Foreground Radio Sources and the VSA

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Extragalactic radio sources are a foreground that can potentially contaminate observations of primordial structure in the Cosmic Microwave Background. This contamination becomes worse as measurements are made at higher angular resolution. For observations with the VSA we have adopted a scheme of source surveying using the Ryle Telescope to identify these sources, which will then be continuously monitored by a purpose-built, single-baseline interferometer.

1 Introduction

In order to achieve the goal of accurately measuring the primordial fluctuations in the Cosmic Microwave Background (CMB), it is necessary to remove the effects of various foregrounds. The most important of these foregrounds are emission from the galaxy and extragalactic radio sources. The spectra of the various components of galactic emission are fairly well known, so observations at different frequencies will allow separation of these contaminants from the black-body CMB. Extragalactic sources however have a wide variety of different spectra, with some fraction of them having spectra of $\alpha = -2$ (where $S \propto (\nu/\nu_0)^{-\alpha}$); an example of such Gigahertz Peaked Spectrum (GPS) source which peaks around 30 GHz at a flux of almost 1 Jy is shown in Figure 1[1]. These sources are generally unresolved on the angular scales of interest in primordial CMB work. The contribution that a Poisson-distributed population of point sources will make to the power spectrum in a unit logarithmic multipole increases as ℓ^2 (ref[2]). Therefore correctly removing point sources will become increasingly important as we attempt to measure the second and third acoustic peaks. To do this we can exploit the fact that the sources have small angular sizes by mapping the target region of sky at high resolution, where the contribution from primordial fluctuations will be negligible. In this paper I will outline the method that we are using for the VSA (see B. Rusholme, these proceedings) to survey the sky for contaminating point sources, and then how we will continuously monitor them.

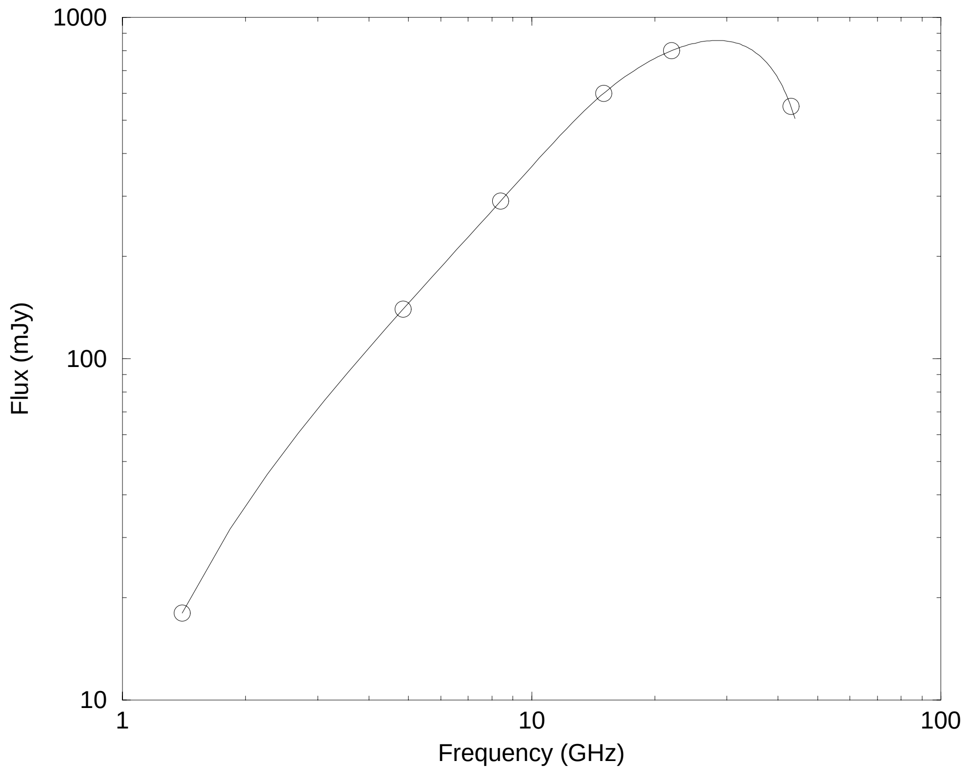

Figure 1: Spectrum of the GPS source RXJ1459+33 measured with the VLA. This source has a spectral index very close to $\alpha = -2$ up to 30 GHz, *ie* the same spectrum as the the black-body CMB. Therefore attempts to subtract this type of source spectrally will fail and we must use high resolution mapping to remove it.

2 Source Confusion and the VSA

In order to calculate the level of source confusion that the VSA will suffer we need to know the form of the differential source counts. These are not well known at 30 GHz, but extrapolating from lower frequency it is possible to estimate that if no source subtraction were done then the rms source confusion noise in a VSA synthesised beam would be approximately 100 mJy. This systematic error is much higher than the corresponding thermal noise for a long VSA integration where

$$\sigma_{\rm Thermal} = 24 \left(\frac{T}{200{\rm hr}}\right)^{-1/2} \ {\rm mJy}.$$

It is therefore clear that source subtraction is vital for the VSA. We estimate that in order to reduce the confusion noise to a level significantly below the thermal noise we must identify and measure the fluxes of all sources in the field above 80 mJy (A. Taylor, these proceedings).

3 Surveying

The VSA observes in the range 26–36 GHz. This is a much higher frequency than has been used for any all-sky radio survey (cf NVSS at 1.4 GHz[3] and Green Bank at 5 GHz[4]). Therefore we have surveyed the VSA fields with the Ryle Telescope[5] (RT) at 15 GHz to a $1-\sigma$ sensitivity of 4 mJy. This allows us to identify all sources above 20 mJy at 15 GHz, which corresponds to our desired goal of 80 mJy at 30 GHz even allowing for highly inverted spectra sources with $\alpha = -2$. It is not possible to use the existing 1.4 and 5 GHz surveys to calculate a source spectrum and then extrapolate to higher frequency because the surveys do not go deep enough (despite NVSS having a source detection level of 2.5 mJy) to allow for GPS sources in the extrapolation.

Figure 2: One of the two 3.7 m dishes that comprise the single baseline source monitoring system for the VSA (M. Jones). Each dish is housed in its own enclosure to prevent ground-spill. These enclosures are located just to the south of the VSA main array enclosure at the Observatorio del Teide, Tenerife.

Indeed in the first $28\ \mathrm{deg}^2$ patch of sky to be surveyed by the RT we have found five sources that were not predicted by such an extrapolation.

4 Monitoring

Once the surveying by the RT has produced a source list, we will continuously monitor the fluxes of these sources with a single baseline interferometer comprising two 3.7 m dishes (Figure 2). This monitoring must be done simultaneously with the observation made by the main array because GPS sources are often variable by a factor of two or more on short timescales. The pair of dishes will be equipped with the same RF amplifiers, cryostat, IF system and correlators that are used on the main array and are located on the same site. Thus they are essentially the same telescope, which will make intercalibration with the main array more accurate. The sensitivity of this single baseline system for determining the fluxes of point sources is

$$\sigma_{\rm Thermal} = 5\left(\frac{T}{1{\rm hr}}\right)^{-1/2}\ {\rm mJy}.$$

First light was achieved on 6 May 2000 (Figure3). Correlating a pair of dishes together is preferable to the alternative of correlating one “outrigger” dish against the rest of the array because to get sufficient sensitivity the dish diameter would have to be 12 m.

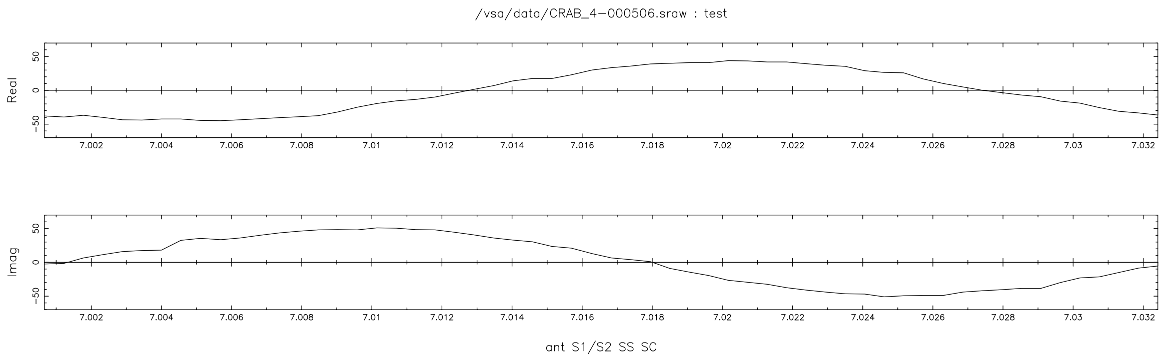

Figure 3: First fringes detected by the single baseline source monitoring interferometer on the Crab Nebula, observed on 6th May 2000.

5 Conclusions

Point source subtraction is vital for the VSA to prevent our results being dominated by systematic errors. This subtraction is a two stage process, firstly surveying of the VSA fields with the RT and then monitoring the sources found with the single baseline interferometer at the same frequency as the main array observations. Extrapolations from existing radio surveys at low frequency are inadequate for finding the sources of interest. It is also necessary for the source monitoring to be done continuously and simultaneously with the main observations in order to overcome source variability.

Acknowledgments

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