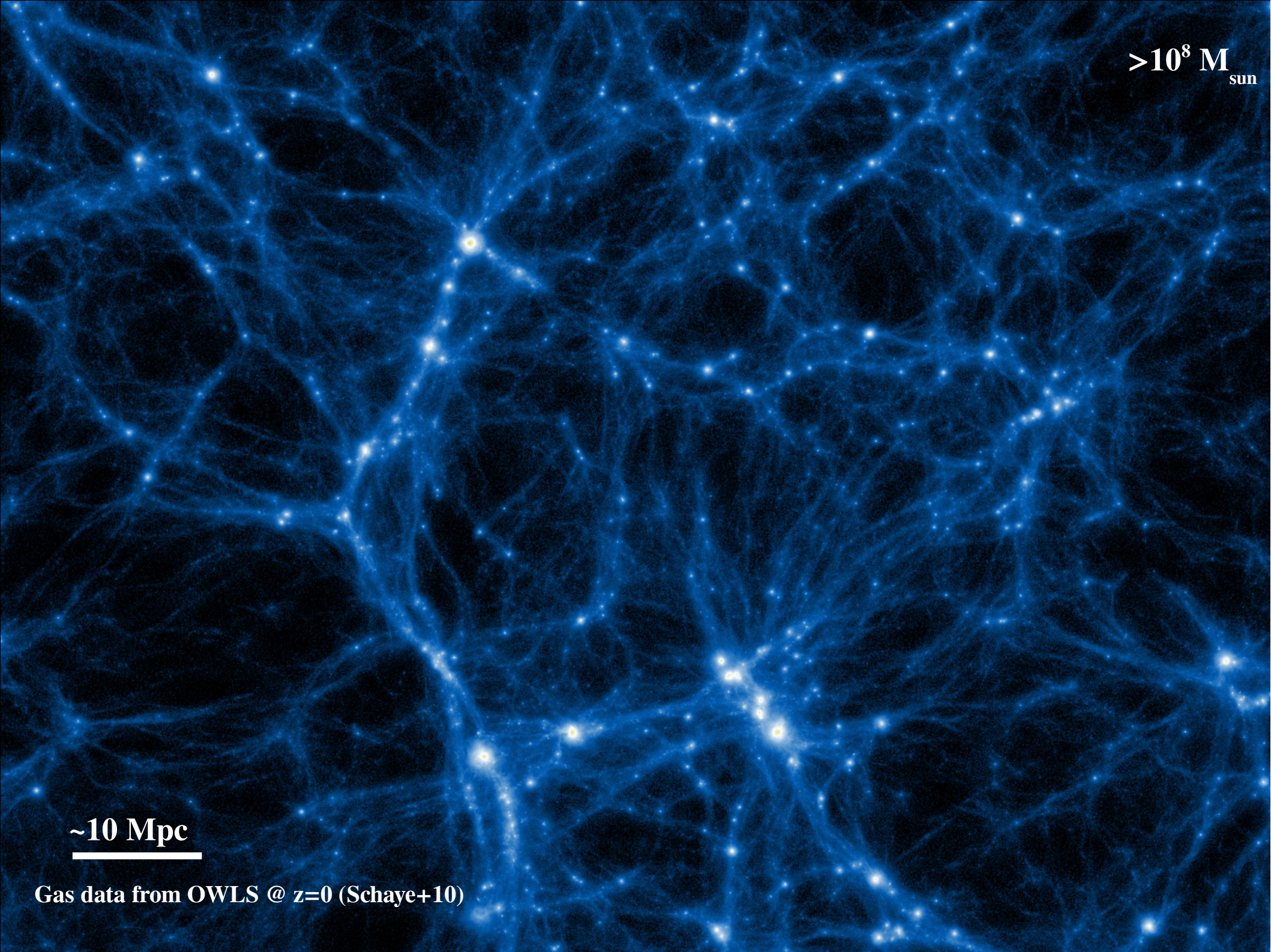
UNIVERSITY OF CALIFORNIA
SANTA CRUZ

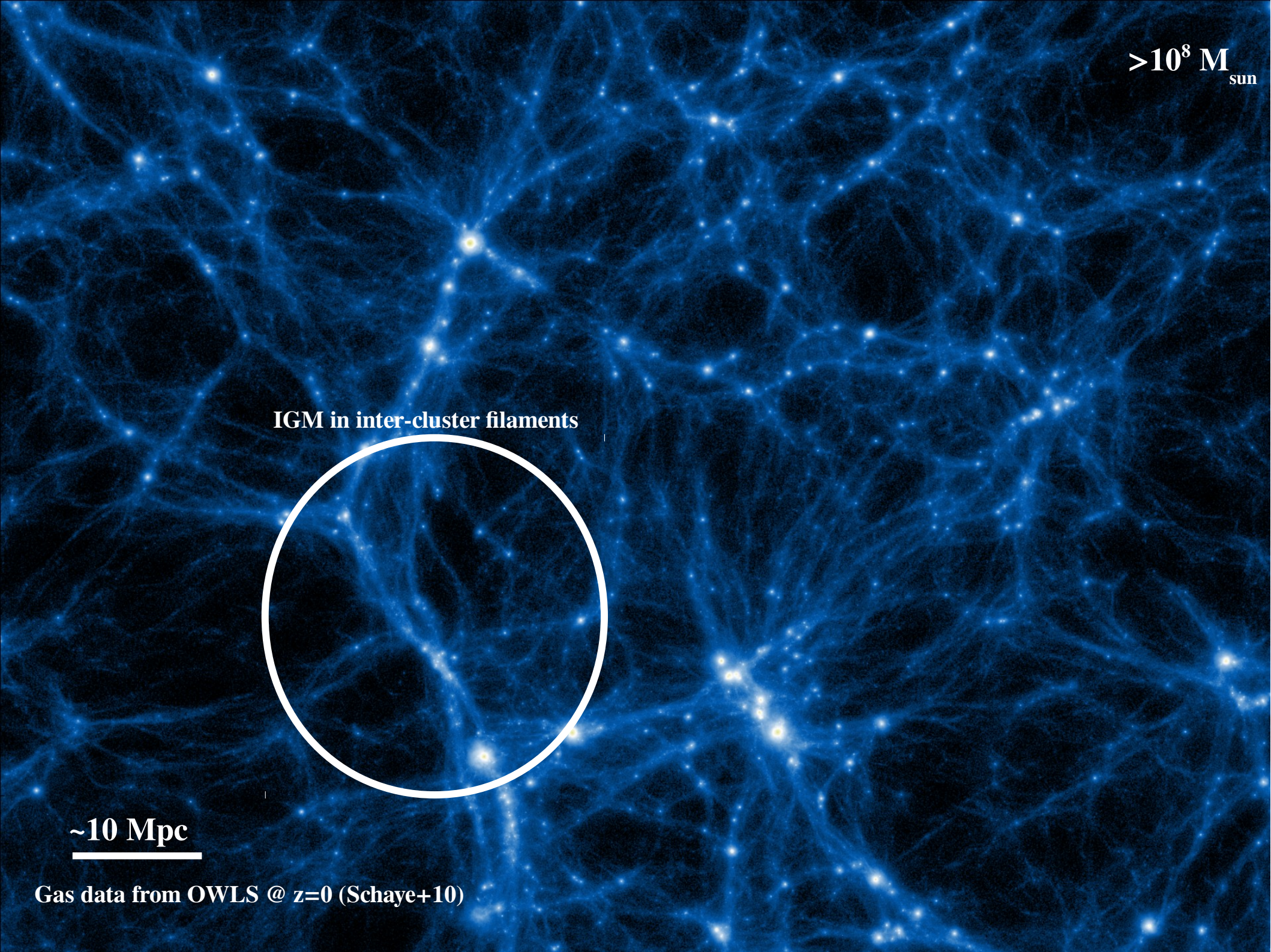
The intergalactic medium in inter-cluster filaments

Nicolas Tejos

(IMPS Fellow, UCO/UC Santa Cruz)

Xavier Prochaska, Simon Morris, Neil Crighton, Nelson Padilla, Tom Theuns, Jessica Werk, Rich Bielby, Charles Finn


>10^8 M_sun
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)


>10^8 M_sun
IGM in inter-cluster filaments
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)

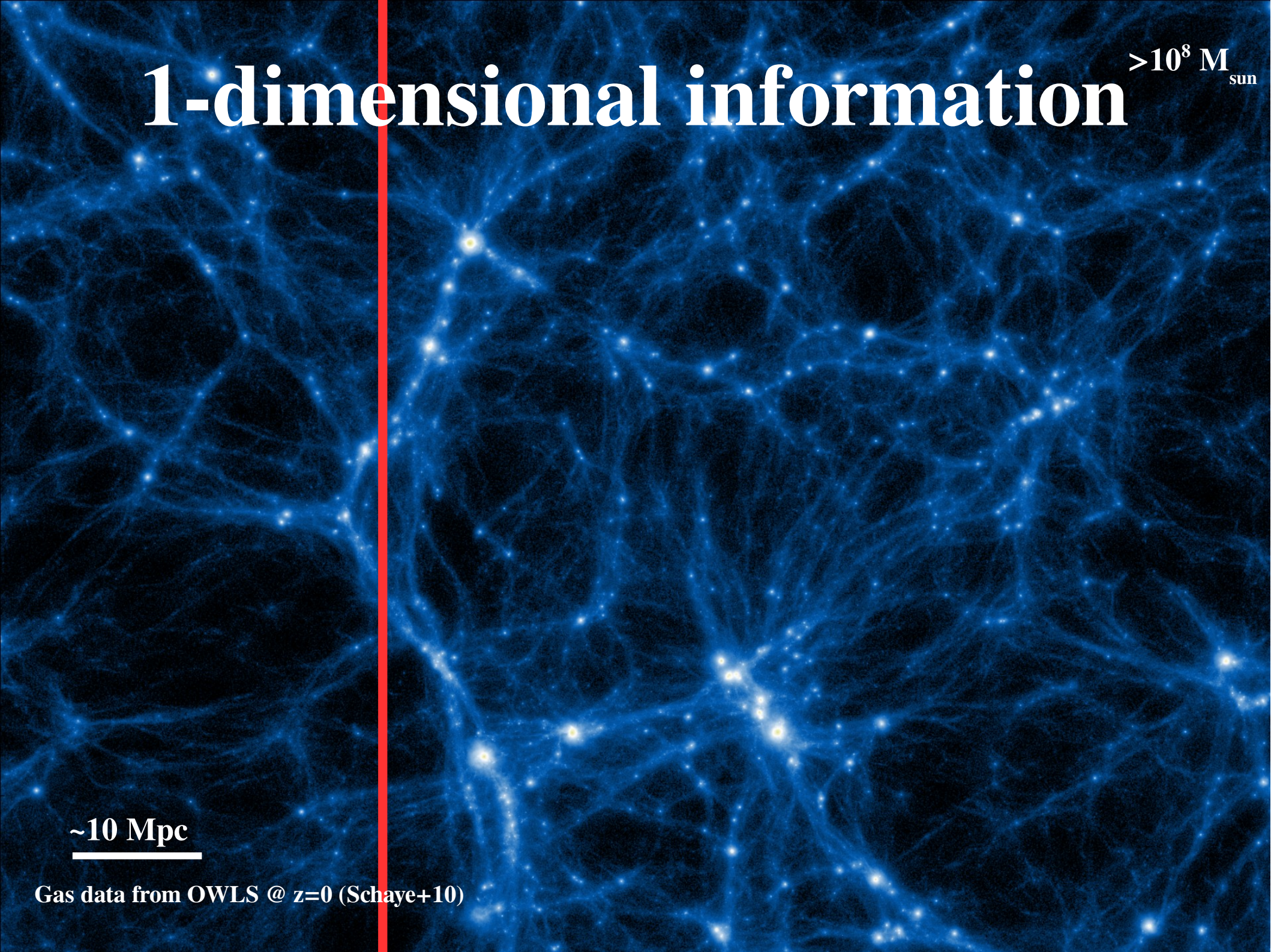
Outline

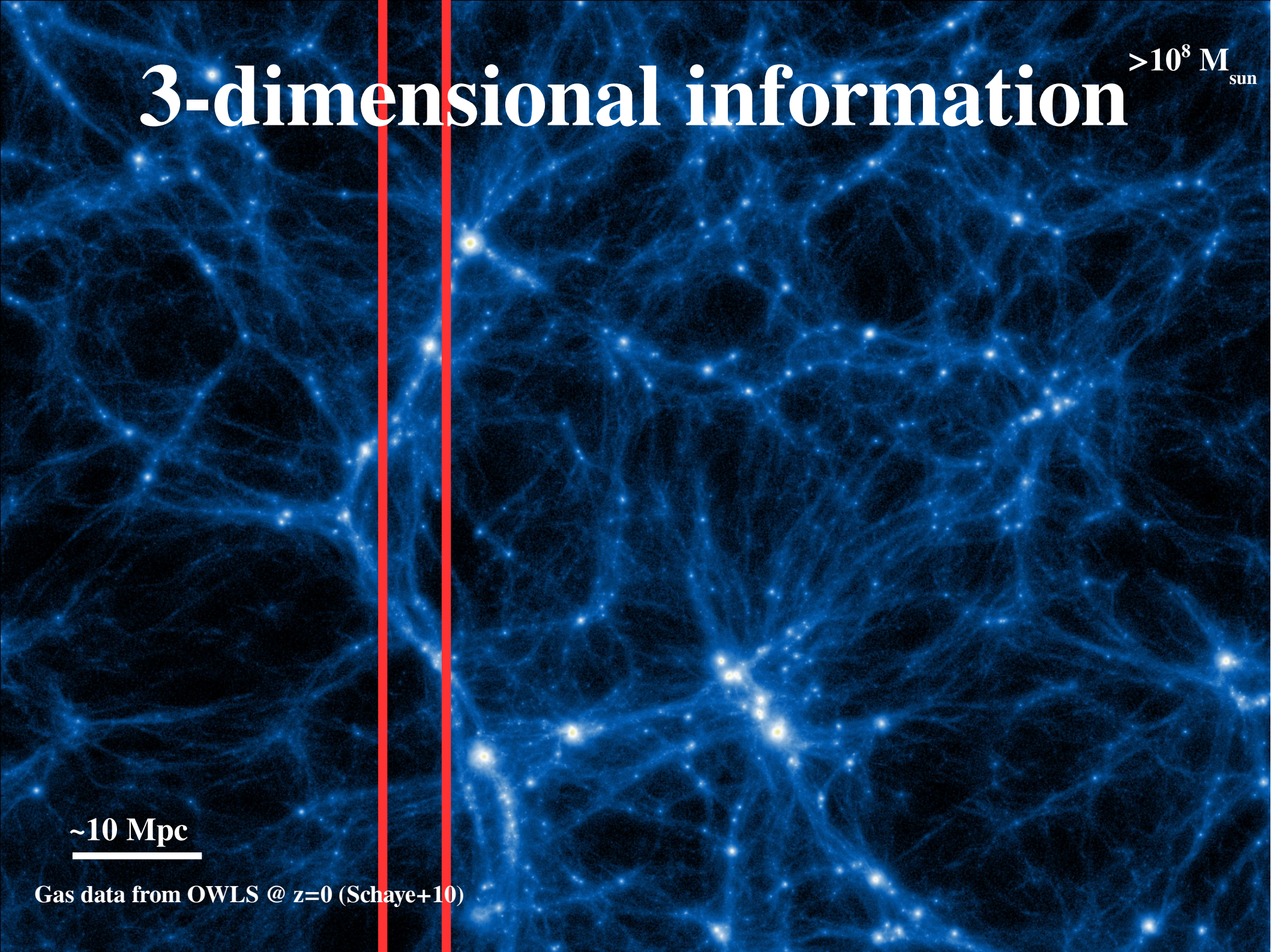
- **I: Experimental design**
- **II: The observations**
- **III: Results**
- **IV: Summary & Conclusions**
- **(Future work)**

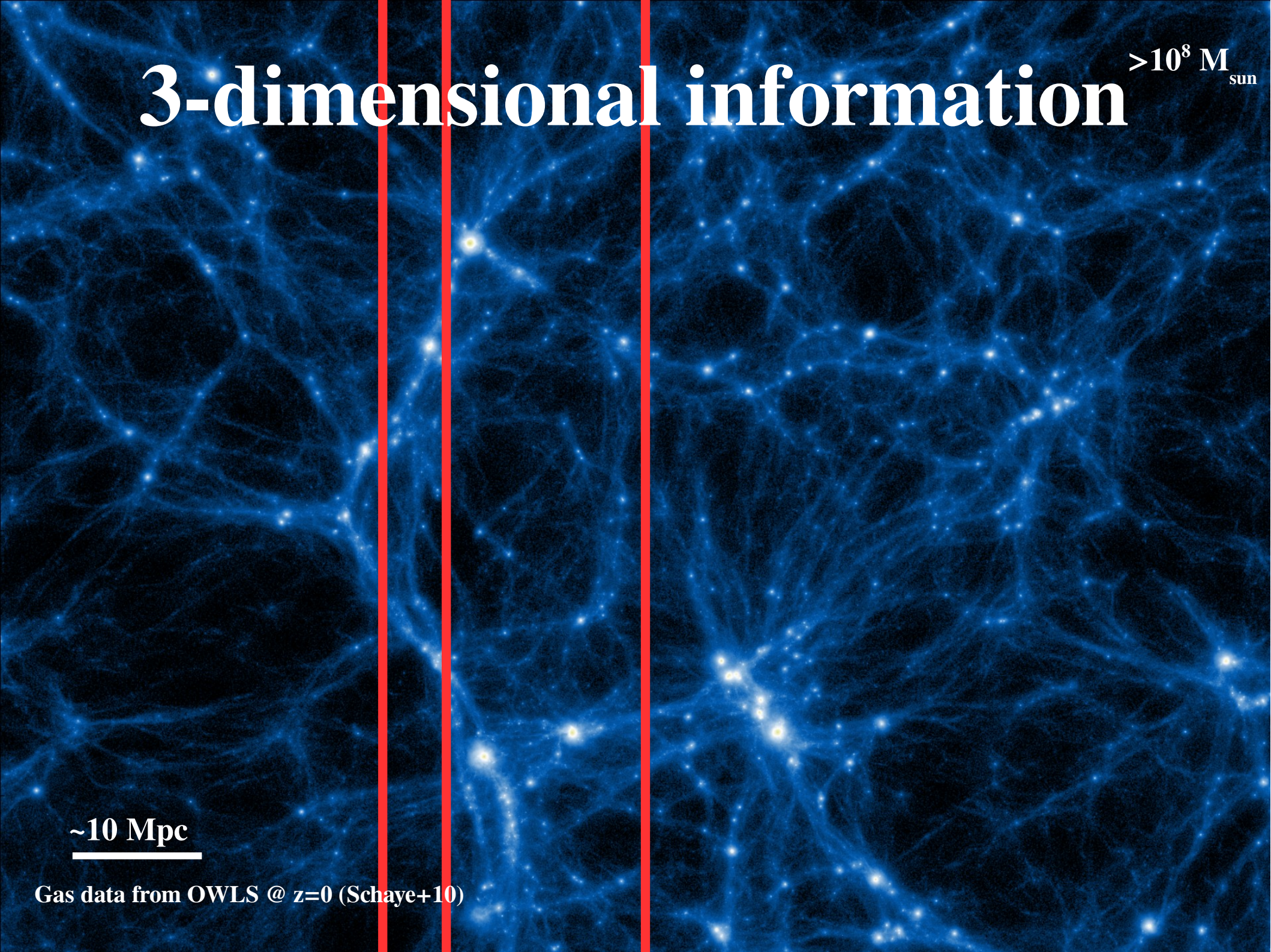
(Tejos+15, submitted)

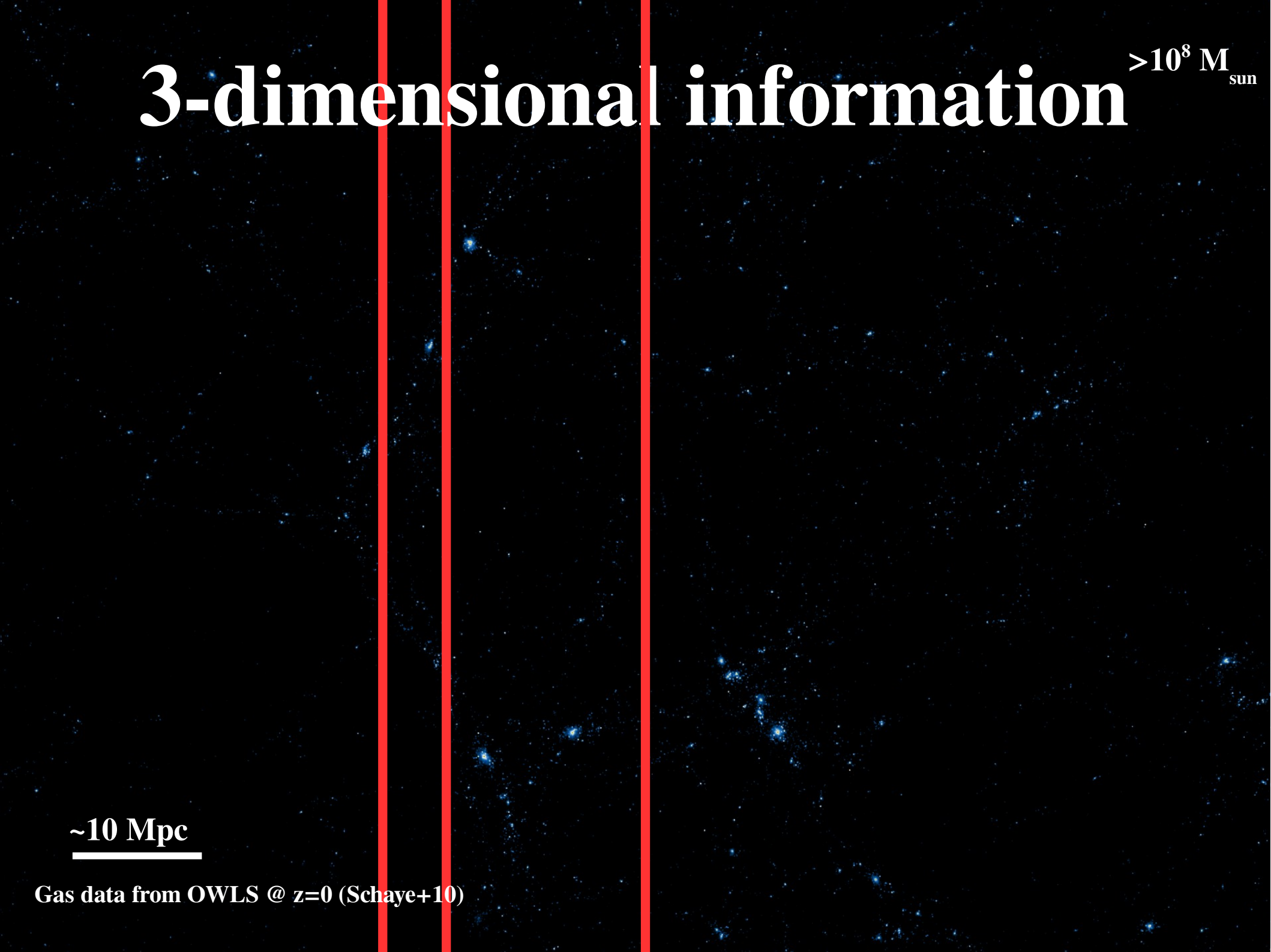
Part I:

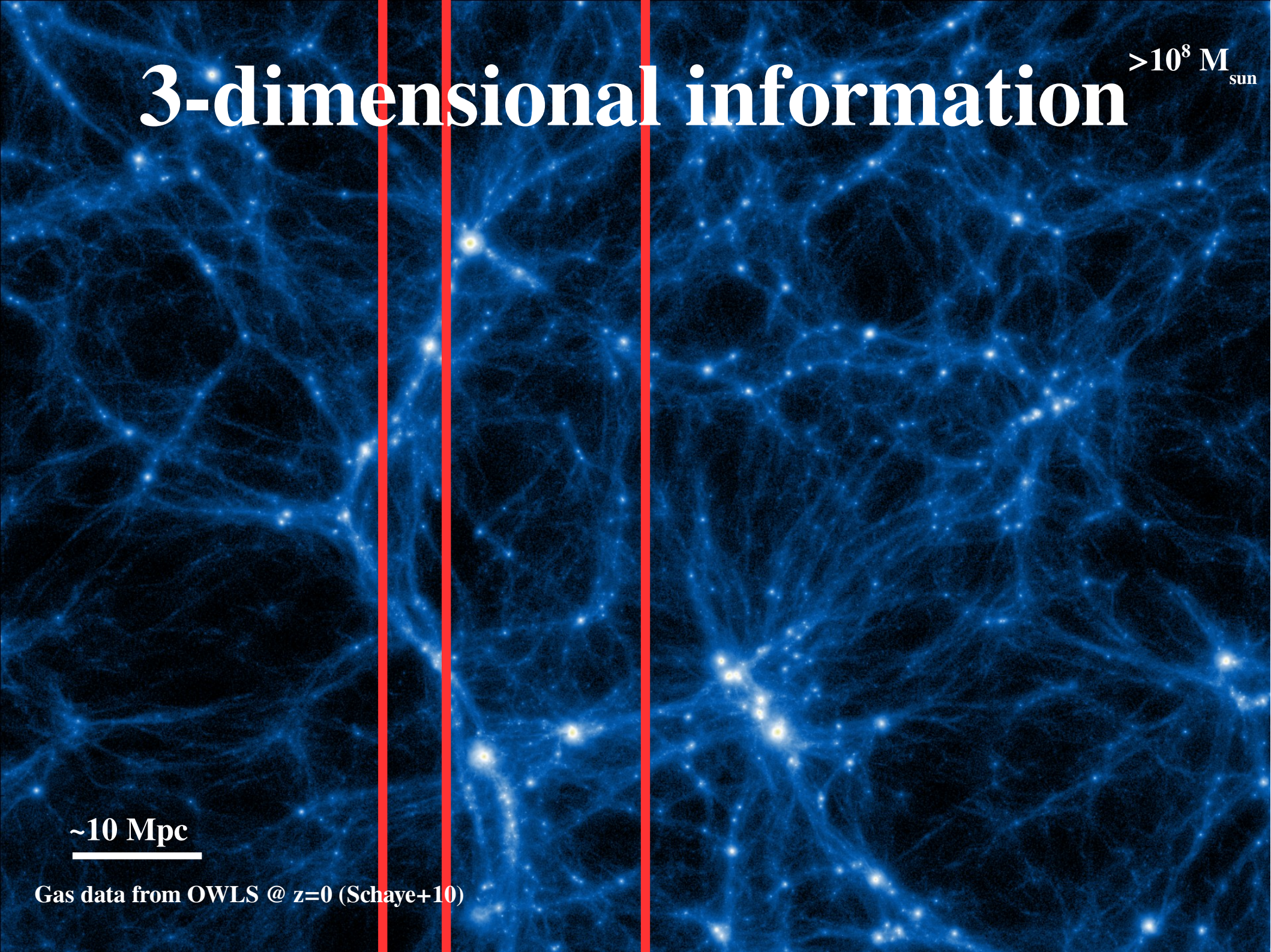
The experimental design


1-dimensional information
>10^8 M_sun
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)


3-dimensional information
>10^8 M_sun
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)


3-dimensional information
>10^8 M_sun
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)


3-dimensional information
>10^8 M_sun
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)


3-dimensional information
>10^8 M_sun
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)

At low-z there is a good mapping of galaxies

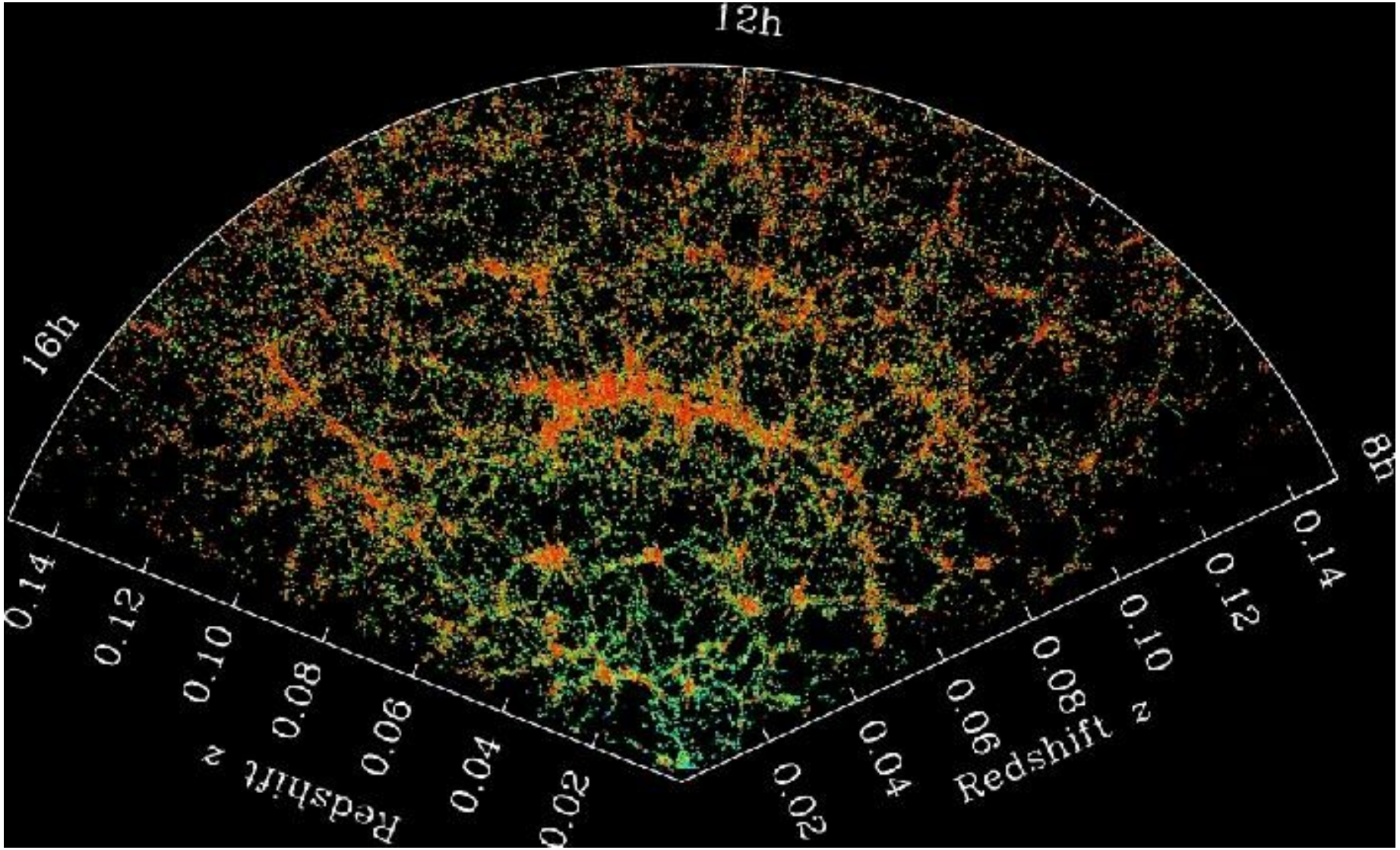


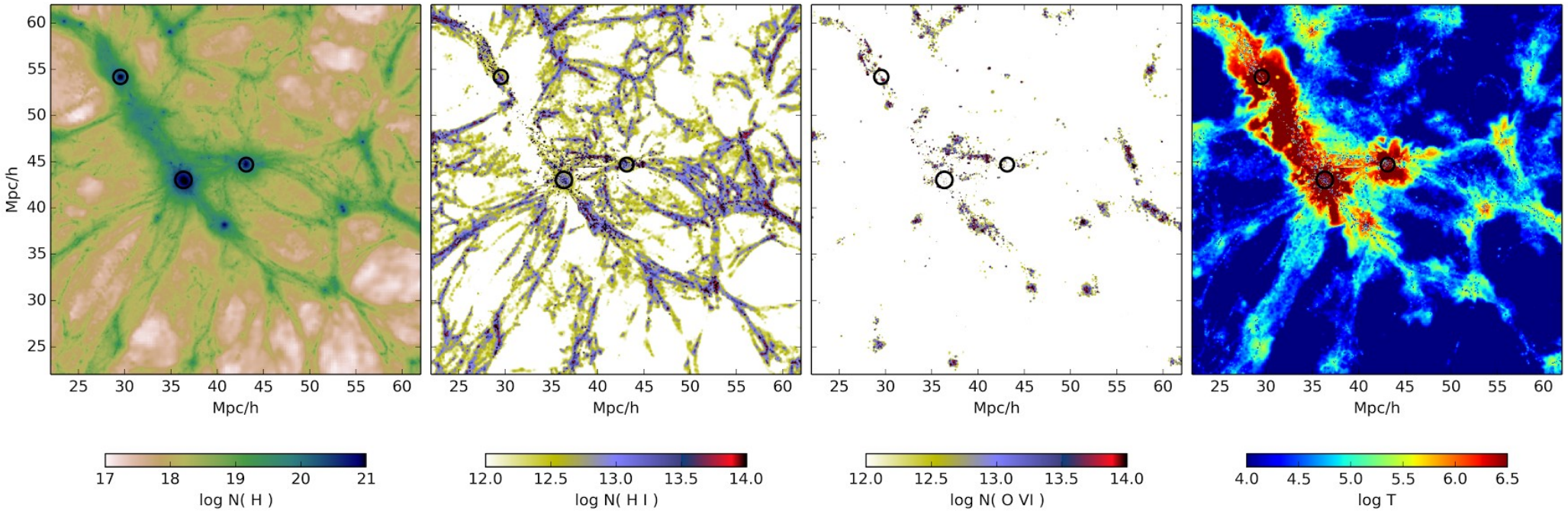
Fig: SDSS galaxy survey

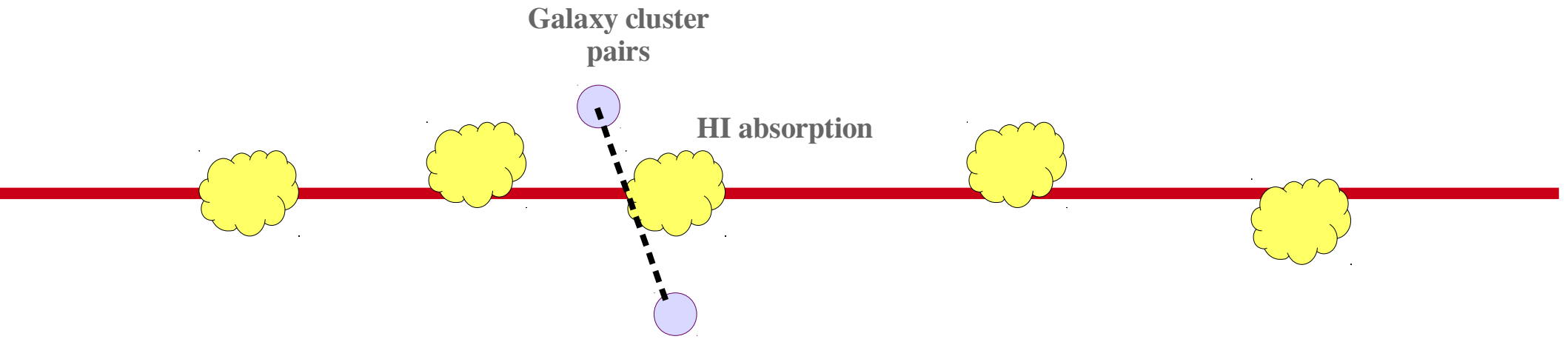
But we need space-based UV spectroscopy

Fig: NASA

Experimental design

Data from OWLS (Schaye+10)

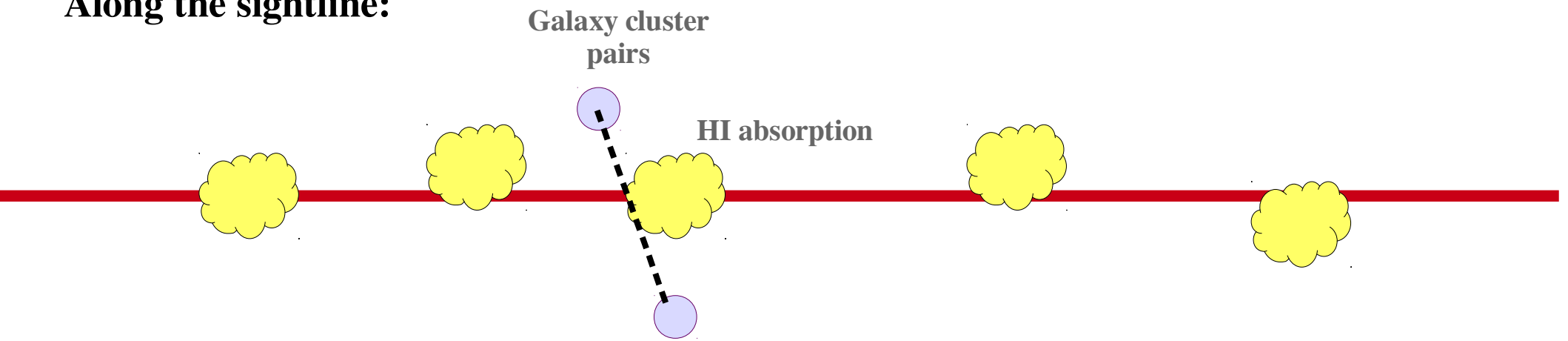




Experimental design

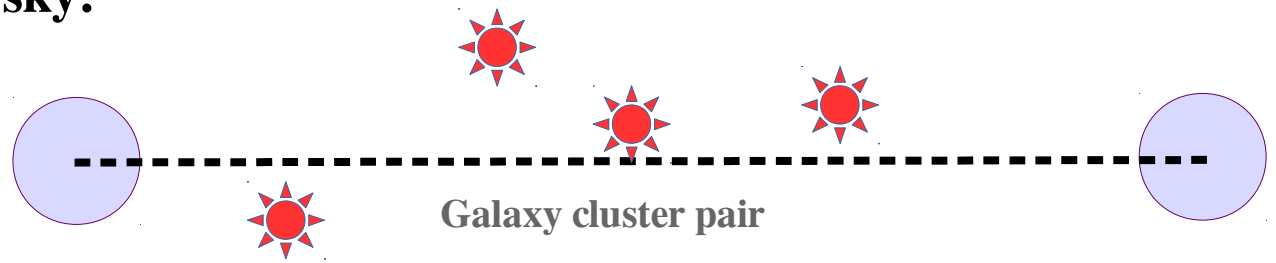
Projected in the sky:

Along the sightline:

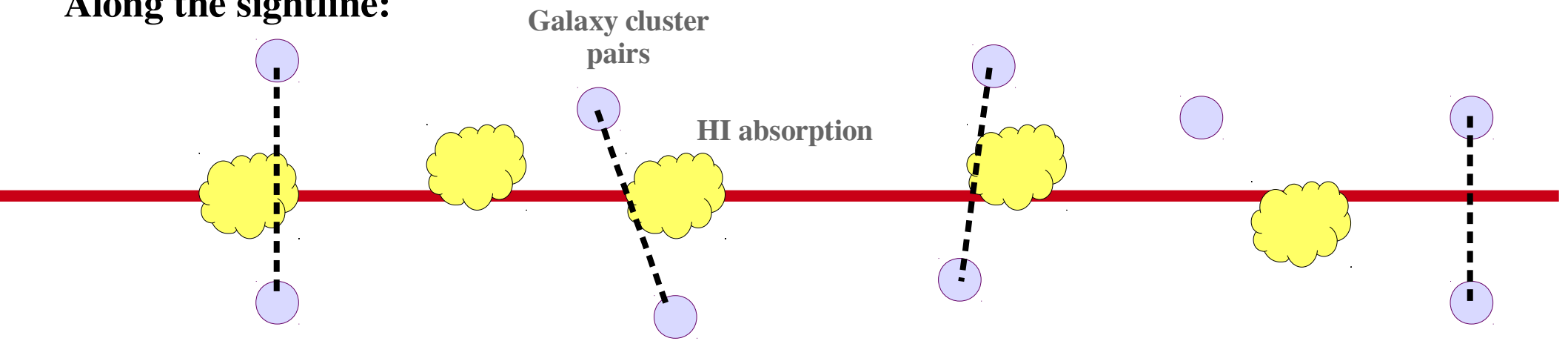


We need multiple probes

Projected in the sky:



Along the sightline:

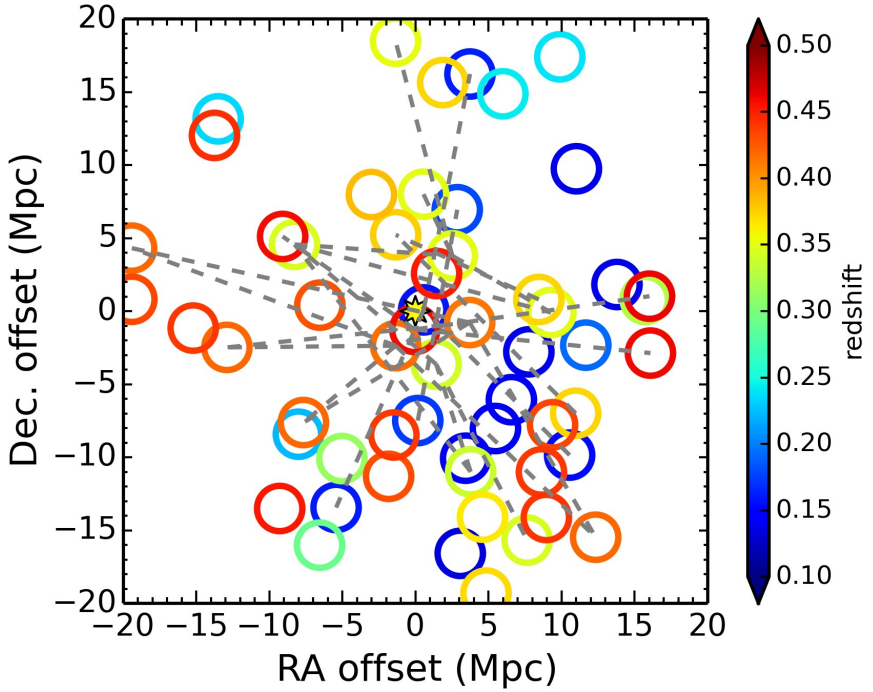


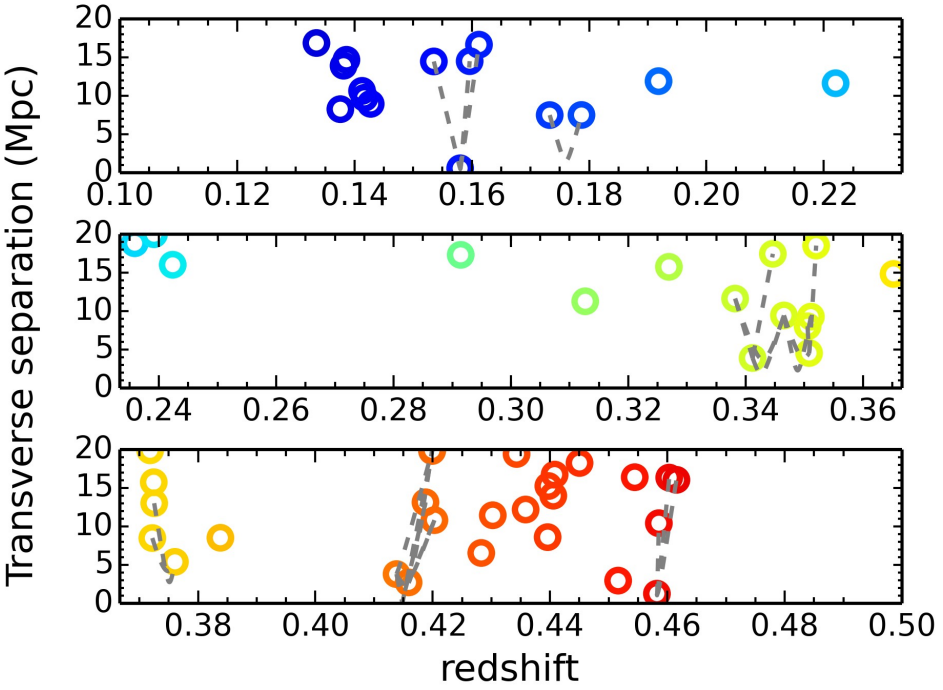
Part II:

The observations

Unique sightline

- **HST/COS** (12 orbits)
- 1 QSO whose sightline intersects **7 independent** cluster-pairs within 3 Mpc
- The random expectation is **~1 ± 1 independent** cluster-pairs within 3 Mpc
- Clusters from redMapper catalog (Rykoff+14)

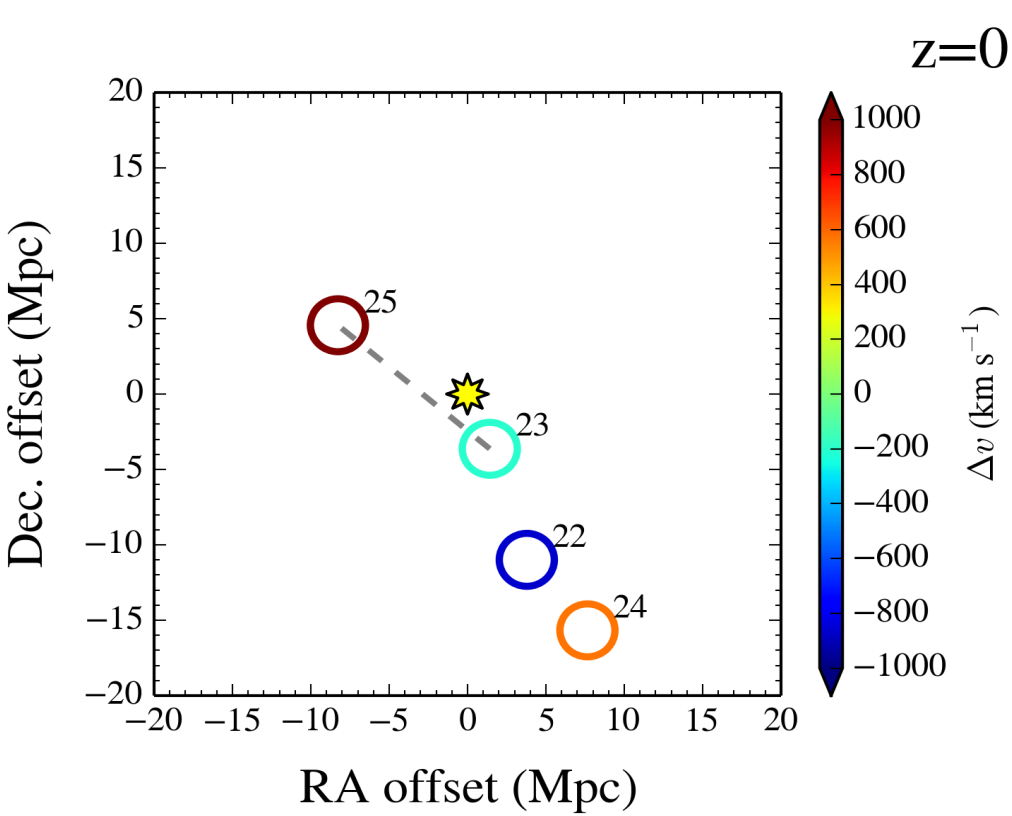


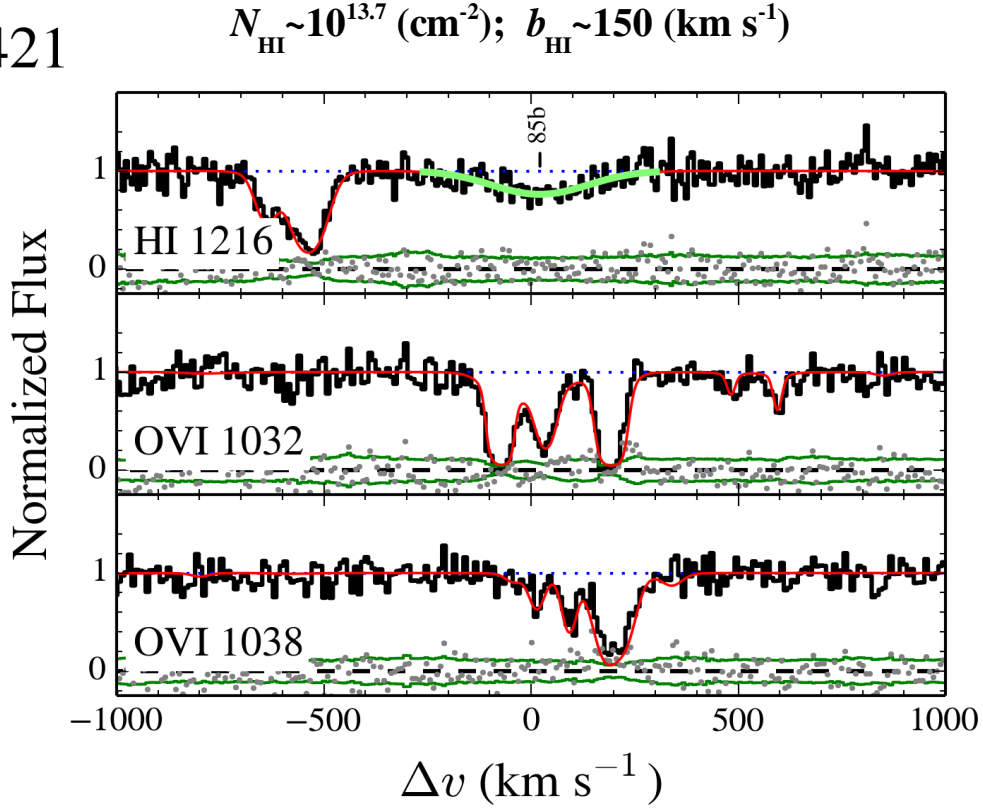


This is a highly exceptional sightline!

Tejos+15, submitted

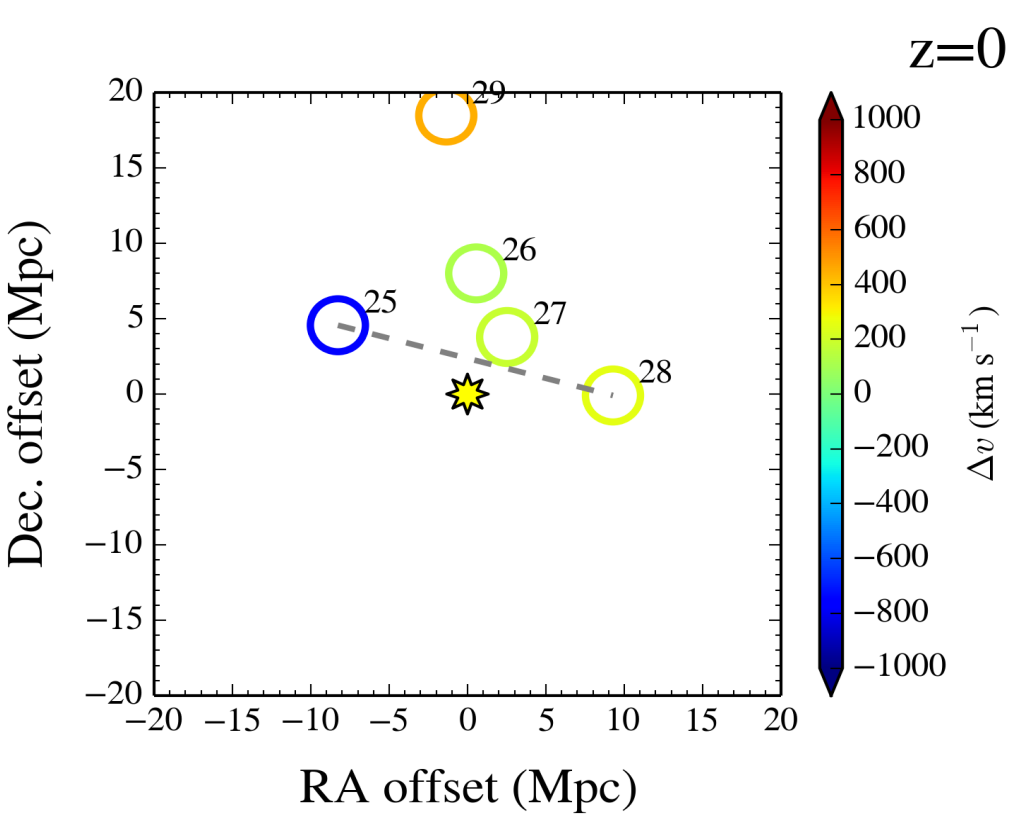
Examples

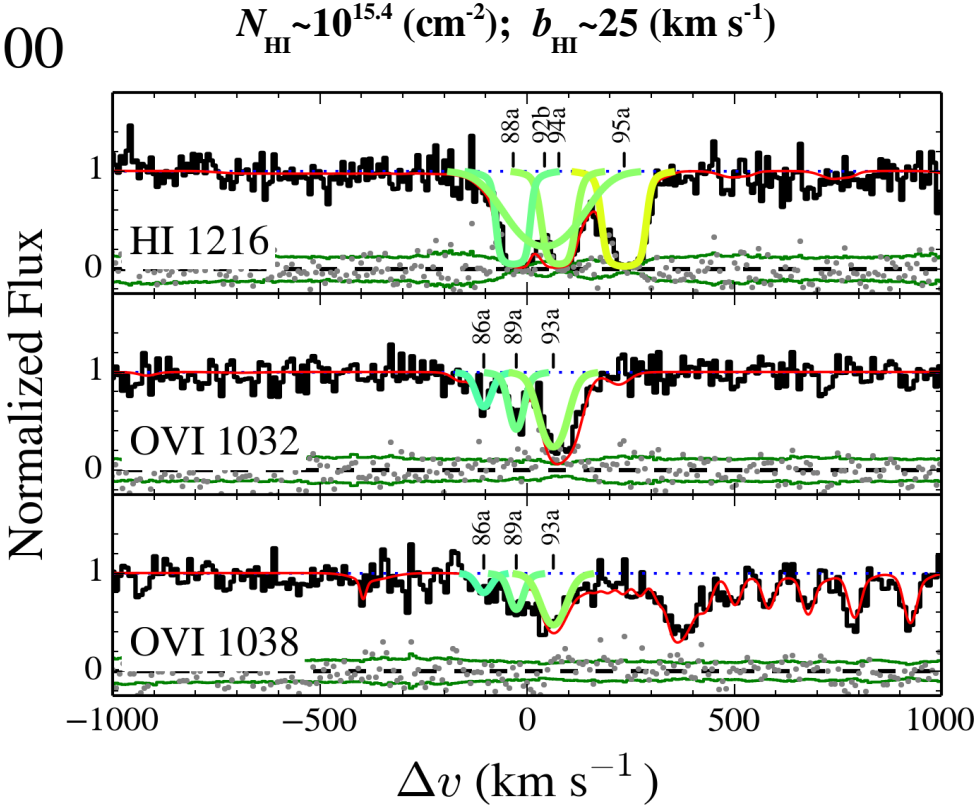




Tejos+15, submitted

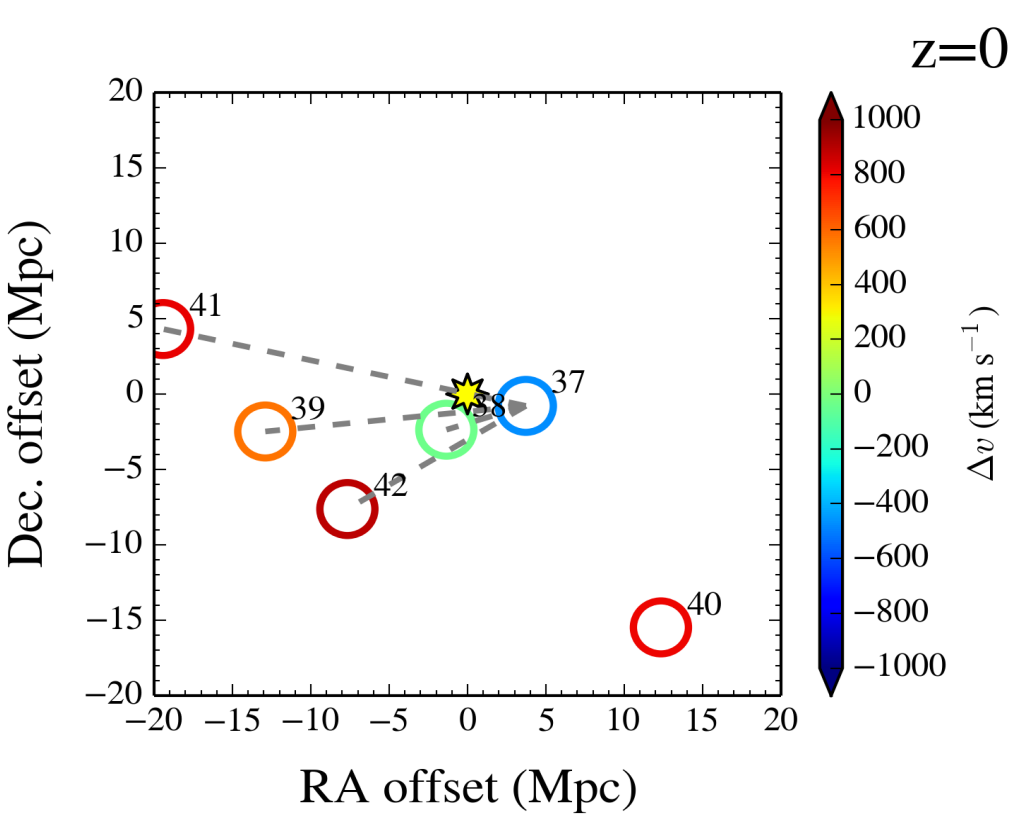
Examples

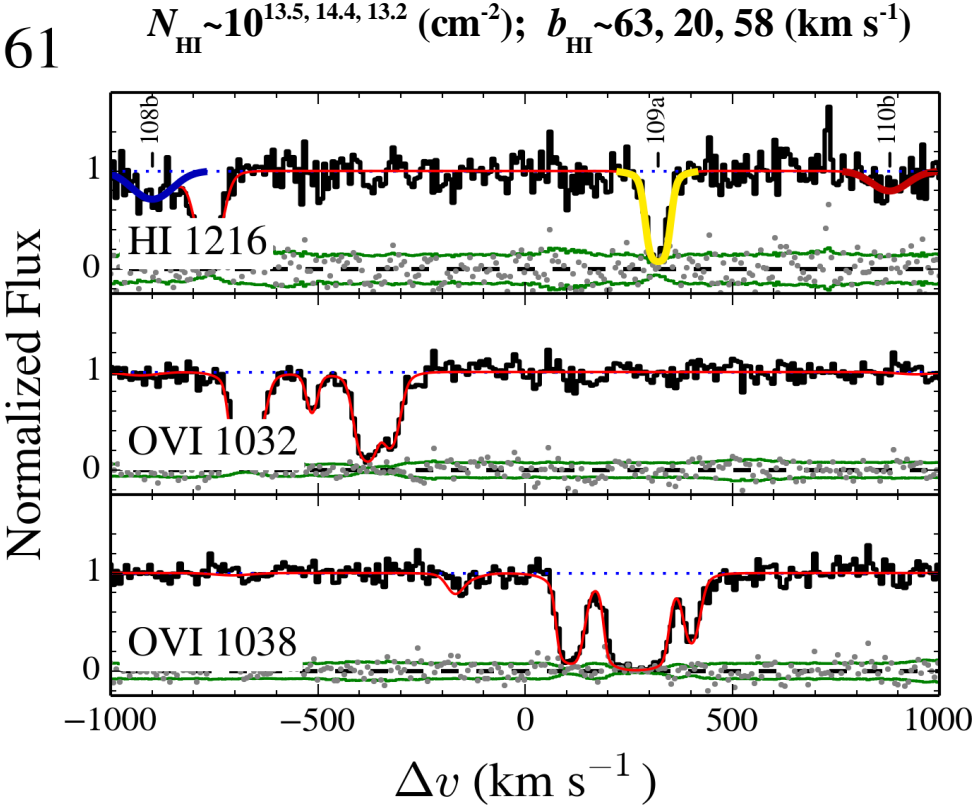




Tejos+15, submitted

Examples





Tejos+15, submitted

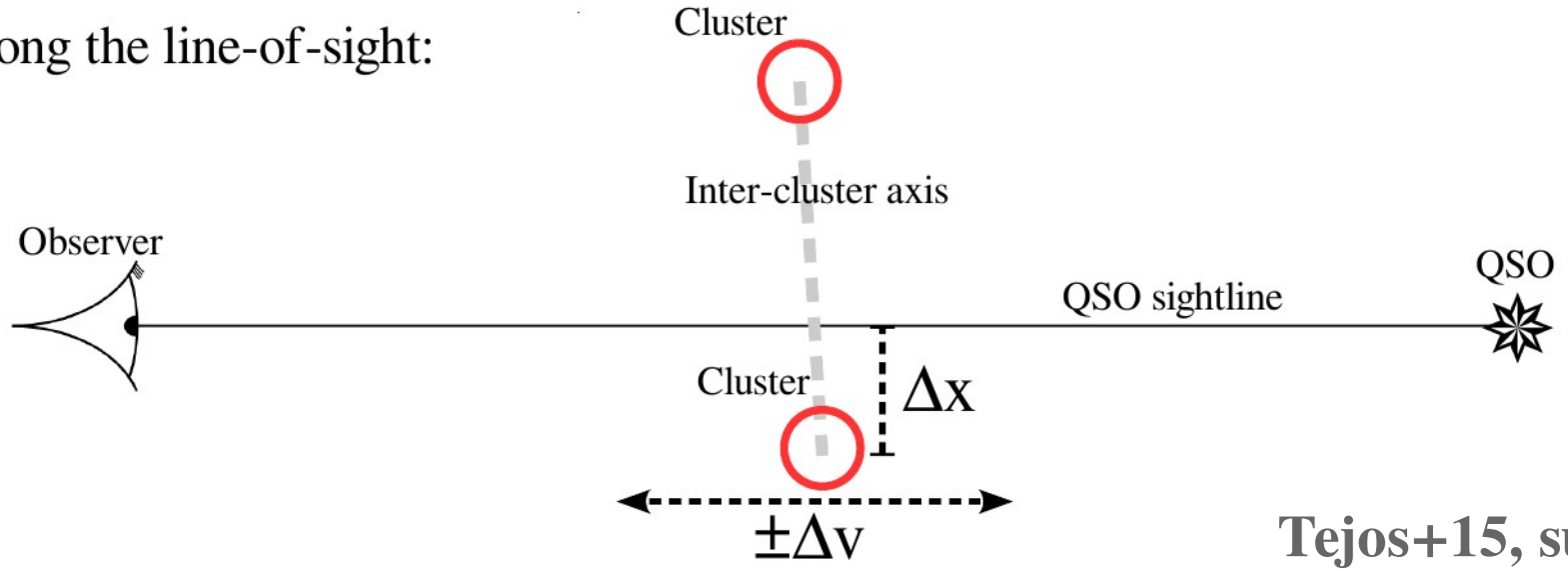
Part III:

Results

Diagram

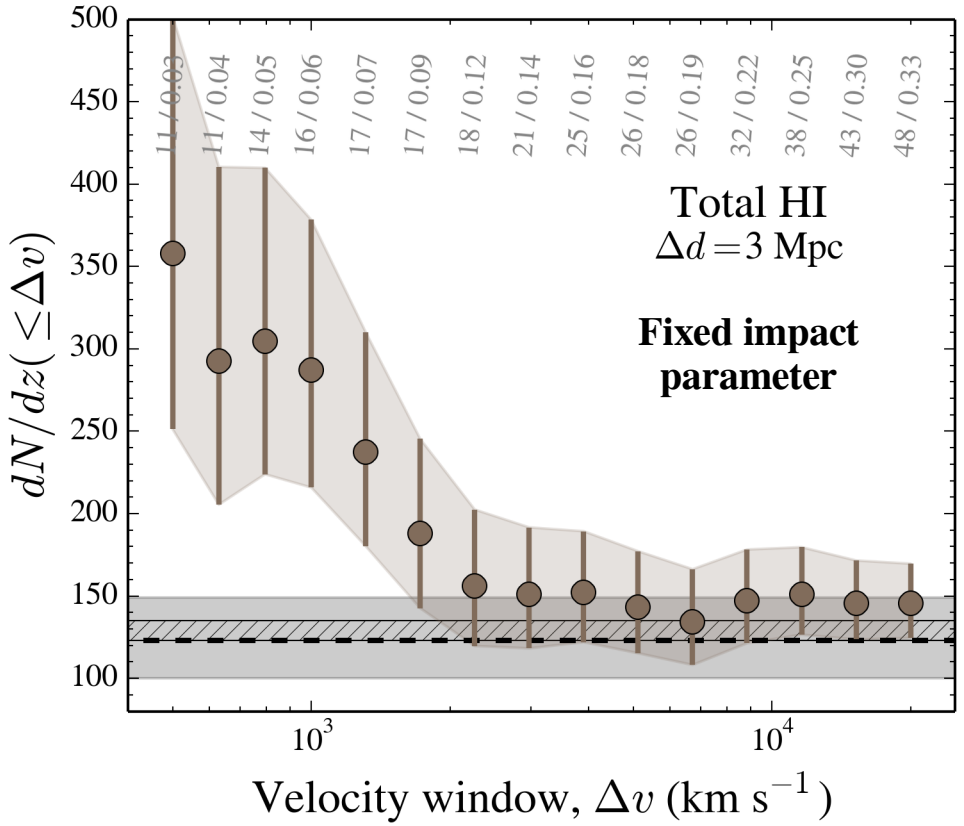
Projected in the sky:

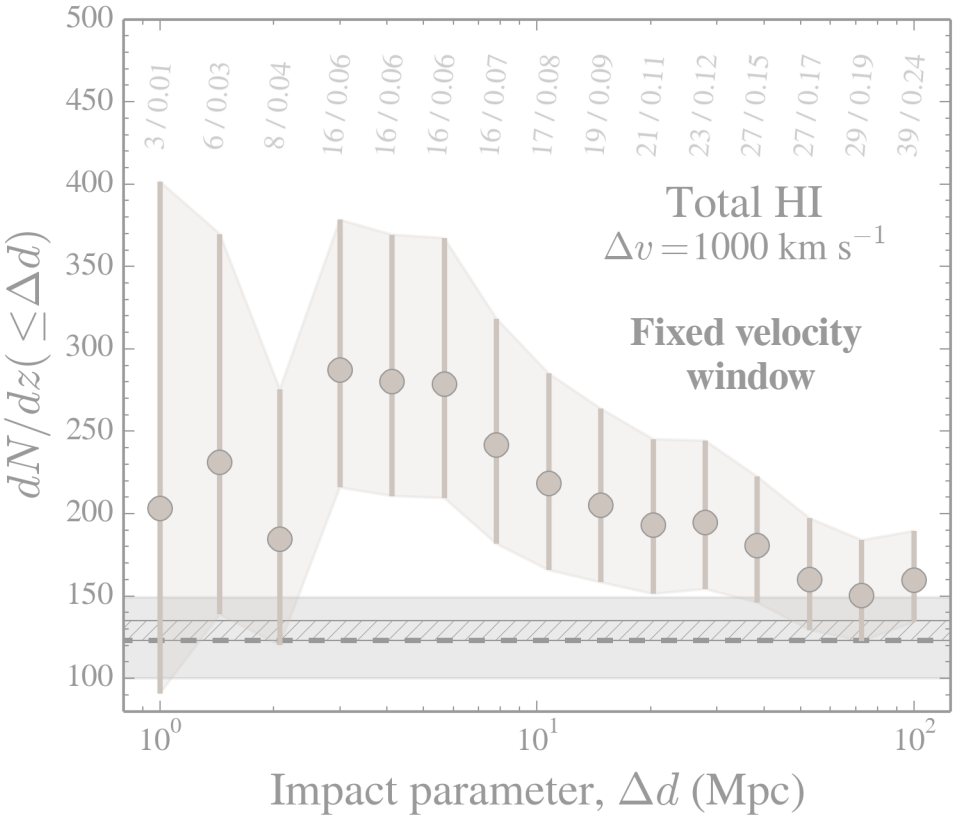
Along the line-of-sight:



Tejos+15, submitted

HI in filaments

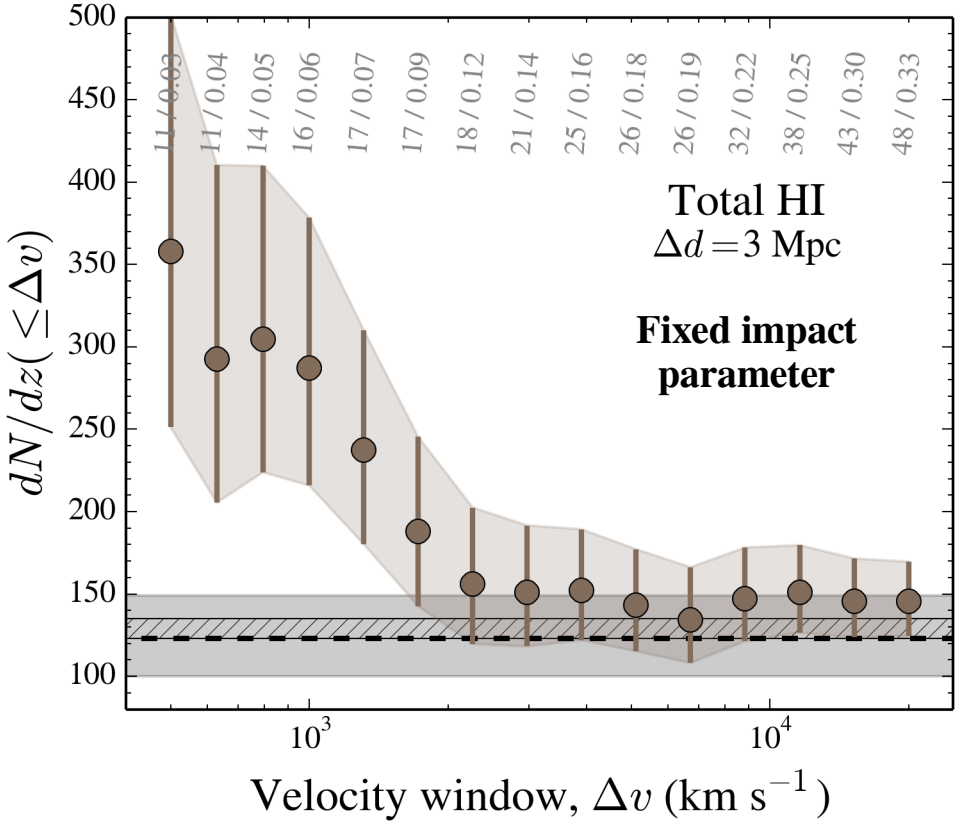


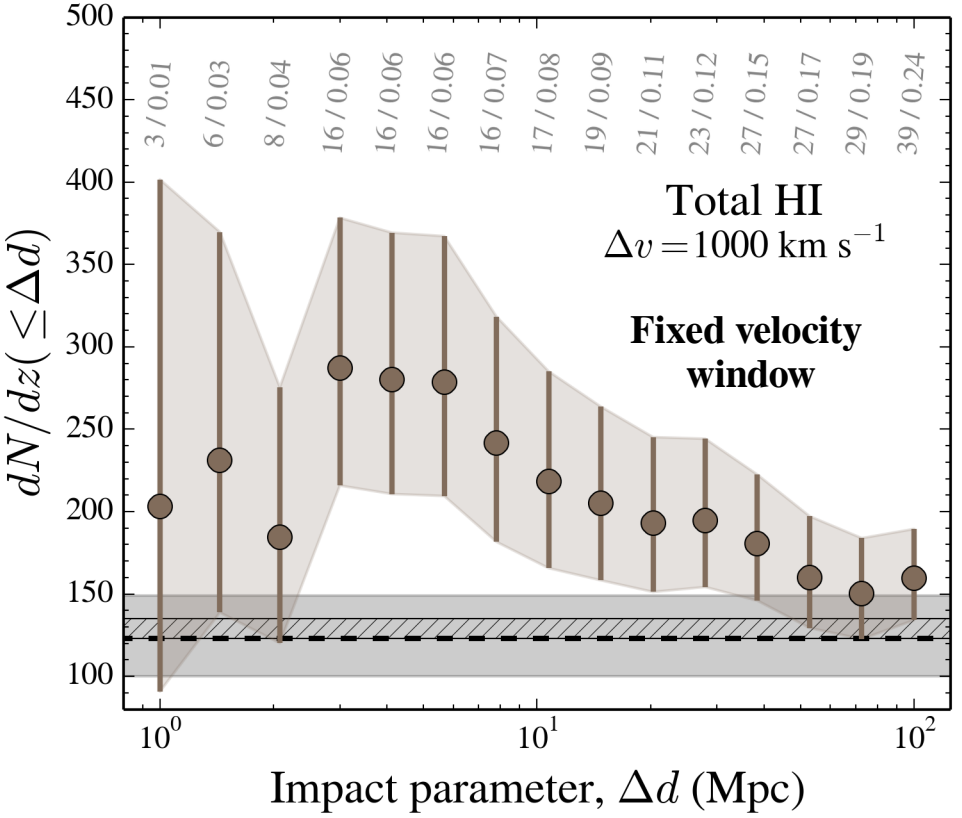


A factor of ~2 excess!

Tejos+15, submitted

HI in filaments



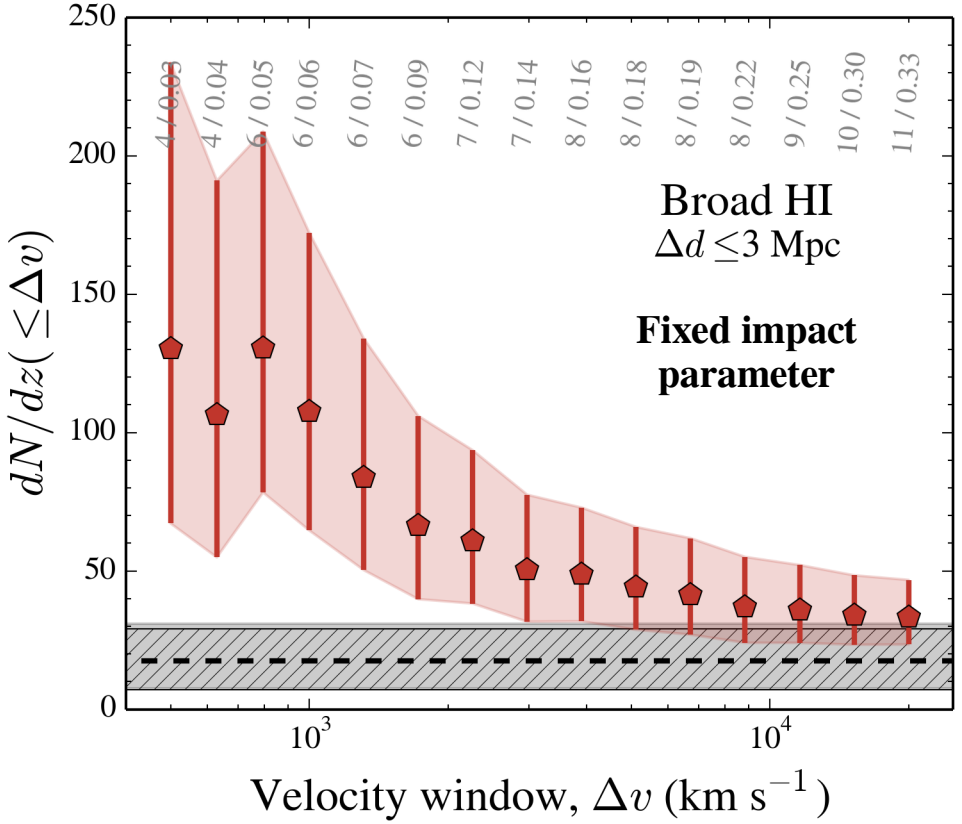


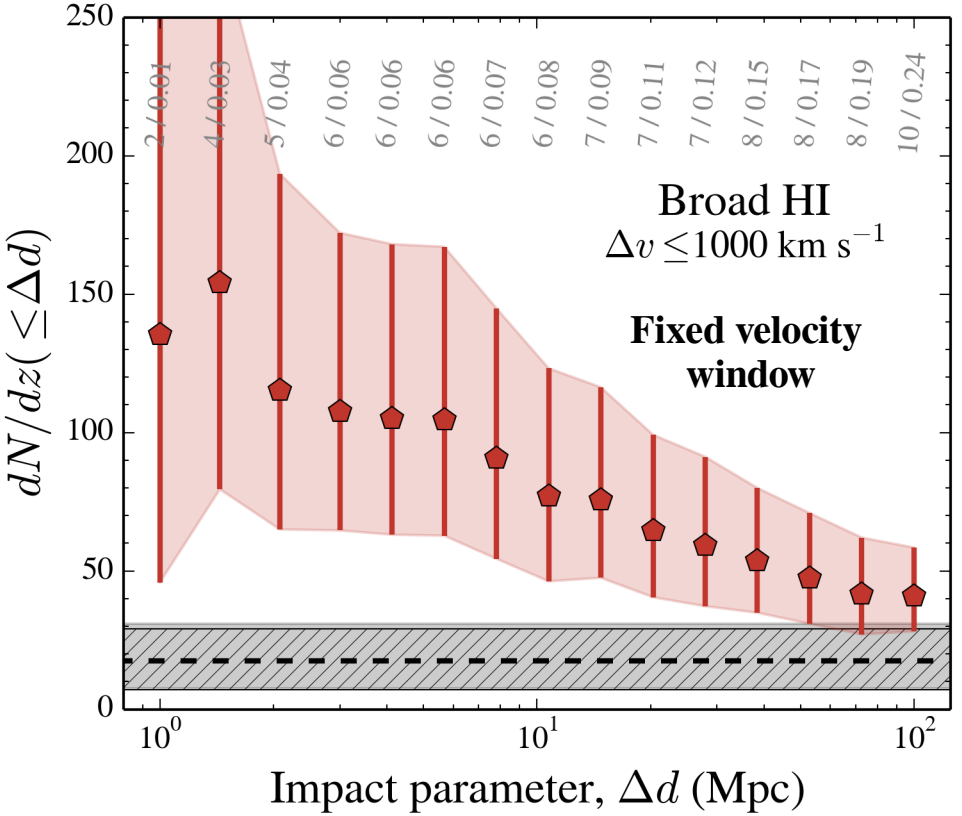
A factor of ~2 excess!

Tejos+15, submitted

Broad HI in filaments

$b > 50$ km/s



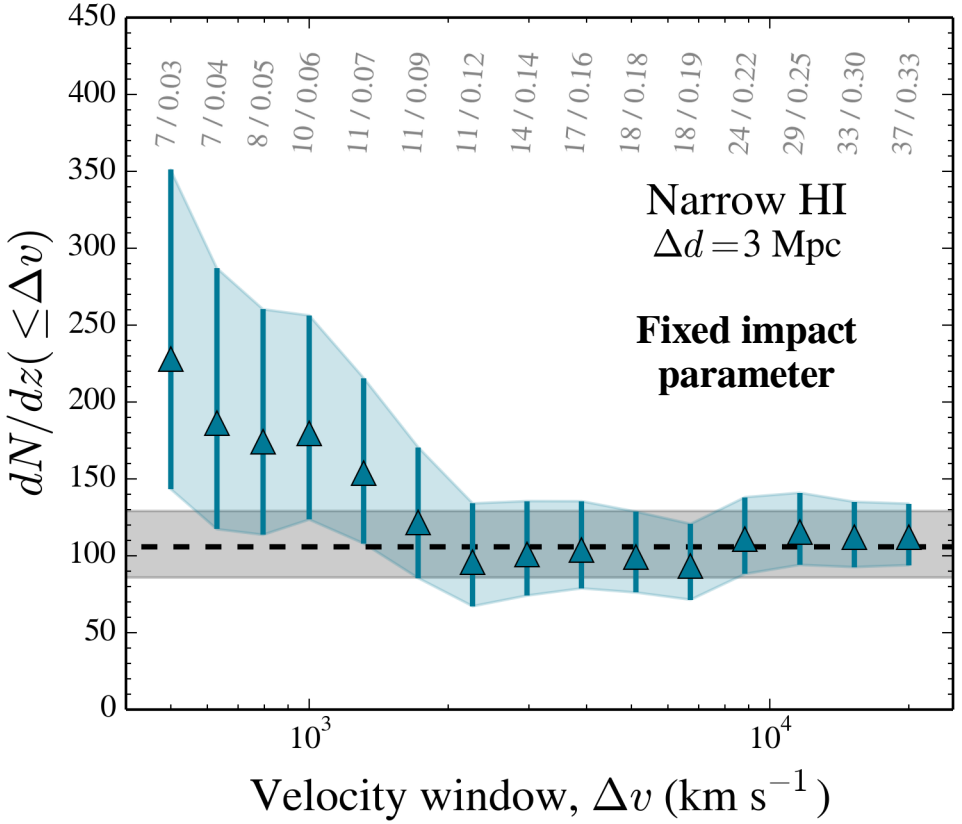


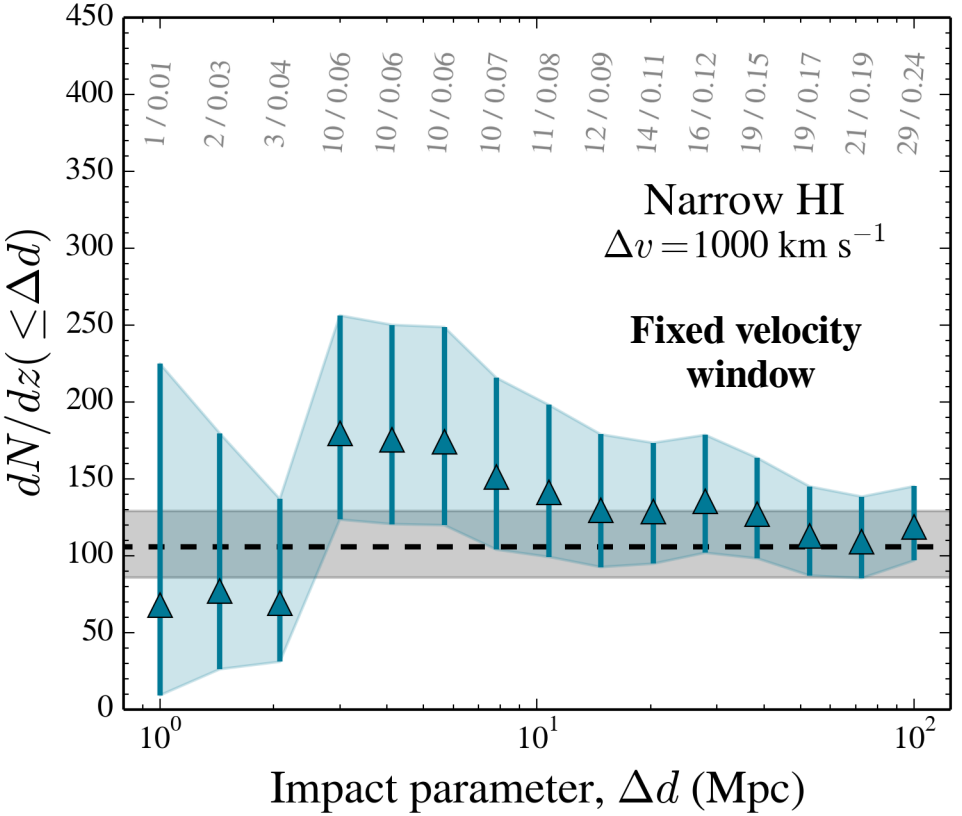
A factor of ~6 excess?

Tejos+15, submitted

Narrow HI in filaments

$b < 50$ km/s

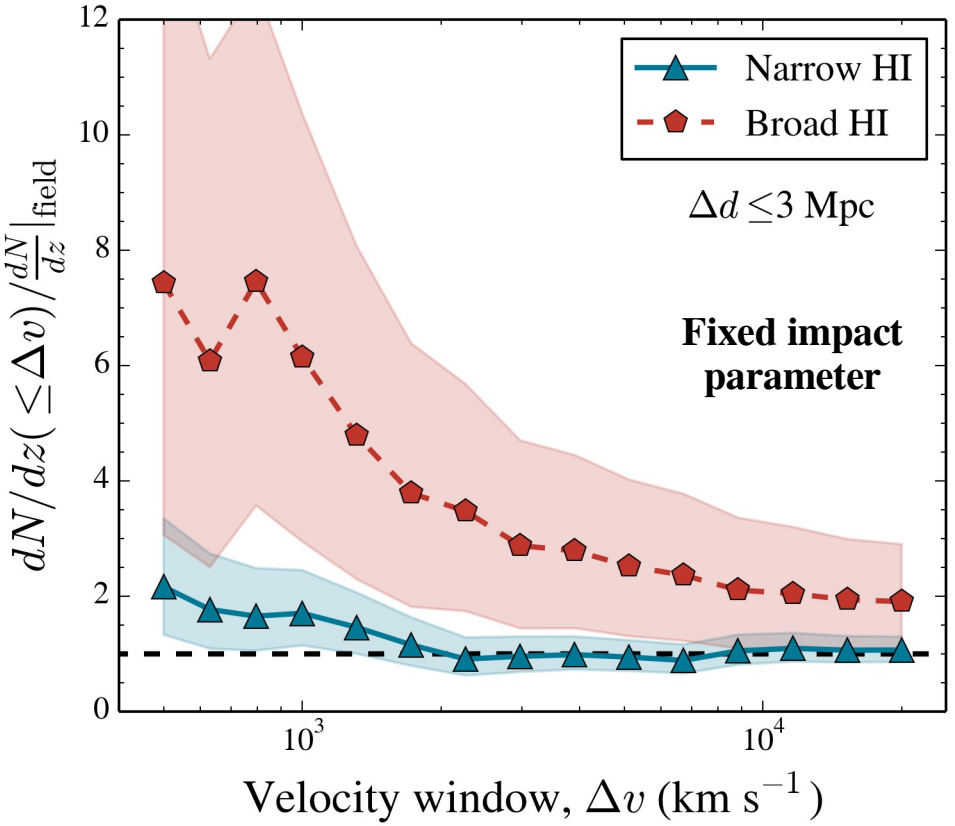


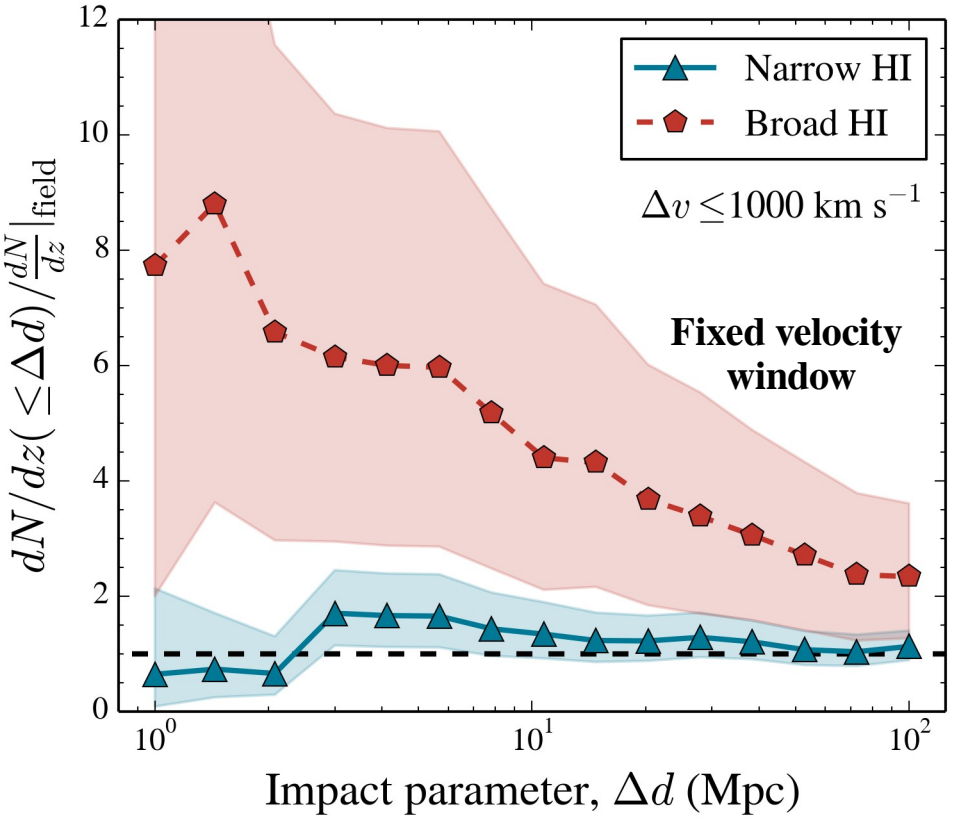


A factor of ~2 excess?

Tejos+15, submitted

Statistical evidence of the WHIM

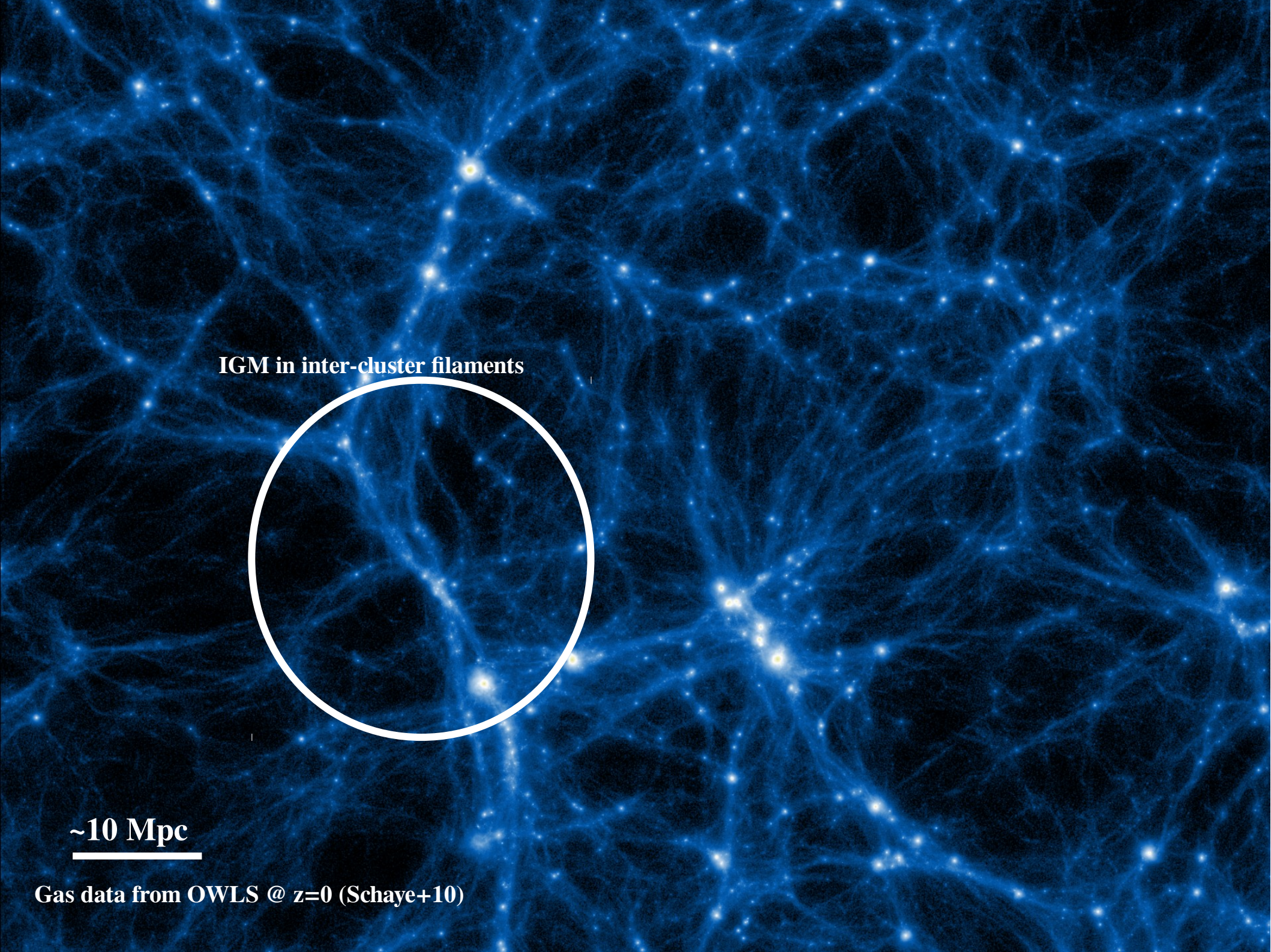


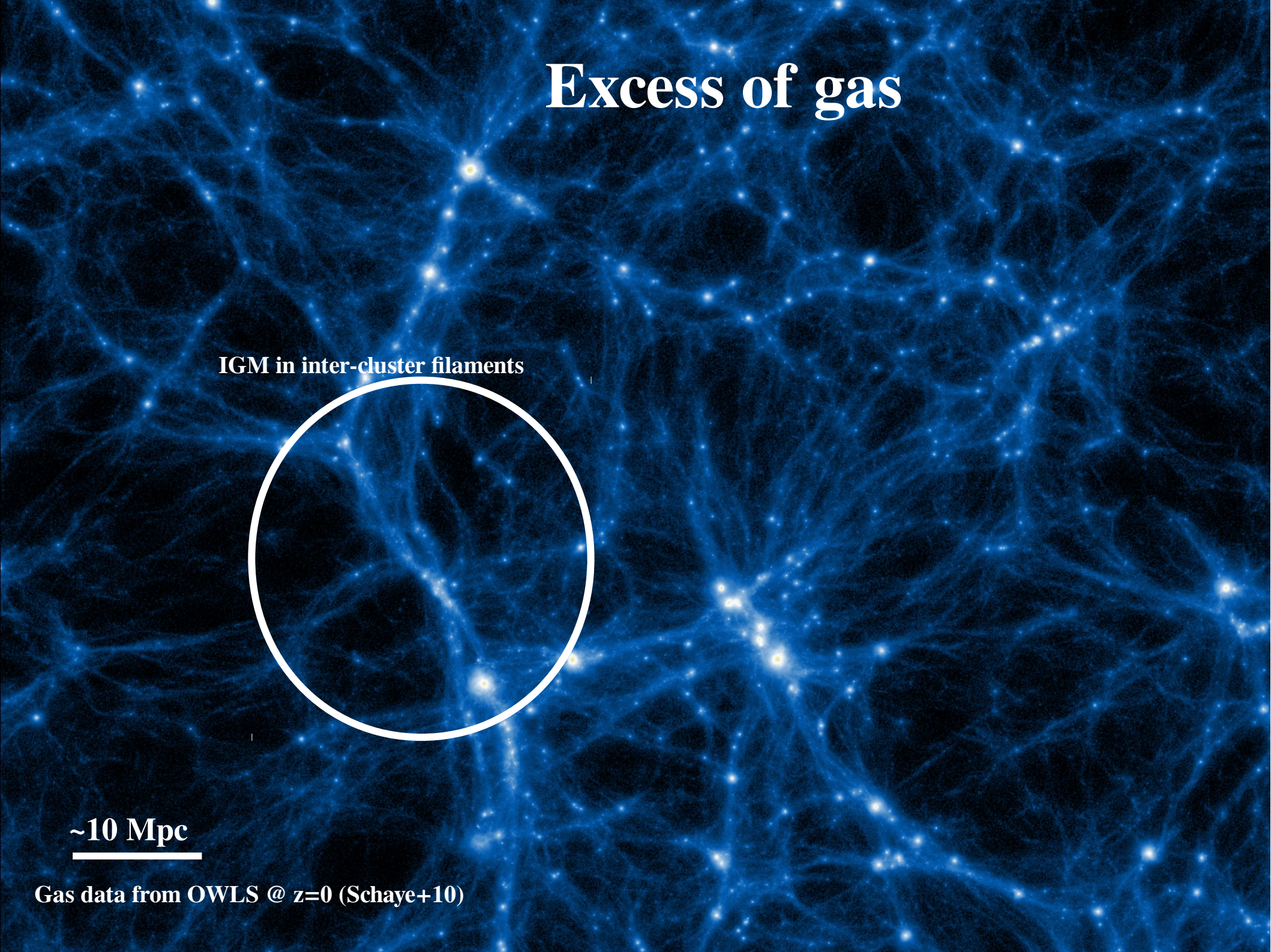


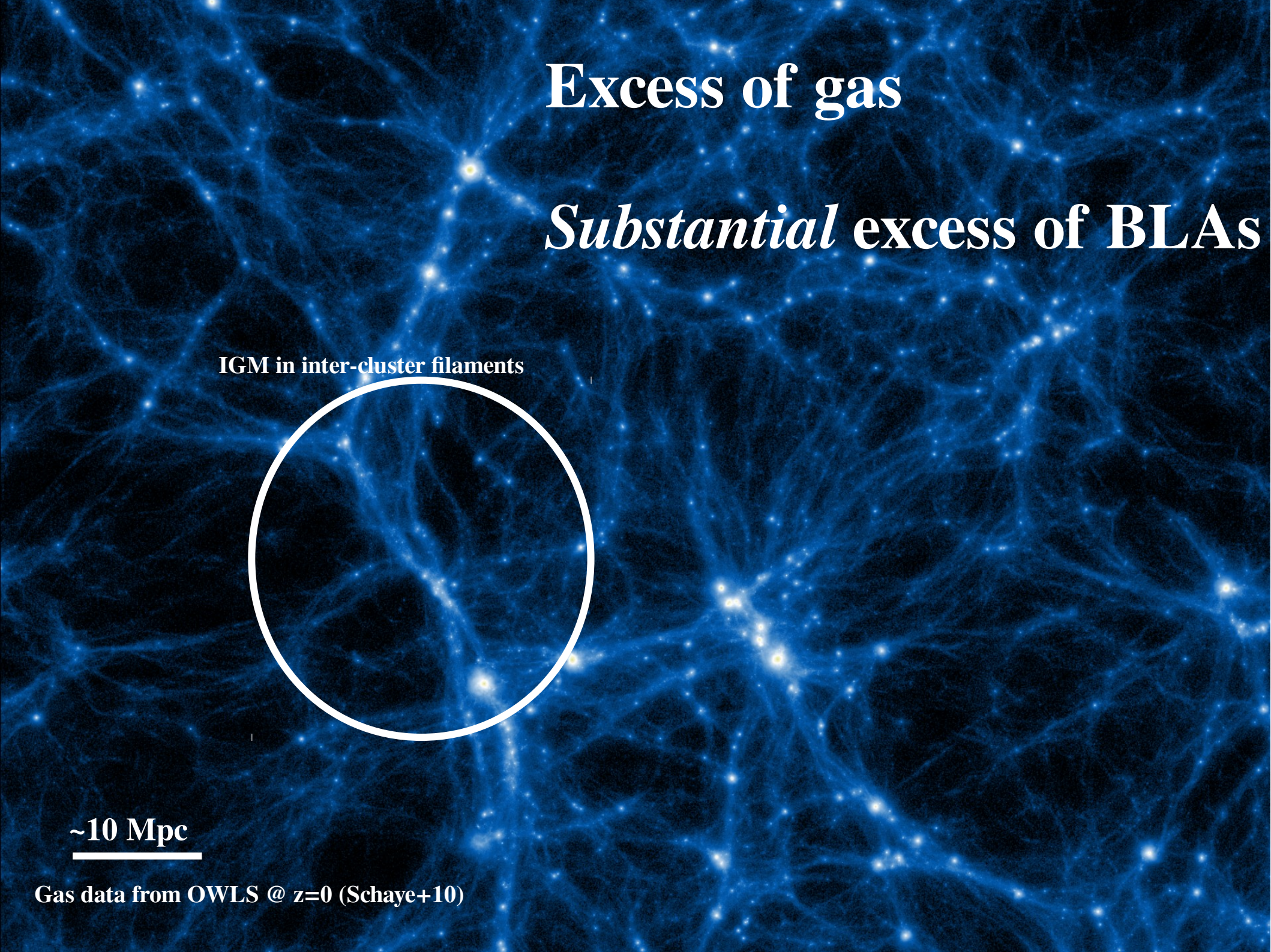
WHIM: Warm-Hot Intergalactic Medium

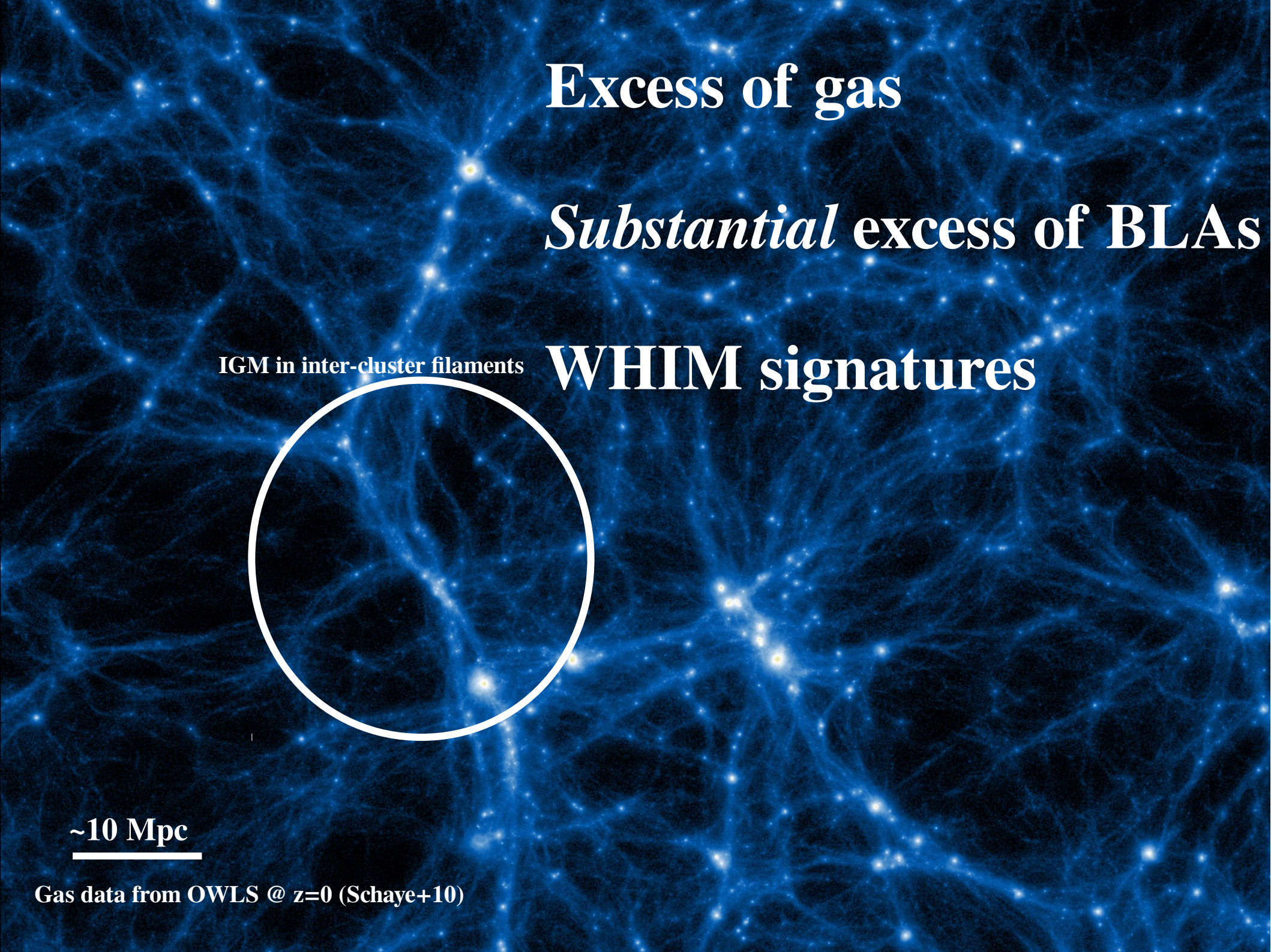
Tejos+15, submitted

Summary & Conclusions


IGM in inter-cluster filaments
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)

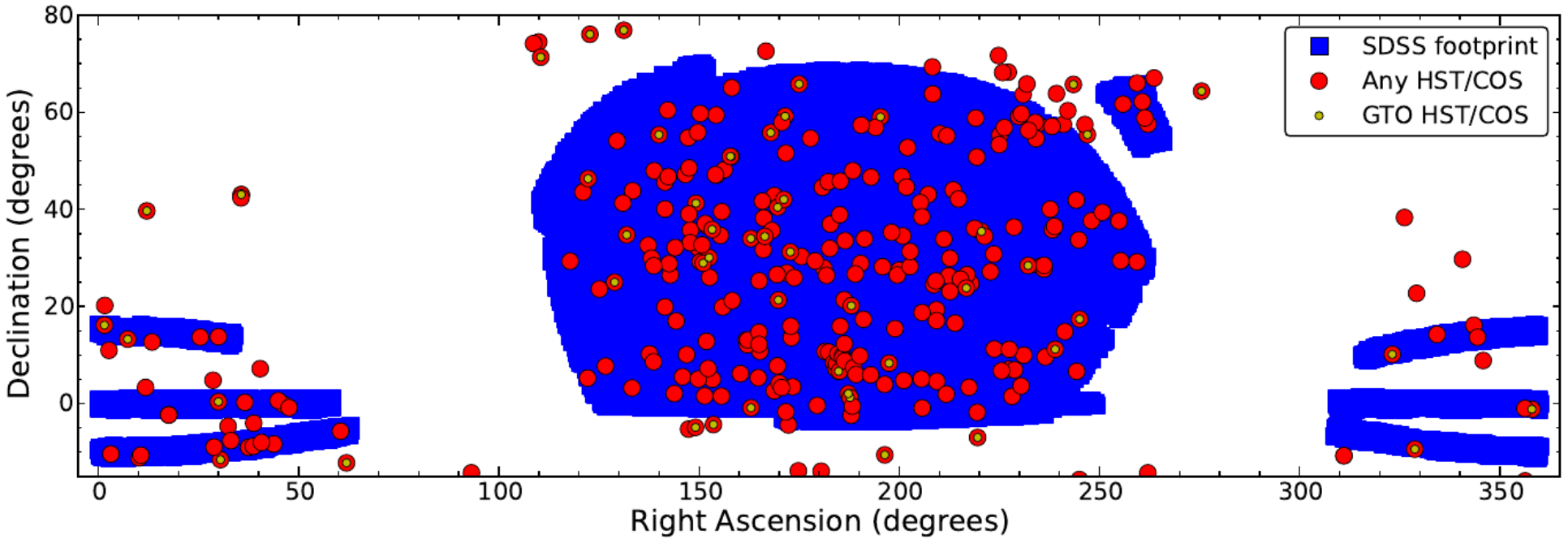

Excess of gas
IGM in inter-cluster filaments
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)


Excess of gas
Substantial excess of BLAs
IGM in inter-cluster filaments
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)


Excess of gas
Substantial excess of BLAs
WHIM signatures
IGM in inter-cluster filaments
~10 Mpc
Gas data from OWLS @ z=0 (Schaye+10)

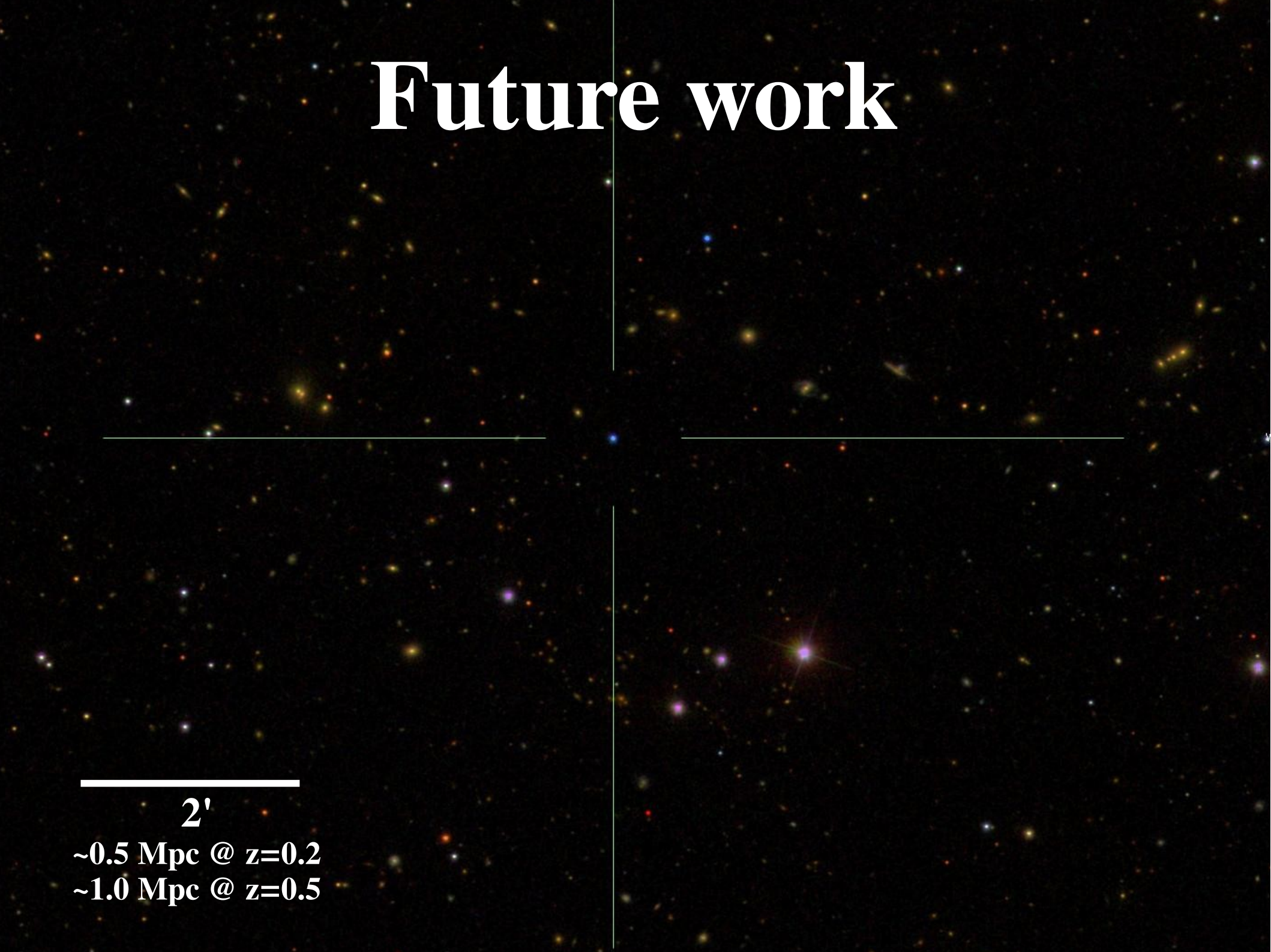
Future work

Future work

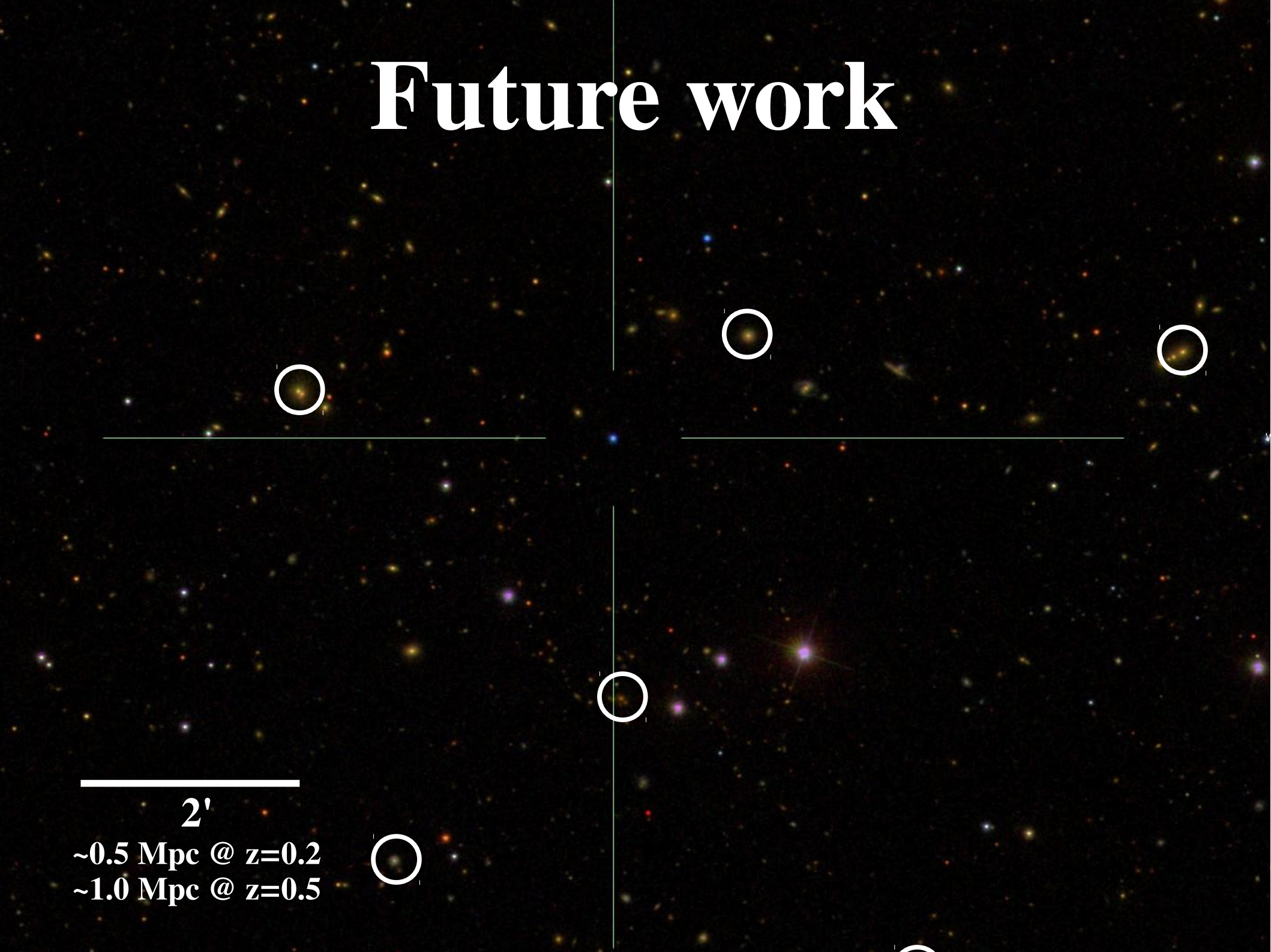


We will increase the samples to reduce statistical and systematic uncertainties.

Future work



Future work

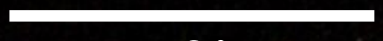


Future work

Recently awarded (PI Tejos):

VLT/MUSE
VLT/VIMOS
HST/COS

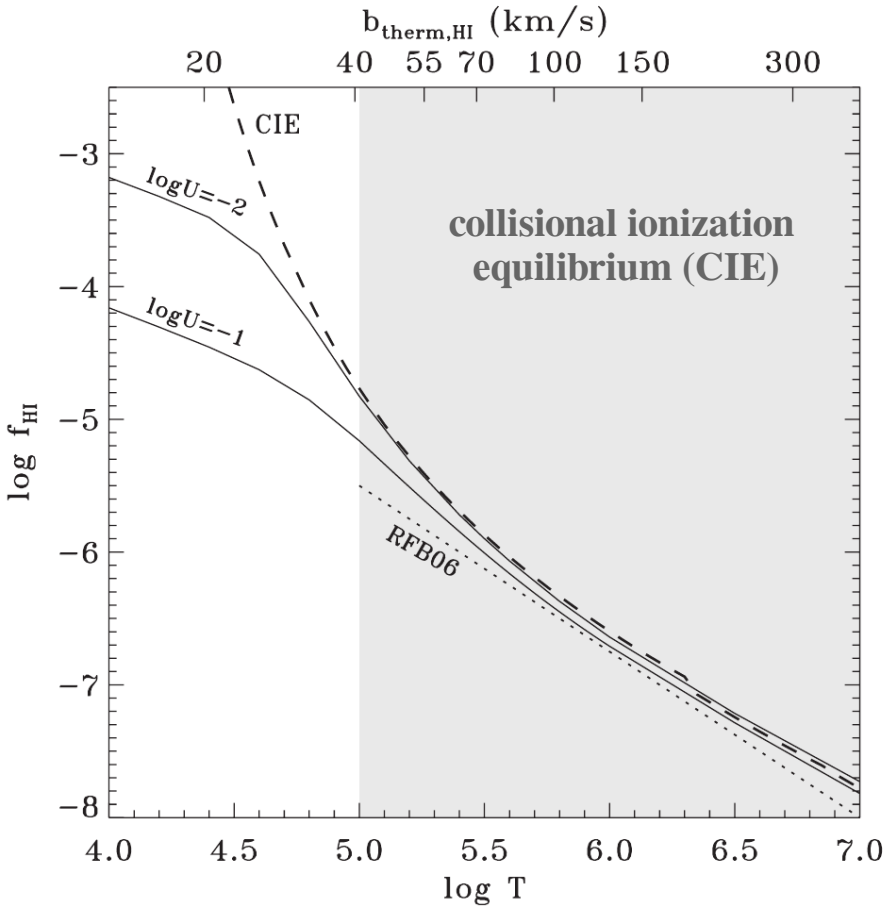
To map galaxies in these filaments and repeat the experiment in another field.



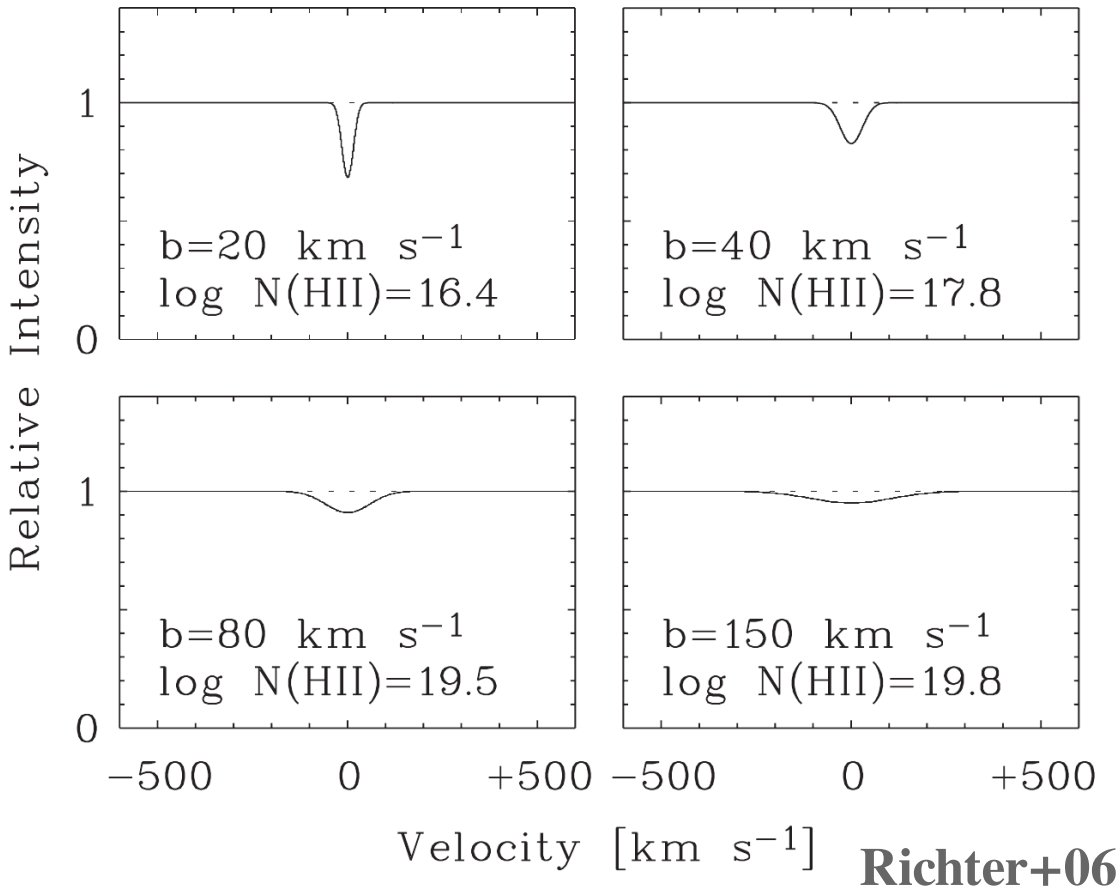
2'

~0.5 Mpc @ z=0.2
~1.0 Mpc @ z=0.5

Experimental challenge



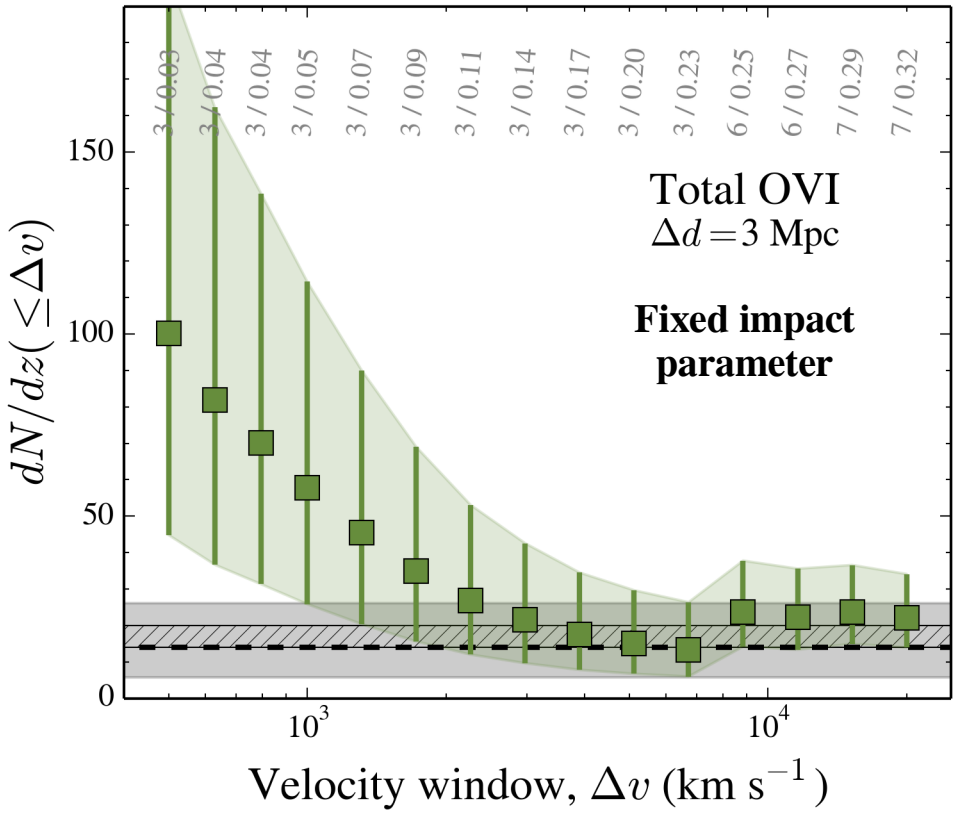
Danforth+10

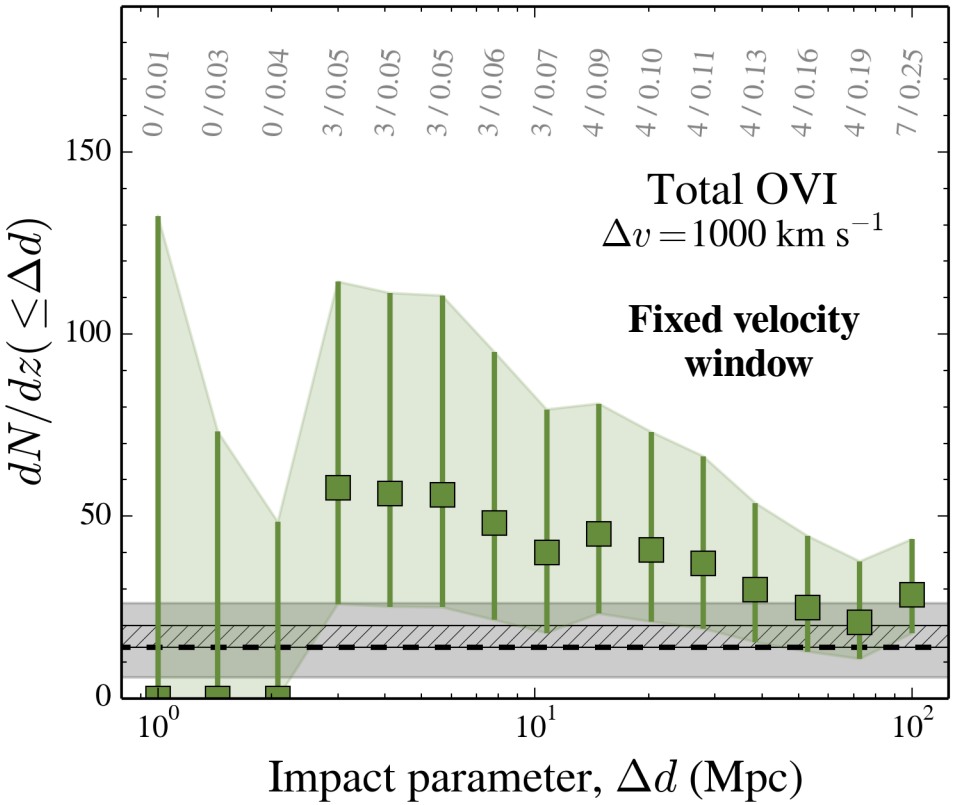


Richter+06

The higher the temperature, the more difficult to detect HI in absorption

OVI in filaments

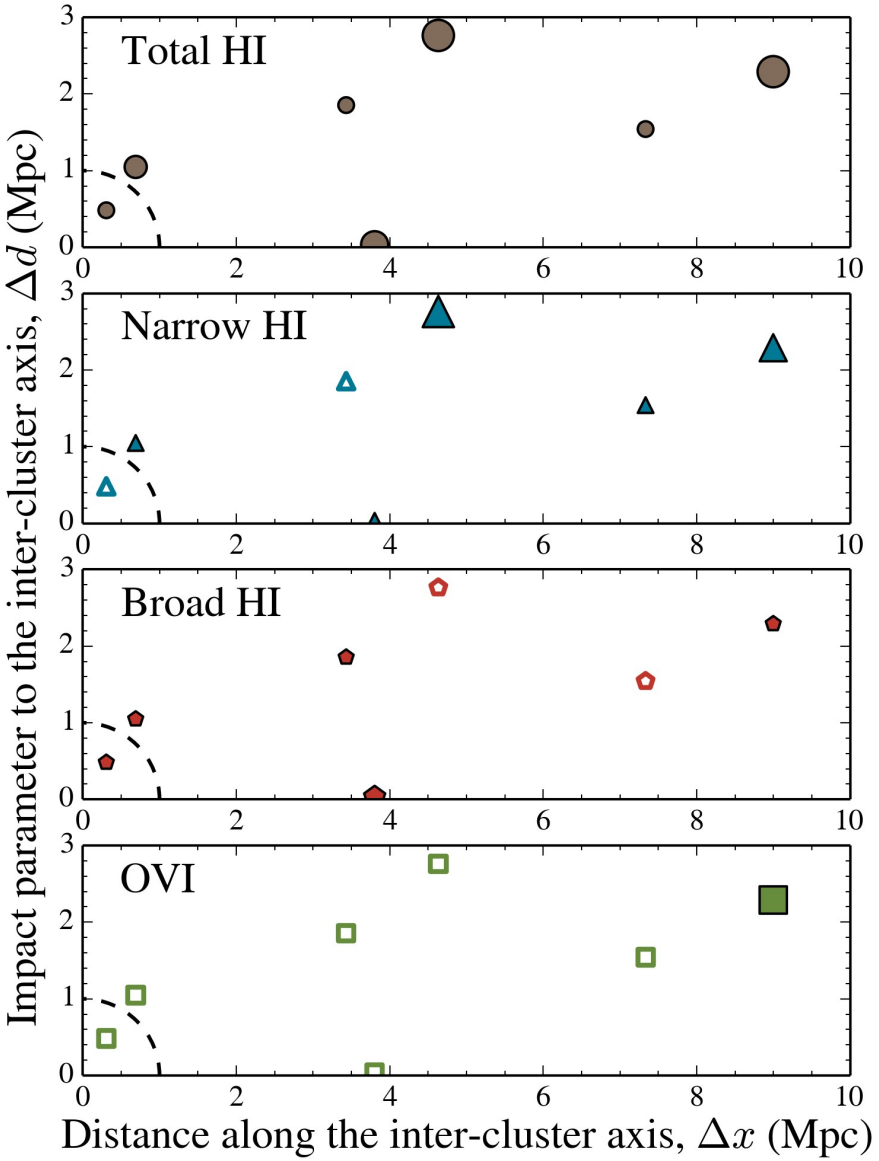




A factor of ~4 excess?

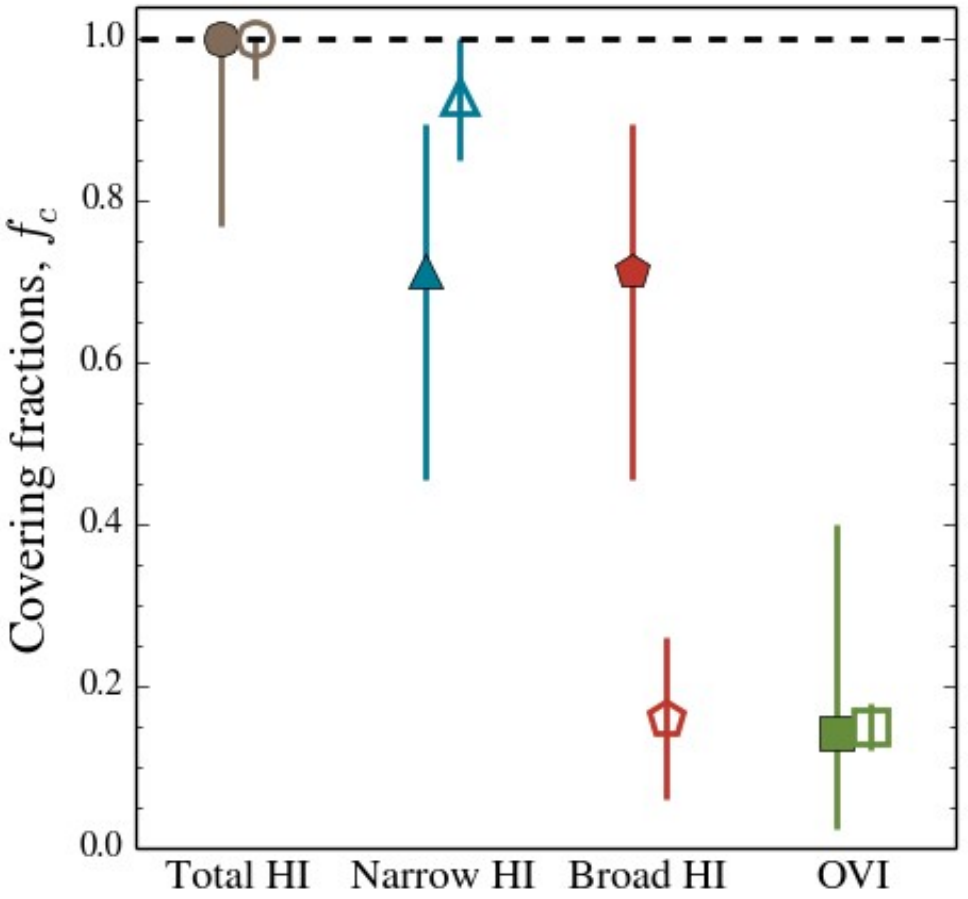
Tejos+15, submitted

Filamentary structure?

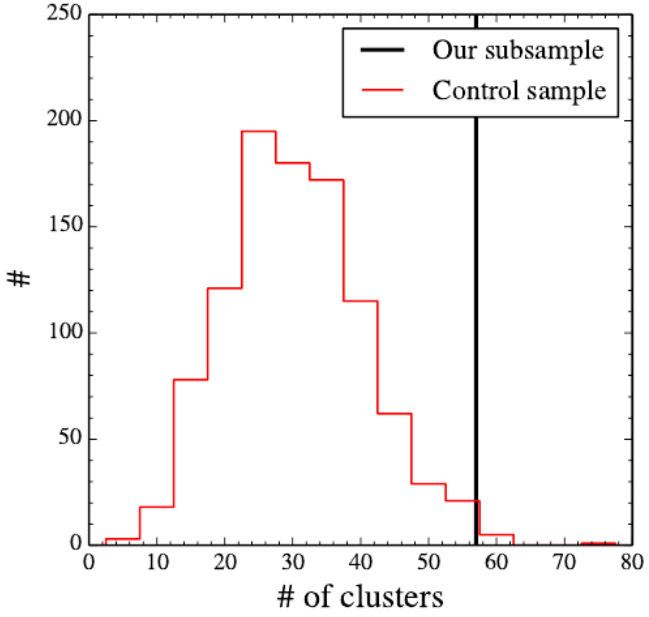


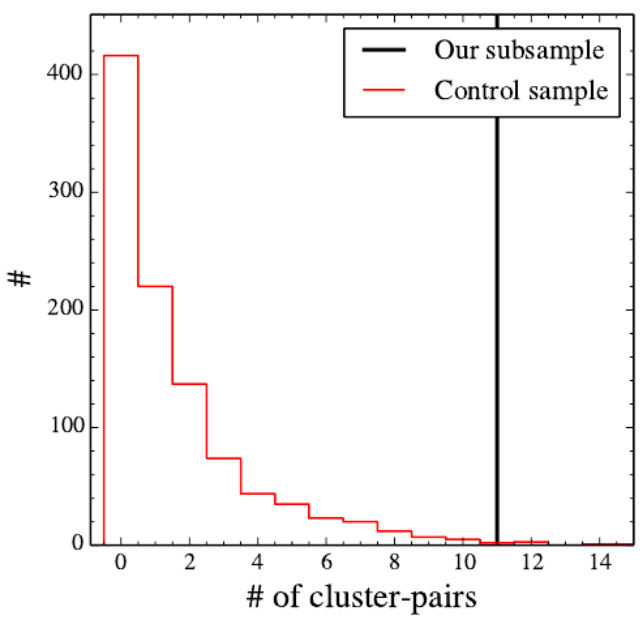
Tejos+15, submitted

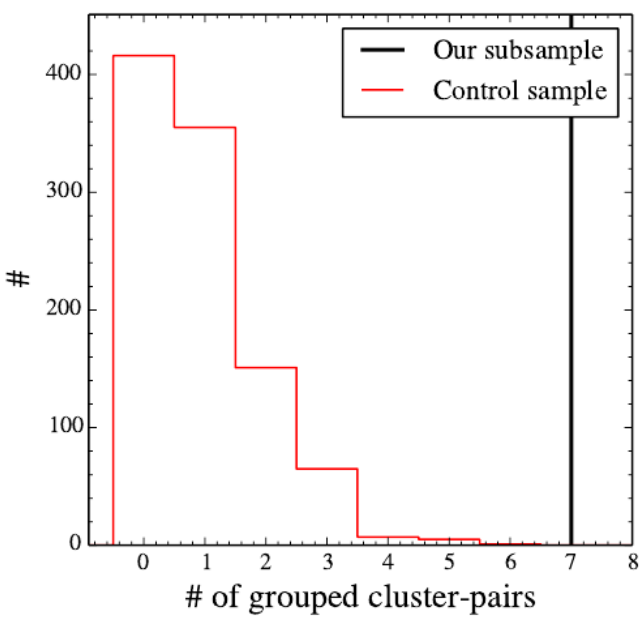
Covering fractions

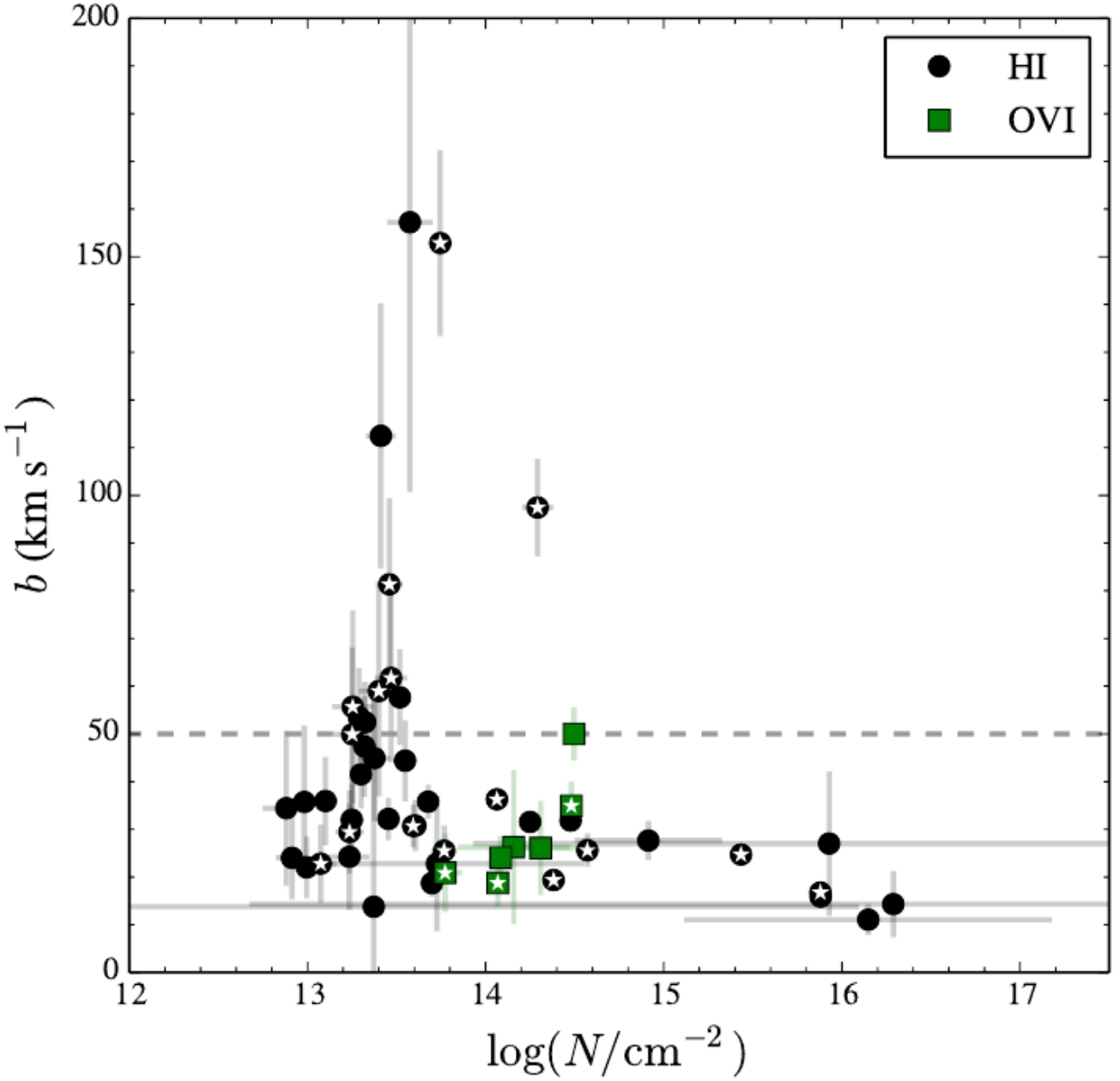


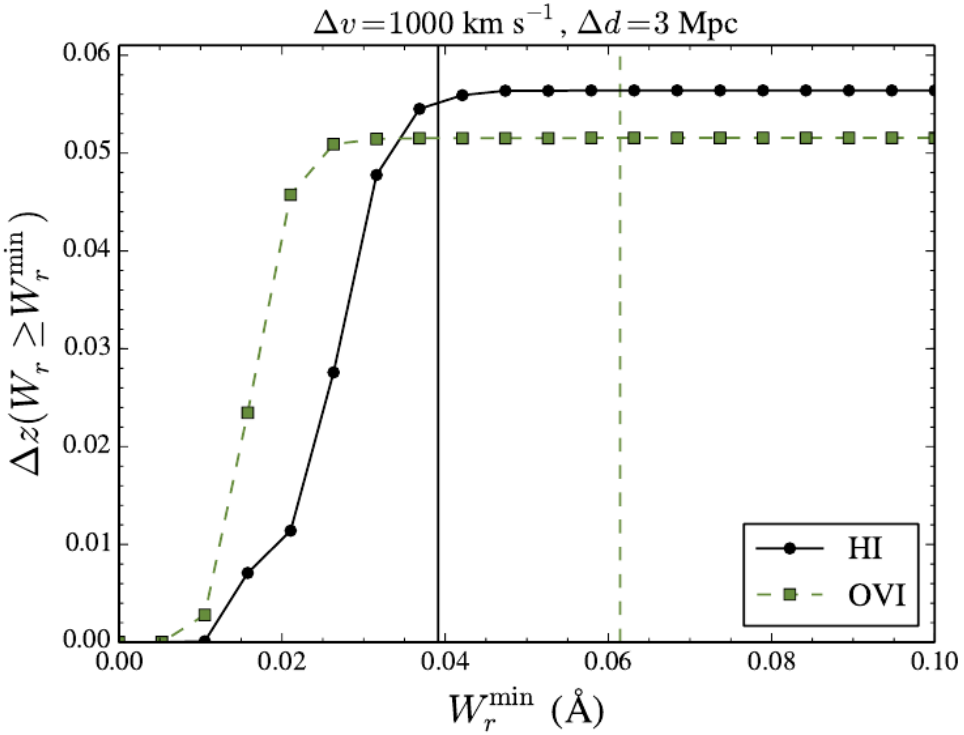
Tejos+15, submitted

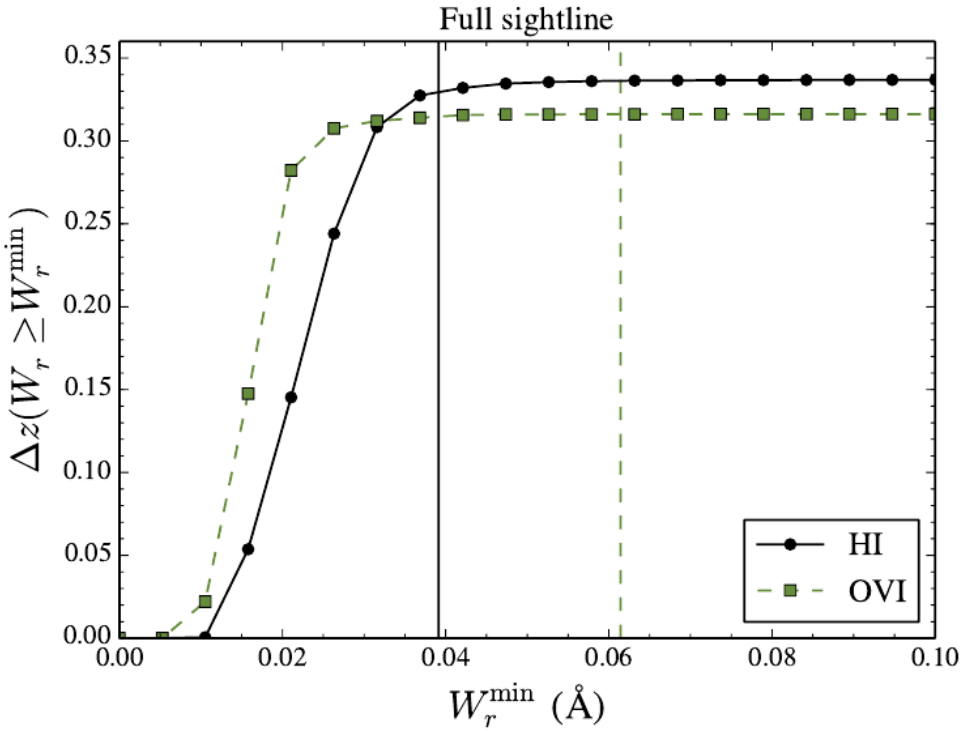

Our subsample
Control sample
#
# of clusters
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80


Our subsample
Control sample
#
# of cluster-pairs
0
100
200
300
400
0
2
4
6
8
10
12
14


Our subsample
Control sample
#
# of grouped cluster-pairs
0
100
200
300
400
0
1
2
3
4
5
6
7
8


HI
OVI
200
150
100
50
0
12
13
14
15
16
17
b (km s^{-1})
log(N/cm^{-2})


$\Delta v = 1000$ km s^{-1}, $\Delta d = 3$ Mpc
$\Delta z(W_r \geq W_r^{\rm min})$
$W_r^{\rm min}$ (Å)
HI
OVI
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.00
0.02
0.04
0.06
0.08
0.10


Full sightline
$\Delta z(W_r \geq W_r^{\rm min})$
$W_r^{\rm min}$ (Å)
HI
OVI
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.00
0.02
0.04
0.06
0.08
0.10