Radio source contamination in the upcoming SZ surveys

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Background

APEX-SZ: The APEX SZ-survey† is the first of several upcoming large area (10^2-10^3 $\deg^2$) bolometer surveys that will detect and catalog thousands of galaxy clusters from their Sunyaev-Zel'dovich (SZ) imprints in the cosmic microwave background at mm-wavelengths, and is due to start *early next year.* The main goal is to put tight constraints on the cosmological parameters from the number counts and the redshift distribution of clusters, in particular the yet not well constrained overdensity parameter σ_8 and the dark energy equation of state.

Radio sources: For SZ cluster number counts to be useful it is crucial to quantitatively estimate the contamination from foreground and background point sources in the cluster field. One of the most important contaminants to the SZ-signal at mm-wavelengths will come from radio sources (such as QSOs and cD galaxies within clusters), which can partially or totally offset the SZ decrement because the SZ surveys cannot resolve the clusters spatially.

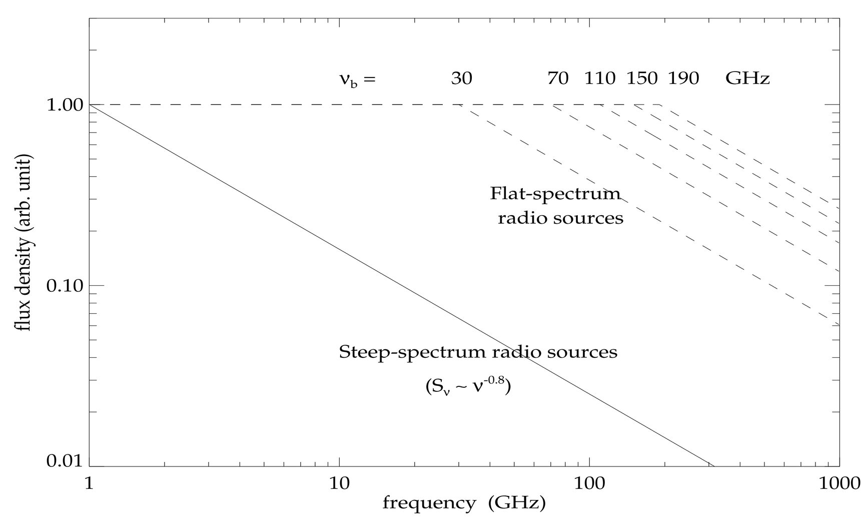

Figure 1: A schematic diagram for the rest-frame SEDs of steep- and flat-spectrum radio sources. The emission from steep-spectrum sources come from optically thin regions, so their spectrum is a synchrotron power-law with average spectral index ~ 0.8. The flat-spectrum sources sources remain optically thick up to some break frequency ν_b, after which they become optically thin and their spectra drop in a similar manner to the steep-spectrum sources. Moreover the fluxes of the flat-spectrum sources often show time variability. The ratio of flat- to steep-spectrum sources in cluster fields is roughly $0.3-0.4$, which is the same as in field sources, but whether this holds true for high-redshift clusters is unknown. Also the distribution of break frequencies and spectral slopes after the break are poorly understood.

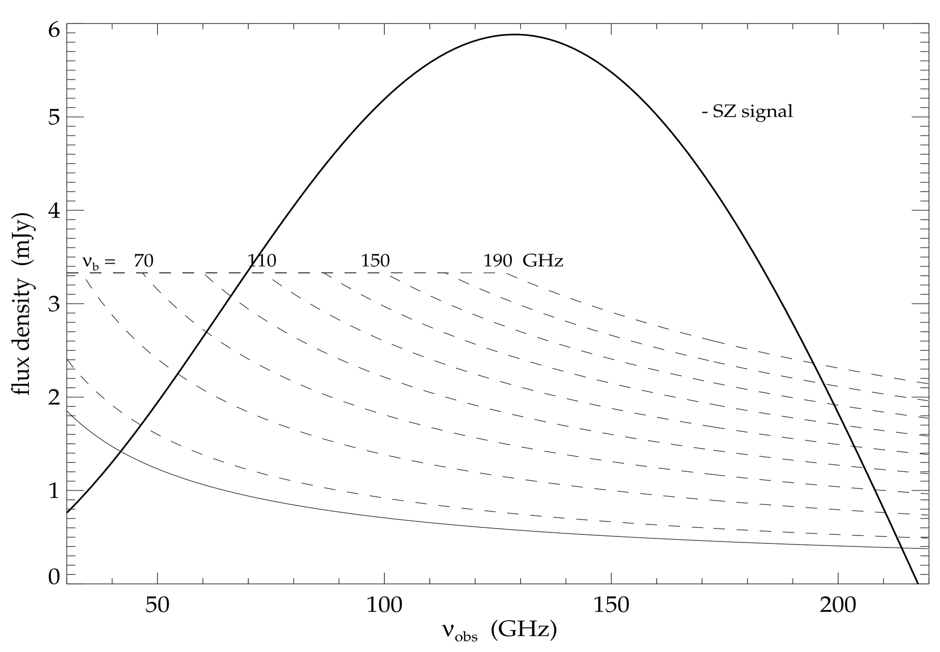

Figure 2: Expected average flux density of radio sources in a typical SZ cluster of size 1.5 Mpc at $z = 0.5$ (1 arcmin beam). The thick solid line is the expected SZ decrement intensity, and various other lines show the contribution from an embedded radio source with different spectral properties. We are particularly interested in the flat-spectrum sources (dashed lines). The numbers on the curves mark the rest-frame break frequencies.

Problem

Recently Voss et al. (2005) obtained three flat-spectrum radio sources in the MAMBO blank field survey (250 GHz) with rest frame break frequencies above 190 GHz, which is in contradiction to previous studies (e.g. Holdaway et al. 2005) that predicted a break below 100 GHz for most of the sources. This apparent conflict shows our poor understanding of the radio source spectral properties at mm-wavelengths, where SZ-surveys are planned.

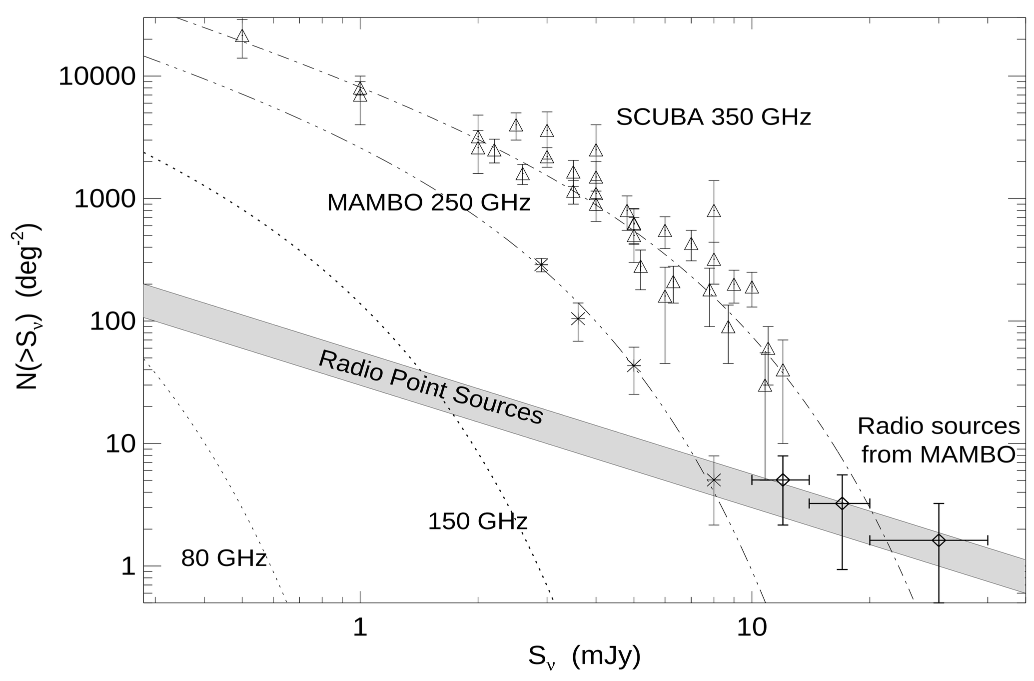

Figure 3: Number counts of radio and sub-mm point sources at SZ-survey frequencies. The sub-mm galaxy counts were obtained by empirically fitting the SCUBA and MAMBO data, and then extrapolating to lower frequencies assuming $S_\nu \propto \nu^{2.5}$ at these frequencies. The grey band is a possible range for non-thermal source counts, whose upper limit is a fit to the MAMBO non-thermal sources (Voss et al. 2005), and the lower limit is a fit for 30-40 GHz from Knox et al. (2004). Contrary to expectation the radio source counts at mm-wavelengths do not show any strong variations, which motivated our study.

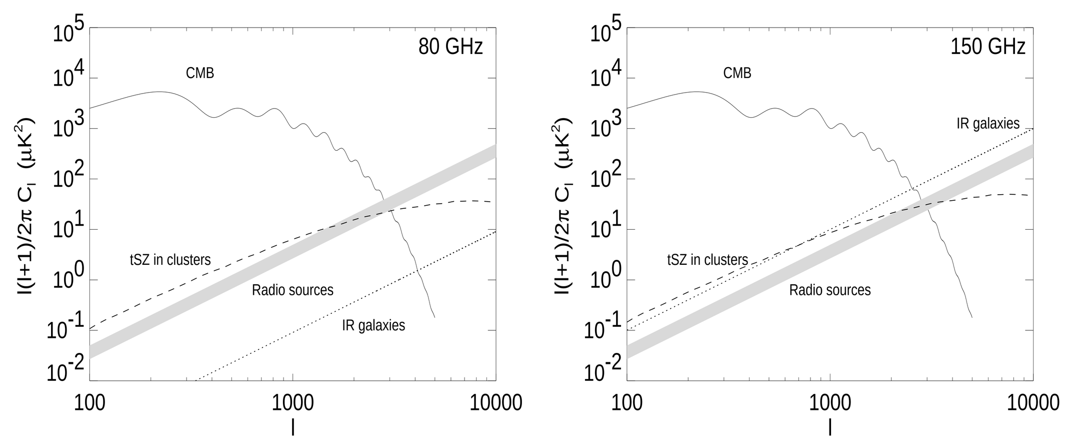

Figure 4: Temperature anisotropies from thermal and non-thermal point sources at 80 & 150 GHz, assuming no clustering in these sources. The dotted lines are the contribution from the sub-mm galaxy population, and the grey band again shows the impact of radio sources. Also shown are the thermal-SZ signal in clusters and the CMB power spectrum for comparison. Clearly at 80 GHz most of the contamination is caused by the radio sources.

Impact on SZ-surveys: A large population of flat-spectrum radio sources at mm-wavelengths will strongly affect the choice of the best observing frequency for the APEX-SZ (and other future surveys): choosing between better sky stability and less thermal source population vs. higher contamination from non-thermal sources. This will in turn affect the efficiency of cluster extraction from the sky-maps, and the resulting estimation of cosmological parameters will be poor.

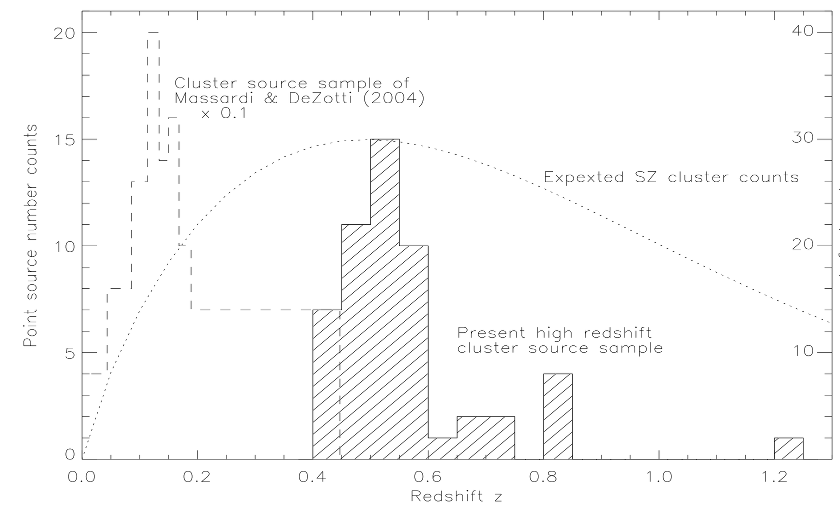

Figure 5: The redshift distribution for the high-z clusters under our study, compared to the sample in a previous work (Massardi & De Zotti 2004). The dotted line shows the differential counts computed for a flux limit of 2 mJy (roughly 3σ detection limit for APEX-SZ) assuming the concordance model. This plot shows the importance of our cluster sample in order to better understand their impact on the upcoming SZ surveys.

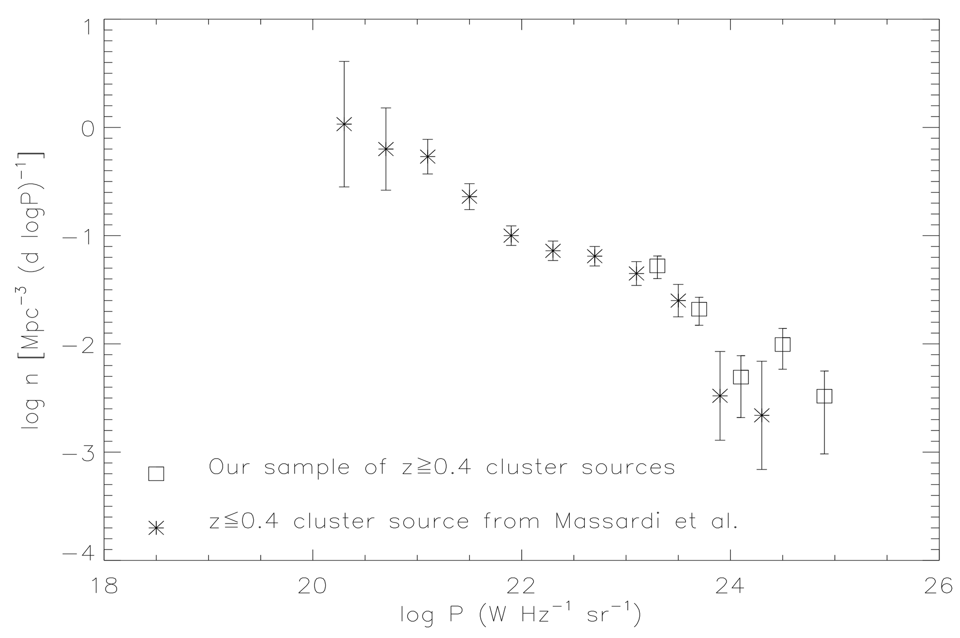

Figure 6: Luminosity function of cluster radio sources at 1.4 GHz found from our sample (squares, $z_{\mathrm{mean}} = 0.5$), compared with that of Massardi & De Zotti (stars, $z_{\mathrm{mean}} = 0.1$). Apparently the radio source distribution in our high-z sample is consistent with that at lower z, apparently implying no strong evolution.

Our work

In Bonn we are working on the problem of radio-source contamination in the SZ-signal from both theoretical and observational perspectives.

- We aim to make a systematic study of the radio source contamination in intermediate- and high-redshift clusters important for the upcoming SZ-surveys, and compare the result with low-redshift samples.
- As a part of this project, we shall observe several known high-redshift clusters containing radio sources with the Effelsberg 100m telescope and the IRAM Platue de Bure Interferometer to better understand their SEDs at mm-wavelengths.
- Knowing the spectral properties and overdensity of these sources in the cluster fields at mm-wavelengths, we aim to realistically simulate SZ-skymaps at frequencies relevant for upcoming SZ-surveys.
- As a by-product of our work, we aim to improve the understanding of spectral slopes and break frequencies in flat-spectrum radio sources at cm- to mm-wavelengths, which is at present poorly understood.

References

• Holdaway & Owen 2005, ALMA Memo 520 • Knox, Holder & Church 2004, ApJ, 612, 96 • Massardi & De Zotti 2004, A&A, 424, 409 • Voss et al. 2005 (in preparation)

† The APEX-SZ project (Co-PIs Menten, Bertoldi, Lee) is a joint collaboration between the sub-mm group at MPIfR and the bolometer cosmology group at UC Berkeley