Disentangling correlated scatter in cluster mass measurements

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work with Joanne Cohn

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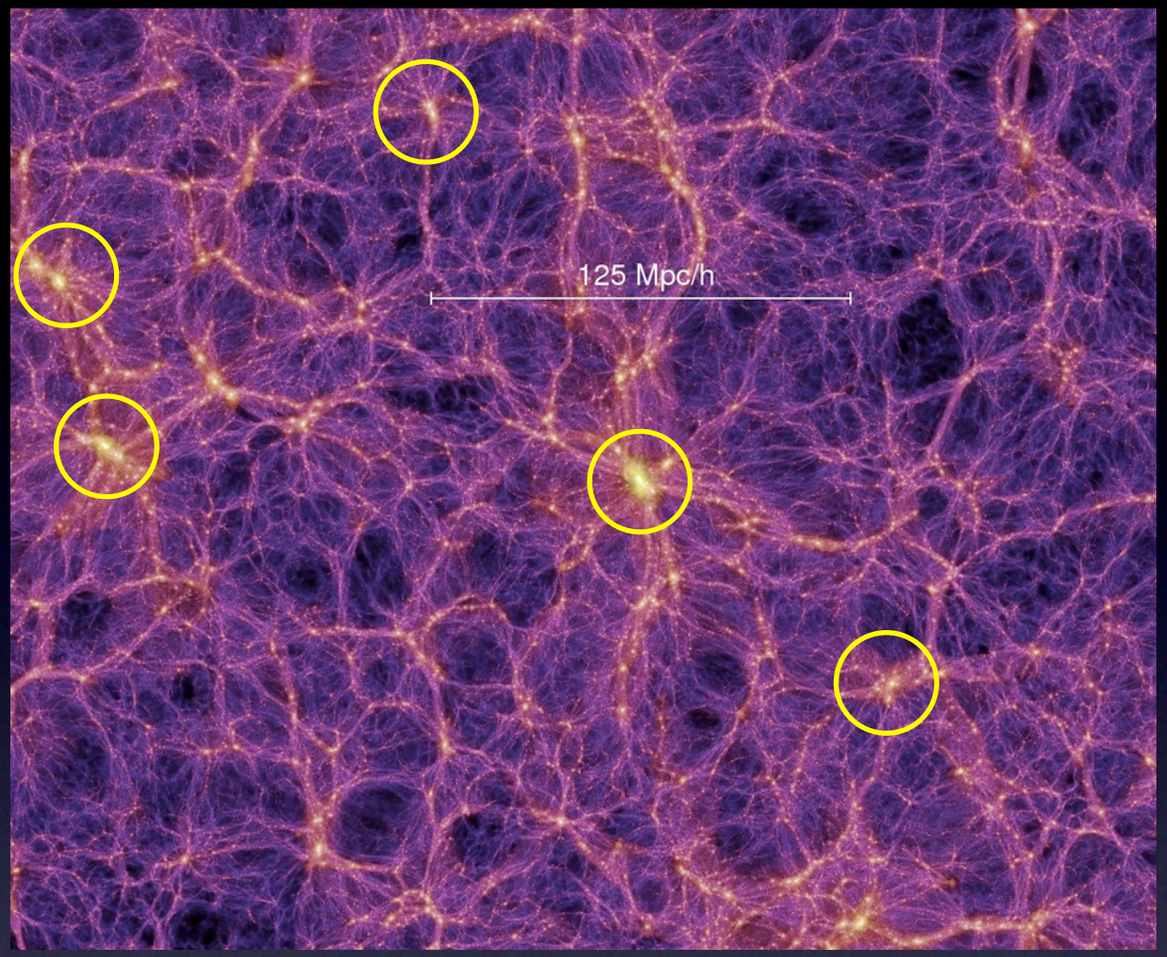
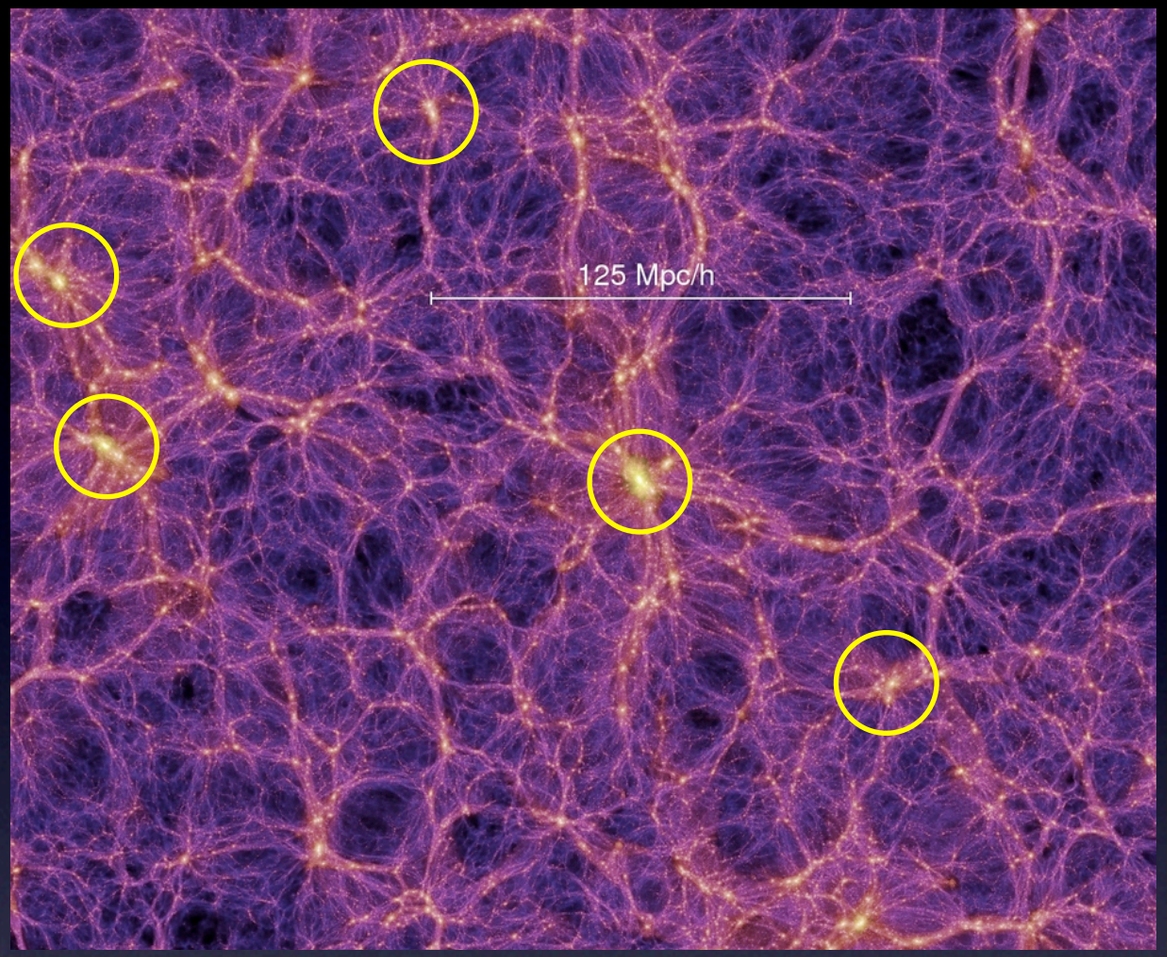
Cosmology on the beach 2012



Clusters are the largest, most massive virialized objects lying at the nodes of cosmic web

- Cosmological probe
- Special environment of galaxy formation
- Hosting extreme astrophysical phenomena



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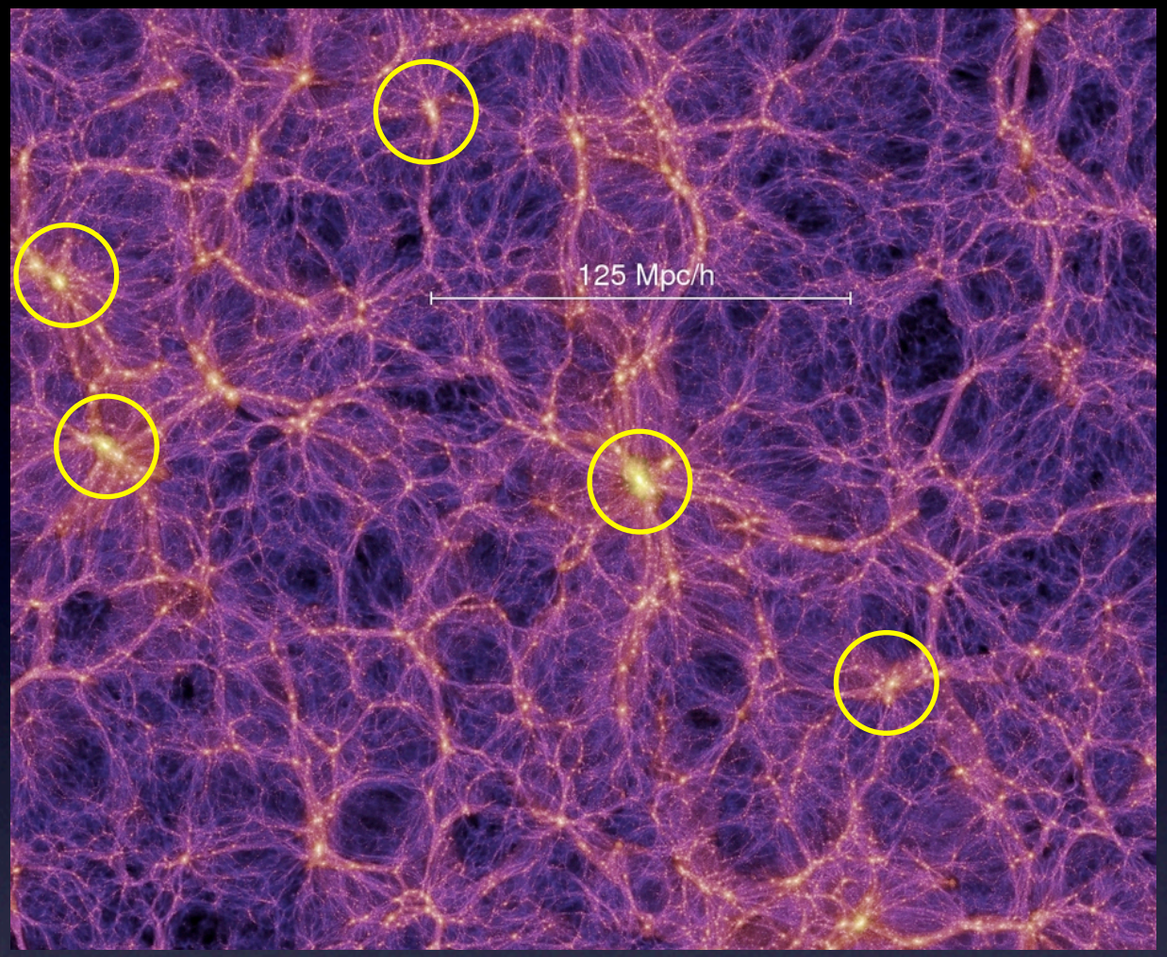
Cluster mass is a crucial property



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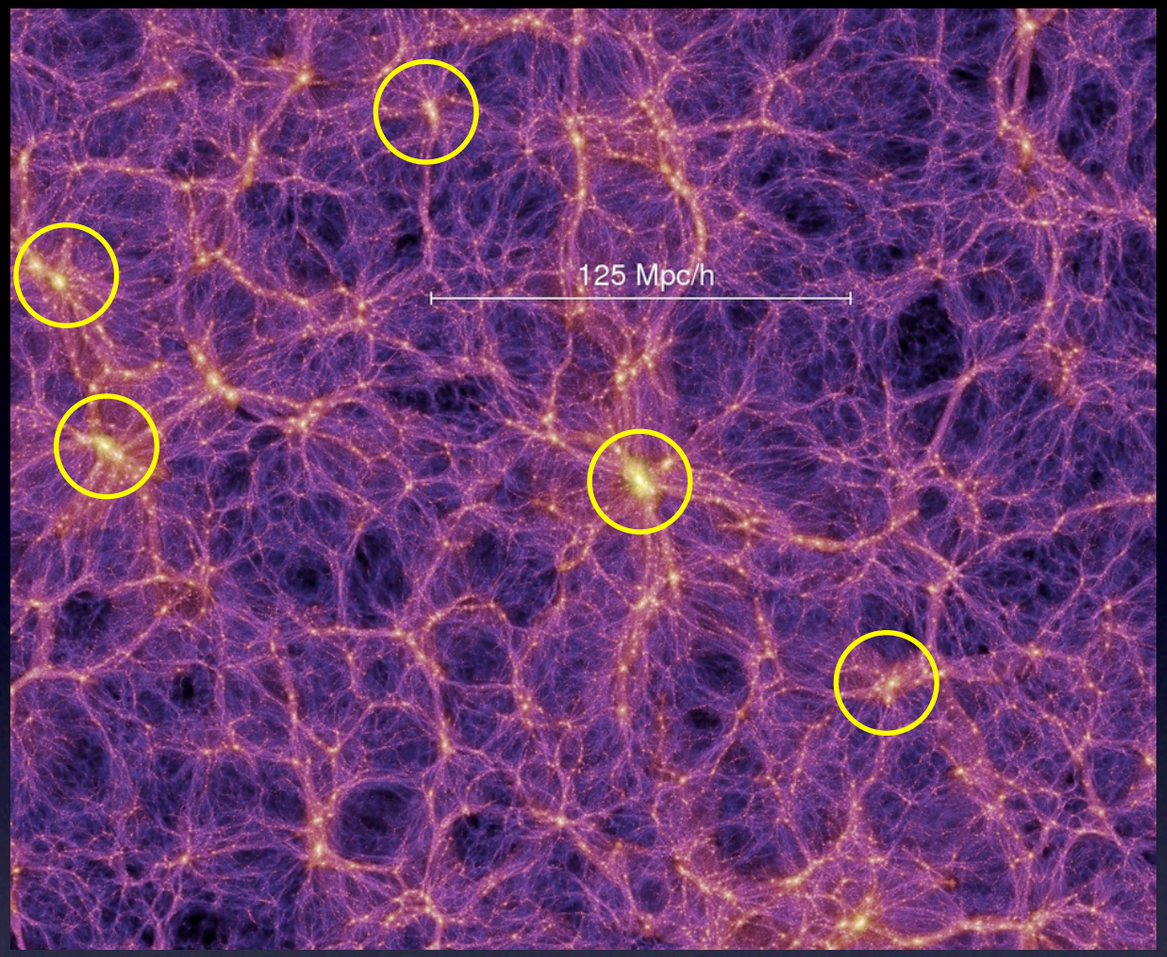


Clusters are the largest, most massive virialized objects lying at the nodes of cosmic web

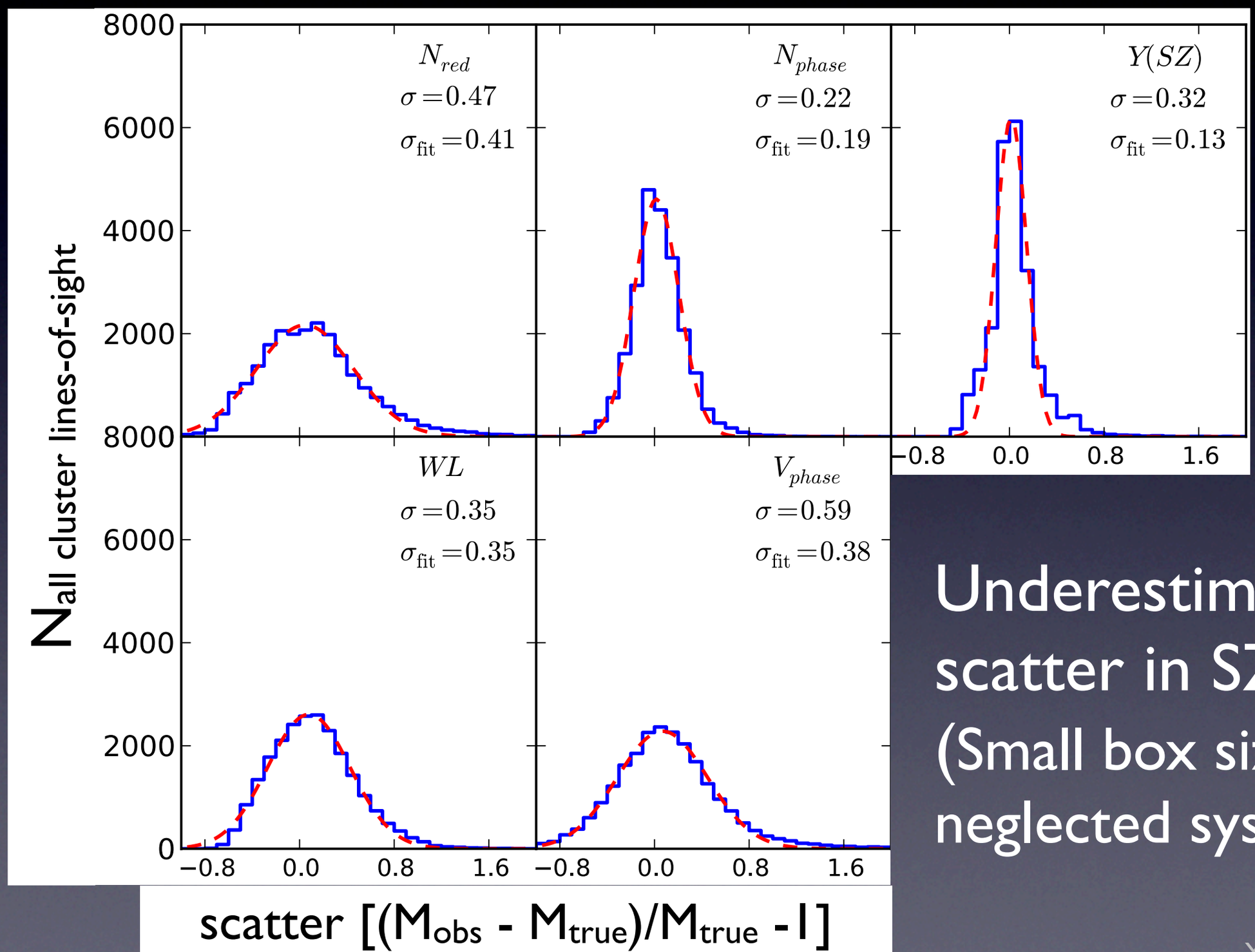
- Difficult to isolate the clusters from the cosmic web

- Consider line-of-sight (including projection) effects on multi-wavelength measurements
- Consider cluster to cluster properties

Simulation

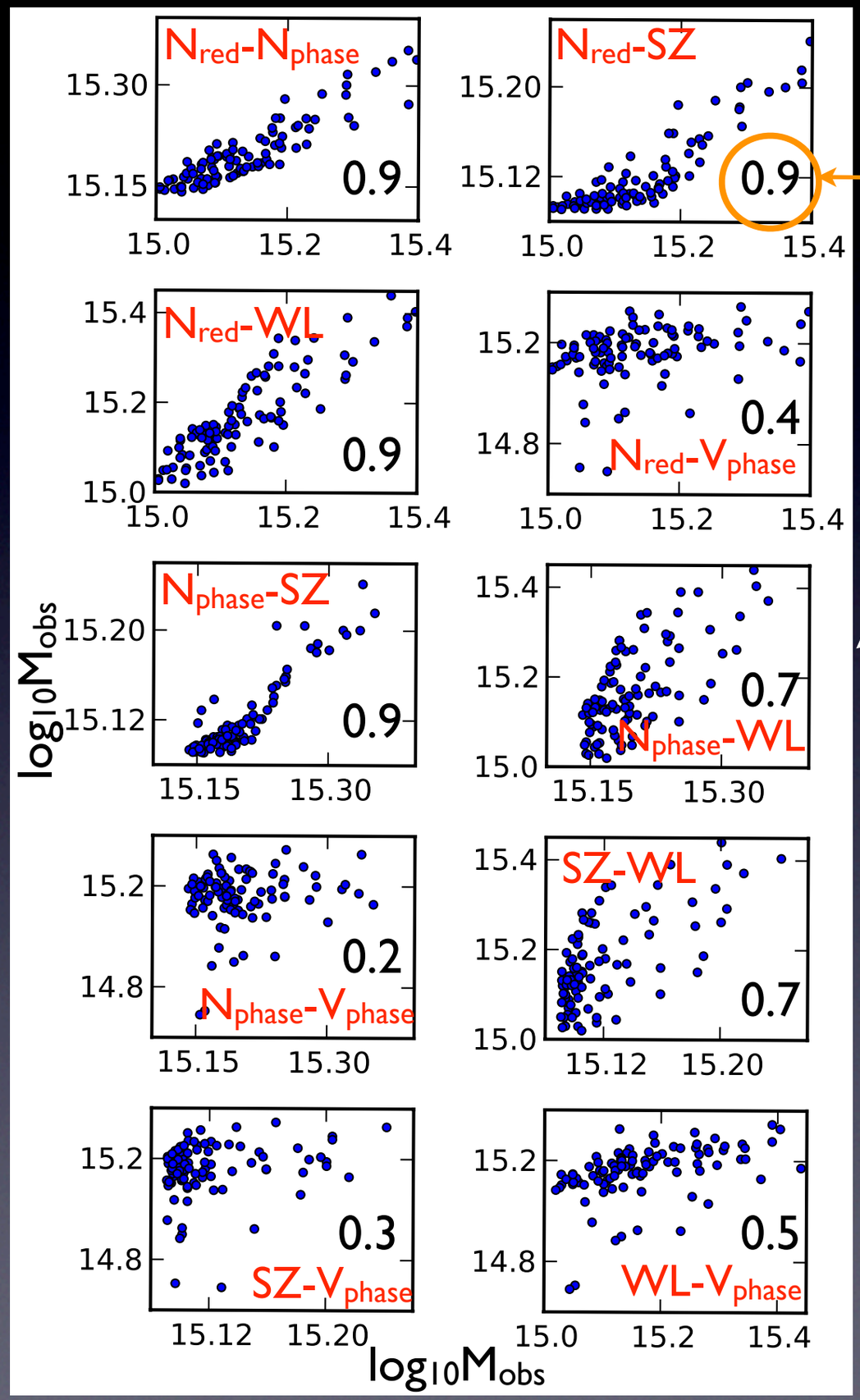
- N-body simulation (TreePM code, White 02)
  - z=0.1, 250 Mpc/h box, 2048^3 particles
  - Ω_m= 0.274, h =0.72, n=0.95, σ_8 = 0.8
  - Halos via FoF with linking length ~0.168
    - 243 Clusters ($M_{halo} \geq 10^{14}\ M_\odot/h$)
- Mock observations (White, Cohn, Smit 10)
  - Based on dark matter and subhalo distribution
  - Velocity dispersions, Richness, SZ flux, Weak lensing
  - 96 different line-of-sight mass measurements

Scatter in Cluster Mass Measurements



Underestimate the scatter in SZ and WL (Small box size, some neglected systematics)

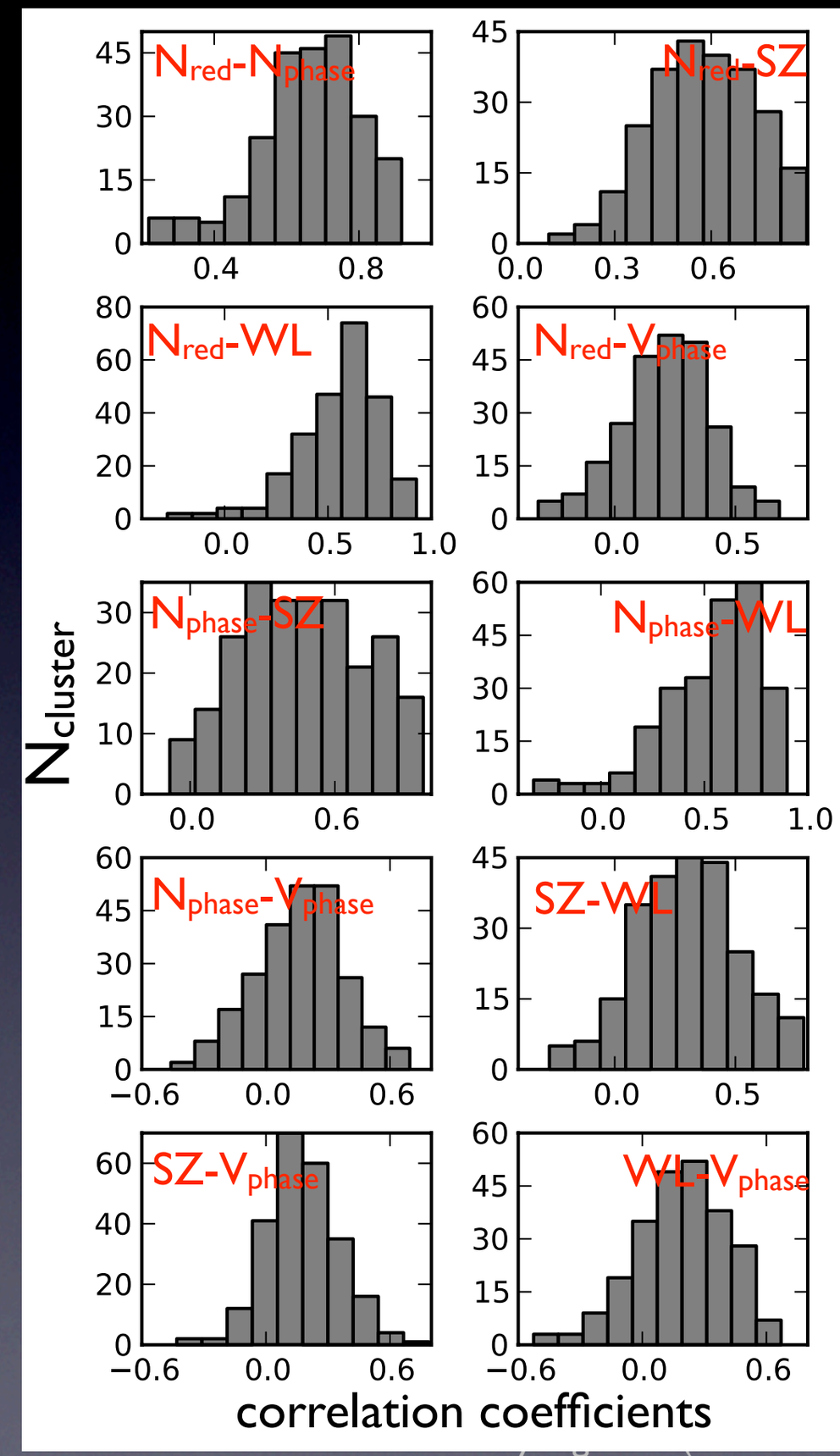
Correlated Mass Scatter



corrln. coeff.

A single cluster

Ensemble of clusters



Correlated Mass Scatter

- Why it is interesting
  - Stacking of ensemble of clusters can give a bias
  - Error estimates can be incorrect for the joint measurement of one cluster

    Rykoff++08, Stanek++10, White, Cohn & Smit 10, etc.

- How to take care of it
  - Calibrate with simulations
  - Understand what it is physically related to

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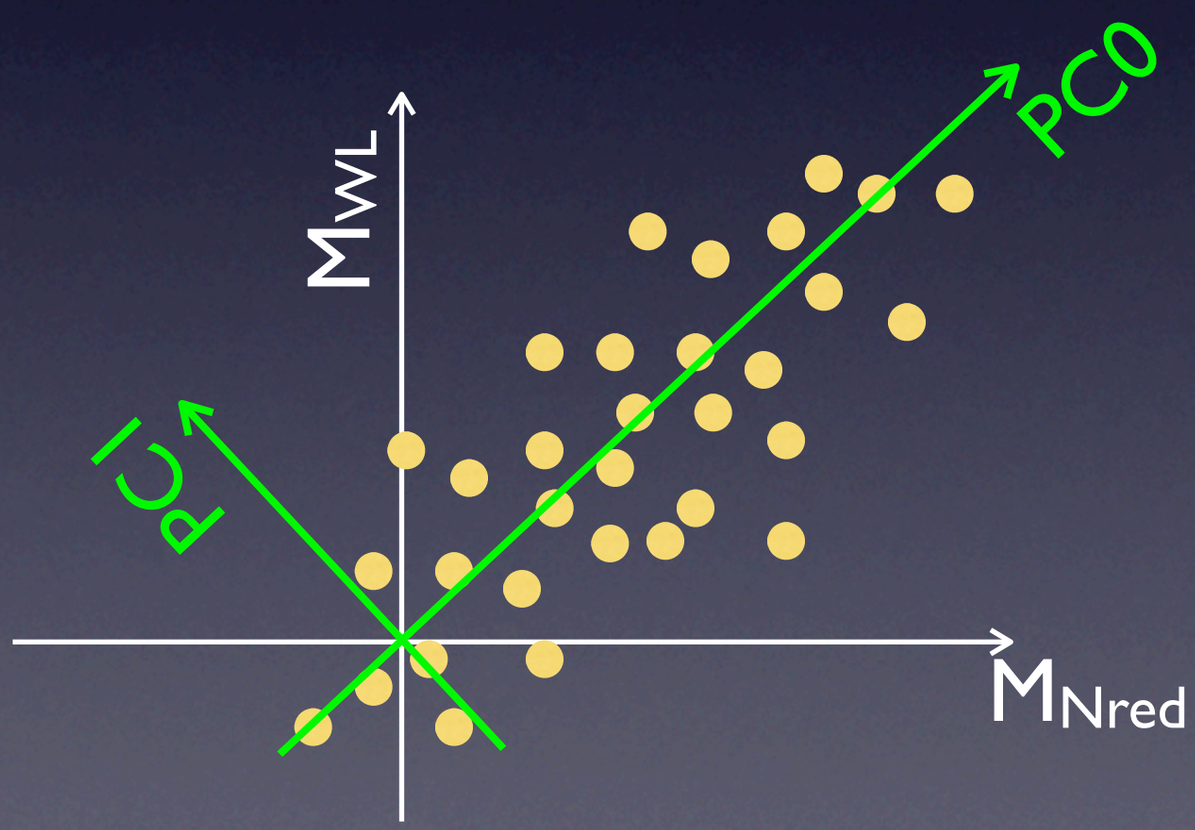
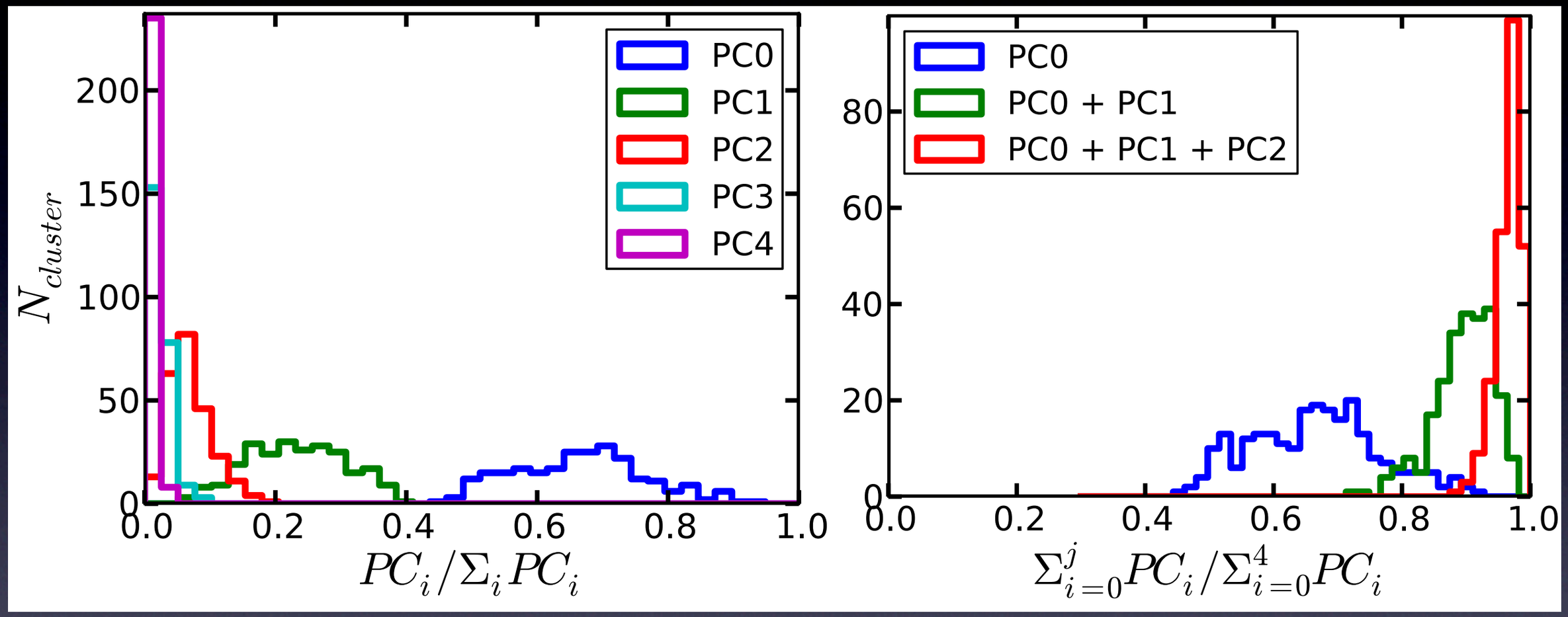
Principal Component Analysis(PCA)

- Convert a set of correlated variables into a set of independent variables



- PCs are eigenvectors of covariance/correlation matrix
- Corresponding eigenvalues indicate the importance of PCs
  - PC0 gives the direction of the largest variance

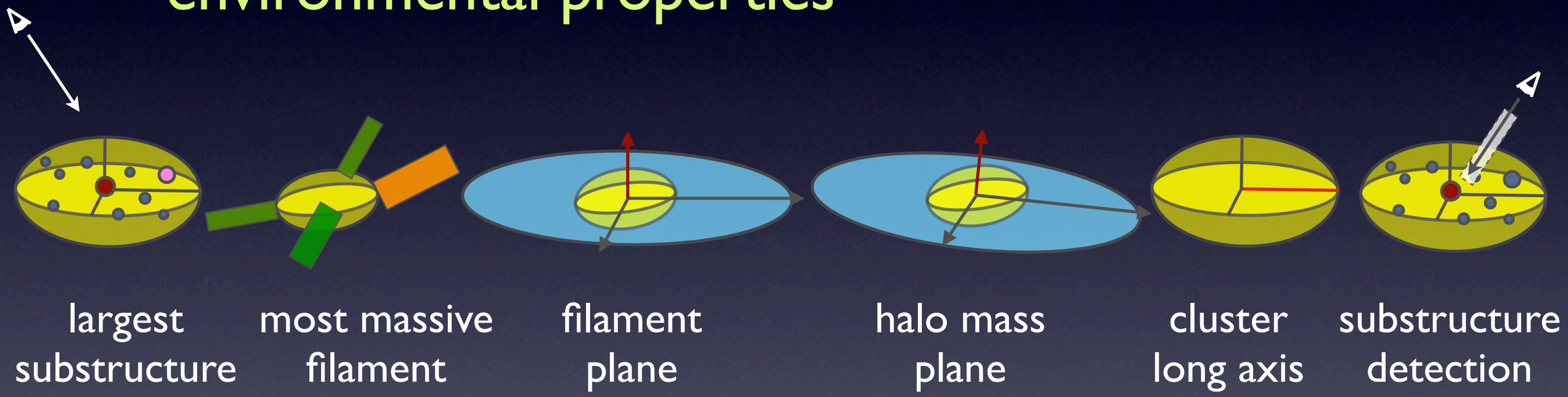
PCA for Cluster Observables



- PC0 accounts for 70% of total variance on average
- Including PC0 and PC1 accounts for 95% of total variance on average

Cluster Properties depending on line-of-sight

- Consider directional dependent intrinsic and environmental properties

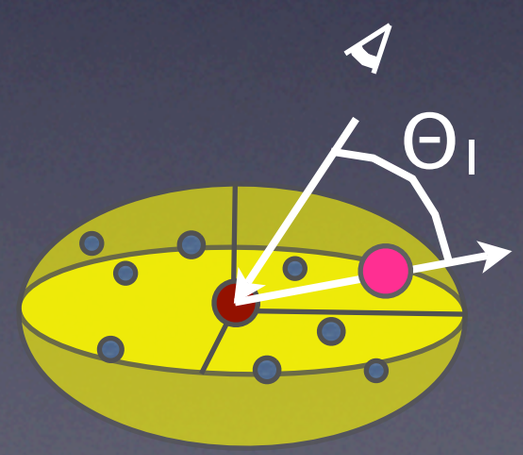


For the detail of filaments, see Noh&Cohn (11) arXiv: 1011.1000

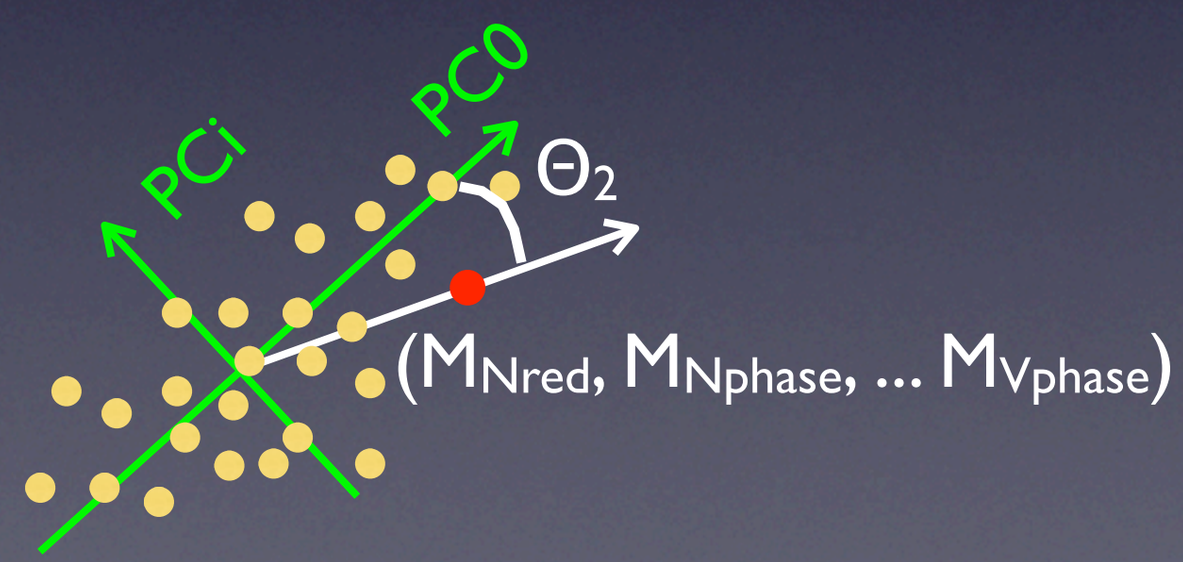
Cluster Properties depending on line-of-sight

- Calculate the correlations between
  - |cosine angle| between line-of-sight direction and each of directional properties (or the substructure detection probability)
  - cosine angle of the mass scatter along each line-of-sight to PC0 direction

e.g.



and



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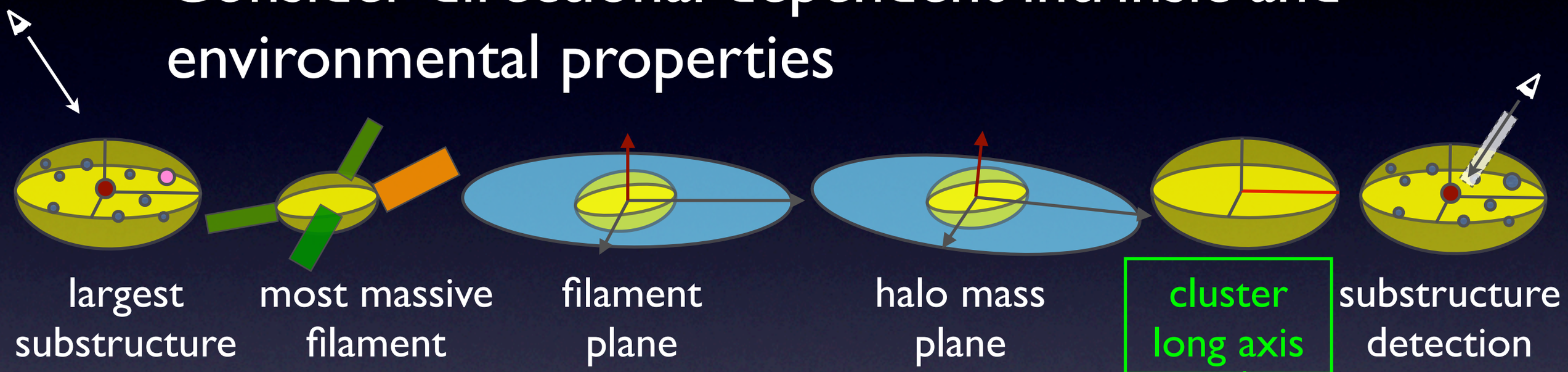

The largest correlation/covariance
→ observing along long axis has largest contribution from PC0

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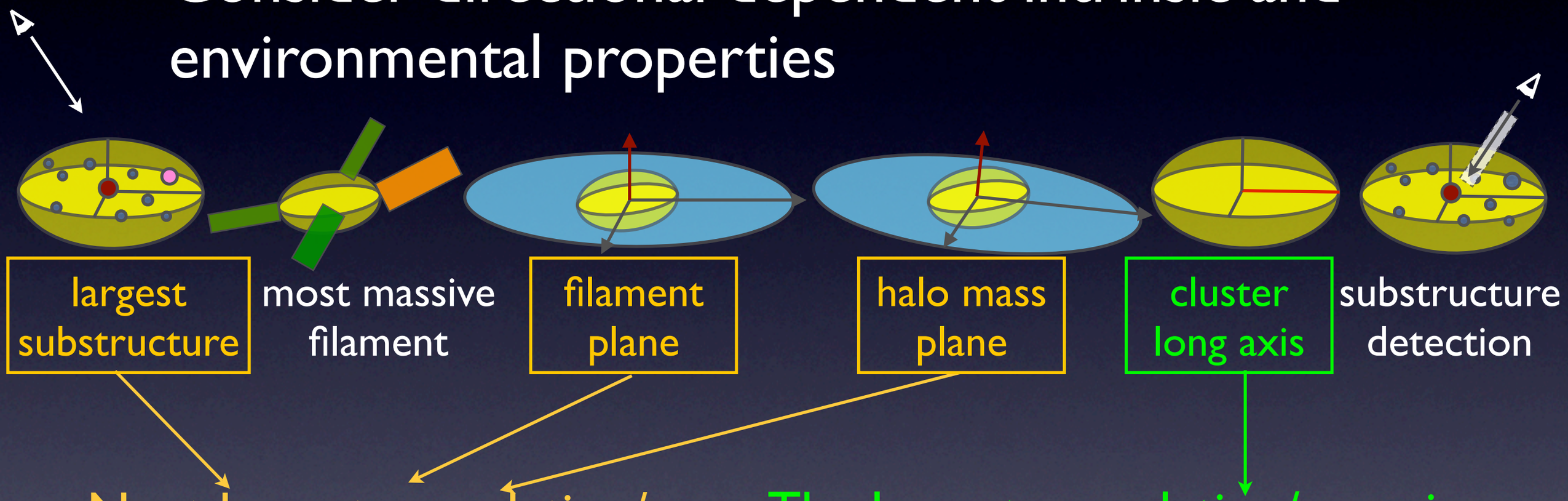

Next largest correlation/ covariance

The largest correlation/covariance
→ observing along long axis has largest contribution from PC0

Cluster Properties depending on line-of-sight

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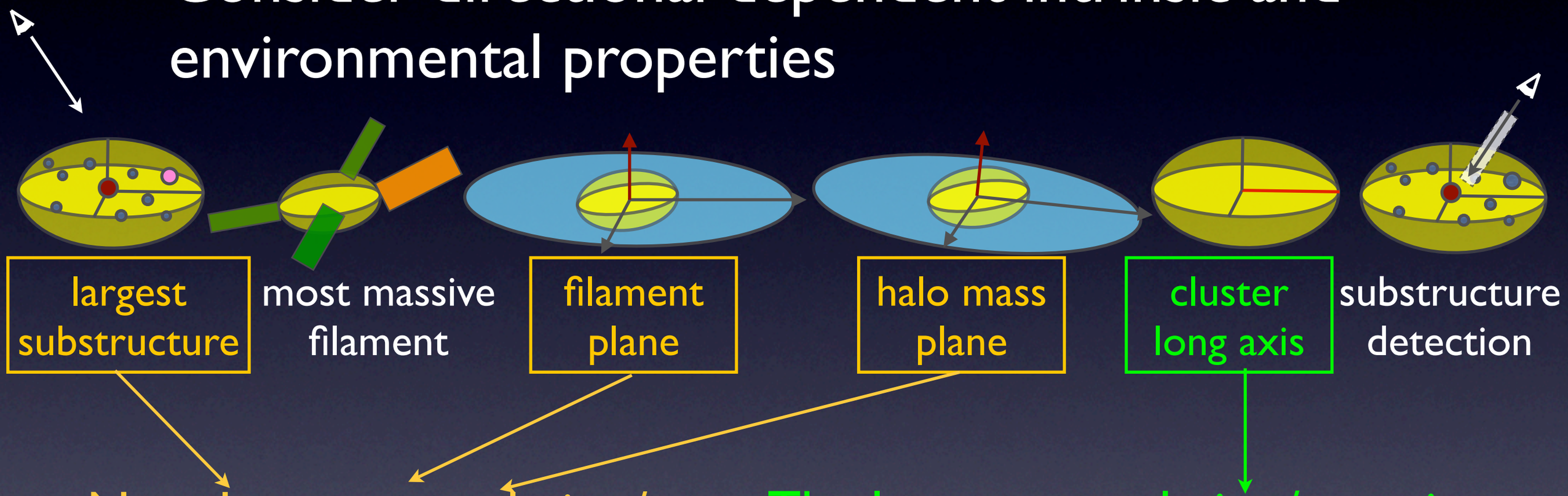


Next largest correlation/ covariance

The largest correlation/covariance
→ observing along long axis has largest contribution from PC0

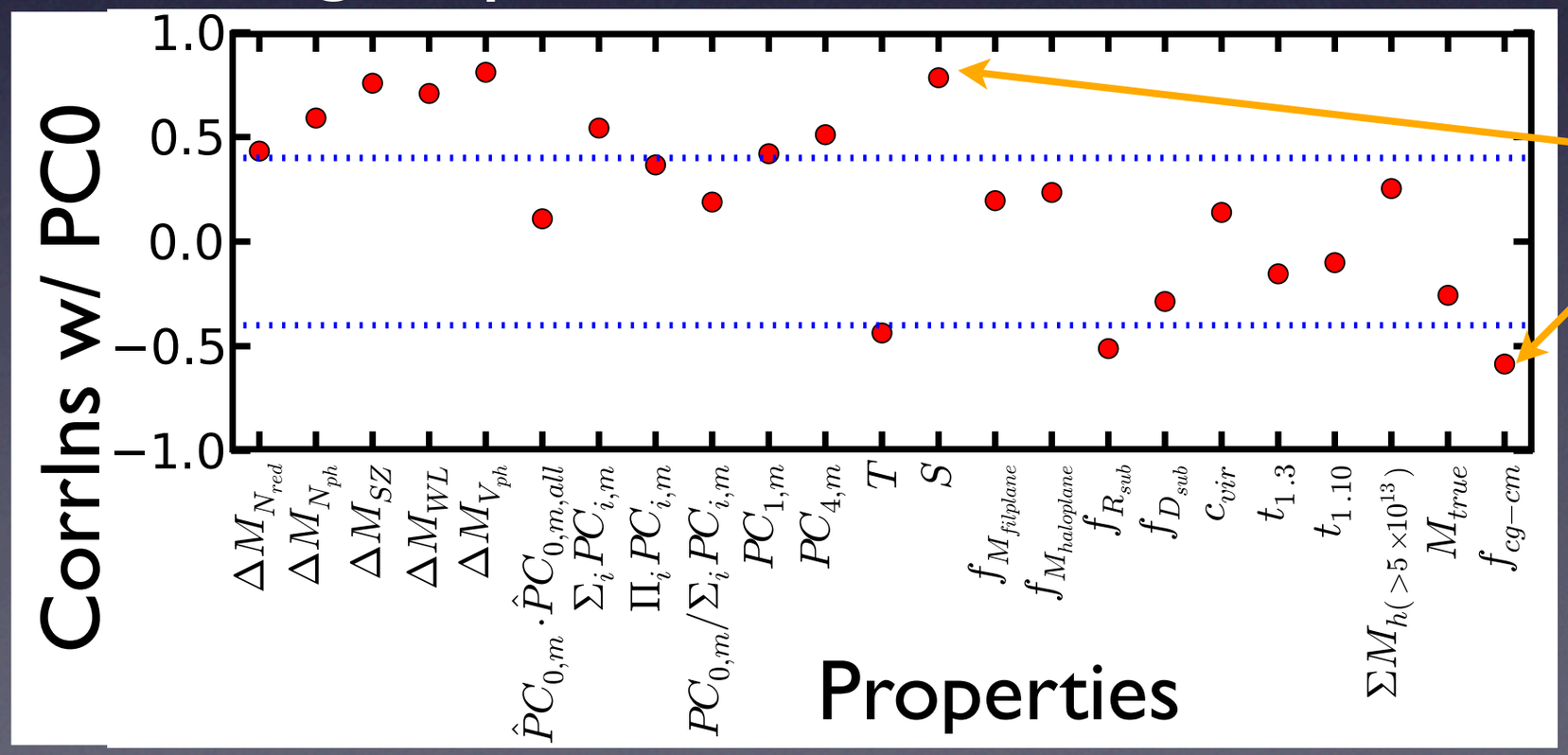
Many of these axes are close to each other in direction

PCA for Ensemble of Clusters

- Calculate PC's for scalar properties
  Earlier related work: Jeeson-Daniel++, Einasto++, Skibba&Maccio(11)
  - Mass scatter properties: average scatter (i.e. [$<M_{obs}>$ - M_{true}]/M_{true}), PC's from mass scatter PCA, etc.
  - Physical properties: mass fraction in filament plane, richness fraction in biggest sub halos, triaxiality, etc.
- PC0 accounts for ~20% of total variance
  - Including up to PC4 accounts for ~50% of total variance

PCA for Ensemble of Clusters

- Correlate the properties with PC's
- Classify the properties into groups if they show similar tendencies with correlations with PC
  - e.g. mass measurement scatter and shape parameters are in a group



Summary

- Scatters in mass measurements are correlated with each other
  - PC0 accounts most of total variance
  - Cluster long axis is most correlated with PC0
- We classify some number of cluster to cluster properties into a few of groups
  - Mass measurement scatter has strong correlation with shape parameters