

SOURCES WITH LOW-FREQUENCY STEEPNESS SPECTRUM CONCERNING THE UNIFIED MODEL

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ABSTRACT. Based on data of the data of the Grakovo catalogue of the extragalactic sources, detected at the decametre band with the UTR-2 radio telescope, it was established, that properties of radio sources with low-frequency steepness of spectrum are in accordance with the long evolution. At that, quasars and galaxies with low-frequency steep spectra often are the sources of the infrared and the X-ray radiation. In the last case we use the possibility of alternative determination of the magnetic field strength in the sources necessary for the estimate of the ratio of the magnetic field energy and the energy of the relativistic particles. Also we obtained the relations of sources luminosities at the radio, infrared, optical, X-ray bands that revealed evolution effects. The analysis of considered relations for quasars and galaxies with low-frequency steepness of radio spectrum testifies for the unified model of sources.

Key words: radio spectrum, quasar, galaxy, magnetic field strength

Introduction

Radio sources with low-frequency steepness spectrum (type C+) correspond to conception of the long evolution of this class of sources, when the critical frequency of the synchrotron emission can displace to values less than 10 MHz. Before [1] we received estimates of the main physical parameters of quasars and galaxies with steepness spectrum over the sample of objects at the decametre band (at that the value of low-frequency spectral index exceeds 1). The examined sample of objects with spectrum C+ is compiled at the base of the Grakovo catalogue of extragalactic sources detected with the UTR-2 telescope at the declination ranges $\delta = -13^{\circ} \dots +20^{\circ}$ and $\delta = 30^{\circ} \dots 40^{\circ}$ with flux density more than 10 Jy at the frequency 25 MHz [1]. With given criteria 148 sources are selected, including 52 galaxies, 36 quasars and 60 optically non-identified objects. The optical and high-frequency data for sample sources have been get from the NED database (<http://nedwww.ipac.caltech.edu>). Note, that the redshift range of objects is enough vast and forms $z = 0.017 \dots 2.4$.

Calculations of the physical parameters of radio sources with spectrum C+ were carried out at the frame of Λ CDM -Universe model. These calculations showed, that galaxies and quasars of the sample have the great luminosity (by order of 10^{28} W/Hz ster at the frequency 25 MHz) and very extent radio structure with linear size by order of 1 Mpc and characteristic age by order of 100 million years [1].

Independent estimation of the magnetic field strength

Our further analysis of properties of considered sources with spectrum C+ reveals that 14 objects from 36 sample quasars are the infrared sources, and 15 objects from the sample are the X-ray sources. It is known that many extragalactic X-ray sources have the non-thermal X-ray spectrum. At the assumption that the X-ray emission of quasars and galaxies may be due to the inverse Compton scattering of radio photons of the microwave background by relativistic electrons, it is the independent estimation of the magnetic field strength of objects. To obtain the magnetic field strength B_{IC} (at the inverse Compton scattering) by the flux density of X-ray emission we transform the relation from [2]:

$$B_{IC} = ((5.05 \cdot 10^4)^{\alpha} \cdot 1.15 \cdot 10^{-16} \cdot (1+z)^{\alpha+3} \times \times S_r \cdot \nu_r^{\alpha} \cdot S_X^{-1} \cdot \nu_X^{-\alpha})^{\frac{1}{\alpha+1}} (Gauss) \quad (1)$$

where all values are at the CGS system, α - is a spectral index of steep radio spectrum, z is a redshift of object, S_r is a flux density of radio emission at the frequency ν_r , S_X is a flux density of X-ray emission at the frequency ν_X . We accept $\nu_X = 2.42 \cdot 10^{17}$ Hz (at the energy of X-ray photons 1 keV), $\nu_r = 2.5 \cdot 10^7$ Hz (decameter band). As a result of calculations from (1), we receive the estimates of the magnetic field strength for quasars (mean value) in the sample with spectrum C+: $\langle B_{IC} \rangle = 1.03(\pm 0.45) \cdot 10^{-6}$ Gauss, and for galaxies (mean value) in the sample with spectrum C+: $\langle B_{IC} \rangle = 0.67(\pm 0.25) \cdot 10^{-6}$ Gauss. Let us compare these estimates with the values of the magnetic field strength B , derived by us for the same objects at the assumption about the equipartition of the magnetic field energy and the energy of relativistic particles in the sources [1]: $B = 6.15(\pm 0.30) \cdot 10^{-6}$ Gauss - for quasars in the sample with spectrum C+, $B = 8.14(\pm 0.58) \cdot 10^{-6}$ Gauss - for galaxies in the sample with spectrum C+. As one can see from the derived estimates, the value of magnetic field strength B_{IC} is, in average, by one order less than the value B , determined at the equipartition condition.

It is possible to estimate the energy of relativistic particles by the value B_{IC} and the value of radio

luminosity L [3] in sources. So, in our case, the energy of relativistic electrons in sources with spectrum C+ is:

$$W_e = \frac{10^{12} \cdot L}{B_{IC}^{3/2}} \cdot \frac{v_2^{(1/2)-\alpha} - v_1^{(1/2)-\alpha}}{v_2^{1-\alpha} - v_1^{1-\alpha}} \cdot \frac{2-2\alpha}{1-2\alpha} (erg) \quad (2)$$

where $v_1 = 10MHz$, $v_2 = 100MHz$. Note, that the energy of relativistic particles in sources, when take into account the relativistic protons, may be $W_p = 100 \cdot W_e$. Then the mean values of the energy of relativistic particles with (2) are: $\langle W_p \rangle = 3.32(\pm 1.72) \cdot 10^{63} erg$ (for quasars) and $\langle W_p \rangle = 3.77(\pm 1.55) \cdot 10^{61} erg$ (for galaxies) in the examined sample. It is known that the magnetic field energy in sources is:

$$W_{IC} = \frac{B_{IC}^2}{8\pi} \cdot V(erg) \quad (3)$$

where V is the volume of a source. The mean values of the magnetic field energy from (3) are: $\langle W_{B_{IC}} \rangle = 1.19(\pm 1.13) \cdot 10^{62} erg$ (for quasars) and $\langle W_{B_{IC}} \rangle = 9.35(\pm 4.05) \cdot 10^{58} erg$ (for galaxies) in the examined sample.

It turned out, that the mean values of the ratio of the magnetic field energy and the energy of relativistic particles for sources with spectrum C+ are: $\langle W_{B_{IC}} / W_p \rangle = 0.13(\pm 0.07)$ (for quasars) and $\langle W_{B_{IC}} / W_p \rangle = 0.91(\pm 0.81)$ (for galaxies) in this sample.

So, we conclude from these ratios about the prevalence of the energy of relativistic particles over the energy of the magnetic field in the examined sources. The great extent of radio structure (~1Mpc) of quasars and galaxies with steepness spectrum at the decameter band may evidence in favor of such situation.

Ratios of emission at the different bands

Also, we examine the estimates of ratios of flux densities of emission in the different bands: decameter (frequency 25 MHz), centimeter (frequency 5000 MHz), infrared (IR), optical (opt), X-ray band for quasars and galaxies of the sample (at the logarithmic scale). These are identical to the ratios of the corresponding monochromatic luminosities (Table 1).

One can see, the mean values of corresponding ratios for quasars and galaxies in Table1 have enough close quantities. In that case, the obtained characteristics of radio sources with spectrum C+ are in concordance with the unified model of sources [4, 5]. Also, it follows from the presented ratios (Table 1), that galaxies contain more dust (which is responsible for the infrared emission) than quasars.

Let us examine relations for derived characteristics of quasars and galaxies with spectrum C+. In particular, the relation of the ratio of monochromatic luminosities at the decameter and infrared bands versus the redshift for the sample objects is presented in Figure 1.

Table 1. Mean values of the ratios of monochromatic luminosities at the different bands for quasars and galaxies with spectrum C+

Mean value of the ratio	Quasars	Galaxies
$\langle \lg(\frac{S_{25}}{S_{5000}}) \rangle$	1.69(±0.08)	1.74(±0.05)
$\langle \lg(\frac{S_{25}}{S_{IR}}) \rangle$	4.30(±0.11)	3.67(±0.19)
$\langle \lg(\frac{S_{25}}{S_{opt}}) \rangle$	5.00(±0.10)	5.15(±0.12)
$\langle \lg(\frac{S_{25}}{S_X}) \rangle$	7.78(±0.17)	7.89(±0.33)
$\langle \lg(\frac{S_{IR}}{S_X}) \rangle$	3.54(±0.20)	4.68(±0.47)

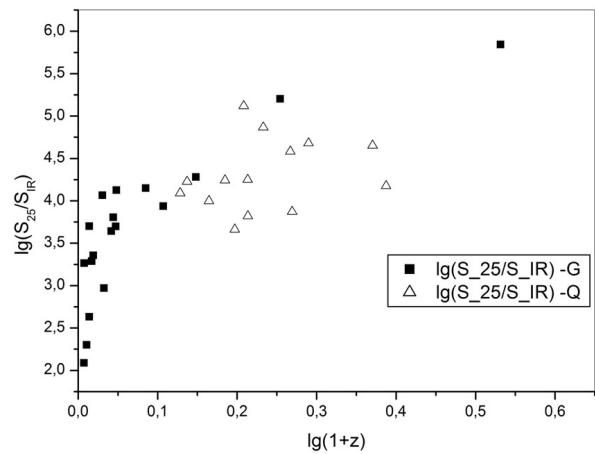


Figure 1: The ratio of monochromatic luminosities at the decameter and infrared bands versus the redshift

This relation evidences for the essential cosmological evolution of luminosities of sources with spectrum C+. The analogous picture is displayed in the relation of monochromatic luminosities of the sample objects at the decametre and optical bands versus the redshift (Figure 2).

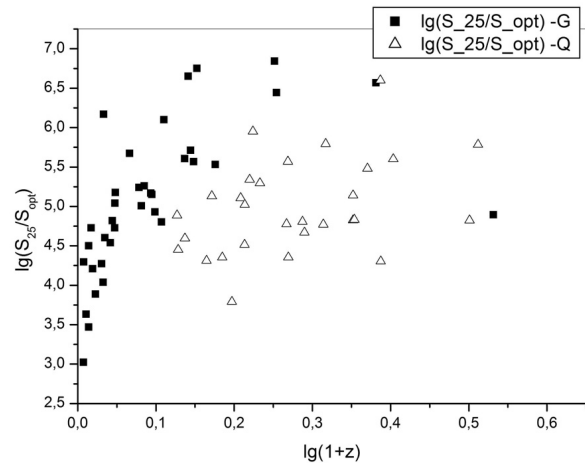


Figure 2: The ratio of monochromatic luminosities at the decameter and optical bands versus the redshift

The trend to increase of contribution of the decameter emission for more extent sources is noticeable in the relation of monochromatic luminosities versus the linear size of sources with spectrum C+ (Figure 3, Figure 4). The mutual relation of the monochromatic luminosities (Figure 5) for galaxies and quasars with spectrum C+ perhaps has maximum, indicating on the recurrence of the source's activity at the different bands.

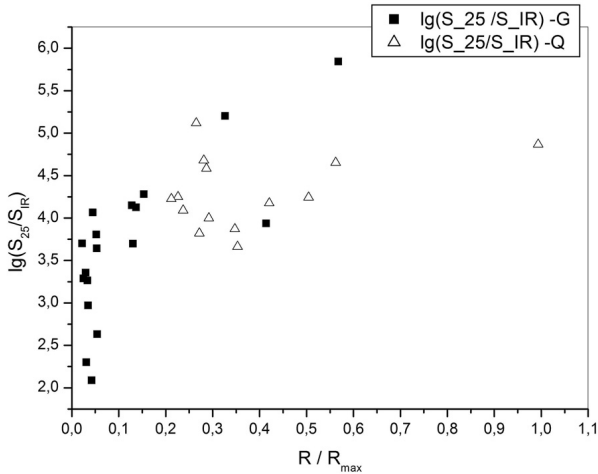


Figure 3: The ratio of monochromatic luminosities at the decameter and infrared bands versus the linear size

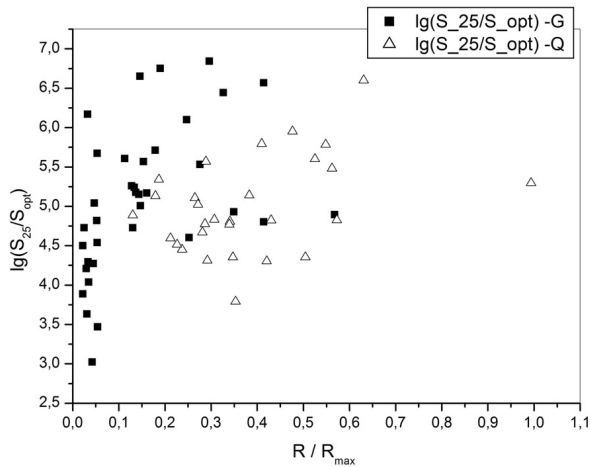


Figure 4: The ratio of monochromatic luminosities at the decameter and optical bands versus the linear size

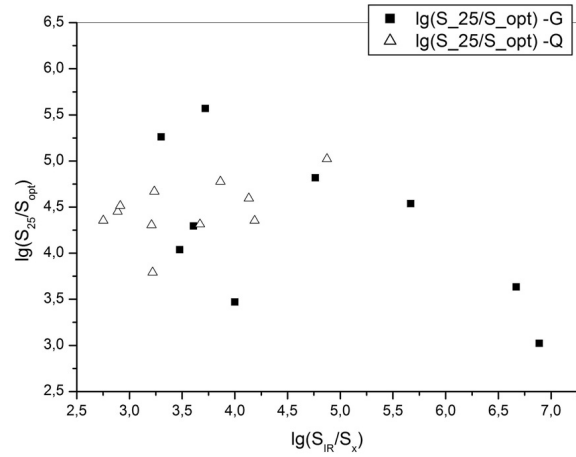


Figure 5: The mutual relation of monochromatic luminosities for the sample objects

Conclusion

The independent estimation of the magnetic field strength of the sources with spectrum C+ have been derived at the assumption about inverse Compton scattering for the X-ray emission of sources.

The contribution of the decameter emission increases for more extent sources with spectrum C+ and displays the evolution.

Similarity of the structure and the physical characteristics of galaxies and quasars with spectrum C+ testifies for the independence from the power of active nuclei and corresponds to the unified model of sources.

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