Calculating Scaling Relations of DES Galaxy Clusters using Multiwavelength Data

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Purpose

Validate galaxy clusters and data found by DES using the VT method and explain discrepancies found in mass and redshift.
VT cluster finder in 2+1D

**VT first run:** cluster candidates detected in photo-z shells

\[ \Delta z = 2\sigma_z (1 + z) \]

**VT second run:** boxes centered at each candidate allows to eliminate false detections due to projection effects and edge effects.
Background-DES

- Sky survey-began collecting data late last year
- Cosmology-focused
- 5000 square degree survey planned-1500 so far
- Optical wavelengths (grizY bands): from ~400nm to ~1μm
Galaxy clusters are the largest structures in the universe. Clusters are formed and held together by gravity. Composed primarily of dark matter, gas, and galaxies. Massive; usually $10^{13}$-$10^{15}$ solar masses.
Catalogs Used

Data was taken from the following:

- Stripe 82 SDSS coadd VT Cluster Catalog
- DES ‘gold’ VT Cluster Catalog
- SDSS Max BCG Public Catalog
- XMM and MCXC X-ray Cluster Catalogs
- Hasselfield et al. (2013) (ACT-SZ)
- Song et al. (2012) (SPT-SZ)
- Ruel et al. (2013) (SPT-SZ)
- SZ in MaxVis, MainSPT, and SpecZ catalogs
Matching of Clusters

- Clusters were first matched by right ascension and declination using the Hierarchical Triangular Mesh method (a python module), with the cutoff match radius set at 1.5′

- Redshift differences—given redshifts in most catalogues tended to be given with an error of ~.03-.09, the cutoff of redshift differences was set to .2

- This was done by creating a ‘box’ around the to-be matched cluster of z, RA, and dec

- Nvt was also limited to be greater than 9 as smaller clusters tend to give less accurate results
Estimated masses of each cluster were calculated using variables supplied by their respective catalogues (including $y$, luminosity, velocity dispersion, et cetera), or by the mass already estimated by the catalogue.

Equations for each method are included in their respective slides.

Masses for the VT clusters were obtained with the Weak Lensing methods devised by Matt Wiesner and Huan Lin.

For the ‘gold’ catalog, the following was used $M_{200c} = 1.44A\left(\frac{N_{VT}}{20}\right)^B$.

Masses were plotted using matplotlib—a python matlab simulator.
maxBCG vs ACT-SZ

Initial check
Average $\frac{M}{M_{VT}} = 1.48$
Median $\frac{M}{M_{VT}} = 1.23$
Average $\frac{M}{M_{VT}} = 2.02$

Median $\frac{M}{M_{VT}} = 1.69$
Nonthermal20

Average $\frac{M}{M_{VT}}=2.47$

Median $\frac{M}{M_{VT}}=2.08$
Average $\frac{M}{M_{VT}}=1.99$
Median $\frac{M}{M_{VT}}=1.87$
Mass UPP

Average $\frac{M}{M_{VT}} = 2.23$
Median = 1.83

UPP Mass is based on the $y$
Parameter (For Stripe 82 clusters, $M_{200c} = A\left(\frac{N_{VT}}{20}\right)^B$
was used)
Mass B12

Average $\frac{M}{M_{VT}} = 2.96$

Median = 2.43

Based on the B12 model
Nonthermal20 mass

Average $\frac{M}{M_{VT}} = 3.49$
Median = 2.96
Based on the Nonthermal20 model
Dynamical mass

Average $\frac{M}{M_{VT}} = 2.87$
Median = 2.31
Dynamical Mass is based off of velocity dispersion and is detailed in Sifon et al. 2011
\[ M_{200c} = M_{200|20} \left( \frac{N_{200}}{20} \right)^{\alpha} \]

Equation 9 of Simet et al. 2012

Average \( \frac{M}{M_{VT}} = 1.34 \)

Median = .98
$yE_z^{-2} \alpha M_{500c}$

Eq. A4 of Marriage et al. 2011

Slope=.2556

Y-intercept=.4989
Velocity Dispersion (SPT-SZ)

\[
\frac{M_{200c}}{10^{14} M_\odot} = \frac{10}{h(z)} \left( \frac{\sigma_{DM}}{\sigma_{15}} \right)^{\frac{1}{\alpha}}
\]

Eq. 2 of Buckley-Geer et al. 2011

(Originally Evrard et al.)

Average $\frac{M}{M_{VT}} = 4.67$, median = 2.20
\[ \sqrt{\langle \xi^2 \rangle - 3} = A \left( \frac{M}{5 \times 10^{14} M_\odot h^{-1}} \right)^B \left( \frac{1 + z}{1.6} \right)^C \]

Equation 1 of Vanderlinde et al 2010

Average \[ \frac{M}{M_{VT}} = 5.22 \], median = 2.92
Luminosity (XMM& MCXC)

- $L_X \propto F_z^{7/3} M_{\text{total}}^{4/3}$

Equation 16 of Giodini et al 2013
Slope=0.405
Y-Intercept=0.039
Website

Data (including redshift, RA, dec, mass, etc.) was compiled into an html file including pictures of clusters

Site makes for quick and easy access of findings
Reasoning for discrepancy

- Many VT clusters did not find matches of other established catalog, indicating they may be fake or unreal clusters
- Equations across separate papers are not consistent
Conclusions

- In every case, the mass predicted by weak lensing was less than the mass predicted by the respective relationship for each catalogue, by a semi-consistent factor of ~2-3
- Most plots show a weak correlation of masses, suggesting a problem with VT mass calibration
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