SEARCH FOR SMALL SCALE ANISOTROPY OF THE 3K EMISSION OF THE UNIVERSE

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One of the greatest mysteries of nature is the absence of any trace of the present structure of the nearby universe in its relict 3K emission.

If we live in an evolving world (which evolves from extremely smooth to extremely structural), our radio telescopes should see observable temperature variations of 3K in practically any world model.

The second, and maybe even greater, mystery is the (observable by radio means) fact of thermodynamic equilibrium of different volumes of the primordial gas, which are separated by such distances that they are causatively independent in standard Big Bang theory.

These problems provide strong motivation for observers. It is not possible to review here all observations in the U.S., U.S.S.R., and Europe (see Boynton 1974; Partridge 1979). We realize that there has been an overinterpretation of Soviet results (many wrong corrections and statements, and even confusion about observing facilities). Our early (from 1968) results may be found in the references to Parijskij (1973), A short summary of the next attempt with RATAN-600 was published by Parijskij et al. (1977). Here we shall review our recent 1980-1981 results, again with RATAN-600.

The observations were made during March-May 1980 in meridian (transit mode) and in February-March 1981 in azimuth 30° (transit mode again) at wavelengths of 1.38 cm, 2.08 cm, 3.9 cm, 7.6 cm, 8.2 cm, and 31 cm with real sensitivities 70 mK, 30 mK, 15 mK 2 mK, 7 mK, and 50 mK (τ = 1 s). From about 120^d (2880^h) of the telescope time it was possible to collect 64^d (1536^h) of observations with our best 7.6 receiver (Berlin et al. 1981) and 2100^h observations with all other receivers. This time was spent on the narrow strip of the sky centered at a declination of SS 433 and about 10' wide at half power level at 7.6 cm, and about 45' at the level 0.1.

At 7.6 cm the resolution in right ascension is $0\overset{'}{.}9$. At other wavelengths the beams are proportionally scaled. Thus, we have considerable information about the anisotropy of the sky on scales from 7" to 2π. The best results were obtained at 7.6 cm. We used 31 cm to allow for the galaxy noise, and 3.9 cm and 2.08 cm for atmospheric thermal emission correction. A special feed system and screens were used to reduce

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spillover effects down to 2%. The feed system was optimized to a maximum brightness temperature sensitivity (with some losses in gain). After averaging over 64^d we expect to have "thermal receiver noise" on the main protocluster scale ($\sim$ 7'), a sensitivity of 1.2×10^{-5} in $\Delta T/T$ and 3000 independent points of the mean curve. Thus, to check the "null hypothesis," the expected 1σ accuracy in $\Delta T_A/T$ is $1.2 \times 10^{-5}/\sqrt{3000} = 2.2 \times 10^{-7}$, or 6×10^{-7} in $\Delta T_B/T$, when all the usual corrections were made.

Up to now only 5% of the data have been fully reduced, the main problem being not the thermal receiver noise but the confusion, the atmosphere and galaxy emission and man-made interference. Figure 1 shows r.m.s. fluctuations of antenna temperature as a function of scale. At the left the galactic and atmospheric noises dominate, at the right the confusion. We have realized that at the deepest point of the curve receiver noise dominates.

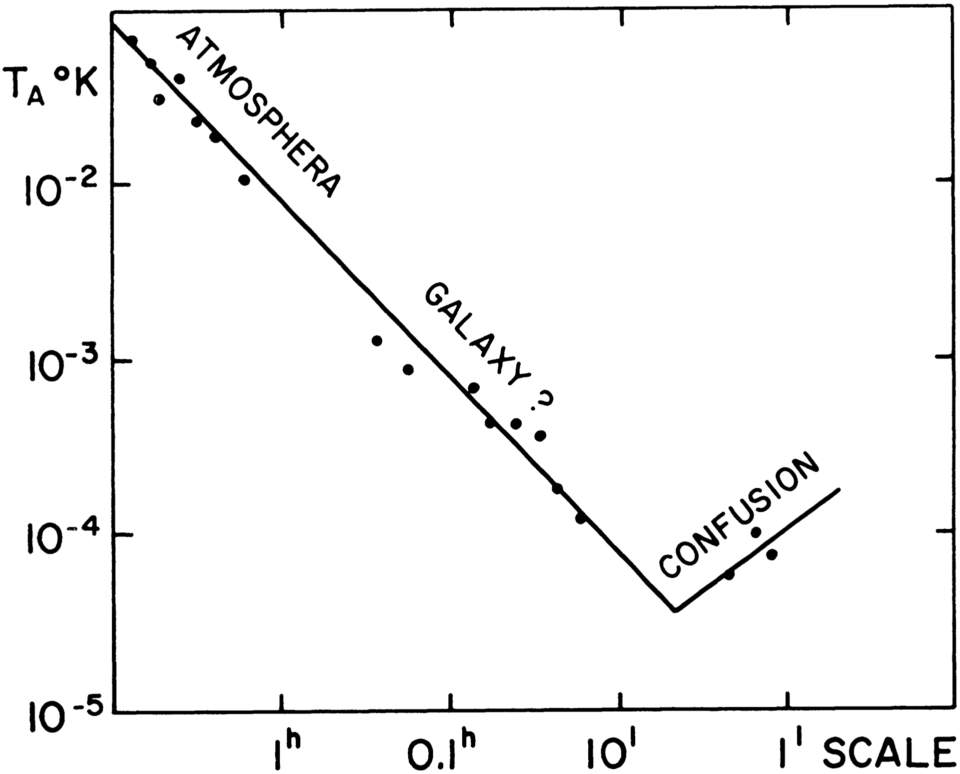

Figure 1. Antenna temperature as a function of scale at λ 7.6 cm. At least at some scales at the left galactic noise dominates. Confusion noise definitely dominates at the scales below 2'.5. We expect to have receiver (radiotelescope) noise on scales smaller than 1' due to the small integration time.

"Null hypothesis" correlation control confirms that the 1σ level in less than 10^{-5} in $\Delta T/T$ on scales from 4!5 to 9'. Rough estimates of the upper limits for the anisotropy on other scales give the following results: 10^{-5}; 2×10^{-4}; 2×10^{-2}; 1 for mass scales of 10^{15} $M_{\odot}$, 10^{11} $M_{\odot}$, 10^{5} $M_{\odot}$, and 1 $M_{\odot}$, respectively, at the 1 σ level.

No trace on the supercluster scale is visible. In a scale of 1°, the upper limit we have reached is about 3×10^{-5} (1 σ level).

Our results confict with all the published predictions in "fragmentation theories," inclusing massive neutrino variants. The disagreement is less for "Clustering Theories," with early developed galaxies (or globular clusters or stars). But our present philosophy is that it is practically impossible to reject absolutely any world model by our negative results alone.

We have a long-term program to reach the 10^{-6} level and we hope to achieve positive results which alone can tell about the real history of the universe. Black body isotropic emission gives us zero information on that subject, as a state of maximum entropy.

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DISCUSSION

de Zotti: The fluctuations due to discrete sources on angular scales of about 10' at λ ∿ 7 cm, as estimated from source counts, exceed by more than a factor of 10 the upper limit to $\Delta T/T$ you quoted; therefore, a very delicate subtraction of sources must be needed to derive your result. Can you comment on the uncertainties related to such subtraction?

Wilkinson: At a wavelength of 7 cm, confusion from radio sources is a major problem, as you have found. How accurately do you have to subtract radio sources in order to reach your upper limit of $(\Delta T/T)_{2.7} < 10^{-5}$ for 4.5' to 9' angular scales? In other words, what would your limit be if sources were not subtracted?

Parijskij (in answer to both *de Zotti* and *Wilkinson*): We have our own experience in counting radio sources down to S < 1 mJy at 7.6 cm and we can prove that many old nondirectly obtained lgN-lgS curves suffer from great overestimation of the number of very weak sources. Direct counting at Westerbork at 21 cm and the VLA at 6 cm and 21 cm confirms this, at least down to 1 mJy. Preliminary P(D) analysis which I have shown here gives us some indication that the flattening of lgN-lgS at 7.6 cm increases even at a lower level (below 1 mJy). At the present time we expect that there is no great problem in subtraction of the sources above 1 mJy. There is some indication that of the 0.1 - 0.3 mJy level about 30% of the energy is connected with more numerous, very weak sources. We hope to have a more definitive statement after reduction of all our data. To go deeper in $\Delta T/T$ estimates, we have to change frequency and/or use the aperture synthesis mode of observations at RATAN-600. We have just finished testing observations of this kind.

Baldwin: With what accuracy do you expect to be able to remove atmospheric fluctuations by observations at more than one frequency?

Parijskij: We expect to decrease the atmospheric noise by a factor of close to ten in 80% of the records.

Stecker: In view of the problems with theory, is it at all possible that in your analysis you have oversubtracted or missed fluctuations of cosmological significance, resulting in a background which is too smooth?

Parijskij: We really lose all information concerning scales comparable with beamwidth (1' - 3'); but in the most interesting region (4!5 - 9'), we hope there is no "overfiltration."

Wilkinson: I believe that your projected accuracy of $\Delta T/T)_{2.7\ K} < 10^{-6}$ is too optimistic. Foreground effects from: 1) ground radiation (if you beam switch); 2) atmospheric radiation (if you don't beam switch); 3) galactic emission; and 4) radio sources present exceedingly difficult problems at this level of accuracy. Using the NRAO maser on the 140' telescope (T_{SYS} = 50 K, λ = 1.5 cm, θ = 1.5 arcmin). Juan Uson and I only barely managed to overcome these difficulties at an accuracy of $\Delta T/T)_{2.7\ K} < 10^{-4}$. I don't believe that a two-order-of-magnitude improvement is possible from any telescope, and especially at λ = 7 cm.

Parijskij: The 10^{-6} goal is set by the limit imposed by thermal receiver noise with an integration time of about one year. With our multifrequency method, we hope to filtrate atmospheric noise and confusion noise close to that figure. We also expect to use shorter wavelengths (4 cm; 2.6 cm).