ANALYSIS OF THE COSMIC RADIO BACKGROUND IN THE DOMAIN OF SPATIAL FREQUENCIES

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Since extra-Galactic radio sources are distributed unevenly over the celestial sphere, accumulated experimental data in the domain of spatial frequencies are used. The author was unable to explain discrepancies between experimental and model spectra by errors of calculation or experiment. A possible explanation is the presence of Galactic fluctuations in the cosmic radio background.

1. Spectrum of Spatial Frequencies at the Output of a Radio Telescope

As 30 years of experience in the search for hypothetical irregularities in the cosmic radio background have shown, separating the radiation itself and the contribution of radio sources has proved to be a very complicated problem. And it is becoming more complicated with the increasing sensitivity of receiving systems. In ground-based observations, the problem of the atmosphere is added to the problem of background radio sources. A solution is suggested by Campbell's theorem [1], which relates the temporal and frequency parameters of shot noise. It looks like this: if a time series \( X(t) \) is the sum of a large number of pulses of the same shape \( A(t) \) and of amplitude \( S_k \),

\[
X(t) = \sum_{i=1}^{n} S_k A(t - t_k)
\]

while the pulse amplitude \( S_k \) is a random function with a finite dispersion, while the pulse times \( t_k \) are distributed by a Poisson law with a mean rate \( \alpha \), then the power spectrum of \( X(t) \) is

\[
F(f) = \alpha S^2 V(f)^2
\]

where \( S^2 \) is the mean square of \( S_k \) and \( V(f)^2 \) is the power spectrum of \( A(t) \). The process \( X(t) \) is stationary and ergodic in this case.

The process at the output of a radio telescope through the field of view of which compact radio sources pass fully satisfies the conditions of Campbell's theorem: radio sources are distributed very uniformly over the celestial sphere, while their average angular size, for fluxes less than 100-200 mJy, is less than 10" [2]. If the antenna beam pattern is sufficiently wide, the telescope's reaction to the passage of radio sources will have a single form. The response to the passage of a single radio source (the instrumental function) depends not only on the beam pattern but also on the operating regime of the telescope.

In accordance with (2), the power spectrum at the telescope output duplicates the power spectrum of the instrumental function. Since the instrumental function of the radio telescope is two-dimensional, while the differential statistics on radio sources is defined as
we write (2) for observations in the regime of scanning in right ascension,

\[ F(f) = T \int_{-\pi}^{\pi} V(f, \delta - \delta_0)^2 d\delta dS, \]

where \( \delta_0 \) is the observed declination, \( f \) is the spatial frequency, \( |V(f, \delta - \delta_0)|^2 \) is the power spectrum of the instrumental function over the section \( \delta - \delta_0 \), \( S(\delta - \delta_0) \) is the threshold for detection over the section \( \delta - \delta_0 \), and \( T \) is the size of the section of the celestial sphere in right ascension. Equation (4) shows that if the instrumental function does not depend on the telescope’s position or the observations are made on a stationary antenna, the power spectra of any two observed sections of sky are similar. And if the sections of sky are the same size, their spectra are equal to within the statistical error for the radio sources.

What does knowledge of the power spectrum of radio sources provide?

First, we have the possibility of investigating the behavior of the statistics on radio sources at a level below the detection threshold. The depth of the analysis depends on the errors of the spectrum obtained. Second, we can make a statistical search for extended objects, the sizes of which are consistent with the frequency characteristic of the telescope’s instrumental function. The presence of such objects in the radio background inevitably introduces distortions into the ideal spectrum determined by compact radio sources. By comparing experimental and calculated spectra, we can estimate the significance of the distortions, their amplitude, and their angular scale. Here there is no need to “clean out” radio sources from the recordings as an interfering factor. On the contrary, their spectrum is the NULL from which we reckon the unknown distortions of the spectrum.

And, third, it is possible that the parameters of the radio background fluctuate in space and in time. And then with temporal or spatial accumulation, which presumes that the background irregularities are frozen, they will be hard detect. The accumulation of instantaneous spectra enables one to solve this problem without constraint.

The character of the distortions depends not only on the sizes of the irregularities but also on their distribution over the sky. If they are distributed regularly, then we should see a spectral line at the corresponding spatial frequency. And this is the simplest and most realistic case. If they are randomly distributed, then according to the same Campbell’s theorem their spectrum is determined from (2). This means that, under standard assumptions about the shape of these formations (the Gauss or Butterworth form or a simple cylinder), their power spectrum reaches a maximum at the null frequency. The process of observations and processing is inevitably accompanied by “cutting out” of the null frequency and frequencies close to it. We can therefore judge the scales of the irregularities only from the “tail” of their spectrum. The latter statement is valid, naturally, not only in the frequency domain but also in the spatial domain.

To obtain the power spectrum of radio sources in a refined form, the observations and data processing must be carried out in the appropriate way.

The output signal from an actual receiving system contains two components, correlated and uncorrelated, each of which has several ingredients. The correlated component consists of the sources of cosmic radio emission, the parameters of which vary insignificantly over the observing period for the vast majority of objects. The uncorrelated component — the system’s internal noise and the noises of the atmosphere, antenna, and surrounding medium — varies on scales of from seconds to hours. We are interested in the correlated component. It is natural to use the well-known method of sums and differences to isolate it. Sums contain information about the two components, correlated and uncorrelated. Differences contain information only about the uncorrelated component. Accordingly, the power spectra of these arrays contain the same information.

We designate the power spectra of sums and differences as \( F^+ (f) \) and \( F^- (f) \), respectively. Their difference is the...