Probing dynamical substructure in galaxy clusters using simulations & observations

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Old et. al., 2014, MNRAS 449, 1897
Old et. al., 2015, MNRAS 441, 1513

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Motivation

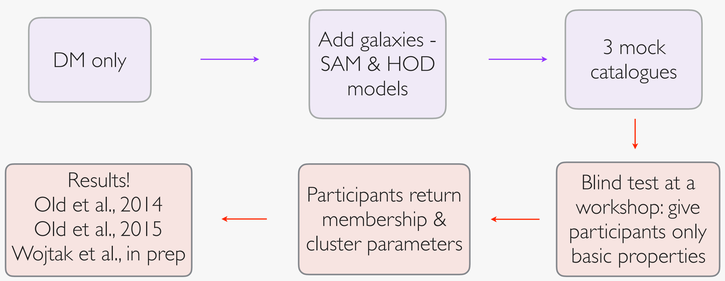
- Dynamical analyses of galaxy clusters provide a way of extracting both the **local and global dynamical history** of today's cluster galaxies.
- These analyses separate galaxies that reside in **dynamically distinct subgroups,** which are likely to have been **recently accreted** and also characterise the history of the galaxy's global environment e.g., by deducing whether clusters exhibit signs of a recent merger.
- To date, dynamical analysis has been generally restricted to clusters at low-z due to lack of spectroscopic redshifts. Here, I show preliminary results on the dynamical analyses of the **GCLASS** sample (PIs: Muzzin, Muzzin et. al., 2012) of **10 clusters at z~1**, for which there are an unprecedented number of spectra at this redshift.

Q. Does dynamical substructure impact cluster mass estimation?

Q. How prevalent is significant dynamical substructure at different epochs?

Testing whether dynamical substructure impacts cluster mass estimation

- We can use data from **The Galaxy Cluster Mass Reconstruction Project (GCMRP)** to test the impact of dynamical substructure on cluster mass estimation.
- The GCMRP is an on-going **blind study of 25 commonly-used cluster mass estimation techniques.** These galaxy-based methods were tested on several different mock galaxy cluster catalogs containing ~970 clusters each.
- The estimated vs. true cluster properties including mass, velocity dispersion, radius and cluster membership were then compared.



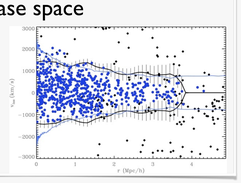
The cluster mass estimation techniques

The **25 different cluster mass estimation methods** are assigned a category based on the main galaxy population **property** used to estimate mass.

Phase space

Mass obtained via the positions and line-of-sight velocities of member galaxies.

E.g., Serra & Diaferio 2013



Richness

$N \propto M$

Velocity dispersion

Via the viral theorem: $M \propto \sigma^3$

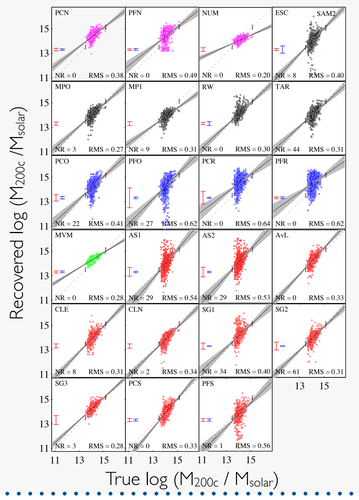
Abundance matching

Masses are estimated via matching a cluster to a halo from a theoretical halo mass function using the simulated cluster r-band luminosity function.

Radial

A dark matter profile is fitted to obtain the radius, or the RMS radius is estimated via the projected distance of galaxies from the cluster centre.

Estimated vs. true cluster mass for the whole sample



Richness
Phase space
Radial
Abundance matching
Velocity dispersion

What did we find?

- The scatter in recovered mass for majority of techniques is very high, a **factor of ~2-12** for varying mock catalogues.
- Many methods **over-predict** masses, pushing more clusters into higher mass bins. This is detrimental due to steeply falling high mass end of cluster mass function.

Measuring dynamical substructure

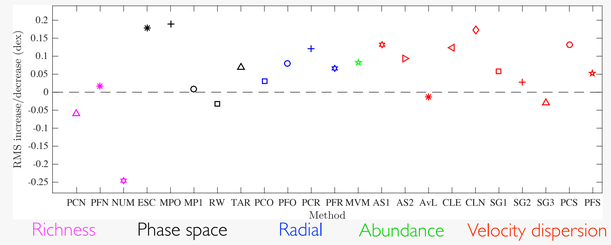
- The **Dressler-Shectman (DS) test** quantifies the **difference between local & global kinematics** by computing a deviation for the i-th cluster member: $\delta_i^2 = (\frac{N_{\rm nn}+1}{\sigma_{\rm c}})[(\overline{\nu}_{\rm local} - \overline{\nu}_{\rm global})^2 + (\sigma_{\rm global} - \overline{\nu}_{\rm c})^2].$
- The deviations are then summed to give the DS statistic: $\Delta = \sum_i \delta_i$
- This statistic is used to compute a P-value by performing 1000 Monte Carlo realisations, shuffling the velocities amongst positions. Here, we reject the null hypothesis that a cluster does not have significant substructure if P ≤0.01 (Dressler & Shectmann 1988, Hou et al. 2012).

Does dynamical substructure impact mass estimation?

We separate the sample of 968 clusters from the GCMRP into those that have significant dynamical substructure and those that don't and look at the fractional increase/decrease in mass errors:

Increased mass errors

Decreased mass errors

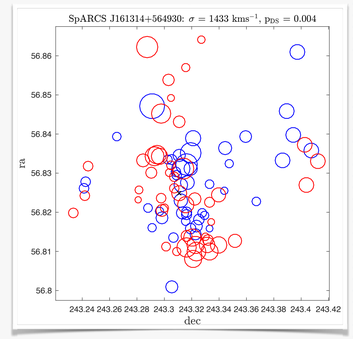


We find that methods have up to ~20% increased mass errors for clusters that have significant dynamical substructure!

Detecting dynamical substructure in cluster samples at z~1

PRELIMINARY

- GCLASS (PI: Muzzin) is a follow-up spectroscopic survey of 10 of the richest SpARCS clusters at z~1 where there are spectra of ~50 members per cluster.
- Only **1/9 clusters** has a DS P ≤0.01 indicating significant substructure - SpARCS J161314+564930 at z~0.871.
- Next: we need to check whether the sample complete-ness would impact the DS test.



Take home messages

- The scatter in estimated cluster masses for galaxy-based techniques is very high, **factor of ~2-12** for varying mock catalogues.
- **Significant dynamical substructure increases errors** in mass estimation with galaxies by up to ~20%.
- With new spectroscopic cluster samples such as **GCLASS, GOGREEN** (PI: Balogh), we can now attempt to detect dynamical substructure in large samples of clusters at high-z and compare this to low-z samples.

References

Muzzin et. al., 2012, ApJ 746 188 ✦ Old et. al., 2014, MNRAS 449, 1897, ✦ Old et. al., 2015, MNRAS 441, 1513 ✦ Serra & Diaferio 2013, ApJ 768 116 ✦ Dressler & Shectmann 1988, AJ 95 4 ✦ Hou et al., 2012, MNRAS 421, 3594

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