Probing into Cosmic Evolution Implication on Astronomical Distance Using Extragalactic Radio Sources

Jeremiah Chukwuemerie Ezeugo, Ph.D.

Department of Physics and Industrial Physics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

E-mail: chuksemerie@yahoo.com

ABSTRACT

We have used statistical methods to find the effects of cosmic evolution on astronomical distance using extragalactic radio sources. This we have done by carrying out linear regression analysis of observed source linear sizes (D) of radio-loud quasars and their corresponding observed redshifts, (z).

With appreciable correlation coefficient, result shows that D has an inverse relationship with redshift, z. We have also pointed out that this relation could be interpreted to mean cosmic evolution dependence on distance between any two points in a free space. This is true if D is taken to be distance between any two points in an empty space. Moreover, the result of linear size/luminosity (D-P) data shows that observed source size has an inverse power-law function with observed luminosity. Combining the effects of dynamical and cosmological evolutions, we find the relation, $D \sim P^{-19.47}(1+z)^{-0.76}$. This may be interpreted to mean combined effects of dynamical evolution (D_P) and cosmic evolution (D_Z) of an extragalactic radio source. The source luminosity is attributable to dynamical evolution because, it has been shown to have a direct relationship with source kinetic power. Finally, we estimated the percentage effects of both D_P and D_Z on the source observed linear size. Results show that effect due to dynamical evolution is 96%; while that due to cosmic evolution is 4%. Conclusively, the result obtained for cosmic evolution suggestively indicates that if D is taken to be a distance between any two regions in an empty space, then the evolution of this distance is entirely cosmic.

(Keywords: cosmic evolution, linear size, astronomical distance, luminosity, radio sources, quasars, dynamical evolution)

INTRODUCTION

Extragalactic radio sources (EGRS) radiate copious amount of radio radiation. They are those sources with high ratio of radio to optical emission. This ratio is generally defined by the quotient of the two flux densities given by $S_{5\ \mathrm{GHz}}/S_{6\times10^5\mathrm{GHz}} > 10$ [1–5]. They are located beyond the confines of the Milky Way, our galaxy. They comprise radio galaxies, radio quasars, and BL Lacertae objects [4–5]. Radio emission from these sources commonly takes the form of two opposite sided relativistic jets that connect the base of the accretion disk to two radio-emitting lobes that straddle the central component that is more or less coincident with the nucleus (or the core) of the host galaxy [4, 7–8]. In some sources, the lobes contain hotspots believed to be the termination points of the jets [4, 6–8] (see Figures 1–3).

The more extended EGRS have linear sizes, D, given by $D > 20\ \mathrm{Kpc}$ assuming Hubble constant, $H_0 = 75\ \mathrm{kms^{-1}Mpc^{-1}}$. In most cases, their linear sizes extend into intergalactic media. Their radio luminosity is in excess of 10^{26}Wat $5\ \mathrm{GHz}$ and overall luminosities $(P_{bol} \geq 10^{37}\mathrm{W})$ in common with the Compact Steep Spectrum Sources (CSS) [4–12].

Furthermore, it has been well noted that the presence of jets in radio sources simply suggests presence of gaseous ambient media [13-18]. A number of hydrodynamic simulations of jet propagations have been performed to examine their physical state [13–14]. These studies show that jet materials have smaller masses than those of the ambient medium. Ezeugo and Ubachukwu (2010) [10] created a model for evolution of compact steep spectrum (CSS) sources (which is a subclass of EGRS) and used it to estimate their ambient densities.

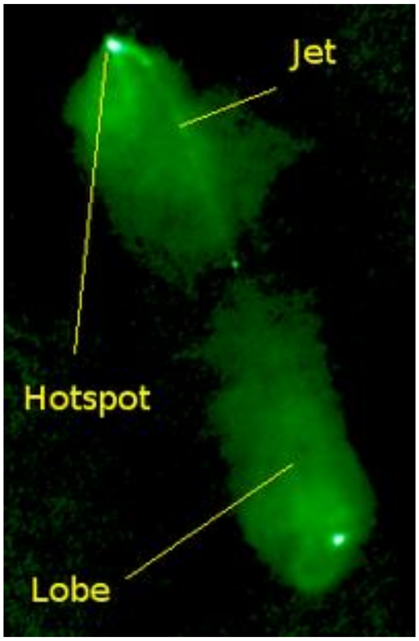

Figure 1: An EGRS (Source: Wkipedia).

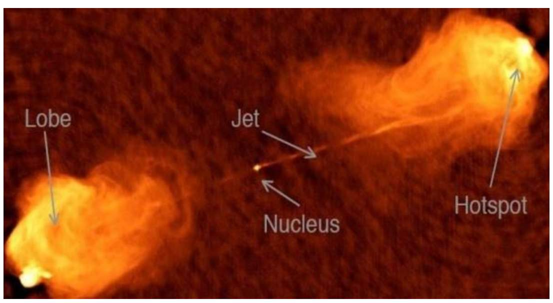

Figure 2: Cygnus A – An EGRS.
(Source: slideplayer.com)

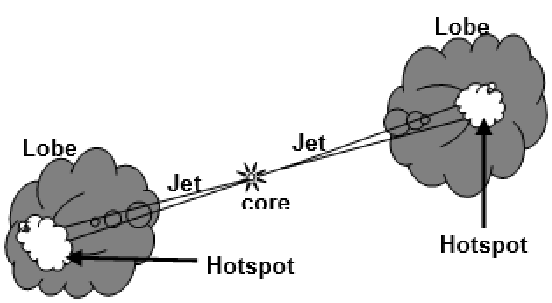

Figure 3: The Structure of a Typical EGRS.
(Source: [1], [2])

In this work, we want to probe into cosmic evolution using some of these extragalactic radio sources. The extragalactic radio sources used in the analyses are obtained from [20]. They are made up of 170 radio-loud quasars and 109 radio galaxies; hence, we have a total of 279 sources in our sample.

OBSERVED SOURCE LINEAR SIZE AND REDSHIFT RELATION

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

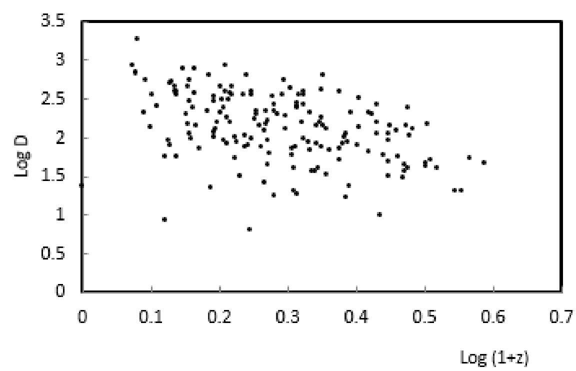

Figure 4: The Scatter Plot of Source Observed Linear Sizes against Observed Redshifts for the Quasars.

Results of the regression show that D relates with z according to the equation:

$$\mathrm{Log}D = 2.562 - 1.522\mathrm{Log}(1 + \mathrm{z}) \qquad (1)$$

The correlation is appreciable (correlation coefficient, $r = 0.41$); hence, Equation (1) may be transformed to be:

$$D \sim (1 + z)^{-1.5} \qquad (2)$$

Or

$$(1 + z) \sim D^{-2/3} \qquad (3)$$

This implies that:

$$z = z(D) \qquad (4)$$

Therefore, if we take D to be distance between any two points in free space, then Equation (3) suggestively indicates that cosmic evolution has an inverse power-law function with any distance between any two positions.

OBSERVED SOURCE LINEAR SIZE AND LUMINOSITY RELATION

Moreover, from $D - P$ data (Figure 5), we find the relation:

$$\text{Log } D = 66.34 - 38.93 \text{Log P} \quad (5)$$

(with correlation coefficient, $r = 0.52$), which connects the source linear size, D, and luminosity, P. Transforming the equation, we obtain:

$$D \sim P^{-3.9} \quad (6)$$

This shows that observed source size has an inverse power-law function with observed luminosity. It has been shown from theory by Ezeugo [21] that source luminosity shows a direct dependence on the source core-jet power (or jet kinetic power), P_{cj}, according to the following relation:

$$P = \frac{P_{cj} e c^2 t^2}{D^2 (1 - e)} \quad (7)$$

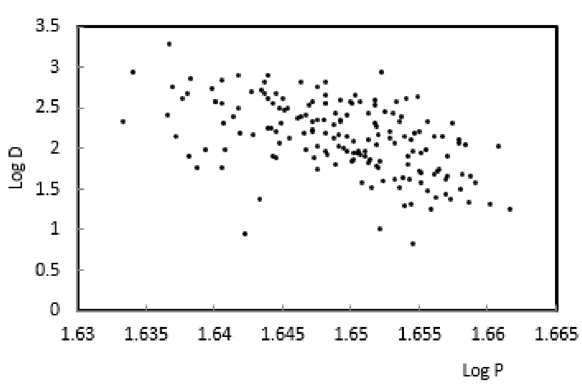

Figure 5: The Scatter Plot of Source Observed Linear Sizes against Observed Luminosities for the Quasars.

The last equation is the power with which the jet materials use to escape from the central core.

$e =$ conversion efficiency of kinetic power into radiation

$c =$ light speed

$t =$ source dynamical age

This shows that source luminosity is a measure of source kinetic power.

Furthermore, since the last equation which is obtained from theoretical method [21] indicates an inverse relation between source linear size and source luminosity, it simply shows that the empirical result in (6) is in consonance with the theory in (7).

OBSERVED SOURCE LINEAR SIZE, REDSHIFT, AND LUMINOSITY RELATIONS FOR THE RADIO GALAXIES

We also obtained $D - z$ and $D - P$ data (Figures 6 and 7) for the radio galaxies in our sample. Results obtained show that there are no significant relationships between the source linear size and redshift; as well as between the linear size and observed luminosity. Correlation coefficient, r, shows $r \approx 0.3$ for $D - z$ data. However, if we assume this marginal correlation to be appreciable enough for the observed physical data, we will have the following relation:

$$\text{Log} D = 2.577 - 1.193 \text{Log}(1 + \text{z}) \quad (8)$$

Rewriting it, we have:

$$D \sim z^{-1.2} \quad (9)$$

which is in order with result obtained for the quasar in (2).

It is noteworthy that there is poor correlation (with $r \approx 0.1$) for $D - P$ data (Figure 7). This inconsistency with result obtained for the quasars may be attributable to strong luminosity-selection effects – quasars are more visible at higher redshifts than the radio galaxies [21]. This implies that we will use only results obtained for the quasars in our further analyses in this paper.

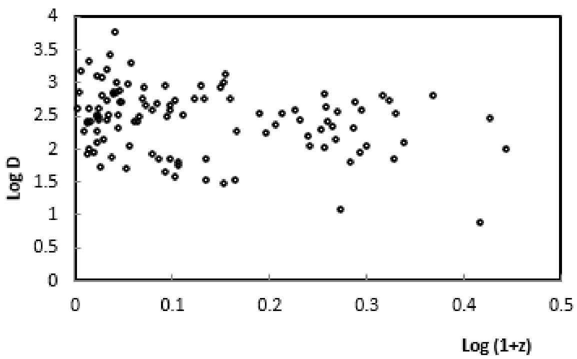

Figure 6: The Scatter Plot of Source Observed Linear Sizes against Observed Redshifts for the Radio Galaxies.

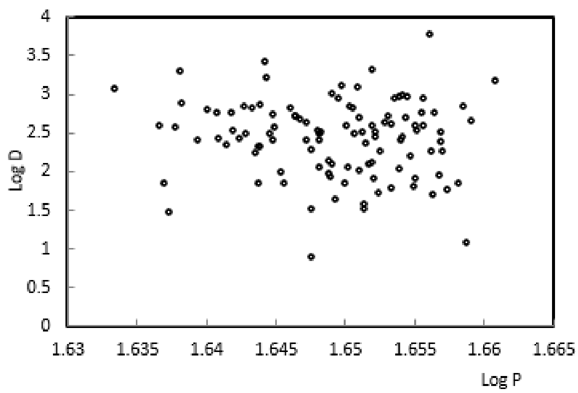

Figure 7: The Scatter Plot of Source Observed Linear Sizes against Observed Luminosities for the Radio Galaxies.

DYNAMICAL AND COSMIC EVOLUTIONS

Combining the effects of dynamical and cosmic evolutions by solving Equations (1) and (5) simultaneously, we obtain:

$$D = (2.82 \times 10^{34}) P^{-19.47} (1+z)^{-0.76} \qquad (10)$$

Or we have:

$$D \sim P^{-19.47} (1+z)^{-0.76} \qquad (11)$$

Equation (11) can be interpreted to mean combined effects of dynamical evolution (D_P) and cosmic evolution (D_Z) of an extragalactic radio source. 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.

Moreover, using the indices of (11), the percentage effects of both D_P and D_Z are estimated to be 96% and 4%, respectively.

DISCUSSION AND CONCLUSION

We have carried out linear regression analysis of observed source linear sizes (D) of the quasars and their corresponding observed redshifts, z, (Figure 4). Result shows that D relates with redshift(z) according to the equation, $D \sim (1+z)^{-1.5}$ (with correlation coefficient, $r = 0.41$). We have also pointed out that this relation could be rewritten as $(1+z) \sim D^{-2/3}$. This implies that $z = z(D)$ which can be interpreted to mean cosmic evolution dependence on distance between any two points in space. This is true if D is taken to be distance between any two points in space.

Moreover, the result of$D - P$ data (Figure 5) shows that D relates with P according to the expression,$D \sim P^{-3.9}$. This shows that observed source size has an inverse power-law function with observed luminosity. It has been shown from theory by Ezeugo [21] that source luminosity shows a direct dependence on the power with which the jet materials use to escape from the central core according to the following relation: $P \sim P_{cj}$ (see Equation (7). This power is referred to as core-jet power (or jet kinetic power) (P_{cj}). The relation shows that source luminosity is a measure of source kinetic power.

Furthermore, since the relation (7), which is obtained from theoretical method [21] indicates an inverse relation between source linear size and source luminosity, we may simply state that the empirical result (6) is in consonance with the theory in (7).

In addition to the foregoing, we obtained$D - z$ and $D - P$ data (Figures 6 and 7) for the radio galaxies in our samples. Results obtained show that there are no significant relationships between the source linear size and redshift; as well as between the linear size and observed luminosity. For the $D - z$ data, correlation coefficient, (r) shows $r \approx 0.3$. However, if we take this marginal correlation to be good enough for the observed physical data, we may have the following relation: $D \sim z^{-1.2}$which is comparable to the result obtained for the quasar in (2).

We find poor correlation, with $r \approx 0.1$, for $D - P$ data (Figure 7). This inconsistency with result obtained for the quasars may be attributable to strong luminosity-selection effects – quasars are more visible at higher redshifts than the 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 (1) and (5) simultaneously, we obtain, $D \sim P^{-19.47}(1+z)^{-0.76}$. This may be interpreted to mean combined effects of dynamical evolution (D_P) and cosmic evolution (D_Z) of an extragalactic radio source. 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 (11), we estimated the percentage effects of both D_P and D_Z on the source observed linear size. Results show that effect due to dynamical evolution is 96%; while that due to cosmic evolution is 4%. Conclusively, the result obtained for cosmic evolution suggestively indicates that if D is taken to be a distance between any two regions in an empty space, then the evolution of this distance is entirely cosmic.

REFERENCES

1. Ezeugo, J.C. 2021. "Jet in the More Extended Radio Sources and Unification with Compact Steep Spectrum Sources". *The Pacific Journal of Science and Technology*. 22(1):14 – 19.

2. Ubah, O.L. and J.C. Ezeugo. 2021. "Relativistic Jet Propagation: Its Evolution and Linear Size Cosmic Dilation". *International Astronomy and Astrophysics Research Journal*. 3(3): 1–6.

3. Urry, C.M. 2004. "AGN Unification: An Update". Astronomical Society of the Pacific Conference series 1. No vol.

4. Ezeugo, J.C. 2015. "Compact Steep-Spectrum Radio Sources and Ambient Medium Density". *International Journal of Astrophysics and Space Science*. 3(1): 1–6.

5. Ezeugo, J.C. 2015. "On the Dependence of Spectral Turnover on Linear Size of Compact Steep-Spectrum Radio Sources". *International Journal of Astrophysics and Space Science*. 3(2): 20–24.

6. Readhead, A.C. 1995. "Evolution of Powerful Extragalactic Radio Sources". In proc. Colloquium on Quasars and Active Galactic Nuclei. M. Kohen and K. Kellermann. (editors). National Academy of Sciences, Berkman Center: Irvine, CA. 92, 11447–11450.

7. Robson, I. 1996. *Active Galactic Nuclei* John Wiley and Sons: London, UK.

8. Jackson, J.C. 1999. "Radio Source Evolution and Unified Schemes". *Publications of Astronomical Society of the Pacific*. 16: 124–129.

9. Kawakatu, N. and M. Kino. 2007. "The Velocity of Large-Scale Jets in a Declining Density Medium". In: *Serie de Conferenciad, Triggering Relativistic Jets*. W.H. Lee and E. Ramirez-Ruiz (editors.). 27: 192–197.

10. Ezeugo, J.C. and A.A. Ubachukwu. 2010. "The Spectral Turnover–Linear Size Relation and the Dynamical Evolution of Compact Steep Spectrum Sources". *Monthly Notices of the Royal Astronomical Society*. 408: 2256–2260.

11. O'Dea, C.P. 1998. "The Compact Steep Spectrum and Gigahertz Peaked Spectrum Radio Sources". *Publications of the Astronomical Society of the Pacific*. 110: 493–532.

12. Fanti, C., R. Fanti, D. Dallacasa, R.T. Schillizzi, R.E. Spencer, and C. Stanghellini. 1995. "Are Compact Steep Spectrum Sources Young?" *Astronomy and Astrophysics*. 302: 317–326.

13. Ezeugo, J.C. 2021. "On the Intergalactic Media Densities, Dynamical Ages of Some Powerful Radio Sources and Implications". *Journal of Physical Sciences and Application*. 11(1): 29–34.

14. Ezeugo, J.C. 2021. "Compact Spectrum Source Size and Cosmological Implication". *Journal of Research in Applied Mathematics*. 7(2): 1–4.

15. Jackson, J.C. 1999. "Radio Source Evolution and Unified Schemes". *Publications of Astronomical Society of the Pacific*. 16: 124–129.

16. Mahatma, V.H., M.J. Hardcastleand, and W.L. Williams. 2019. "LoTSS DR1: Double-Double Radio Galaxies in the HETDEX Field". *Astronomy and Astrophysics*. 622:A13.

17. Mingo, B., J.H. Croston, and M.J. Hardcastle. 2019. "Revisiting the Fanaroff-Riley Dichotomy and Radio Galaxy Morphology with the LOFAR Two-Meter Sky Survey (LoTSS)". *Monthly Notices of the Royal Astronomical Society*. 488:2701-2721.

18. Hardcastle, W.L., W.L. Williamsand, and P.N. Best. 2019. "Radio-Loud AGN in the First LoTSS Data Release — The Lifetimes and Environmental Impact of Jet-Driven Sources". *Astronomy and Astrophysics*. 622: A12.

19. Dabhade, P., M. Gaikwad and J. Bagchi. 2017. "Discovery of Giant Radio Galaxies from NVSS: Radio and Infrared Properties". *Monthly Notices of the Royal Astronomical Society*. 469(3): 2886–2906.

20. Nilsson, K. 1998. "Kinematical Models of Double Radio Sources and Unified Scheme". *Monthly Notices of the Royal Astronomical Society*.132: 31–37.

21. Ezeugo, J.C. "On Cosmic Epoch and Linear Size/Luminosity Evolution of Compact Steep Spectrum Sources". *American Journal of Astronomy and Astrophysics*. 9(1): 8–12.

ABOUT THE AUTHOR

Dr. Jeremiah Chukwuemerie Ezeugo, is a Lecturer in the Department of Physics and Industrial Physics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. He holds a Ph.D. degree in Astrophysics from the University of Nigeria, Nsukka. His research interests are in the areas of Extragalactic Radio Astronomy and Cosmology.

SUGGESTED CITATION

Ezeugo, J.C. 2022. "Probing into Cosmic Evolution Implication on Astronomical Distance Using Extragalactic Radio Sources". *Pacific Journal of Science and Technology*. 23(1): 11-16.

Pacific Journal of Science and Technology