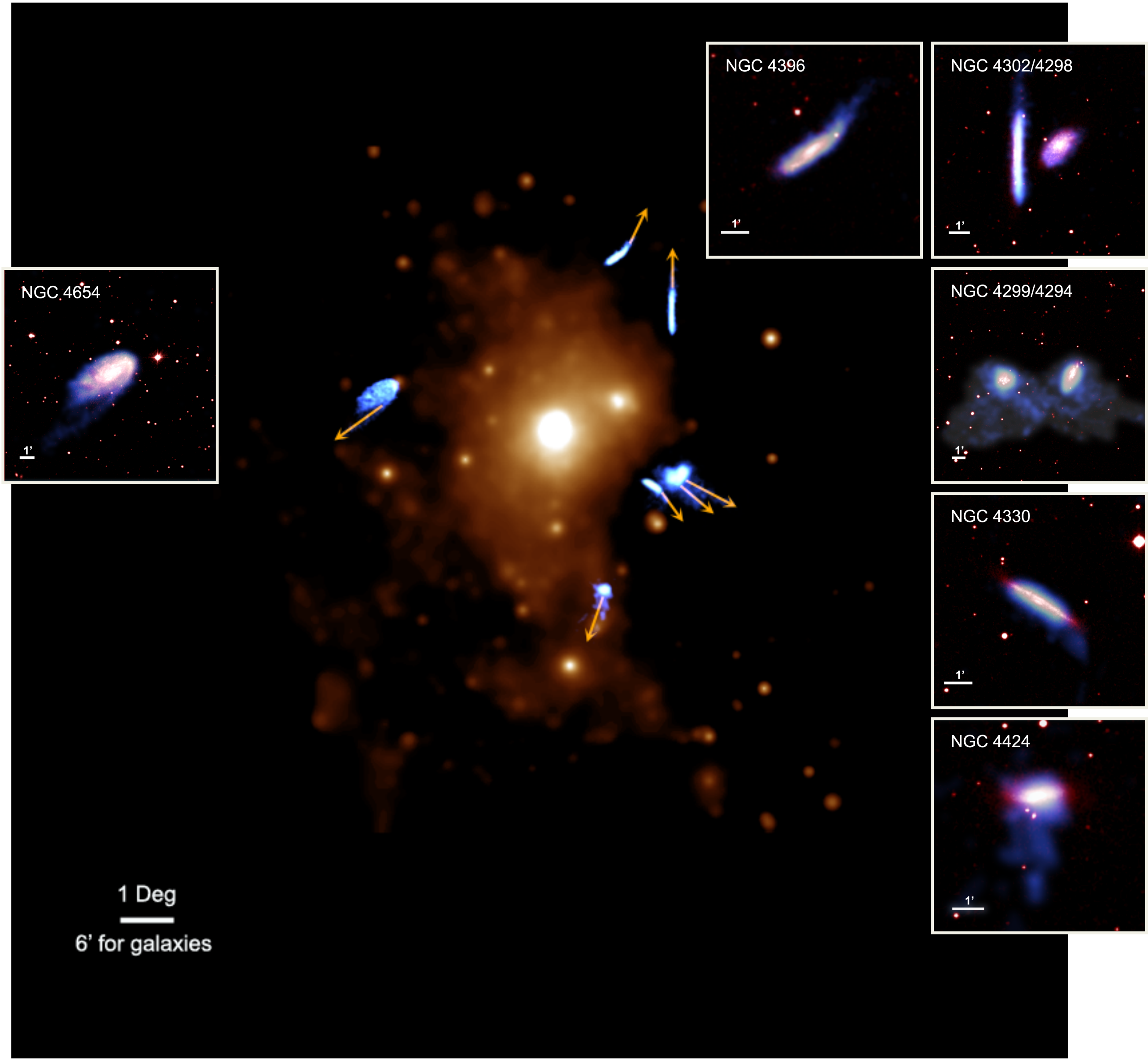
Use simulation to make a more sophisticated guess

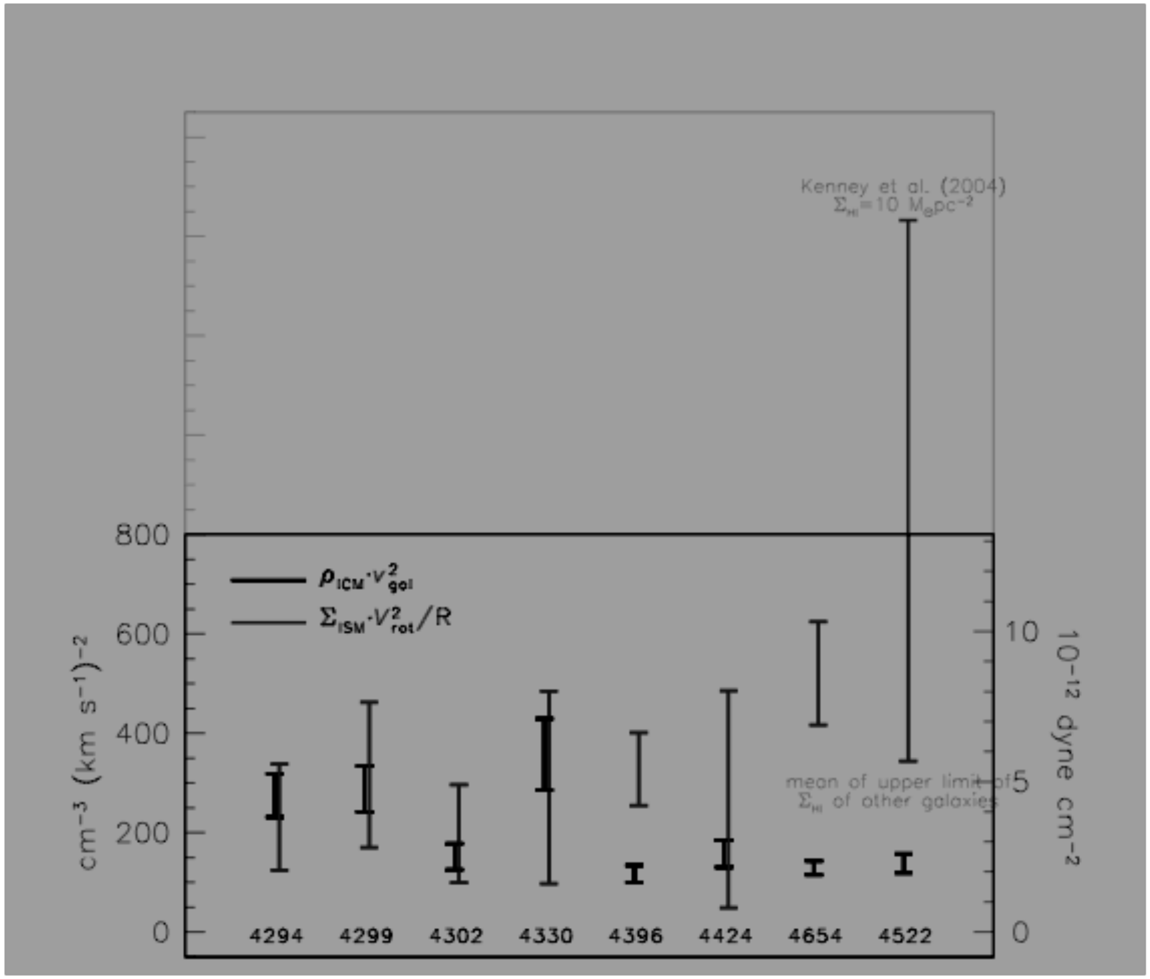
Compare timescales from stellar population synthesis with timescales from simulation


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
N4192
N4419
N4548
N4302
N4501
N4689
N4654
N4254
I3355
N4402
N4222
N4189
M86
N4569
N4388
N4216
M87
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)
NGC 4808
(760km/s)
UGC 08053
(718km/s)
CGCG 043-077
1 Deg
6' for galaxies
1. Large D_{HI}/D_{opt}
2. Tails, dwarfs, rings
3. Kinematical peculiarities
Galaxy-galaxy interactions and gas accretion


NGC 4396
1'
NGC 4302/4298
1'
NGC 4654
1'
NGC 4299/4294
1'
NGC 4330
1'
NGC 4424
1'
1 Deg
6' for galaxies



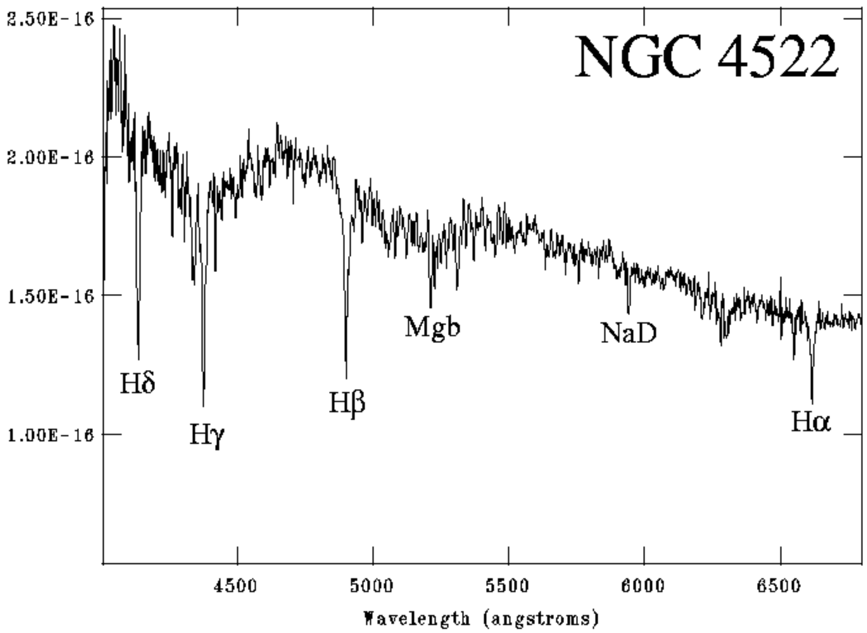
Can these tails be formed by ram pressure stripping?

Five galaxy tails could have been formed by ram pressure

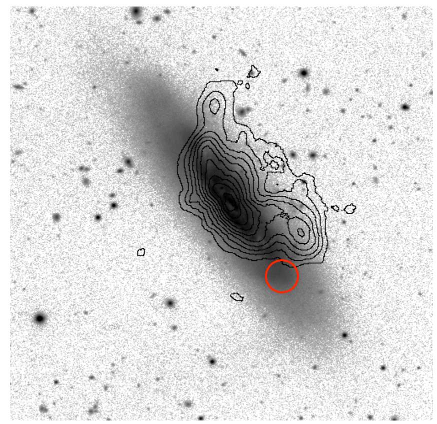
N4654 probably combination of gravitational and rp

N4396 possibly also, or viscous stripping

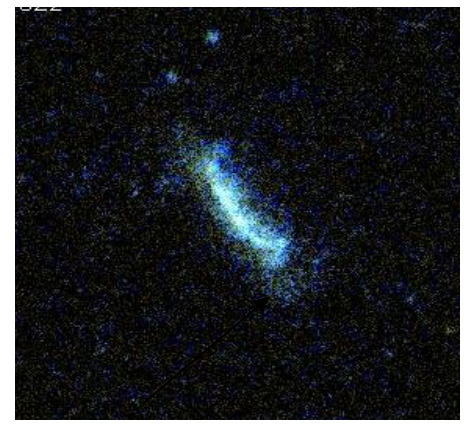
Young Stellar Population in Stripped Outer Disk of NGC 4522



OPT + HI



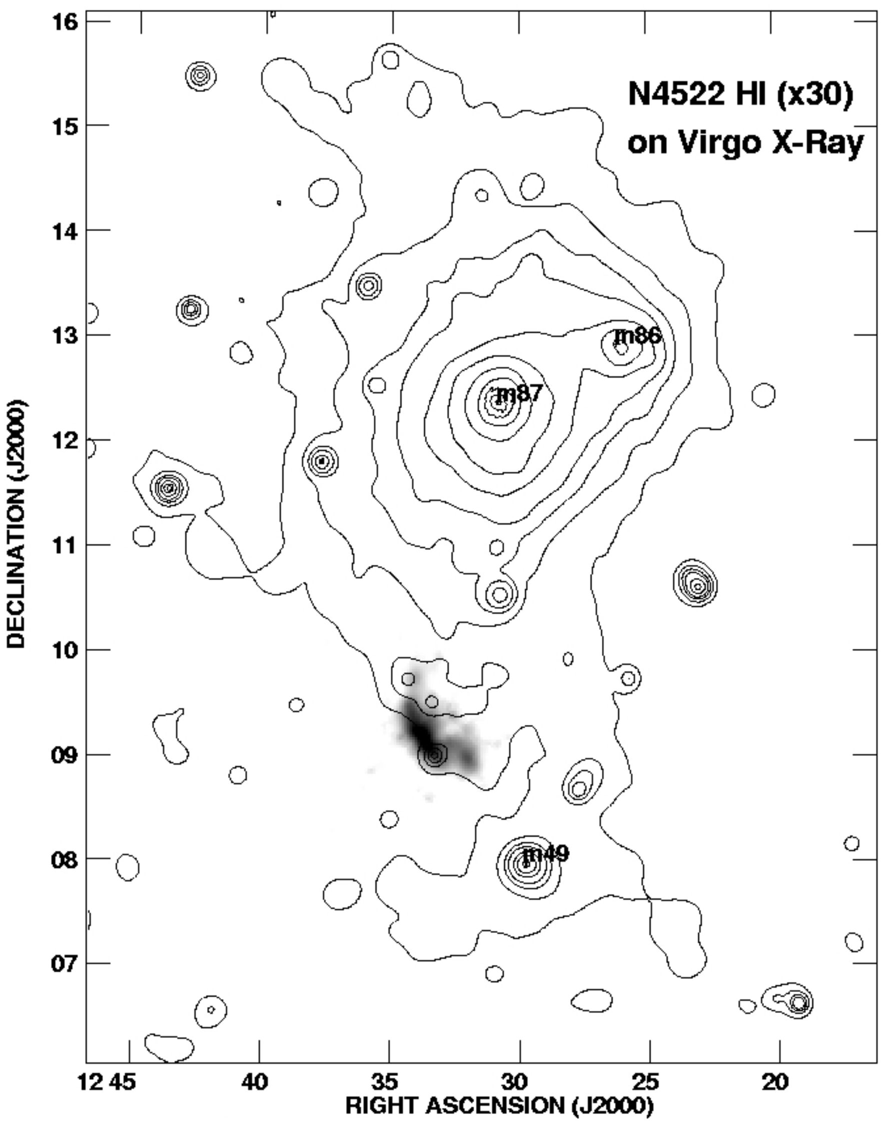
GALEX FUV+NUV



Strong Balmer lines and bright FUV emission in stripped outer disk indicate star formation stopped only ~100 Myr ago

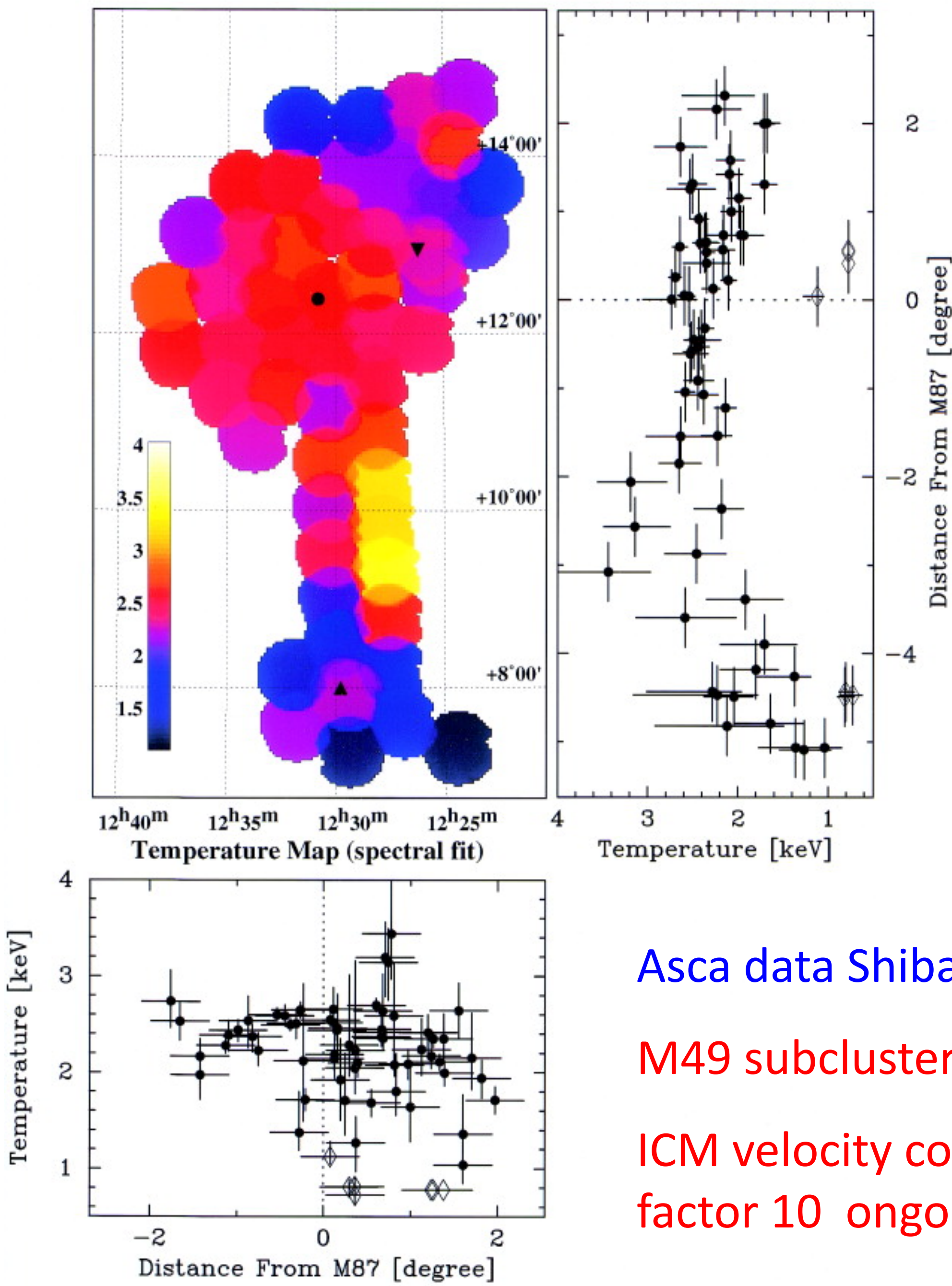
--> disk was stripped recently

Crowl & Kenney 2006



NGC 4522 is stripped locally and not in core

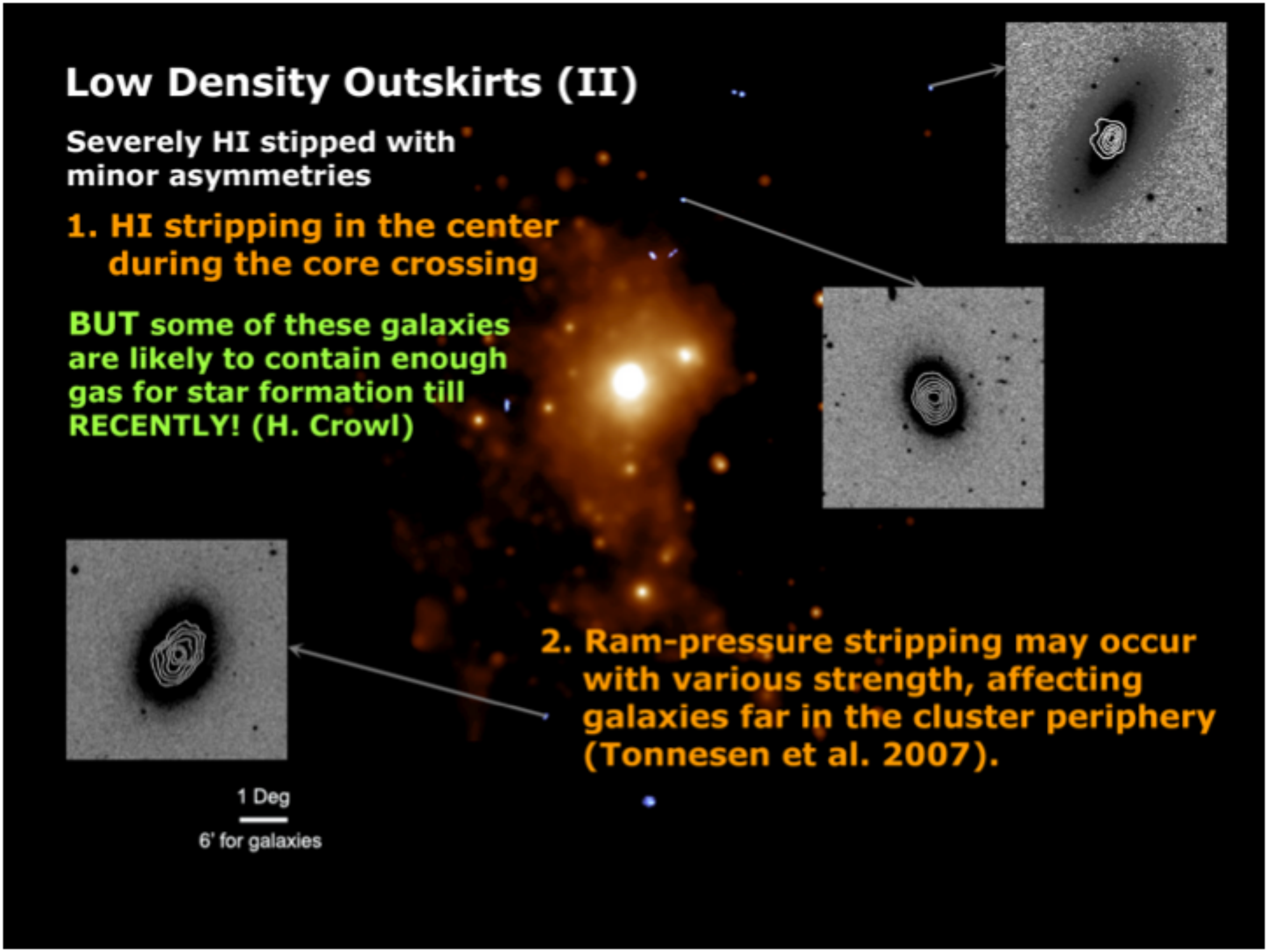
- NGC 4522 cannot travel far in 100 Myr, so must be stripped locally & not in cluster core
- NGC 4522 is located 3.5° = 0.8 Mpc from M87
- Time to reach core ~700 Myr

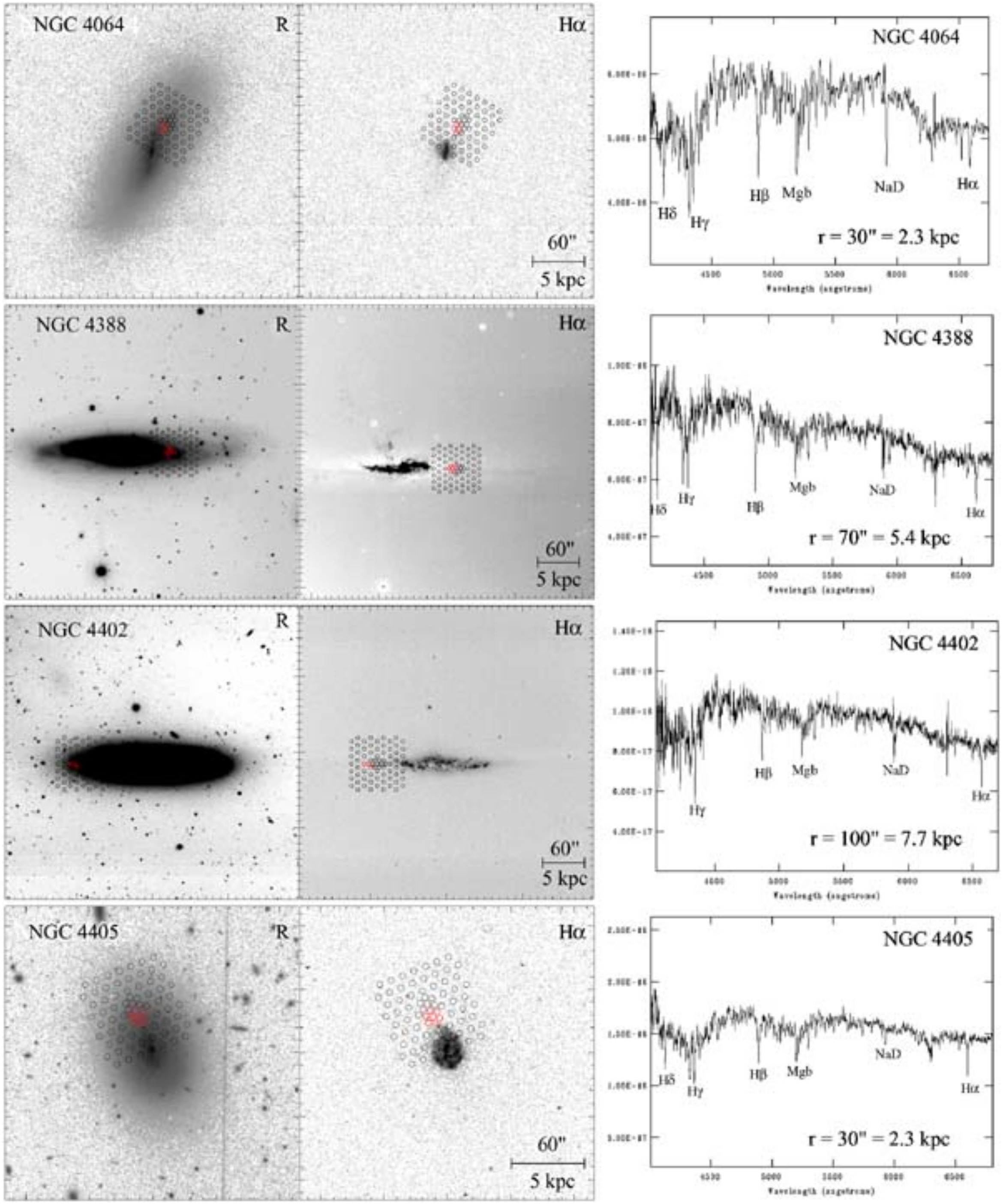


Asca data Shibata et al 2001

M49 subcluster falling in 1300km/s

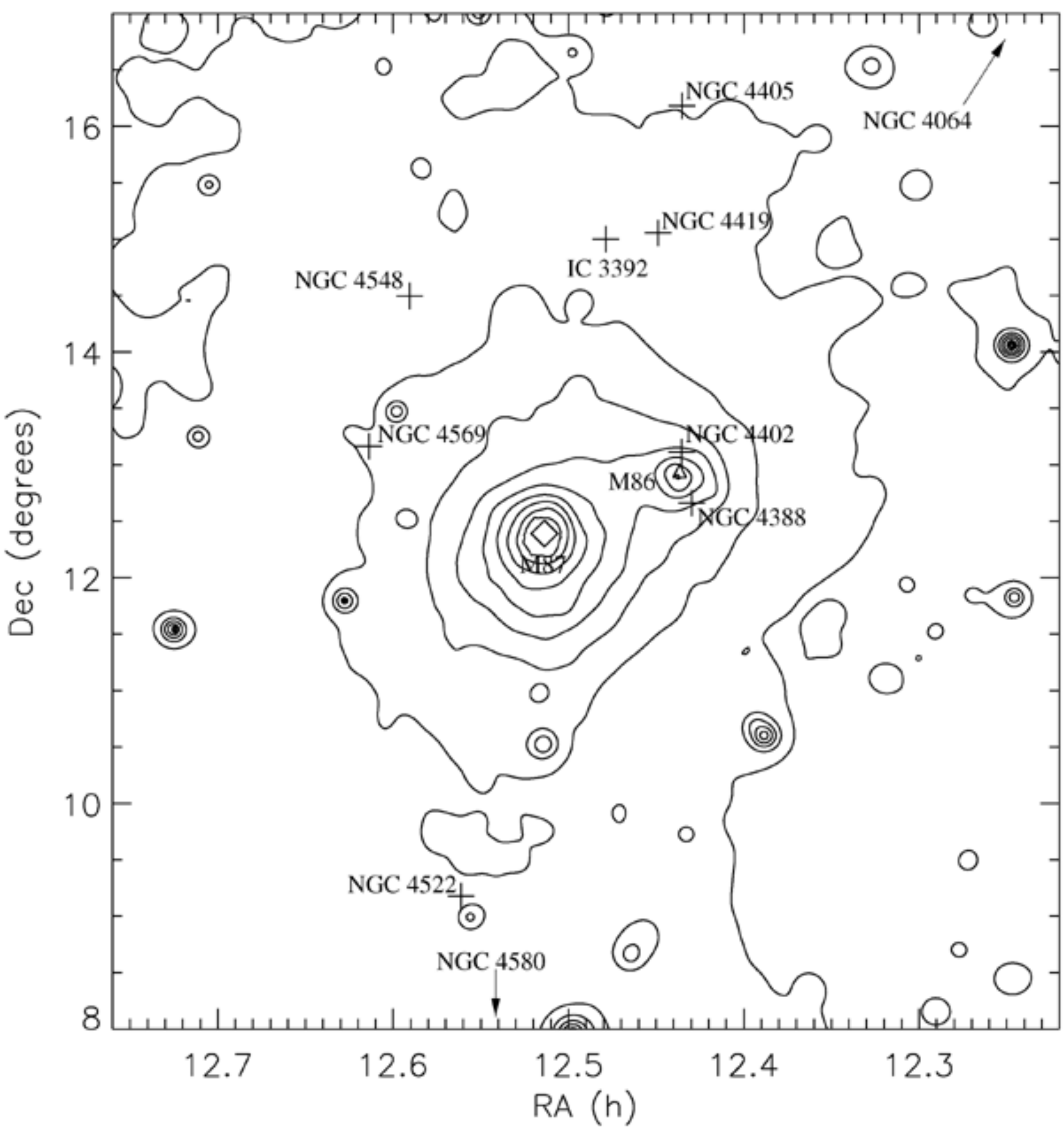
ICM velocity could increase ram pressure by factor 10 ongoing stripping


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



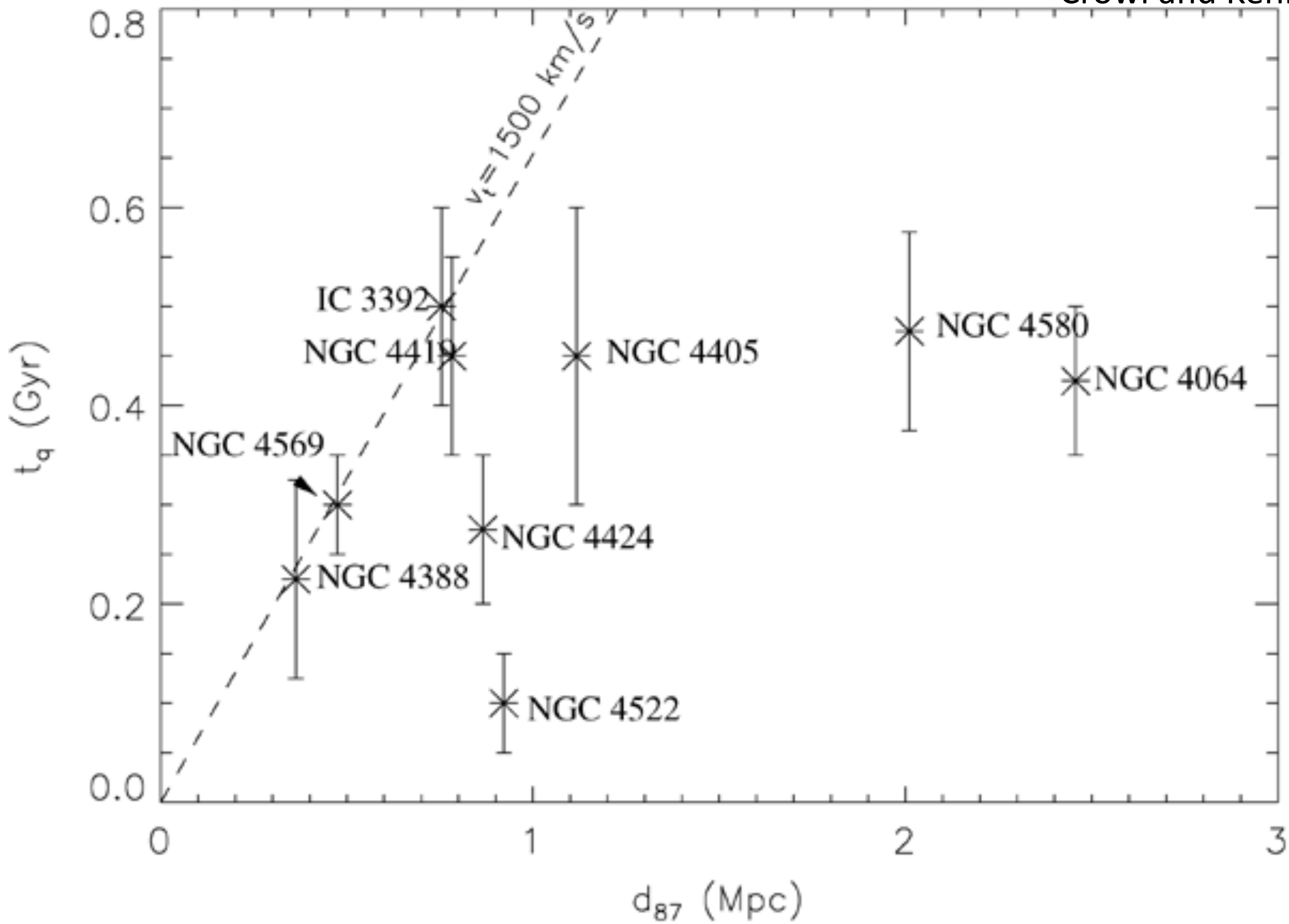
Crowl and Kenney 2008

- SparsePak positions on *R-band image (left) and Hα image (center). The composite spectrum from several summed fibers (**indicated by the red circles on the images) is also shown (right). The radius given for each composite spectrum is the distance from the galaxy center to the center of the composite spectrum region. Shown here are images and spectra for NGC 4064, NGC 4388, NGC 4402, and NGC 4405.*

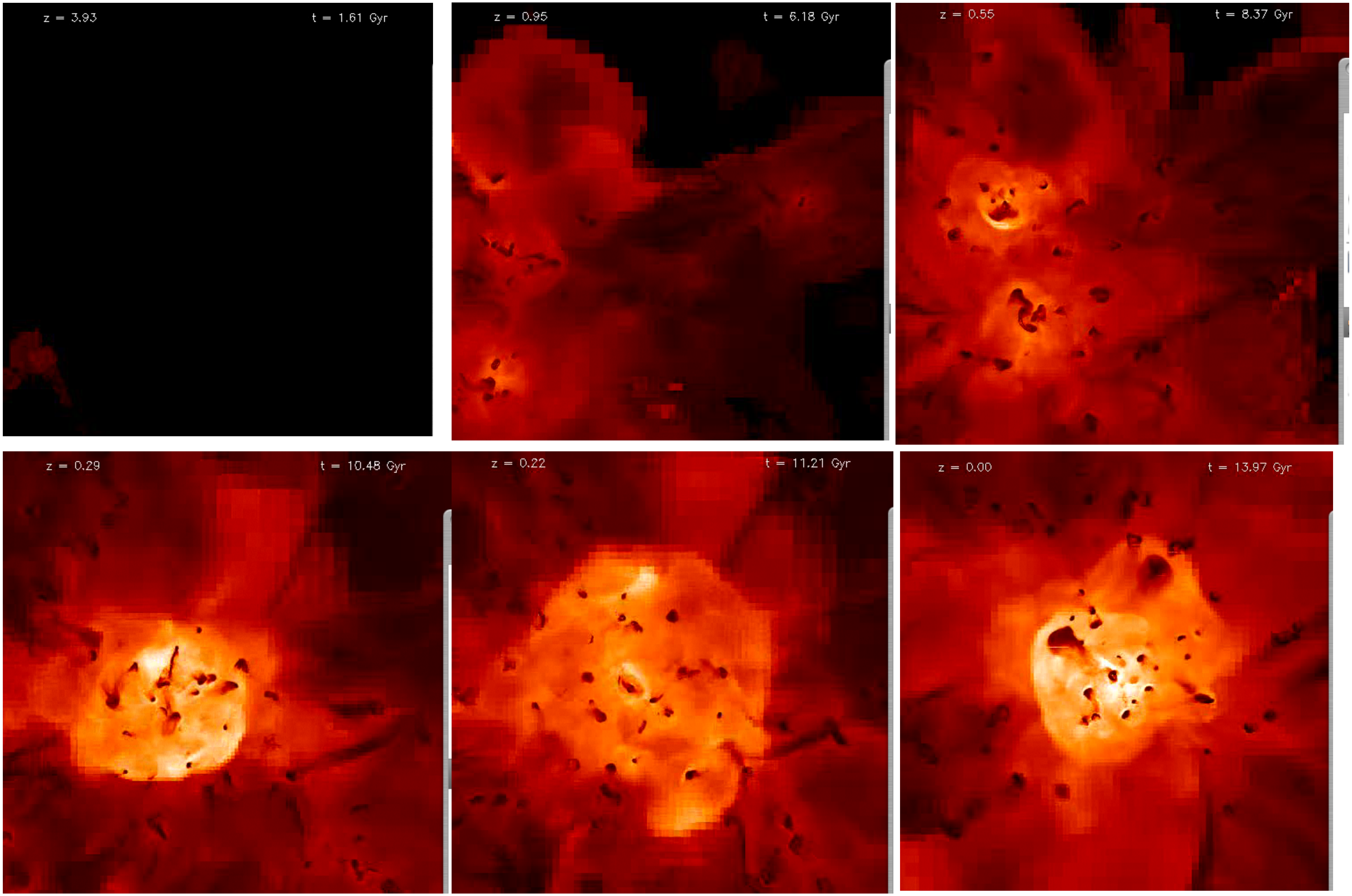


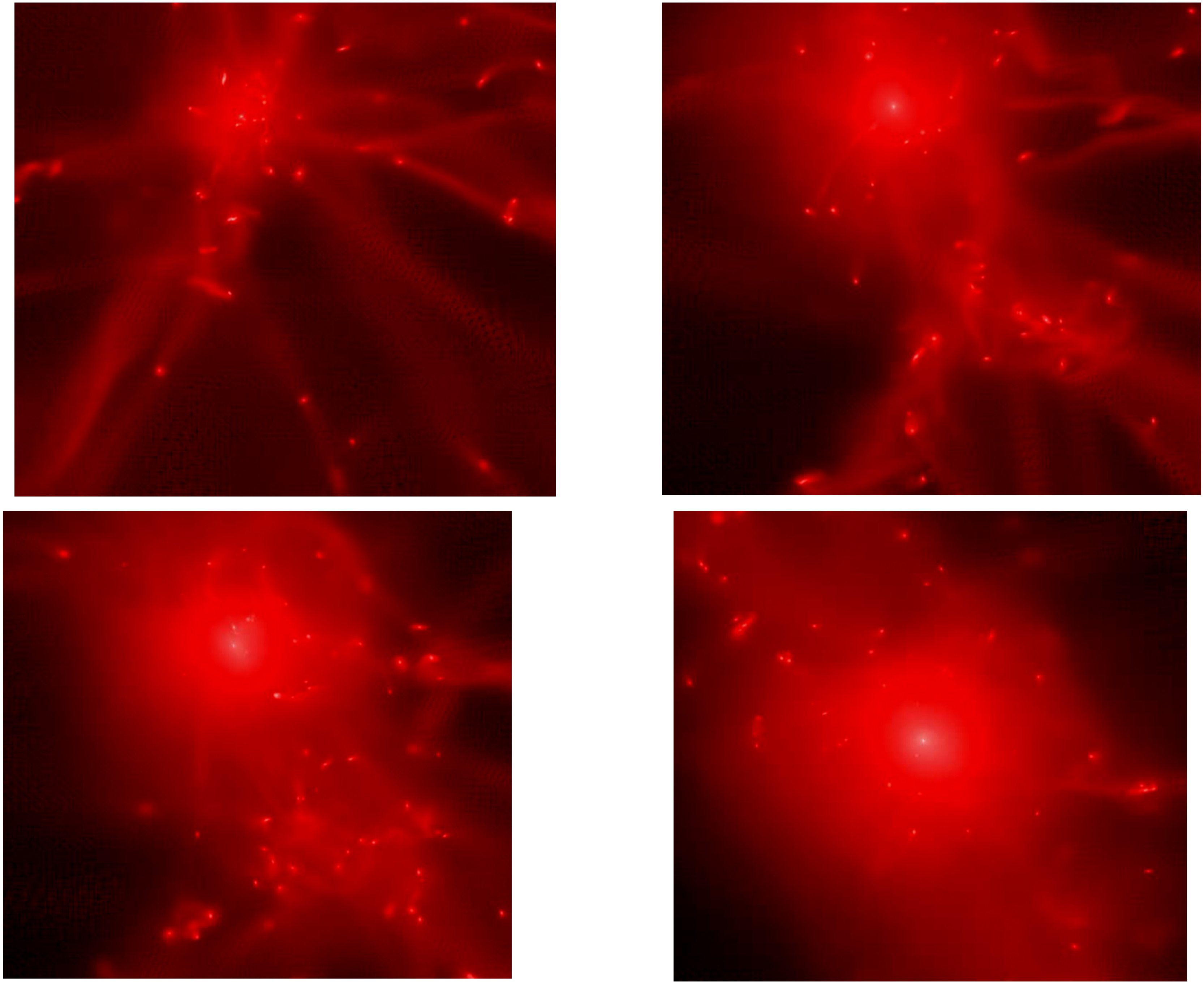
NGC 4405
NGC 4064
NGC 4419
IC 3392
NGC 4548
NGC 4569
NGC 4402
M86
NGC 4388
M87
NGC 4522
NGC 4580
16
14
12
10
8
Dec (degrees)
12.7
12.6
12.5
12.4
12.3
RA (h)

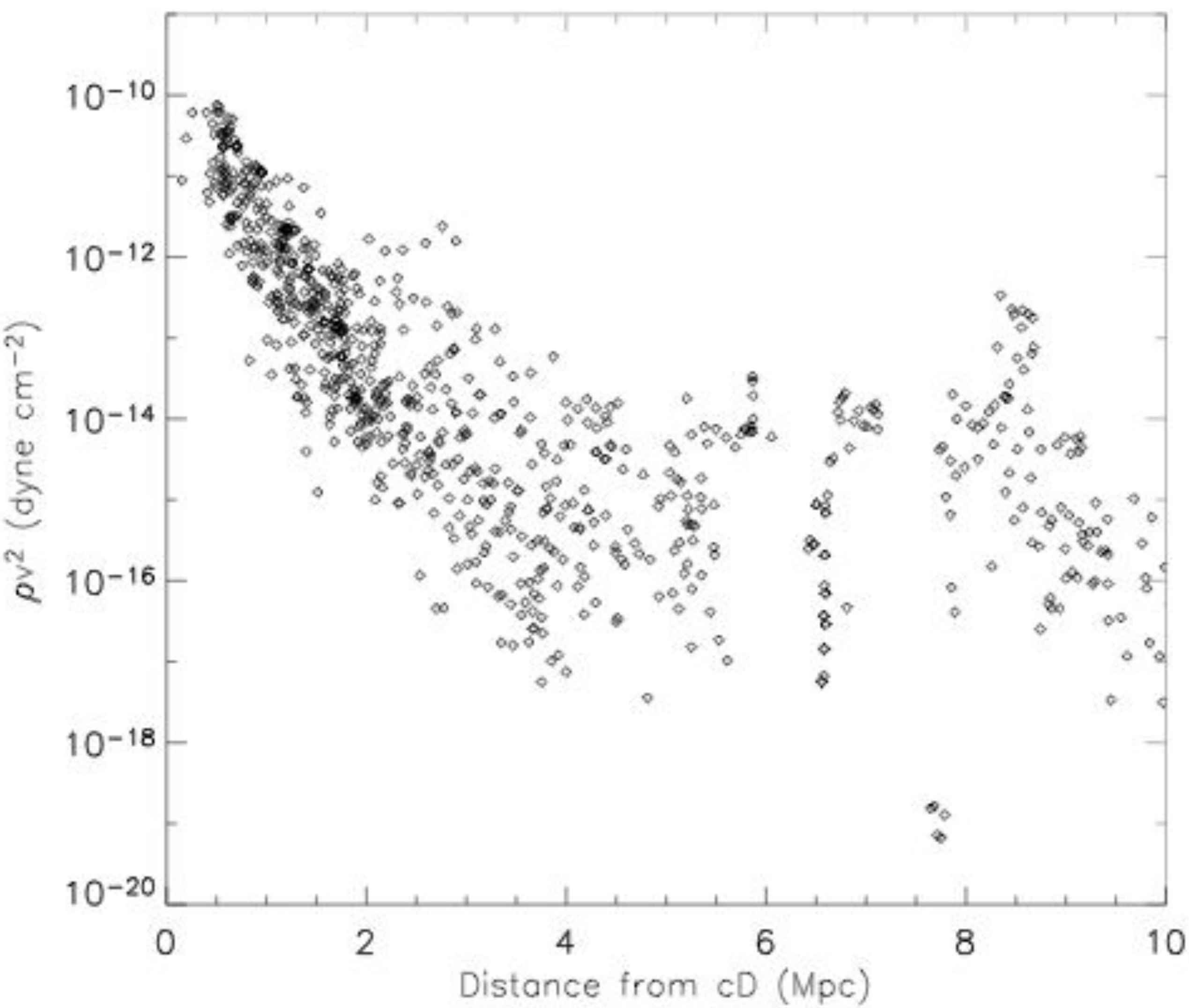
Crowl and Kenney 2008



Quenching time for the sample of stripped spirals against projected distance from the central elliptical galaxy M87. Also shown (as a dashed line) is the position a galaxy would have if its star formation were halted in the core and it had been traveling 1500 km s^{-1} in the plane of the sky away from M87


z = 3.93
t = 1.61 Gyr
z = 0.95
t = 6.18 Gyr
z = 0.55
t = 8.37 Gyr
z = 0.29
t = 10.48 Gyr
z = 0.22
t = 11.21 Gyr
z = 0.00
t = 13.97 Gyr

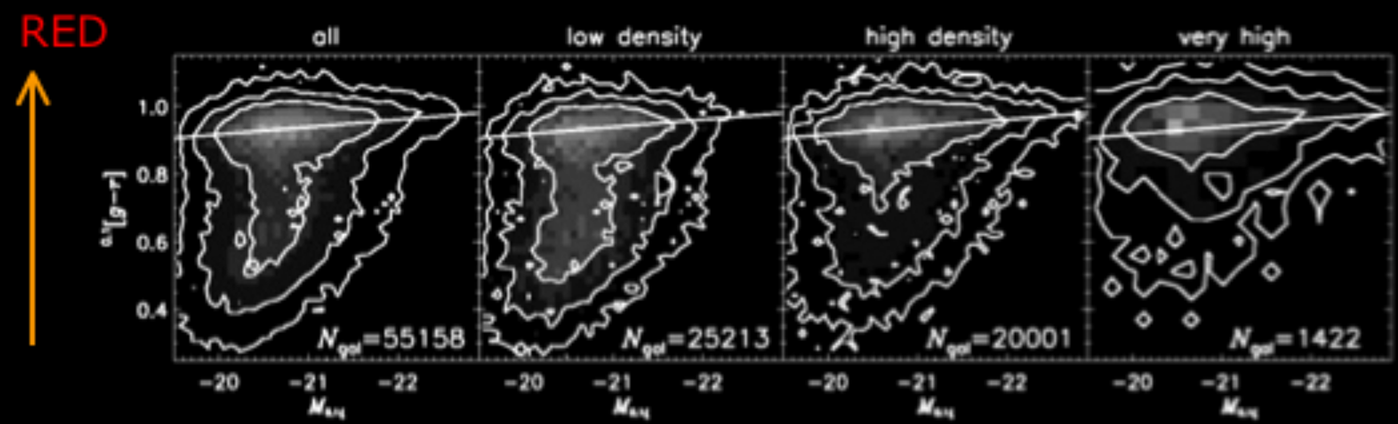




Ram pressure as function of distance from center

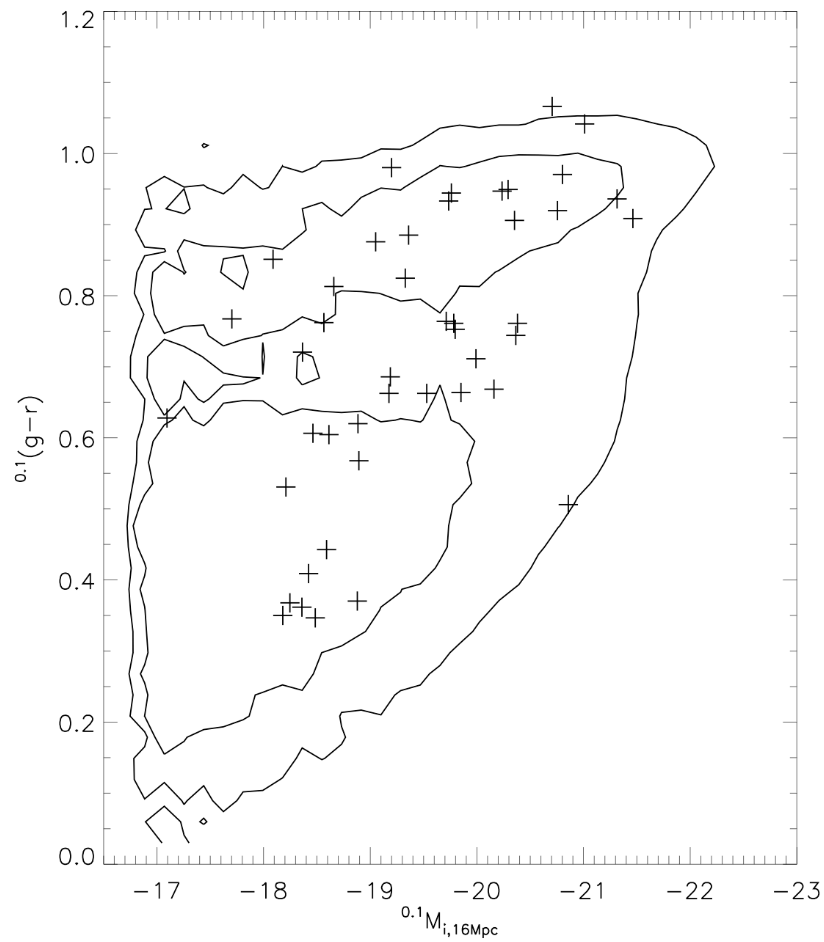
Tonnesen et al 2007

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?

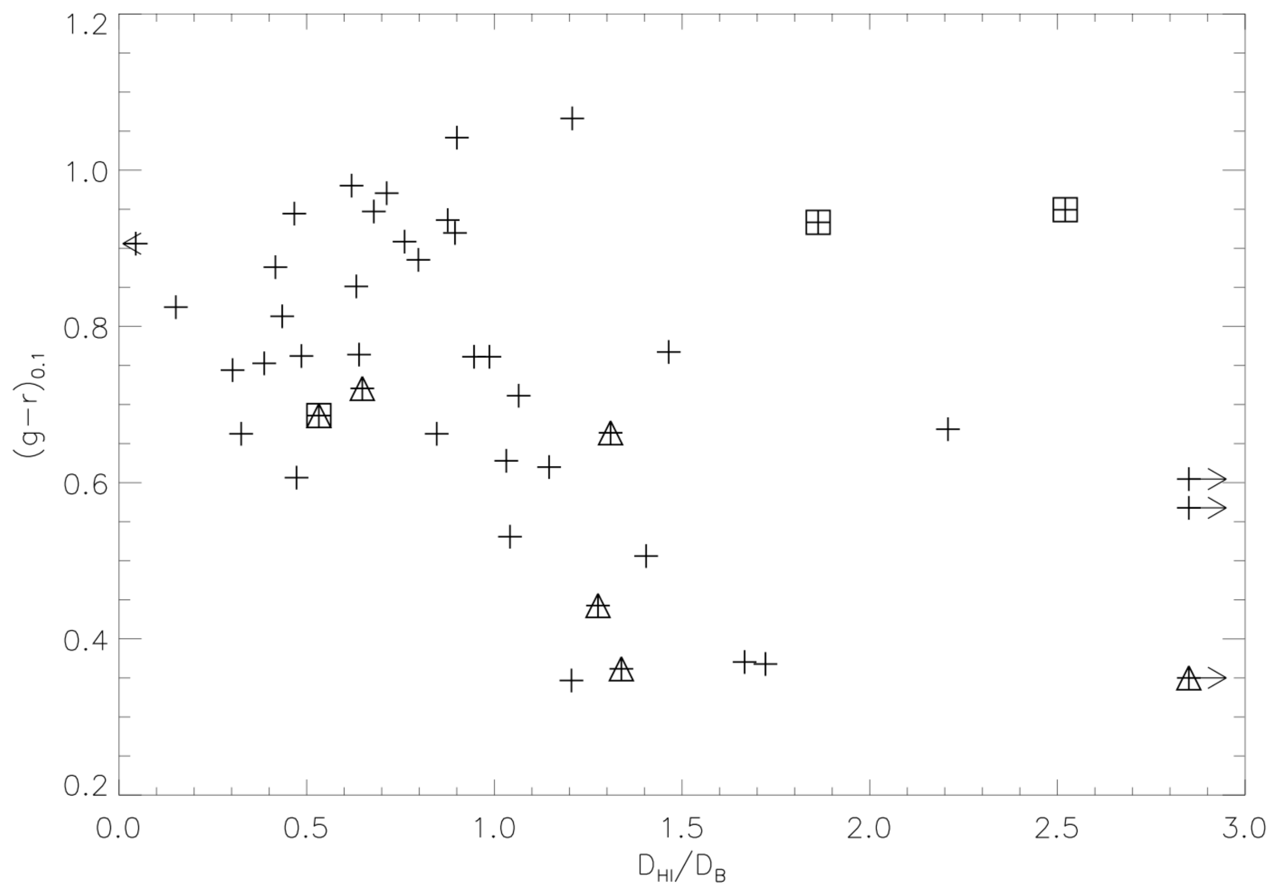
Crowl, Chung et al 2011 in preparation



Crosses VIVA galaxies   contours SDSS

Galaxies in blue cloud have D(HI)/D_{opt} > 1

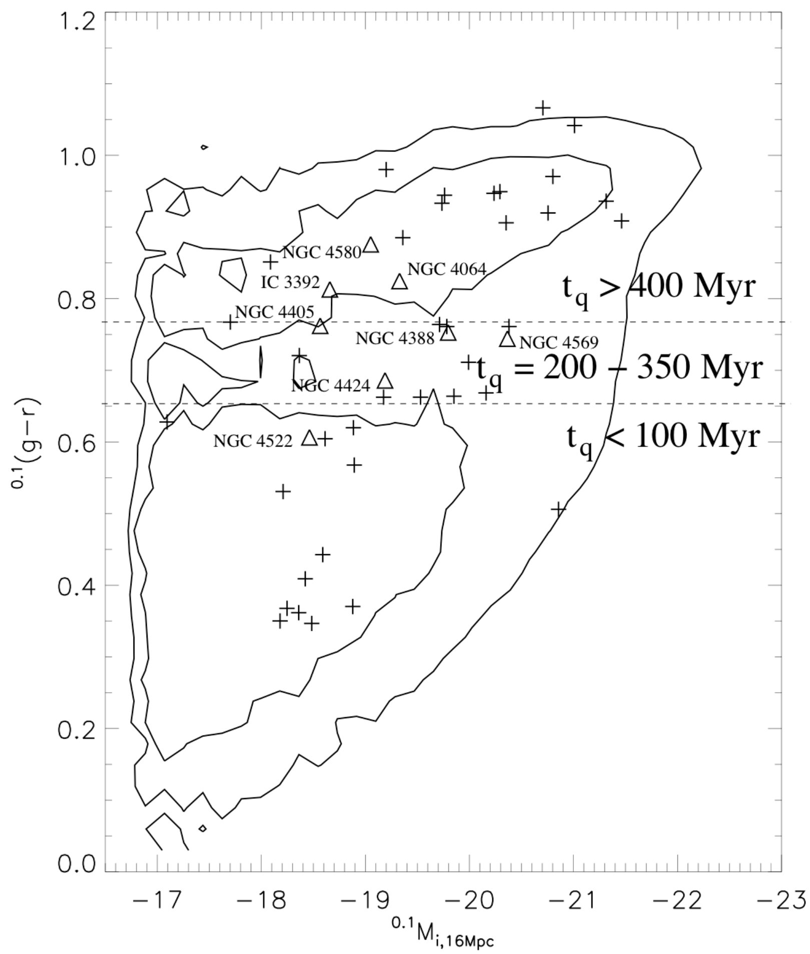
Galaxies on red sequence have mostly D(HI)/D_{opt} <1



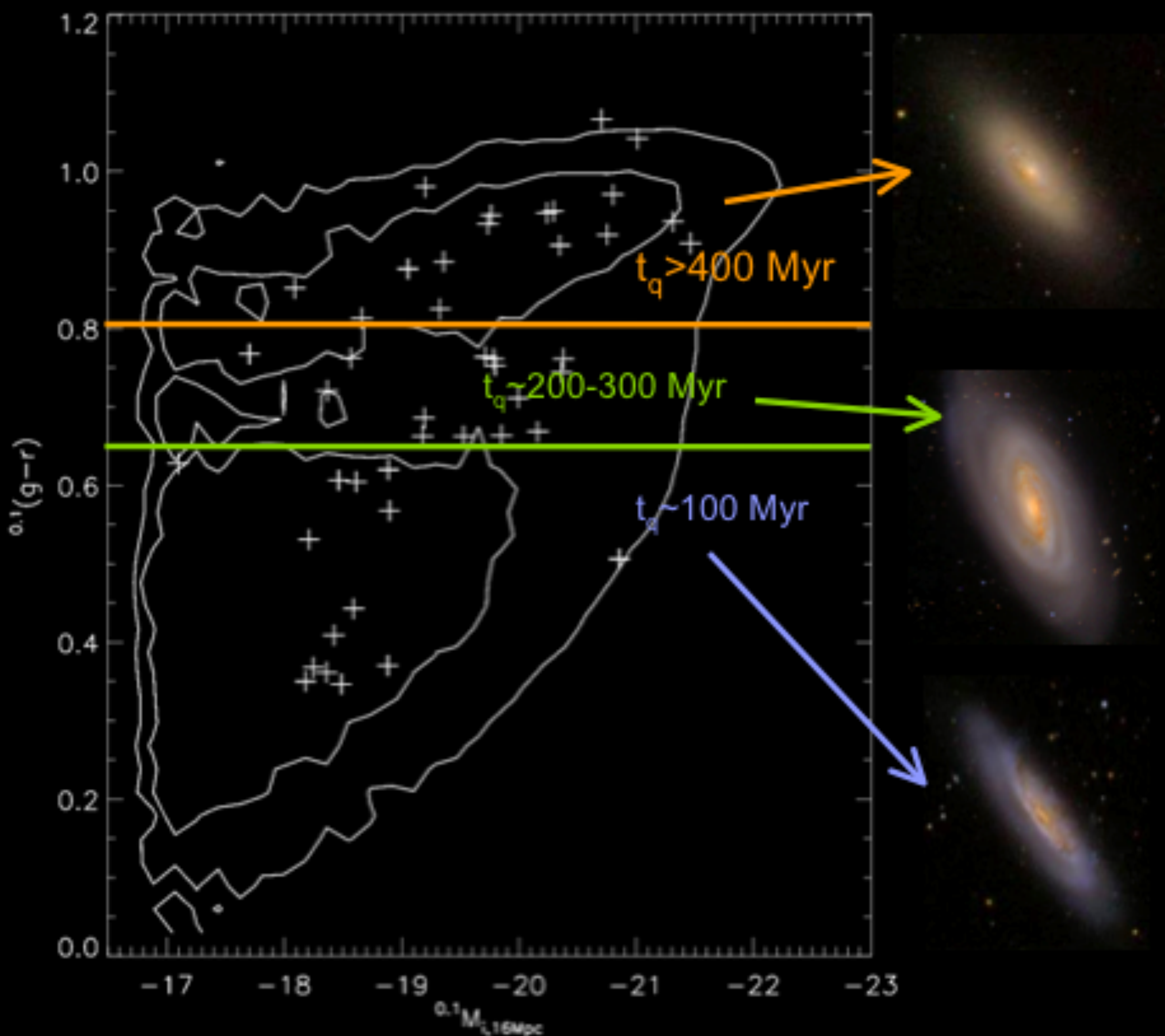
Triangles HI tails at about the virial radius of Virgo; squares merger remnants

For ram pressure stripped galaxies we can derive the timescale to cross the green valley

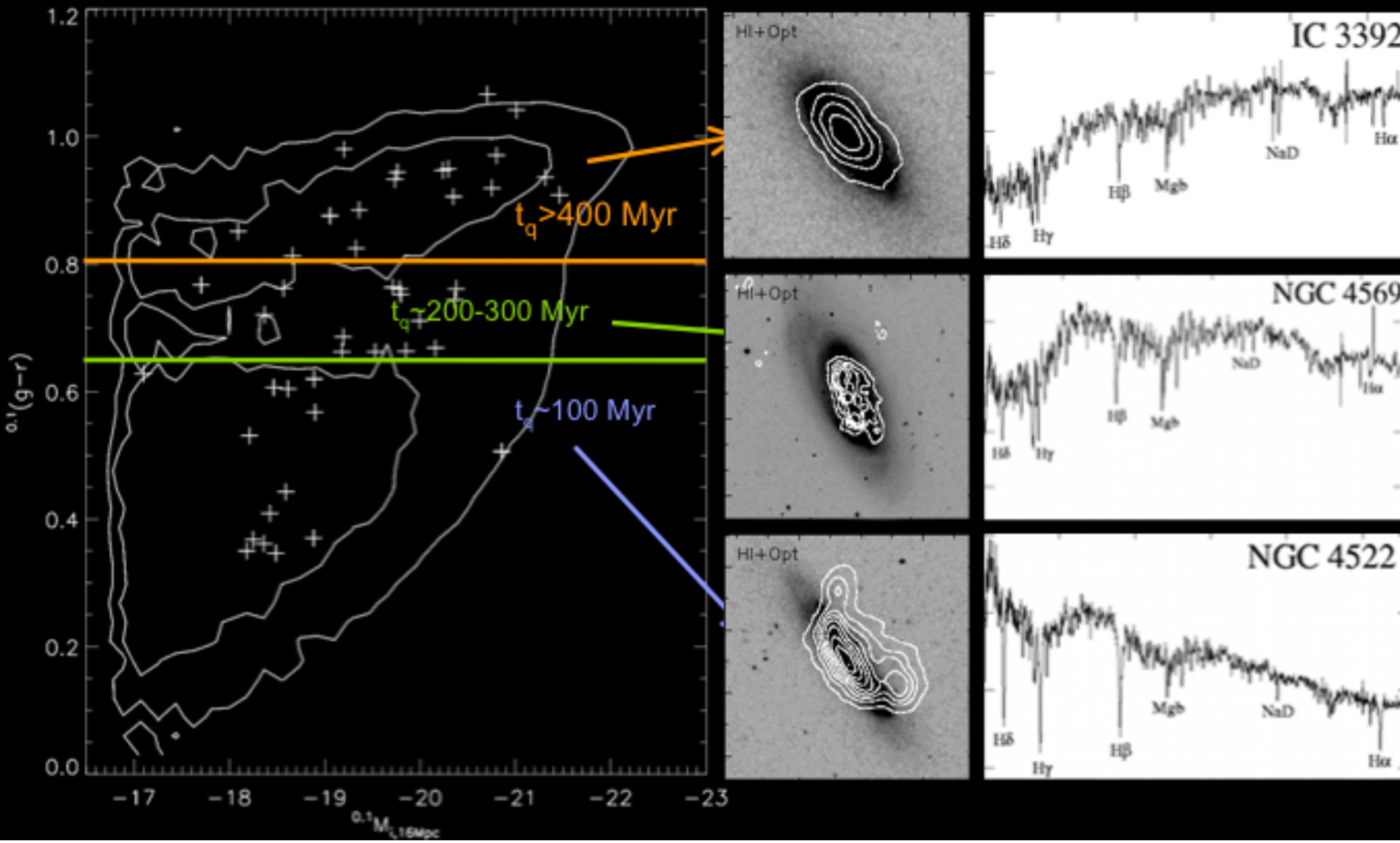
using the spectroscopically derived SF history   Crowl and Kenney (2008)



Color-Magnitude Diagram of VIVA Sample



Color-Magnitude Diagram of VIVA Sample



Contours 140000 SDSS galaxies (Blanton et al 2003); + VIVA galaxies (Crowl et al 2011 in prep)

Conclusions from HI imaging of selected galaxies

In center we see very small HI disks.. Almost certainly due to ram pressure stripping

The stripping is important for the color evolution of the galaxies.

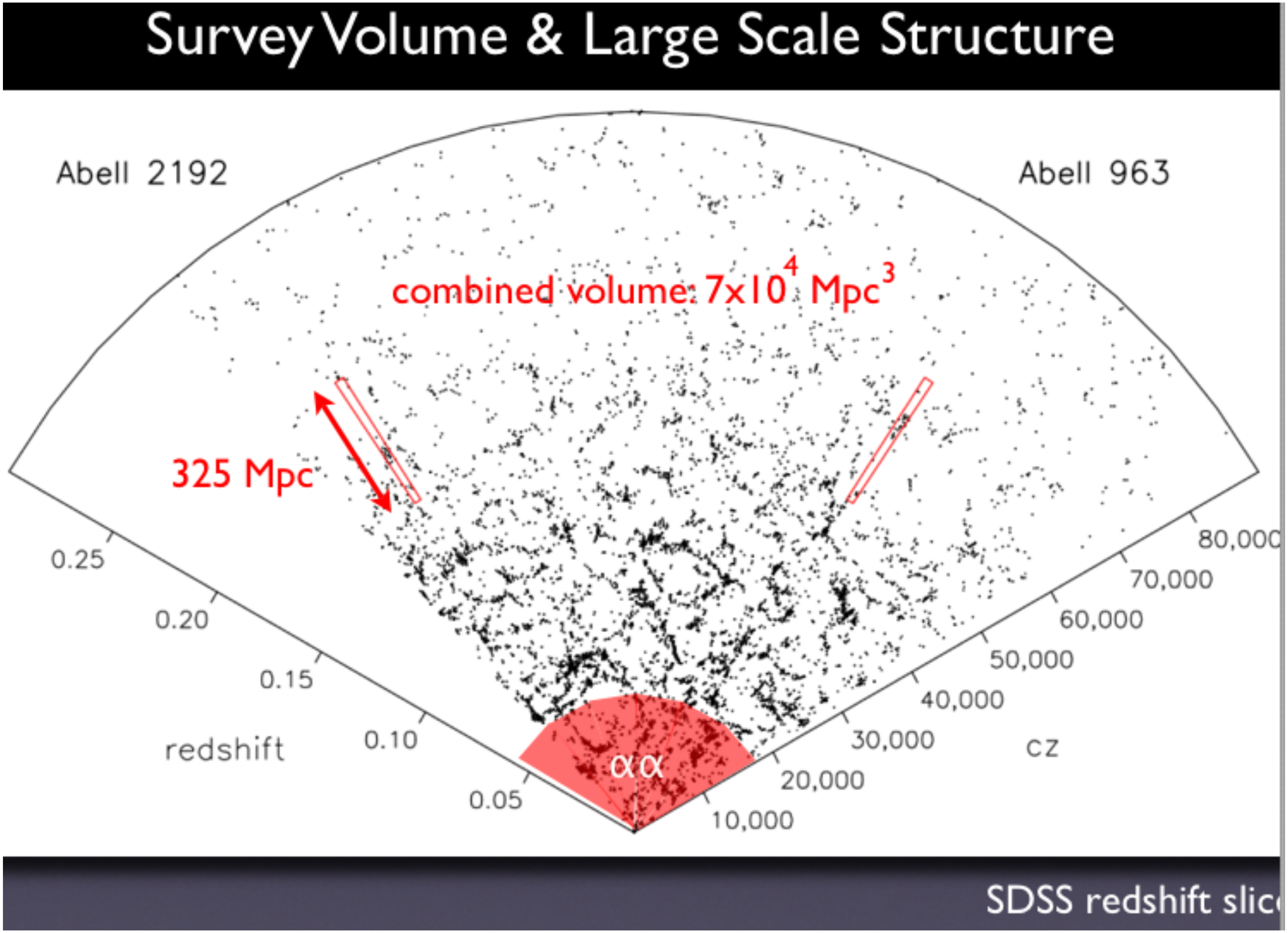
H alpha imaging (Koopmann Kenney 1998, 2004) shows that Virgo galaxies have reduced star formation rates compared to the field. This is primarily caused by truncation of starforming disks. A strong correlation is found between HI deficiency and normalized H alpha flux

Global colors are related to relative size of HI disks. It takes a few 100 Myr to change from blue to red after stripping to within disk

We see for the first time galaxies being affected at intermediate distances. Galaxies falling in radially are being affected by ram pressure and/or gravitational interactions.. preprocessing

Some galaxies at large distances being affected by strong rampressure.

Evidence for a dynamic ICM



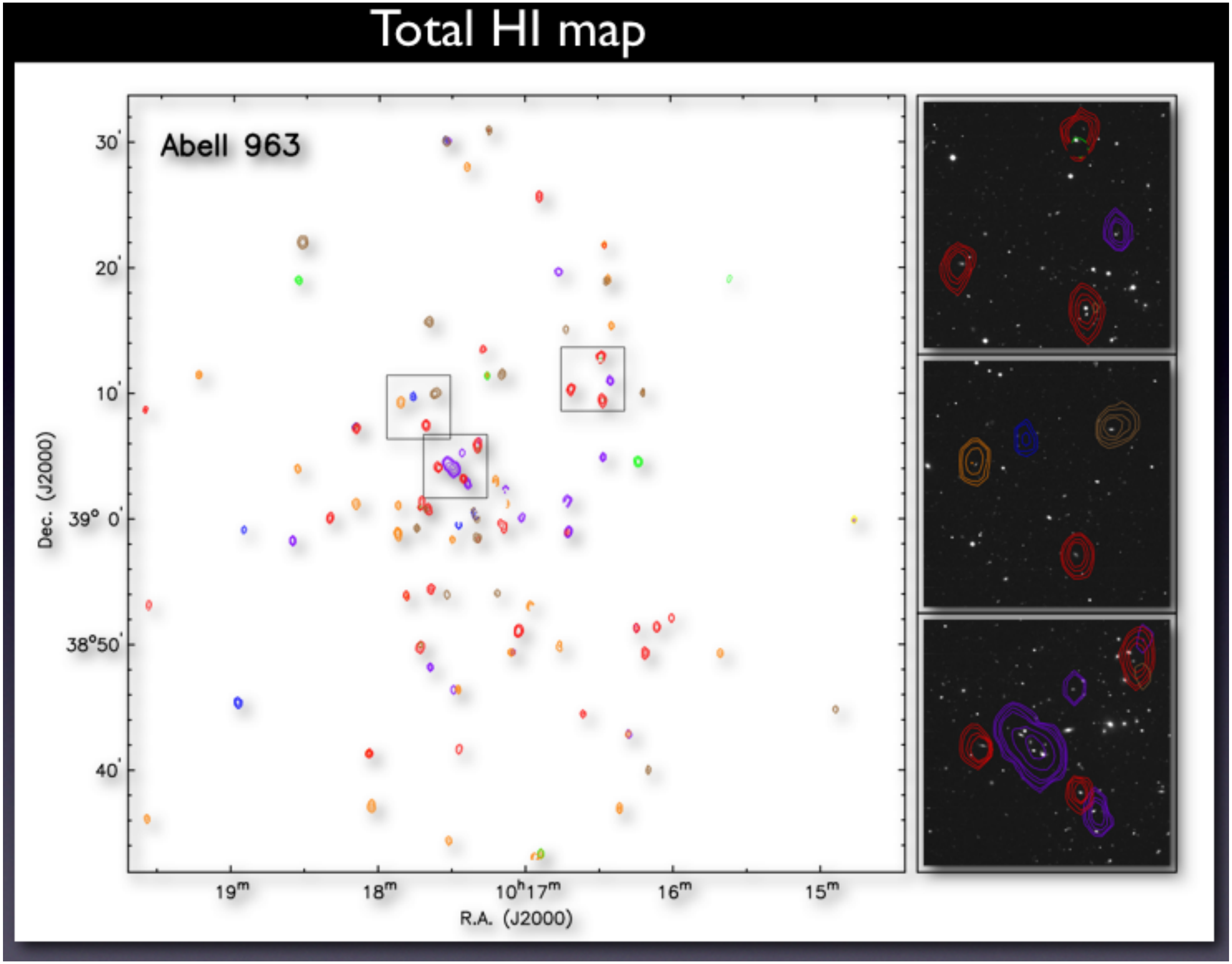
Verheijen et al

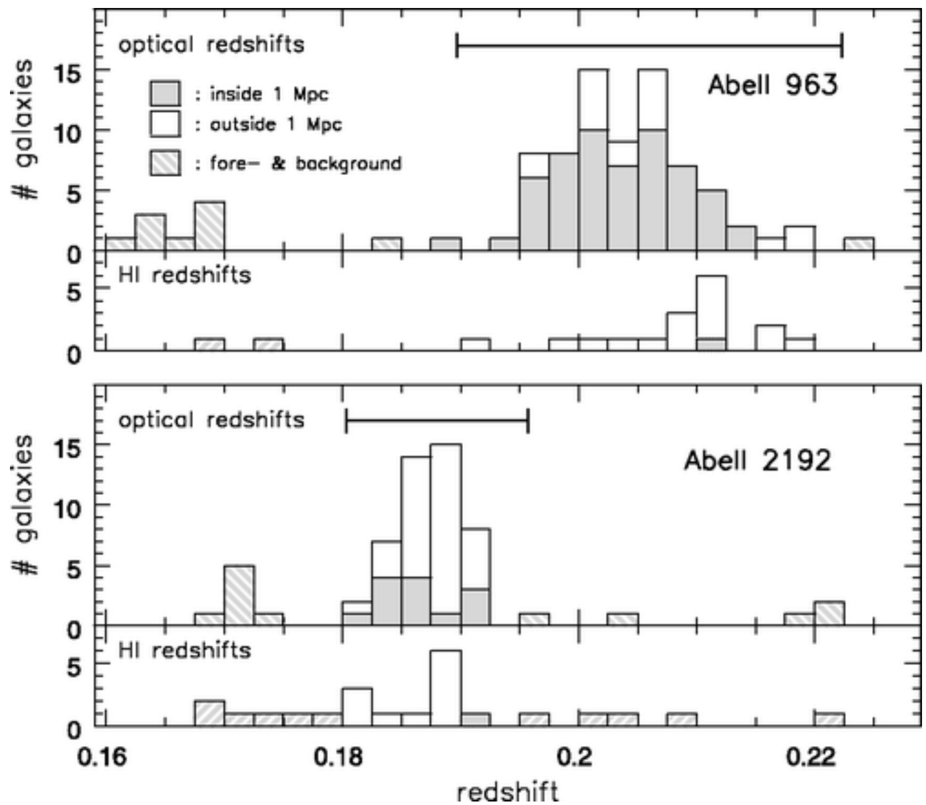
HI imaging of clusters at z=0.2

Verheijen, JvG, Szomoru, Dwarakanath,Poggianti, Schiminovich, 2007, ApJL, 688, L9

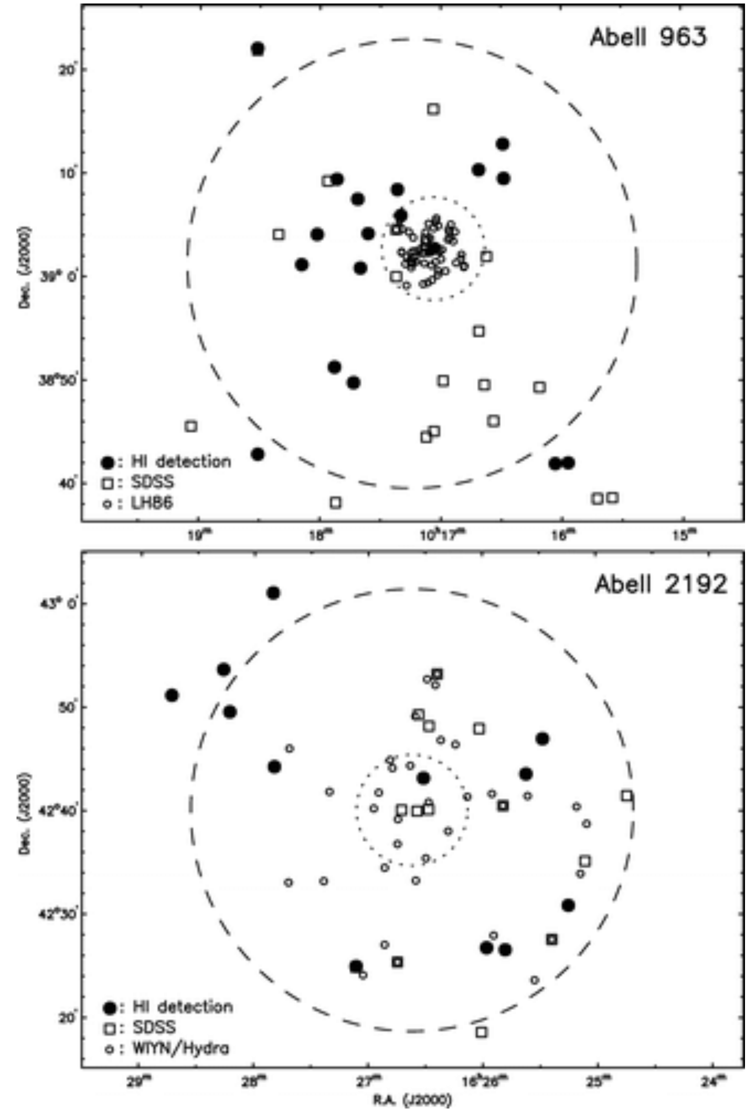
Boris Deshev, Montero-Castano, Chung, Yun, Ryan

Deshev, Verheijen et al, in prep 2011

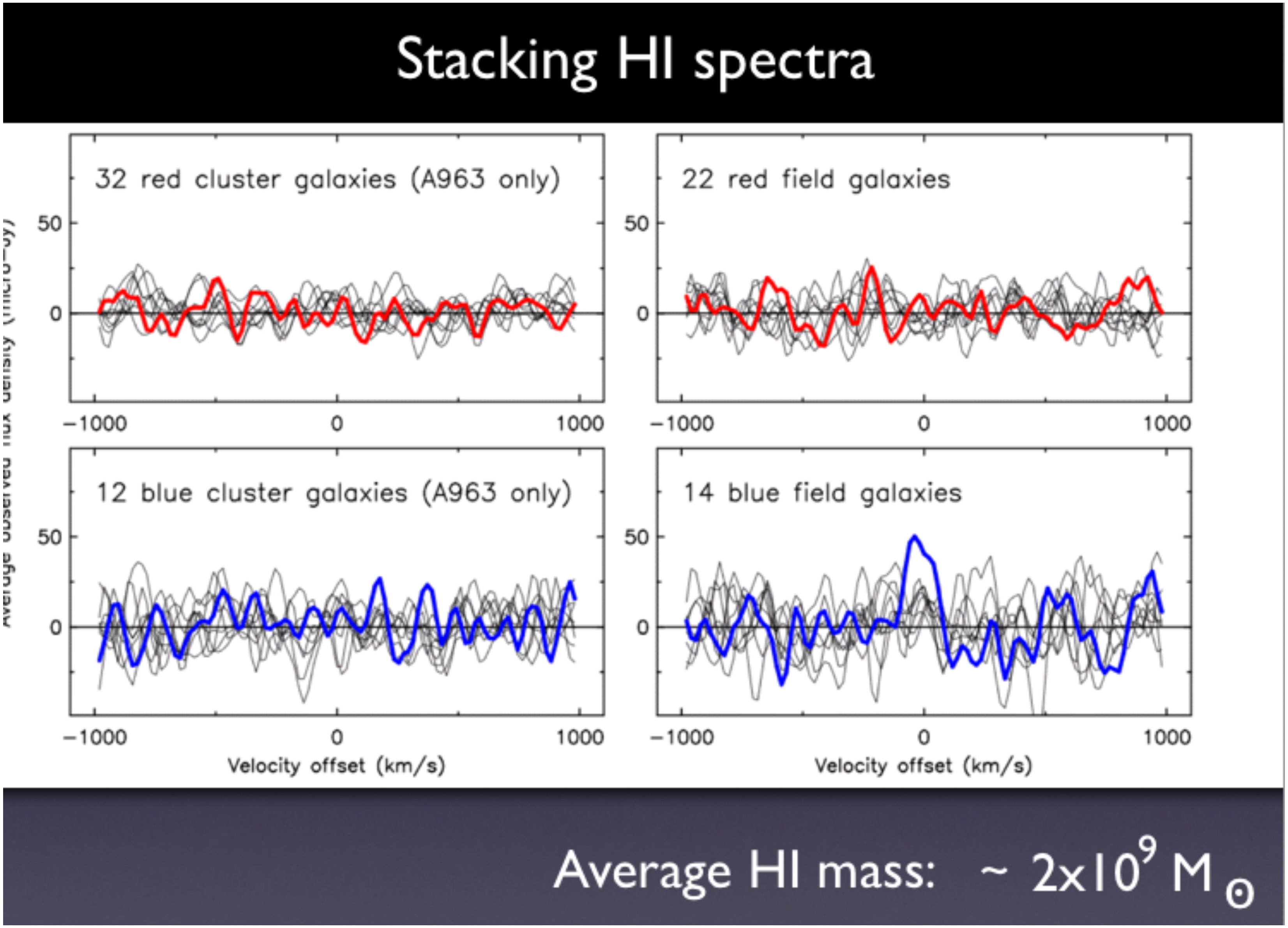




optical redshifts
Abell 963
: inside 1 Mpc
: outside 1 Mpc
: fore- & background
galaxies
HI redshifts
optical redshifts
Abell 2192
galaxies
HI redshifts
0.16
0.18
0.2
0.22
redshift

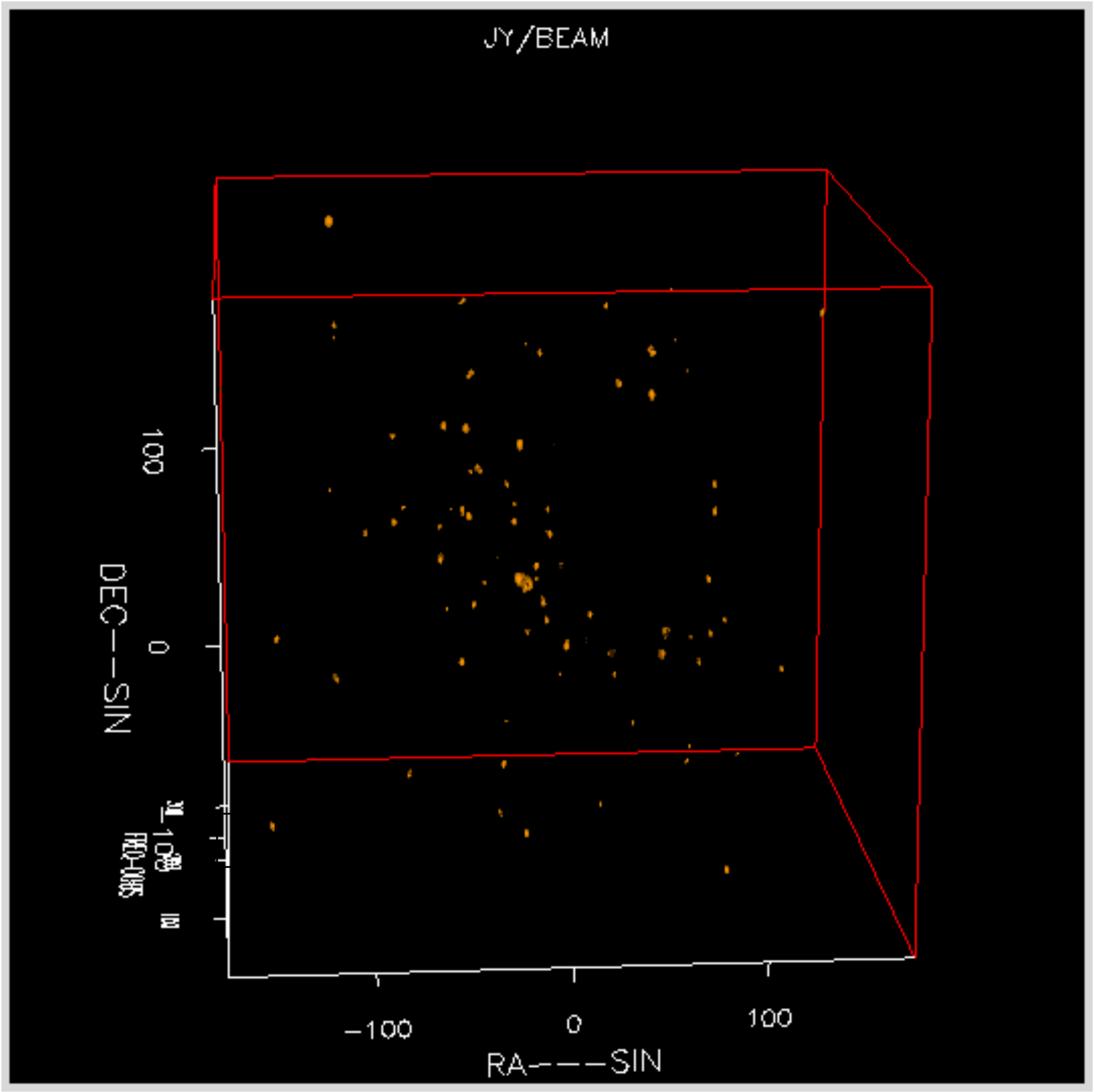


Abell 963
Dec. (J2000)
: HI detection
: SDSS
: LH86
Abell 2192
: HI detection
: SDSS
: WIYN/Hydra
R.A. (J2000)



BO galaxies in last phase of star formation

Verheijen et al.. HI cube



12 x 12 Mpc

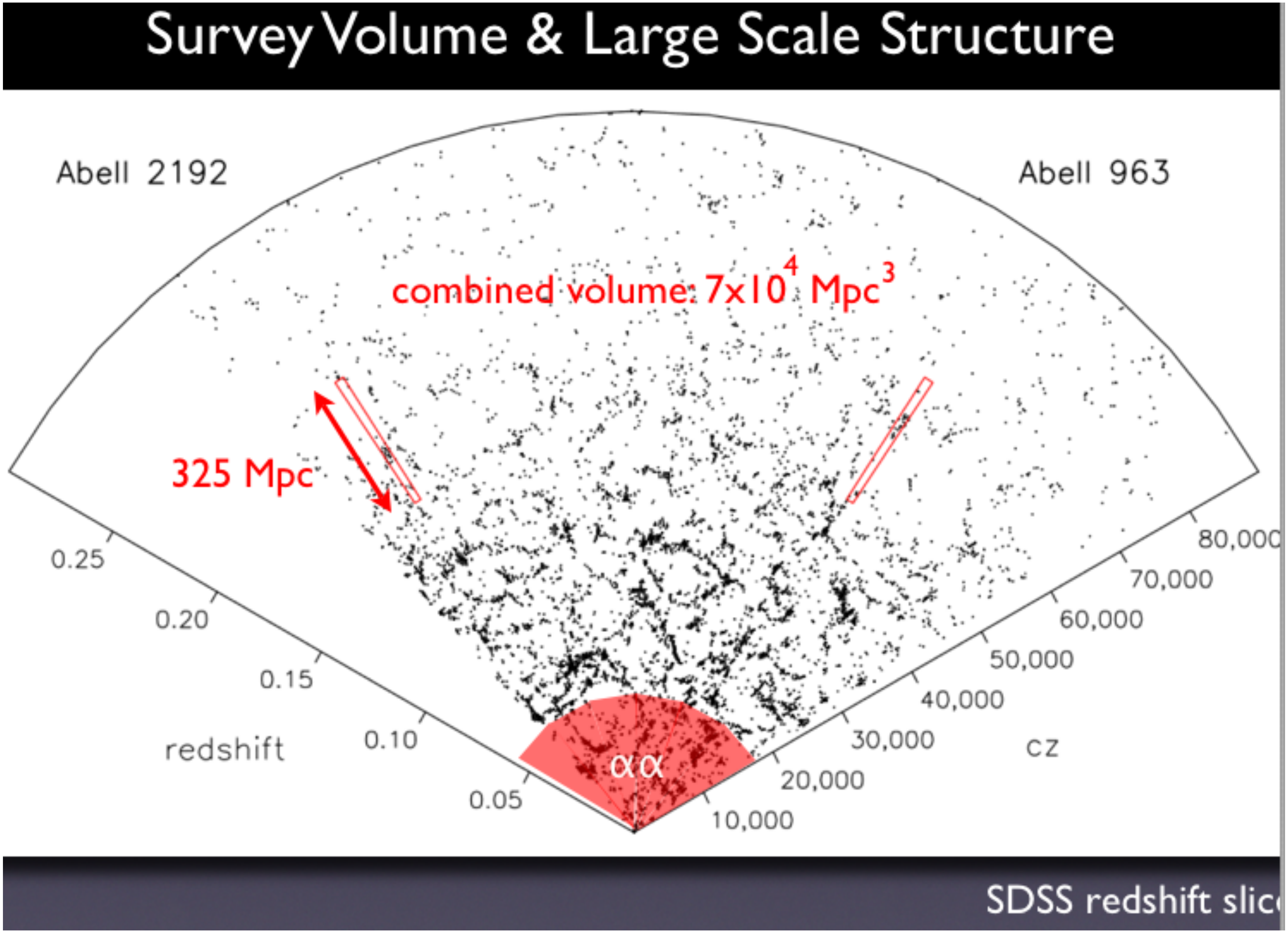
HI in void galaxy at z=0.2

The future

A number of telescopes will be able to do single pointing "large" redshift range imaging surveys:

EVLA, MeerKAT, ASKAP, Apertif , and eventually SKA

deep wide



EVLA can now do z=0 to z=0.18   futurr z=0 to z=0.45

A pilot for an EVLA HI Deep Field

One pointing in COSMOS field

JvG, Momjian, Kreckel, Pisano, Fernandez, Chomiuk, Wilcots, Lazio, Henning, van de Weygaert, Oosterloo, Scoville, Schiminovich, Bershady, Hess

60 hours in B array (5 arcsec at z=0) , data taken in April.. 2.5 Tbyte

32 sub bands 16384 channels (1420-1190 MHz; z=0 to 0.2) vel resolution 3.3 km/s

Detection limits		
	z=0.07	$7\text{x } 10^{8}\ M_{sun}$
	z=0.13	$4\text{x } 10^{9}\ M_{sun}$
	z=0.2	$1.3 \text{ x } 10^{10}\ M_{sun}$

Column density sensitivity $3\text{x}10^{19}\ \text{cm}^{-2}$

The FUTURE

EVLA HI deep field pointed at the COSMOS field.
pilot $z=0-0.2$

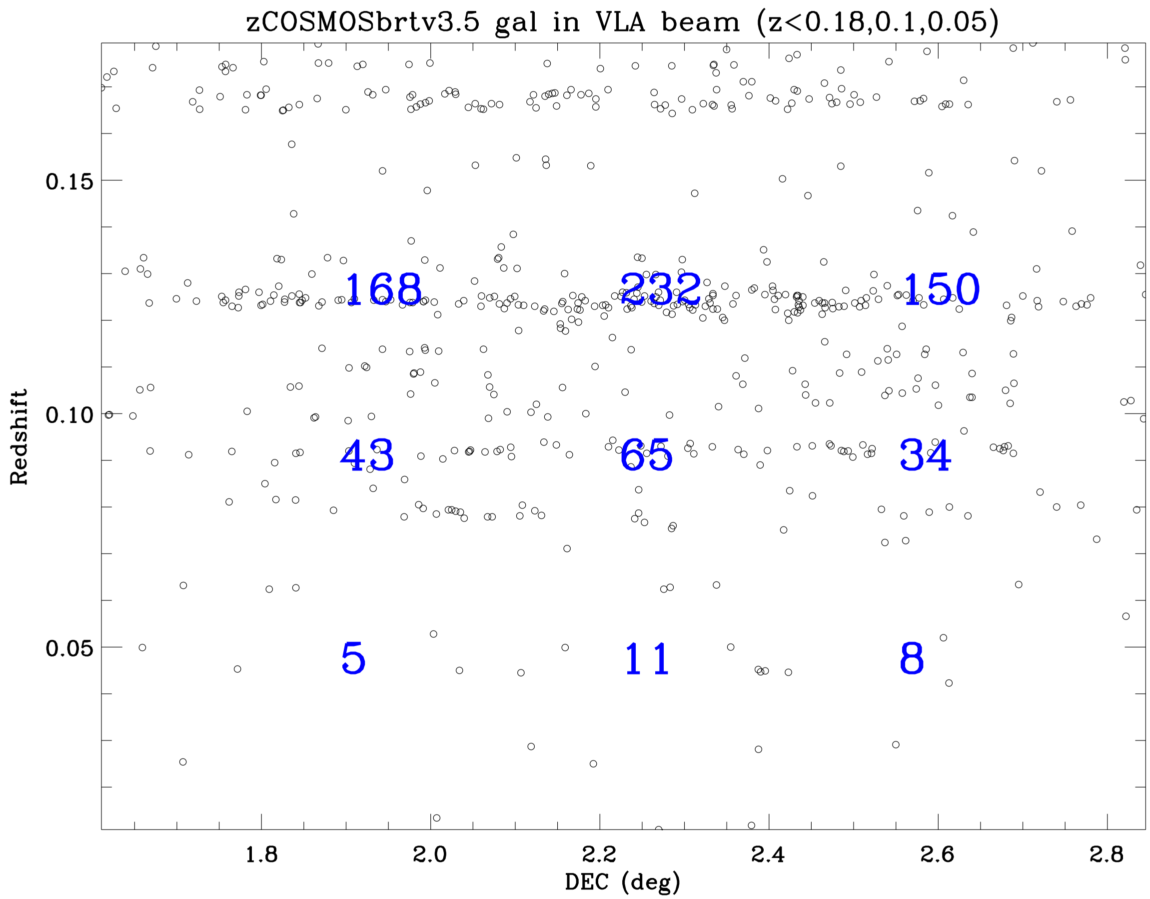
Goals: Demonstrate we can handle the data
Integrate down to thermal noise
Do some science

Remove RFI..profile is the same for Plains of San Augustin and Drente

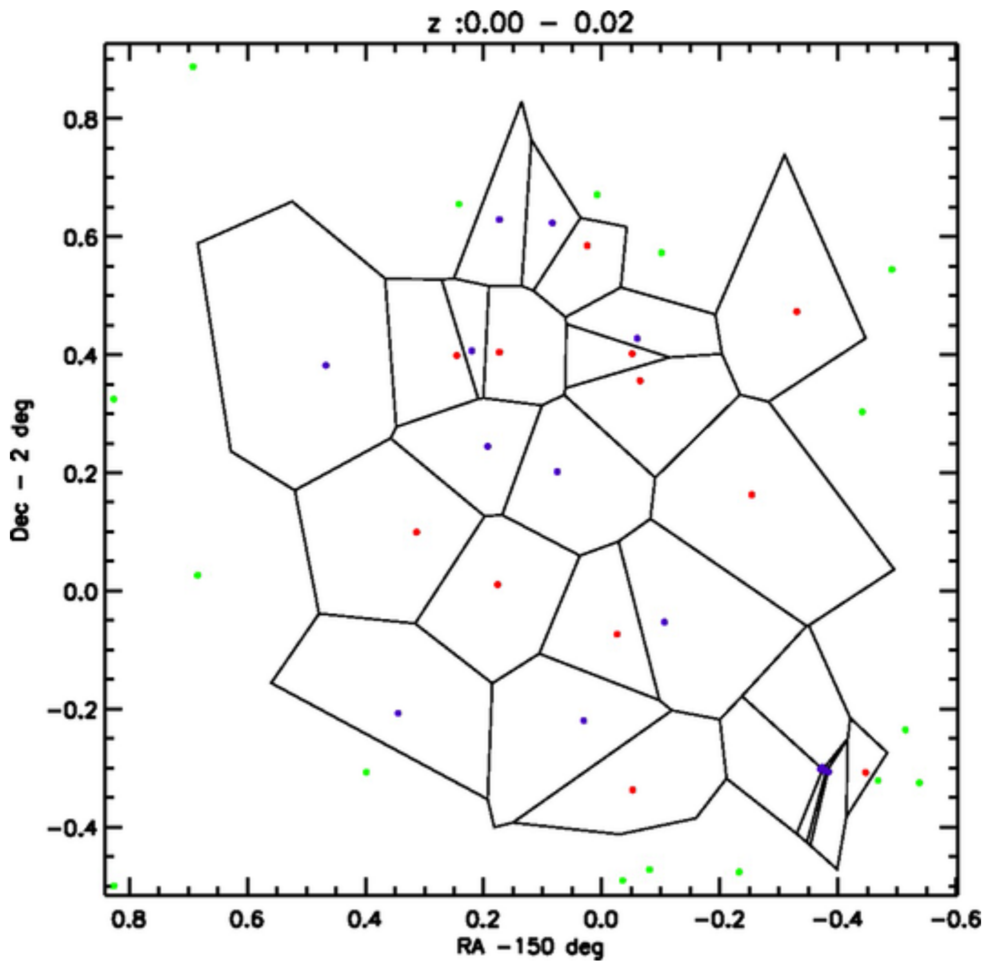
Satellites! But the good news is.. Not much RFI at baselines > 4km

real HI deep field $0<z<0.45$ will be possible in 2013

A movie made of the Voronoi tesselation of cosmos from $z=0$ to 0.45 by Scoville



zCOSMOSbrtv3.5 gal in VLA beam (z<0.18,0.1,0.05)
0.15
0.10
0.05
Redshift
1.8
2.0
2.2
2.4
2.6
2.8
DEC (deg)
168
232
150
43
65
34
5
11
8



z :0.00 – 0.02
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
Dec – 2 deg
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
RA −150 deg