



Cosmological effects on Size Evolution of some Extragalactic Radio Sources and Quasar/Galaxy Unification

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Authors' contributions

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

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ABSTRACT

We use analytical methods to develop a mathematical model that expresses the relationship between the linear size (\mathcal{D}_0) of some extragalactic radio sources (EGRS) and their redshift (z). Result shows that $\mathcal{D}_0 \sim (1+z)^\mathcal{L}$, where $\mathcal{L} = -4.5$. For the purpose of obtaining an empirical relation of similar form, we carry out simple linear regression analyses of the observed linear sizes of these EGRS in our sample against their respective observed redshifts. We obtain an empirical relation of the form, $\mathcal{D}_0 \sim (1+z)^\xi$, where $\xi \approx -1.4$ and -1.3 for radio-loud quasars and radio galaxies respectively, with correlation coefficients given by, $r \approx 0.3$ for each of the sources. The correlation is marginal/slight. Comparing the theoretical and empirical relations, we find that the $\mathcal{D}_0 - z$ data show an inverse correlation which is similar to the theory. This suggestively indicates presence of cosmological effects on the size evolution of the radio sources. Moreover, we find that similarity in the behavior of the two sources in the $\mathcal{D}_0 - z$ plane, simply supports quasar/galaxy unification scheme in which the different observable properties that characterize these two subclasses of radio sources are aspect-dependent.

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1. INTRODUCTION

In terms of their luminosities, galaxies are grouped into two main classes; namely, normal galaxies and active galaxies. Active galaxies are those galaxies that radiate in excess of $10^{36}W$ [1,2,3,4,5,6]. While the normal galaxies radiate their light from their individually combined constituent stars, an active galaxy radiates abundantly from its three major components – (i) the central core which is believed to contain a supermassive blackhole, (ii) two-sided radio jets emanating from the core, and (iii) two-sided radio lobes. These radio-emitting lobes are believed to be fed by the radio-emitting jets [1,2,3,4,5,6] (For clarity, see Figs 1 and 2).

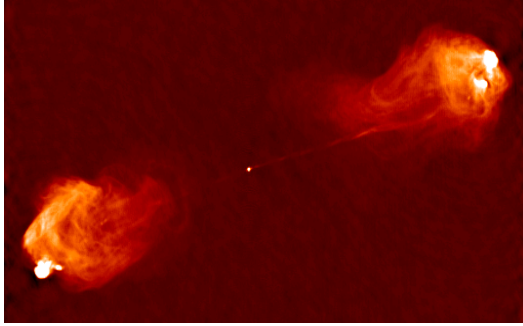


Fig. 1. Cygnus A – an EGRS
Source: Wikipedia

Usually, extragalactic radio sources (EGRSs) are those radio sources that have high ratio of radio to optical emission. Generally, it is defined by the ratio of the two flux densities given by $S_{5\text{ GHz}}/S_{6 \times 10^5\text{ GHz}} > 10$ [1,2,3,4,5,7]. These radio sources include radio galaxies, quasars and BL Lacertae objects [1,2,3,4,5,7]. The radio emission from these radio sources usually takes the form of relativistic jets that connect the base of the accretion disk to the two radio emitting lobes that straddle the central component that is more or less coincident with the nucleus of the host galaxy [1,2,3,4,5,7]. In some radio sources, the lobes contain hotspots believed to be the termination points of the jets [1,2,3,4,5,7]. Presence of jets in EGRS indicates presence of gaseous ambient media [5,7]. A number of hydrodynamic simulations of jet propagations have been performed to examine their physical state [6,8]. These studies show that jet materials have smaller masses than those of the ambient medium.

In this paper, we have used analytical methods to obtain a theoretical model that may show a relationship between the linear size of an EGRS and its redshift. After this, we find an empirical relation of similar form between the two observable parameters using 462 EGRS in our sample. These sources are from [9] and they are made up of 203 radio-loud quasars and 259 radio galaxies.

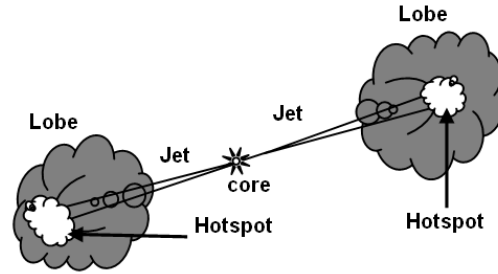


Fig. 2. The structure of a typical EGRS
Source: the author

2. COSMOLOGICAL EVOLUTION OF RADIO SOURCE SIZE

The synchrotron aged spectrum model for radio sources may be expressed generally as [6,7,10,11,12].

$$T_{syn} = 1610 \frac{B^{\frac{1}{2}}}{B^2 + B_{CMB}^2} ((1+z)v_{br})^{\frac{1}{2}} \quad (1)$$

where B is magnetic field intensity, $B_{CMB} = 3.25(1+z)^2$ in μG is the magnetic field equivalent to the microwave background, T_{syn} in Myr is elapsed time since the source formation, v_{br} in GHz is the breaking frequency. Substituting for B_{CMB} , we obtain [6,7]

$$T_{syn} = 1610 \frac{B^{\frac{1}{2}}}{B^2 + 10.56(1+z)^4((1+z)v_{br})^{\frac{1}{2}}} \quad (2)$$

Simplifying, we have

$$T_{syn} = \frac{1610B^{\frac{1}{2}}}{(1+z)^{\frac{9}{2}}[B^2(1+z)^{-4} + 10.56]v_{br}^{\frac{1}{2}}} \quad (3)$$

Since $(1+z)^{\frac{9}{2}} \gg (1+z)^{-4}$, we ignore the smaller term to obtain [6,7]

$$T_{syn} \approx \frac{1610B^{\frac{1}{2}}}{10.56v_{br}^{\frac{1}{2}}(1+z)^{\frac{9}{2}}} \quad (4)$$

Moreover, kinematic age, \mathcal{T} , of a radio source can be expressed simply as a function of the source linear size, \mathcal{D}_0 , as [6,7,12]

$$\mathcal{T} = \int_{\mathcal{D}_m}^{\mathcal{D}_0} \frac{d\mathcal{D}_0}{\mathcal{V}_\ell} \quad (5)$$

where \mathcal{D}_m is the lower limit of the linear size, \mathcal{V}_ℓ is lobe velocity. Assuming radiation age has similar value with the kinematic age [7], we combine the last two equations to obtain

$$\mathcal{D}_0 \approx \frac{1610B^{\frac{1}{2}}\mathcal{V}_\ell}{10.56v_{br}^{\frac{1}{2}}(1+z)^{\frac{9}{2}}} \quad (6)$$

Hence, we have

$$\mathcal{D}_0 \sim (1+z)^{-4.5} \quad (7)$$

which can be referred to as theoretical relation. It can be interpreted to mean that the linear size of an EGRS possibly may be affected by cosmological evolution [6,7].

Moreover, for the purpose of obtaining an empirical relation of similar form, we carry out simple linear regression analysis on the observable source linear sizes against their respective observed redshifts (Figs. 3 and 4). Fig. 3 is for the radio-loud quasars while Fig. 4 is for the radio galaxies. Results of the regression show,

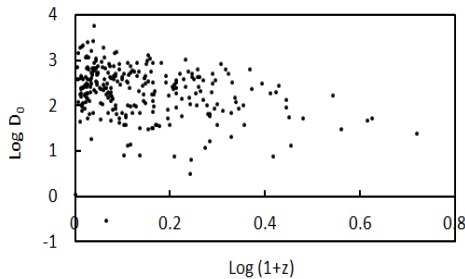


Fig. 4. The scatter plot of linear size against redshift for the radio galaxies

$$\text{Log}\mathcal{D}_0 = -1.4\text{Log}(1+z) + 2.5 \quad (8)$$

and

$$\text{Log}\mathcal{D}_0 = -1.3\text{Log}(1+z) + 2.5 \quad (9)$$

For radio-loud quasars and radio galaxies respectively. Their correlation coefficients have similar values and are given by 0.3 each. This shows marginal or slight correlation. Rewriting equations (8) and (9) yields respectively

$$\mathcal{D}_0 \sim (1+z)^{-1.4} \quad (10)$$

and

$$\mathcal{D}_0 \sim (1+z)^{-1.3} \quad (11)$$

These last two relations can be referred to as empirical relations for the radio source $\mathcal{D}_0 - z$ relationship. In comparison with the theoretical relation (equation (7)), we notice that for the quasars and galaxies, $\mathcal{D}_0 - z$ data show inverse correlations. These are in consonance with the theoretical relation. So, this similarity between the empirical result and theoretical result may be attributable to cosmic effects on size evolution of radio sources.

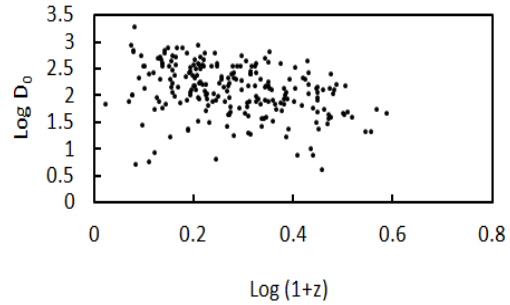


Fig. 3. The scatter plot of linear size against redshift for the radio-loud quasars

3. DISCUSSION AND CONCLUSIONS

We have used analytical methods with some plausible assumptions to find a mathematical model (equation (7)) which plausibly may indicate a source size dependence on cosmological evolution. However, for the purpose of obtaining an empirical relation of similar form, we carry out linear regression analyses of observed linear sizes against their respective observed redshifts for radio-loud quasars (Fig. 3) and radio galaxies (Fig. 4). The power-law relations obtained are of the form, $\mathcal{D}_0 \sim (1+z)^\xi$; where the index, ξ , is found to be $\xi \approx -1.4$ and -1.3 for quasars and galaxies respectively.

Correlation coefficients are generally marginal with 0.3 for each of the sources.

In comparison with the theoretical relation (i.e. equation (7)), it can be seen that for the quasars and galaxies, the linear size (\mathcal{D}_0) shows an inverse relationship with redshift (z). This empirical result is similar to the theoretical relation. Hence, the similarity simply suggests that cosmological evolution may have some consequences on the size evolution of these radio sources.

Moreover, the similarity in the behavior of the two sources in the $\mathcal{D}_0 - z$ plane (that is, similar gradients and intercepts), simply supports quasar/galaxy unification scheme. In this scheme, it is assumed that the different observable properties that characterize these two subclasses of radio sources are aspect-dependent [13,14].

COMPETING INTERESTS

Author has declared that no competing interests exist.

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