EVOLUTION EFFECTS FOR QUASARS AND GALAXIES WITH JET STRUCTURE

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ABSTRACT. We determine the key physical characteristics of quasars and galaxies with jet structure from the observed data. The analysis of relationship of radio and optical luminosities versus the redshift for these objects is carried out. We estimate the lifetime of jet sources by different methods. Also, we study the relation of spectral indices of objects with cosmological epoch.

Keywords: jet, synchrotron radiation, characteristic age.

1. Introduction

Stream outflows from the cosmic object nuclei - jets, containing the relativictic particles, thermal plasma, magnetic field, are seeing in about 70% of radio galaxies and about 50% of quasars. The luminosity of the powerful radio sources with jets is of order $\sim 10^{42}$ erg/s, and of weak radio galaxies with jets $\sim 10^{38}$ erg/s. Linear sizes of jets are in the wide range - from some parsecs to dozens parsecs.

It is known the mean linear size of radio galaxies is decreases monotonously with the redshift, indicating on dependence of their characteristic life time from cosmological epoch (Guerra & Daly, 1998). Also radio sources observations testify, that jet propagation velocity increases with redshift (Wan et al., 2000).

At the synchrotron mechanism of jet radio emission the life time of relativistic electrons may arrive values of 10^8 years. At these characteristic times it is possible to expect the display not only the dynamic but the cosmological evolution of cosmic radio sources. So, the study of evolution relations of the key physical parameters of radio sources with jet structure is of interest.

2. Physical parameters of jet objects in our sample

In this paper the sample of radio sources with jets was considered on the basis of observed data at high radio frequencies (Bridle & Perley, 1984; Kuhr et al., 1981; Lawrence et al., 1986). In addition, we used the according data for sample objects at the optical and decametric band (Braude et al., 2003; Veron & Veron, 1991).

Our sample consists of 132 radio sources with jets, including 76 galaxies and 56 quasars. The mean sample redshift value is 0.066 ± 0.012 for galaxies, and 0.982 ± 0.110 for quasars. In whole for our sample the mean redshift value is 0.510 ± 0.063. The mean spectral index for objects with redshift $z \leq \langle z \rangle$ has value $\langle a \rangle = 0.75 \pm 0.04$, and $\langle a \rangle = 0.64 \pm 0.06$ for objects with redshift $z > \langle z \rangle$ in the given sample.

At accounts of physical parameters of objects we suppose the synchrotron mechanism of generation of optical and radio radiation of active nuclei. In this work the flat model of the Universe with parameter $q_0 = 0.5$ and the constant of Hubble $H_0 = 100\ km/s \cdot Mpc$ is used. As jets are well collimated flows, we consider, that the losses of energy of relativistic electrons on adiabatic expansion of a jet are insignificant in relation to losses of their energy on synchrotron radiation. The jets can be kept from expansion both external pressure, and own magnetic field.

For definition of a magnetic field strength of radio sources we accept a hypothesis about equipartition of energy of a magnetic field and energy of relativistic particles. Under such condition of the magnetic field strength of a radio source we find from the ratio (Ginzburg, 1987):

$$B = \left[48kA(\gamma, \nu) \frac{S_\nu}{r\varphi^3} \right]^{\frac{2}{7}}, \qquad (1)$$

where $k = 100$ (proton to electron energy ratio); $A(\gamma, \nu)$ is the tabular function; γ - index of the electron energy distribution; S_ν is the flux density at frequency ν; r is the jet distance; φ is the jet angular dimension.

The determined values B are in the range from $\sim 10^{-2}$ to 10^{-5}G, that is corresponded to known data. The mean value of the magnetic field strength is $\langle B_G \rangle = 1.37(\pm 0.99) \cdot 10^{-4}$G for galaxies and $\langle B_Q \rangle = 1.6(\pm 1.2) \cdot 10^{-3}$G for quasars in our sample. Then we estimate values of minimal total energy

$$E^{\min} = E_{rel} + E_B = \frac{7}{4}\,(1+k)\,A(\gamma,\nu) r^2 \frac{S_\nu}{B^{3/2}}, \quad (2)$$

and total luminosities for jet objects by using values of magnetic field strength,

$$L_{tot} = c\pi R^2 B^2. \quad (3)$$

These values are: $\langle E^{\min}\rangle_G = 3.77(\pm 1.65)\cdot 10^{60}$erg, $\langle L_{tot}\rangle_G = 5.68(\pm 3.23)\cdot 10^{48}$erg/s, $\langle E^{\min}\rangle_Q = 7.14(\pm 2.45)\cdot 10^{60}$erg, $\langle L_{tot}\rangle_Q = 1.03(\pm 0.16)\cdot 10^{49}$erg/s, respectively, for galaxies and quasars.

As we derived the characteristic size of ratio structure (mean value of object radii) $\langle R\rangle_G = 2.54(\pm 0.77)\cdot 10^{23}$cm, $\langle R\rangle_Q = 2.07(\pm 0.34)\cdot 10^{23}$cm, respectively, for galaxies and quasars of the sample.

We consider that the luminosity of active nuclei of jet sources L_{tot} is about value of the critical luminosity

$$L_{edd} = 1.2\cdot 10^{38}\frac{M}{M_\odot}, \quad (4)$$

which corresponds to Eddington limit at given object mass M (which is related to the Sun mass $M_\odot$). From this ratio we estimate object masses of $\langle M_G\rangle = 4.73(\pm 2.69)\cdot 10^{10}M_\odot$, $\langle M_Q\rangle = 8.55(\pm 1.30)\cdot 10^{9}M_\odot$, respectively, for galaxies and quasars.

Basing at our data, we account the characteristic time of the synchrotron decay of relativistic electrons in jet sources:

$$t_b = \left(\frac{340B^{-3}}{\nu}\right)^{1/2}, \quad (5)$$

where t_b is in years, B is in Gauss, ν is in MHz. This value is $\langle t_b\rangle_G = 4.39(\pm 1.84)\cdot 10^6$ years for galaxies and $\langle t_b\rangle_Q = 1.44(\pm 0.41)\cdot 10^6$ years for quasars at the centimeter band. At the decametric band these estimates are increase to one order, that is $\langle t_b\rangle_G \sim 5\cdot 10^7$ years, $\langle t_b\rangle_Q \sim 10^7$ years.

From the other side, we derive the minimal source age t_L as

$$t_L = \frac{E^{\min}}{L_{tot}}, \quad (6)$$

and it is $\langle t_L\rangle_G = 2.36(\pm 0.72)\cdot 10^4$years, $\langle t_L\rangle_Q = 1.92(\pm 0.32)\cdot 10^4$ years.

To estimate the velosity of jet propagation we used value t_L and value of radius R of a source:

$$v = \frac{R}{t_L}. \quad (7)$$

For our sample we derived the sublight velocities of jet propagation which indicate the dependence from the redshift, and the correspondent mean values are: $\langle v\rangle_G = 4.98(\pm 2.14)\cdot 10^9$ cm/s, $\langle z\rangle_G = 0.07$; $\langle v\rangle_Q = 1.99(\pm 0.71)\cdot 10^{10}$ cm/s, $\langle z\rangle_Q = 0.98$. It conforms with the increase of jet propagation velocity versus the redshift (Wan et al., 2000).

Assuming that object luminosity L_{tot} is due to a matter flowing, we obtained the rate of a matter flowing $\frac{dM}{dt}$ for galaxies and quasars from relation:

$$L_{tot} = \frac{1}{2}\frac{dM}{dt}v^2. \quad (8)$$

Then, the mean values of a matter flowing rate $\langle\frac{dM}{dt}\rangle$ are the next: $\langle\frac{dM}{dt}\rangle_G = 1.15(\pm 0.34)\cdot 10^4 M_\odot$/year, and $\langle\frac{dM}{dt}\rangle_Q = 5.33(\pm 1.04)\cdot 10^3 M_\odot$/year for galaxies and quasars, respectively. So we obtained the additional estimate of the jet object age:

$$t_M = \frac{M}{\frac{dM}{dt}} \quad (9)$$

of values $\langle t_M\rangle_G = 2.10(\pm 1.67)\cdot 10^7$ years and $\langle t_M\rangle_Q = 8.23(\pm 3.04)\cdot 10^7$ years for galaxies and quasars.

The value of relation of monochromatic luminosities of radio sources at low and high frequencies is of a great interest. At the first, the luminosity relation is independent from the choice of the world model. At the second, it is known from observations, the relation of object luminosities at low and high frequencies characterize the relation of luminosities of their extended (connected with jets) component and nucleus component (core).

We calculated the ratio of the monochromatic luminosities of jet objects at 25 MHz, 5 GHz and in optics. The luminosity ratio mean values for our sample are the next: $\langle\lg(\frac{L_{25}}{L_{opt}})\rangle_G = 4.40 \pm 0.20$; $\langle\lg(\frac{L_5}{L_{opt}})\rangle_G = 2.77 \pm 0.13$ for galaxies and $\langle\lg(\frac{L_{25}}{L_{opt}})\rangle_Q = 5.11 \pm 0.14$; $\langle\lg(\frac{L_5}{L_{opt}})\rangle_Q = 3.48 \pm 0.09$ for quasars.

3. Evolution relations for jet objects

The plot of our estimates of jet velocity against the redshift for sample objects indicates the correlation of this parameters (Fig.1). We have considered the relations between the magnetic field strength and the redshift and the spectral index, indicating a large dispersion of these values for jet objects. An analogous character has the relation between the object linear size and the spectral index and the redshift.

For galaxies and quasars in our sample we derived the evolution trend of luminosity ratio for decametric and optical bands (Fig.2), and for centimeter and optical bands (Fig.3). Note, that these relations indicate the smaller dispersion at the first case (see Fig.2). This corresponds to the synchrotron mechanism of the object radiation, when the radio sources evolve more rapidly at more higher frequencies with evidence of cosmological evolution. Note, that the luminosity ratio for galaxies at low redshifts has higher value then one for

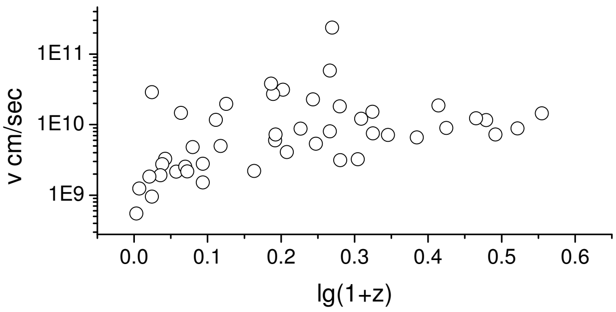

Figure 1: The jet propagation velocity against the redshift for jet objects.

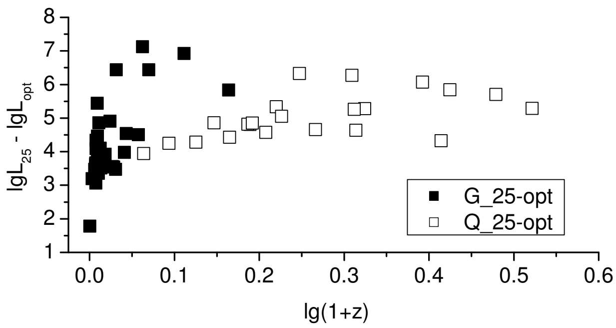

Figure 2: The ratio of luminosity at 25 MHz and optical luminosity against the redshift for jet objects.

quazars. That is, the luminosity of extended component dominates in galaxies especially.

It is interesting, that relation between the radio spectral index and the redshift for jet objects has the quasiperiodic character (Fig.4). In this plot we take the mean value of spectral indices in the redshift intervals $\Delta \lg(1+z) = 0.3$. Maybe, it is the evidence for assumption about the recurrence of activity of the quazar and galaxy nuclei.

4. Conclusions

The relation between the luminosity ratio of galaxies and quazars and the redshift corresponds to the synchrotron mechanism of radiation and indicates the cosmological evolution of object luminosity.

The evidence of correlation between the jet velocities and redshifts is derived in our sample.

The values of the jet propagation velocity received from estimate of the minimal source age points to the sublight velocity values.

The characteristic age of jet objects has the value of $10^6 \div 10^8$ years.

The relation between the ratio spectral index and the redshift for jet sources has a quasiperiodic trend.

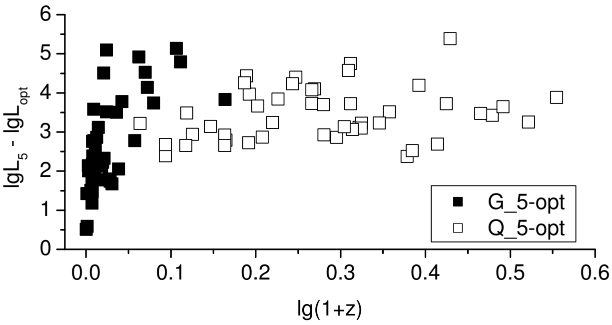

Figure 3: The ratio of luminosity at 5 GHz and optical luminosity against the redshift for jet objects.

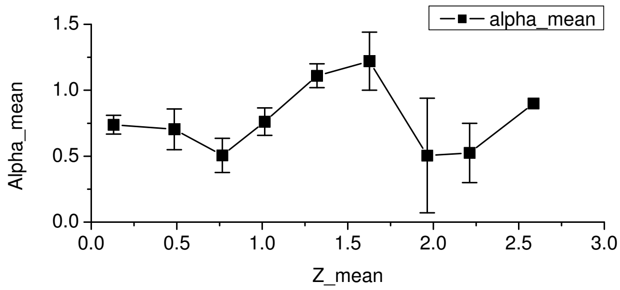

Figure 4: The spectral index against the redshift for jet objects.

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