Disentangling correlated scatter in cluster mass measurements

Yookyung Noh[1]
& Joanne Cohn
(UC Berkeley)

[1] ynoh@berkeley.edu

Abstract

Galaxy clusters lie at the intersection of filaments in the cosmic web. For almost all observational methods, this cosmic web is inevitably included when one measures cluster mass. In particular, it can lead to correlations between scatters in mass obtained via different observational methods (e.g. weak lensing and richness). We use an N-body simulation to study mass measurements and correlated scatters of clusters via several current observational methods, with an eye to understanding how these vary depending upon extrinsic and intrinsic cluster properties. We use Principal Component Analysis(PCA) to study how scatters from several different observational mass methods change coherently. In addition, we compare the PCA combinations of observational mass scatter with different extrinsic and intrinsic physical properties; often the largest mass scatters occur when observing along the cluster's long axis.

Simulation

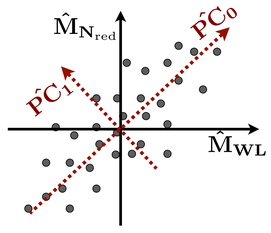
- We use a N-body simulation in a 250 Mpc/h box side with 2048^3 particles from M. White.
- We construct a filament catalogue using an extension of the halo based filament finder of Zhang et al. (2009) (for details, see Noh & Cohn 2011).

Cluster mass measurements

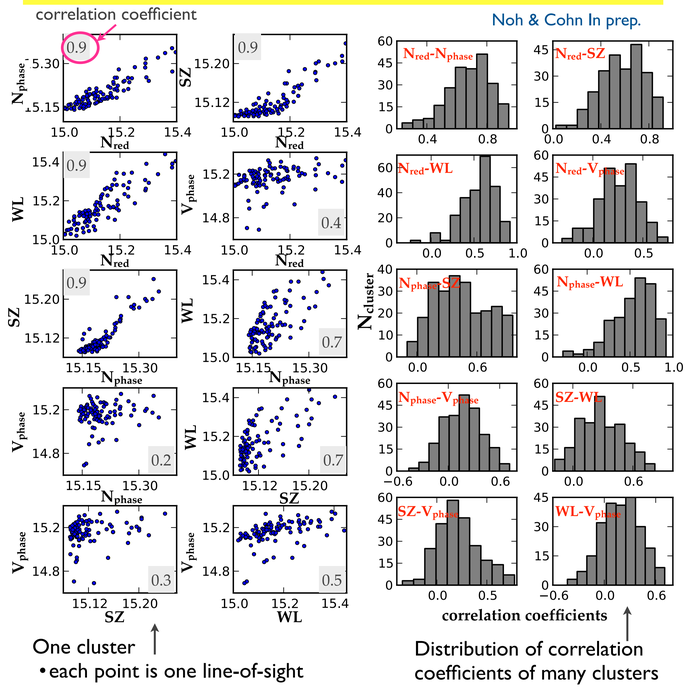
- Cluster mass is a crucial property for studying cluster physics, using clusters as a cosmological probe or considering clusters as an environment for galaxy formation.
- We have mock observations for 5 mass measures of each cluster with filamentary environment map: two galaxy richnesses(N_{red}, N_{phase}), a velocity dispersion(V_{Phase}), Compton decrement(SZ), weak lensing mass(WL); these are our different M_{obs} (White, Cohn and Smit 10 (WCS)).
- Masses are measured along 96 lines-of-sight for each cluster, ($M_{obs,\ i\text{-}los}$).

Principal Component Analysis(PCA)

- Convert a set of correlated variables into a set of independent variables
- How?
  - Get eigenvectors of covariance/ correlation matrix
  - The eigenvectors are PCs and the corresponding eigenvalues indicate the size of scatter
  - Here PC0 accounts for a large fraction of the scatter.



Scatters of different observed masses are correlated

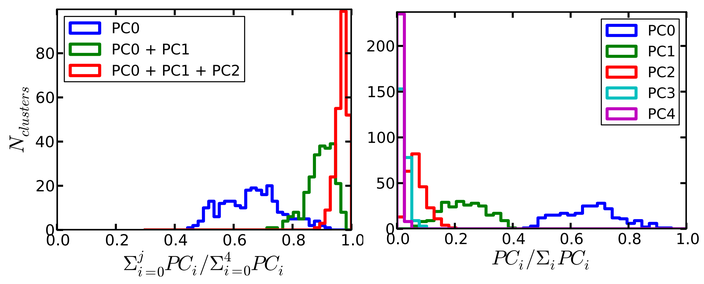


Correlated scatter

- can induce bias in stacking (Rykoff++08, Stanek++10, WCS etc.).
- should be included in the error estimate for individual cluster mass measurements.

PCA for individual clusters

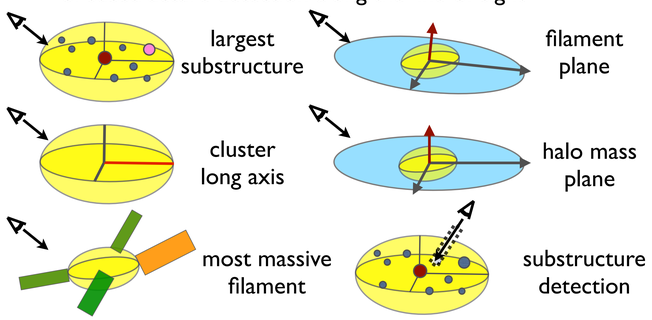
- We did PCA for each cluster using the covariance of different mass scatters for all lines-of-sight (i.e. $[M_{obs,\ i\text{-}los} - \langle M_{obs,\ i\text{-}los}\rangle]/M_{true}$).



- PC0 accounts for 70% of total variance on average.
- Including PC0 and PC1 accounts for, on average, 95% of total variance; scatters in other directions are relatively small.

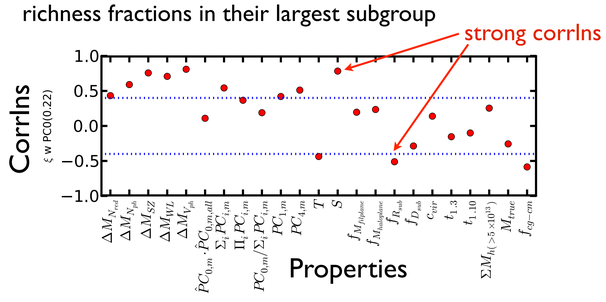
Correlations of mass scatter with cluster properties depending on line-of-sight for individual clusters

- We correlate between
  - the cosine angle of the mass scatter along each line-of-sight to PC0 direction.
  - the |cosine angle| between the line-of-sight and each of following directional dependent properties or the probability of substructure detection along the line-of-sight



- The largest correlation or covariance is with the direction of cluster long axis ➔ observing along long axis has largest contribution from PC0 (largest comb^n of correlated scatters)
- The next largest signals are with the direction orthogonal to the mass plane normal, the orthogonal to the filament plane normal and the direction of the largest substructure.
  - Many of these axes are close to each other in direction

PCA for cluster ensembles

For earlier related work, see Jeeson-Daniel++(11), Skibba&Maccio(11), Einasto++(11)

- Calculate PC's for some number of properties per cluster (in our case, e.g., 20-30, such as total variance in mass scatter, triaxiality, etc.).
- Calculate correlations of properties with PC's.
- Classify scalar properties of clusters into groups if they show strong and similar tendencies with correlations with PC's.
  - For example, higher triaxiality clusters tend to have higher richness fractions in their largest subgroup