第3回銀河進化研究会: 2016/6/1-3 @東北大学

Cosmic Galaxy-IGM HI Relation at z~2-3 probed in the COSMOS/UltraVISTA

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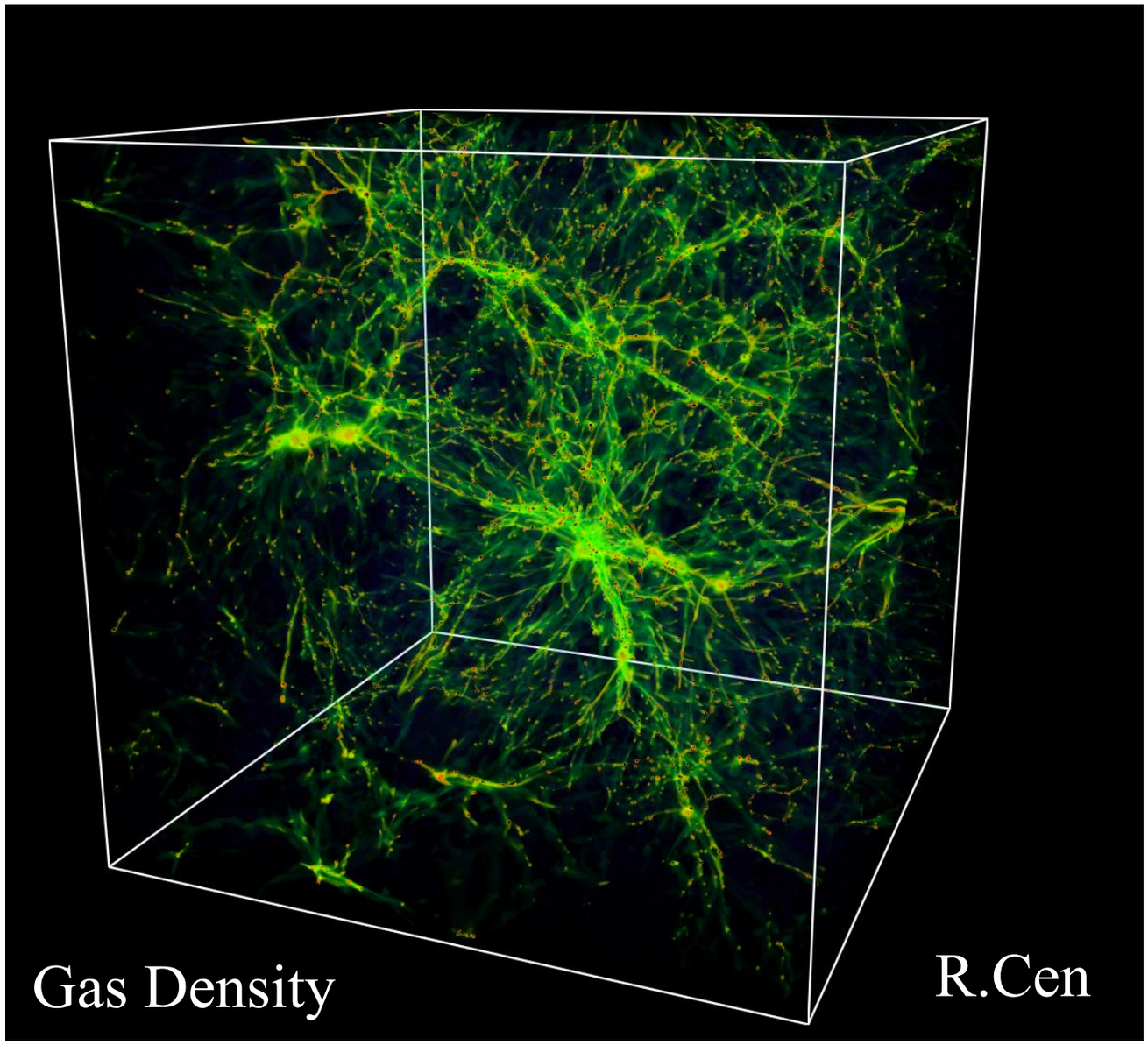
Baryonic processes in the large scale structures

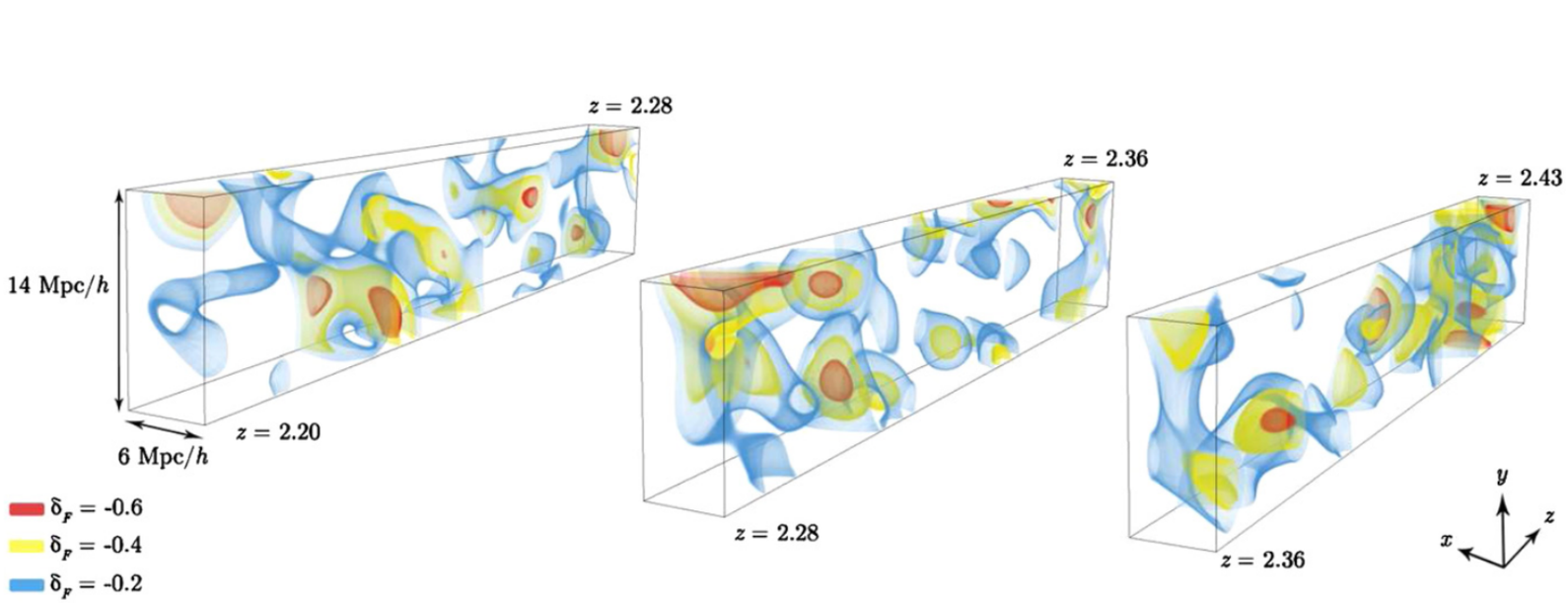
- baryonic processes
  between galaxies and the intergalactic medium (IGM)
  in the large scale structures(LSSs)
  is a clue to understand the galaxy formation



HI is probed with Lyα forest absorptions

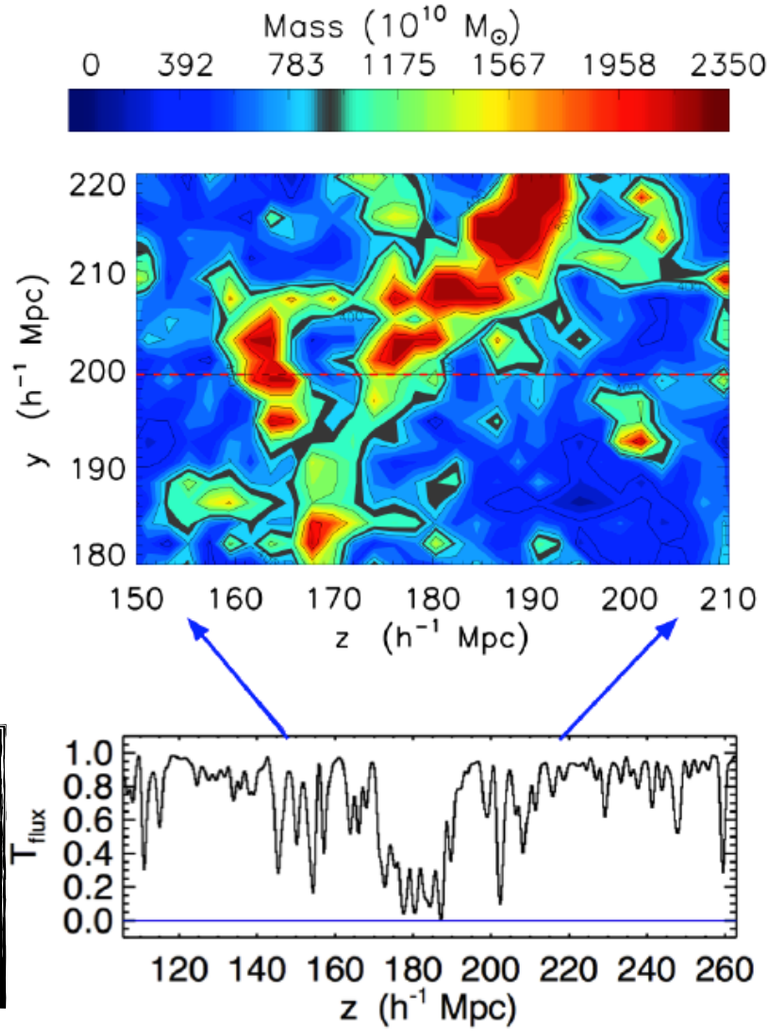
- Neutral hydrogen HI in IGM is probed with Lyα forest absorptions in spectra of background quasars (+bright star-forming galaxies)
- Multiple sightlines provide the spatial distribution of HI gas

  —>Recent active studies illustrate the distribution of HI in LSSs



Lyα forest tomography (KG. Lee+14,+16) —> **KG's talk**

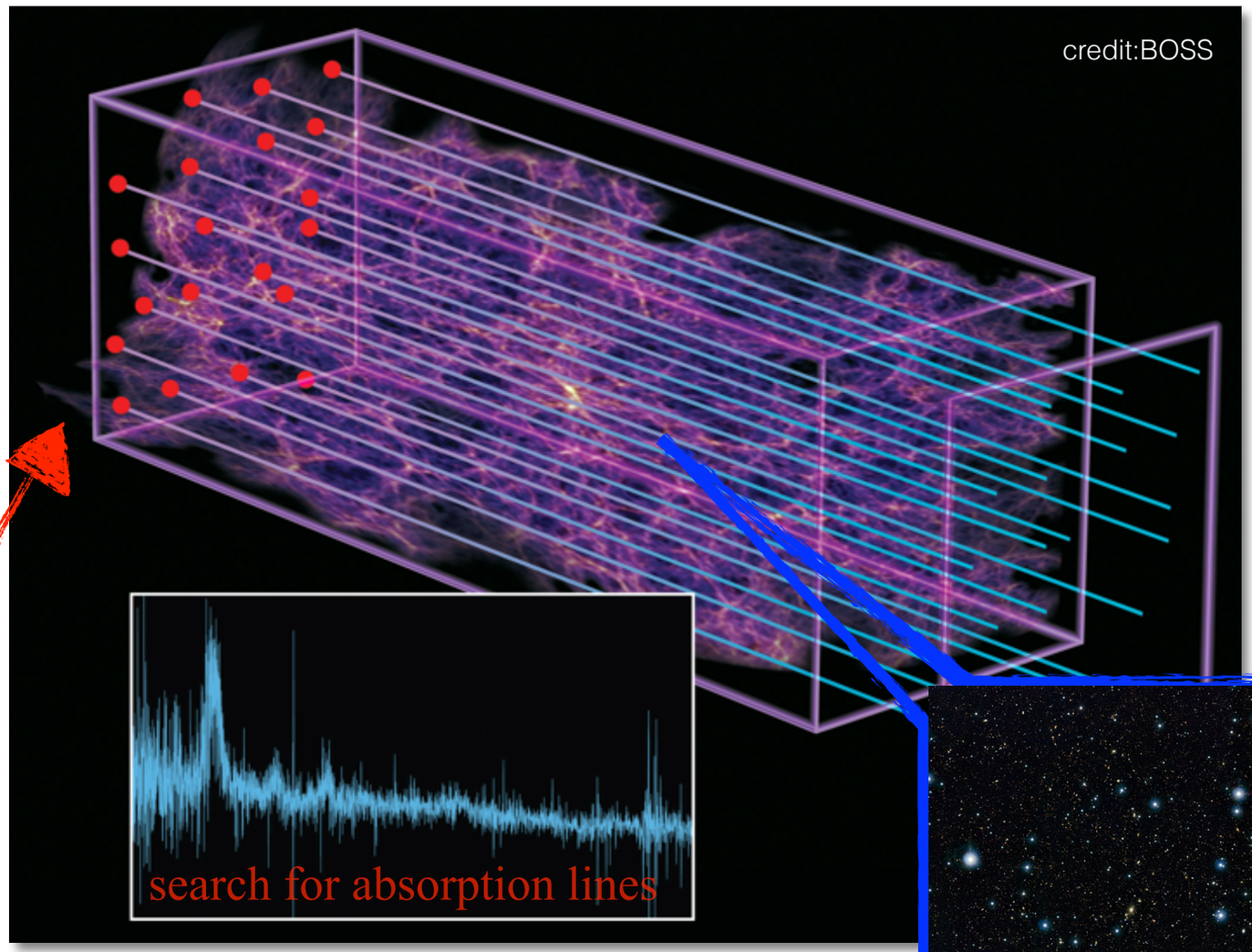
We would like to know;
what is **galaxy-HI relation in large-scale** like?



MAMMOTH (Cai+15)

What is galaxy-HI relation in large-scale like?

- We investigate spatial correlations of galaxies and HI
  in the COSMOS/UltraVISTA field covering the 1.62deg^2
- Compiled photo-z galaxies & Background quasars from SDSS

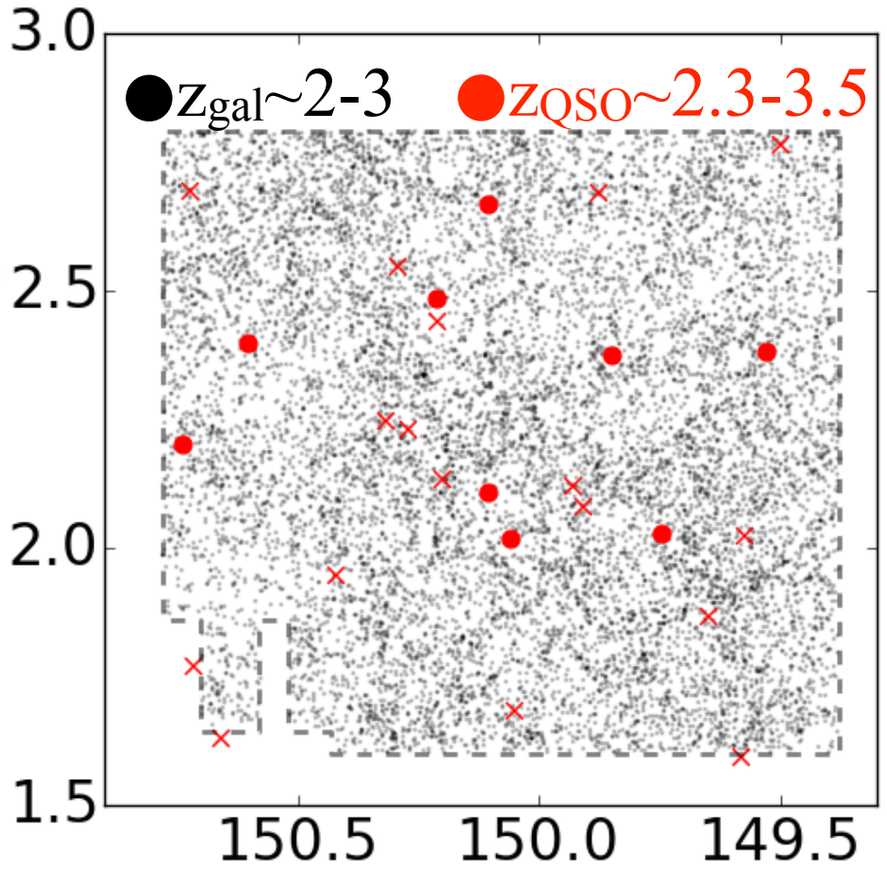


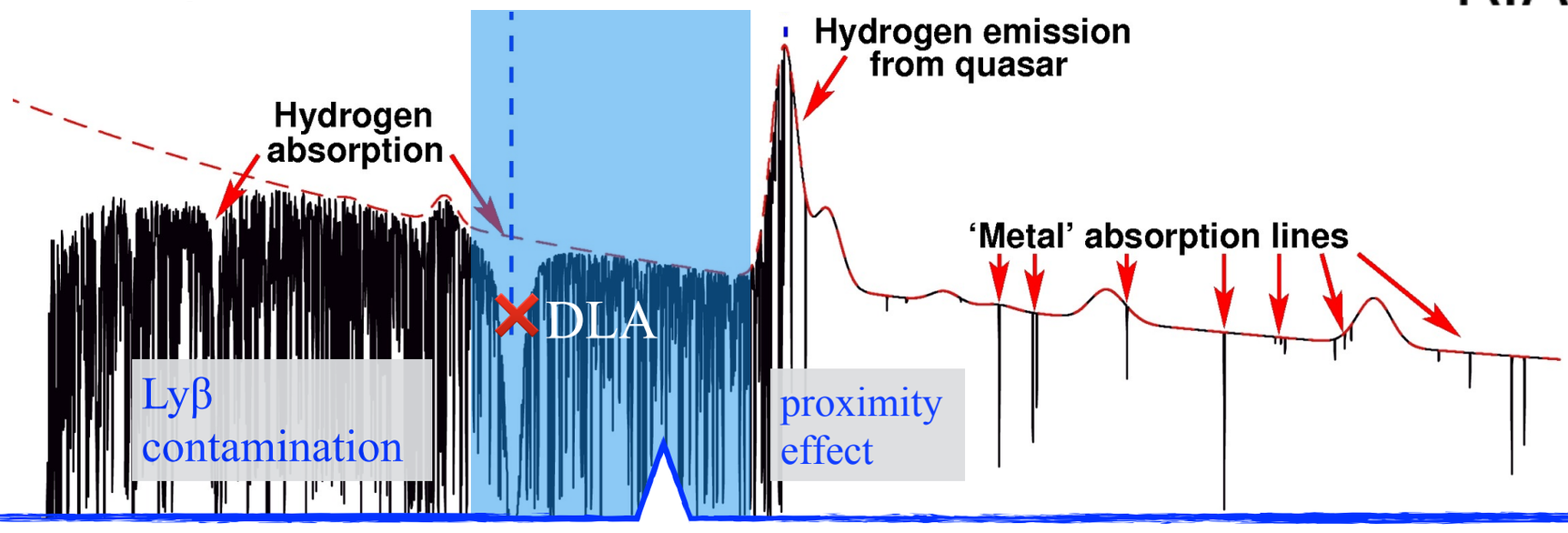
Background QSOs
from the SDSS-III

Data

- COSMOS/UltraVISTA(1.62deg^2)
- 13,415 photo-z galaxies at z~2-3 with Ks < 23.4 (Muzzin+13)
- 9 (out of 26) background quasar spectra from BOSS&SDSS (KG+13, Alam+15)

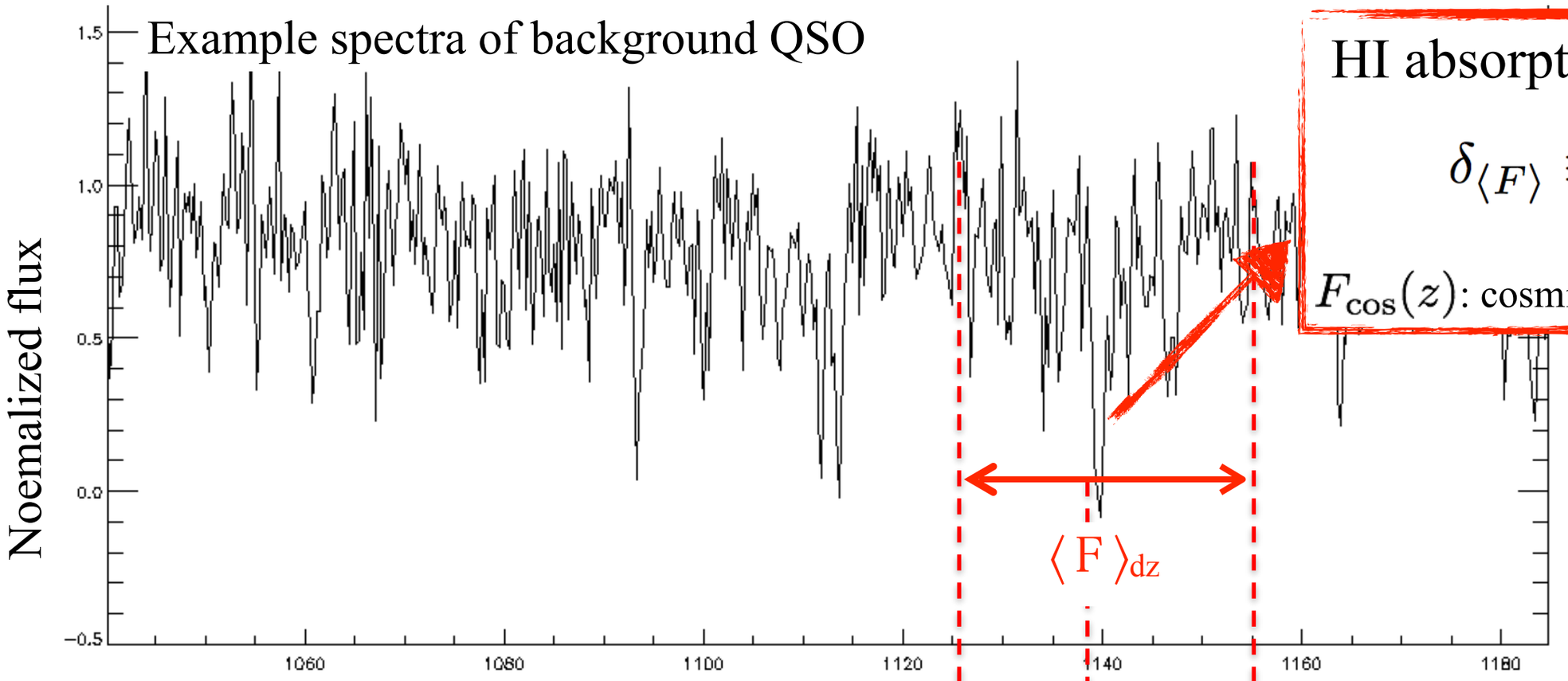
- We do not use spectra with damped Lyα systems(DLAs)
  broad absorption lines(BALs)





Lyα forest wavelength range: 1041-1185 Å in the quasar rest frame

Galaxy and HI Overdensity Estimation



HI absorption Estimation:

$$\delta_{\langle F \rangle} \equiv \frac{\langle F \rangle_{dz}}{F_{\cos}(z)} - 1$$

$F_{\cos}(z)$: cosmic mean flux (FG+08)

: Galaxy

Background QSO

Zabs

r = 5 arcmin
(~2.5 pMpc at z~2.5)

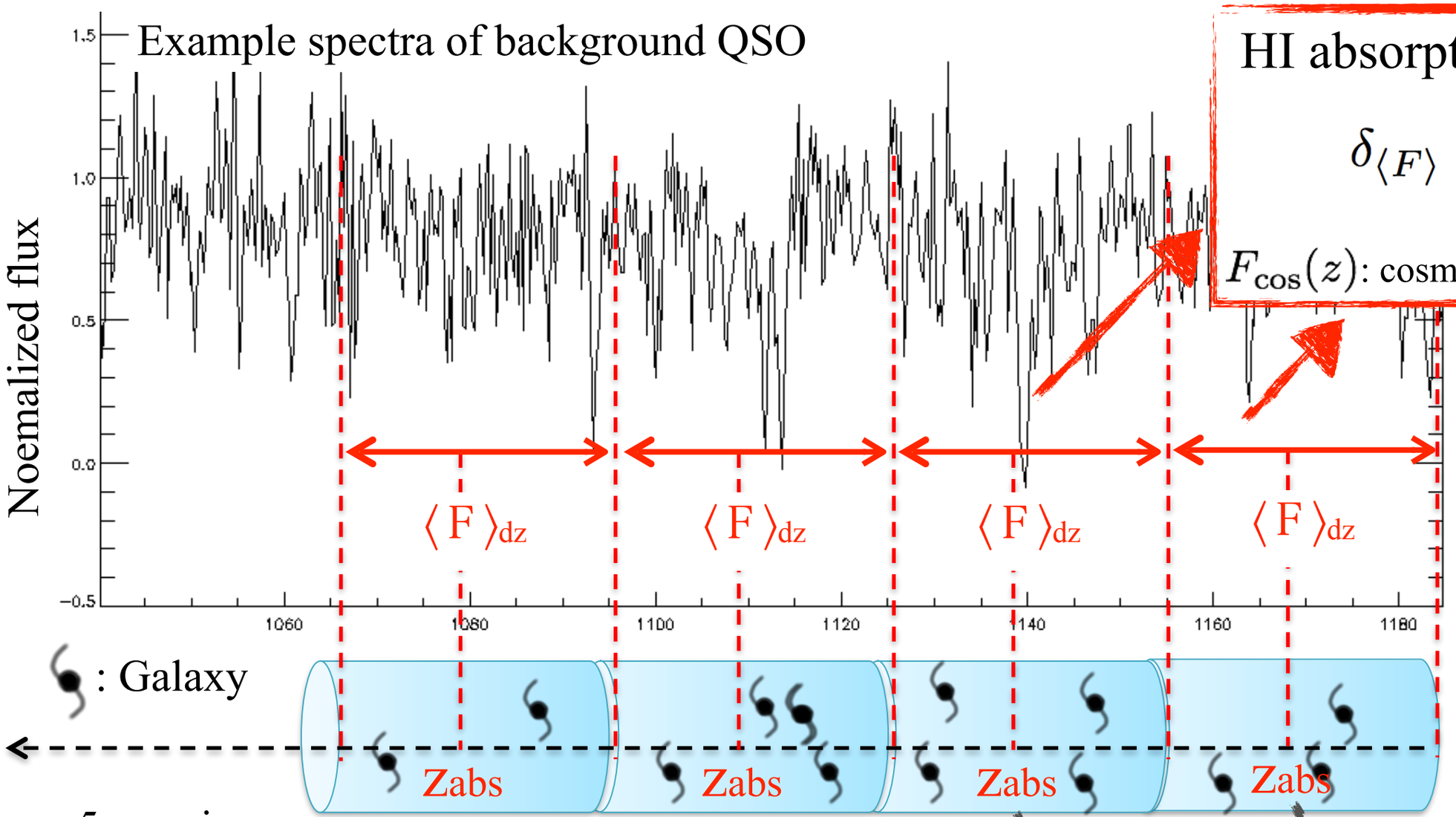
dz = σ_z = 0.025(1+z)

Chiang+14

Galaxy Overdensity Estimation: $\delta_{\rm gal} \equiv \frac{n_{\rm gal}}{\overline{n}_{\rm gal}} - 1$

The height of the cylinder along the line of sight is given by the average photometric redshift uncertainty

Galaxy and HI Overdensity Estimation



HI absorption Estimation:

$$\delta_{\langle F \rangle} \equiv \frac{\langle F \rangle_{dz}}{F_{\cos}(z)} - 1$$

$F_{\cos}(z)$: cosmic mean flux (FG+08)

$\mathrm{S/N}_{\langle F \rangle} \geq 4$

Chiang+14

Galaxy Overdensity Estimation: $\delta_{\mathrm{gal}} \equiv \frac{n_{\mathrm{gal}}}{\overline{n}_{\mathrm{gal}}} - 1$

The height of the cylinder along the line of sight is given by the average photometric redshift uncertainty

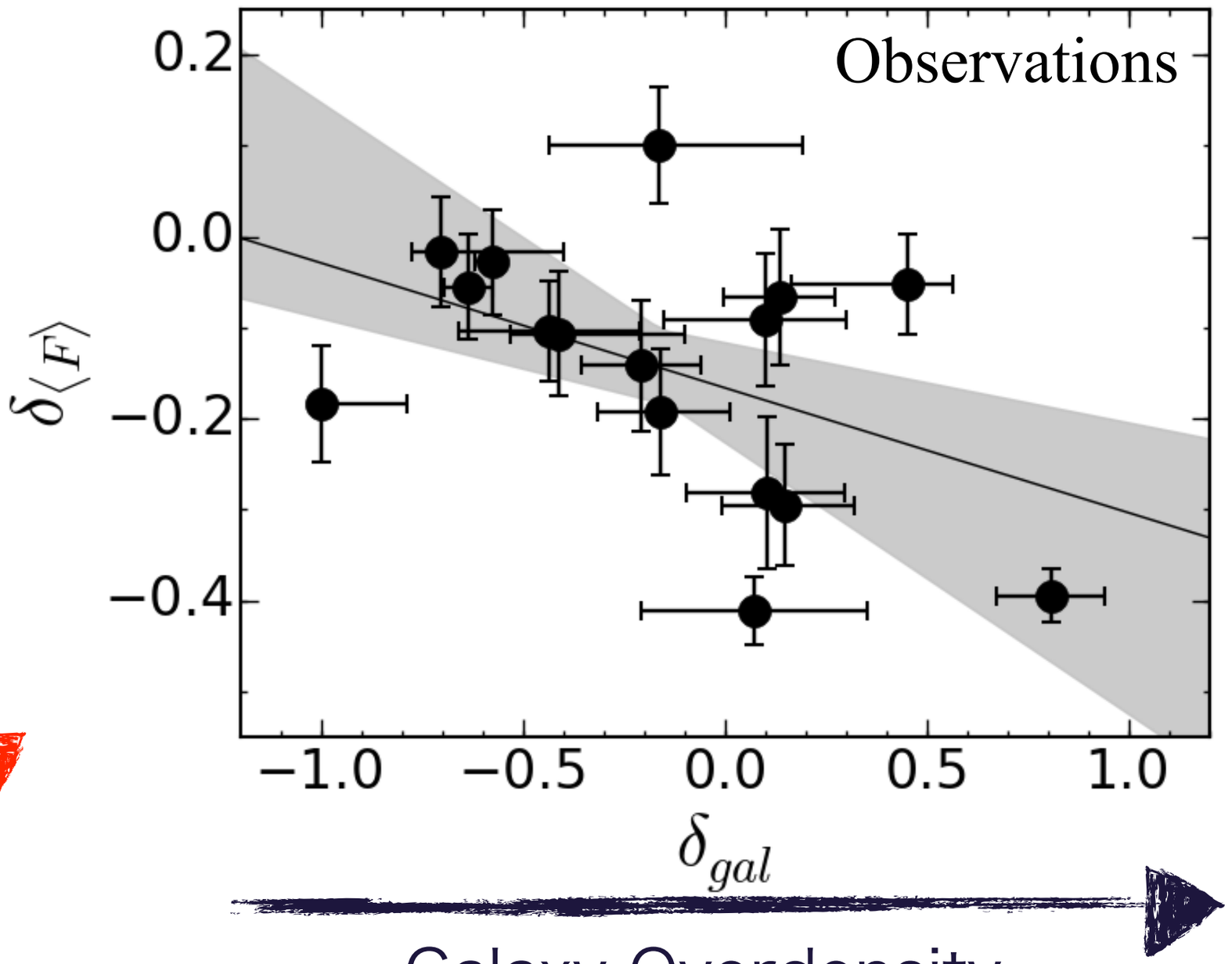
Galaxy-IGM HI Correlation

HI absorption Estimation:

$$\delta_{\langle F \rangle} \equiv \frac{\langle F \rangle_{dz}}{F_{\cos}(z)} - 1$$

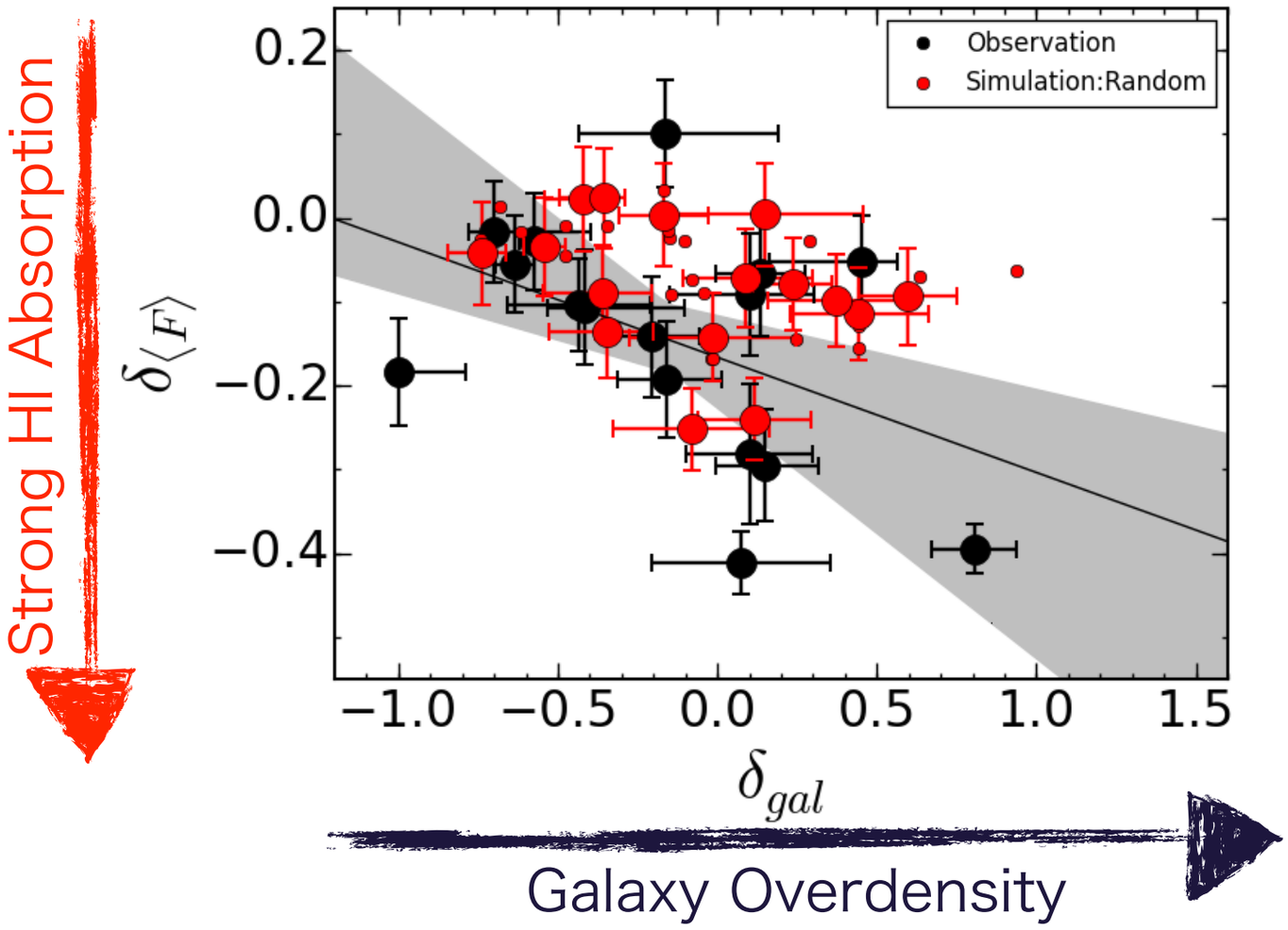
$F_{\cos}(z)$: cosmic mean flux (FG+08)

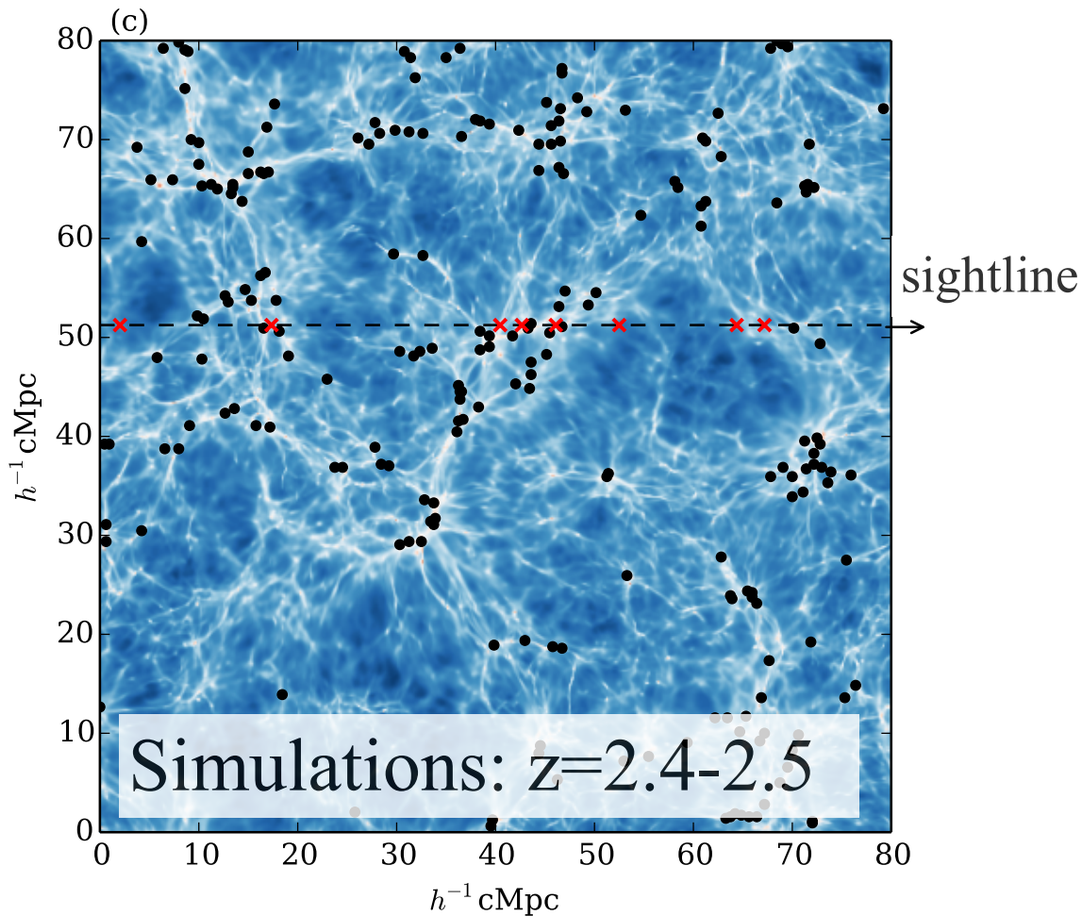
Strong HI Absorption



- a spatial anti-correlation between $\delta_{\rm gal}$ and $\delta_{\langle F \rangle}$
- Spearman's rank correlation coefficients $\rho_{\rm obs}$ = - 0.39 (~90% c.l.)
- high-z galaxies exist around an excess of HI gas in the Lyα forest

Simulated Galaxy-IGM HI Correlation

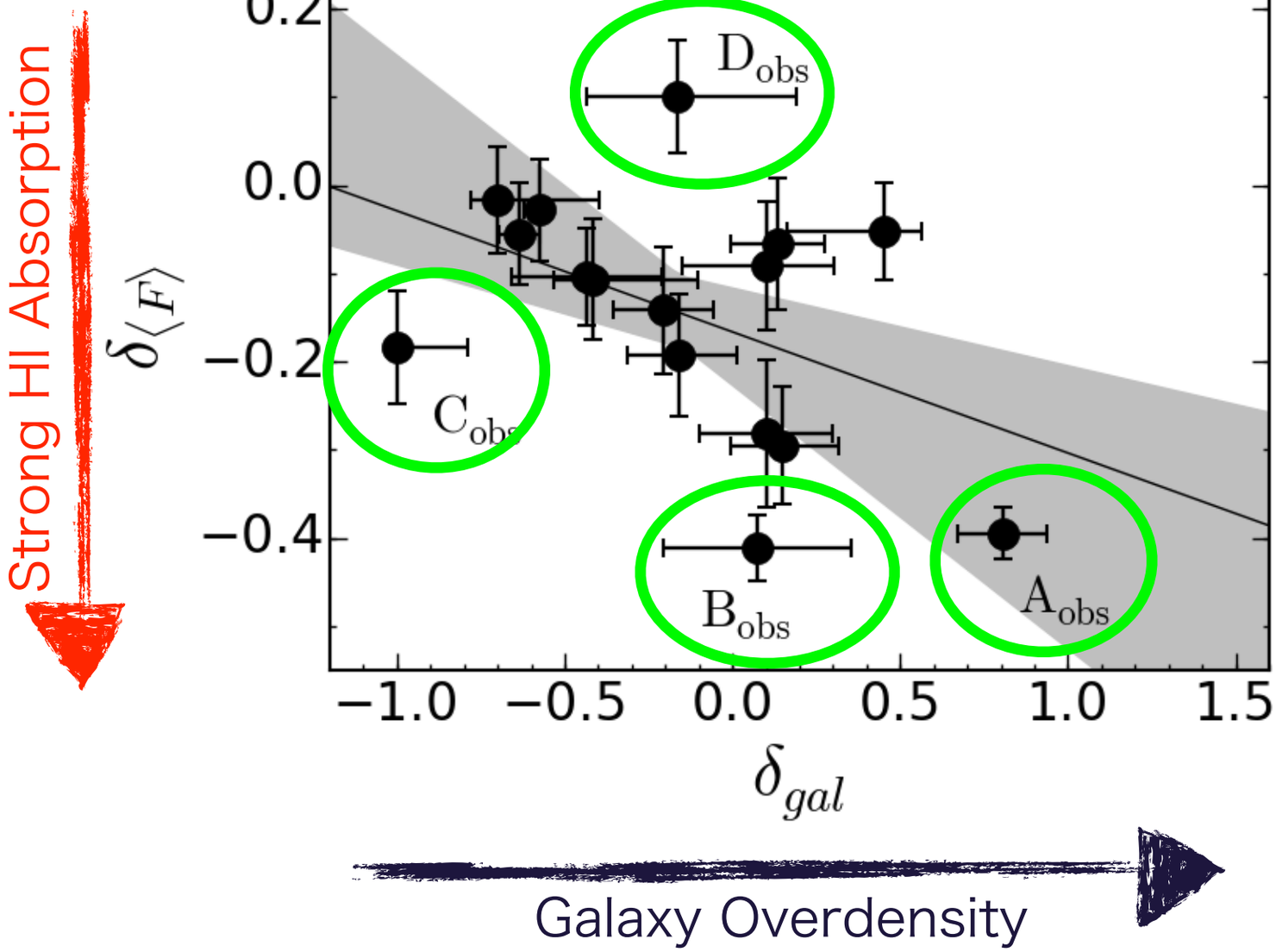




Volume $(80\ h^{-1}\mathrm{cMpc})^3$ 512^3cells
DM halo—> mock galaxy:
Abundance Matching & SHMR
Lyα transmitted flux: FGPA

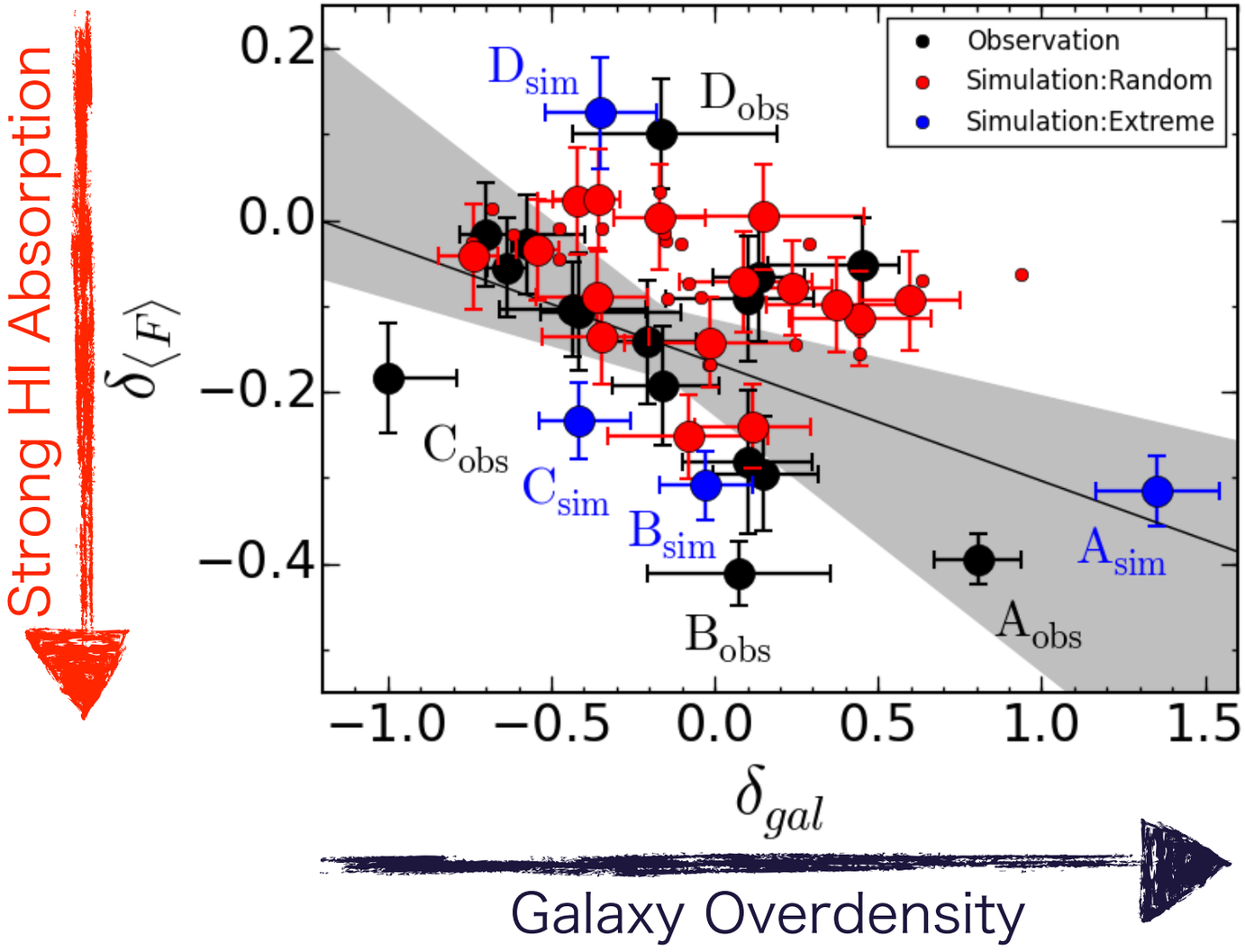
- Cosmological hydrodynamical simulation with the RAMSES code
- a weak anti-correlation agreeing with the observational results

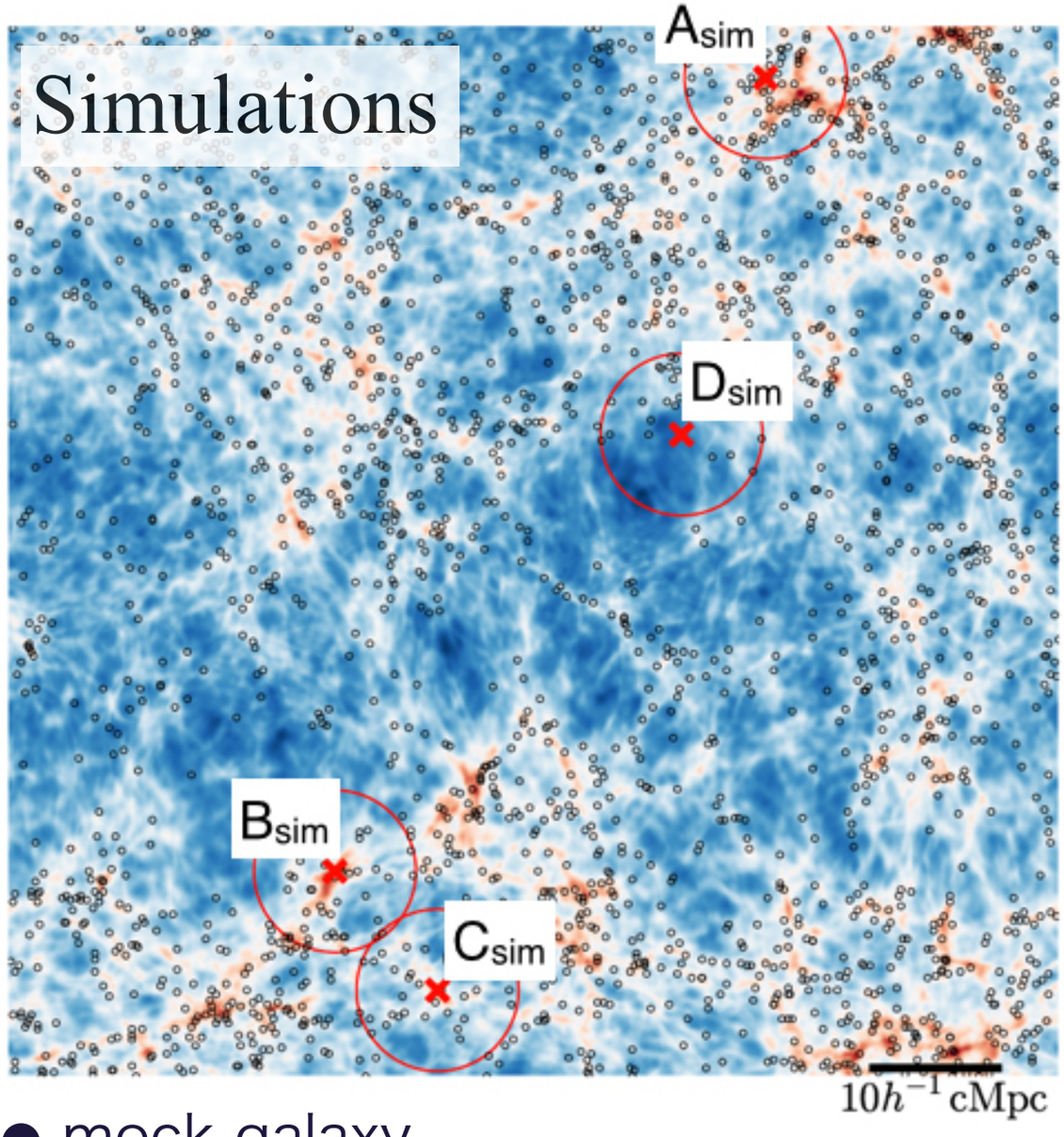
Simulated Galaxy-IGM HI Correlation



- We find 4 cosmic volumes that have extremely large(small) values

Simulated Galaxy-IGM HI Correlation





● mock galaxy

Background color: projected $\delta_{\langle F \rangle}$

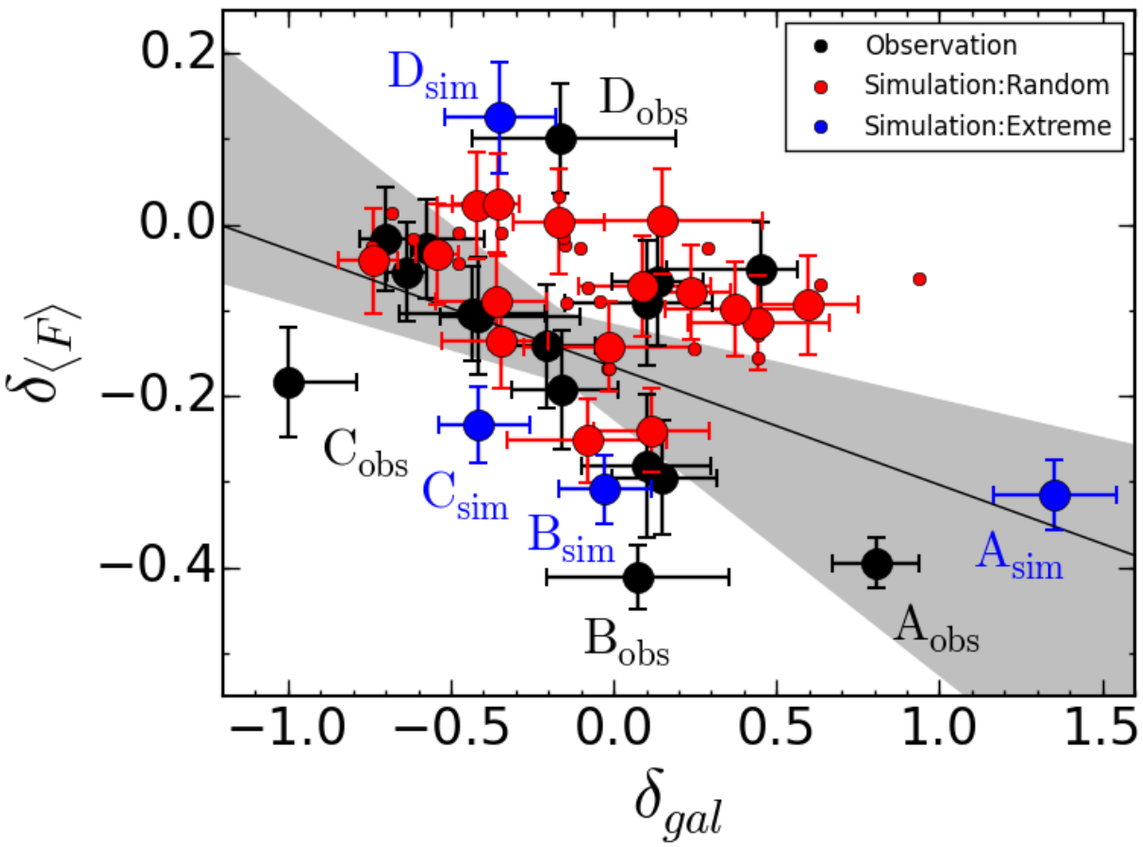
- We use the simulations and search for cylinders whose δ_{gal} - $\delta_{\langle F \rangle}$ value are similar to the 4 cylinders from observation results

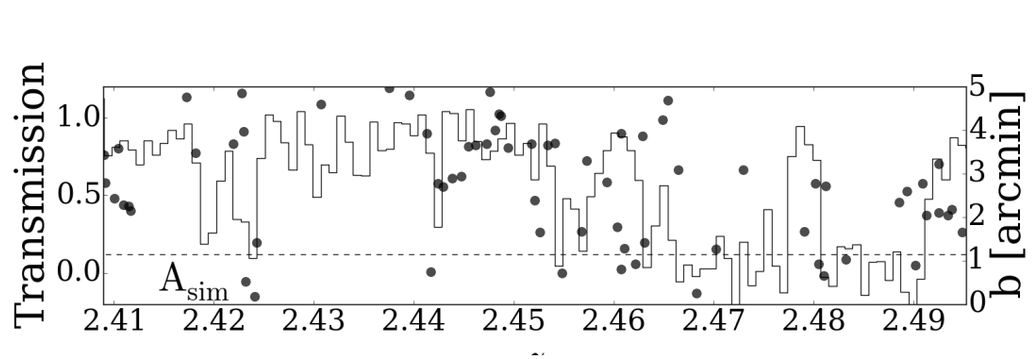
Four Cylinders with an extreme value: Physical origin?

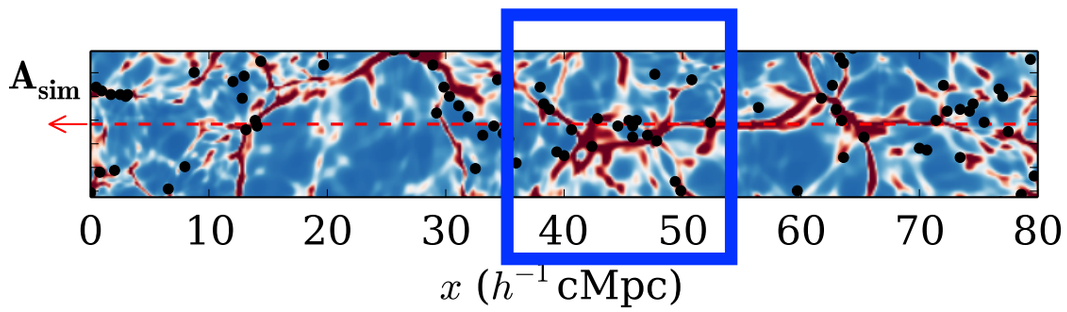
Cylinder A:

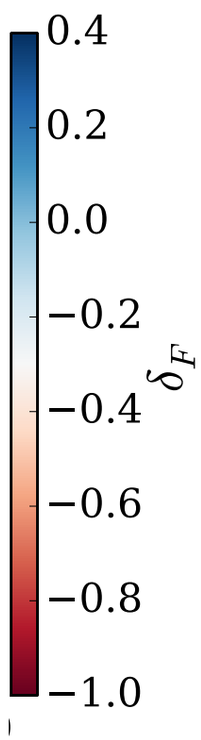
A_{obs} coincides with one of the proto-cluster candidates (Chiang+14)

a large galaxy overdensity is associated with the large amount of HI gas









A_{sim} penetrates
a galaxy overdensity

Four Cylinders with an extreme value: Physical origin?

Cylinder A:

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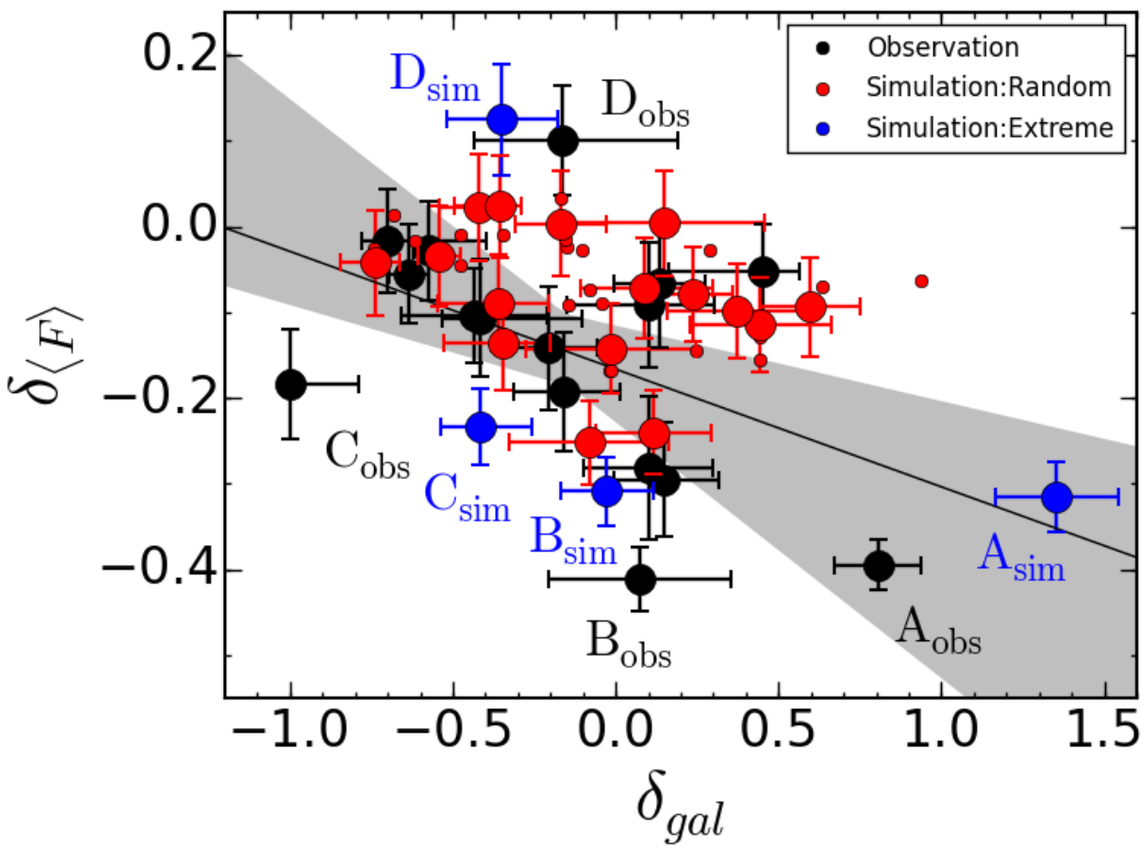
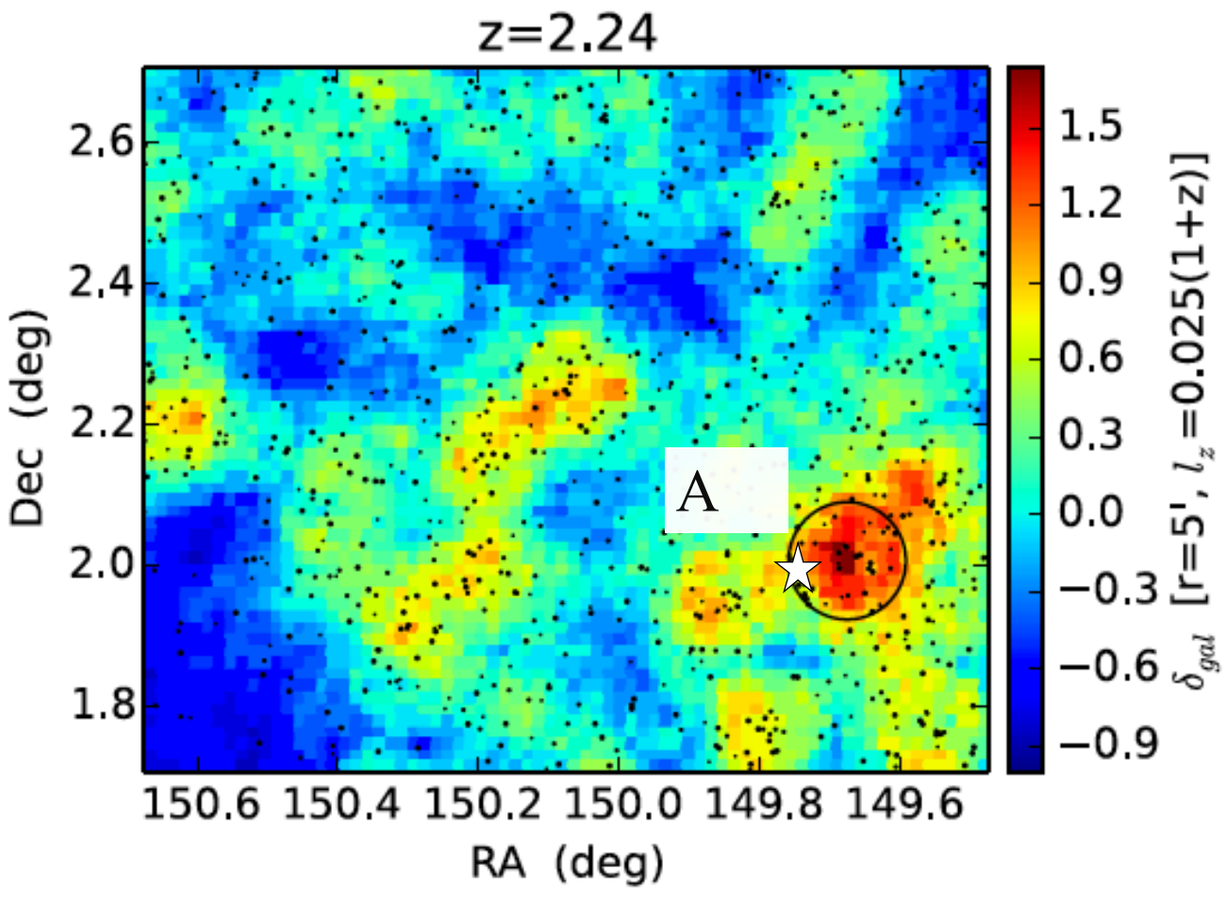




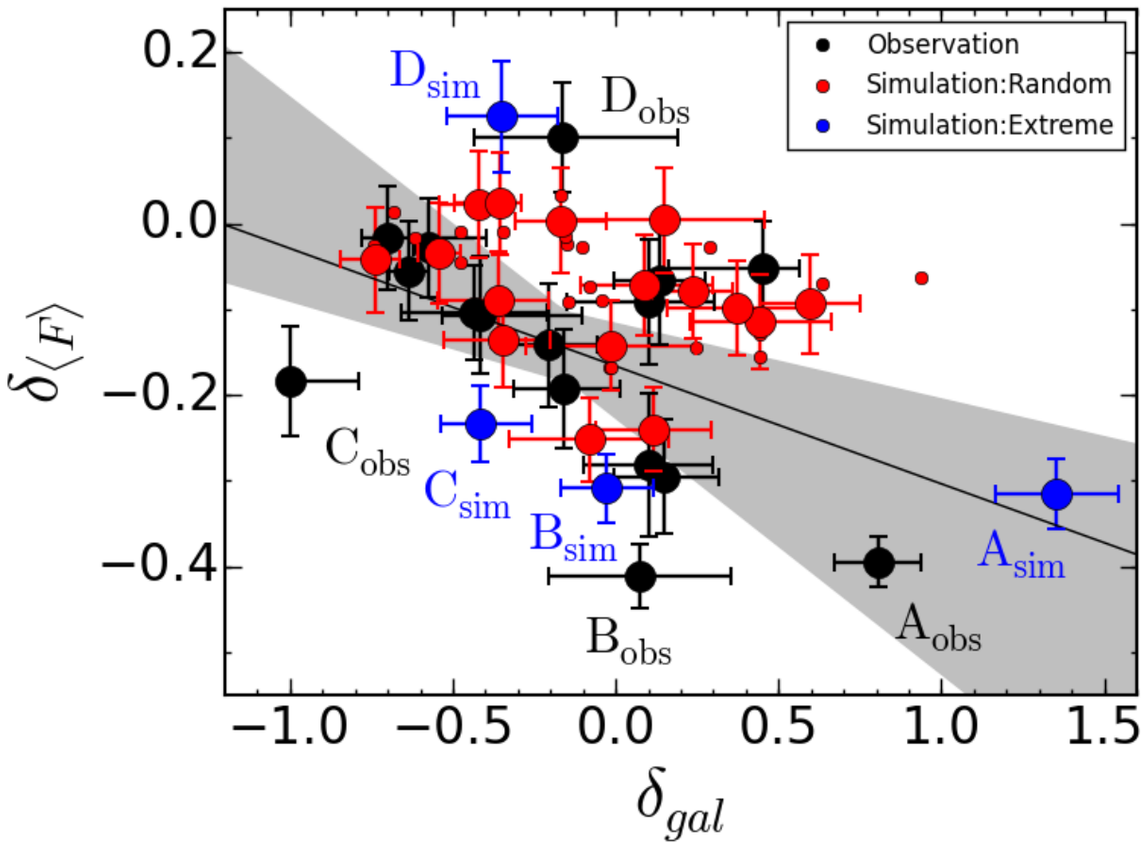
δ_{gal} map investigated by photo-z (Chiang+14)

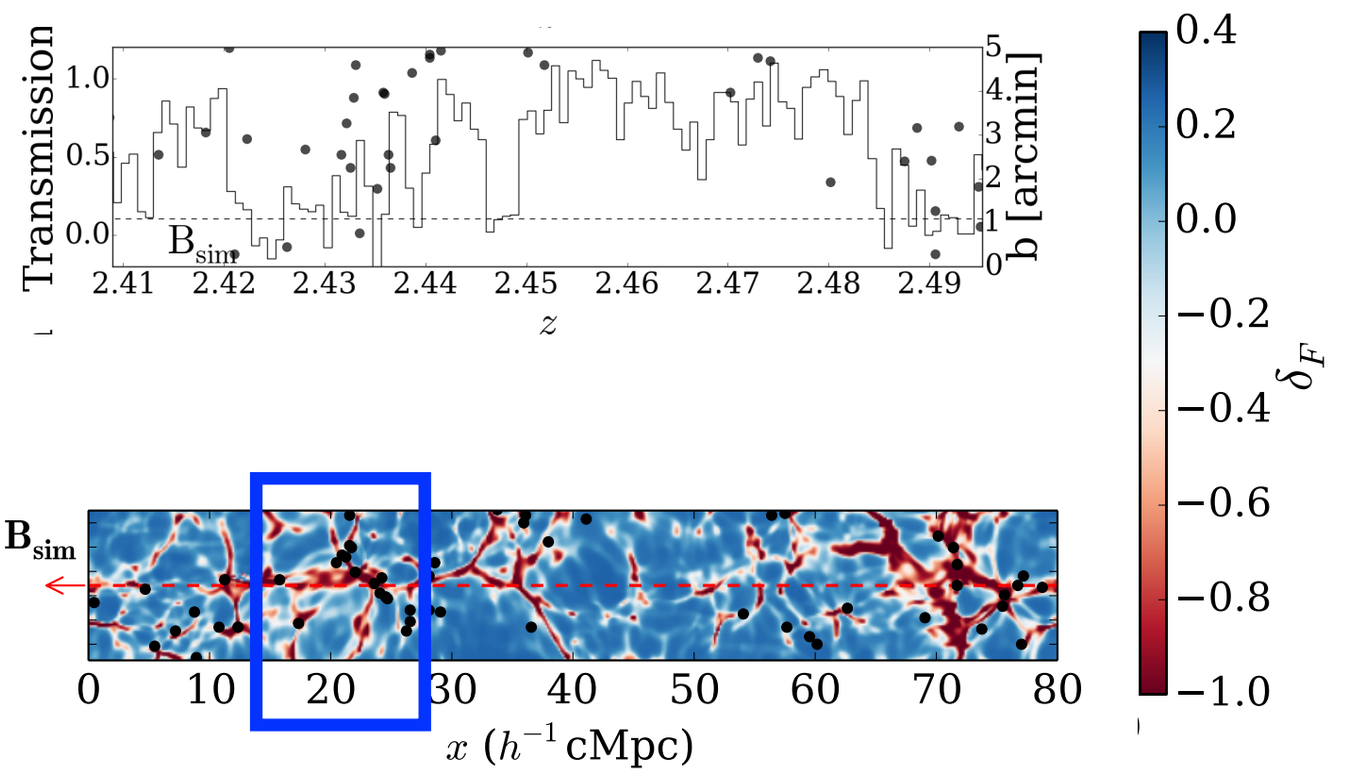
Four Cylinders with an extreme value: Physical origin?

Cylinder B:

B_{sim} goes through gas filaments

B_{obs} would penetrate gas filaments with moderate number of galaxies





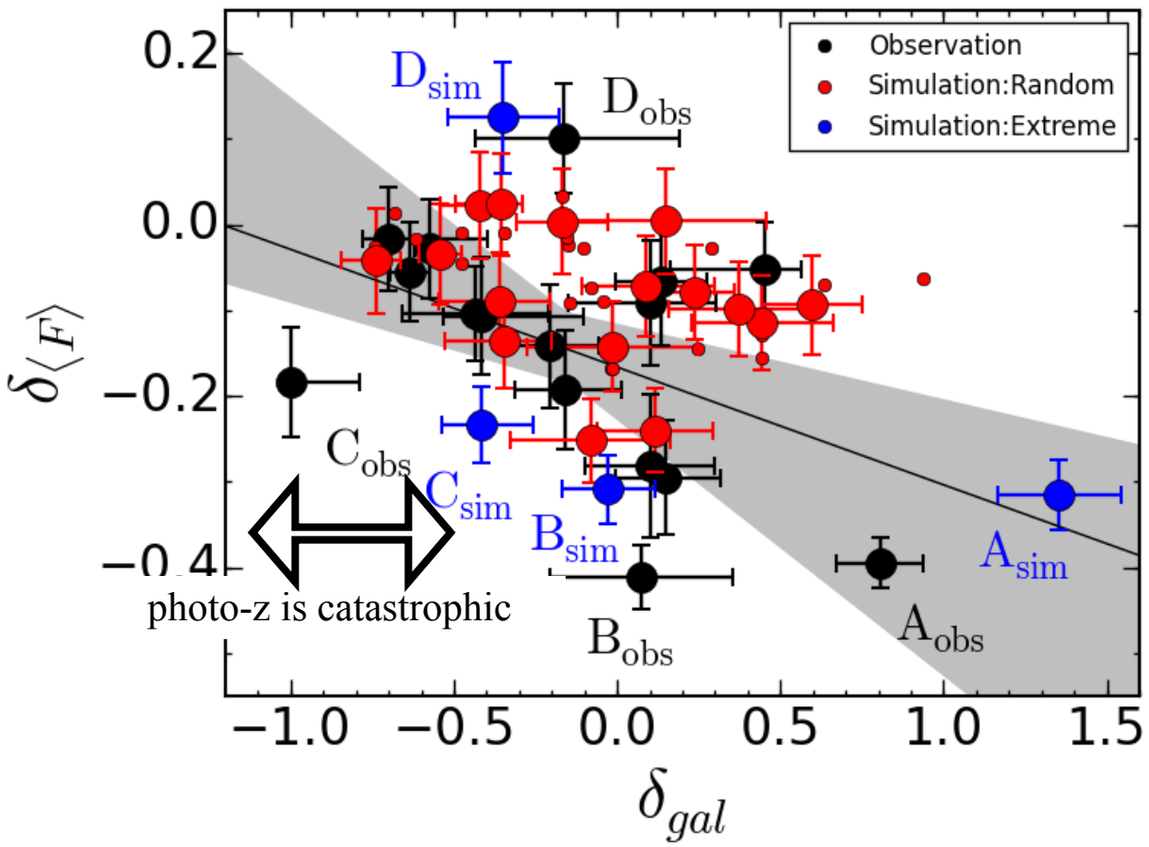
B_{sim} penetrates gas filaments

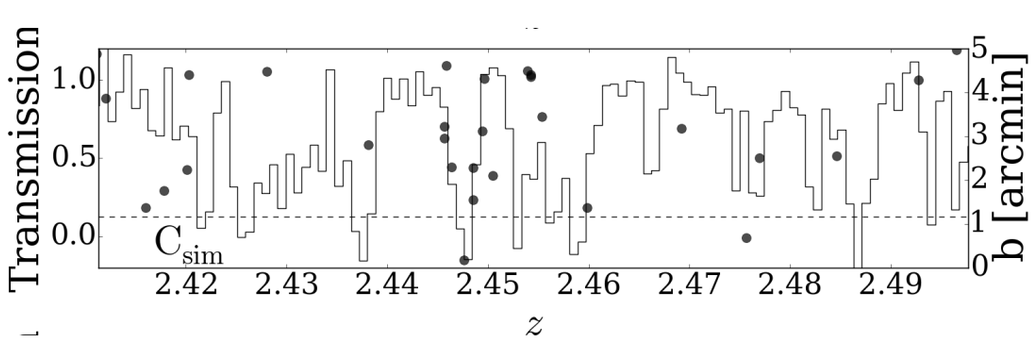
Four Cylinders with an extreme value: Physical origin?

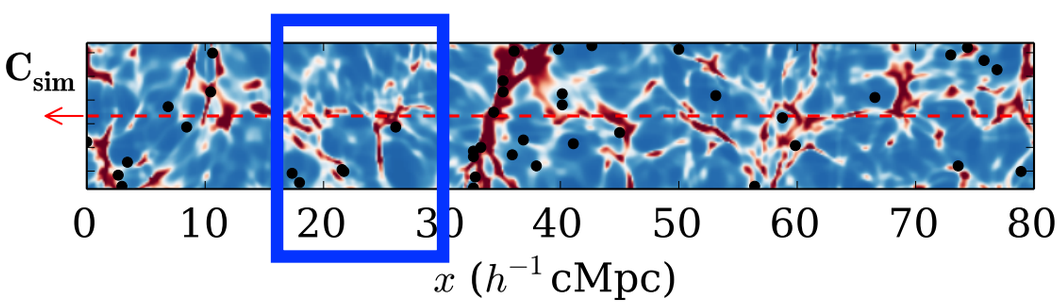
Cylinder C:

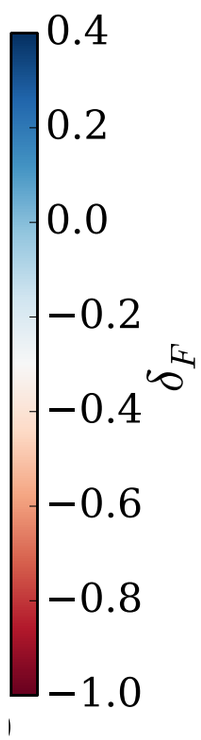
Csim penetrates a large void of LSSs and goes across a gas filament

Cobs would penetrate large void and go across a gas filament









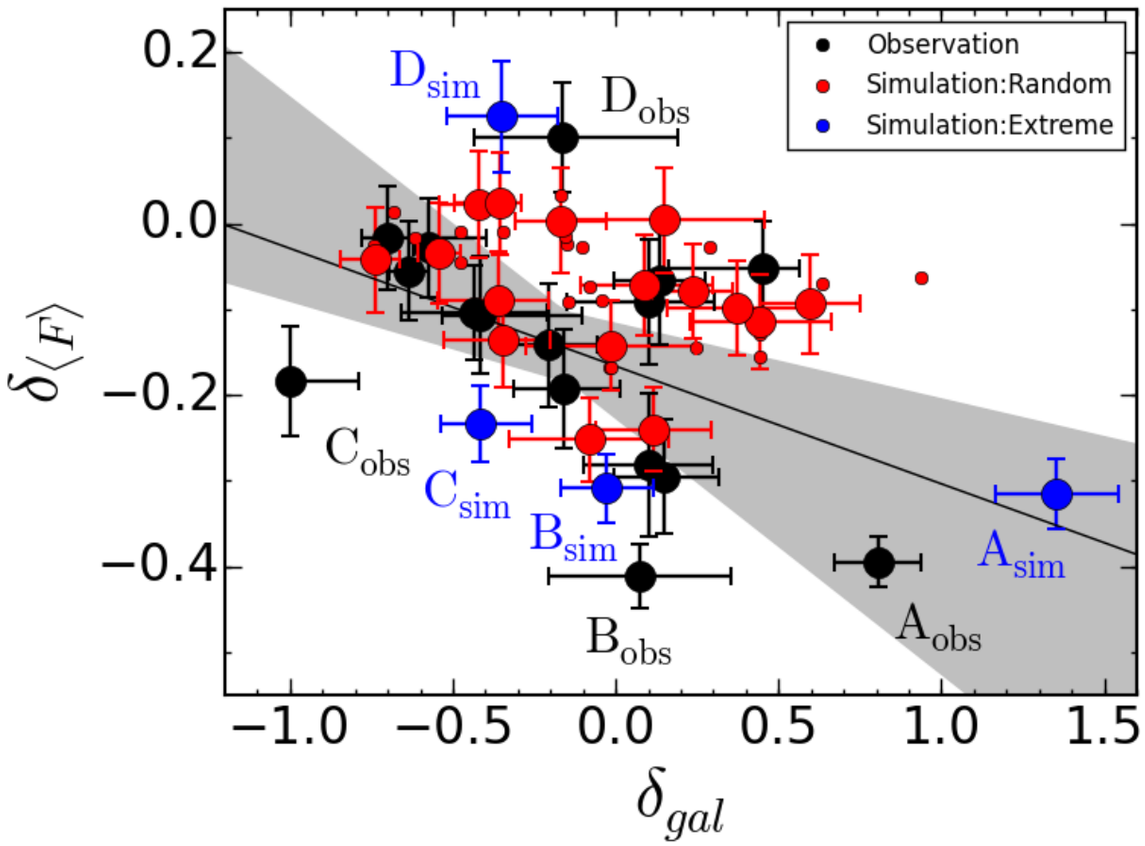
C_{sim} penetrates
a large void of LSSs
and goes across gas filaments

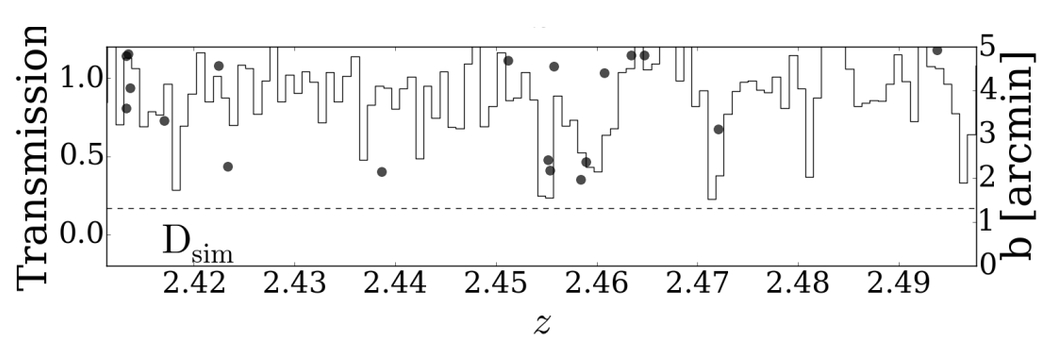
Four Cylinders with an extreme value: Physical origin?

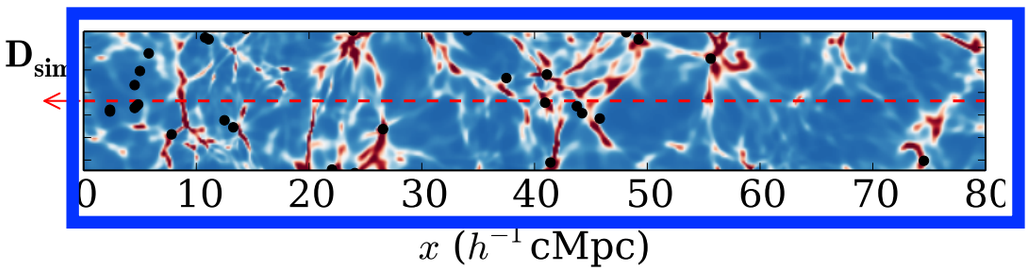
Cylinder D:

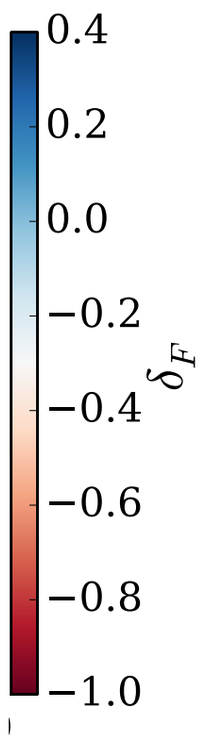
D_{sim} penetrates low density filaments

D_{obs} would through the orthogonal low-density filaments



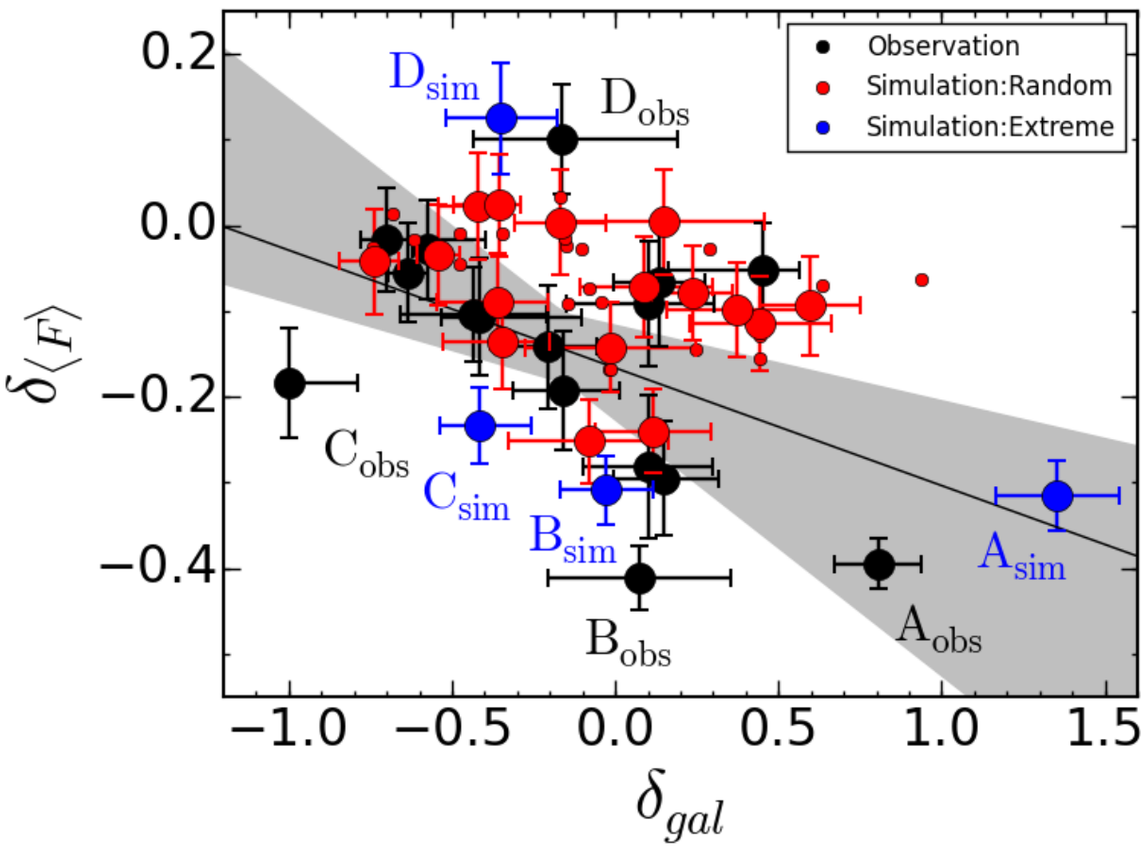




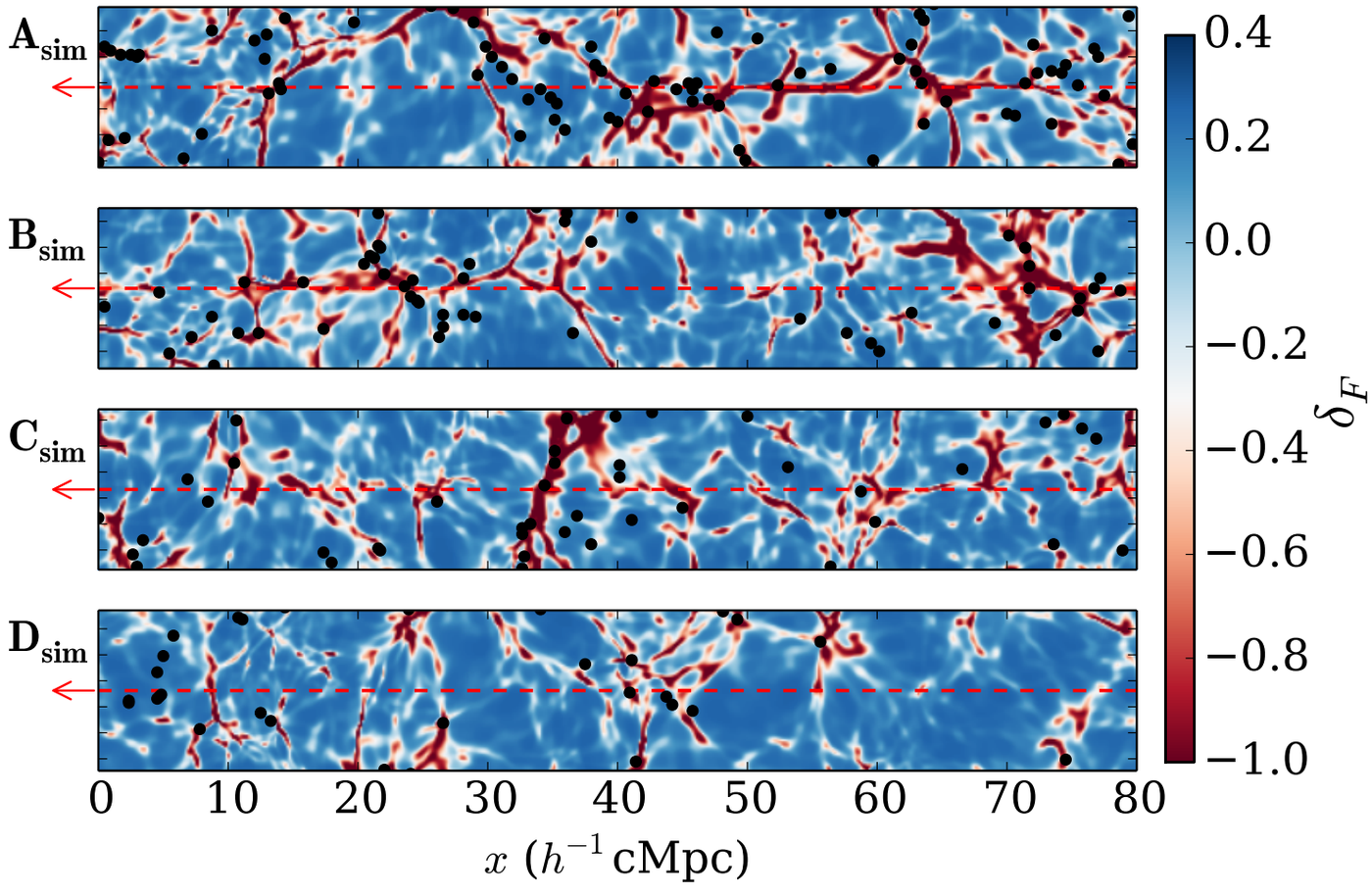


D_{sim} penetrates
orthogonal low density filaments

Possible physical pictures



filamentary large-scale structures



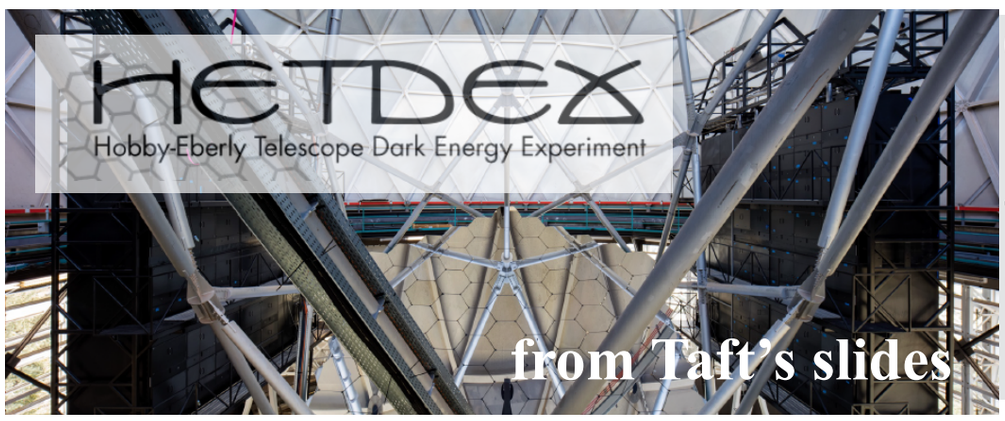
- simulations suggest that the observations would penetrate...
  a galaxy overdensity like a proto-cluster, gas filaments, a large void, and orthogonal low-density filaments
- filamentary large-scale structures and observations sightline effects

Summary

We investigate spatial correlations of galaxies and IGM HI
in the COSMOS/UltraVISTA 1.62 deg^2 field at z~2-3

1. an weak anti-correlation between δ_{gal} and $\delta_{\langle F \rangle}$
   confirmed by both observation and simulations

2. 4 cosmic volumes that have extremely large(small) values:
   sightlines would penetrate a galaxy overdensity
   /filaments/a large void/orthogonal low-density filaments



Ongoing Work:

HETDEX(Hobby Eberly Telescope Dark Energy Experiment)
434deg^2, z=1.9-3.5, 0.8M LAEs

“Correlation studies of z~2-3 LAEs and HI/metal absorbers“
(Mukae, Ouchi, Schulze, HETDEX Collaboration)