Compact Steep Spectrum Sources – Subclass Diversity and Implication

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ABSTRACT

In this paper, we apply statistical methods of analyses to find some empirical diversity in some parametric relations between two subclasses of compact steep spectrum (CSS) sources; namely, the CSS quasars and CSS galaxies. This is done by carrying out linear regression analysis of observed source linear sizes (D) of CSS quasars against their respective observed redshifts (z); as well as, observed source linear sizes against their respective observed luminosities (P).

For the CSS quasars, result indicates that with marginal correlation coefficient $(r \approx 0.4)$, observed linear size shows an inverse relationship with observed redshift $[D \sim (1+z)^{-2.3}]$; while for the CSS galaxies, the converse is the case, $D \sim (1+z)^{2.9}$, where $r \approx 0.4$. Moreover, on the $D-P$ plane, we obtain similar trends respectively for the CSS quasars and CSS galaxies. That is, for the quasars, result shows an inverse relationship between linear size and luminosity according to the relation, $D \sim P^{-0.6}$; whereas for the galaxies, the relationship between the two observable parameters is direct, with $D \sim P^{0.2}$.

The results literally show that $D-P/z$ data for the CSS quasars evolve in size and radiated power output with time; while the converse is the case with the $D-P/z$ data for the CSS galaxies. These observations may be interpreted to mean that at earlier epoch, CSS galaxies are larger in both sizes and radiated power than their quasar counterparts. Therefore, in conclusion, we may state that CSS quasars are younger than their galaxy counterparts when matched at the same epoch.

(Keywords: linear size, luminosity, redshift, radio sources, quasars, galaxies, steep spectrum, epoch)

INTRODUCTION

Beyond the confines of our home galaxy are extragalactic sources. They can be classified as active and non-active galaxies. The active galaxies are further sub-divided into radio-loud sources and radio-quiet sources. The radio-loud sources are generally referred to as extragalactic radio sources. Generally, extragalactic radio sources (EGRS) radiate copious amount of radio waves. They are sources that have high radio to optical emission ratio; and is given by, $S_{5\text{ GHz}}/S_{6\times10^5\text{GHz}} > 10$ [1–11].

Based on their observed linear sizes, they can be classified into two groups; namely, the large extended sources – their observed linear sizes (D) are in the range, $D > 30\text{ kpc}$; and the compact steep spectrum sources – whose observed linear sizes are $D < 30\text{ kpc}$ [1,2,4–6]. Usually, the radio morphology of the EGRS assumes the form of two opposite sided relativistic jets of plasma that connect the base of the accretion disc to two radio-emitting lobes that envelope the nucleus. The nucleus or central core is believed to host a supper-massive blackhole and is taken to be the central engine that fuels the activities that characterize any active galaxy. [1–11].

In some sources, the lobes contain hotspots which is generally assumed to be the termination points of the radio jets; while the observed jets are assumed to be the conduits through which the lobes are fed with jet materials [1, 4, 5]. Figure 1 shows the schematic structure of a typical EGRS; while, Figure 2 shows Cygnus A – an example of EGRS.

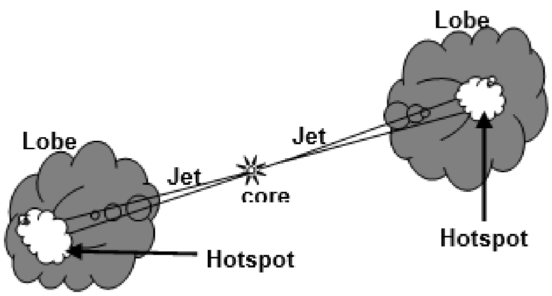

Figure 1: The Schematic Structure of a Typical EGRS. (Source: The author).

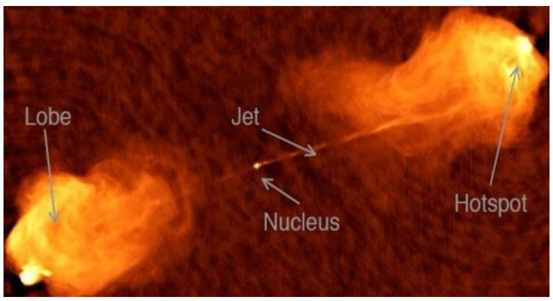

Figure 2: Cygnus A – An EGRS. (Source: slideplayer.com)

As mentioned earlier, the more extended EGRS have linear sizes well above $30\,\mathrm{Kpc}$ assuming Hubble constant is $75\,\mathrm{kms^{-1}Mpc^{-1}}$. This simply means that their linear sizes extend into intergalactic media since the size of a typical galaxy is around $30\,\mathrm{Kpc}$ [5]. Their radio luminosity is in excess of $10^{26}\mathrm{W}$ at $5\,\mathrm{GHz}$ with bolometric luminosities given as $10^{37}\mathrm{W}$ – which is common with those of the CSS sources [1,5].

CSS sources comprise of a sub-class of EGRSs [12–19]. The major difference between a typical CSS source and a large extended EGRS is easily seen in their small sizes, even though they are as powerful in radiation as the more extended sources [12–19].

Generally, their spectral indices show steep spectra (spectral index, $\alpha < 0.5$, $S_\nu \propto \nu^{-\alpha}$; where S_ν is flux density). They are full-fledged radio galaxies and quasars complete with jets and lobes [12–19] (see Figures 1 and 2). They are normally seen at high redshifts (generally, they tend to have redshift distribution of $z \leq 4$) and are among high luminosity sources [12–19].

In addition, it has been well stated in the literature that observation of jets in radio sources should mean presence of gaseous ambient media [5,7,12,15]. Some hydrodynamic simulations of jet propagations through ambient media have been carried out in order to study their observed properties [5–11].

These studies show that jet materials have smaller masses than those of the ambient medium; hence, indicating that jet particles are simply light particles such as electrons and positrons. Ezeugo and Ubachukwu [12] worked on dynamical evolution of CSS sources and used it to estimate their ambient densities. This simply shows that CSS sources are surrounded by dense gases in their host galaxies.

In this paper, we use these CSS sources to find some empirical diversity in some parametric relations between two subclasses of CSS sources: namely, the CSS quasars and CSS galaxies. The CSS sample used in the analyses are obtained from O'Dea (1998) [13]. They comprise of 31 CSS quasars and 28 CSS radio galaxies. The sizes of all these sources are entirely sub-galactic; and hence, their observed linear sizes are less than $20\mathrm{kpc}$. This shows that they lay within their host galaxies.

OBSERVED SOURCE LINEAR SIZE AND REDSHIFT (CSS QUASARS)

We carry out linear regression analysis of observed source linear sizes, D, of the CSS quasars against their corresponding observed redshifts, z, in our sample (Figure 3).

On the $D - z$ plane (Figure 3), we obtain the relation:

$$\mathrm{Log}D = -2.301\mathrm{Log}(1 + \mathrm{z}) + 0.637 \qquad (1)$$

with correlation coefficient, $r = 0.4$. Even though the correlation is marginal, if we assume it is good enough for observed physical parameters such as those in the field of astronomy, we transform (1) to obtain:

$$D \sim (1 + z)^{-2.3} \qquad (2)$$

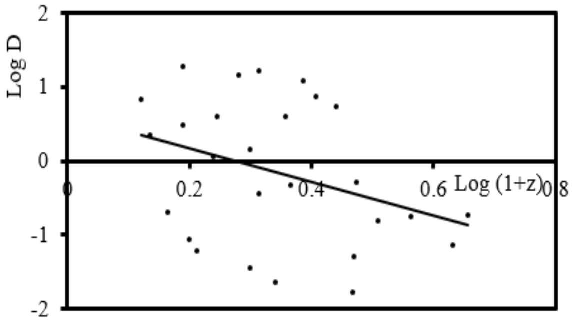

Figure 3: The Scatter Plot of Linear Size Against Redshift for the CSS Quasars.

OBSERVED LINEAR SIZE AND LUMINOSITY (CSS QUASARS)

Moreover, from linear size/luminosity $(D - P)$ data for the CSS quasars (Figure 4), we obtain a relation given by:

$$\text{Log } D = -0.573\text{Log P} + 15.88 \qquad (3)$$

(with marginal correlation coefficient given as $r = 0.4$), which connects the source linear size, D, and luminosity, P. Transforming the equation, we obtain:

$$D \sim P^{-0.6} \qquad (4)$$

This indicates that observed source size shows an inverse power-law function with observed luminosity.

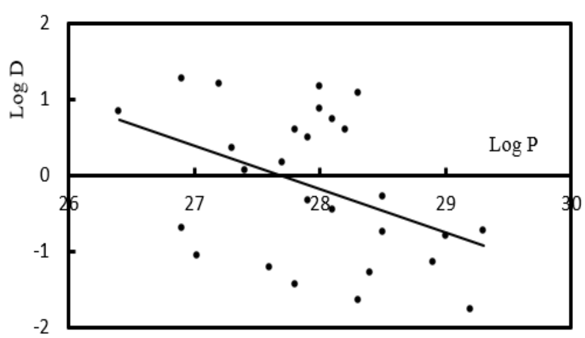

Figure 4: The Scatter Plot of Source Observed Linear Sizes against Observed Luminosities for the CSS Quasars.

OBSERVED LINEAR SIZE AND REDSHIFT (CSS RADIO GALAXIES)

In addition to the foregoing, we obtain $D - z$ data (Figure 5) for the CSS radio galaxies in our sample.

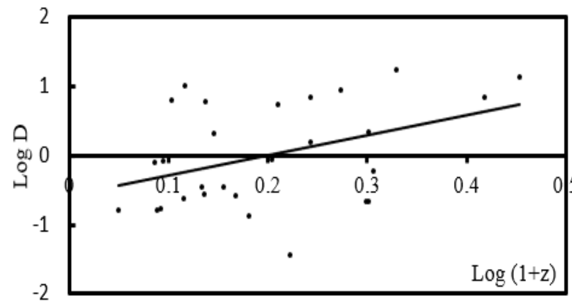

Figure 5: The Scatter Plot of Source Observed Linear Sizes against Observed Redshifts for the CSS Radio Galaxies.

Results show that marginal relationship exists between the source linear size and redshift ($r \approx 0.4$). However, if we assume just as before, that this marginal relationship is appreciable enough for the observed physical data, we will have the following relation for the CSS radio galaxies:

$$\text{Log}D = -0.581 + 2.921\text{Log}(1 + \text{z}) \qquad (5)$$

Rewriting it, we have:

$$D \sim (1 + z)^{2.9} \qquad (6)$$

We notice that this is out of order with result obtained for the quasar (see Equation (2)).

OBSERVED LINEAR SIZE AND LUMINOSITY (CSS GALAXIES)

Moreover, from linear size/luminosity $(D - P)$ data for the CSS galaxies (Figure 6), we obtain a relation given by:

$$\text{Log } D = 0.207\text{Log P} - 5.613 \qquad (7)$$

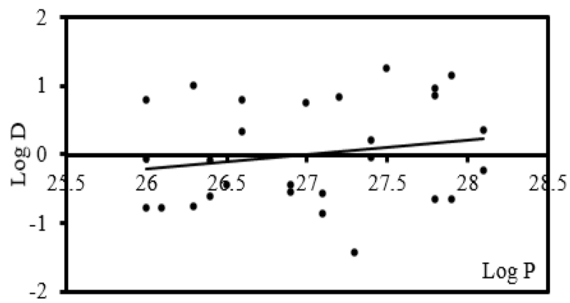

Figure 6: The Scatter Plot of Source Observed Linear Sizes against Observed Luminosities for the CSS Radio Galaxies.

(with poor correlation coefficient given as $r = 0.2$). If we assume the poor correlation is caused by lack of observation of CSS galaxies at high redshifts due to poor observational instruments), we may transform the last equation to obtain:

$$D \sim P^{0.2} \quad (8)$$

Hence, we may state that the observed source size shows a direct power-law function with observed luminosity just like we have seen in the $D - z$ data for the galaxies.

These inconsistencies in the results obtained from $D - P/z$ data for the quasars and the $D - P/z$ data for the galaxies may have possible implications. They are discussed in the next section.

DISCUSSION AND CONCLUSION

We have carried out linear regression analysis of observed source linear sizes, D, of the CSS quasars and their corresponding observed redshifts, z, (see Figure 3) in our sample. On the $D - z$ plane, we obtain the following relation: $D \sim (1 + z)^{-2.3}$, with correlation coefficient given as $r = 0.4$. We have stated that even though the correlation is marginal, we should take it to be good enough for observed physical parameters such as those in the field of astronomy.

Moreover, from linear size/luminosity $(D - P)$ data for the CSS quasars (see Figure 4), we obtain a relation, $D \sim P^{-0.6}$. The correlation coefficient is 0.4. The relation connects the source linear size and luminosity, P. This shows that observed source size has an inverse power-law function with observed luminosity.

Also, we obtain $D - z$ data (Figure 5) for the CSS radio galaxies in our sample. Results show that marginal relationship exists between the source linear size and redshift ($r \approx 0.4$) just like in their quasar counterparts. However, if we assume as before that this marginal relationship is appreciable enough for the observed physical data, we will have the following relation for the CSS radio galaxies: $D \sim (1 + z)^{2.9}$. This is not in consonance with results obtained for the CSS quasar (see Equation (2)).

In addition, from linear size/luminosity $(D - P)$ data for the CSS galaxies (Figure 6), we also obtain a relation given by, $D \sim P^{0.2}$. We may state that the observed source size shows a direct power-law function with observed luminosity just like we have seen in the $D - z$ data for the galaxies.

These inconsistencies in the results obtained from $D - P/z$ data for the quasars and the $D - P/z$ data for the galaxies may have possible implications. For the CSS quasars, result indicates that observed linear size shows an inverse relationship with observed redshift $[D \sim (1 + z)^{-2.3}]$; while for the CSS galaxies, the converse is the case, $D \sim (1 + z)^{2.9}$.

On the $D - P$ plane, we obtain similar trends respectively for the CSS quasars and CSS galaxies. That is, for the quasars result shows an inverse relationship between linear size and luminosity according to the relation, $D \sim P^{-0.6}$; while for the galaxies, the relationship between the two observable parameters is direct, with $D \sim P^{0.2}$. These results literally indicate that in the $D - P/z$ data for the CSS quasars, the CSS quasars evolve (increases) in size and radiated power output with time, while the converse is the case with the $D - P/z$ data for the CSS galaxies.

Significance of these observations is that at earlier epoch, CSS galaxies appear more powerful in both sizes and radiated power than the CSS quasars. Therefore conclusively, an implication of these results is that CSS quasars appear younger than their galaxy counterparts when matched at the same epoch.

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