Cluster Environment Effects on Cluster Mass Observables

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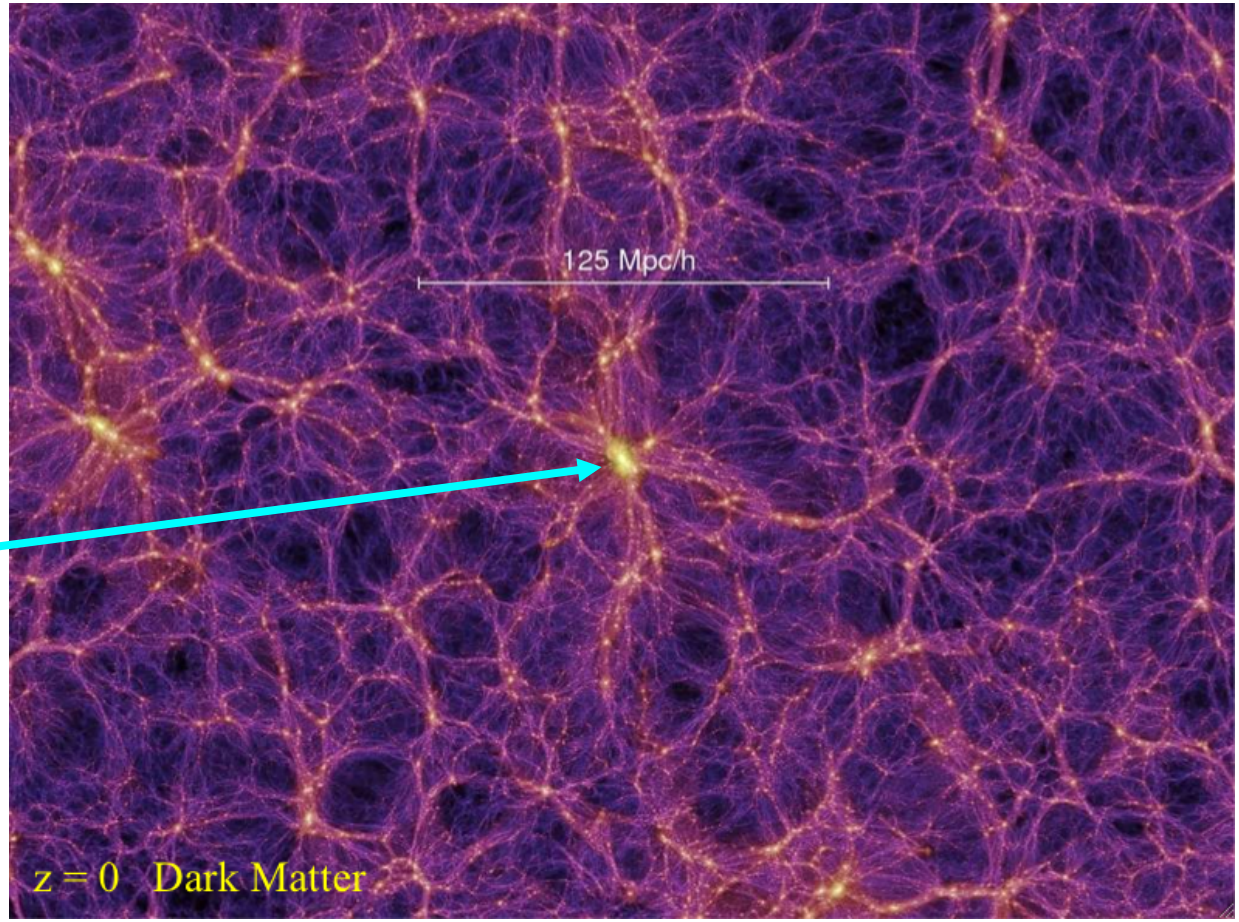
arXiv:1005:3022,1011:1000
MNRAS and MNRAS to appear

Clusters are special components in the cosmic web of large scale structure:

"the largest virialized objects in the universe"

cluster



Millennium dark matter simulation (Springel++,Lemson++) with a massive halo (=cluster) at the center.

Many reasons to be interested in clusters:

1. Constraining cosmological parameters:

   Methods include using counts, clustering, fair sample of universe, gas fraction evolution, strong lensing arcs to get constraints

2. Understanding cluster formation/astrophysics:

   Deep potential wells where new phenomena occur

3. Galaxy formation:

   Clusters host the most luminous galaxies in universe and and transform others within it.

For all of these: cluster ***mass*** is important property

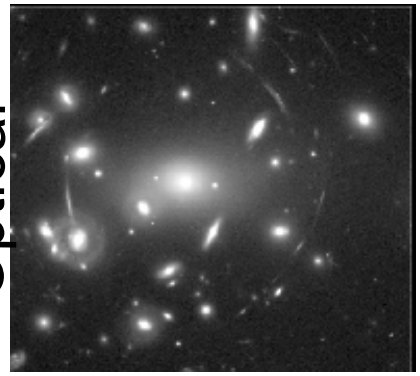
Theory mass:

Separate cluster from web using full 3d info:

Mass = mass in simulation

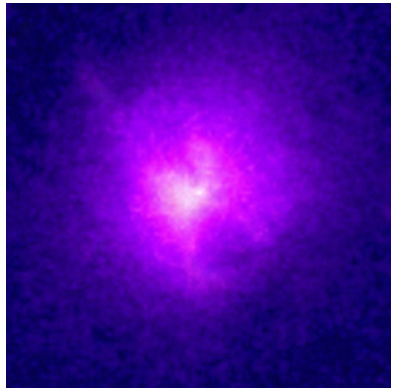
Observational masses:*

Optical



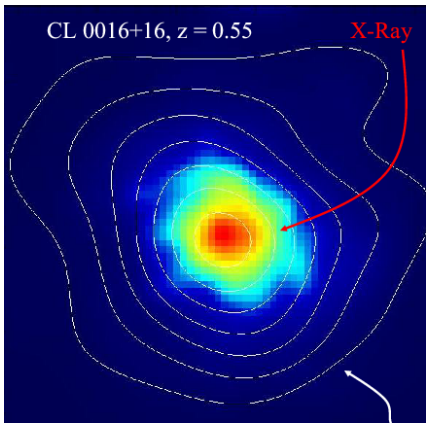
As cluster of gals:
Mass via
richness
vel dispersions
Also--lensing

X-ray



Potential well with hot gas:
Mass from temp, amount of gas

SZ



As “hole/source” scattering CMB:
Mass from change in CMB towards cluster

*some common methods, not all!

ISSUES!!

Theory mass:

Different mass defns:

✔Need to define clearly what mass is used.

*some common methods, not all!

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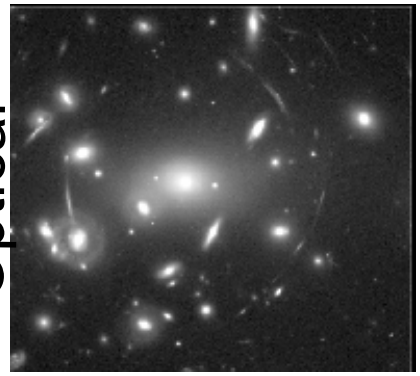
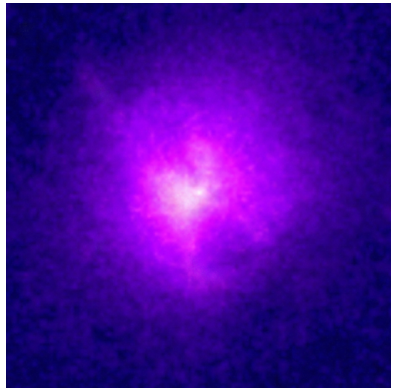


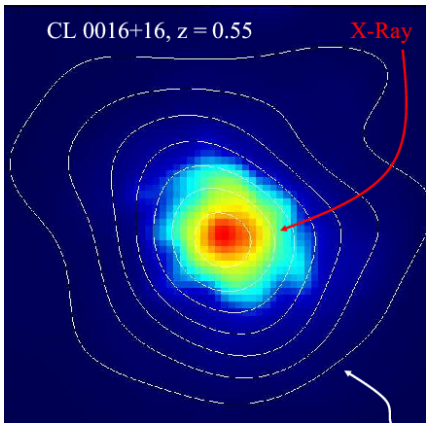
In terms of gals: Projection effects, signal drops as redshift⇑

X-ray



Potential well with hot gas: Dynamical state, signal drops as redshift ⇑

SZ



As “hole/source” scattering CMB: Projection effects, redshift info hard to get

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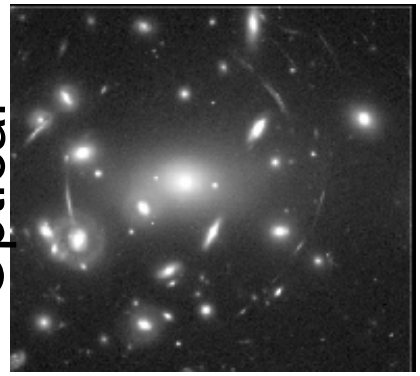

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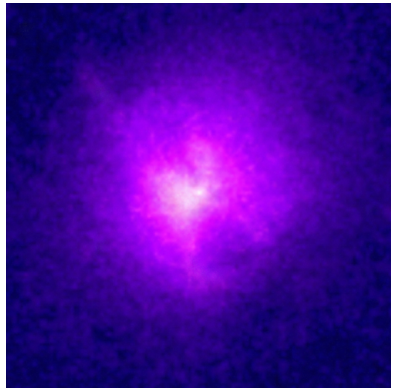

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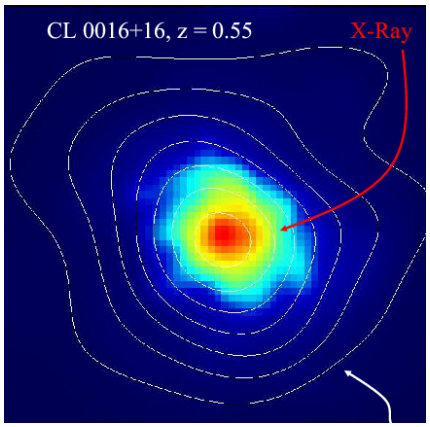
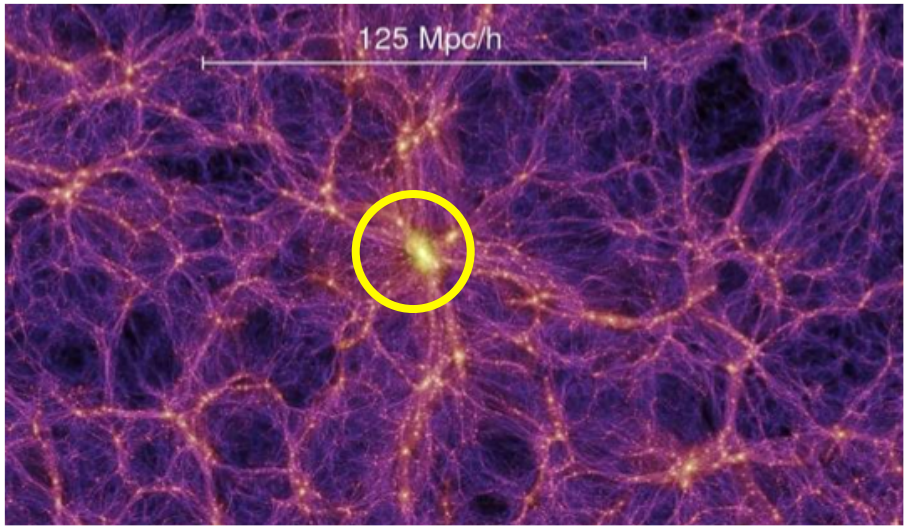


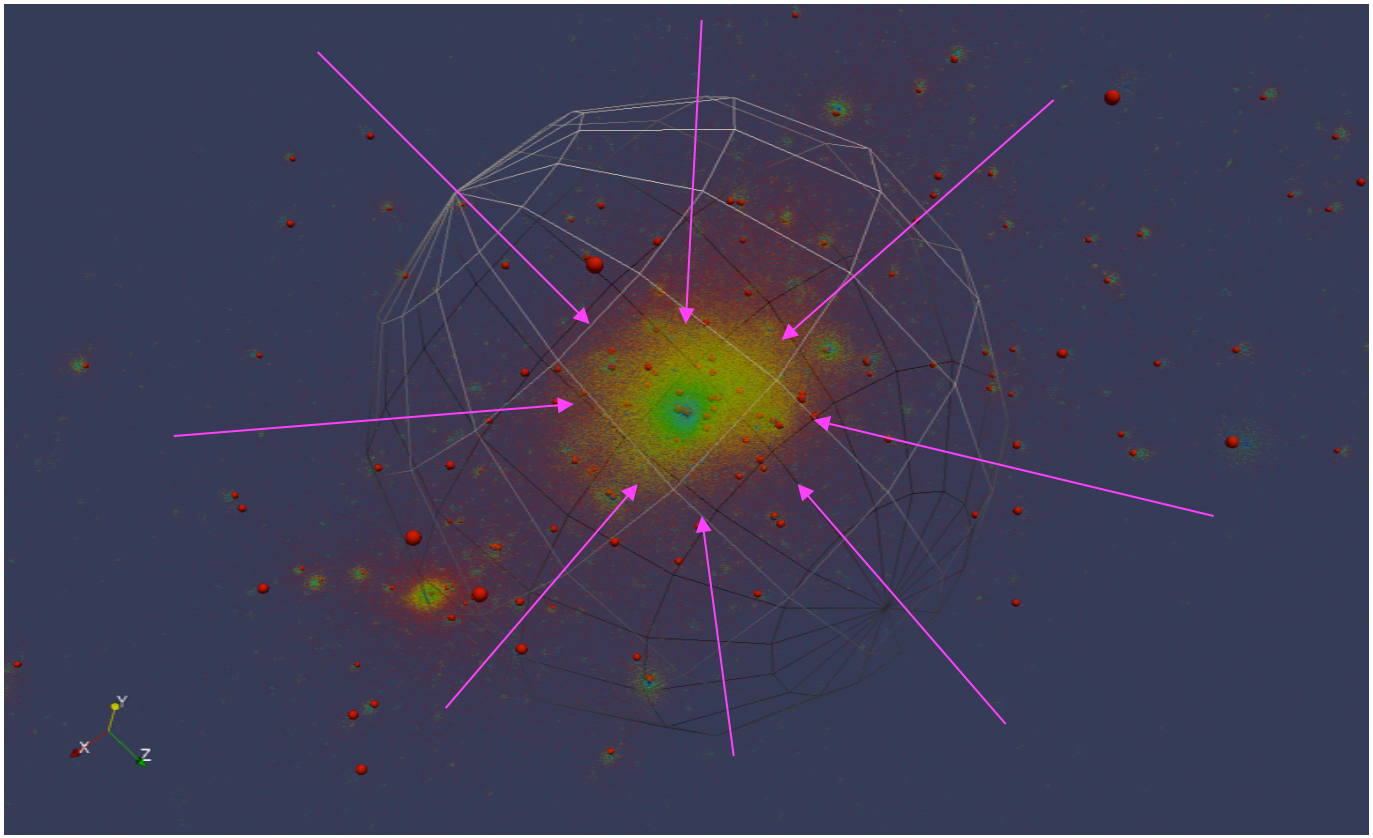
As “hole/source” scattering CMB: Projection effects, redshift info hard to get

Interest here: *Projection effects* ~ *difficulty in separating clusters out from the cosmic web*



In particular, we focus on the effect of projection effects on *multiwavelength measurements*

- Multiwavelength measurements used to combat difficulties in any particular method.



Use N- body Simulations [M. White's: 2048^3 parts, 250Mpc/h box]

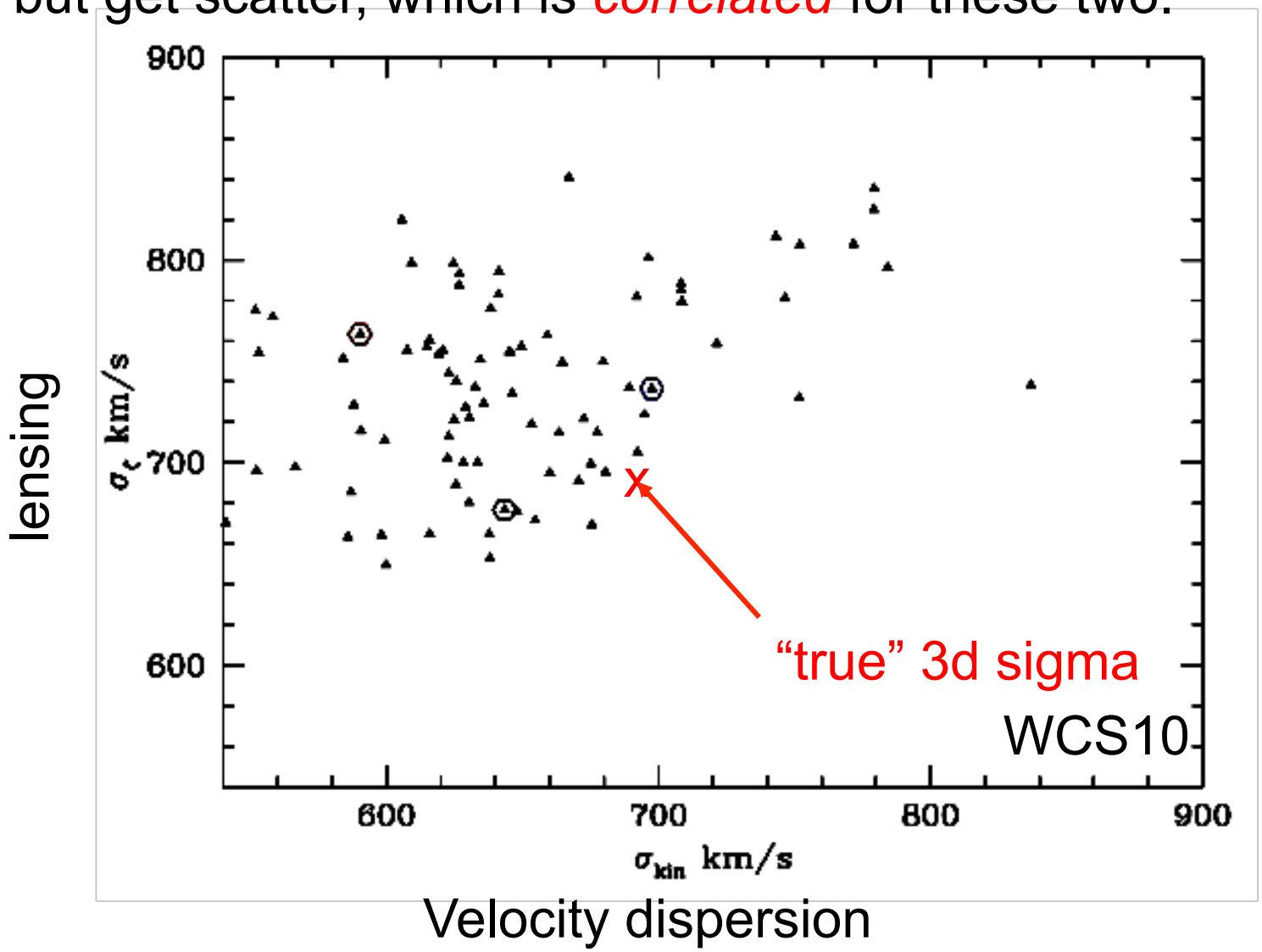
Mass along **96 lines of sight** for each of 83 $M>2.e10^{14}\ M_o/h$ clusters

Mass via: (White,Cohn,Smit 10)

1. Velocity dispersions: dynamics of galaxies in clusters
2. Richness (red galaxies, colors using Skibba &Sheth 09)
3. Richness (all, cluster membership using Yang, Mo, van den Bosch08, phase space)
4. SZ flux (cylinder, r180b)
5. Weak lensing dispersion (r180b)

Case in point:

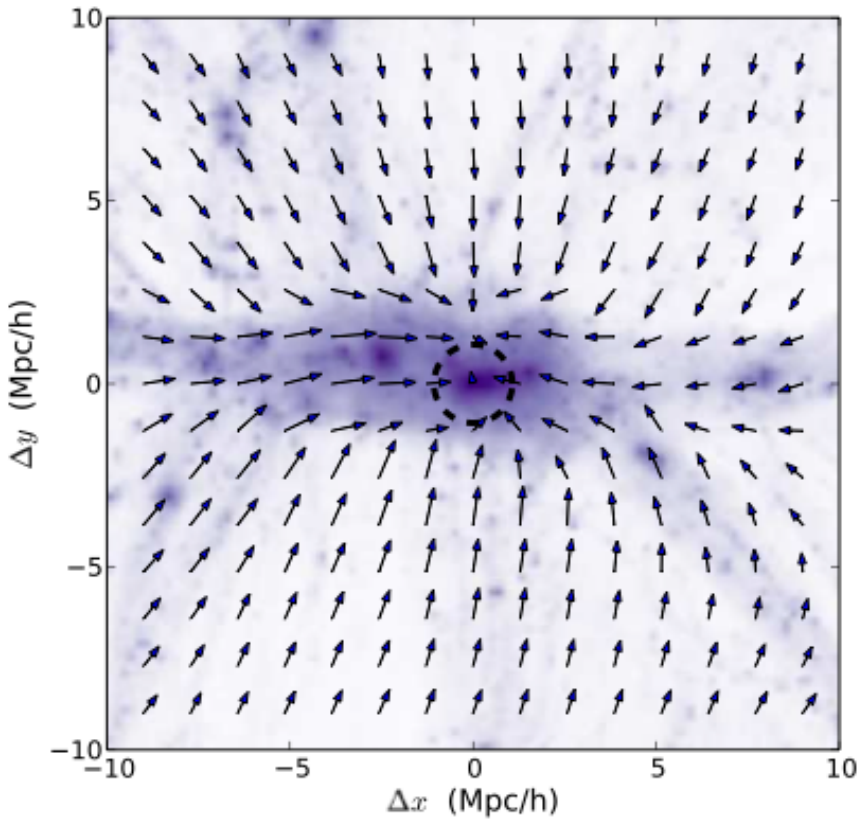
Take *one* cluster along 96 lines of sight and measure σ using velocity dispersions and lensing: should **all be same value**, but get scatter, which is *correlated* for these two.

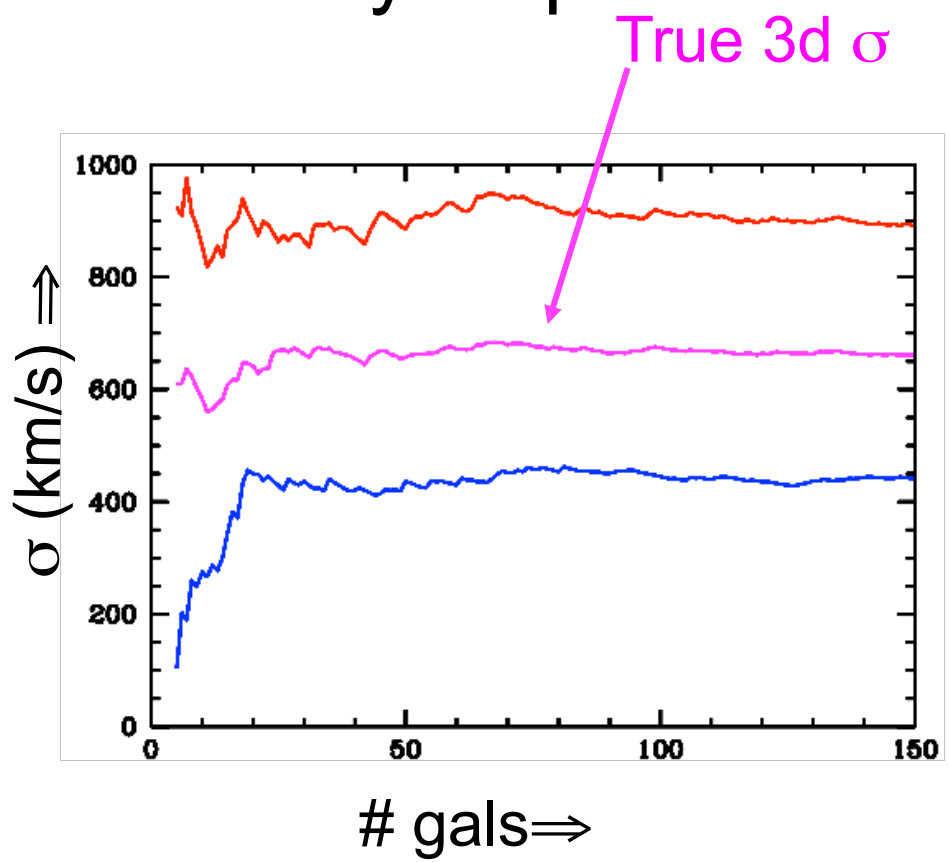


All points are for same cluster-- just along different los!!!

Note!

Direction dependence even for velocity dispersions!!





The direction of the velocity knows about the filamentary nature of large-scale structure (cluster at center).

See also Kasun & Evrard 05, Tormen 97 for studies using DM particles

"mass" along different lines of sight converges when add more galaxies, but often to wrong value!

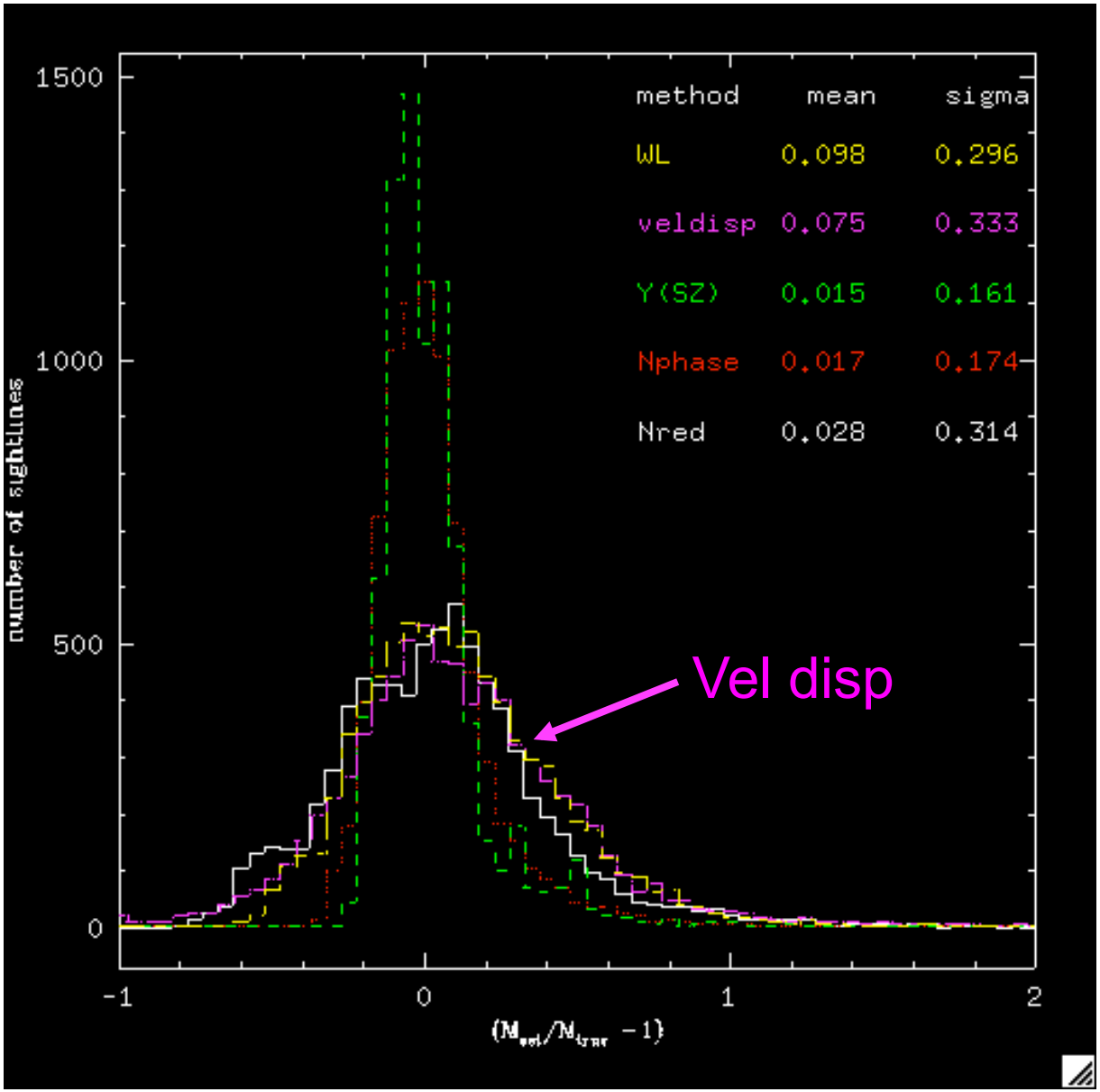
(only true cluster gals here, slightly more scatter with interlopers, which we included)

Compare measures:

- WL*
- Y* (SZ)
- Red gal richness
- Phase richness

Velocity dispersion scatter ~ to others

*Note WL and SZ only across 250 Mpc/h box, so underestimate their scatter due to line of sight.



Mass Scatter

M_{est}/M_{true} -1 [83 clusters, 96 los]

Findings: (White, Cohn, Smit 10)

Scatters in mass predictions are ***big***:

- At least one measure off by 50% for 1/3 of all lines of sight

Multiwavelength measures ***help:***

- *Pairs of measurements both off by 50% for only 8% of lines of sight*

But as expected, multiwavelength scatters are ***correlated***:

- Important consequences for error estimates and stacking (see paper or ask me or Martin)
- Not surprising:

  if cosmic web has anything to do with it, scatter in measurements related to something real next to cluster

⇒*if cosmic web has anything to do with it, scatter in measurements related to something real next to cluster….*

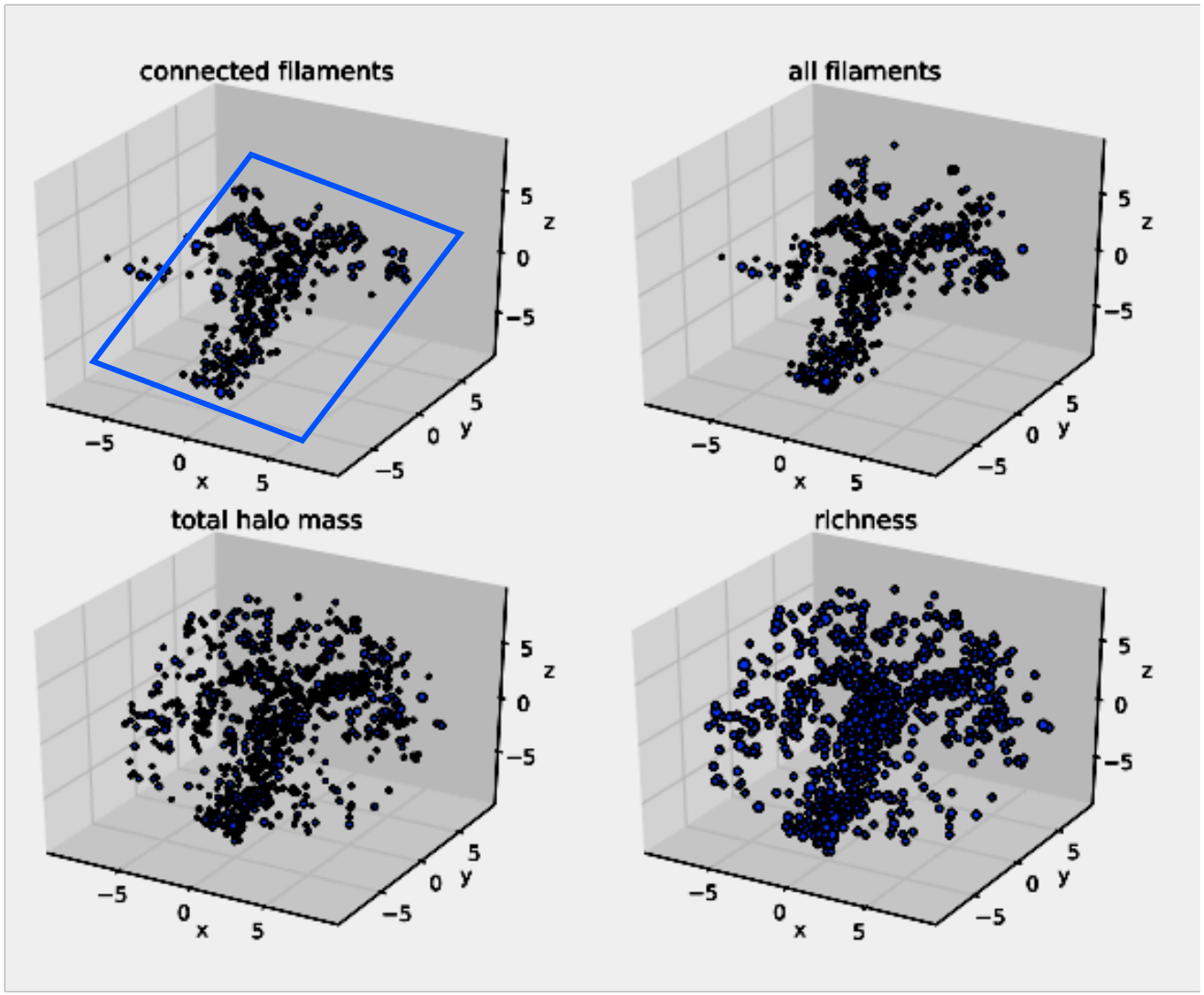
Can look at web directly! (Noh & Cohn, '10)

- Use filament finder (Zhang++09) on same simulation
  - Filaments ~ "bridges" between more massive halos
  - by construction <= 10 Mpc/h long
  - out of halos, not dark matter directly
  - many other finders out there (potential based, using dynamics, etc.), no unique definition
- Look at filaments in 10 Mpc/h radius sphere around cluster
- Filaments tend to lie in disk (~sheet from which they condensed)

Cluster neighborhood:
Take 3 Mpc/h high sheet in 10 Mpc/h sphere and choose direction to maximize enclosed mass or richness

--contains on ave 70-80% of fil mass or halo mass, or >60% richness

--cluster major axis tends to be in plane

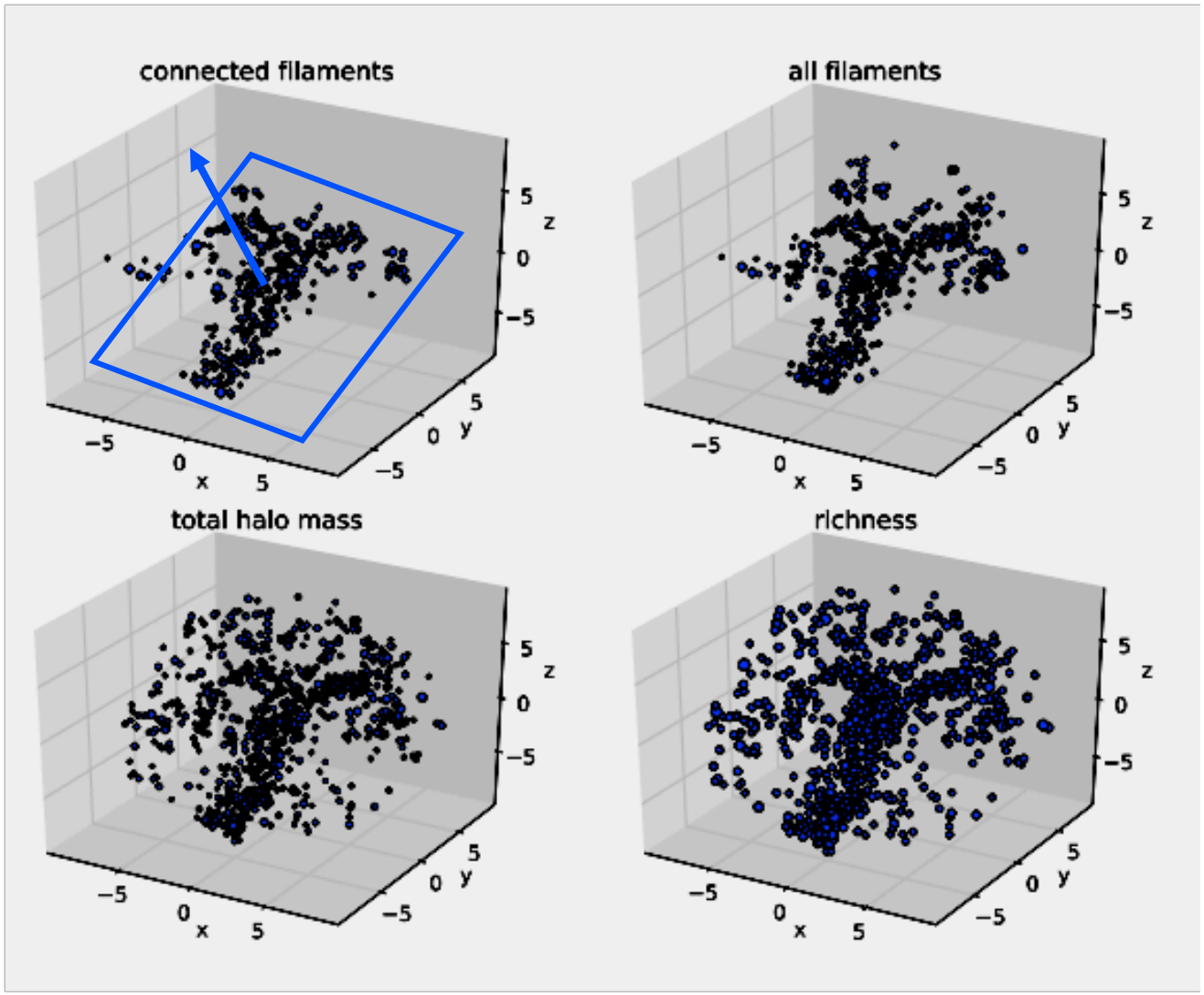


Cluster neighborhood:
Take 3 Mpc/h high disk in 10 Mpc/h sphere and choose direction to maximize enclosed mass or richness

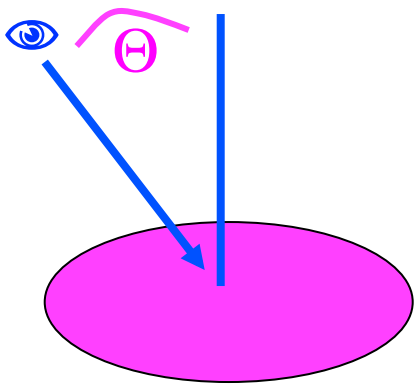
--contains on ave 70-80% of fil mass or halo mass, or >60% richness

--cluster major axis tends to be in plane

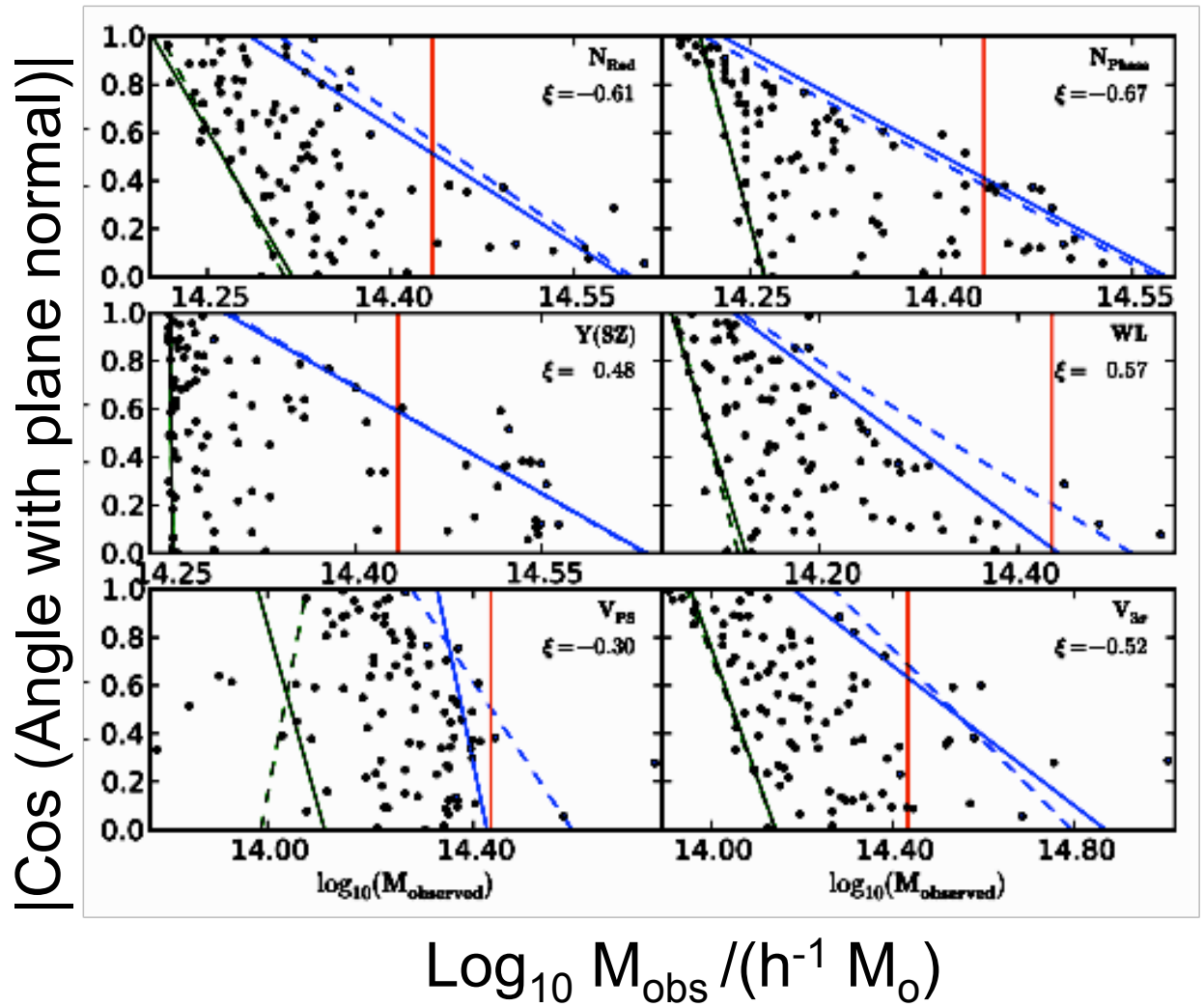
--gives preferred direction in cluster environment



Correlated scatter for one individual cluster: observed mass vs cos angle Θ with cluster plane normal



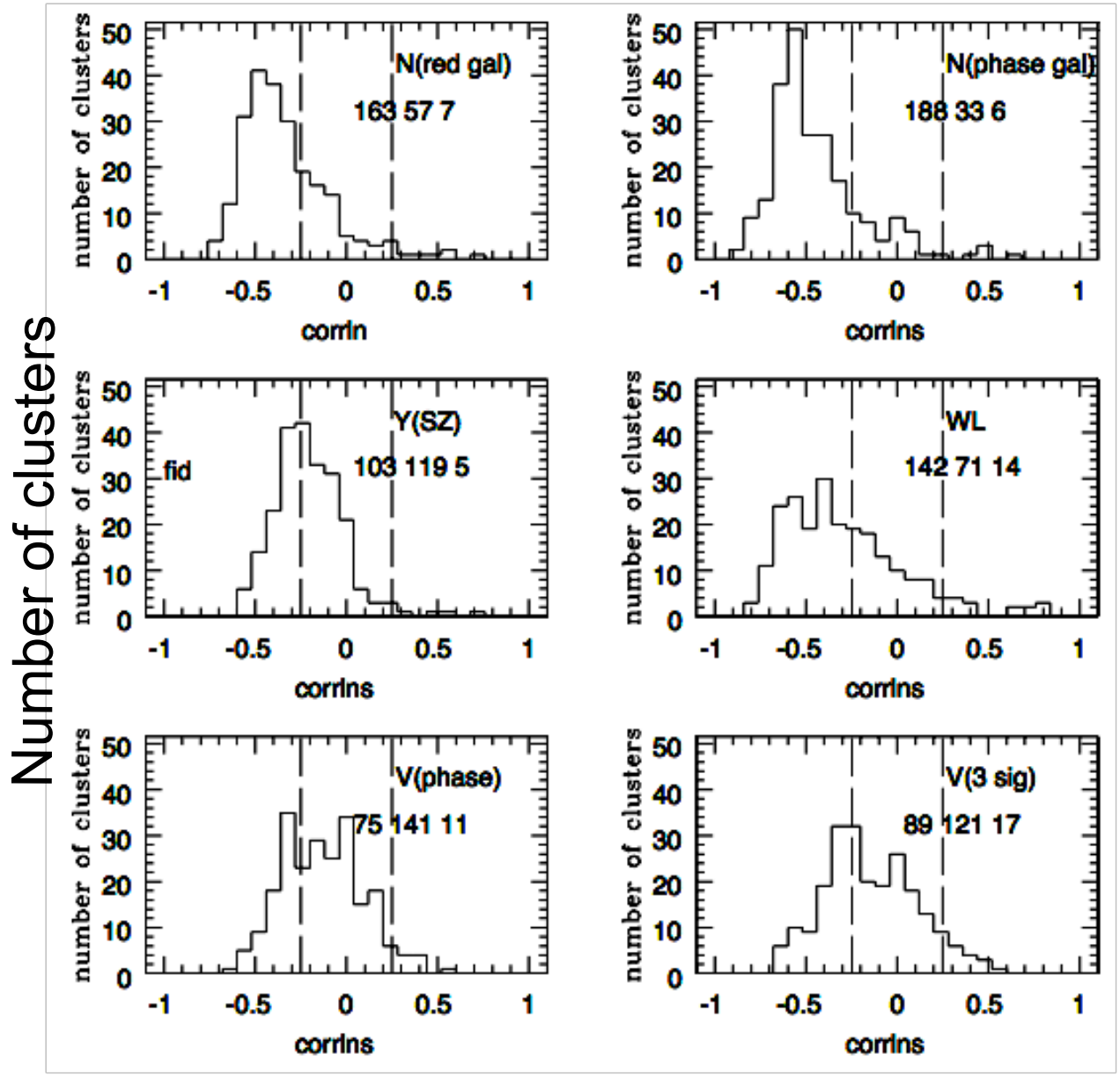
N_{red}	N_{ps}
SZ	WL
σ_{ps}	σ_{3sig}



Strong corrlns between mass scatter and normal to filament plane:

- For many clusters
- For many mass measurements

Correlation coefficients



Summary

- Many cluster mass observables have projection effects: richness, SZ, WL, velocity dispersions
- $\Rightarrow$Direction dependent scatter can be *large*
  - Even for velocity dispersions, i.e. galaxies *in* cluster
- Mass scatter can be seen to be correlated with local 10 Mpc/h environment
  - Can identify filaments and their sheet directly
  - Implies correlated scatter for many observables:
    - Issues for error calculations
    - Issues for stacking

Papers: White,Cohn,Smit ‘10, Noh & Cohn, ‘10

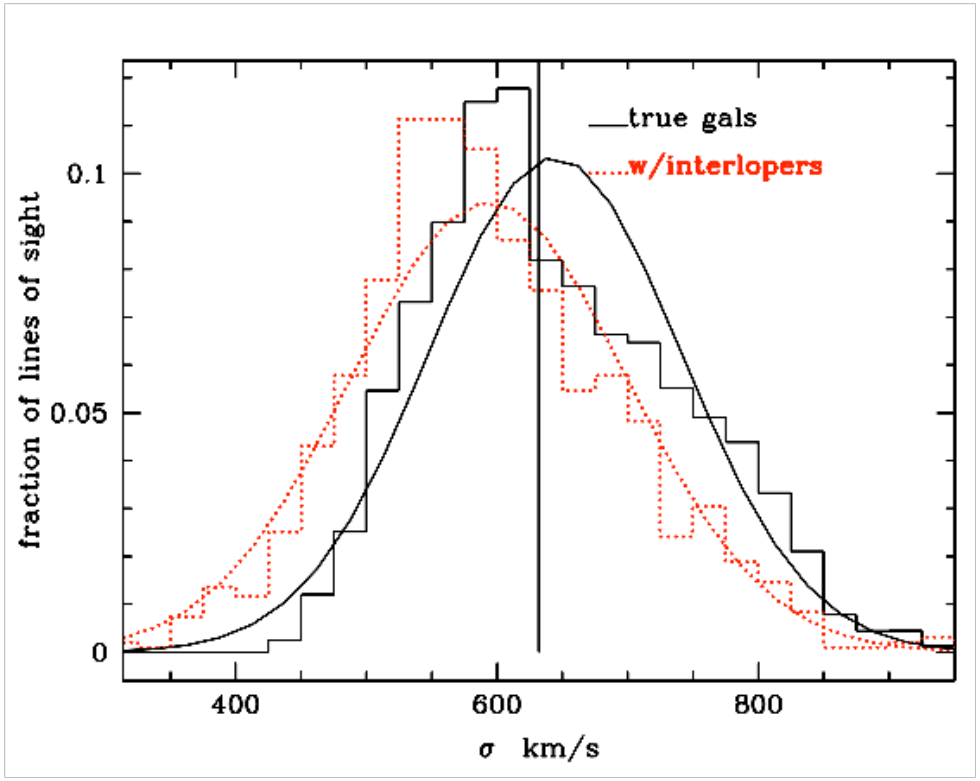
The End

Points about Correlated scatter:

- Two measurements can agree and be *wrong*.
- Error estimates need to take corrln into account
- Environment:

  joint outliers (>50% mass errors) have higher numbers of nearby massive halos, nearby less massive halos and substructure than lines of sight without these errors, but do not dominate systems with any of these properties
- Stacking when correlations are present can introduce a bias, e.g. stacking on richness and measuring lensing vs. SZ may give a biased relation.
  - Strongest for higher end of mass function
  - Correlations strong here *but* richness such noisy fn of mass that bias is too small to be seen in our relatively low mass sample
  - For example with X-ray see Rykoff++08
- Here looked at full line of sight correlations
  - for intrinsic correlations (Xray, SZ, 3d vel disp.), see Stanek++10.

Velocity distributions give large scatter



Scatter distribution for 10 clusters with 3e14≤ M ≤ 3.5e14
(This is NOT a stacked velocity distribution histogram!!)