Evolution of HI gas contents and morphology types in galaxy groups

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FAST construction

Construction completed 2016-09-25

2. General Technical Specification

Spherical reflector：Radius～300m, Aperture～500m, Opening angle 110~120°

Illuminated aperture：D_{ill}=300m

Focal ratio：f/D =0.467

Sky coverage：zenith angle 40°（up to 60° with efficiency loss) tracking hours 0~6h

Frequency：70M ~ 3 GHz（up to 8GHz in future upgrading）

Sensitivity (L-Band)：A/T~2000, T~20 K

Resolution (L-Band)：2.9′

Multi-beam (L-Band)：19, beam number of future FPA >100

Slewing：<10min

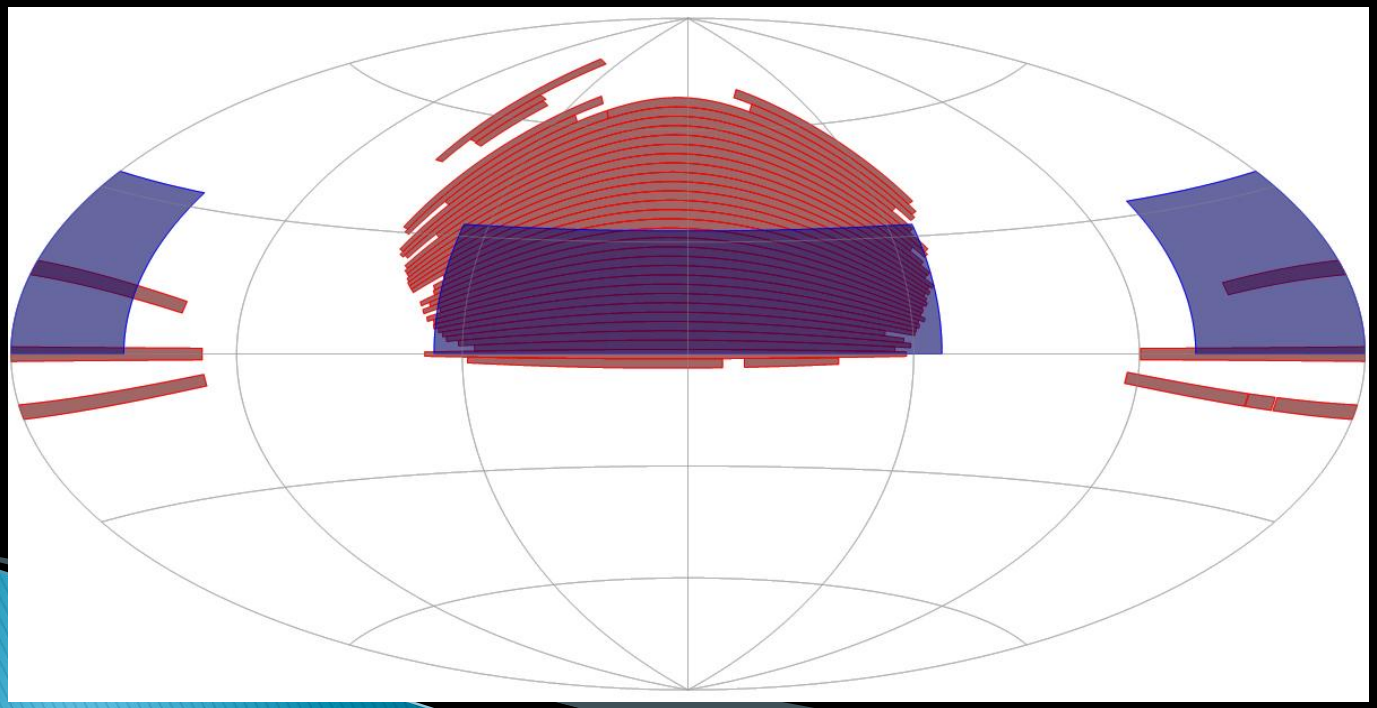
Pointing accuracy：8″

HI studies with FAST (Nan et al. 2011)

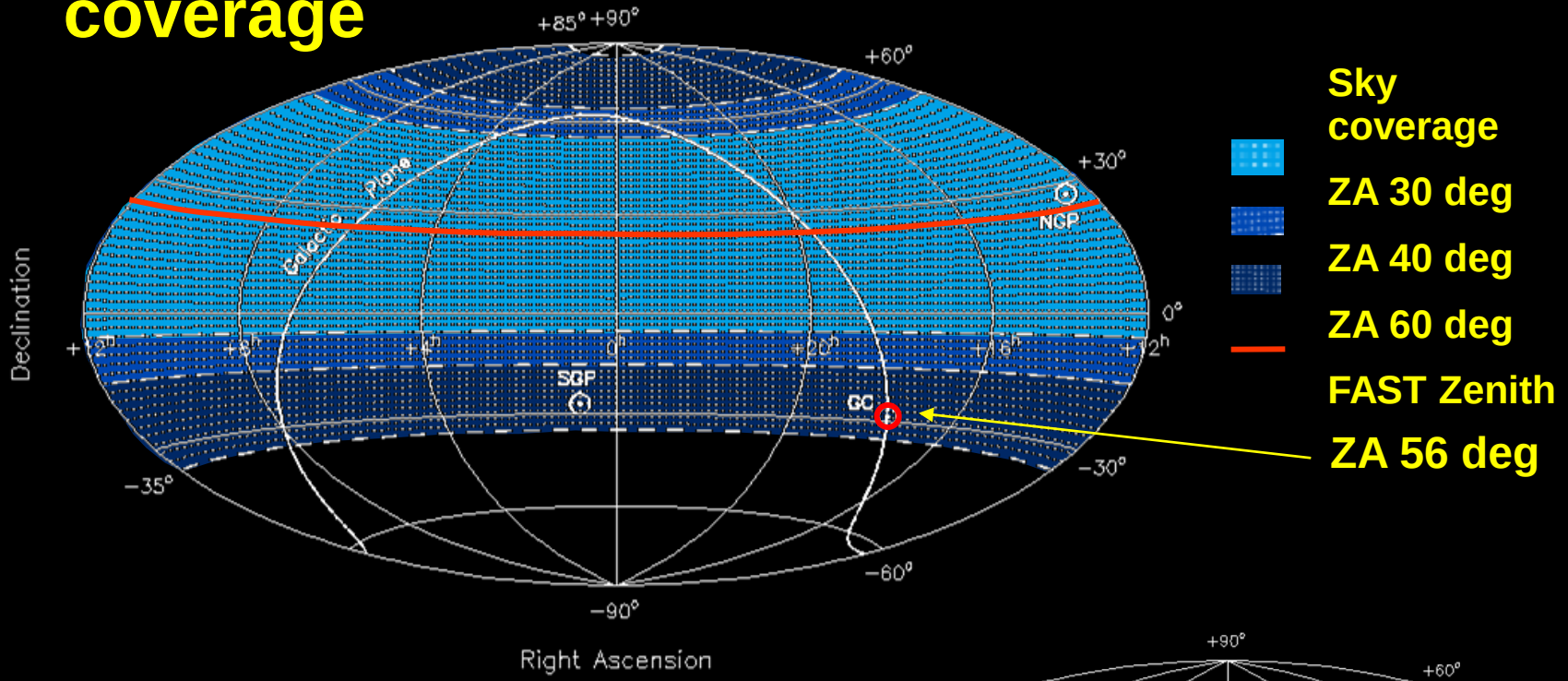
- Extent of HI Disk - truncation
- Extended rotation curve to extreme large distance
- Large scale structure and Cold Dark Matter (ΛCDM)
- HI Mass Function
- Voids
- Surveying Milky Way (FV, Magellanic Stream …)
- HI gas in high redshift galaxies (including HI absorptions)
- HI gas in galaxy clusters and groups
- High z OH megamaser

FAST all-sky HI survey

- Using a 19 beam L-band receiver to map the FAST sky at 20- 40 sec per beam, doable in 1-2 yrs.
  - Expect about 1 million detections (Duffy et al. 2008, 2012) with $M_{HI} < 10^{11} M_{\odot}$ out to z ~ 0.15 in a range of environments including Hydra, Persues-Pisces supercluster plus neighboring voids.

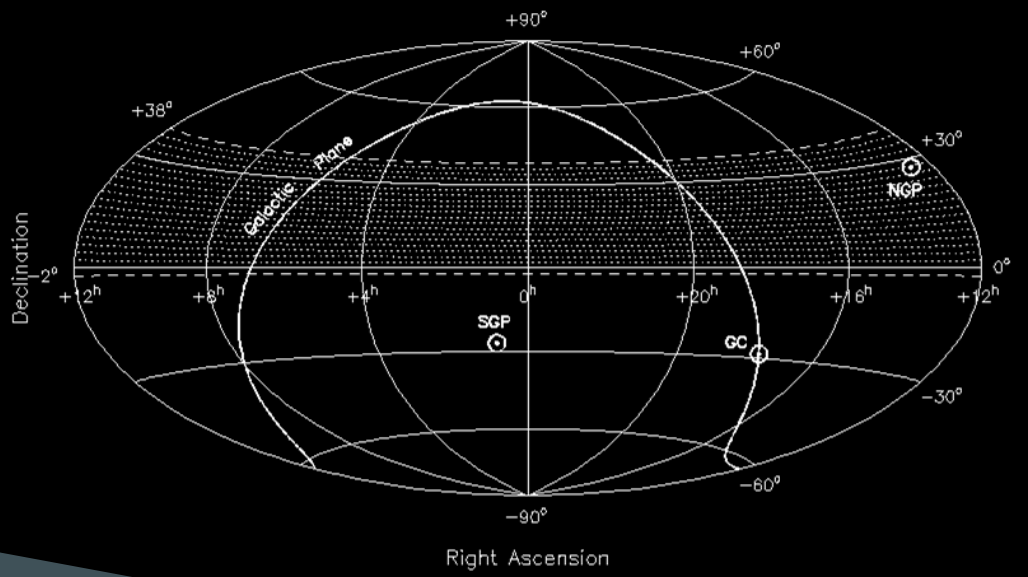


Opening angle - sky coverage



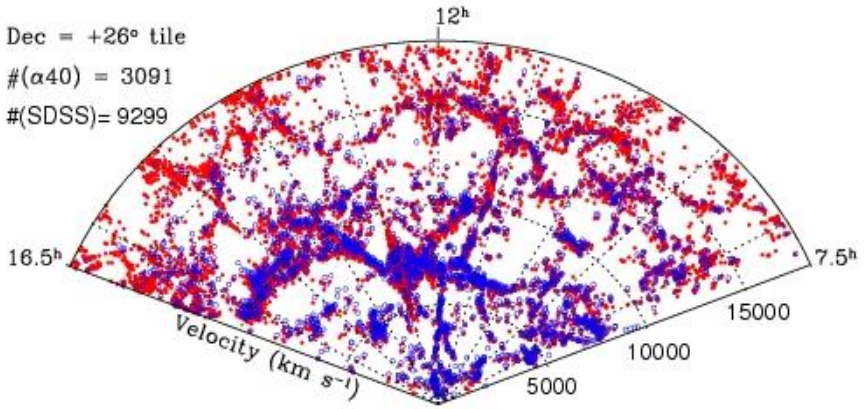
Sky coverage

FAST vs. Arecibo



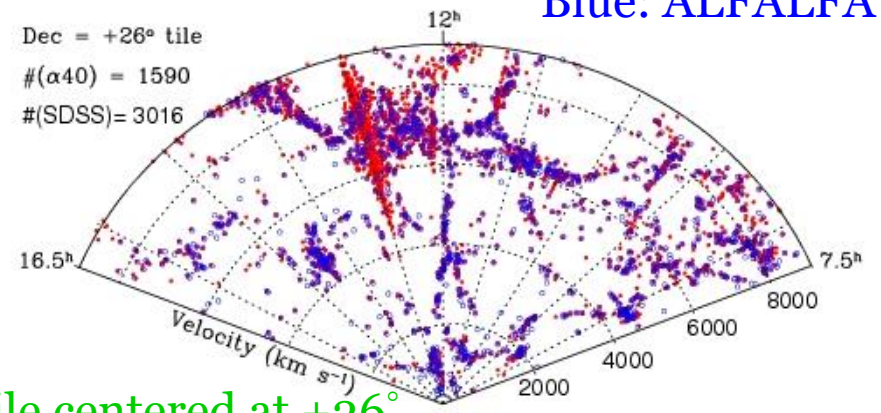
ALFALFA 40% catalog (Haynes + 2011)

- Undersamples clusters but traces well the lower density regions



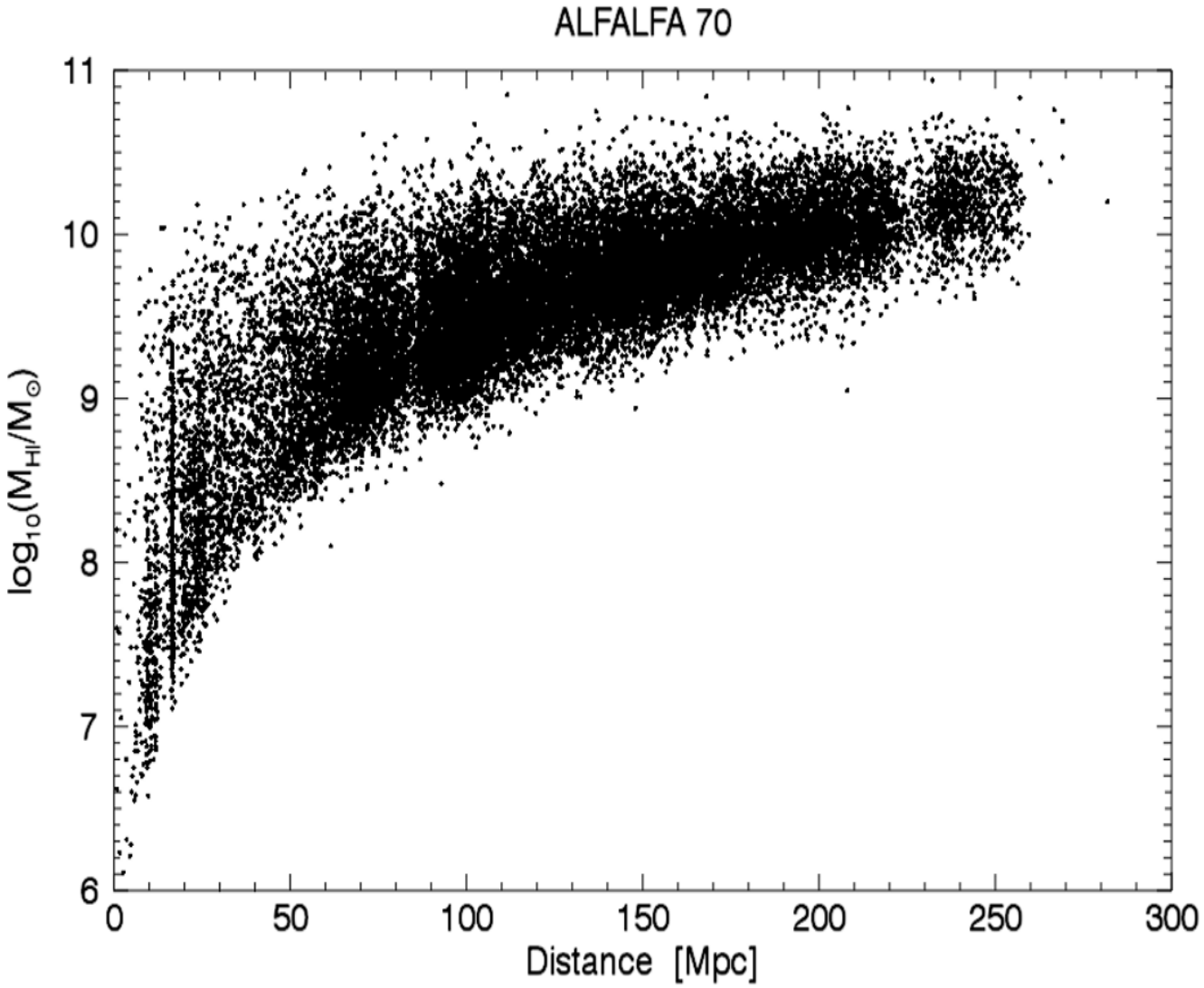
Red: SDSS

Blue: ALFALFA



4° tile centered at +26°

ALFALFA70


ALFALFA 70
11
10
9
8
7
6
0
50
100
150
200
250
300
log10(MHI/M⊙)
Distance [Mpc]

High z HI galaxies z=0.38 (Fernande et al. 2016)

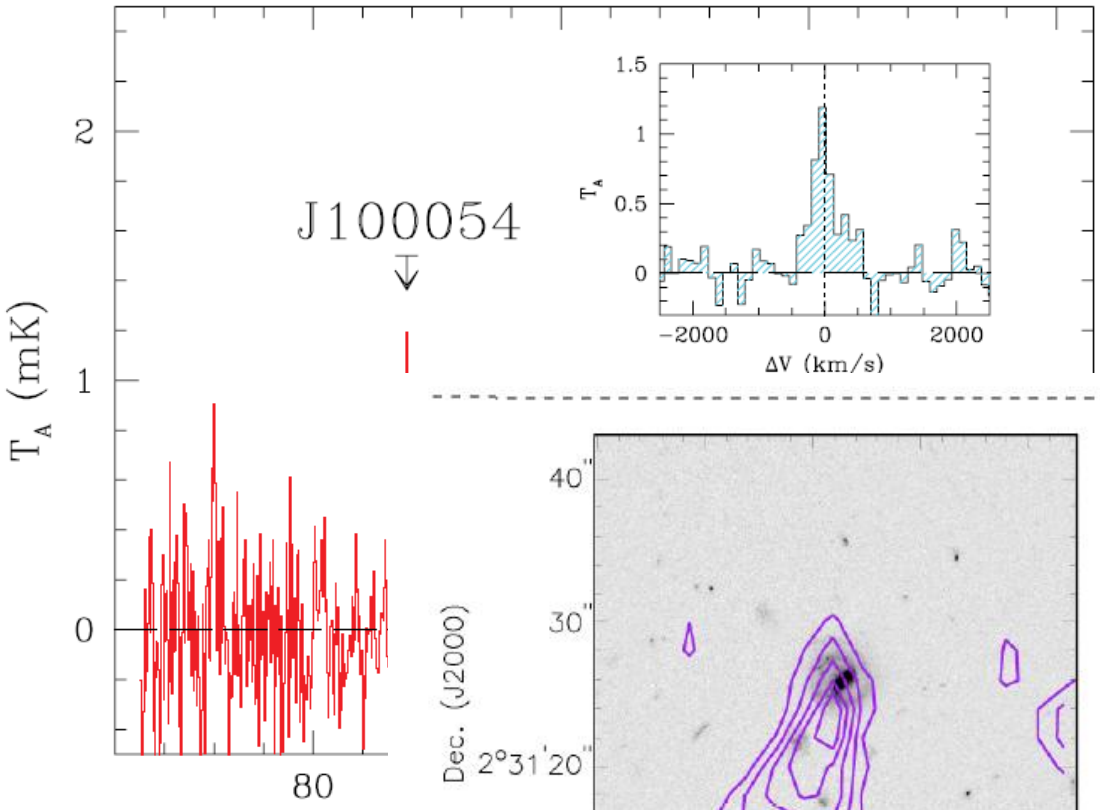
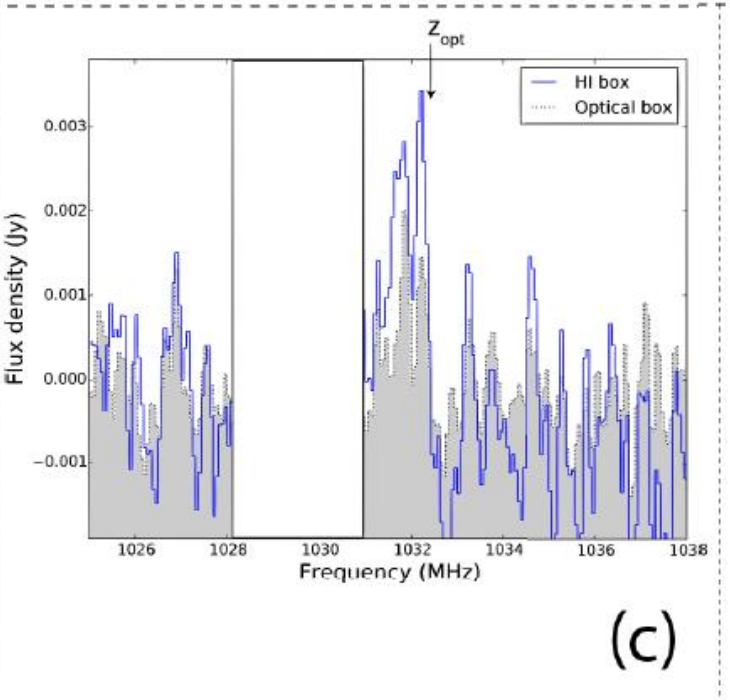
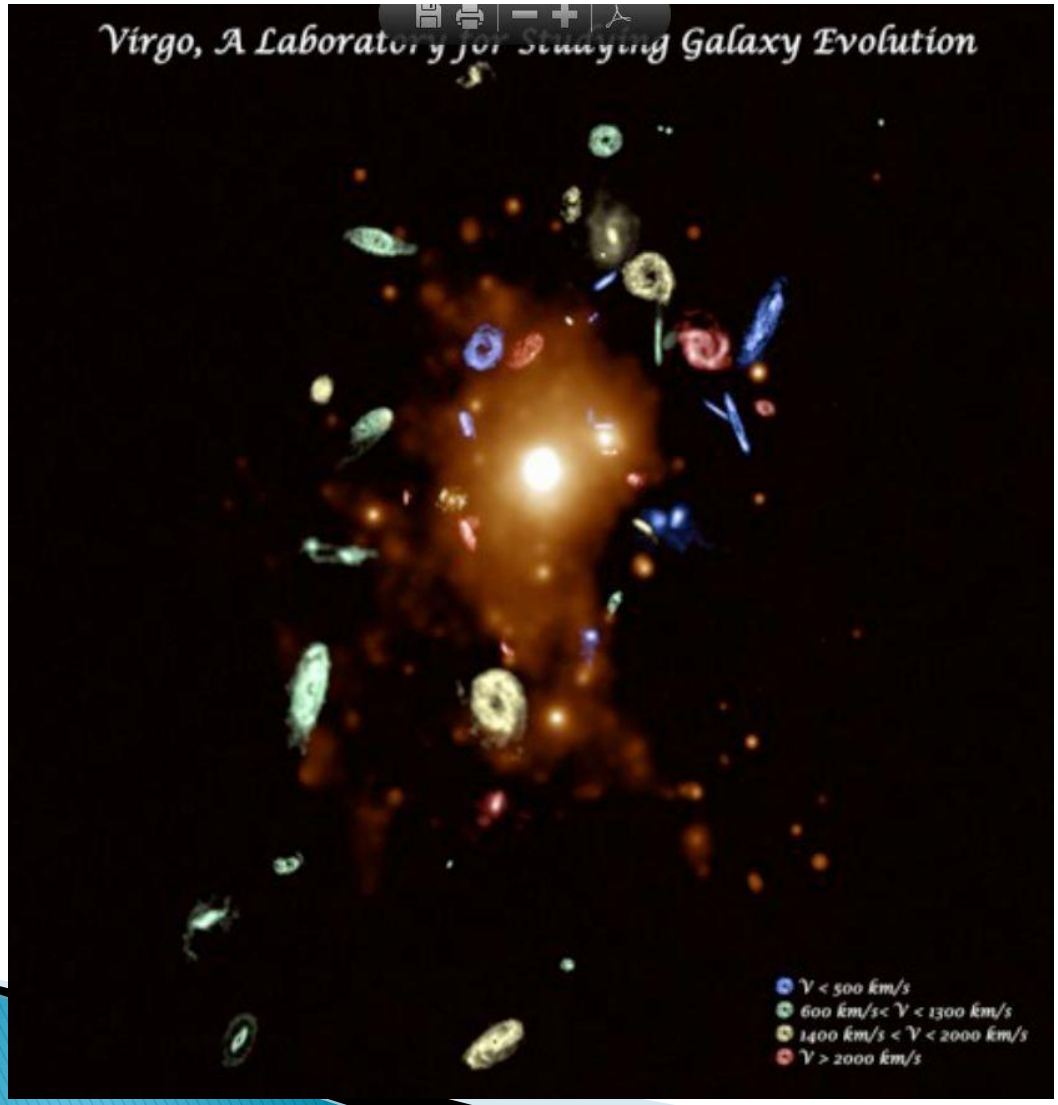


FIG. 2.— CO spectru
the LMT. The larger pa
nset shows a zoom-in
($z = 0.376$).



Groups and clusters



Chung et al.（ 2009）

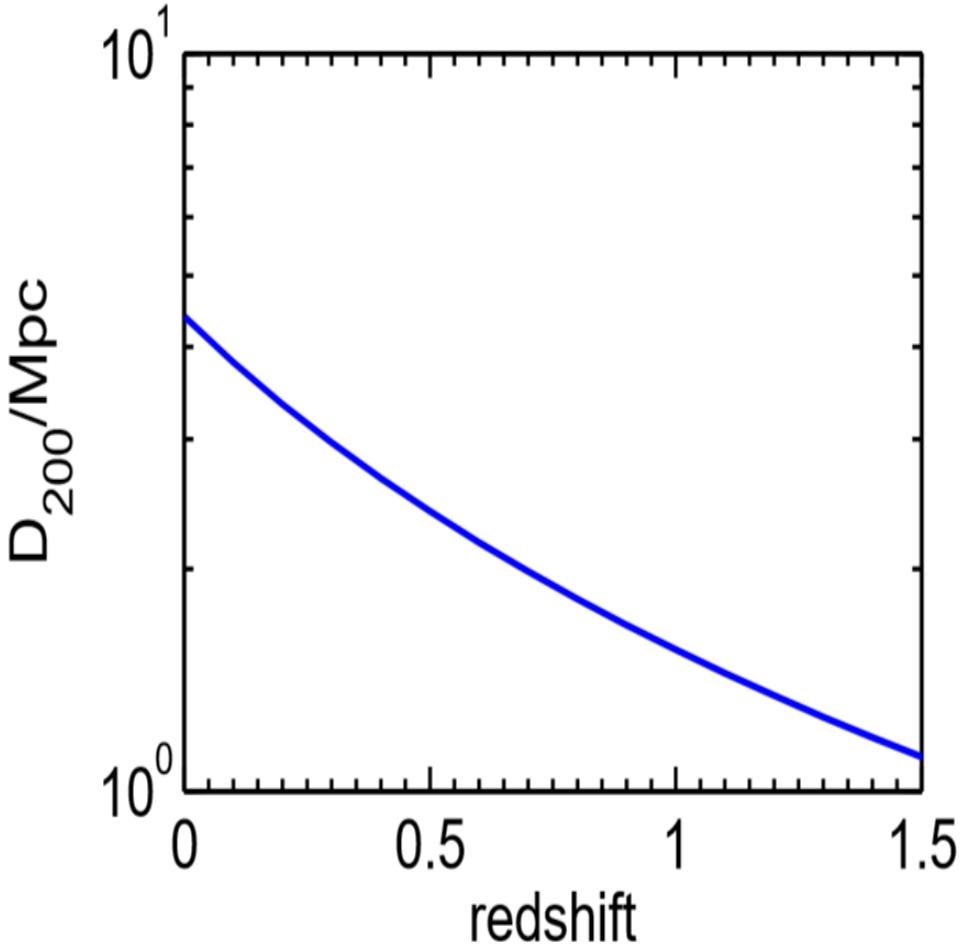
Beam size

FAST Beam size：
2.95’(1+z)

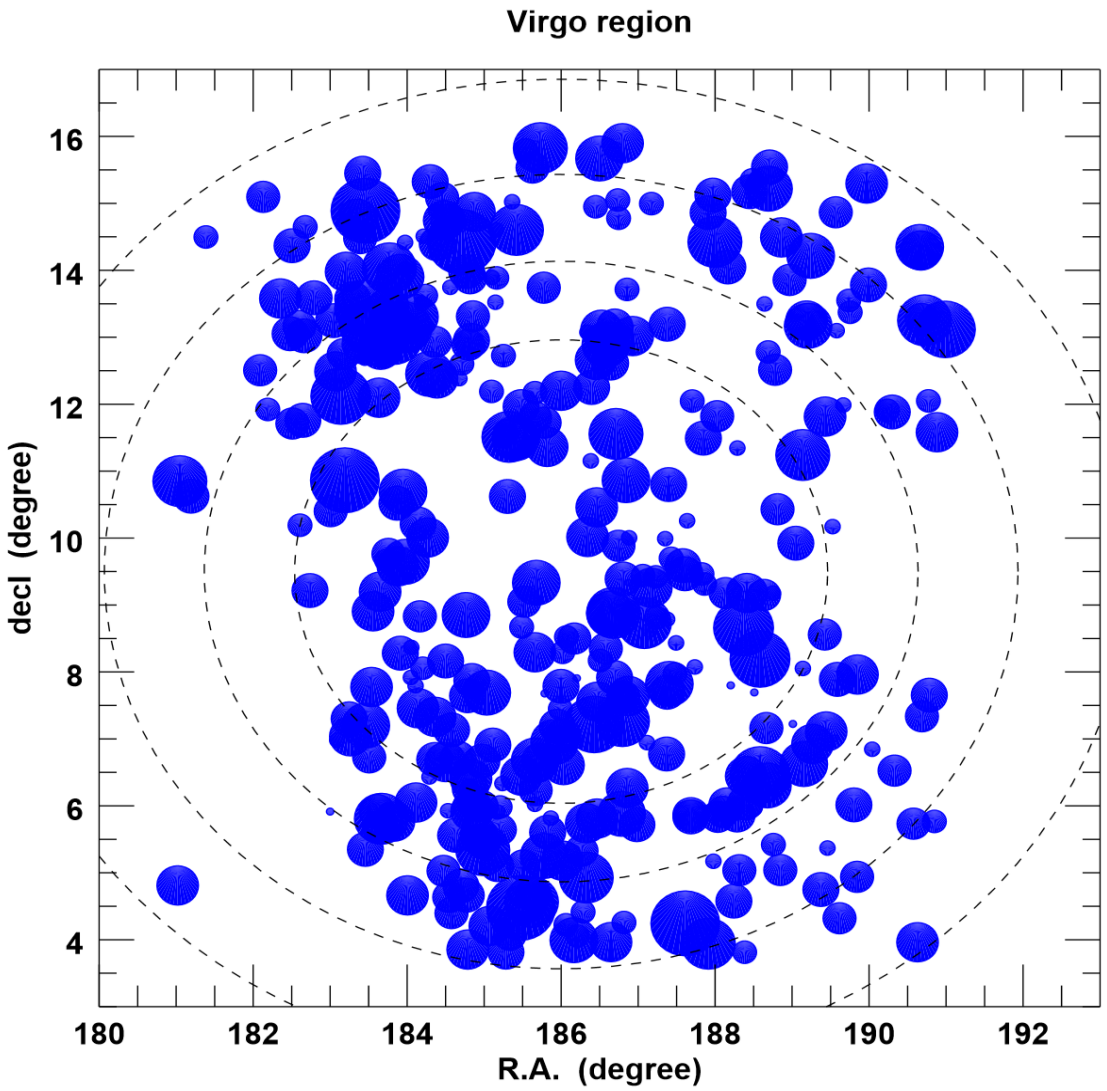
Dark matter growth（White &Frenk1991），

r = $r_0(1+z)^{-3/2}$

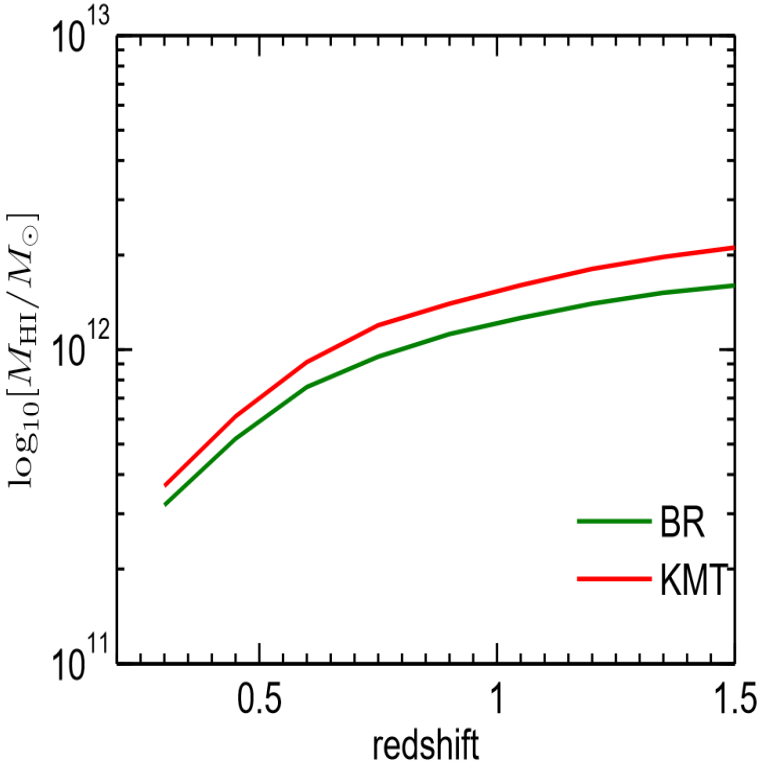
r_0=1.95Mpc



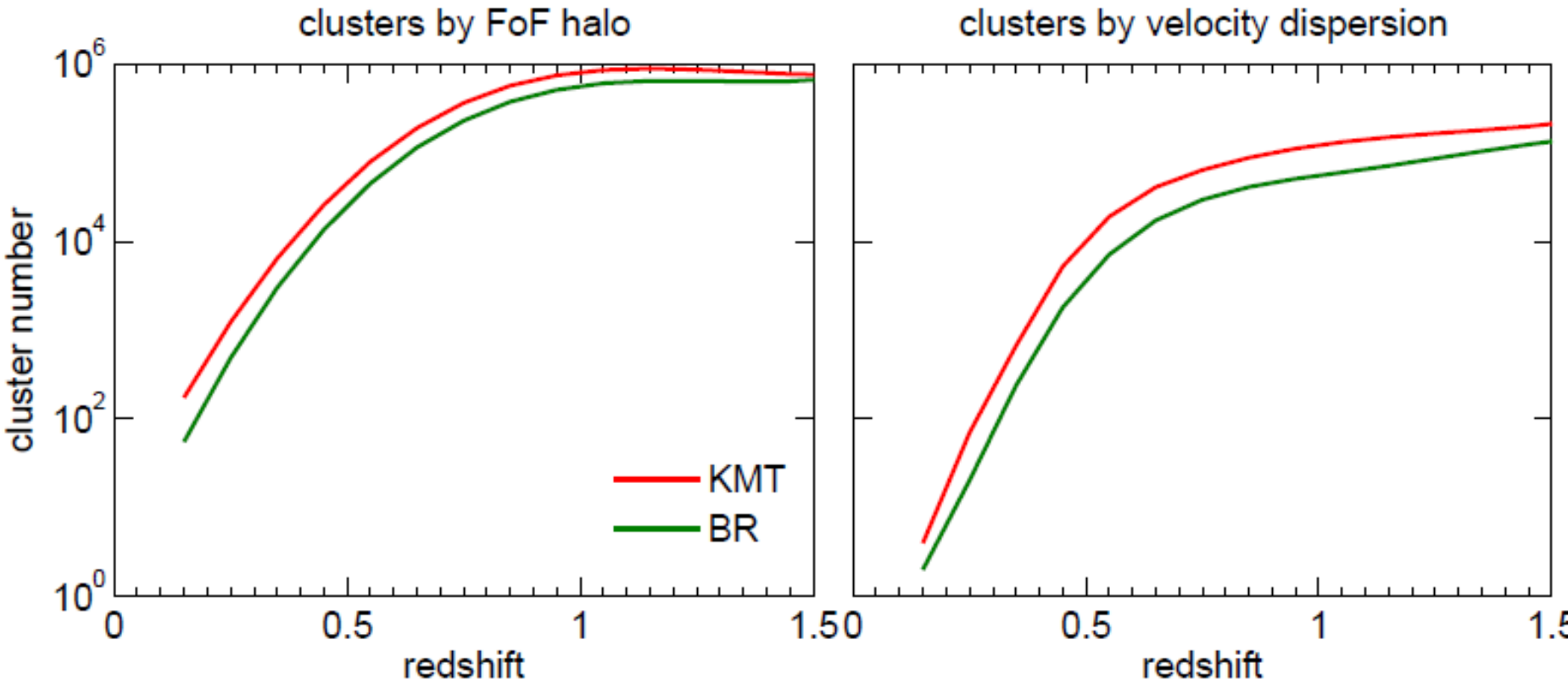
FAST observations of groups



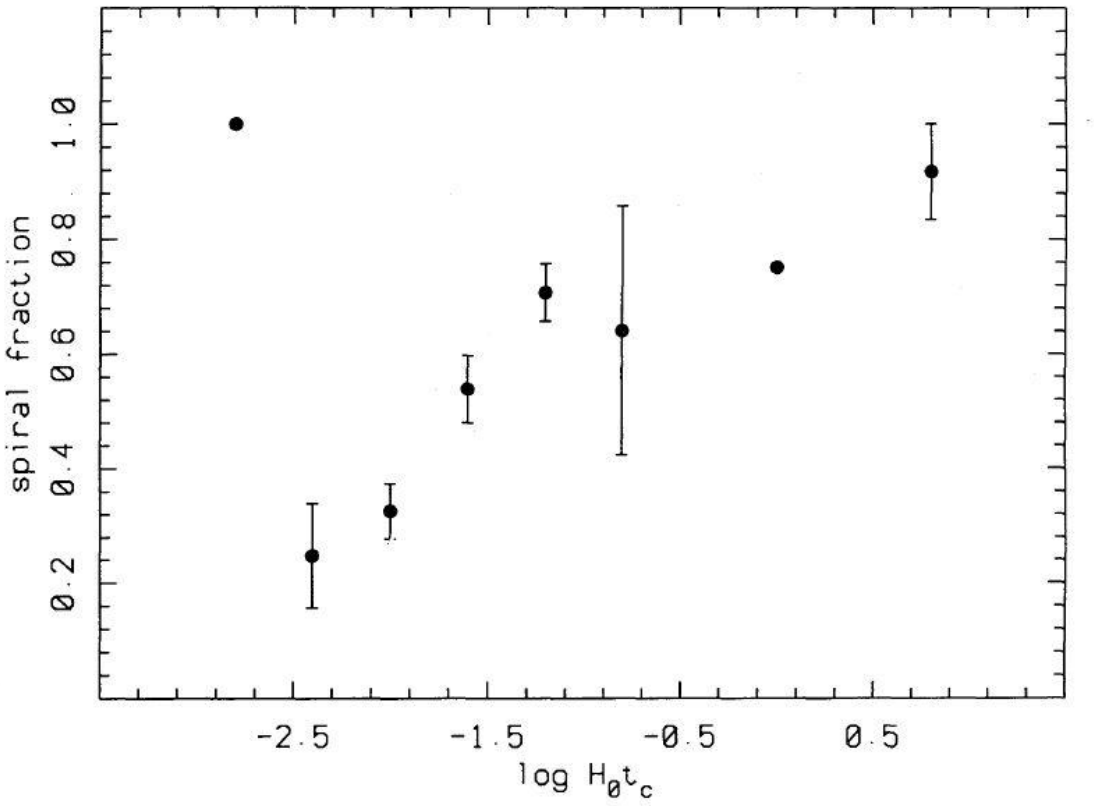
Redshift	M_{HI}	S_{peak}	τ	w	Beam position	Beam size	$N_{\rm beam}$	Luminosity Distance
	$10^{10}M_{\odot}$	10^{-2}mJy	minit	km/s		Mpc		Mpc
0.1	1.30	52.0	5	500	(183.5,13)	0.36	17	460.3
0.2	2.26	19.9	35	500	(183.5,13)	0.70	38	
0.3	4.20	14.8	64	500	(183.5,13)	1.02	69	
0.4	5.35	9.6	151	500	(183.5,13)	1.33	99	
0.5	9.75	7.4	258	700	(186,9.5)	1.62	249	
0.6	15.69	7.6	240	700	(186,9.5)	1.89	335	
0.7	16.20	5.4	478	700	(186,9.5)	2.15	350	
0.8	16.20	3.9	920	700	(186,9.5)	2.39	350	
0.9	16.20	2.9	1645	700	(186,9.5)	2.62	350	
1.0	16.20	2.3	2768	800	(186,9.5)	2.83	350	
1.1	16.20	1.8	4436	800	(186,9.5)	3.04	350	
1.2	16.20	1.4	6824	800	(186,9.5)	3.23	350	
1.3	16.20	1.2	10141	800	(186,9.5)	3.41	350	9140.5
1.4	16.20	1.0	14630	800	(186,9.5)	3.58	350	10017.5
1.5	16.20	0.8	20571	800	(186,9.5)	3.74	350	10908.4



Predictions of clusters detected by FAST (Ai, Zhu & Fu 2017)



Galaxy Groups at z=0

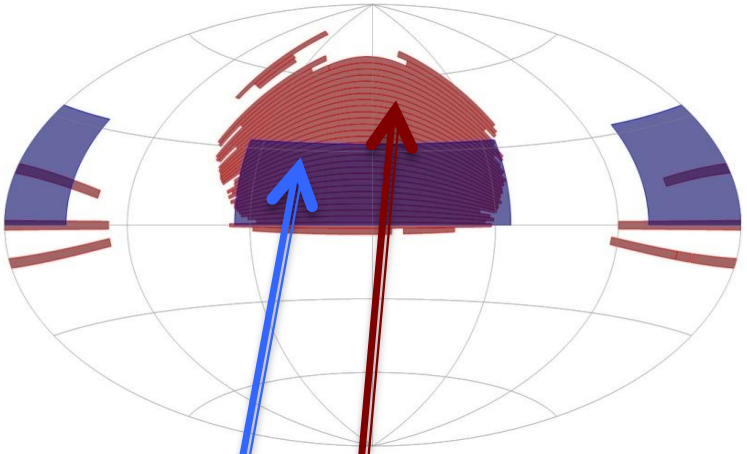


$$t_c = \frac{1.51^{1/2} R_{\rm rms}}{3^{1/2} \sigma_{\rm p}}$$

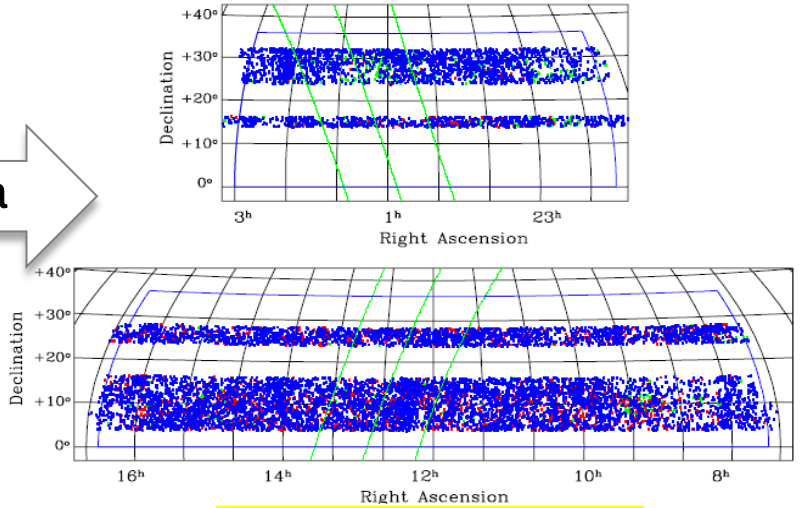
Hickson et a. （1992）

Cross matching HI cat + SDSS +Galaxy Zoo

SDSS-a.70 → Group members → Galaxy Zoo → HI and virial mass → HI fration and spiral fraction



70% area

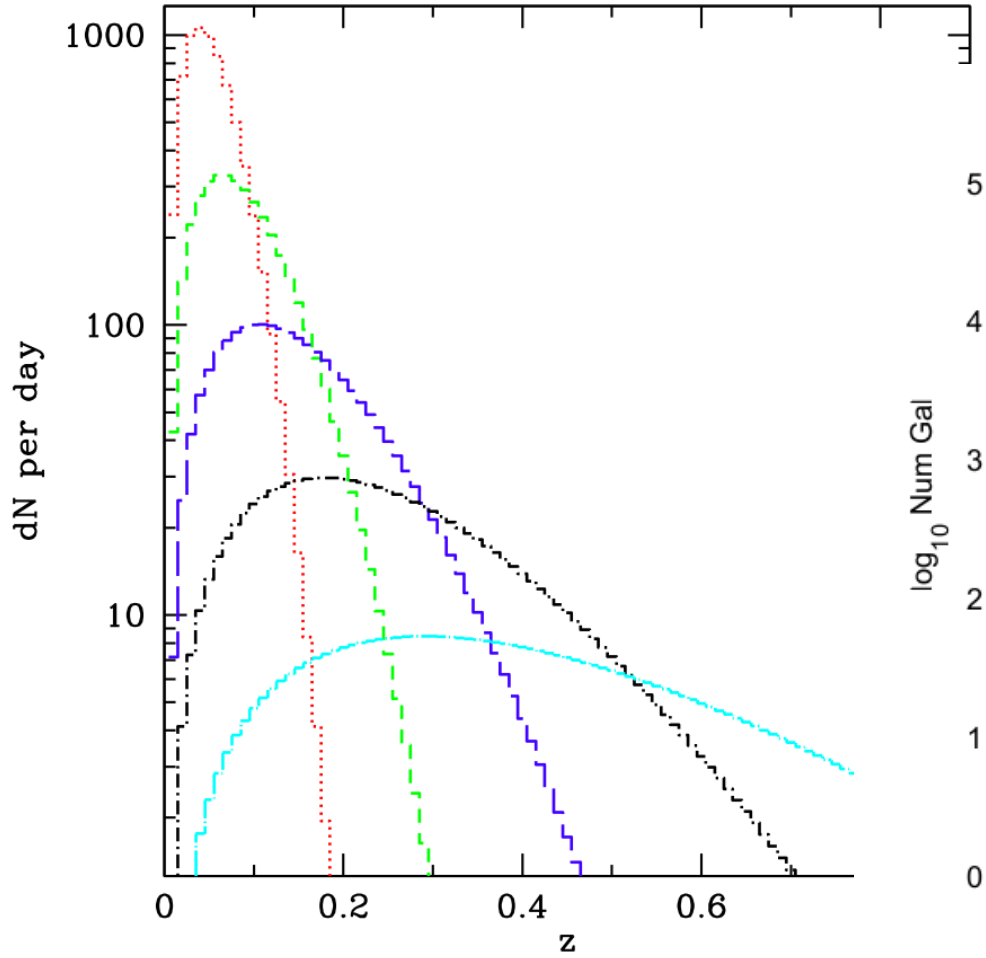


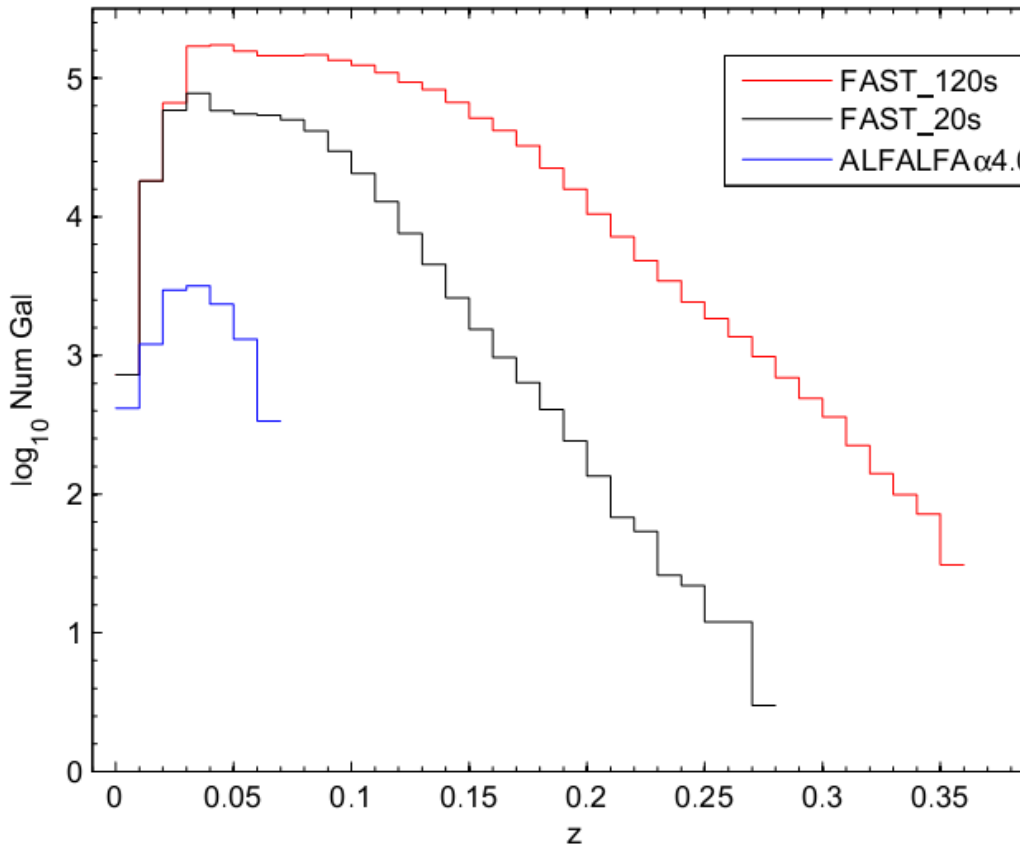
ALFALFA: Arecibo HI survey
SDSS: Sloan survey

a.70: 4800 deg^2

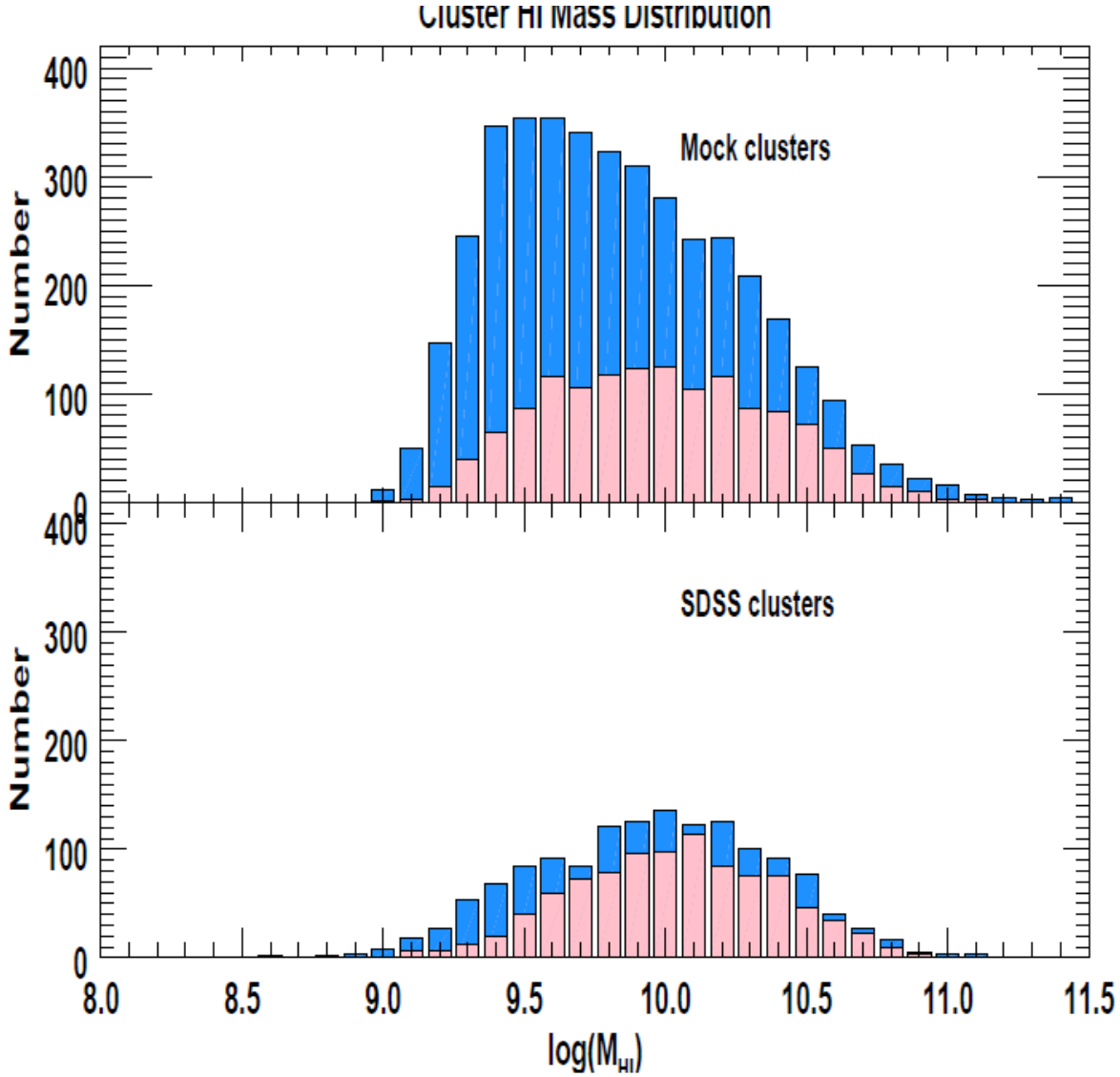
FAST HI survey: simulation

Duffy et al, 2012





HI in groups


Cluster HI Mass Distribution
Mock clusters
SDSS clusters
Number
Number
400
300
200
100
0
400
300
200
100
0
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
log(M_HI)

The 120s sample: over-estimate groups' HI

1)SDSS limit mag <-18, ALFALFA detction limit:

$$12.3 f_\beta t_s^{1/2} \left(\frac{M_{\rm H\,I}}{10^6\ M_\odot}\right) D_{\rm Mpc}^{-2} \left(\frac{W_{\rm km\,s^{-1}}}{200}\right)^{\gamma} > 6$$

Z=0.02 $2.78 \times 10^8 M_\odot$

Z=0.04 $1.11 \times 10^9 M_\odot$

2)"Missing Satellite Problem"

FAST detection limit would be :

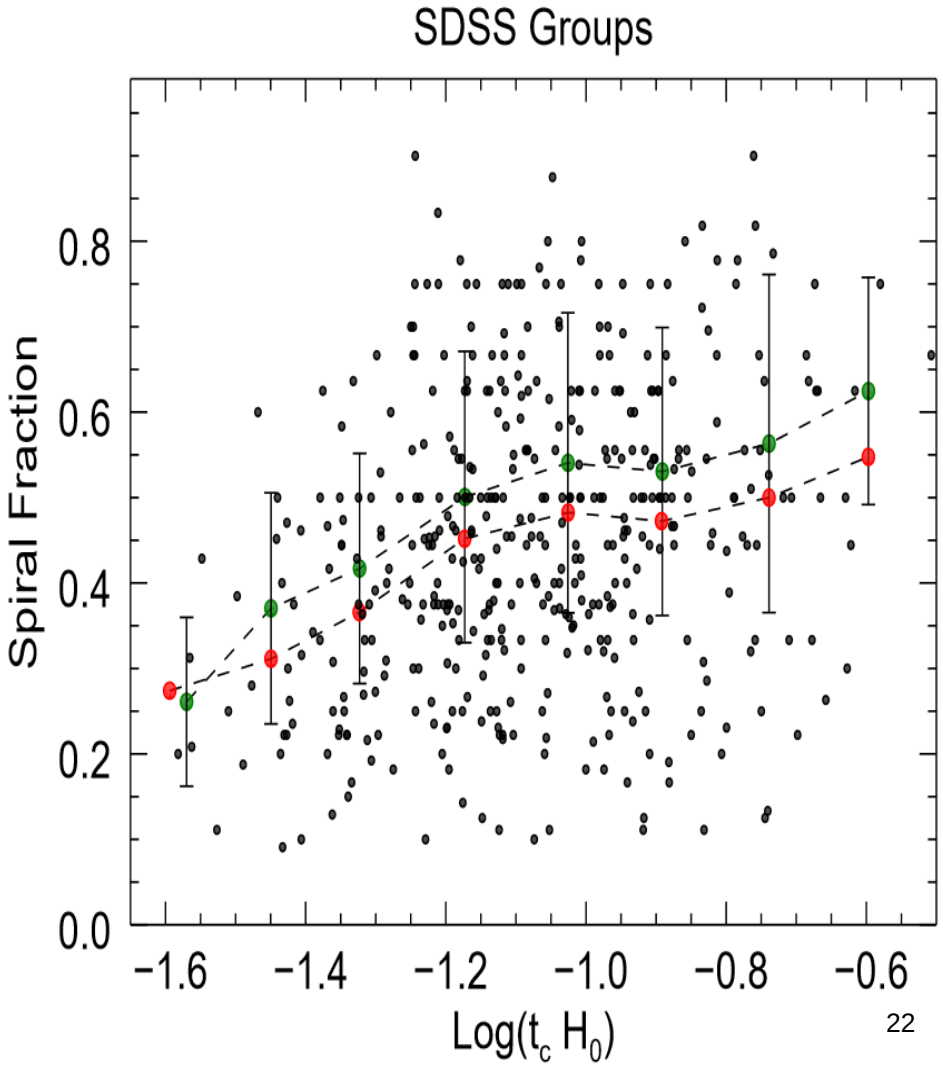
(for z=0.02 0.04)

$5.83 \times 10^7 M_\odot$ $2.33 \times 10^8 M_\odot$

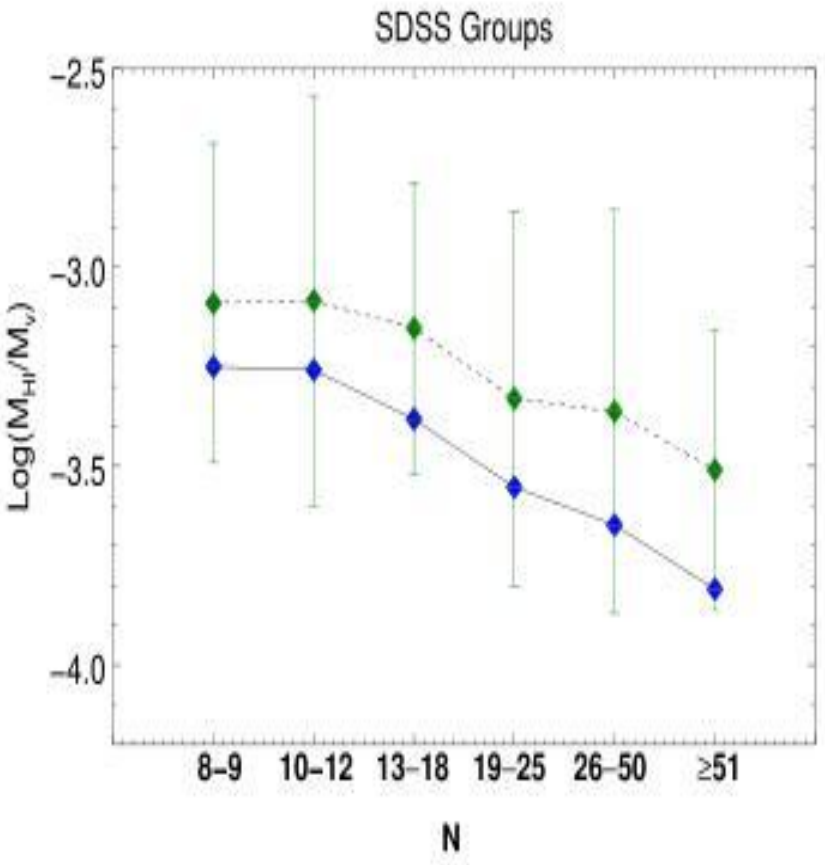
Morphology types

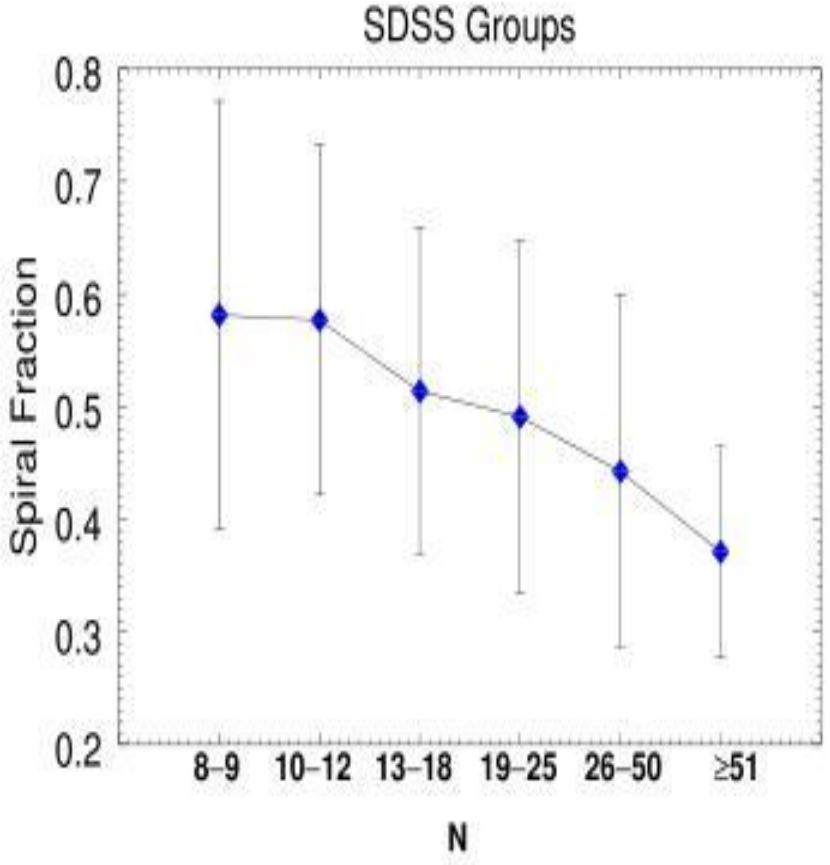
Group catalog from Berlind et al. (2006)
SDSS DR7
Mr < -18

Morphology from Galaxy Zoo (threshold 0.6)

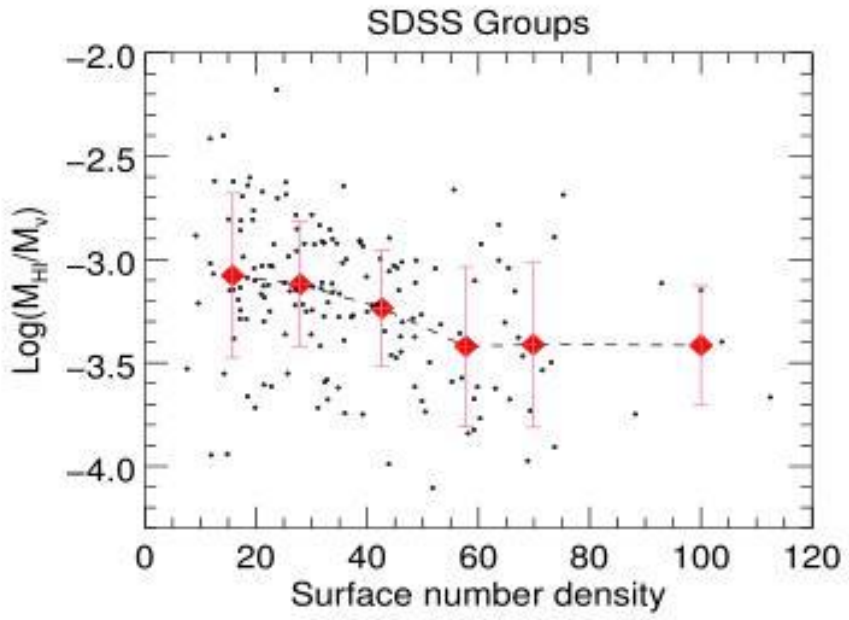


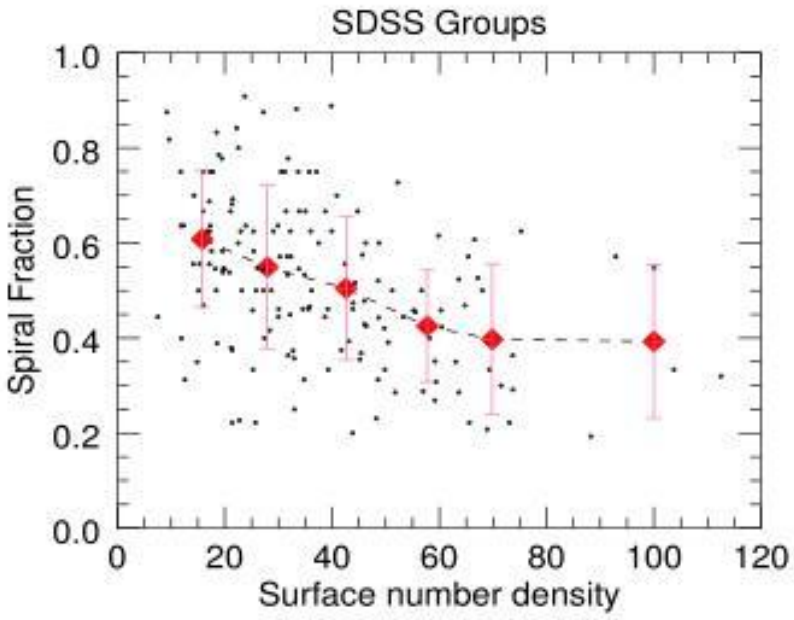
HI fraction and Spiral Fraction



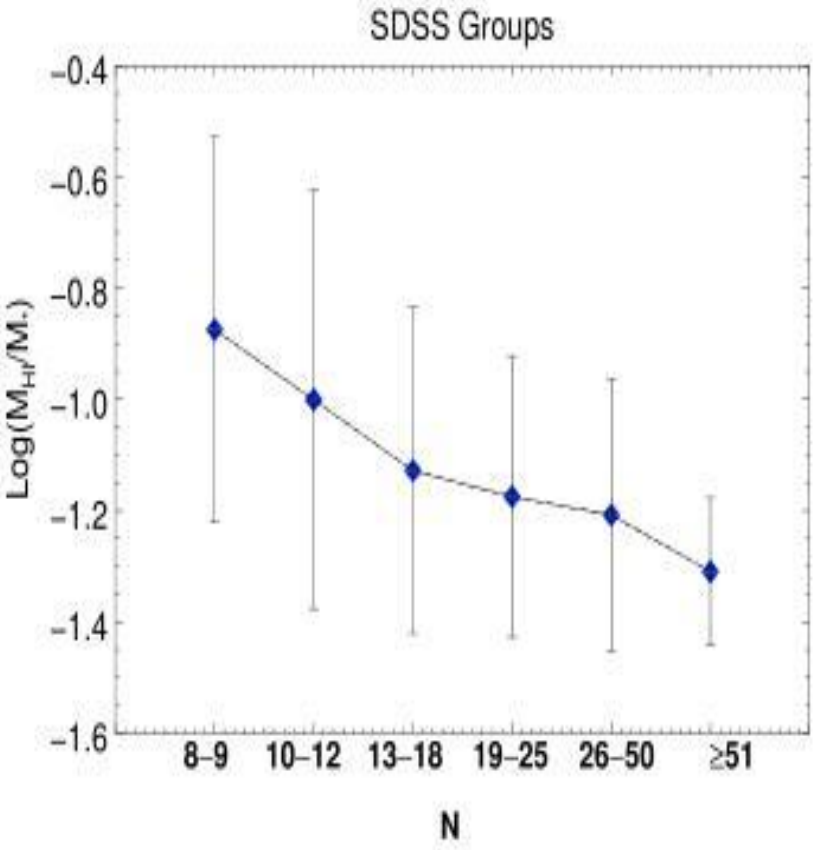


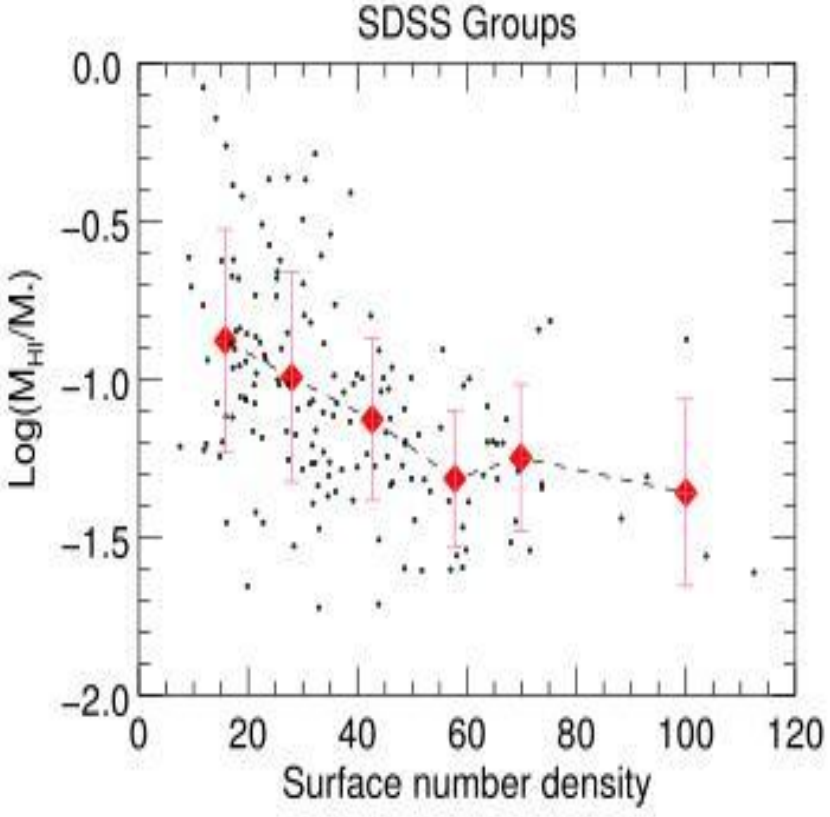
HI fraction and Spiral Fraction





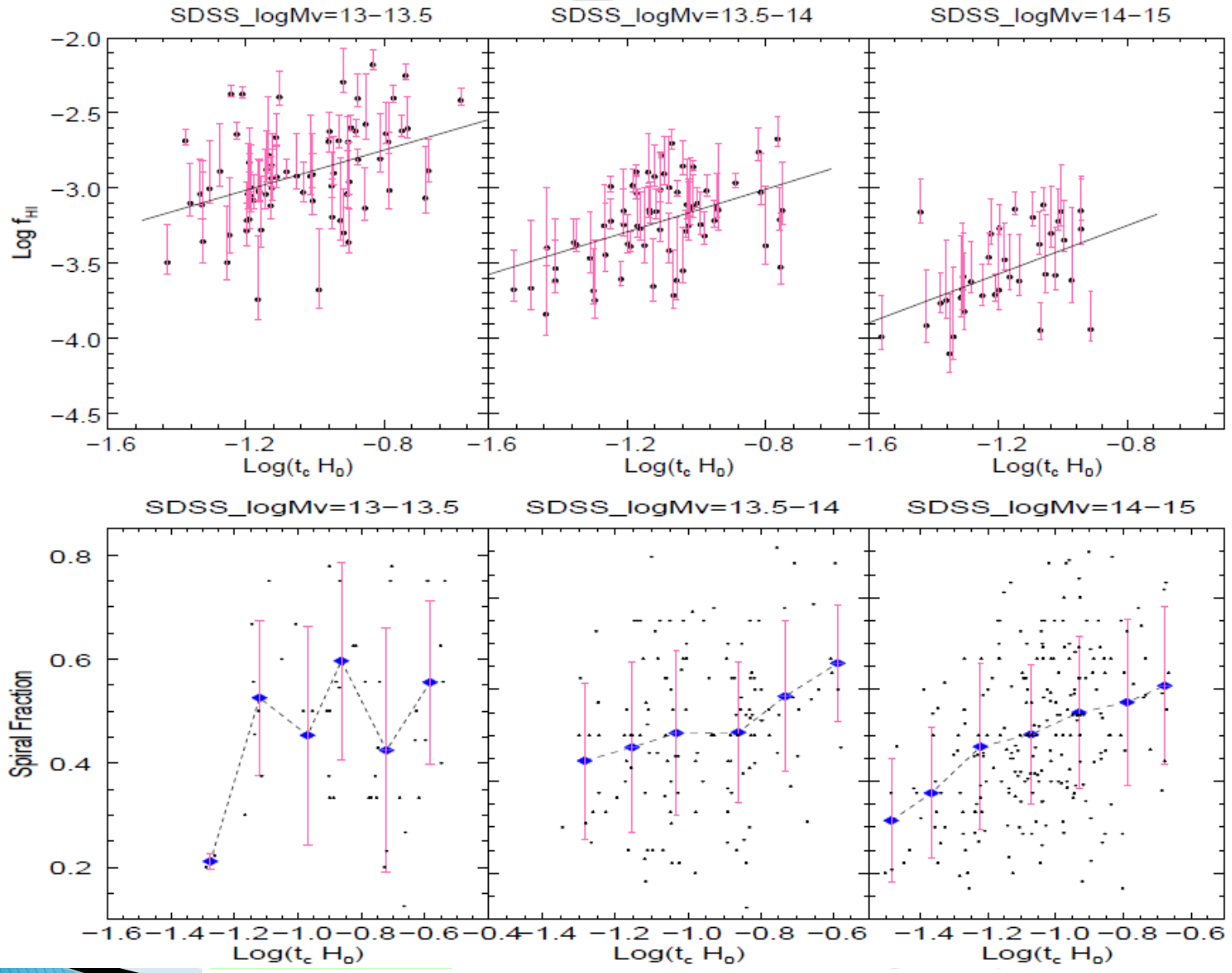
MHI/M*


SDSS Groups
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
Log(M_HI/M.)
8–9
10–12
13–18
19–25
26–50
≥51
N


SDSS Groups
0.0
−0.5
−1.0
−1.5
−2.0
Log(M_HI/M.)
0
20
40
60
80
100
120
Surface number density

°

HI fraction vs t_c



$$\log(M_{\rm HI}/M_*) = 1.09431 - 3.08207(g-r))$$

Summary

- We found a weak correlation between the group HI mass fraction and the group crossing time.
- The group crossing time is a good indicator of the group's age
  - younger groups with larger crossing time have more spiral galaxies and higher fraction of HI gas
- FAST will be a powerful telescope for studying HI evolution in groups