ORIGINAL RESEARCH ARTICLE

ON COMPACT STEEP SPECTRUM RADIO QUASARS/GALAXIES AND YOUTH SCENARIO

Abstract

Statistical methods of analyses have been used to find some difference in some parametric relationships in the two subclasses of compact steep spectrum (CSS) sources. These sub-classes include CSS quasars and CSS galaxies. This is done by carrying out linear regression analysis on the observed source linear sizes(D) against their respective observed redshifts(z) – the analysis is done individually for the quasars and the galaxies. Moreover, the similar regression is applied on the observed source linear sizes against their respective observed luminosities (P). For the CSS quasars, result indicates that observed linear size shows an inverse relationship with observed redshift; while for the CSS galaxies, the converse is the case. On the linear size/luminosity plane, similar trends respectively for the CSS quasars and CSS galaxies are obtained. That is, for the quasars result shows an inverse relationship between linear size and luminosity; while for the galaxies, the relationship between the two observable parameters is direct. The $\mathrm{D} - \mathrm{P}/\mathrm{z}$ data show that CSS quasars evolve both in size and radiated power output with time; while for the galaxies the opposite is the case. These results suggestively indicate that at earlier epoch, CSS quasars appear more extended in sizes and radiated power than the CSS galaxies. Therefore, in conclusion, we may state that in addition to supporting Youth Scenario (i.e. young sources evolving in dense ambient media), dynamical evolution of CSS galaxies is different from that of quasars – while CSS galaxies evolve dynamically and progressively as well, CSS quasars suffer retrogressive dynamical evolution.

Keywords: evolution, linear size, luminosity, redshift, radio sources, quasars, galaxies, steep spectrum, youth scenario

1. Introduction

Outside our home galaxy, the Milky Way, are extragalactic sources. Based on their power output, they can be classified as active and non-active galaxies. The non-active galaxy is a galaxy whose total power output comes from the combined power outputs of its constituent stars; while the active one radiates its copious amount of power from a central core referred to as the central engine [1]. The central core is believed to house a super massive blackhole. It is good to note that the power radiated by this central core, by far, outweighs that radiated by the combined constituent stars [1]. 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 generally defined by, $S_{5\ \mathrm{GHz}}/S_{6\times10^{5}\mathrm{GHz}} > 10$ [2,3,4,5,6,7,8,9,10,11].

Depending on their observed linear sizes, they can be classified into two groups; namely, the large extended sources whose linear sizes (D) are in the range, $D > 30$ kpc; and the compact steep spectrum sources with observed linear sizes well below 30 kpc [2,3,4,5,6,7,8,9,10,11]. 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 super massive blackhole which is taken to be the central engine that fuels the activities that characterize any active galaxy. [2,3,4,5,6,7,8,9,10,11]. In some sources, the lobes contain hotspots which are 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 [3,5,9,11].

Just as mentioned earlier, the more extended EGRS have linear sizes well above 30 Kpc, assuming Hubble constant is $75 \text{ kms}^{-1}\text{Mpc}^{-1}$. This simply means that their linear sizes extend into intergalactic media since the size of a typical galaxy is around 30 Kpc (Robson 1996). Their radio luminosity is in excess of 10^{26}W at 5 GHz with bolometric luminosities given as 10^{37}W – which is in consonance with those of the CSS sources [1,9].

CSS sources comprise of a sub-class of EGRSs [3,12,13,14]. 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 [3,12,13,14,15]. 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 [3,12,13,14,16]. They are normally seen at high redshifts (generally, they tend to have redshift distribution of $z \leq 4$), and are among high luminosity sources [3,12,13,14]. Some authors have wondered on the relationship between CSS sources and the more extended EGRSs. As a result, there are models for the evolution of CSS sources in the literature. These include: Youth Scenario (i.e. young evolving sources), Frustration Scenario (i.e. sources confined by ambient dense gases), Relativistic Beaming and Orientation Effects (i.e. the source sizes are foreshortened by orientation and projection effects) [3,12,13,14]. In addition, it has been well stated in the literature that observation of jets in radio sources should mean presence of gaseous ambient media [5,9,12,13,14,15]. Some hydrodynamic simulations of jet propagations through dense ambient media have been carried out by some authors in order to study their observed properties [4,6]. 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. Besides, Ezeugo and Ubachukwu (2010) [17] 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.

2. Data and Analyses

In this work, we use these CSS sources to find some empirical difference in some parametric relationships in the two subclasses of CSS sources – the subclasses are the CSS quasars and CSS galaxies. The CSS sample used in the analyses are obtained from O'Dea (1998) [14]. 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 20kpc. This shows that they lay within their host galaxies.

3. Size / Redshift $(D - z)$ Plane for the 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 1).

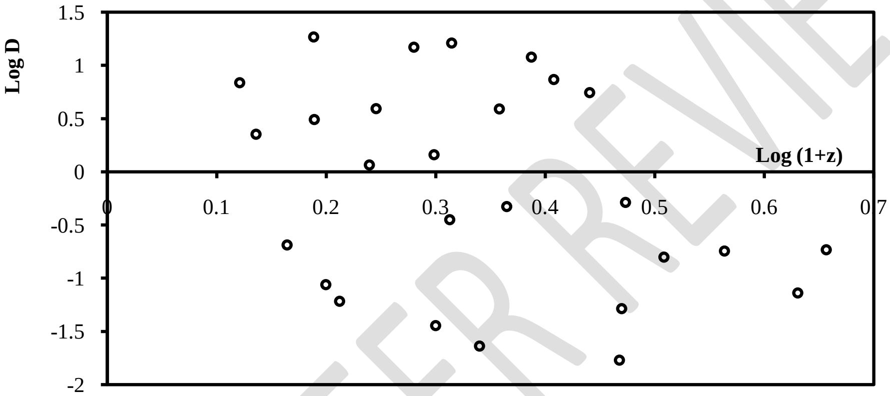

Figure 1: The scatter plot of linear size against redshift for the CSS quasars

On the $D - z$ plane, we obtain the relation:

$$\text{Log}D = -2.301\text{Log}(1 + \text{z}) + 0.637 \tag{1}$$

with correlation coefficient given as $r = 0.4$. In the field of Astrophysics, the correlation is appreciable enough; hence, we may transform (1) to obtain

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

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

4. Size / Luminosity $(D - P)$ Plane for the CSS Quasars

Moreover, from linear size/luminosity $(D - P)$ data for the CSS quasars (Figure 2), 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 is considered appreciable enough in the field of Astrophysics. The equation 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.

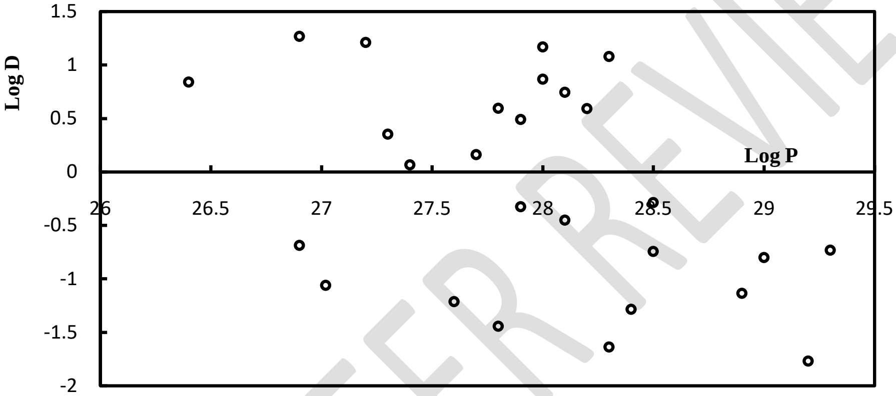

Figure 2: The scatter plot of source observed linear sizes against observed luminosities for the CSS quasars

5. Size / Redshift $(D - z)$ plane for the CSS Galaxies

In addition to the foregoing, we obtain $D - z$ data (Figures 3) for the CSS radio galaxies in our sample.

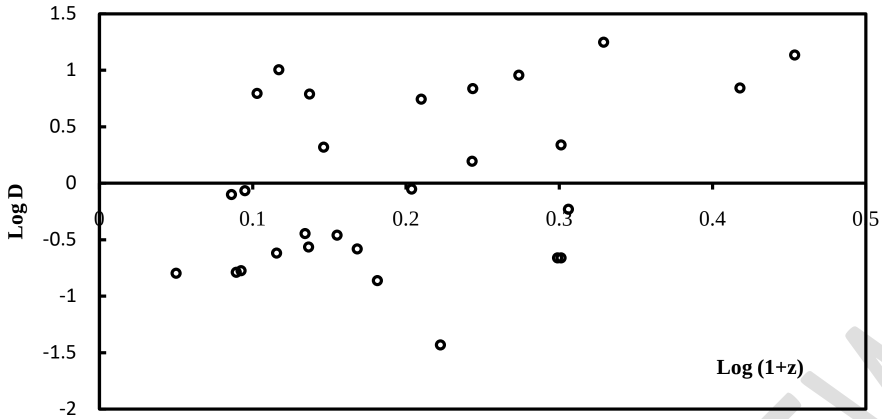

Figure 3: The scatter plot of source observed linear sizes against observed redshifts for the CSS radio galaxies

Results show that marginal relationship also exists between the source linear size and redshift ($r \approx 0.4$). Hence we obtain the following relation for the CSS radio galaxies:

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

Rewriting it, we have

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

However, the presence of positive index indicates that it is in disharmony with result obtained for the quasar (see equation (2)). Here, equation (6) states that linear size shows a direct relationship with redshift.

6. Size / Luminosity $(D - z)$ for the CSS Galaxies

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

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

(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

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

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.

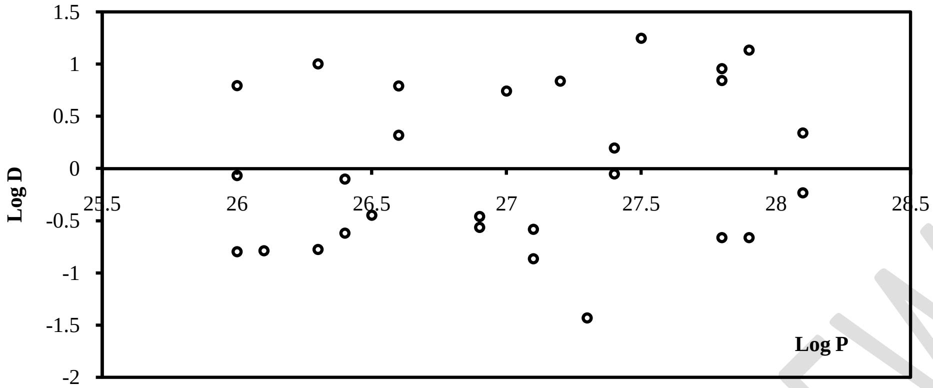

Figure 4: The scatter plot of source observed linear sizes against observed luminosities for the CSS radio galaxies

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.

7. Discussion

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 1) 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, it is considered good enough for observed physical parameters in the field of Astrophysics.

Moreover, from linear size/luminosity $(D - P)$ data for the CSS quasars (see Figure 2), 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 (Figures 3) 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; therefore, we have the following relation for the CSS radio galaxies: $D \sim (1 + z)^{2.9}$. However, this is not in consonance with results obtained for the CSS quasars (see equation (2)).

In addition, from linear size/luminosity $(D - P)$ data for the CSS galaxies (Figure 4), 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 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 $D \sim P^{0.2}$.

8. Conclusion

These results suggestively implies 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. These results suggestively indicate that at earlier epoch, CSS quasars appear more extended in both sizes and radiated power than the CSS galaxies. Therefore, in conclusion, we may state that in addition to supporting Youth Scenario which assumes that these sources are evolving in dense ambient media (see [13,17]), dynamical evolution of CSS galaxies is different from that of quasars – while CSS galaxies is besieged with progressive dynamical evolution, CSS quasars suffer retrogressive dynamical evolution. However, more data are needed to verify this assertion.

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