PROCEEDINGS OF SCIENCE

Constraining cosmology with SZ cluster surveys

J. Geisbuesch*
Astrophysics Group, Cavendish Laboratory, University of Cambridge
E-mail: joern@mrao.cam.ac.uk

The galaxy cluster redshift distribution is a sensitive test of the cosmological model. We discuss how up-coming Sunyaev-Zel'dovich surveys can be used to constrain cosmological parameters. Our discussion includes aspects of cluster selection, sample contamination and systematics of these surveys. Furthermore, we take account of effects due to late cluster physics. Our contribution compares the performances of different instruments and detection algorithms.

From Planets to Dark Energy: The Modern Radio Universe
1^{st}-5^{th} October 2007
The University of Manchester, United Kingdom

*Speaker.

PoS(MRU)095

1. SZ cluster surveys

Cluster abundances at different redshifts depend strongly on the (linear) growth of matter perturbations and the observed space volume. Hence they are a useful probe of cosmology. The SZ effect represents a powerful way of detecting clusters due to its 'redshift independence'. There are several SZ survey instruments operational and up-coming, such as ACT, AMI, Amiba, APEX-SZ, OCRA, SPT and the Planck satellite. Figure 1a shows a simulated radio interferometer observation. The simulation assumes a frequency band of 6 GHz centred at 15 GHz. Generally, data is contaminated by noise, fore- and backgrounds and beam convolved. Thus, to obtain a cluster sample from observations, data have to be processed and cluster extraction algorithms have to be applied. Common cluster extraction algorithms are based on various methods, such as matched filtering (MF) and parametrised Markov Chain Monte Carlo object detection (see also [1], [2], [3], [4] and [5]).

Methods differ in speed, memory requirements and success and failure rate. Important cluster sample characteristics, by which methods can be compared when applied to the same data, are the completeness and the purity of the sample. In general, these benchmarks are governed by the instrument design, the observing strategy and the cluster detection algorithm. Figure 1b shows the redshift cluster mass selection of a deep interferometric blank field cluster SZ survey, as it can be obtained by applying a MFMF or a MCMC method respectively. Samples of both these algorithms are characterised by very high purity. The MCMC sample is slightly more complete, the method computationally more costly.

2. Mass functions

The mass function gives a cosmology dependent prediction of the cluster number count within a mass bin and at a given redshift. A widely used mass function is the Jenkins one, which

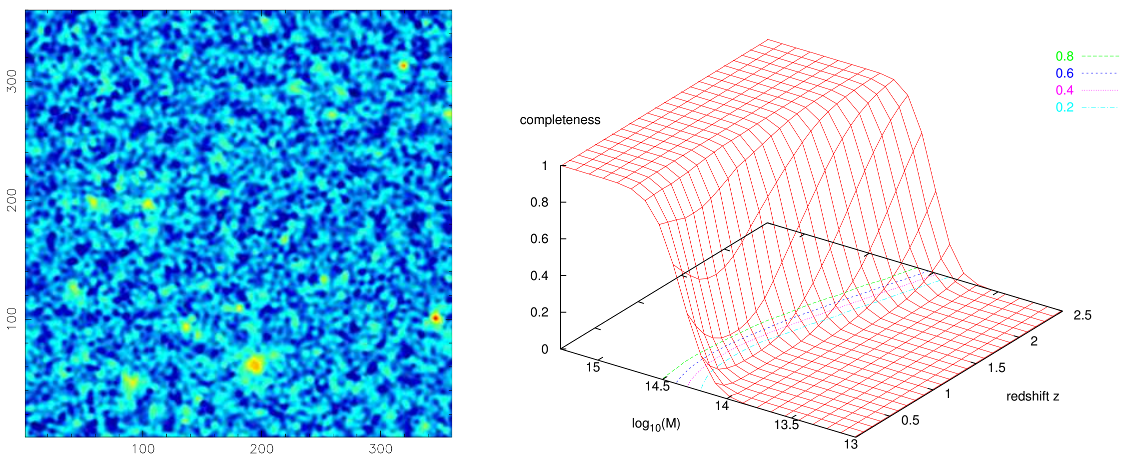


Figure 1: (a) Simulated interferometric SZ observation at 15 GHz. (b) Cluster detection completeness as function of mass and redshift as obtainable by application of a MFMF method to the data.

has been found to provide good fits to a wide range of N-body simulations and cosmologies. However, for most clusters it is not possible to determine their mass directly by observation.

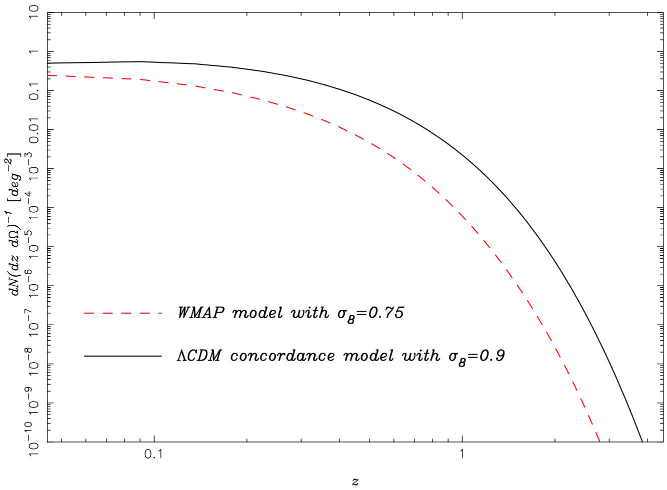
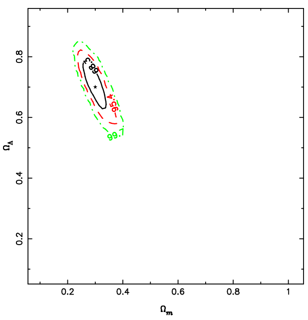


Figure 2: Cluster number counts per square degree for surveys with a flux limit of $Y_{\rm lim} = 1 \times 10^{-3}$ arcmin^{-2}.

In order to compare observed cluster number counts with theoretical predictions, scaling relations between observables and the cluster mass are required. For SZ surveys it is the relation between the integrated Comptonization parameter Y (cluster flux) and the cluster total mass $M_{\rm cl}$ which is commonly used, due to its rather low dispersion around the mean scaling. A general parametrised form of this relation is given by: $Y \propto \beta_*^{-1}(1+z)^{(1-\alpha)} d_a^{-2}\,[\Delta_c\Omega_m/\Omega_m(z)]^{1/3} M_{\rm cl}^{\gamma}$ (equation 1), where the parameters α, β_* and γ may depend on cosmology as well as on (late) cluster physics and evolution. Based on an assumed scaling relation, Figure 2 shows cluster number count predictions above a set survey flux limit for different cosmological models.

3. Cosmological constraints



By statistical techniques cosmological parameters can be constraint by the redshift distribution of the sample clusters. See Figure 3 for constraints obtainable from an all-sky Planck satellite survey. Galaxy cluster number counts are very sensitive to the *rms* matter fluctuations on cluster scales (e.g. $8h^{-1}$Mpc: σ_8). They are further sensitive to the total (non-relativistic) matter density of the Universe, Ω_m and can place constrains on the curvature of the Universe as well as on the nature of dark energy (see Figure 4).

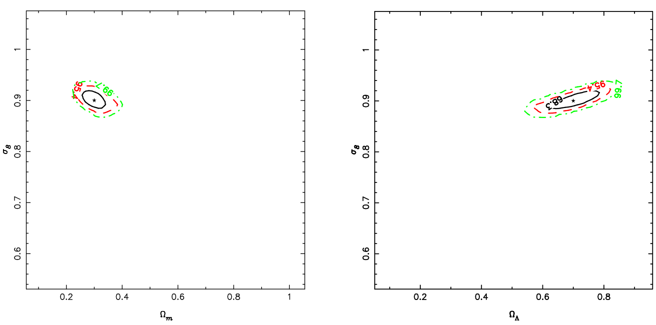


Figure 3: Two-dimensional parameter confidence contours for a Planck cluster sample obtained by application of a MCMC algorithm (see also [4]).

As it is evident from equation 1, the number count above a flux limit depends not only on cosmology, but also on cluster physics. In a self-calibration analysis one aims to constrain cosmological and cluster physical parameters at the same time. Figure 5 shows such a self-calibration analysis for an interferometric SZ survey (which assumes the same observing strategy as in Figure 4; see [5]).

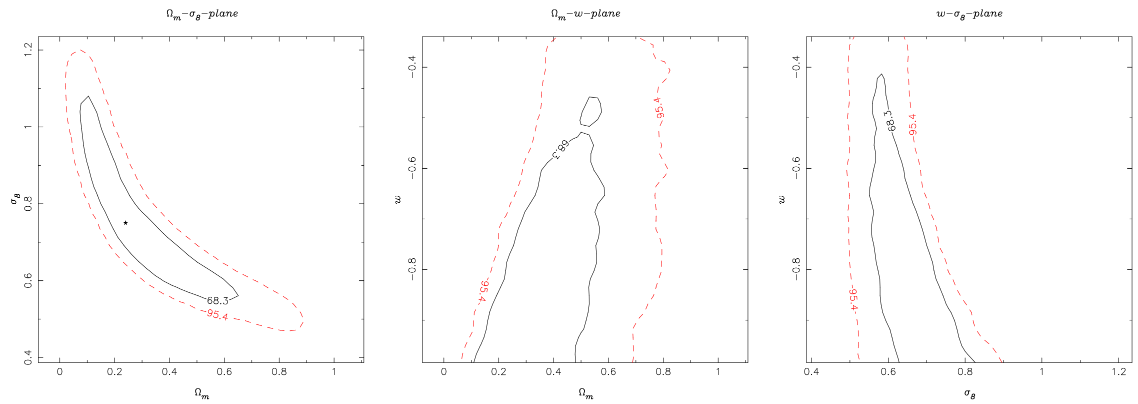


Figure 4: Confidence contours on Ω_m, σ_8 and w as obtainable from an interferometric survey (such as AMI).

4. Conclusions

SZ cluster surveys and available cluster extraction methods will yield cluster samples extending to high redshifts. Due to deep high resolution surveys the number of known clusters at $z \geq 1$ will increase by 10 to 100 times. Our simulations suggest that SZ cluster samples extracted by the methods described above will be highly complete down to low cluster masses ($M_{\rm cl} \gtrsim 10^{14}h^{-1}M_\odot$) and will be of high purity. Thus they can be used for placing tight constraints on cosmological parameters. The recent SKA reference design with a targeted frequency extent of up to 10 GHz might be suitable for studying galaxy clusters via their SZ imprint in the case that adequate aperture plane coverage and bandwidth are granted. Nevertheless, the SKA and its pathfinders will certainly gain new insights into cluster internal physics, such as the interactions of cluster central active galactic nuclei with their electro-thermal environments.

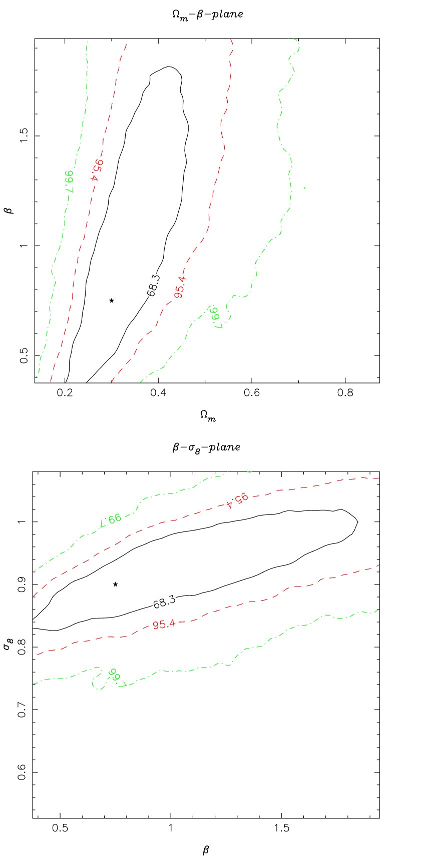


Figure 5: Self-calibration analysis based on a sample as expected to be obtainable by an interferometric survey (such as AMI).

References

[1] Geisbuesch J., Kneissl R. & Hobson M., MNRAS, 360, 2005, 41-59.

[2] Herranz D. et al., MNRAS, 336, 2002, 1057-1068.

[3] Schaefer B., Pfrommer C., Hell R., Bartelmann M., MNRAS, 370, 2006, 1713-1736.

[4] Geisbuesch J. & Hobson M., MNRAS, 382, 2007, 158.

[5] Geisbuesch J., PhD, 2006, University of Cambridge.