International Astronomy and Astrophysics Research Journal

3(4): 25-30, 2021; Article no.IAARJ.79753

Cosmological Evolution Effects on the Galactic Size Using Compact Steep Spectrum Sources

Ezeugo Jeremiah Chukwuemerie[1*]

[1]Department of Physics and Industrial Physics, Nnamdi Azikiwe University, Awka, Nigeria.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

Editor(s):
(1) Prof. Magdy Rabie Soliman Sanad, National Research Institute of Astronomy and Geophysics, Egypt.
(2) Prof. Hadia Hassan Selim, National Research Institute of Astronomy and Geophysics, Egypt.
Reviewers:
(1) Sergey G. Fedosin, Perm State University, Russia.
(2) Hanan Abd Ali Thjeel Al-Ogaili, Wasit University, Iraq.
(3) Fabiano F. Santos, Universidade Federal do Rio de Janeiro, Brazil.
(4) Shouvik Sadhukhan, Indian Institute of Technology, India.
(5) Javier Joglar Alcubilla, Spain.
Complete Peer review History, details of the editor(s), Reviewers and additional Reviewers are available here:
https://www.sdiarticle5.com/review-history/79753

Original Research Article

Received 23 October 2021
Accepted 25 December 2021
Published 27 December 2021

ABSTRACT

Here, we use statistical methods of analyses to find the effects of cosmological evolution on the galactic sizes using compact steep spectrum (CSS) sources. We have done this by carrying out linear regression analysis of observed source linear sizes (D) of CSS quasars against their observed redshifts (z). Result shows that D has an inverse relationship with z; correlation coefficient $(r \approx 0.4)$ is marginal. If D is taken to be distance between any two points within a galaxy, this result may be taken to mean cosmological evolution dependence on distance between any two points in an interstellar medium (ISM). In addition, the result of linear size/luminosity $(D-P)$ data indicates that CSS source size shows an inverse power-law function with luminosity. We notice that source luminosity may have a direct link with dynamical evolution; because, it (P) has been shown to have a direct relationship with source kinetic power. Therefore combining the effects of dynamical evolution and cosmological evolution, we find the relation, $D \sim P^{-0.76}(1+z)^{-1.52}$. This suggestively implies combined effects of dynamical evolution (D_P) and cosmological evolution (D_Z) on a CSS source size. Finally, we estimate the percentage effects of both D_P and D_Z on the CSS source size. Results indicate that the effect due to dynamical evolution is 33%; while that due to cosmological evolution is 67%. From the foregoing, the result obtained for cosmological

---

**Corresponding author: E-mail: chuksemerie@yahoo.com;*

evolution simply shows that if D is taken to be a distance separating any two positions in any ISM, then the evolution (or expansion) of this distance is appreciable when compared to other forms of evolution. Therefore, we may conclude by stating that as the universe is expanding with time, each galaxy is also expanding in size.

Keywords: Cosmological evolution; linear size; galactic size; luminosity; radio sources; quasars; dynamical evolution; steep spectrum.

1. INTRODUCTION

Generally, extragalactic radio sources (EGRS) emit large amount of radiation in the radio region. These are sources that have high radio/optical emission ratio, given by, $S_{5\,\mathrm{GHz}}/S_{6\times10^5\mathrm{GHz}} > 10$ [1–11]. They are located beyond the confines of our galaxy. They are made up of the following sub-classes: radio galaxies, radio quasars, BL Lacertae objects, and compact steep spectrum (CSS) sources [1,2,4–6]. The radio morphological structure of these sources usually takes the form of two opposite sided relativistic jets that connect the base of the accretion disk to two radio-emitting lobes that envelope the central component. This central component/core is believed to host a super massive blackhole and is taken to be the nucleus of the host galaxy [1–11]. In some sources, the lobes contain hotspots which is believed to be the termination points of the radio jets [1,4,5] (see Fig. 1 for clarity).

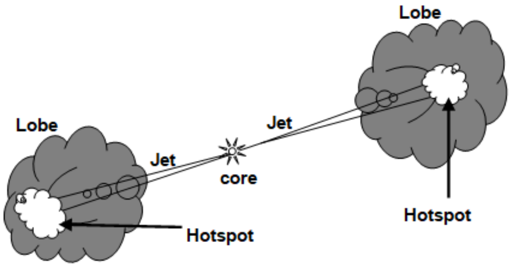

Fig. 1. The schematic structure of a typical CSS source
Source: The author

Generally, the more extended EGRS have linear sizes well above $30\,\mathrm{Kpc}$ if we assume Hubble constant is $75\,\mathrm{kms^{-1}Mpc^{-1}}$. This simply shows 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].

On the other hand, CSS sources constitute a sub-class of EGRSs [12–19]. The major difference between the CSSs and the extended EGRSs lies in their smallness, even though they are as powerful in radiation as the more extended sources [12–19]. Generally, their spectral index shows steep spectrum (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]. 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].

Moreover, it has been well noted that presence of jets in radio sources generally signifies presence of gaseous ambient media [5,7,12,15]. Some hydrodynamic simulations of jet propagations through ambient media have been carried out to examine the dynamical evolution of EGRSs [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. Besides, Ezeugo and Ubachukwu [12] worked on dynamical evolution of CSS sources and used it to estimate their ambient densities. In this work, we use these CSS sources to find effects caused by cosmological evolution on the galactic size. The CSS sources used in the analyses are obtained from O'Dea [13]. They constitute 31 CSS quasars and 28 CSS radio galaxies. The sizes of all these sources are sub-galactic $(D < 20\mathrm{Kpc})$; implying, they are buried in interstellar media (ISM).

2. SIZE / REDSHIFT RELATION

We carry out linear regression analysis of observed source linear sizes, D, of the quasars and their corresponding observed redshifts, z, (Fig. 4) in our sample.

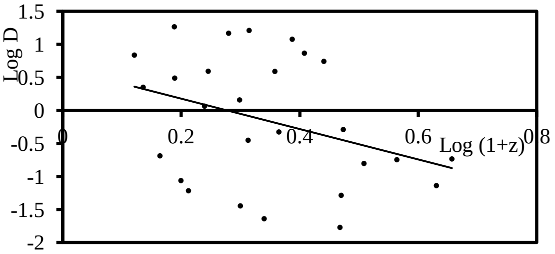

Fig. 2. The scatter plot of linear size against redshift for the CSS quasars

On the $D - z$ plane (Fig. 2), 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 these in the field of astronomy, we transform (1) to obtain

$$\mathrm{D} \sim (1 + \mathrm{z})^{-2.5} \qquad (2)$$

Or, writing $(1 + z)$ in terms if D, we find

$$(1 + \mathrm{z}) \sim \mathrm{D}^{-0.4} \qquad (3)$$

This implies that

$$\mathrm{z} = \mathrm{z}(\mathrm{D}) \qquad (4)$$

Therefore, if we take D to be distance between any two points in the interstellar medium (ISM), then equation (3) may mean that cosmological evolution shows an inverse power-law function with any distance between any two positions in such medium.

3. SIZE/LUMINOSITY RELATION

Moreover, from linear size/luminosity $(D - P)$ data (Fig. 3), we obtain a relation given by,

$$\mathrm{Log}\, D = -0.573\mathrm{Log}\, \mathrm{P} + 15.88 \qquad (5)$$

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

$$D \sim P^{-0.6} \qquad (6)$$

This indicates that observed source size shows an inverse power-law function with observed luminosity. Ezeugo J.C. [19] has shown from theory that source luminosity has a direct dependence on the source core-jet power (or jet kinetic power), P_{cj}, according to the following relation:

$$\mathrm{P} = \frac{\mathrm{P_{cj}ec^2t^2}}{\mathrm{D^2(1 - e)}} \qquad (7)$$

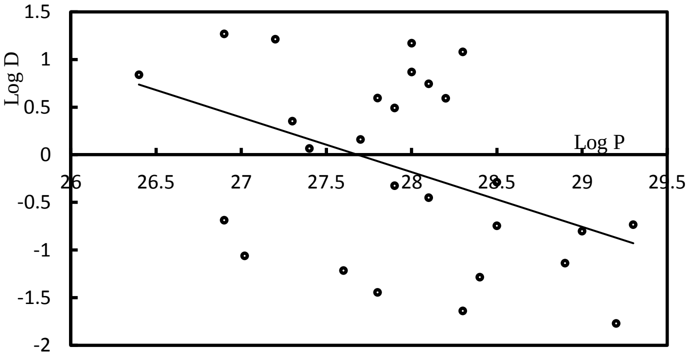

Fig. 3. The scatter plot of source observed linear sizes against observed luminosities for the CSS quasars

The last equation is the power with which the jet materials use to escape from the central core. e is conversion efficiency of kinetic power into radiation, c is light speed, t is source dynamical age. This shows that source luminosity is a measure of source kinetic power.

Moreover, since the last equation which is obtained from theoretical method [19] indicates an inverse relation between source linear size and source luminosity, it simply implies that the empirical result (equation (6)) is in consonance with the theory (equation (7)).

4. SIZE/REDSHIFT AND LUMINOSITY RELATION FOR THE CSS RADIO GALAXIES

In addition to the foregoing, we obtain $D-z$ and $D-P$ data (Figs. 4 and 5) for the CSS radio galaxies in our sample.

Results show that marginal relationship exists between the source linear size and redshift ($r \approx 0.4$); while between the linear size and observed luminosity, the relationship is poor ($r \approx 0.2$). However, if we assume this marginal relationship is appreciable enough for the observed physical data, we will have the following relation for the CSS radio galaxies:

$$\mathrm{LogD} = -0.581 + 2.921\mathrm{Log}(1+\mathrm{z}) \qquad (8)$$

Rewriting it, we have

$$\mathrm{D} \sim (1+\mathrm{z})^{2.9} \qquad (9)$$

This is out of order with result obtained for the quasar (equation (2)).

The inconsistency with results obtained for the quasars may be attributable to strong luminosity-selection effects – quasars are more visible at higher redshifts than the radio galaxies [19]. Therefore, we will use only results obtained for the quasars in our further analyses in this paper.

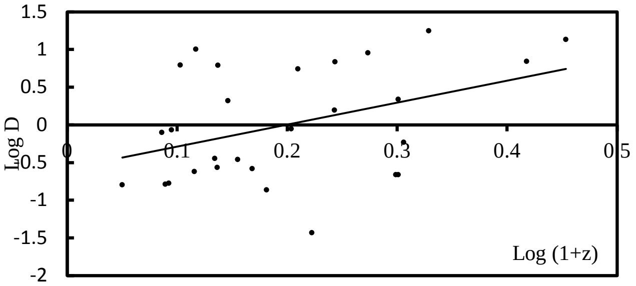

Fig. 4. The scatter plot of source observed linear sizes against observed redshifts for the CSS radio galaxies

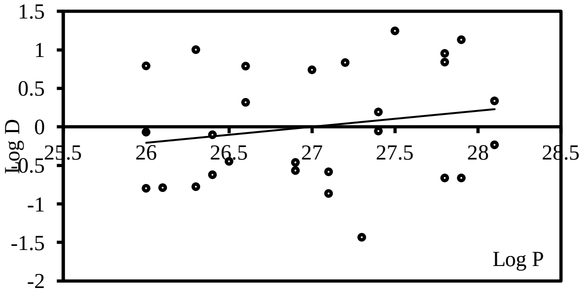

Fig. 5. The scatter plot of source observed linear sizes against observed luminosities for the CSS radio galaxies

5. DYNAMICAL AND COSMOLOGICAL EVOLUTIONS

Here, we combine the effects of dynamical and cosmological evolutions: solving equations (1) and (5) simultaneously, we obtain,

$$\mathrm{D} = (1.81 \times 10^{7})\mathrm{P}^{-0.76}(1+\mathrm{z})^{-1.52} \qquad (10)$$

Or we have

$$\mathrm{D} \sim \mathrm{P}^{-0.76}(1+\mathrm{z})^{-1.52} \qquad (11)$$

Equation (11) shows combined effects of dynamical evolution (D_P) and cosmological evolution (D_Z) in a CSS radio quasar. The source luminosity, P, is attributable to dynamical evolution because, as we pointed out earlier, it has direct relationship with the power supplied by the central core to the jet.

In addition, we use the indices of equation (11) to estimate the percentage effects of both D_P and D_Z. We obtain 33% and 67% respectively.

6. DISCUSSION AND CONCLUSION

We have carried out regression analysis of observed source linear sizes$(D)$of the quasars and their corresponding observed redshifts, z, (Fig. 2). Result shows that D relates with redshift (z) according to the equation, $D \sim (1+$ $z-2.5$ (with correlation coefficient, $r=0.4$). We have also pointed out that this relation could be rewritten as $(1+z) \sim D^{-0.4}$. This implies that $z = z(D)$ which may be interpreted to mean cosmological evolution dependence on distance between any two positions within a galaxy (or ISM). This is true if D is taken to be distance between any two points within the galaxy.

Moreover, the result of $D-P$ data for quasars (Fig. 3) shows that D relates with P according to the expression, $D \sim P^{-0.6}$. This shows that observed source size has an inverse power-law function with observed luminosity. It has been shown from theory that source luminosity indicates a direct dependence on the power with which the jet materials use to escape from the central core according to the following relation [19]: $P \sim P_{cj}$ (equation (7)). This power is referred to as core-jet power (or jet kinetic power) (P_{cj}). The relation shows that the magnitude of source luminosity is a measure of the magnitude of the source kinetic power.

Furthermore, since the relation (7), which is obtained from theoretical method [19] indicates an inverse relation between source linear size and source luminosity, we may simply state that the empirical result, $(D \sim P^{-0.6})$, is in consonance with that obtained from theory (equation (8)).

Moreover, we obtain $D-z$ and $D-P$ data (Figs. 4 and 5) for the CSS radio galaxies in our samples. Results obtained are not in consonance with those obtained for the CSS quasars. The inconsistency in the two sets of results may be attributable to strong luminosity-selection effects – quasars are easily observed at higher redshifts, unlike radio galaxies. This implies that only results obtained for the quasars are used in the further analyses.

Combining the effects of dynamical and cosmological evolutions by solving equations (1) and (5) simultaneously.

We obtain, $D \sim P^{-0.76}(1+z)^{-1.52}$, which may be interpreted as combined effects of dynamical evolution (D_P) and cosmological evolution (D_Z) in a CSS radio quasar. The source luminosity, P, is attributable to dynamical evolution because, it has direct relationship with source kinetic power (P_{cj})..

Finally, from the indices of equation (11), we estimate the percentage effects of both D_P and D_Z on the source observed linear size. Results show that while effect due to dynamical evolution is 33%, that due to cosmological evolution is 67%. From the analyses, result obtained for cosmological evolution shows that if D is taken to be a distance between any two points in any ISM, then the evolution (or expansion) of this distance is appreciable in comparison with other forms of evolution. Therefore, we may conclude by stating that as the universe is expanding with time, each galaxy is also expanding in size.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Ezeugo JC. Jet in the more extended radio sources and unification with compact steep spectrum sources. The Pacific Journal of Science and Technology. 2021;22:14–19.

2. Ubah OL, Ezeugo JC. Relativistic Jet propagation: Its evolution and linear size cosmic dilation. International Astronomy and Astrophysics Research Journal. 2021;3(3):1–6.
3. Urry CM. AGN Unification: An Update. Astronomical Society of the Pacific conference series 1; 2004.
4. Readhead AC. Evolution of powerful extragalactic radio sources. In proc. Colloquium on Quasars and Active Galactic Nuclei, ed. Kohen, M., and Kellermann, K. (USA: National Academy of Sciences, Berkman Center, Irvine). 1995;92:11447–11450.
5. Robson I. Active galactic nuclei, John Wiley and Sons Ltd, England; 1996.
6. Jackson JC. Radio source evolution and unified schemes. Publications of Astronomical Society of the Pacific. 1999; 16:124–129.
7. Kawakatu N, Kino M. The velocity of large-scale jets in a declining density medium. In Serie de Conferencias. Triggering Relativistic Jets, ed. W.H. Lee and E. Ramirez-Ruiz. 2007;27:192–197.
8. Mahatma VH, Hardcastleand MJ, Williams WL. LoTSS DR1: Double-double radio galaxies in the HETDEX field. Astronomy and Astrophysics. 2019;622:A13.
9. Mingo B, Croston JH, Hardcastle MJ. Revisiting the fanaroff-riley dichotomy and radio galaxy morphology with the LOFAR two-meter sky survey (LoTSS). Monthly Notices of the Royal Astronomical Society. 2019;488:2701–2721.
10. Hardcastle WL, Williams WL, Best PN. Radio-loud AGN in the first LoTSS data release — The lifetimes and environmental impact of jet-driven sources. Astronomy and Astrophysics. 2019;622:A12.
11. Dabhade P, Gaikwad M, Bagchi J. Discovery of giant radio galaxies from NVSS: Radio and infrared properties. Monthly Notices of the Royal Astronomical Society. 2017;469(3):2886–2906.
12. Ezeugo JC, Ubachukwu AA. The spectral turnover–linear size relation and the dynamical evolution of compact steep spectrum sources. Monthly Notices of the Royal Astronomical Society. 2010;408: 2256–2260.
13. O'Dea CP. The compact steep spectrum and gigahertz peaked spectrum radio sources. Publications of the Astronomical Society of the Pacific. 1998;110:493–532.
14. Fanti C, Fanti R, Dallacasa D, Schillizzi RT, Spencer RE, Stanghellini C. Are compact steep spectrum sources young? Astronomy and Astrophysics. 1995; 302:317–326.
15. Ezeugo JC. On the intergalactic media densities, dynamical ages of some powerful radio sources and implications. Journal of Physical Sciences and Application. 2021;11(1):29–34.
16. Ezeugo JC. Compact spectrum source size and cosmological implication. Journal of Research in Applied Mathematics. 2021; 7(2):1–4.
17. Ezeugo JC. Compact steep-spectrum radio sources and ambient medium density. International Journal of Astrophysics and Space Science. 2015; 3(1):1–6.
18. Ezeugo JC. On the dependence of spectral turnover on linear size of compact steep-spectrum radio sources. International Journal of Astrophysics and Space Science. 2015;3(2):20–24.
19. Ezeugo JC. On cosmic epoch and linear size/luminosity evolution of compact steep spectrum sources. American Journal of Astronomy and Astrophysics. 2021;9(1): 8–12.

© 2021 Chukwuemerie; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/79753