THE TIMING SCALE OF THE STEEP-SPECTRUM SOURCES

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ABSTRACT. We continue to study the properties of the steep-spectrum sources from the Grakovo catalogue received with the radio telescope UTR-2. At this paper the lifetimes of steep-spectrum sources have been estimated. We have used two methods to determine the characteristic ages of the steep-spectrum galaxies and quasars: 1) at independent estimate of the source's magnetic field strength; 2) at well-known condition of the equipartition of the magnetic field energy and the energy of the relativistic particles in objects. The derived alternative estimates of the characteristic age of steep-spectrum sources have been compared. The relations of ages and some physical parameters of the examined objects have been considered. The values of the source's lifetime and the characteristic age indicate on the possibility of the activity recurrence of galaxies and quasars with steep radio spectrum.

Key words: radio spectrum, characteristic age, galaxy, quasar, lifetime

Introduction

The most probable reason of origin of steep-spectrum sources (the spectral index $\alpha >= 1$) at the decametre band is their long evolution. The great extent of radio structure (~ Mpc) of galaxies and quasars with steep spectra testifies in favour of this statement. So, it is important to estimate the characteristic age of objects with steep radio spectra.

The particular interest present sources with great rising of the radio spectrum after a break at low frequencies (it is the spectral type C+). We have selected objects with spectrum C+ at the domain of declinations $\delta = -13^0 ... +20^0$ and $\delta = 30^0 ... 40^0$ detected at the catalogue of extragalactic sources UTR-2 (Grakovo catalogue) [1-6] with flux density more than 10 Jy at the frequency 25 MHz. It was found that 148 radio sources correspond to the selection criteria, including 52 galaxies, 36 quasars and 60 optically non-identified sources. As we have analysed, 10 objects from the galaxy sample have X-ray emission, and the quasar sample reveals 15 X-ray sources.

The necessary optical and high-frequency data for the sample objects have been get from the NED database (http://nedwww.ipac.caltech.edu) and the connected with NED sites.

The characteristic age and lifetime of sources with radio spectrum C+

We estimate the characteristic ages of examined sources with radio spectrum C+ in the UTR-2 catalogue by two methods: 1) at the independent estimate of the source's magnetic field strength; 2) at the well-known condition of the equipartition of the magnetic field energy and the energy of relativistic particles in sources. The independent estimation of the magnetic field strength B_{IC} of the sample sources has been derived at the assumption on origin of X-ray emission of objects by the inverse Compton scattering (IC) of microwave background photons by relativistic electrons.

Like at the recent paper [7], we use in the calculations the relation by Harris & Grindley [8] with our transforming to estimate the value B_{IC} at the frequency of X-ray emission $\nu_X = 2.42 \cdot 10^{17}\, Hz$ (at the energy of X-ray photons 1 keV) and the radio frequency $\nu_r = 2.5 \cdot 10^7\, Hz$ (the decameter band). So, we have determined the mean values of the magnetic field strength:
for galaxies in the sample with spectrum C+: $\prec B_{IC} \succ = 0.88(\pm 0.21) \cdot 10^{-6}\, Gauss$;
for quasars in the sample with spectrum C+: $\prec B_{IC} \succ = 1.69(\pm 0.29) \cdot 10^{-6}\, Gauss$.

2) Also we have derived the estimates of the magnetic field strength B_{equip} of examined sources by the ordinary method – at the condition of equipartition of the magnetic field energy and the energy of relativistic particles in the sources. In that case, the mean values of the magnetic field strength B_{equip} are the next :
$< B_{equip} >= 8.14(\pm 0.58) \cdot 10^{-6}\, Gauss$ – for galaxies in the sample with spectrum C+;
$< B_{equip} >= 6.15(\pm 0.30) \cdot 10^{-6}\, Gauss$ – for quasars in the sample with spectrum C+.

Thus, the values of the magnetic field strength B_{IC} have noticeable smaller quantities comparatively with values B_{equip} (within the limits of one order).

It is known, that the characteristic age of source is determined as the time of synchrotron decay of relativistic electrons in the magnetic field of a source [9]:

$$t_{syn} = 50.3 \frac{B^{0.5}}{B^2 + B_{CMB}^2} [\nu_b (1+z)]^{-0.5} \ ,$$

where t_{syn} is the characteristic age of objects, 10^6 years; B is the magnetic field strength of source, 10^{-5} *Gauss*, the value $B_{CMB} = 0.32(1+z)^2$ is the strength of the equivalent magnetic field which corresponds to the intensity of the microwave background, 10^{-5} *Gauss*, ν_b is the critical frequency of the synchrotron spectrum of the source, GHz. In this paper the calculations of t_{syn} have been carried out at the value of the critical frequency ν_b=10 MHz.

1) So, we have get the estimates of the characteristic ages of the considered objects with radio spectrum C+ at the independent estimate of their magnetic field strengths B_{IC} :
the characteristic age t_{syn} for the sample galaxies (the mean value) is; $< t_{syn} >= 7.44(\pm 1.25) \cdot 10^8$ years
the characteristic age t_{syn} for the sample quasars (the mean value) is $< t_{syn} >= 1.76(\pm 0.27) \cdot 10^8$ years.

2) We have estimated the characteristic age of considered sources with spectrum C+ t_{equip} at the energy equipartition condition:
the characteristic age t_{equip} for the sample galaxies (the mean value) is $< t_{equip} >= 4.66(\pm 0.42) \cdot 10^8$ years;
the characteristic age t_{equip} for the sample quasars (the mean value) is $< t_{equip} >= 2.02(\pm 0.25) \cdot 10^8$ years.

Thus, the values of estimated characteristic age of sources with steepness spectrum C+ are enough great and cover the time interval from 10^8 to 10^9 years.

At the same time as it is interesting to estimate the lifetime t_W for examined radio sources. One can derive this value as the relation of energy of relativistic electrons W_e and low-frequency radio luminosity of source L:

$$t_W = W_e / L$$

We have used the corresponding relationships from [10]. It turned out that the mean lifetime $<t_W>$ for the sample galaxies is

$$< t_W >= 2.13(\pm 0.85) \cdot 10^{10} \text{ years;}$$

and the mean lifetime $<t_W>$ for the sample quasars is

$$< t_W >= 5.18(\pm 1.21) \cdot 10^9 \text{ years.}$$

Since the values of the lifetime of radio sources with spectrum C+ exceed the values of the characteristic age of these objects it is possible to assume the activity recurrence for galaxies and quasars with spectrum C+.

It is important to consider the relationships of the characteristic ages and other parameters of examined objects. As one can see from Figure 1 the relation of the age t_{syn} versus the linear size of objects may point out on two branches in this relation.

We have found that the ratio of infrared and X-ray luminosities, and one of decameter (at 25 MHz) and X-ray luminosities of considered sources correlates with their characteristic ages (see Figure 2,3,4). Hence, the contribution of the relatively low-frequency emission increases at the increase of the characteristic age of the steep-spectrum galaxies and quasars. Also, note that the ratio of the energy of relativistic particles and the magnetic field energy decreases at the increase of the characteristic age of the steep-spectrum sources (Figure 5).

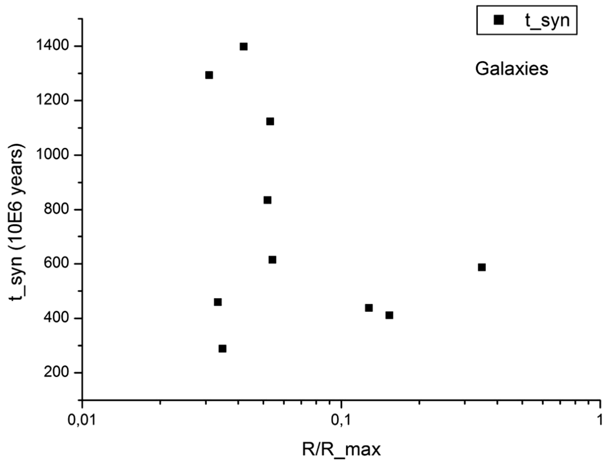

Figure 1: The relation of the characteristic age and the linear size of steep-spectrum sources

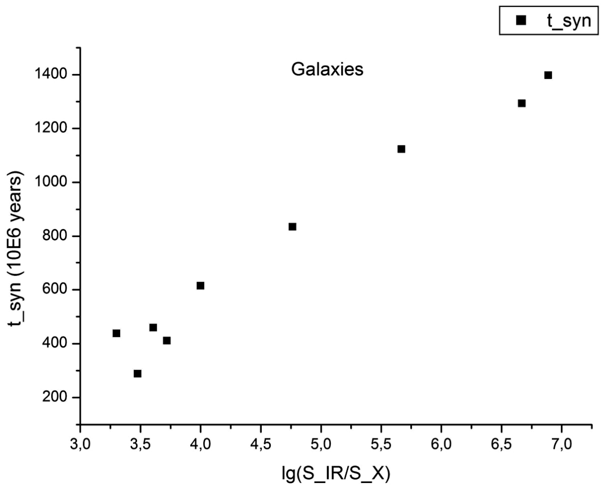

Figure 2: The characteristic age versus the ratio of galaxy's monochromatic luminosities at the infrared and X-ray bands

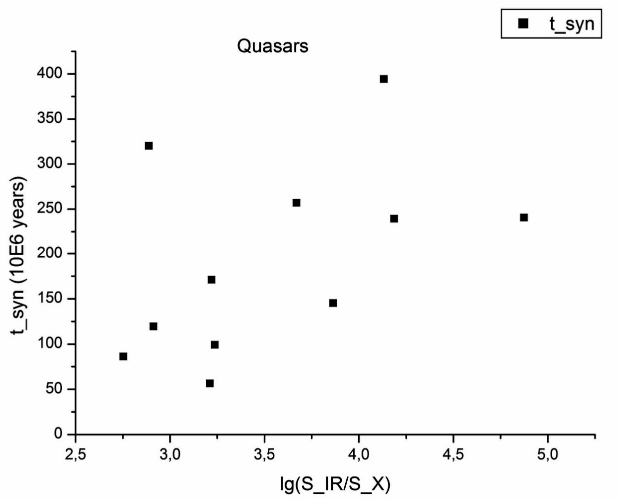

Figure 3: The characteristic age versus the ratio of quasar's monochromatic luminosities at the infrared and X-ray bands

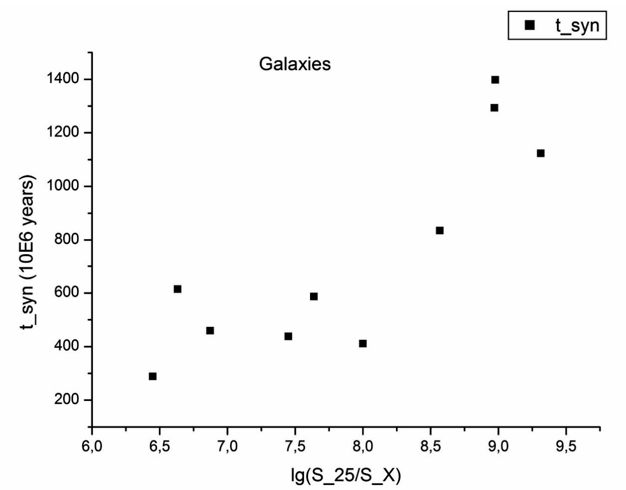

Figure 4: The characteristic age versus the ratio of monochromatic luminosities at the decameter and X-ray bands

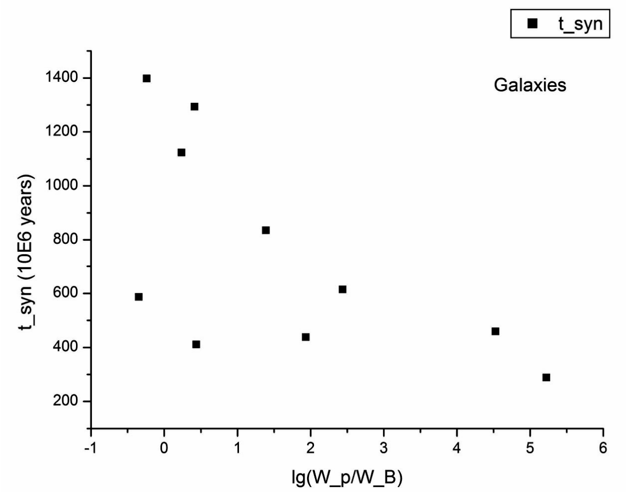

Figure 5: The characteristic age versus the ratio of the source's energy of relativistic particles and energy of magnetic field

Conclusions

The steep-spectrum galaxies and quasars possess the great characteristic age (~$10^8 – 10^9$ years).

The estimate of the lifetime of the steep-spectrum sources has value ~10^{10} years. So, it is possible to assume the activity recurrence for the examined sources.

The contribution of the low-frequency emission increases at the greater characteristic age of steep-spectrum objects.

The ratio of the energy of relativistic particles and the energy of the magnetic field decreases at the greater characteristic age of a source with steep spectrum.

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