LUMINOSITY-LINEAR SIZE RELATION FOR GALAXIES AND QUASARS WITH STEEP RADIO SPECTRUM

A.P.Miroshnichenko

Institute of Radio Astronomy, NAS of Ukraine
4, Chervonopraporna Str., 61002, Kharkiv, Ukraine
mir@rian.kharkov.ua

ABSTRACT. Our data for sources with steep radio spectrum, detected with radio telescope UTR-2 at the decametre band give evidence on the great luminosities, linear sizes, characteristic ages of these objects. In connection with such peculiarities, we examine the luminosity-linear size relation of galaxies and quasars with steep radio spectrum at the decametre band. It turned out, that this relation has similar trends for considered radio sources with linear steep spectrum and break steep spectrum. Also we presented the luminosity ratio-linear size relation at different frequency ranges. We discuss the obtained evolution relations for galaxies and quasars with steep low-frequency radio spectrum.

Keywords: Galaxies: steep radio spectrum – Galaxies: luminosity – Quasars: steep radio spectrum – Quasars: luminosity

1. Introduction

For the purpose of further study of the peculiar class of objects – galaxies and quasars with low-frequency steep radio spectrum (the spectral index values are larger 1), we consider the relation of their radio luminosity and linear size. This relation, as pointed out Shklovskii (1963), may contain the information on the source's evolution. A number of authors (Kapahi, 1989; Gopal-Krishna & Kulkarni, 1992; Neeser et al 1995; Singal, 1996; Luo & Sadler, 2010) have studied the dependence of linear size on luminosity for radio galaxies and quasars, but there is no the single opinion. For instance, Kapahi (1989) obtained for powerful radio galaxies an increase of source's sizes at large luminosities, while Luo & Sadler (2010) established the same trend only for sources with low radio luminosity. Note, that majority of the authors have used samples of objects irrespective of range of the spectral indices. It is known, spectral indices of non-thermal radio spectra may be connected with acceleration mechanisms of relativistic particles and evolution of sources. The detailed study of the identified radio sources with steep spectra at the decametre band (Miroshnichenko, 2010, 2012a, 2012b, 2013, 2014, 2015) shows, that these radio sources have interesting properties. In particular, these objects have great luminosity ($L_{25} \sim 10^{28}$ W/Hz ster), great characteristic age (10^8 years), giant radio structure (~ 1 Mpc). It is noteworthy that the obtained energy ratio for steep-spectrum sources (Miroshnichenko, 2014) testifies that the energy of relativistic particles prevails over the energy of magnetic field in the galaxies and quasars with steep radio spectra.

2. Luminosity – linear size relation for powerful giant sources

From the UTR-2 catalogue (Braude et al., 1978, 1979, 1981a, 1981b, 2003) we have formed sample of radio sources with steep spectrum including objects with linear steep spectrum (S-type) and spectrum with low-frequency steepness after a break (C+ type). Within the declination ranges from -13 to +20 degrees and from 30 to 40 degrees of the UTR-2 catalogue we have identified 78 galaxies and 55 quasars with linear steep spectrum (S-type) and 52 galaxies and 36 quasars with break steep spectrum (C+type) (with flux density at 25 MHz S_{25} > 10 Jy and spectral index larger 1). We use the NED database (http://nedwww.ipac.caltech.edu) for the high-frequency and optical identifications. Estimates of the angular sizes of examined sources we have derived from the corresponding radio images of the NVVS survey (at frequency 1400 MHz), presented at NED database. We suppose, that angular sizes from NVSS are close to angular sizes of corresponding sources at low frequencies. Calculations of the physical parameters of considered radio sources are carried out at cosmological parameters $\Omega_m = 0.27$, $\Omega_\lambda = 0.73$, $H_0 = 71$ km/s Mpc. Table 1 presents the characteristic values of derived parameters of sample objects: <z> - is the mean value of the redshifts of considered class of objects; z_{median} – is the median value of the redshifts; $\langle L_{25} \rangle$ – is the mean value of the monochromatic luminosities at the frequency 25 MHz; <R> – is the mean value of the linear sizes of objects.

Table 1. Parameters of the sample sources

Objects	<z>	z_{median}	$\langle L_{25} \rangle_{(W/Hzsr)}$	<R>(cm)
G_S	0.697 (+-0.105)	0.364	3.27(+-1.18) 10^{28}	6.09(+-0.64) 10^{24}
G_{C+}	0.308 (+-0.076)	0.182	8.14(+-5.73) 10^{27}	3.50(+-0.52) 10^{24}
Q_S	1.029 (+-0.070)	0.944	5.17(+-1.35) 10^{28}	9.75(+-0.53) 10^{24}
Q_{C+}	0.950 (+-0.092)	0.857	4.78(+-1.73) 10^{28}	8.73(+-0.75) 10^{24}

As one can see from the Table 1, galaxies and quasars with steep low-frequency spectrum are characterized by great radio luminosity at the decameter band and the giant linear size. We examine relationship L_{25} (R) of radio luminosity at 25 MHz and linear size for each class of objects in our sample, that is, in 4 subsamples, which are: galaxies with linear steep spectrum (G_S), galaxies with break steep spectrum (G_{C+}), quasars with linear steep spectrum (Q_S), quasars with break steep spectrum (Q_{C+}). At this, the relation L_{25} (R) is considered at different ranges of redshift z relatively to median values z_{median} in given subsamples (see Figure 1 – Figure 6).

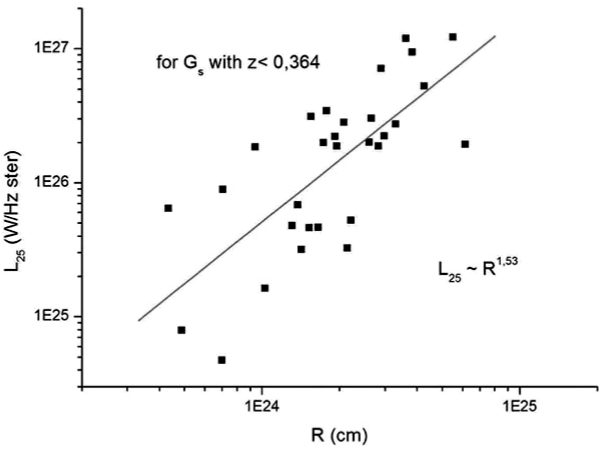

Figure 1: Luminosity at 25 MHz versus linear size for G_S at $z < z_{median}$

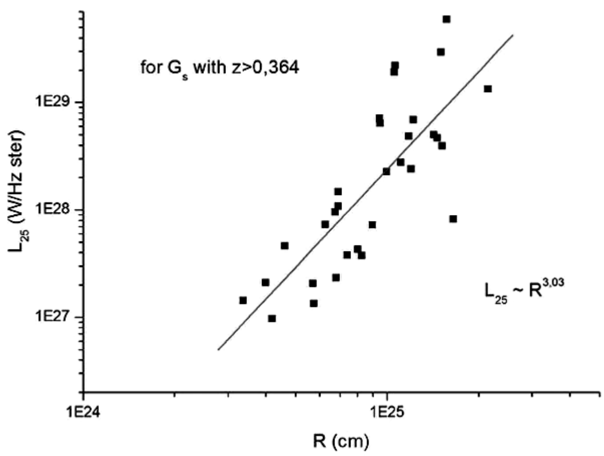

Figure 2: Luminosity at 25 MHz versus linear size for G_S at $z > z_{median}$

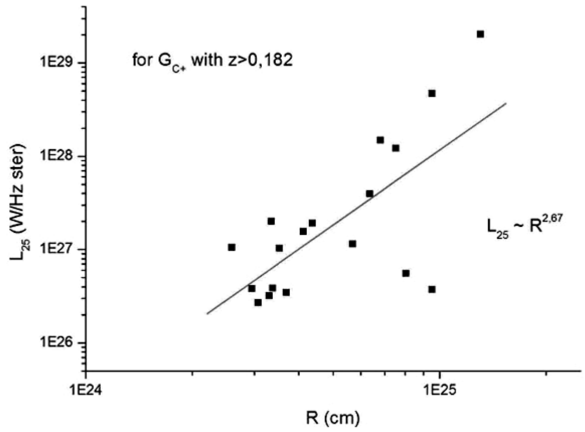

Figure 3: Luminosity at 25 MHz versus linear size for G_{C+} at $z > z_{median}$

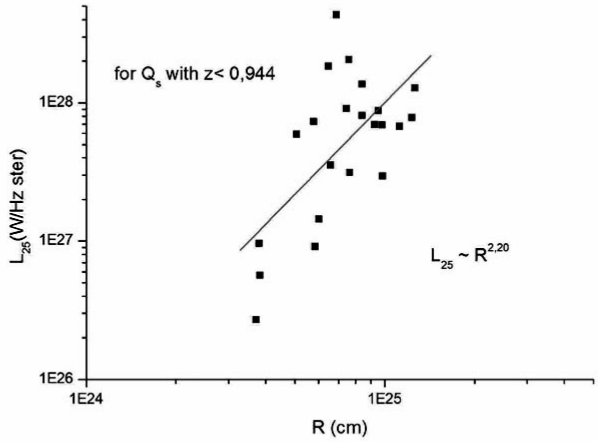

Figure 4: Luminosity at 25 MHz versus linear size for Q_S at $z < z_{median}$

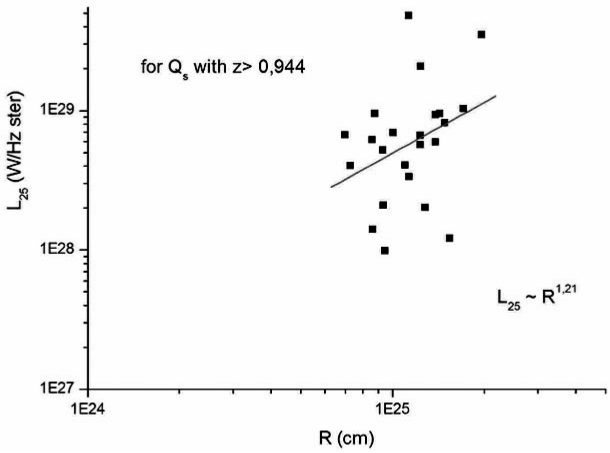

Figure 5: Luminosity at 25 MHz versus linear size for Q_S at $z > z_{median}$

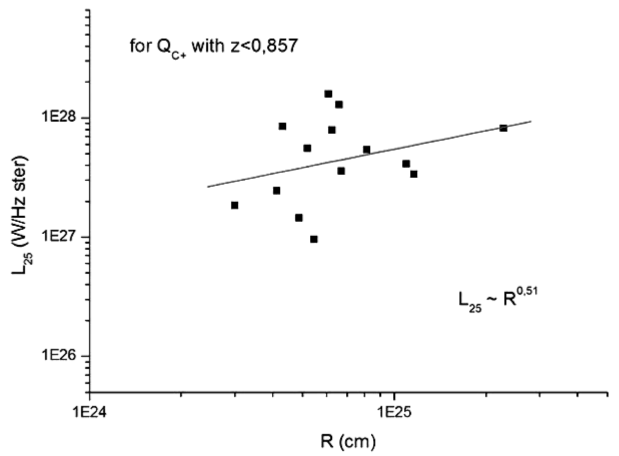

Figure 6: Luminosity at 25 MHz versus linear size for Q_{C+} at $z < z_{median}$

The derived relations L_{25} (R) have the power trend (see Figures 1 – 6 and Table 2).

Table 2. Relations L_{25} (R) in 4 subsamples (G_S, G_{C+}, Q_S, Q_{C+}) at redshift ranges z, less z_{median} , and larger z_{median}

Objects /and their z_{median}	L_{25} (R) at $z < z_{median}$	L_{25} (R) at $z > z_{median}$
G_S /0.364	$L_{25} \sim R^{1.53\ (+-0.27)}$	$L_{25} \sim R^{3.03(+-0.43)}$
G_{C+} /0.182	$L_{25} \sim R^{0.98\ (+-0.40)}$	$L_{25} \sim R^{2.67(+-0.70)}$
Q_S /0.944	$L_{25} \sim R^{2.20\ (+-0.60)}$	$L_{25} \sim R^{1.21(+-0.75)}$
Q_{C+} /0.857	$L_{25} \sim R^{0.51\ (+-0.44)}$	$L_{25} \sim R^{1.57(+-0.98)}$

It is interesting that the ratio of corresponding luminosities at decameter and optical bands (L_{25} / L_{opt}) for sample objects displays the similar correlation with linear size of sources (see Figure 7, Figure 8).

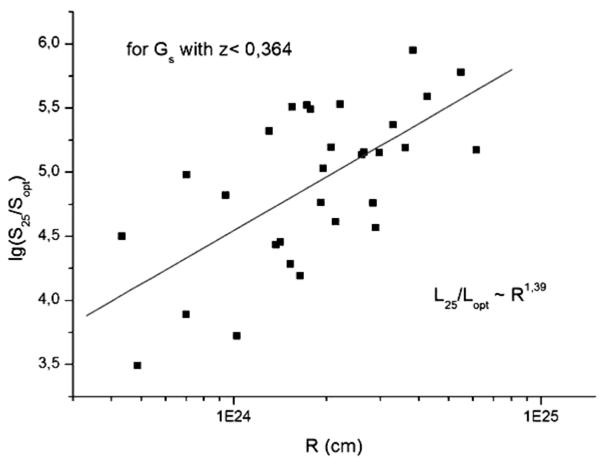

Figure 7: Ratio of luminosities at decametre and optical bands versus linear size for G_S at $z < z_{median}$

We can consider the ratio of decametre and optical luminosities of source as the ratio of emission of extended component and central component of source. As it follows from Figure 7 and Figure 8, the relative contribution of the decametre emission in steep-spectrum sources increases for more extended objects.

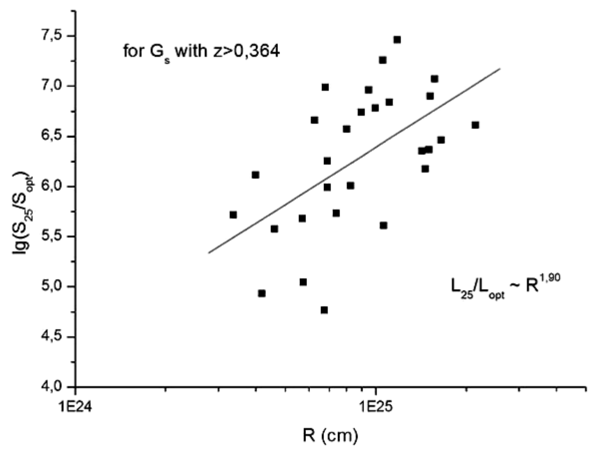

Figure 8: Ratio of luminosities at decametre and optical bands versus linear size for G_S at $z > z_{median}$

Also, we study the relation L_{25} (R) at the same range of redshifts: z = 0 – 0.5 for each subsample of objects. It turned out that obtained relations have the power shape:

for G_S : $L_{25} \sim R^{1.93\ (+-0.22)}$
for G_{C+} : $L_{25} \sim R^{1.81\ (+-0.25)}$
for Q_S : $L_{25} \sim R^{1.80\ (+-1.06)}$
for Q_{C+} : $L_{25} \sim R^{0.25\ (+-0.94)}$

So, galaxies and quasars with steep spectrum and giant radio structure reveal the positive correlation of their radio luminosity and linear size. Within the limits of statistical errors the derived power indices of the relation L_{25} (R) are enough close in values for galaxies and quasars of our sample. The noticeable disperse at the each found relation L_{25} (R) for sources with steep radio spectrum may be caused by cosmological evolution of linear size, that is, the relation of linear size and redshift, R (z). To exclude the influence of itself cosmological model used at calculation of source's physical parameters, we search for the relation R (z) only at given bins of luminosity L_{25} (at bin value Δ lg L_{25} = 1). For example, at the luminosity bin $L_{25} = 10^{28} – 10^{29}$ (W/Hz ster) the derived relation R (z) shows power trend in 4 subsamples:

for G_S : $R \sim (1+z)^{0.74\ (+-0.38)}$
for G_{C+} : $R \sim (1+z)^{0.97\ (+-0.27)}$
for Q_S : $R \sim (1+z)^{0.83\ (+-0.52)}$
for Q_{C+} : $R \sim (1+z)^{1.87\ (+-0.42)}$.

One can note the more considerable evolution of the linear size of quasars with break steep radio spectrum (C+type). This corresponds to great characteristic age of these objects. According to our previous estimates of characteristic age of sources with steep radio spectrum (Miroshnichenko, 2013) the age of galaxies and quasars with spectrum of C+type is ~ 10^8 years, and near one order is larger than the characteristic age of sources with steep spectrum of S – type.

3. Conclusion

Empirical relations of luminosity and linear size have been derived for samples of powerful galaxies and quasars with low-frequency steep spectrum and giant radio structure.

Within the limits of statistical errors the power shape of the relation of luminosity and linear size is, practically, the same for galaxies and quasars with steep spectrum.

The cosmological evolution of linear size of galaxies and quasars with steep radio spectrum have been revealed, at that quasars with spectrum C+ show the more considerable evolution.

The found relation of decametre luminosity and linear size points out on the huge power of the "central engine" of sources with steep radio spectrum, which provides for rejection of jets to giant distances (~ Mpc).

References

Shklovskii I.S.: 1963, *SvA*, **6**, 465.
Kapahi V.: 1989, *AJ*, **97**, 1.
Gopal-Krishna & Kulkarni V.: 1992, *A&A*, **257**, 11.
Neeser M. et al.: 1995, *ApJ*, **451**, 76.
Singal A.: 1996,in *Extragalactic Radio Sources*, Dordrecht, 563.
Luo Q. & Sadler E.: 2010, *e-print*, arxiv: 1003.0667.
Miroshnichenko A.: 2010, in *Astrophysics and Cosmology after Gamow,* New York, AIPC, **80**, 335.
Miroshnichenko A.: 2012a, *Radio Physics and Radio Astronomy,* **3**, 215.
Miroshnichenko A.: 2012b, *Odessa Astron. Publ.,* **25**, 197.
Miroshnichenko A.: 2013, *Odessa Astron. Publ.,* **26/2**, 248.
Miroshnichenko A.:, 2014, in *Multiwavelength AGN Surveys and Studies*, Cambridge, 96.
Miroshnichenko A.: 2015, *e-print*, arxiv: 1505.01870.
Braude S.et al.: 1978, *Astrophys. Space Sci.,* **54**, 37.
Braude S.et al.: 1979, *Astrophys. Space Sci.,* **64**, 73.
Braude S.et al.: 1981a, *Astrophys. Space Sci.,* **74**, 409.
Braude S.et al.: 1981b, *Astrophys. Space Sci.,* **76**, 279.
Braude S.et al.: 2003, *Kinem. Phys. Celest. Bod.,* **19**, 291.