

FLUX DENSITY ABSOLUTE MEASUREMENTS OF SUPERNOVA REMNANTS USING TWO-TEMPERATURE BLACKBODY CALIBRATION STANDARD

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ABSTRACT. The two-temperature standard of noise radio emission consisted of two identical "black" disks with different temperatures is used to increase the accuracy of absolute measurements of cosmic source radio emission flux densities. A brief description is given to the construction of the measuring facility at the RAO NIRFI "Staraya Pustyn'", the measurement procedures and data processing with taking into account apparatus and methodical factors. The results are given of the absolute measurements made in 2003 of the radio emission flux densities of SNRs Cassiopeia A and Taurus A and the radio galaxy Cygnus A at frequencies 2829 and 8834 MHz.

Radio emission flux density absolute measurements of cosmic sources are of principle importance since they permit to measure energetic and associated parameters of astronomical objects.

The method of "blackbody" disks has been designed and thoroughly developed at the Nizhny Novgorod (Gorky) Radiophysical Research Institute (RRI) to carry out flux density absolute measurements of cosmic radio sources. The substance of the method is in radio telescope calibration by noise radio emission of an artificial radiation standard which is a metallic disk covered by a radio-absorbing material; the standard has the radio emission brightness temperature equal to that of the environment.

An essential step in the development of the "blackbody" disk method has become a possibility to place disks in the antenna Fresnel zone and overfocusing the antenna by displacing the feed from the dish focus; the calculation of diffraction corrections; an application of two identical standards with different temperatures (Dugin, 2002; Dugin, 1993). The increase of accuracy in this case is achieved due to the elimination of calculations of the atmosphere temperature behind the disk and diffraction effects that permits to widen the application range of the method (see for details Dugin et al., 2004a; 2004b; 2004c). The calibration of radio

sources by the "blackbody" disk method had been carried out at NIRFI since 1960-s and were cut off in the end of 1980-s. In 2002–2003 the facility to carry out flux density absolute measurements of cosmic sources in the frequency bands of 3 and 10 GHz (in which the first measurements of Cassiopeia A, Taurus A and Cygnus A radio emission flux densities were made in autumn 1952 (Plechkov & Razin, 1956)) was reconstructed and upgraded at the NIRFI Radioastronomical Observatory "Staraya Pustyn'" (100 km to south from city of Nizhny Novgorod). The continuation of the observational series at different frequencies with new technical equipment is essential for getting more accurate data on the time variations of radio emission of SNRs Cassiopeia A and Taurus A that is significant to study the physical processes in the supernova remnants. At the resumption of work on the radio source calibration a task was set to attain an extremely small inaccuracy of absolute measurements.

The facility consists of a 7-m fully-steerable parabolic antenna and a two-temperature calibration standard mounted on a 25-m tower 100 m apart from the radio telescope. The maximum heating temperature of one of the disks is about 55° C. Receivers at 2829 MHz (wavelength 10.6 cm) and 8834 MHz (wavelength 3.4 cm) have the sensitivity threshold 0.1 K at the time constant 1 s. The data processing is made by PC Omnibook XE3100.

During the preparation and carrying out the experiments we have developed a procedure of absolute measurements of cosmic sources radio emission flux densities using two-temperature blackbody calibration standard. The problem of measuring with high accuracy the disk temperature difference proved to be rather complicated. We approved several ways of measurements which finally allowed to find the mean temperature of the heated disk with an accuracy of about 0.1°. A comparative analysis of calibration results using two-temperature calibration standard according to the developed technique and one disk according to the traditional one has shown that the calibration error by

two-temperature standard is 3–5 times less especially at the unstable absorption in the atmosphere. Besides, the application of the two-temperature standard permits to measure some of the correction coefficients and also increases accuracy and reliability of the absolute measurements of the cosmic radio sources flux densities. The advantages of the two-temperature standard will be more visible at the lower frequencies where it is practically impossible to take into account the diffraction corrections for small sizes of disks and their low position above the ground level.

To increase the measurement accuracy we have developed the way of determining the mean error of antenna pointing on the source by radio telescope drive systems directly from the data of conducting measurement series. The correction of the measured signal value by the error of antenna tracking is actual for any precision observations in shortwave bands.

In the process of measurements we used such a way of signal registration when no changes are introduced in the radiometer adjustment, and the computer memory stores the full information on the radio telescope reaction to the actions made. This allows to register continuously the changes in the atmosphere absorption and to introduce the corresponding corrections in the signal values by the developed algorithm. Such a procedure of taking into account the absorption variations during the measurements significantly widens the temporal frames of precision observations at short waves in the middle latitudes where the number of cloudless days is relatively small.

The series of observations of radio sources Cassiopeia A, Taurus A and Cygnus A at two given waves were made in summer and autumn 2003. The following values of SNR radio emission flux densities were obtained at $\lambda = 10.6$ cm: Cassiopeia A — 1059.0 ± 9.3 Jy, Taurus A — 698.1 ± 17.2 Jy. The flux density of the stable source Cygnus A was 666.6 ± 12.5 Jy. Flux density ratios of Cassiopeia A/Cygnus A and Taurus A/Cygnus A are equal, respectively, to 1.59 and 1.047 with errors 2.1% and 3.1%.

Measurements at the wavelength 3.4 cm gave the following values of SNR radio emission flux densities: Cassiopeia A — 416.4 ± 8.6 Jy, Taurus A — 471.2 ± 8.4 Jy. The flux density of the stable source Cygnus A was 163.0 ± 5.1 Jy. Flux density ratios of Cassiopeia A/Cygnus A and Taurus A/Cygnus A are equal, respectively, to 2.55 and 2.89 with errors of about 3%.

Spectral indices α ($S_\nu \sim \nu^{-\alpha}$) of the studied radio sources in the frequency band (3 ÷ 10) GHz are the following:

Cygnus	$\alpha_{\text{Cyg}} = 1.24 \pm 0.03$,
Cassiopeia	$\alpha_{\text{Cas}} = 0.82 \pm 0.02$,
Taurus	$\alpha_{\text{Tau}} = 0.34 \pm 0.01$.

These results are in a good agreement with those obtained at RAO "Staraya Pustyn'" in previous decades:

$$\begin{aligned} \alpha_{\text{Cyg}} &= 1.28 \pm 0.06 && \text{in the wavelength band 2–9 cm,} \\ \alpha_{\text{Cas}} &= 0.82 \pm 0.03, \\ \alpha_{\text{Tau}} &= 0.32 \pm 0.03. \end{aligned}$$

Next series of measurements was made in spring 2004 when we got the error of relative measurements of radio source flux densities less than 1% and that one of absolute measurements of about 2% at both operating frequencies. Strong enough short-term changes of SNR fluxes require regular (1–2 times a year) observations of SNR and calibration sources to reveal peculiarities in their radiation spectra.

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