The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2419-11

Workshop on Large Scale Structure

30 July - 2 August, 2012

Relation Between Galaxy Cluster Optical Richness and SZ Effect

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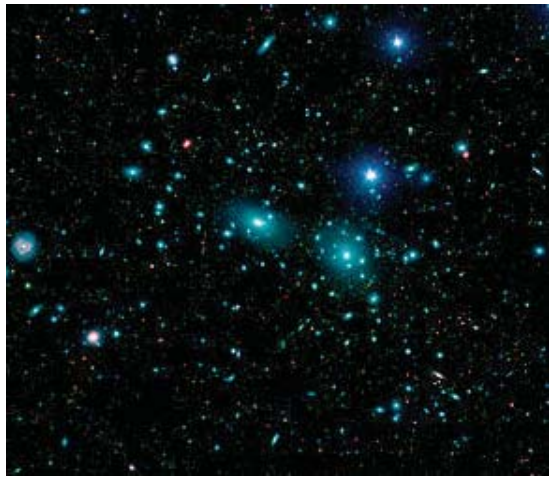
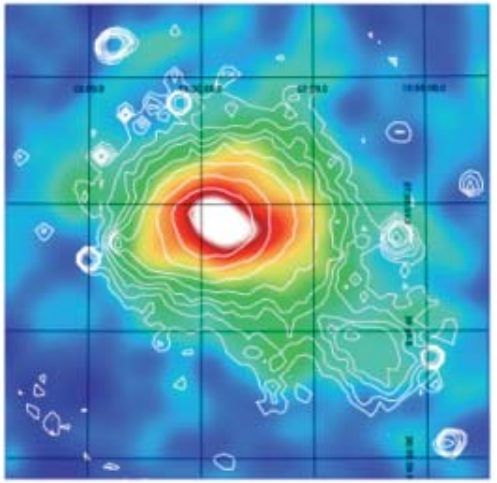
Relation Between Galaxy Cluster Optical Richness and SZ Effect



SDSS



Planck

Neelima Sehgal
Princeton University

Workshop on Large Scale Structure
ICTP, Trieste, Italy - July 31, 2012

Outline

- Motivation for Exploring Relation Between Optical Richness and SZ Signal
- What is ACT and what can it add?
- ACT Results
- Other Literature
- Conclusions

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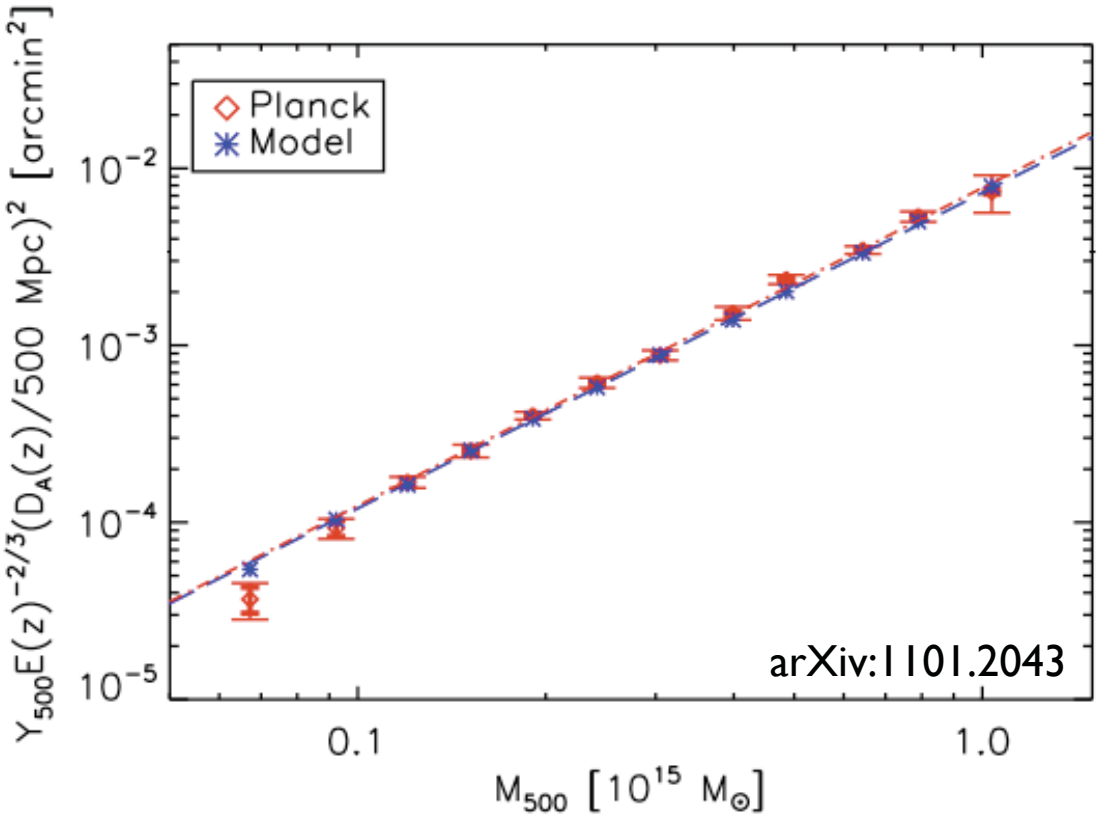
Puzzle...

- Planck stacked X-ray selected clusters, and found agreement between expected and measured SZ signals

- Planck stacked optically-selected clusters, and found disagreement between expected and measured SZ signals

- Both X-ray and Optical samples give same cosmology

Planck Results: SZ/X-ray Scaling Relations

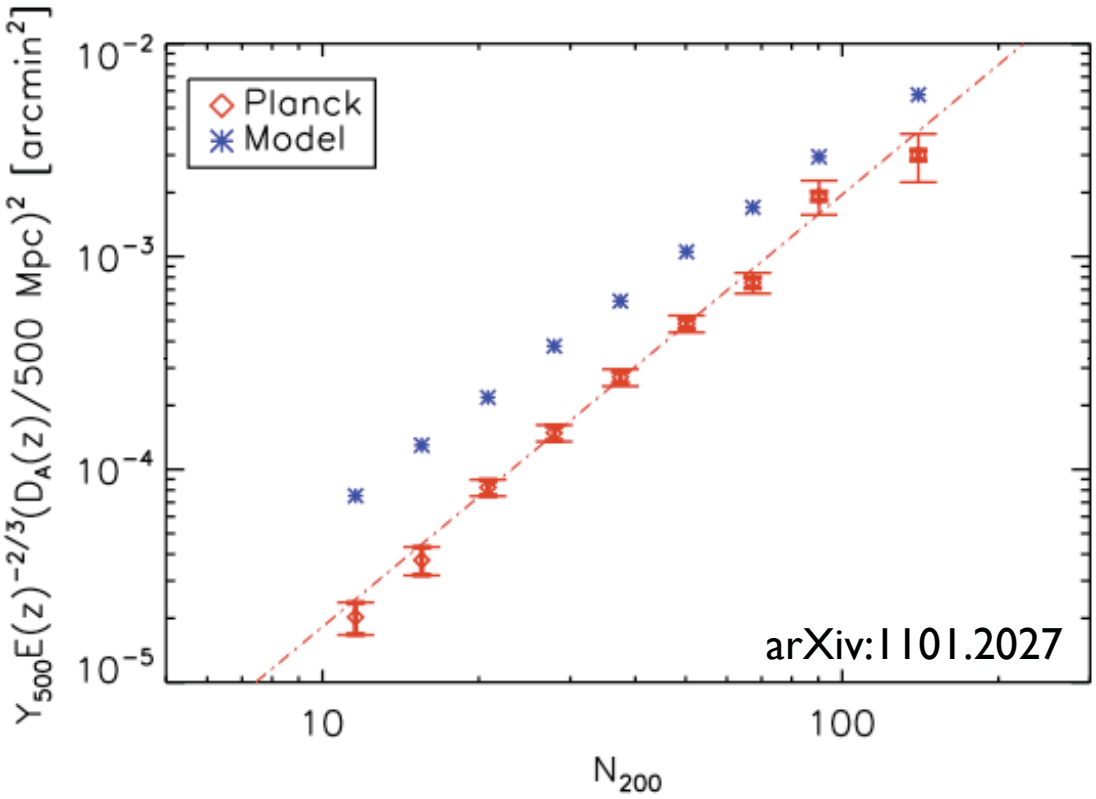


MCXC sample of ~1800 clusters

To predict Y_{500c}:
- Used L_{500c} - M_{500c} relation to get M_{500c} for each cluster
- Used Arnaud et al 2010 relation to get P_{500c} for each cluster

To measure Y_{500c}:
- Used a multi-frequency matched filter
- Measured the norm of an assumed profile
- Profile chosen to be Arnaud et al 2010
- R_{500c} for each cluster's profile size taken from L_{500c} - M_{500c} relation

Planck Results: SZ/Optical Scaling Relations



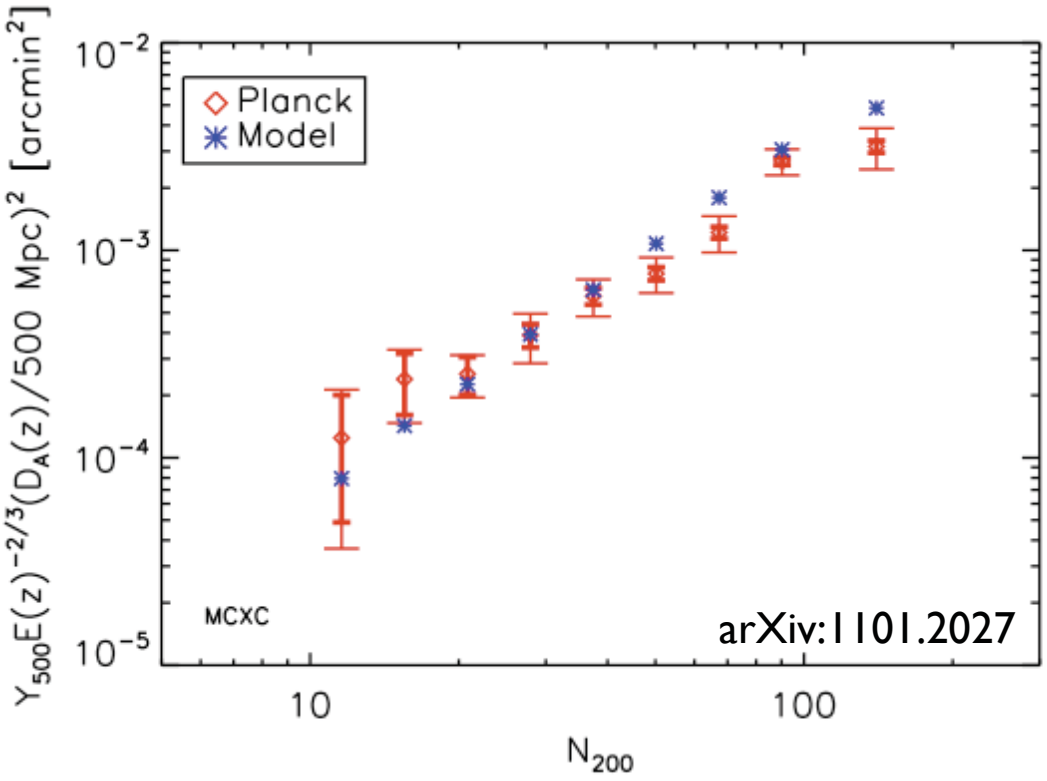
MaxBCG sample of ~14000 clusters

To predict Y_{500c}:
- Used N_{200m} - M_{500c} relation to get M_{500c} for each cluster
- Used Arnaud et al 2010 relation to get P_{500c} for each cluster

To measure Y_{500c}:
- Used a multi-frequency matched filter
- Measured the norm of an assumed profile
- Profile chosen to be Arnaud et al 2010
- R_{500c} for each cluster's profile size taken from N_{200m} - M_{500c} relation

Disagreement corresponds to ~ 50% mass difference

Agreement where samples overlap



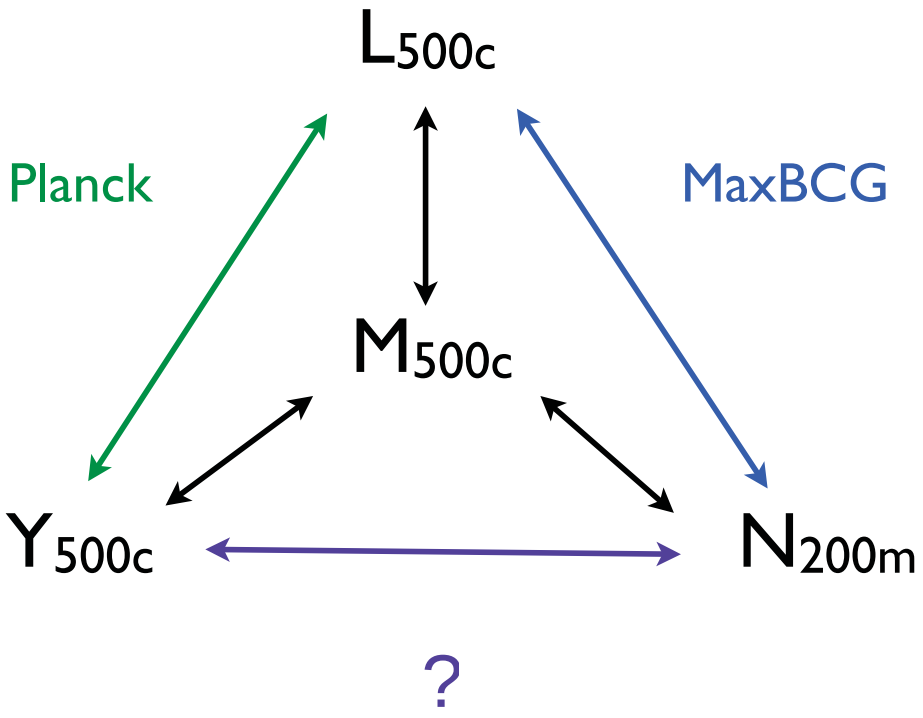
Planck finds agreement when using subsample of 189 clusters in common to MCXC and MaxBCG

Also finds agreement when using MaxBCG subsample with dominant BCGs

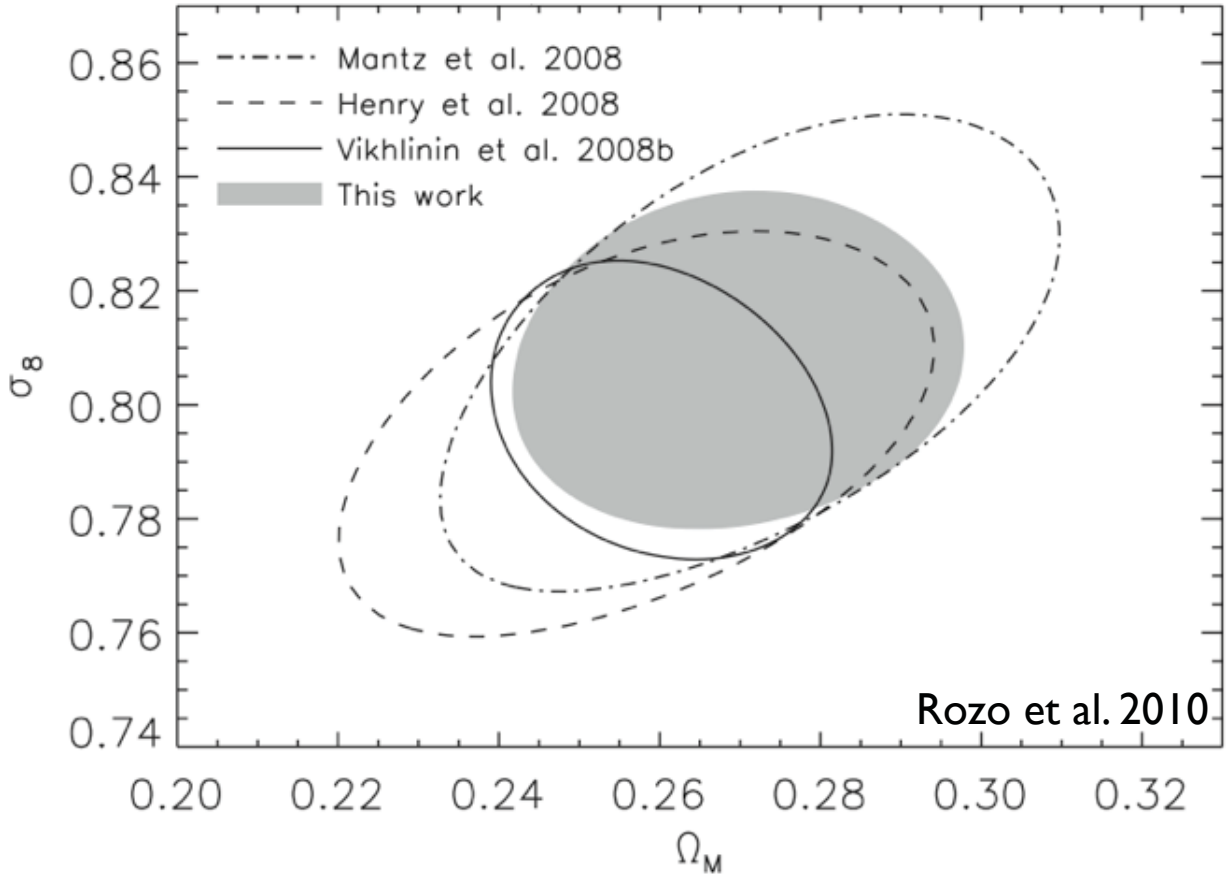
Planck argues for 2 populations of clusters

Normal sample and X-ray/SZ under-luminous sample

Triangle



Both X-ray and Optical Cluster Samples Give Consistent Cosmology



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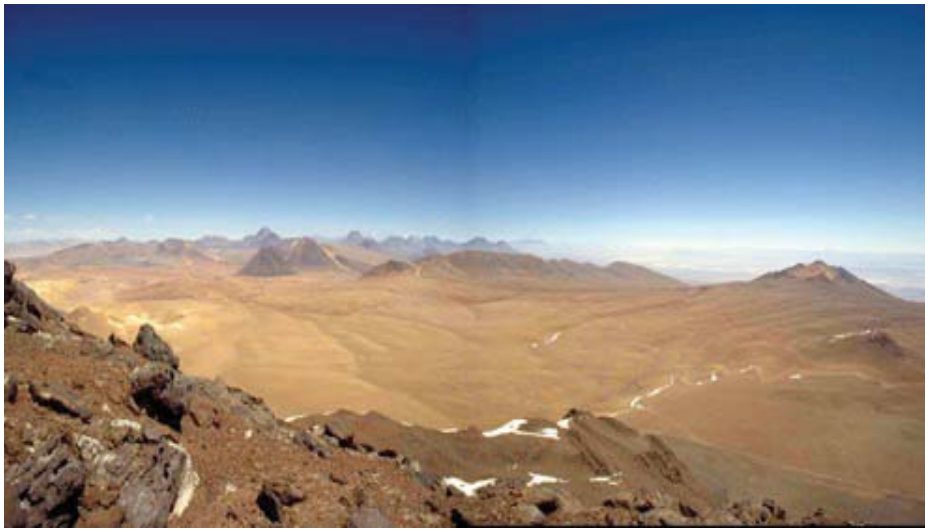
Atacama Cosmology Telescope

6-meter primary mirror, 1 deg field of view

3 frequencies: 148, 218 277 GHz

1.4 arcmin resolution, 3000 TES detectors

Where is ACT?



Atacama Desert

5200 meter elevation

One of driest places on Earth

ACT Collaboration

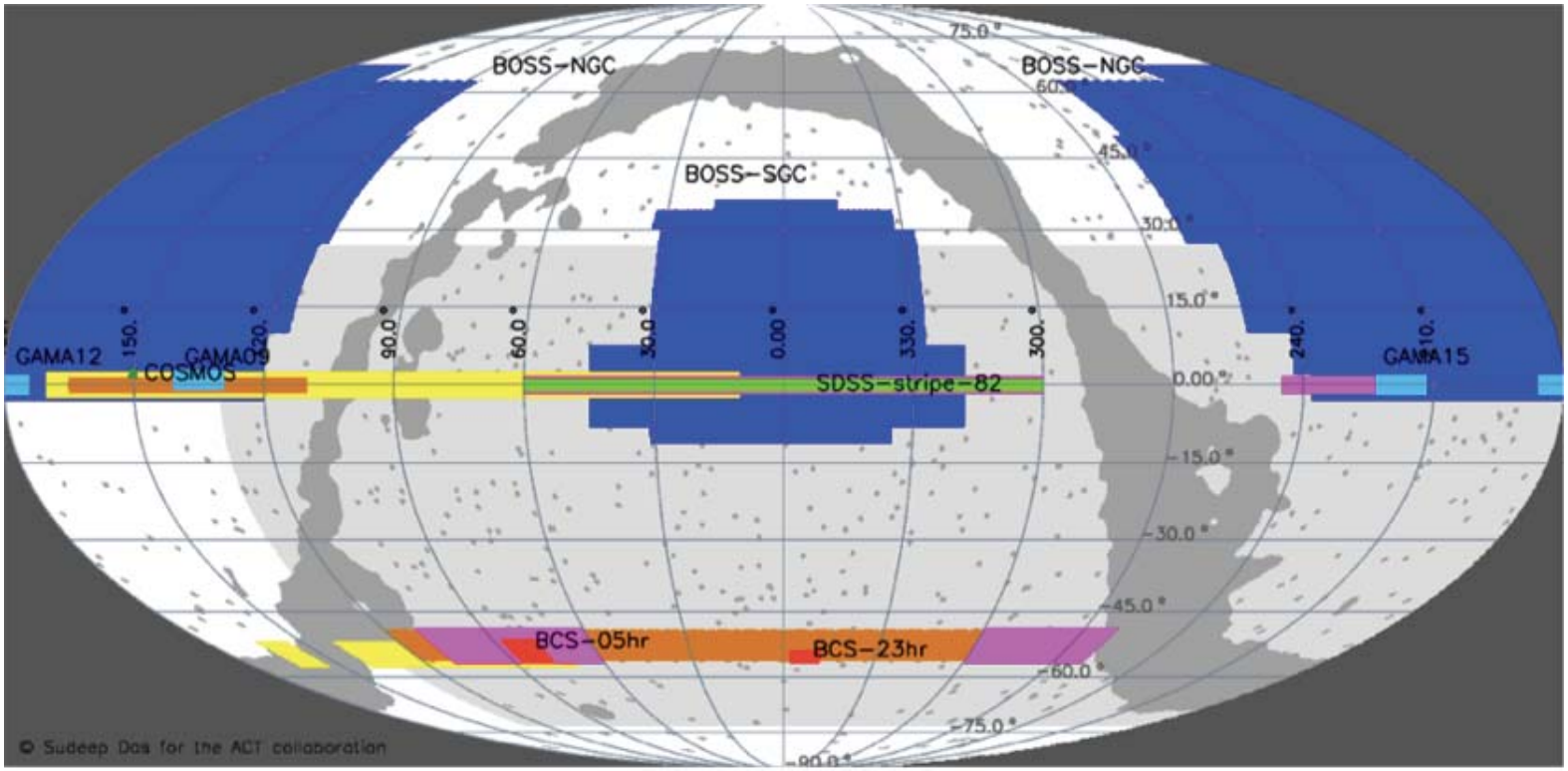
The ACT Collaboration (~90 collaborators)

- Barcelona ICE (Europe)
- UBC (Canada)
- Univ of Cape Town (S. Africa)
- Cardiff Univ (UK)
- Columbia (US)
- Haverford (US)
- INAOE (Mexico)
- Univ of Kwa-Zulu Natal (S. Africa)
- Univ of Massachusetts (US)
- NASA/GSFC (US)
- NIST (US)
- Oxford (UK)
- Univ of Pennsylvania (US)
- Princeton (US)
- Univ of Pittsburgh (US)
- Pontifica Univ Catolica (Chile)
- Rutgers (US)
- Univ of Toronto (Canada)
- With collaborators at La Sapienza, MPI, Miami, Stanford, Berkeley, Chicago, CfA, LLNL, IPMU Tokyo

- PI - Lyman Page, Princeton

ACT Observing Regions

ACT has taken 17 months of data at 3 frequencies, ~1000 deg^2



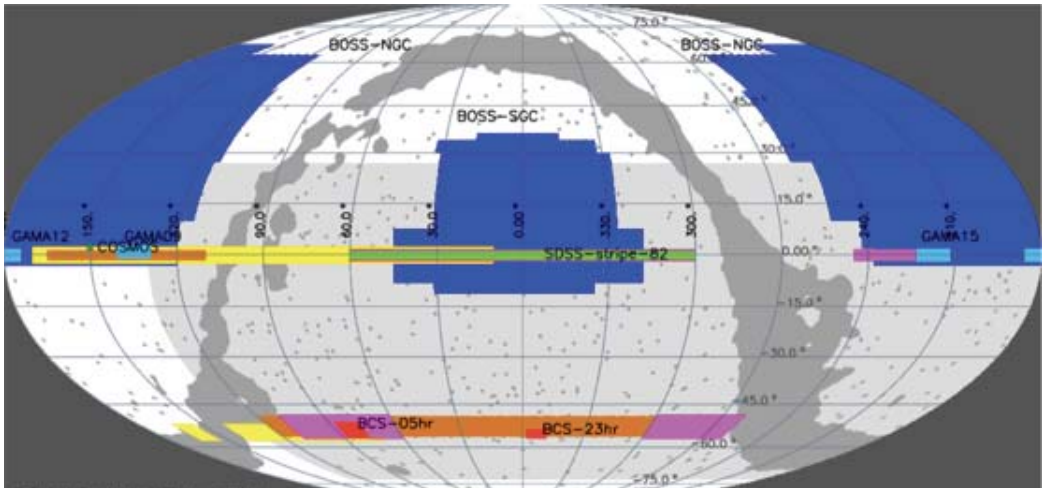
Neelima Sehgal, Princeton

ACT Overlaps SDSS Region

ACT observed ~500 sq. deg in Equatorial region, which includes Stripe 82

Overlaps ~500 MaxBCG clusters

Can investigate Planck SZ/Optical Scaling relation



ACT finer resolution and lower noise can allow us to work towards understanding what is going on

(Sehgal et al, arXiv:1205.2369)

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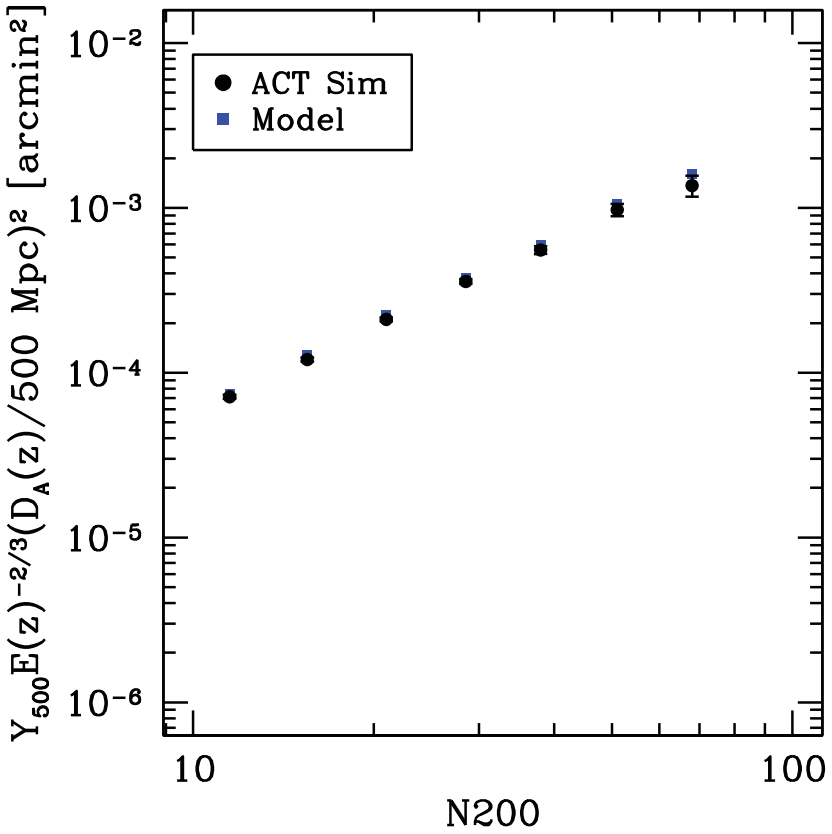
Recovered SZ from Simulated Clusters Embedded in ACT Data



492 MaxBCG clusters fall in the ACT region

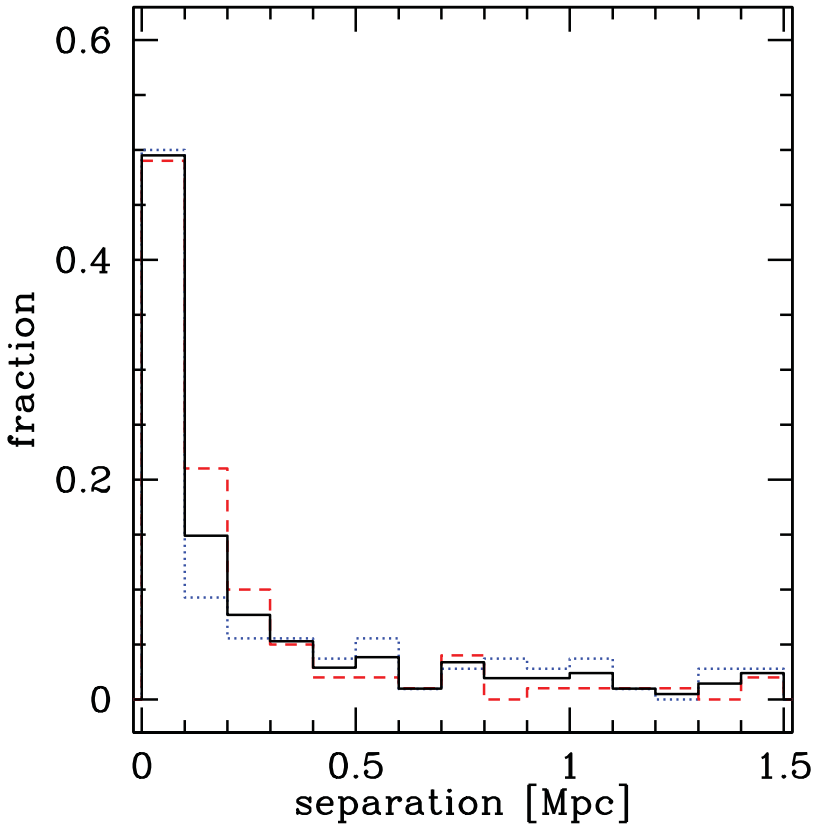
492 simulated clusters embedded in ACT data at random positions

R_{500}, M_{500} of simulated clusters match real clusters

Arnaud et al. 2010 pressure profile assumed

arXiv:1205.2369

Separation Between BCGs and X-ray Peaks for X-ray Sample



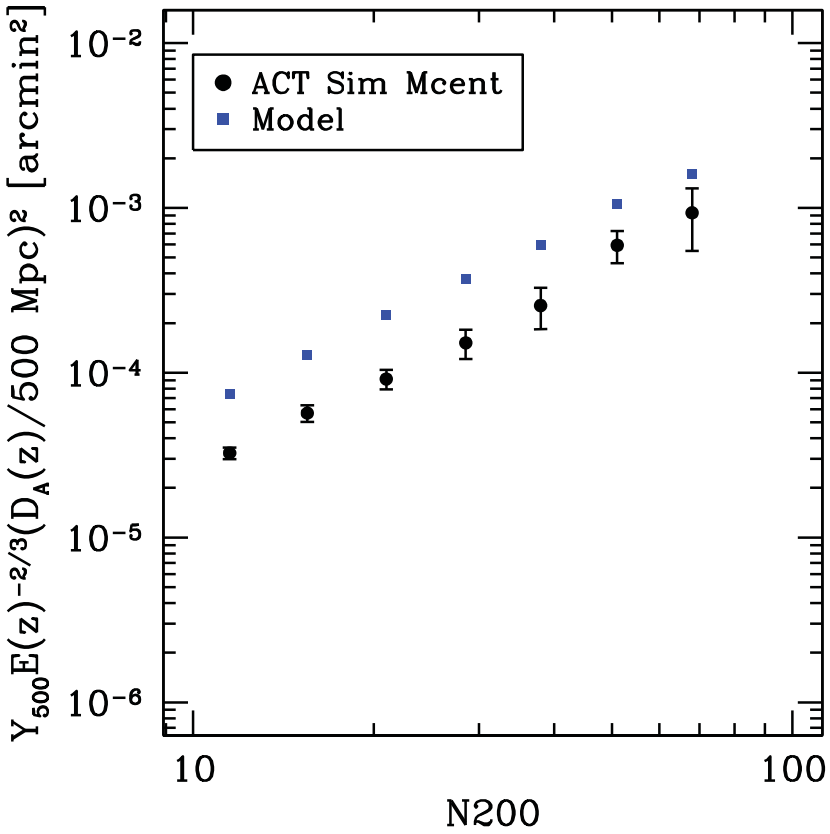
What does ACT expect to see if optical N_{200} - M_{500} relation correct?

189 clusters in common in full MCXC (X-ray) and MaxBCG (Optical) samples - only 6 in common in ACT data

Evidence of separation between BCGs and X-ray peaks

arXiv:1205.2369

Simulated ACT Expected Signal Given BCG/X-ray Peak Separation



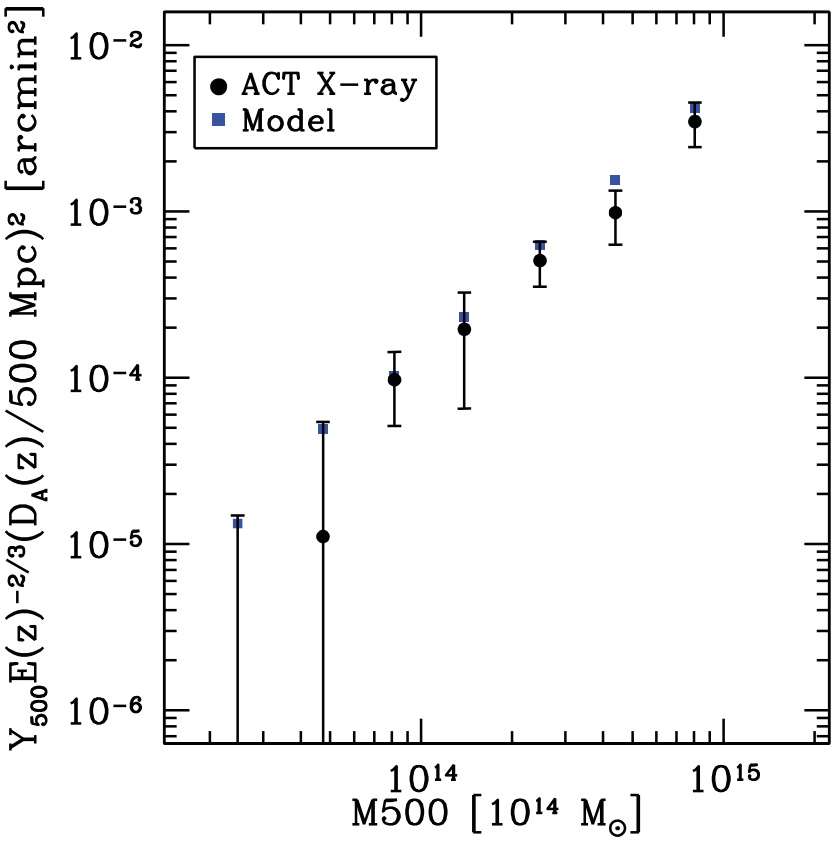
Model BCG/SZ-peak separation in simulated clusters as in Figure above

ACT expects measured signal lower than model even if N_{200} - M_{500} relation correct

arXiv:1205.2369

Measured ACT SZ Signal For 52 X-ray-Selected Clusters

Measured SZ signal of 52 MCXC clusters (X-ray-selected) to check pipeline



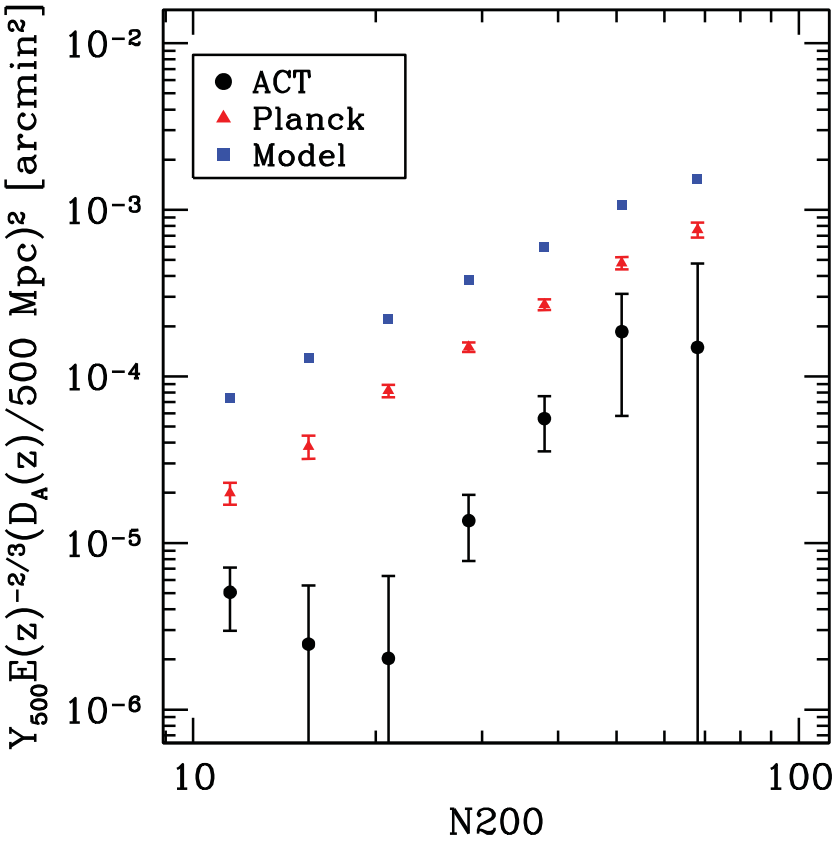
Find agreement between measured and expected SZ signals

Consistent with Planck result

arXiv:1205.2369

Measured ACT SZ Signal For 474 Optically-Selected Clusters

474 MaxBCG (Optically-selected) clusters excluding those near point sources and map edges



Recovered SZ signal lower than that found by Planck

arXiv:1205.2369

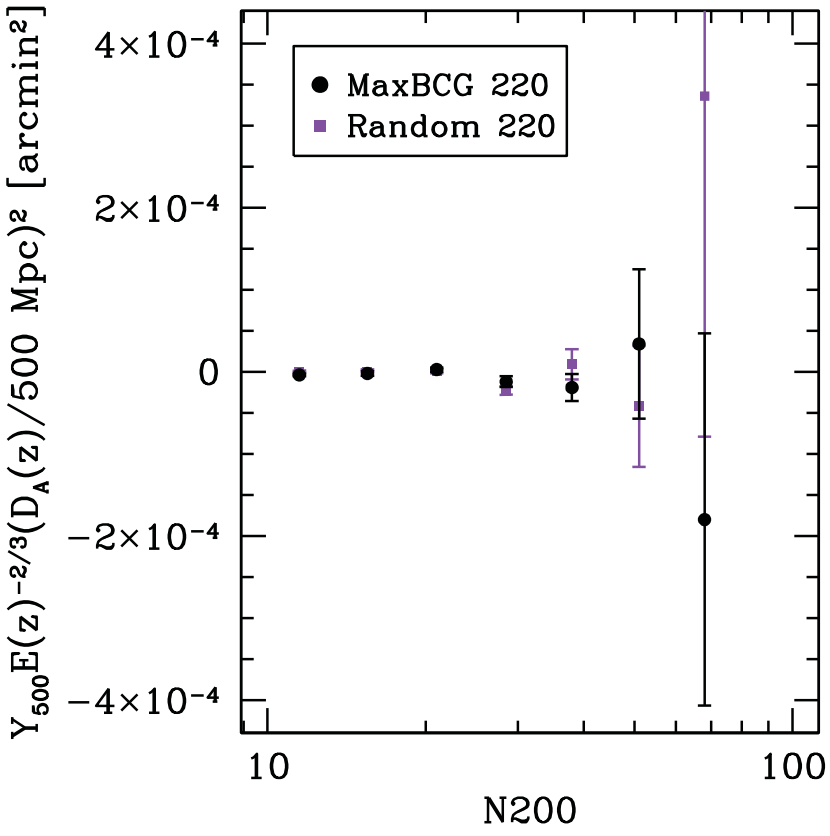
No Evidence for Excess IR Galaxies in Optical Clusters

Radio or infrared galaxies filling in SZ signal?

220 GHz at SZ null - stack optical clusters there

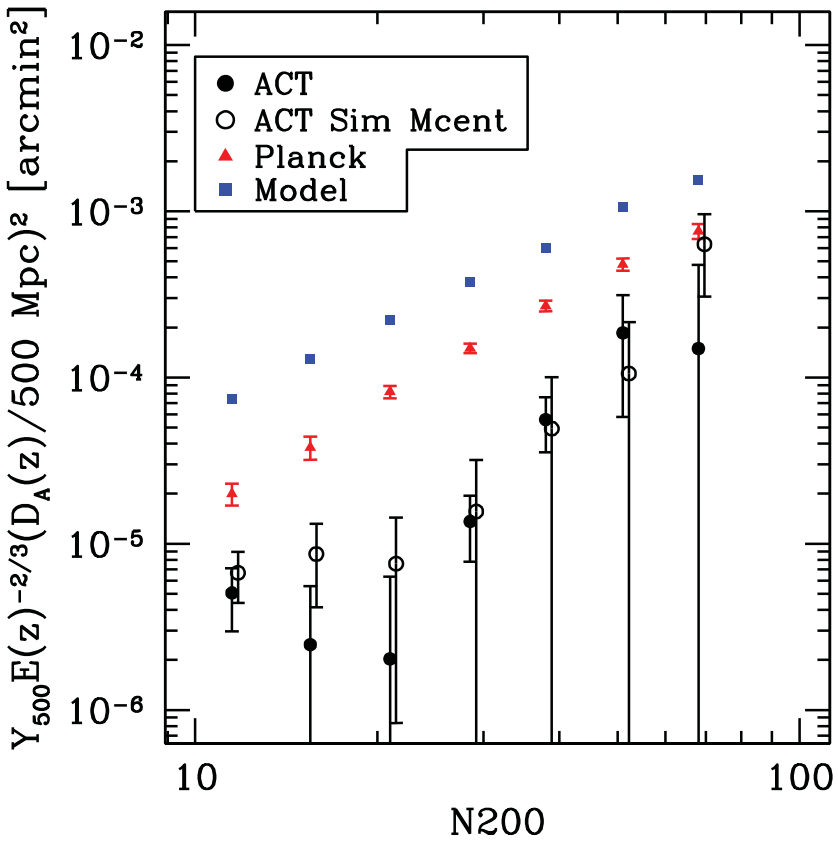
No evidence for excess infrared emission at cluster positions - expected since low-z ($z < 0.3$) cluster sample

Cross-correlated with FIRST radio catalog - no significant excess radio correlation



arXiv:1205.2369

ACT SZ Signal for Optical Clusters Fit with Model of Large BCG/SZ-Peak Separation



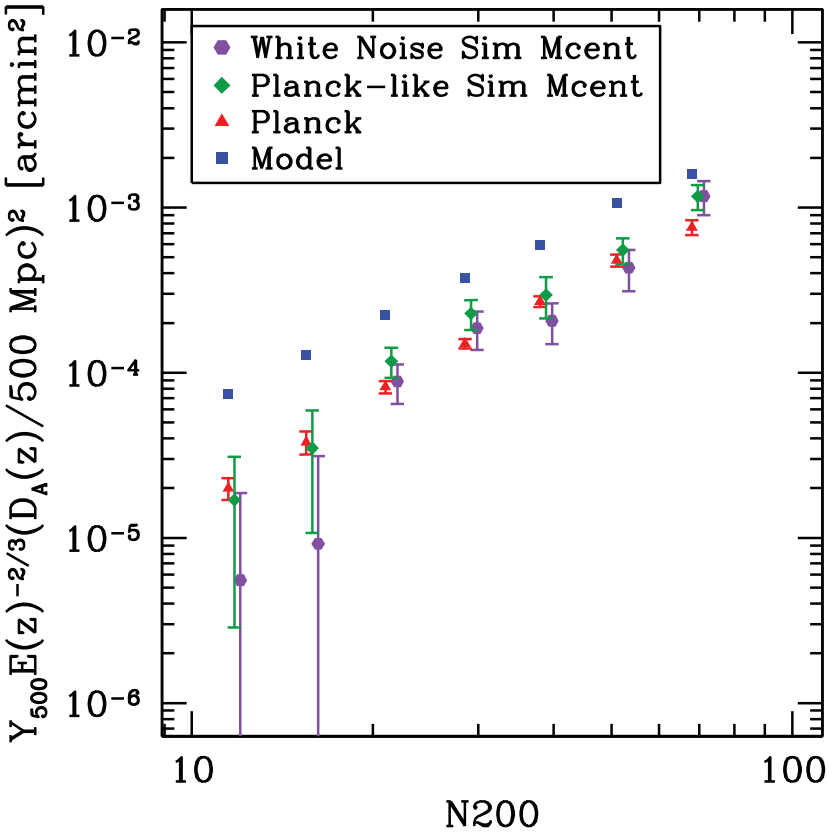
Can we fit ACT SZ measurements with model with larger BCG/SZ-peak separation?

Yes. One model that fits data is BCG/SZ-peak separation with uniform random distribution between 0 and 1.5 Mpc

This separation is much larger than seen for 189 cluster X-ray-selected sample above

arXiv:1205.2369

Planck SZ Signal for Optical Clusters Fit with Same Model

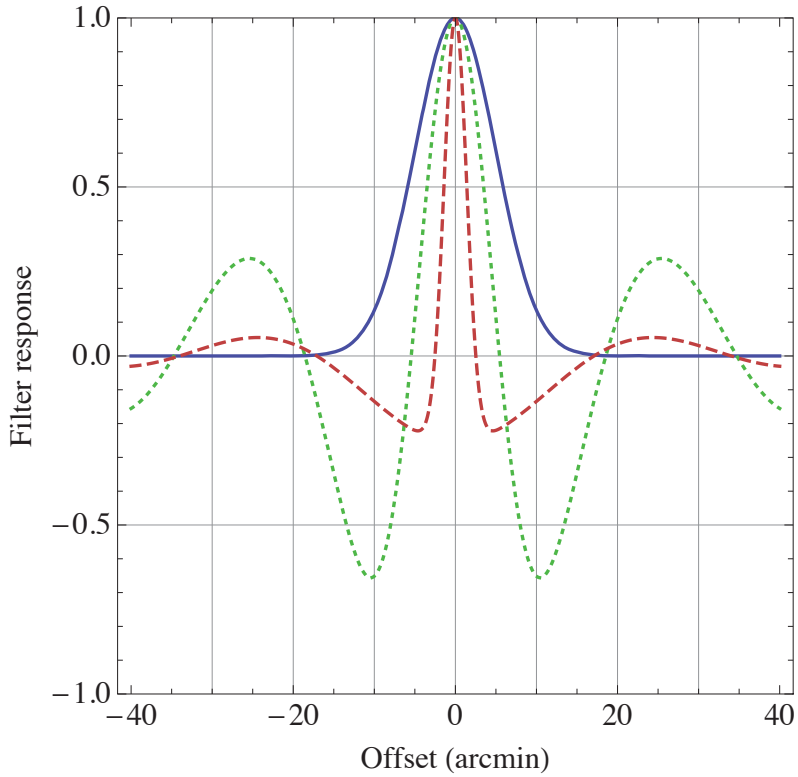


Does this same model of BCG/SZ-peak separation fit Planck data?

Yes.

arXiv:1205.2369

BCG/SZ-Peak Separation Can Give Different ACT and Planck SZ Signals



Higher resolution of ACT (1.4') compared to Planck (5 to 7') makes ACT more sensitive to separation

Due to different noise properties and resolutions of ACT and Planck, separation can yield large differences in measured SZ signals

arXiv:1205.2369

Interpretation of ACT results

- Measured SZ signal for X-ray-selected clusters as expected
  - Infer SZ traces X-ray gas
- Measured SZ signal for Optically-selected clusters lower than model
  - Also lower than Planck measured signal
- Not many effects can cause different ACT and Planck SZ signals
  - BCG/SZ-peak separation is one obvious way
- Other factors can lower SZ signal equally for ACT and Planck
  - Then less BCG/SZ-peak separation would be required to explain difference

Ways to Lower SZ Signal Equally for ACT and Planck

- More false detections in optically-selected sample
- Lower normalization of N_{200}-M_{500} relation
- Low intrinsic SZ signal (e.g. nonthermal pressure)
- Radio or infrared galaxy contamination
  - Needs to be preferential to optical sample

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Other Results in the Literature

- Biesiadzinski et al. 2012 - Planck discrepancy is ok if norm of N_{200}-M_{500} relation is 2σ low
  - Rozo et al. 2012 (1204.6292) shows this would shift significantly cosmology

- Angulo et al. 2012 - norm of N_{200}-M_{500} is incorrect
  - They also emphasize difference between flux-limited and volume-limited samples

Other Results in the Literature

- Bauer et al. 2012 - Rozo et al. N_{200}-M_{500} norm of consistent with the norm they find using lensing magnification of quasars behind clusters
- Rozo et al. 2012 (1204.6292,1204.6301,1204.6305)
  - N_{200}-M_{500} norm may be 10% high
  - Chandra Lx - M_{500} norm 20% low due to nonthermal pressure
  - XMM-Newton Lx - M_{500} norm 10% - 20% lower than Chandra Lx - M_{500} norm

Possible Ways Forward

- Look at individual clusters with high-res SZ instruments such as CARMA or MUSTANG2

- ACTpol - larger area overlapping SDSS/BOSS

Future: ACTpol

ACT has observed during 2008, 2009, and 2010 - in south and over equator - at least 1000 sq deg, goal of ~25μK/arcmin^2

ACTpol is funded by NSF: 3-year survey to begin in 2012

Detectors 2-3 times more sensitive, with polarization capability

4000 sq deg; 20μK/arcmin^2; ~1000 clusters with M>$5 \times 10^{14} M_{\odot}$

Overlaps with SDSS-III/BOSS and HyperSuprime Camera (HSC) on the Subaru telescope (2000 - 8000 sq deg weak-lensing survey)

➡ Spectroscopic cluster redshifts and weak-lensing masses

SDSS-III/BOSS

Subaru Telescope

Conclusions

- Measured SZ signal for X-ray-selected clusters as expected
  - Infer SZ traces X-ray gas
- Measured SZ signal for Optically-selected clusters lower than model
  - Also lower than Planck measured signal
- Not many effects can cause different ACT and Planck SZ signals
  - BCG/SZ-peak separation is one obvious way
- ACT and Planck data can be fit by separation that is, e.g., uniform random between 0 and 1.5 Mpc
  - X-ray-selected sample has 70% within 0.3 Mpc
- Other factors can lower SZ signal equally for ACT and Planck
  - Then less BCG/SZ-peak separation would be required to explain remaining difference