Matter Energy Density and Sunyaev-Zel'dovich Clusters[a]

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Recent technological advances allow for the construction of instruments which can survey the sky for clusters of galaxies via the redshift-independent Sunyaev-Zel'dovich effect, and therefore can test theoretical models of cluster evolution and constrain the model parameters. Our work quantifies these expectations by using cluster gas simulations and the Press-Schechter expression to produce sky maps, and then simulating the telescope observation of these in detail. Key constraints on the matter density, the gas evolution in clusters and the power spectrum can be obtained from the study of clusters selected from a blank field SZ survey. AMI, the Arcminute MicroKelvin Imager, an interferometric array described by Jones and Saunders in this volume, has the performance needed.

Cluster survey sensitivity of the Arcminute MicroKelvin Imager (AMI)

We use dark matter and hydrodynamical simulations[1] of galaxy clusters to generate templates for the integrated cluster gas pressure, and we use the Press-Schechter[2] expression to produce sky maps of the Sunyaev-Zel'dovich[3] (SZ) effect in clusters. Our choice of the model parameters, namely f_g/β = 0.1 (gas fraction over β-parameter) and $\sigma_8 = 0.52/0.87$ (power spectrum normalisations for $\Omega = 1/0.3$) leads to conservative estimates of the results. More optimistic choices (eg. Holder, this volume) lead to higher expectations for the number of clusters for very similar instrument sensitivities. We observe our SZ maps (see Figure 2 in Jones and Saunders for an example) using an algorithm which simulates the performance of AMI, where we take into account the complicated response and noise propertise of an interferometric field observation, and the source recovery process (CLEAN). The expectations for cluster detection with AMI are summarized in the figure.

[a] The poster contribution can be found at http://moriond.in2p3.fr/J00/vendredi/Jones-Saunders/kneissl.ps.gz

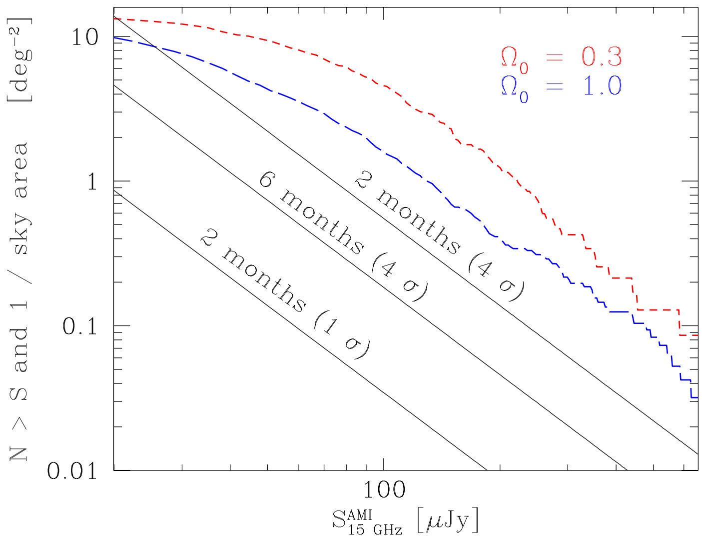

Figure: SZ source counts for low (short dashed; top) and high (long dashed; below) matter density and survey sensitivity lines (solid; labeled) in 1 / sky area as a function of observation time. The ratio between these curves equals the number of detected clusters. At high fluxes the source counts rise steeper than the sensitivity lines, showing that a deeper survey will return more clusters for the same observation time up to the point where confusion sets in. Thus a shallow maximum in the expected number of clusters is seen around 100 μJy for both cosmologies. However the source counts can also be tested over a wider range of fluxes at a low cost of inefficiency. The error on the ratio of the curves and the field-to-field variation is given to a good approximation by Poisson statistics for the number counts.

Estimation of cosmological and cluster gas evolution parameters

The expected change in SZ source counts with cosmology is substantial: $N_{\Omega=0.3}/N_{\Omega=1} \approx 3.5$, so that the SZ survey gives an immediate result. There are degeneracies, illustrated below,

Parameter	Change in percent	fractional change in $N(>S)$
h	20 %	1.3
f_g/β	30 %	1.5
σ_8	7 % ($\sim 1\sigma$)	1.5

which can be broken with optical and X-ray follow-up observations and individual constraints on cosmological and cluster gas evolution parameters can be obtained. Given the small FoV of current and future high sensitivity X-ray telescopes and the low sky density of the SZ sources, the follow-up should be done with observations pointed at the targets found in the SZ survey. The exposure times can then be adjusted to the X-ray count rates to optimally probe the gas evolution and redshift distribution together. Optical follow-up will determine spectroscopically or photometrically individual cluster redshifts.

Conclusions

Since SZ observations measure the integrated gas pressure over a cluster independent of redshift, the selection function of a SZ survey is approximately the total cluster mass assuming hydrostatic equilibrium. Both current simulations and observations seem to indicate that this assumption is significantly violated only for short times. AMI will detect *at least* 20 to 70 clusters per year, depending on cosmology. The number of detected clusters, although affected by degeneracies with other model parameters, is indicative of the cosmology. When the clusters are observed at X-ray and optical wavelengths these degeneracies can largely be broken, and interesting individual estimates can be obtained for the matter density Ω, the gas evolution in clusters $f_g/\beta(z)$ and the power spectrum normalisation σ_8. Clusters found at high redshift will be extremely interesting targets for further observations to study details of the cluster physics.

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References

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