Gas Flow in the Virgo Cluster

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with

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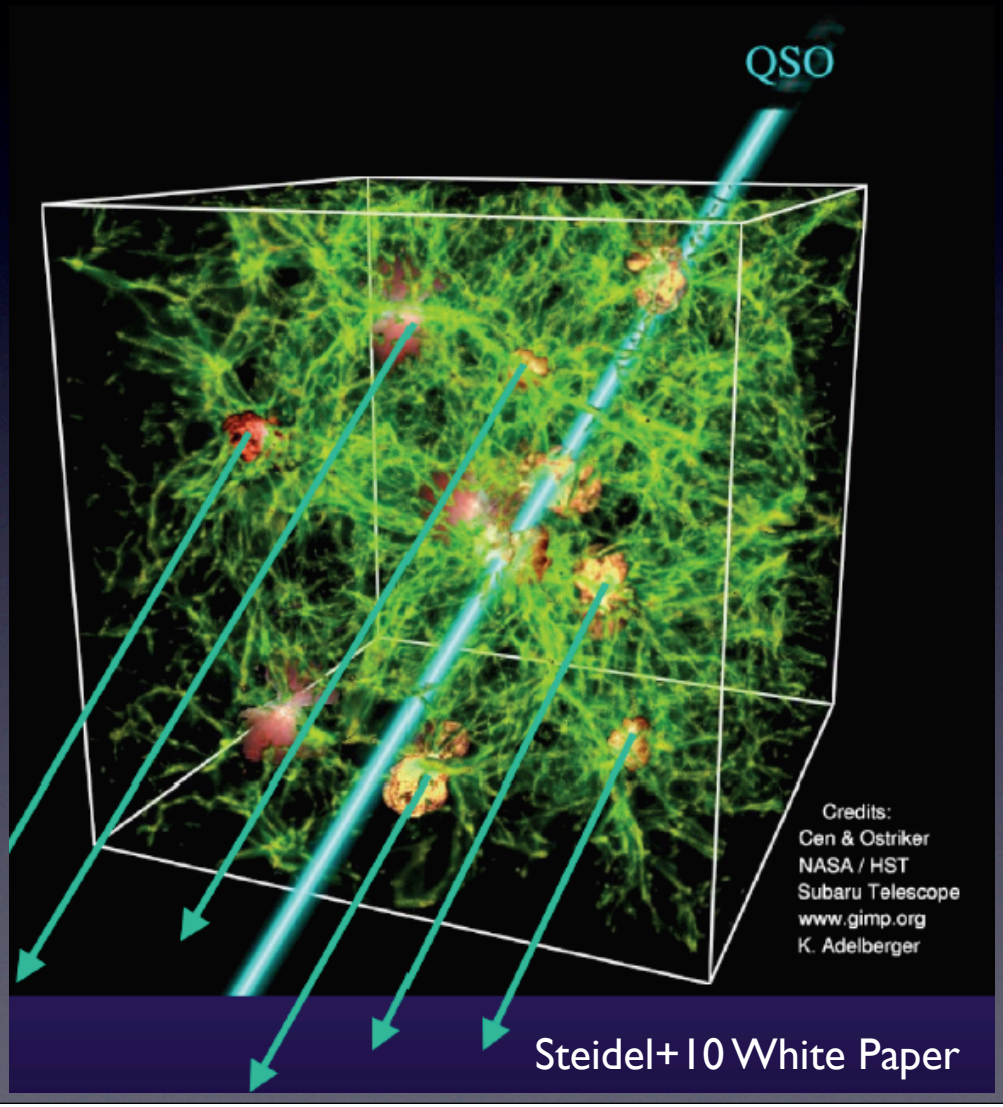
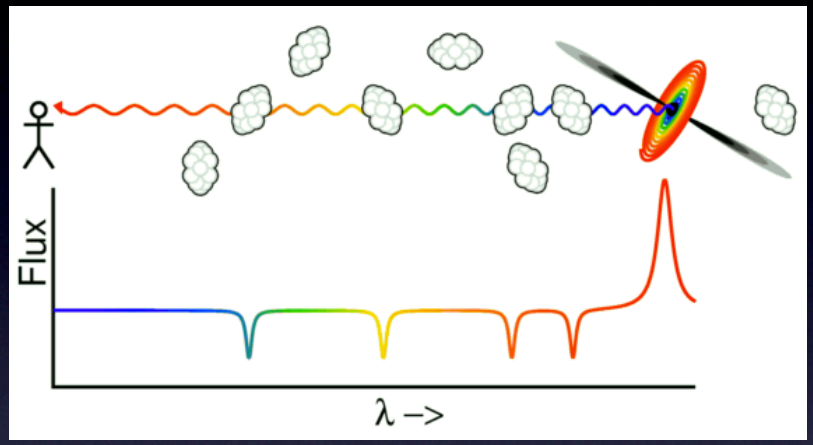
Movie Credit: Greg Bryan

2011 ESO Workshop, Garching

QSO Absorption Lines



Steidel+10 White Paper



- Metal absorption lines.
- Lyα Absorption

Virgo Cluster

- Hot gas (...)
- Stars (...)
- Dust (...)
- Cold gas (<10^4K ...)
- Warm gas (10^4~10^5K, Yoon in prep.)
- 677 references in NED (Krick+11)

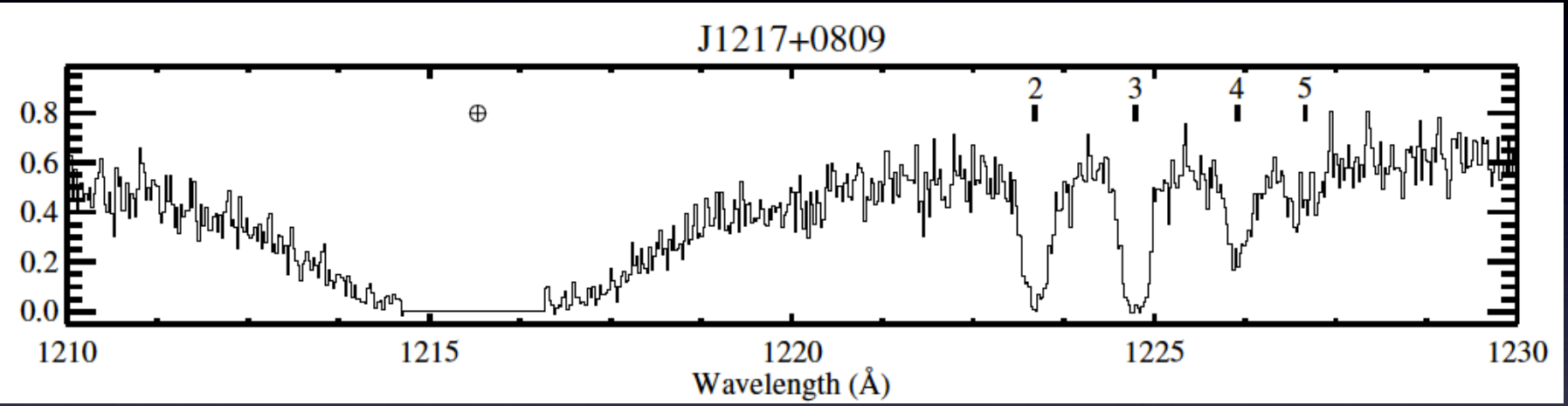
Our Study

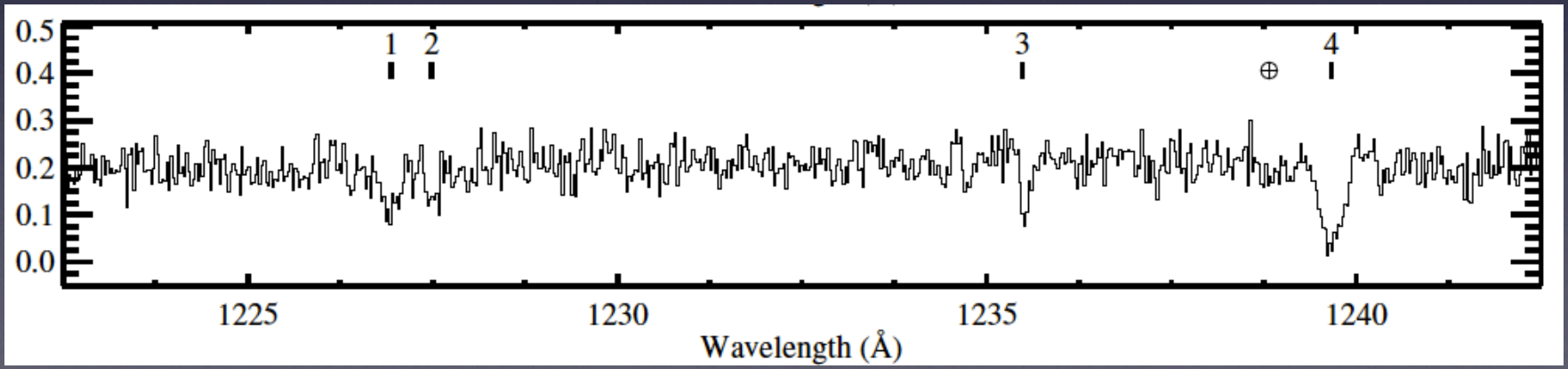
- FIRST study of the distribution of warm gas in the best cluster.
- Gas in difference phases: hot(X-ray), warm (Lyα), and cold(HI) ➔ Cold streams, shock heating...
- Gas motions in a cluster.
  - Bulk motions: Inflow along a filament.
  - Turbulent motions.

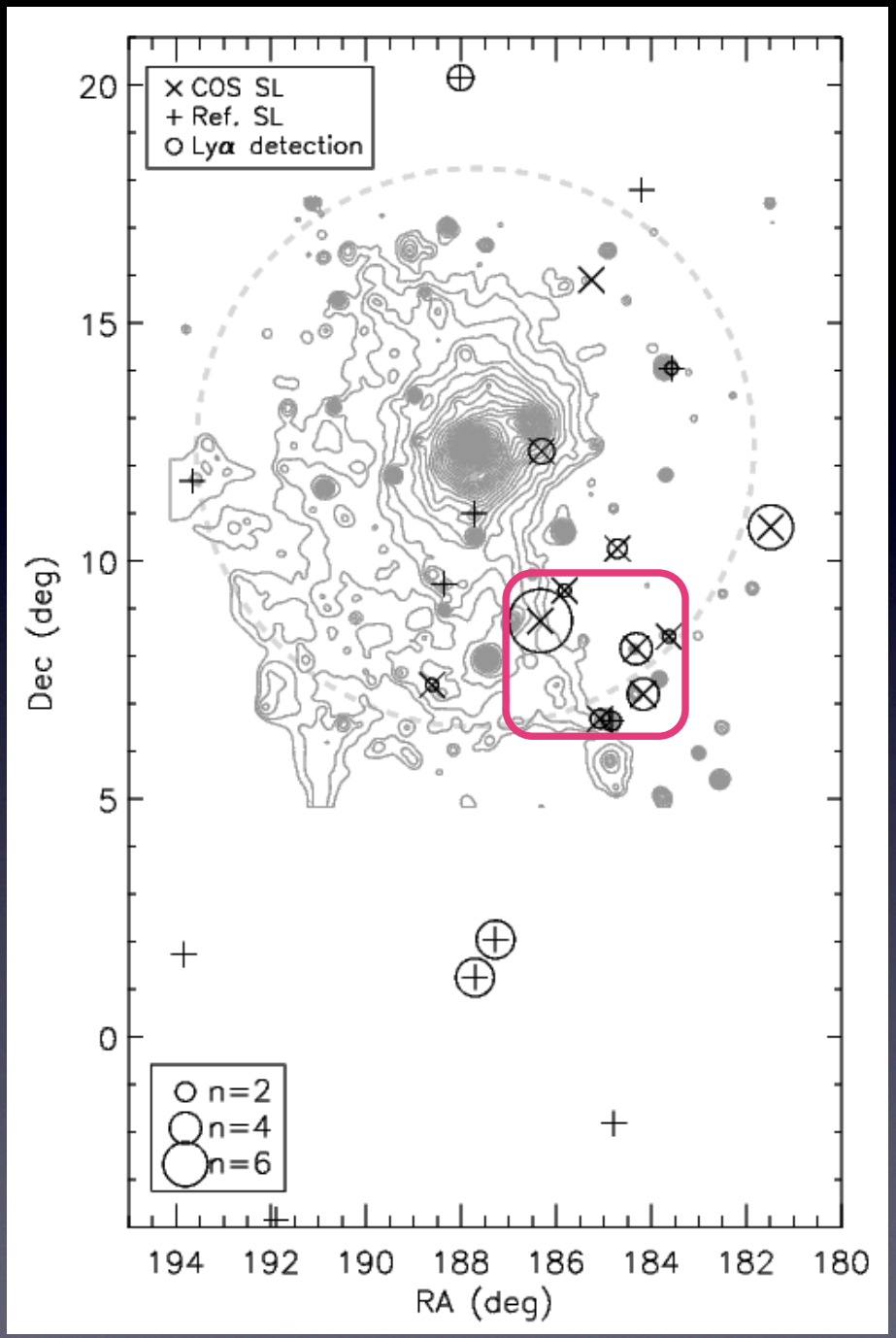
Data

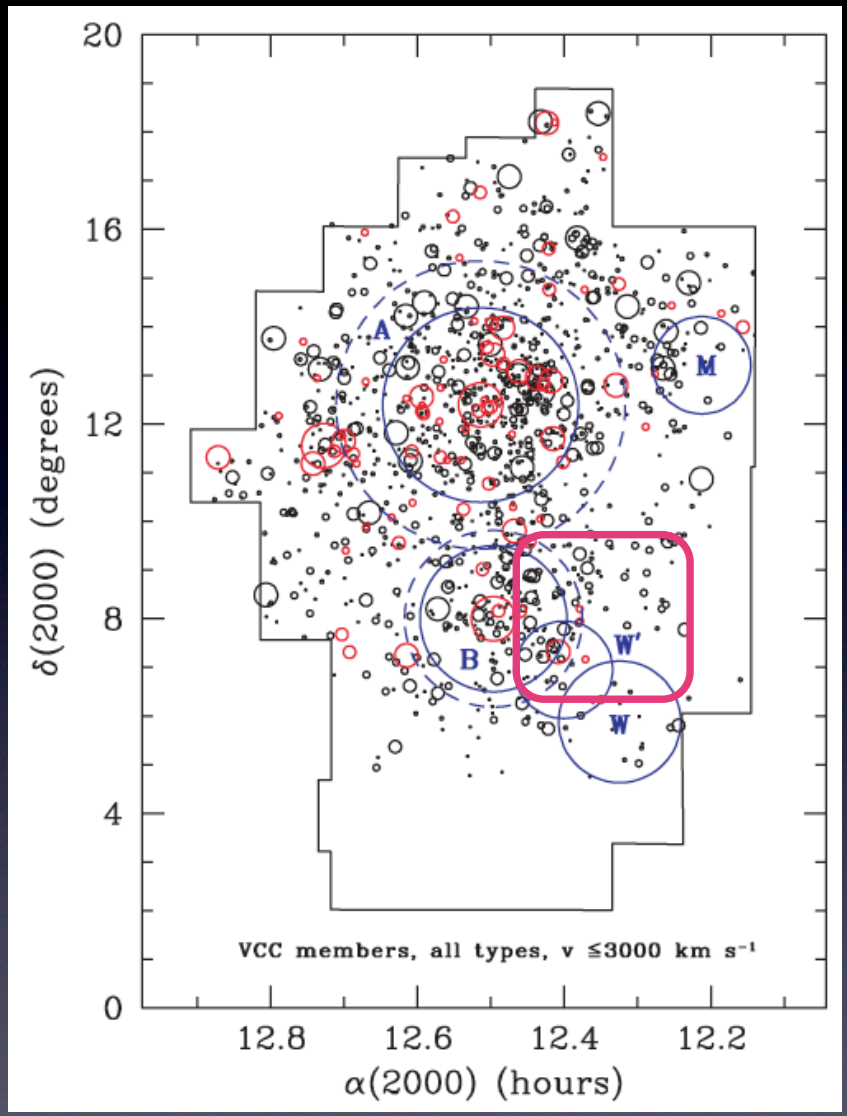
- COS/G130M :
  - 1150 - 1450Å, v_{res}=15km/s, W > 40mÅ (~$10^{13}cm^{-2}$)
  - 11 SLs, 33 Lyα lines
- STIS, GHRS:
  - Impey+99; Penton+00,04; Chen&Mulchaey09; Williger+10
  - 12 SLs, 16 Lyα lines

COS: Lyα Absorption

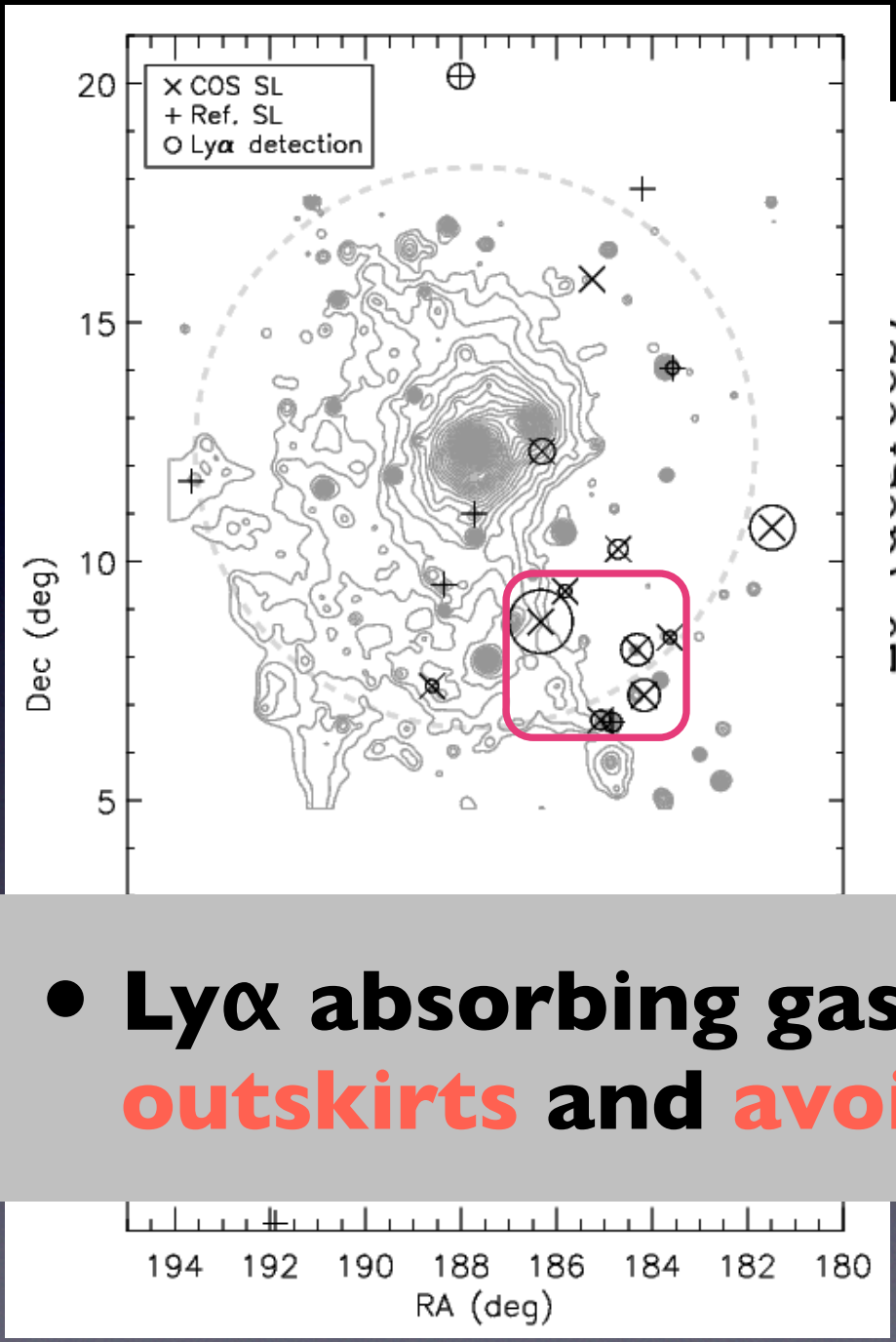


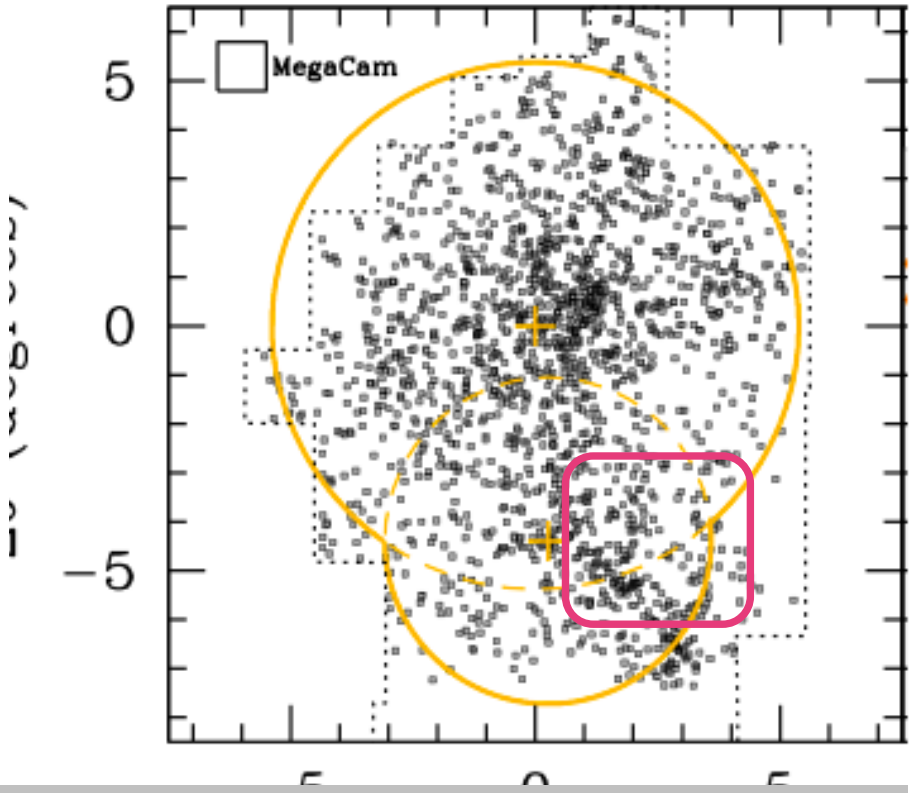



× COS SL
+ Ref. SL
○ Lyα detection
Dec (deg)
RA (deg)
20
15
10
5
0
194
192
190
188
186
184
182
180
n=2
n=4
n=6


δ(2000) (degrees)
α(2000) (hours)
20
16
12
8
4
0
12.8
12.6
12.4
12.2
A
B
M
W'
W
VCC members, all types, v ≤3000 km s⁻¹

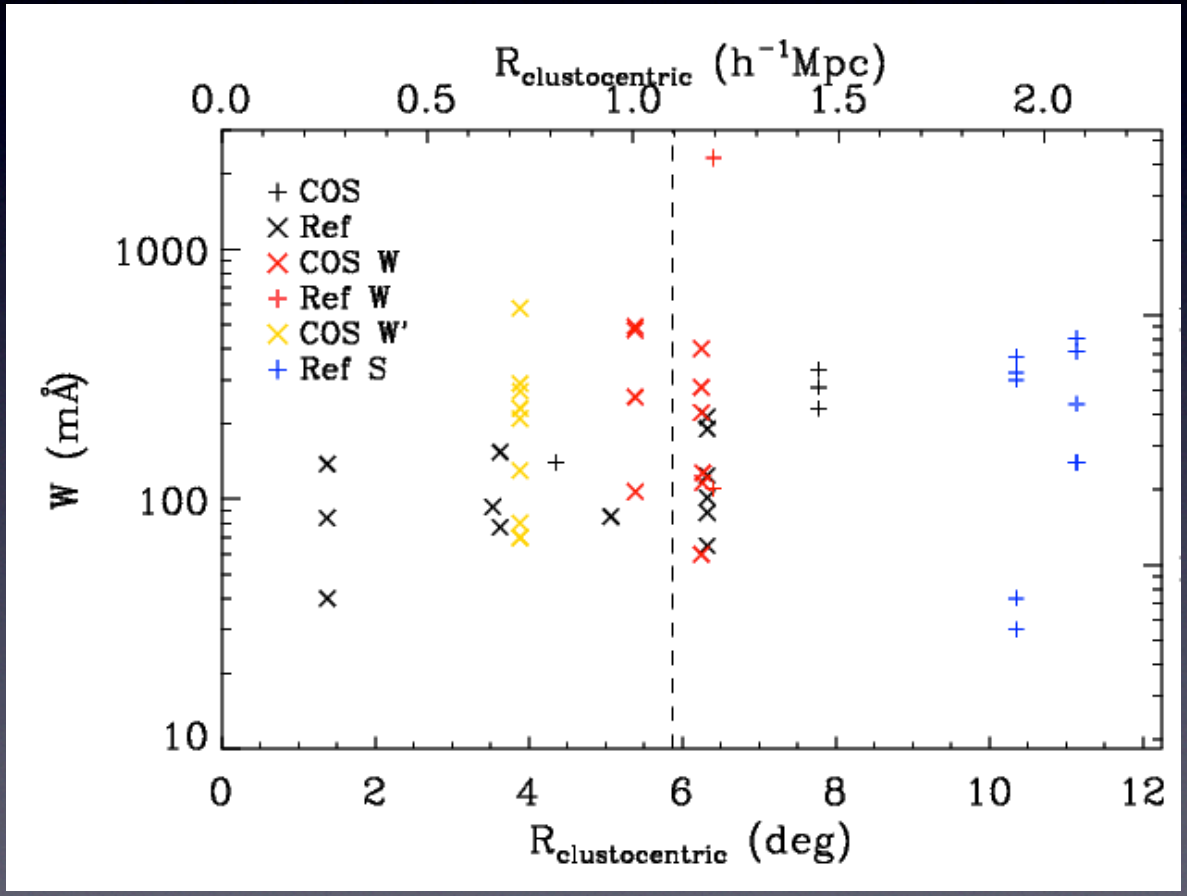
Mei+07

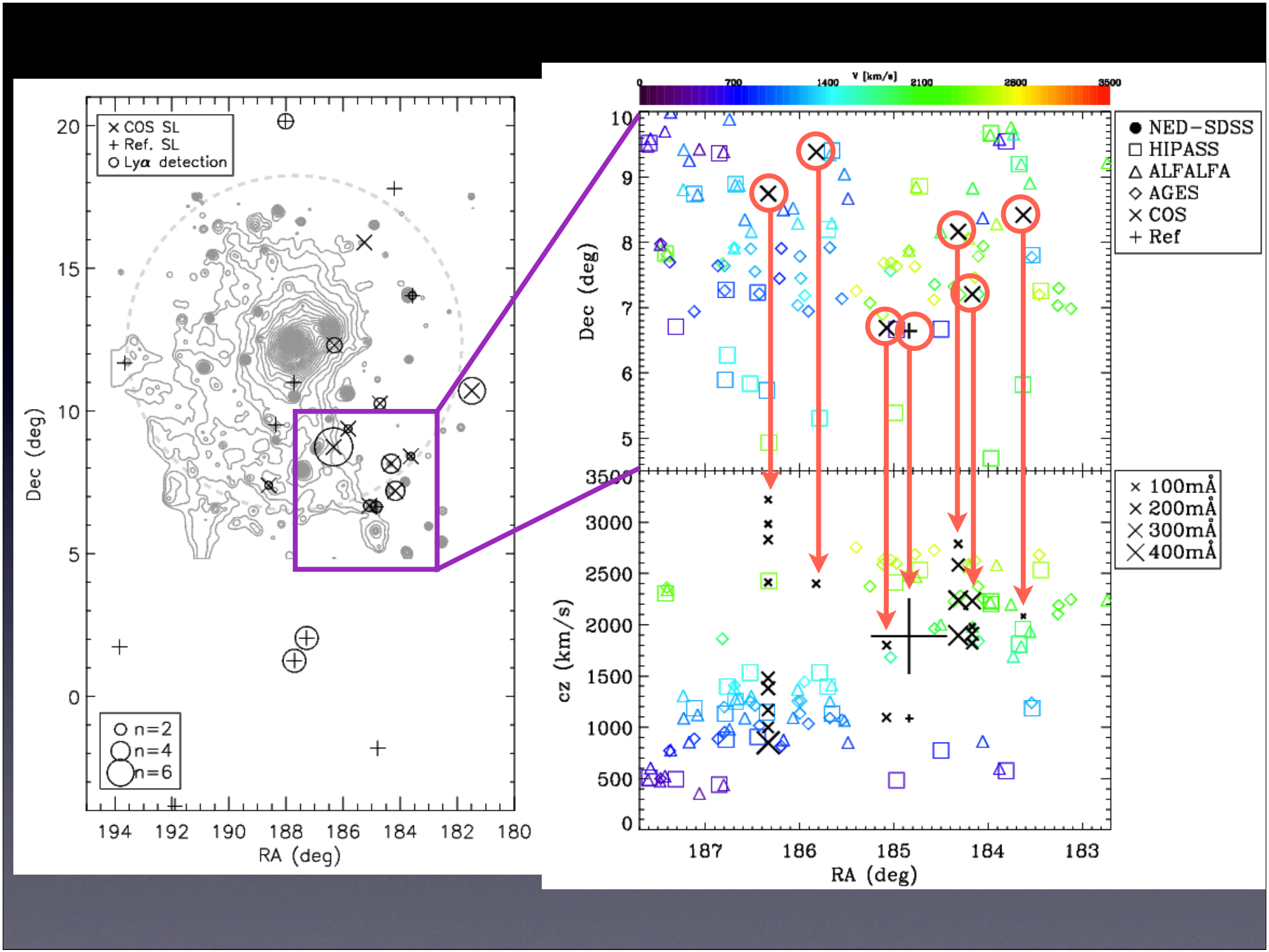


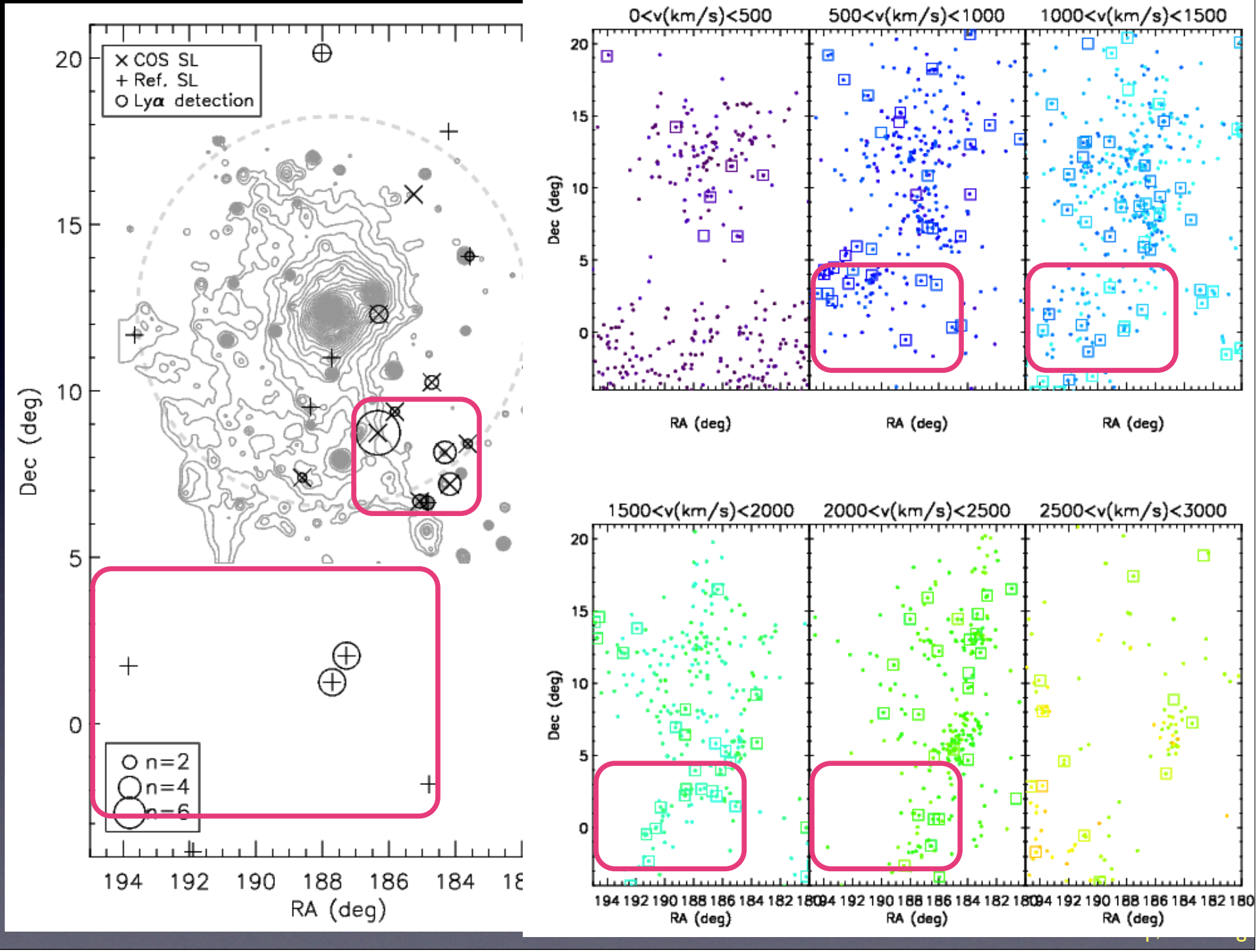


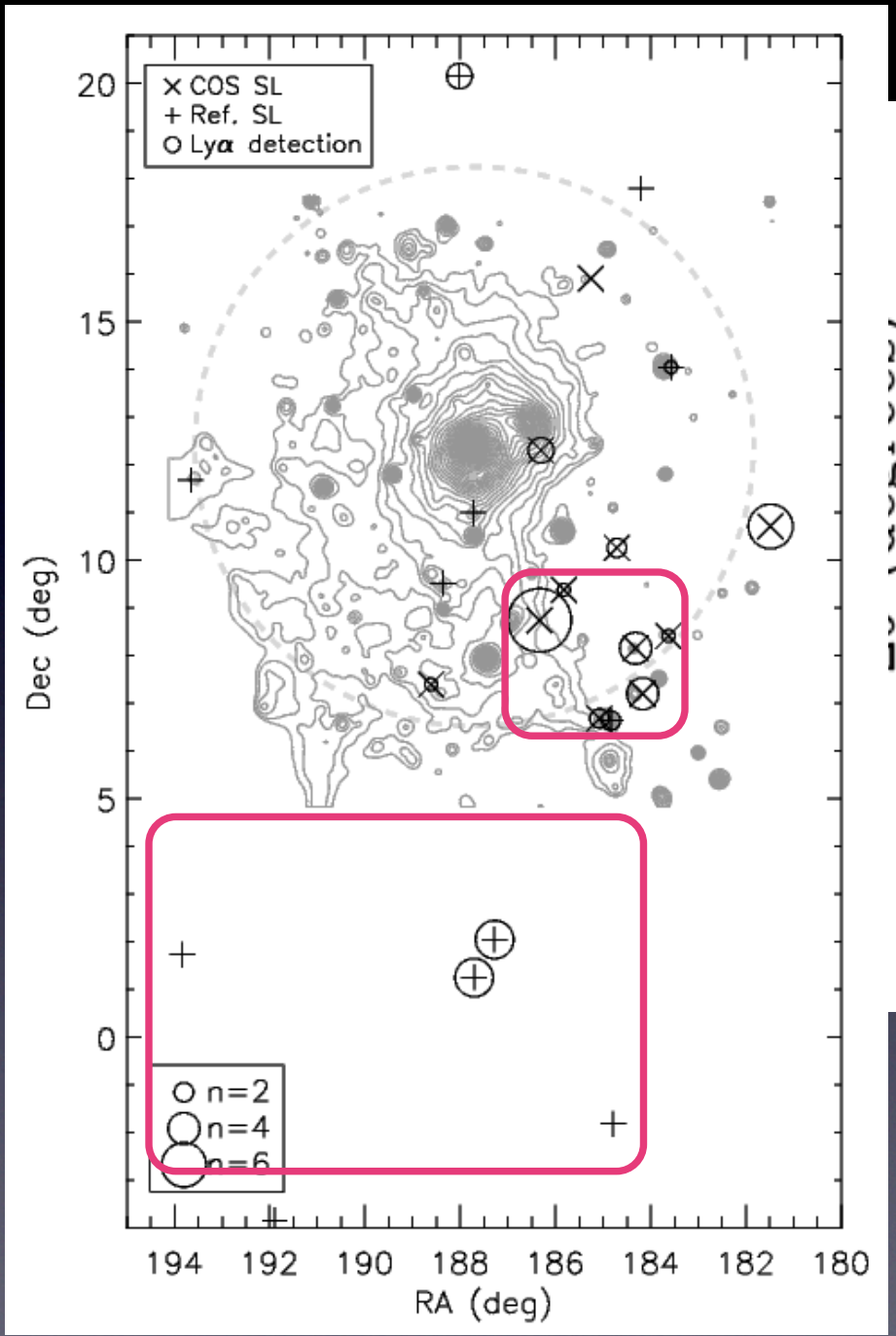
- **Lyα absorbing gas prefer the outskirts and avoid X-ray regions.**

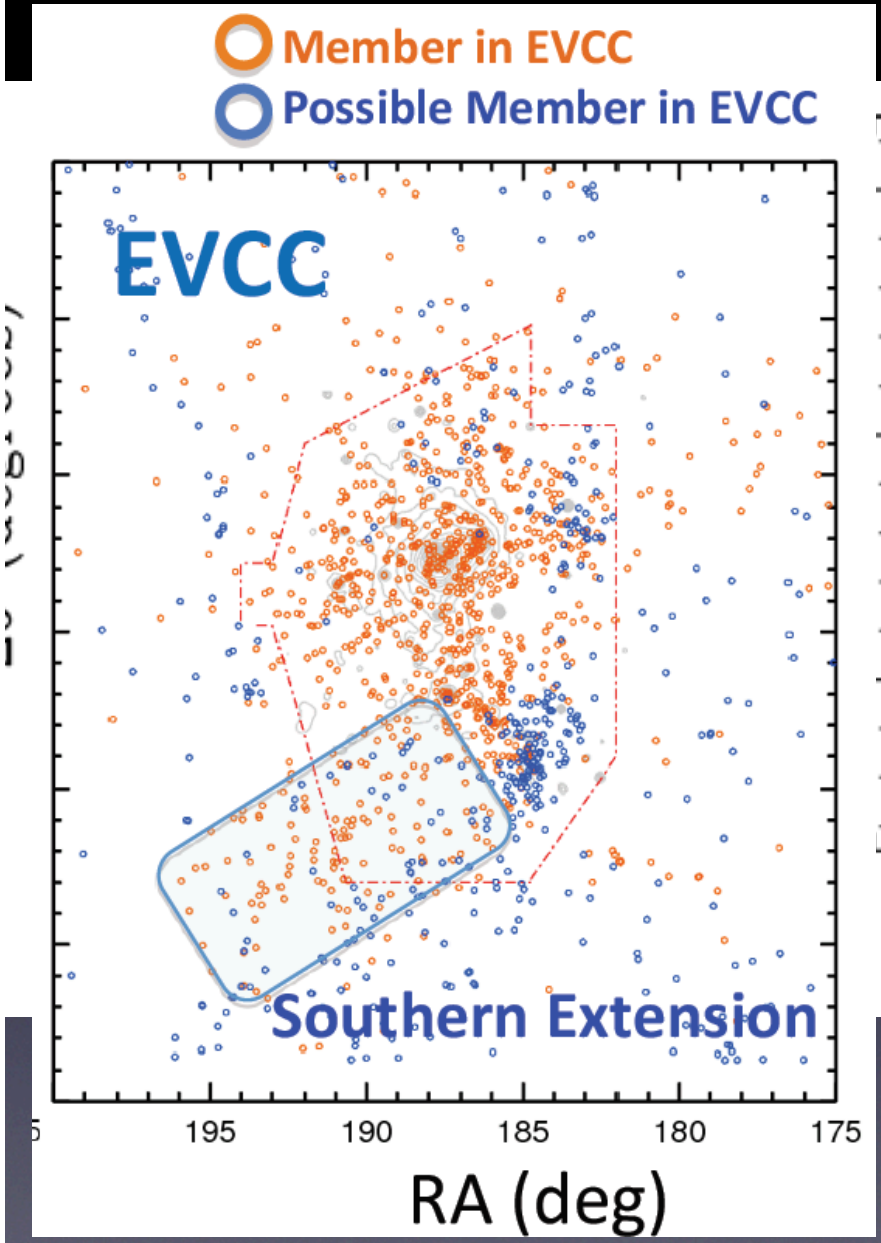
Radial Dist. of Absorbers




× COS SL
+ Ref. SL
O Lyα detection
O n=2
n=4
n=6
Dec (deg)
RA (deg)
V [km/s]
NED−SDSS
HIPASS
ALFALFA
AGES
COS
Ref
100mÅ
200mÅ
300mÅ
400mÅ
cz (km/s)

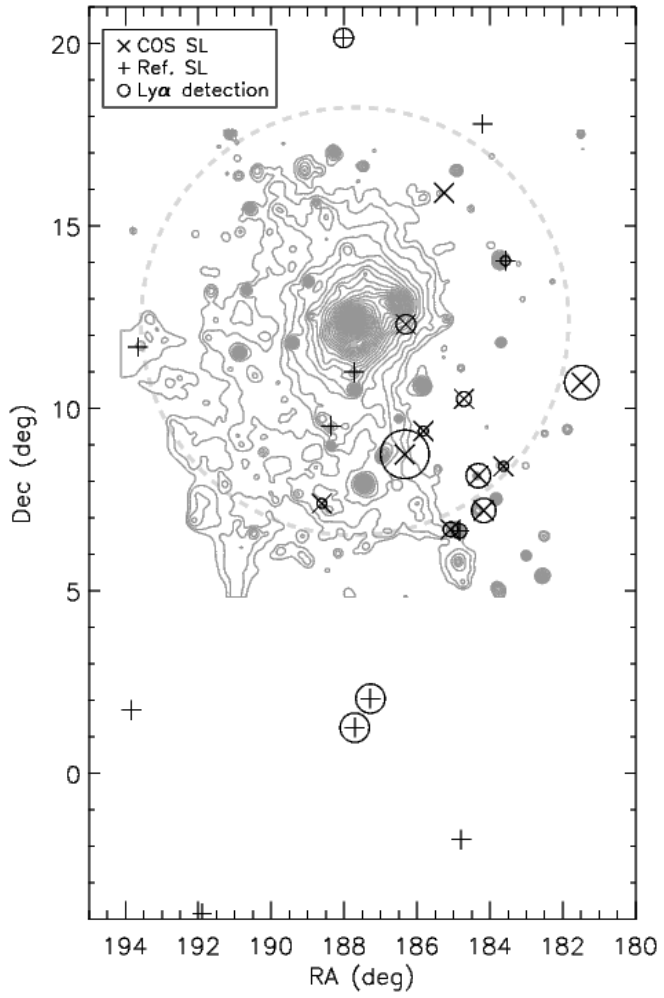

× COS SL
+ Ref. SL
○ Lyα detection
○ n=2
n=4
n=6
Dec (deg)
RA (deg)
0<v(km/s)<500
500<v(km/s)<1000
1000<v(km/s)<1500
1500<v(km/s)<2000
2000<v(km/s)<2500
2500<v(km/s)<3000





Suk Kim's poster

Covering Fraction



	$W > 50$mÅ$(\sim 1\times10^{13}$cm$^{-2})$	>100mÅ	>200mÅ	>300mÅ
0-1$R_{\rm vir}$	0.58±0.13	0.42±0.13	0.17±0.11	0.17±0.11
0-2$R_{\rm vir}$	0.70±0.10	0.60±0.10	0.40±0.10	0.35±0.10
1-2$R_{\rm vir}$	0.88±0.12	0.88±0.12	0.75±0.15	0.63±0.15
0-1$R_{\rm vir}$	0.25±0.14 $(10000-13500$km s$^{-1})$			
0-1$R_{\rm vir}$	0.25±0.14 $(15000-18500$km s$^{-1})$			

- Covering fraction increases with R.
- Twice as large as the background.
- Consistent with preliminary simulations (Private comm. with M. R. Joung).

Summary

- No strong absorbers in the cluster center and in the region of X-ray emitting gas.
- All strong absorbers coincide with the W&W' subgroups.
- Covering fraction increases with R. → Consistent with gas heated in the virial radius
- The Virgo Cluster covering fraction = background x2, consistent with simulations.
- Cluster feeding with both galaxies and IGM.

Ongoing & Future Study.

- Comparison to simulations
  - Cluster structure and Lyα absorbers
  - Gas in different phases.
- Gas turbulent motions in the outskirts.