# Evidence for Turbulent Loading of the M87-Jet

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A source of the non-thermal radio emission 3C58 was discovered in 1952 and identified with a remnant (SNR) of the supernova which had been observed in 1181. The structure of its radio brightness distribution is of the DOS Crab-like type. Like the Crab Nebula, the 3C58 includes the pulsar PSR J0205+6449, which can be observed at radio frequencies in the X-rays. The discovery of the pulsar was followed by a serious problem with identification of the radio source 3C58's age. We discuss it in detail in [1]. Its dynamic age is found to be 5,400 years which has been defined by the pulsar damping period [2]. A closer age value is obtained through the average expansion rate of the nebula 3C58 which was determined after the results obtained in the VLA in1973 and 1998 were compared. It corresponds to the dynamic age of $5000 \pm 2250$ years [3]. Thus, it is found that the pulsar and the radio nebulae ages are almost the same and they are 4 or 5 times older than the supernova observed in 1181.

**Keywords**: Supernova remnant, pulsar, 3C58, flux density.

Measurements of 3C58 flux densities made by a number of observers at different frequencies in order to determine the variability of the parameters of its radio emission, showed the presence of time-dependent changes in its spectrum, a detailed analysis of which is contained in [1]. Measurements in 1985–1987 showed growth of 3C58's flux density. A similar effect from other known galactic DOS was not observed. It can characterize 3C58 as a young object of about 820 years old, i. e. much less than 5000 years. However, measurements in 1996 at a frequency of 5000 MHz showed that the flux remained at the level of 1986 [4]. We needed further measurements of instantaneous spectra to address the issues: whether the flux densities increase was systematic, and evolutionary effects or changes were random. In April and May

2003 we carried out flow density measurements at a number of frequencies using the RT-32 radio telescope of the Svetloe observatory. The flux densities were measured with respect to the spectrum of 3C295 standard source on 4 frequencies: 1550 MHz, 2370 MHz, 4840 MHz and 8450 MHz. The stability of a standard radiation source, the radio galaxy 3C295, was tested by multiple measurements of different authors in the frequency range of RT-32. Density streams were identified in the "artificial moon" scales of flows.

A detailed description of the method of measurement and comparison of data from different ages, as well as the results, are presented in detail in [1]. Observational data 2003 show that the changes in the intensity of the radio emission of 3C58 are non-stationary in time and considerable magnitude. The intensity varies differently at different frequencies, and the energy is redistributed according to the source emission spectrum. Comparison with the spectrum obtained in 1966 shows the growth of flow at 8450 MHz and 4840 MHz, while in 2003 the flux density was lower than in 1966 at 1550 MHz frequency. For 2003 the spectral index $\alpha = -0.041 \pm 0.013$, for 1966 $\alpha = -0.206 \pm 0.006$. Based on our data analysis of 3C58 spectrum, as well as data of other authors in different frequency bands, we make a conclusion from [1] that two supernova remnants interact in the system of 3C58 source, and they differ from each other by their types and age.

It is shown that the supernova explosion observed in 1181 occurred without the birth of the pulsar, which is characteristic of the first type of supernova. Supernova 1181 flushed inside the nebula pulsar DOS, formed 5000 years ago. The complexity of the object is determined by the time-dependent characteristics of its evolution, which can be identified if the systematic remeasurement of its spectrum is continued. Regular measurements of the spectrum of the supernova remnant 3C58 were carried out from February to March 2013, in March 2016 and in May 2016 by the RT-32 radio telescope in Svetloe observatory at four frequencies: 1550 MHz, 2370 MHz, 4840 MHz and 8450 MHz. Neither the methods to measure and compare the data from different ages, nor the scale of flows were changed in comparison with 2003. Results of the spectral measurements in 2003, 2013 and 2016 are shown in Table 1 and Fig. 1.

Table 1

Density streams OCH 3C58: S2, measured in 2013, and the S3, measured in 2003

| f (MHz) | S1 (Jy) | S2 (Jy) | S3 (Jy) | S1/S2 | S2/S3 |
|---|---|---|---|---|---|
| 1550 | 28.7 | 26.9 | 27.0 | 0.94 | 1 |
| 2370 | 28.4 | 29.2 | 27.1 | 1.03 | 1.08 |
| 4840 | 27.3 | 28.4 | 25.4 | 1.04 | 1.12 |
| 8450 | 26.6 | 27.6 | 25.5 | 1.04 | 1.08 |

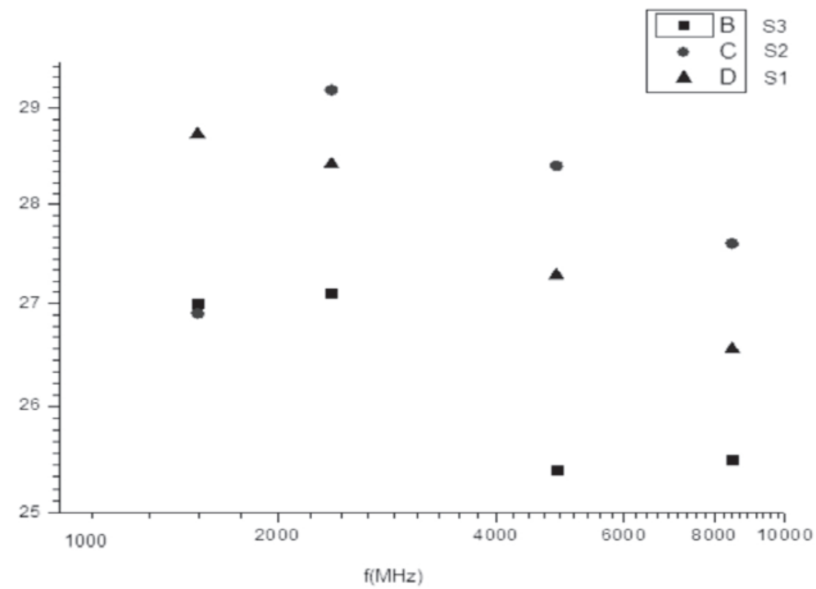


Fig. 1. The spectra of the supernova remnant 3C58, measured in 2003, 2013 and 2016

Designations: S1 (Jy) — flux density, measured in 2016;
S2 (Jy) — flux density, measured in 2016;
S3 (Jy) — flux density, measured in 2016;
$f$ (MHz) — frequency;
Uncertainty of measurement of the flux density, $\delta S \approx 2.5$ %.

It is necessary to pay attention at the features of the spectra in 2013 and 2016, describing them as abnormal. Significant changes in relatively short time intervals were indicated in flux densities, depending on the frequency and instantaneous spectra, which were measured using the single radio telescope. The changes have the following dependence of the frequency: the flux density did not change from 2003 to 2013at the frequency of 1550 MHz, then it grew significantly (6.5 % up) by 2016. There was the following relative growth in the flux density from 2003 to 2013 at higher frequencies: 7.9 % at a frequency of 2370 MHz, 11.6 % at 4880 MHz and 8.4 % at 8450 MHz. The spectrum of 2013 in the frequency range from 1550 to 8450 MHz can be approximated by a power law with a positive spectral index: $\alpha = +0.005 \pm 0.033$. In addition to the positive slope, it differs from the earlier spectra in noticeable deviations of the measured flux densities of the power law, indicating the possibility of the radiation source to differ from a simple synchrotron mechanism. Between 2013 and 2016 the flux density at frequencies 2370 MHz, 4840 MHz and 8450 MHz decreased by (3–4) %. We have considered the pos-

Table 2

| *f* (MHz) | S2 (Jy) | S2 (Jy)c | S3 (Jy) | S3 (Jy)c | S2c/S3c |
|---|---|---|---|---|---|
| 1550 | 3.72 | 3.72 | 2.42 | 2.41 | 1.55 |
| 2370 | 7.72 | 6.62 | 4.28 | 4.41 | 1.55 |
| 4840 | 10.04 | 10.13 | 5.99 | 6.97 | 1.5 |
| 8450 | 11.2 | 11.19 | 8.05 | 7.78 | 1.44 |

sibility of presenting the 3C58 spectrum as the sum of two components: the power spectrum with the spectrum parameters of 1966, decreasing at a rate of 0.595 %/year equally at all frequencies, and the difference spectrum obtained by subtracting the reduced spectrum measured in 2013 from the spectrum of 1966. The difference spectrum is shown in Table 2 and Fig. 2 together with our results of a similar data processing procedure of 2003.

Designations: S2 (Jy) and S2 (Jy)c are the density of the difference spectrum in 2013 and its approximation, respectively; S3 (Jy) and S3 (Jy)c are the density of the difference spectrum in 2003 and its approximation, respectively.

As shown in Table 2 and Fig. 2, the difference spectra in 2013 and 2003 are matching satisfactorily with the spectra of the heat source with the op-

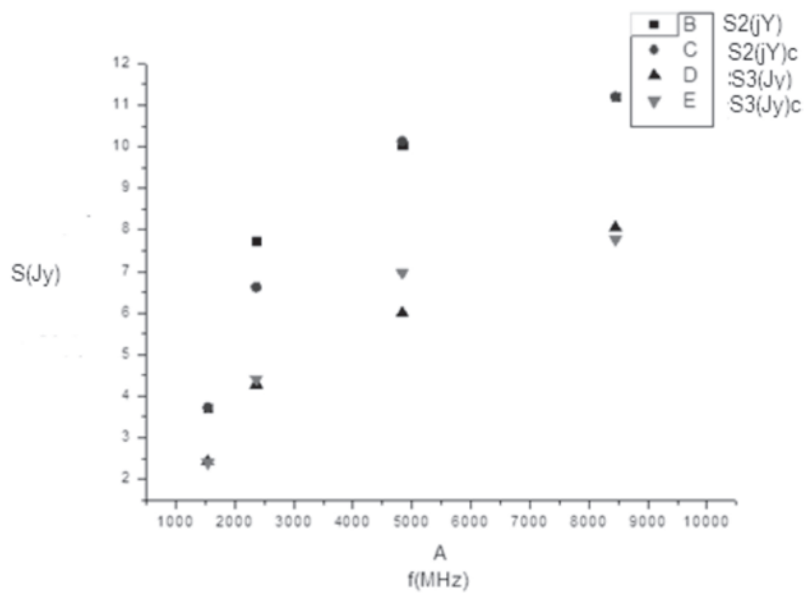


Fig. 2. Difference spectra obtained from measurements of densities flows of supernova remnant 3C58 in 2003: S3(Jy) and S3(Jy)c, and also 2013: S2(Jy) and S2(Jy)c

Table 3

| Epoch | Θ (as) | $D$ (ps) | ME ($cm^{-3}ps^{-1}$) | $N$ ($cm^{-3}$) |
|---|---|---|---|---|
| 2003.4 | 13.6 | 0.21 | $19.8 \times 10^6$ | $9.7 \times 10^3$ |
| 2013.2 | 17 | 0.26 | $18.1 \times 10^6$ | $6.3 \times 10^3$ |

tical thickness of 1 in the frequencies of 2.7 GHz (2013) and 2.9 GHz (2003), respectively. It can be assumed that there is a heat source within the 3C58 with the rapidly growing intensity of radio emission: the average flow rate of growth was 4 %/year. Table 3 shows the evaluation parameters of the heat source with the assumption that 3.2 kpc is removed in the 3C58, and the kinetic temperature of the electrons in the source (Te) is 104 K.

Designations: Θ (as) is an angular diameter, and $D$ (ps) is a linear diameter of the source, ME is an emission measure, $N$ is the concentration of electrons in the source.

We have adopted a two-component model of the 3C58 spectrum which requires a heat source inside. Proceeding from the assumptions that the kinetic temperature of the electrons in the source (Te) is 104 K, and the distribution of the radio brightness is equal, we estimated the dimensions of the source, emission and electron density. The latter two estimates have a very high value and need to be clarified. However, as a result, you can draw some conclusions about the alleged source:

— the intensity of the heat source radiation is growing with the high ($\sim$ 4 %/year) rate at all frequencies of RT-32, which allows to estimate its size;

— the electron density in the source has become $\sim 1.2$ times lower in 10 years, while their number has doubled. The number of electrons is growing; the ionization source is currently unknown;

— availability of a compact heat source within (in a center of) 3C58 can be verified by observations with high resolution at frequencies above 3 GHz. The flux densities at the epoch 2013.2 were: S (4840 MHz) $= 10$ Jy, S (8450 MHz) $= 11.2$ Jy.

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