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On Asymmetries in Powerful Radio Sources and the Quasar/Galaxy Unification

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Abstract. We utilize the distributions of fractional separation difference (x) as asymmetry parameter, linear size (D) and core-to lobe luminosity ratio (R) as orientation indicators, to investigate a consequence of radio source orientation and relativistic beaming effects in a sample of powerful non-symmetric extragalactic radio sources. In this scenario, radio sources viewed at small orientation angles to the line-of-sight are expected to show a high degree of asymmetry in observed radio structures due to relativistic beaming, with foreshortened projected linear sizes. A simple consequence of this is the $x - D$ anti-correlation. Results show a tight correlation ($r > 0.8$) between the total and core radio luminosities and a clear $x - D$ anti-correlation ($r \sim -0.5$). The observed $x - D$ anti-correlation is consistent with average orientation angle $\phi \approx 48°$ and a maximum Lorentz factor $\gamma \sim 2$ for the sample, with minimum angular separation of 26° between radio galaxies and quasars. However, there is no clear $x - R$ correlation. While the results are consistent with quasar/galaxy unification via orientation, intrinsic asymmetry also seems to play a major role.

Key words. Galaxies—active galaxies: quasars—general.

1. Introduction

A typical powerful extragalactic radio source is one that harbours active galactic nucleus (AGN) in which gravitational processes associated with the central super massive black hole, produces powerful jets of highly collimated relativistic plasma. In the high luminosity regimes of these AGNs, the radio source comprises of two lobes fed by well-collimated jets from the central component (Blandford & Rees 1974), interacting with the ambient medium and producing the observed synchrotron emission. The terminating point of these structures form hotspots (the brightest region of the extended radio structure) where kinetic power of the jets is converted into random motion within the relativistic plasma and strengthened magnetic fields (Bridle *et al.* 1994). In classical double radio sources, the twin radio lobes are believed to move out symmetrically from the core at relativistic speeds. Thus, in powerful FR II radio galaxies, which supposedly form the less beamed counterparts of quasars and which are believed to be observed more or less at the plane of the sky, the twin radio lobes are expected to be highly symmetric both in terms of size and emitted power (Gopal-Krishna *et al.* 1996). However, observational evidence (Barthel 1989; Scheuer 1995) suggest that this symmetric scenario is not exactly the case as varying degrees of structural asymmetries and misalignments of the radio lobes are present in many samples of FR II radio sources. These asymmetries can be attributed to factors that could be intrinsic, environmental and/or arising from relativistic beaming and orientation effects.

Several authors have suggested that asymmetries in extragalactic radio sources are primarily a result of relativistic effects and have used the model to argue for a possible unification of the AGN phenomenon. Barthel (1989) reported the relativistic beaming model as the effect of depolarization asymmetry and suggested that all radio-loud quasars are beamed towards the observer while powerful radio galaxies form their rather less beamed parent population. Similarly, Saikia *et al.* (1989), using VLA and MERLIN observations of 15 asymmetric sources, suggested that relativistic beaming effects played a significant role in brightness asymmetry observed in the sources (see also Laing 1988; Ubachukwu *et al*. 2002). In this regard, it has been argued (Garrington *et al.* 1988; Tribble 1992) that the jet approaching the observer at smaller angle to the line-of-sight appears brighter due to Doppler boosting of the radio emission, as well as on being seen through less magneto ionic medium. Best *et al.* (1995) also argued for the quasar/galaxy unification in terms of angular symmetries and the effects of misalignment of the directions of ejection and hotspot velocities for the 3CR sources.

Further, several authors (Chyžy & Zieba 1993; Arshakian & Longair 2000, 2004; Jeyakumar *et al*. 2005) have argued against the asymmetry-based unification of quasars and FR II radio galaxies via relativistic beaming and orientation (they opined that relativistic beaming asymmetry occurs mainly in quasars at kiloparsec regions while FR II radio galaxies exhibit intrinsic/environmental asymmetries). In particular, Kharb *et al.* (2008) suggested that structural asymmetry; parametrized by arm-length ratio (Q) appears to be more sensitive to intrinsic and environmental asymmetries than relativistic beaming effect for a sample of powerful FR II radio galaxies. In this paper, we quantitatively re-examine the implications of relativistic beaming and source orientation on the structural asymmetries of a heterogeneous sample of non-symmetric radio sources, consisting of radio galaxies and quasars, based on observed correlations between the fractional separation difference (x) and known relativistic beaming parameters.

2. Theory of relationships

Relativistic beaming effects in radio source components are usually studied using the core-dominance parameter (R) defined (Fan & Zhang 2003) as

$$R = \frac{P_{\mathrm{C}}}{P_{\mathrm{E}}}, \tag{1}$$

where P_{C} is the core-luminosity and P_{E} is the extended lobe luminosity. However, if relativistic beaming effect at small orientation angle is the main driver, then R can be expressed in terms of the jet speed (β) and inclination angle (ϕ) in the form (Orr & Browne 1982; Bell & Comeau 2012) as:

$$R = \frac{R_T}{2}[(1-\beta\cos\phi)^{-n+\alpha} + (1+\beta\cos\phi)^{-n+\alpha}], \tag{2}$$

where R_T is the value of R at $\phi = 90°$, α the spectral index and n is a parameter that depends on the assumed flow model of the radio jet. For radiating plasma with continuous jet, $n = 2$, otherwise, if the jet consists of a blob, then $n = 3$.

In the relativistic beaming event for radio loud AGNs, the total radio luminosity ($P_{\rm T}$) is assumed to be made of two components, namely, the boosted core component and the isotropic extended component and is usually expressed as a sum of the two components: $P_{\rm T} = P_{\rm C} + P_{\rm E}$ (Fan & Zhang 2003). Thus, it follows from equation (1) that

$$\frac{R+1}{R} = \frac{P_{\rm T}}{P_{\rm C}}. \tag{3}$$

Equation (3) implies that in beamed radio sources in which $R >> 1$, $P_{\rm T} \approx P_{\rm C}$ such that a clear correlation between $P_{\rm T}$ and $P_{\rm C}$, with slope $\sim$1 is anticipated. Thus, analysis of $P_{\rm T} - P_{\rm C}$ data could be used as a qualitative test for relativistic beaming in a sample of radio sources.

An obvious outcome of relativistic beaming effects in AGNs is the wide range of asymmetry observed in their radio structures as shown in Fig. 1. The radio source asymmetry is usually quantified using the arm-length ratio (Q), defined as the ratio of the longer arm ($d_{\rm l}$) to shorter arm (d_s), where 'arm' means the distance between the core and hotspot. Q has been defined in terms of the viewing angle as (Gopal-Krishna & Wiita 2004; Onuchukwu *et al.* 2014):

$$Q = \frac{d_{\rm l}}{d_{\rm s}} = \frac{1+\beta\cos\phi}{1-\beta\cos\phi}. \tag{4}$$

A similar quantity that defines the degree of jet misalignment, otherwise referred to as the bending angle (θ), which is the complement of the angle between the lines connecting the two radio lobes to the core (c.f. Fig. 1), has been used by several researchers in the past (Nilsson 1998; Kharb *et al.* 2008). This parameter is believed to be very sensitive to source orientation, with slight environmental effect (Kharb *et al.* 2008). Alternatively, Banhatti (1980) introduced the fractional

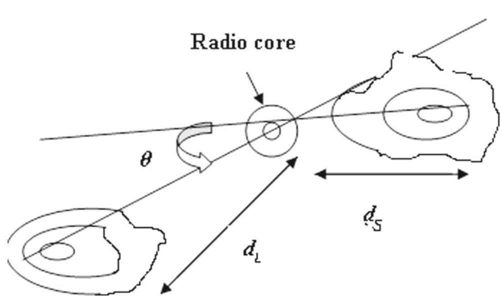

Figure 1. A schematic radio map showing the definition of the asymmetry parameter x.

separation difference (x) as the asymmetry index, which is expressed as a function of Q (Onuchukwu & Ubachukwu 2013):

$$x = \frac{Q-1}{Q+1}. \tag{5a}$$

Possibly, x is more clearly related to orientation than Q and can alternatively be expressed as a simple function of the viewing angle in the form (Onuchukwu & Ubachukwu 2013)

$$x = \beta \cos\phi. \tag{5b}$$

At small angles to the line-of-sight, relativistic beaming in AGNs is fundamentally characterized by beaming enhancement factor (δ) defined as

$$\delta = \gamma^{-1}(1-\beta\cos\phi)^{-1}, \tag{6}$$

Thus, it can be shown from equation (5b) that the asymmetry parameter x can be expressed in terms of the beaming enhancement factor as

$$x = \frac{\delta\gamma - 1}{\delta\gamma}. \tag{7}$$

Equation (7) appears to suggest that there is an association of relativistic beaming (characterized by δ and γ) and radio source asymmetry (characterized by x). However, in an isotropic distribution of radio sources, β may be assumed constant ($\beta \sim 1$ in relativistic jet model) for varying ϕ. In fact, for symmetric sources, which are presumably observed more or less at the plane of the sky, $Q \sim 1$ and $x \sim 0$, while for non-symmetric sources $Q > 1$ and $x > 0$, such that Q or x can be used as a quantitative measure of the viewing angle for non-symmetric sources. Similarly, the projected linear size (D) of an extragalactic radio source depends on the viewing angle according to the relation (Orr & Browne 1982)

$$D = D_0 \sin\phi, \tag{8}$$

where $D_0 = D(\phi = 90°)$ is the intrinsic linear size of the source. All these implies that in non-symmetric sources with $Q > 1$, $x - D$ anti-correlation is expected if relativistic beaming at small viewing angles is responsible for the observed asymmetry. Following Onuchukwu & Ubachukwu (2013), we assume a linear $x - D$ relation of the form

$$x = x_m - \lambda D, \tag{9}$$

where x_m represents the maximum x for a sample and λ is the slope. In principle, equation (9) indeed suggests that x is a maximum at $D = 0 (\phi = 0)$. In practice however, x_m may correspond to minimum $D (\neq 0)$, which supposedly occurs at a critical observation angle ($\phi_c \neq 0$) to the line-of-sight (Odo *et al.* 2012; Odo & Ubachukwu 2013). Within the critical cone angle, relativistic beaming is optimum and δ becomes a constant, so that $\frac{d\delta}{d\phi} = 0$. Thus, if $\beta \sim 1$ for the relativistic jets, analysis of equations (5b) and (6) for optimum beaming yields (Vermeulen & Cohen 1994)

$$\phi_c \approx \sin^{-1}(1/\gamma) \approx \cos^{-1} x_m, \tag{10}$$

Hence, the viewing angle ϕ_c as well as the Lorentz factor γ which characterize the relativistic beaming for non-symmetric source samples can be constrained using the $x - D$ data.

3. Analysis and results

From a sample of extended steep spectrum sources taken from Nilsson (1998), we have selected non-symmetric sources with arm-length ratio $Q \geq 1.2$ (Onuchukwu & Ubachukwu 2013) and updated with Fan & Zhang (2003). Eighty six of these sources – 66 quasars and 20 radio galaxies from the original sample overlap with Fan & Zhang (2003) and form the sample for the present analysis. All the 86 sources in this sample have complete information on the relevant parameters, assuming $H_0 = 70\ \mathrm{kms}^{-1}\,\mathrm{Mpc}^{-1}$ and $\Omega_0 = 1$. For all analyses in this paper, the strength of correlation between parameters is determined by Pearson Product Moment correlation coefficient (r) using MINITAB-17 software.

We show the distribution of the sources in projected linear size on logarithmic scale, in Fig. 2. It is obvious that the sample shows a normal distribution in the parameter, which can be attributed to a number of independent effects. The linear size distribution of a radio source sample could be a result of orientation or environmental effects. The distribution gives a mean value $D_m = 204 \pm 3$ Kpc which suggests that, on an average, the sources are extended in physical dimension. Similarly, Fig. 3 shows the distribution of the sources in the asymmetry parameter (x). The distribution has a minimum value of 0.09 with a mean value $x_m = 0.16\pm 0.04$, which is an indication that they are non-symmetric sources ($x > 0$ for non-symmetric sources). The figure also shows a normal distribution of the sources in the asymmetry parameter.

To examine the property of the sample in view of relativistic beaming model, we show the scatter plot of the total radio luminosity (P_{T}) against the core luminosity (P_{C}) in Fig. 4. A scenario in which sources with most highly boosted core possess the highest total luminosity is evident from the figure. Linear regression of the plot yields: $\log P_{\mathrm{T}} = 0.95 \log P_{\mathrm{C}} + 12.8$, with a correlation coefficient $r = 0.85$ at 95% confidence. The result can be interpreted to indicate that if extended luminosity is

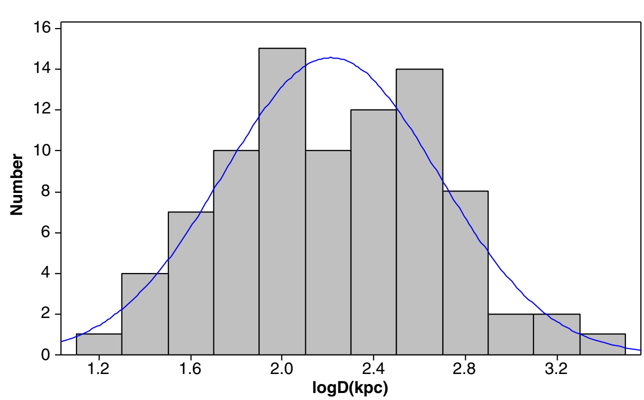

Figure 2. Distribution of the 86 radio sources in linear size on logarithmic scale.

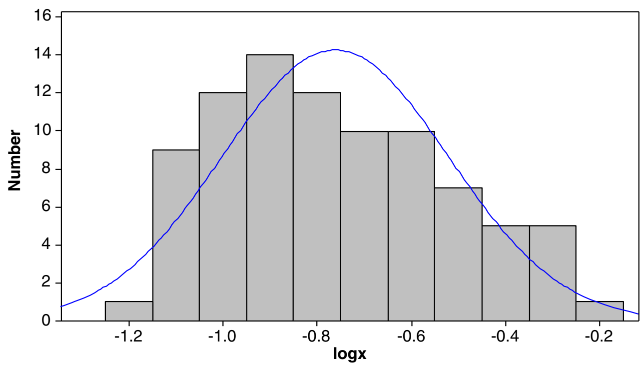

Figure 3. Distribution of the 86 radio sources in fractional separation difference (x) on logarithmic scale.

isotropic, there may be up to 95% confidence that explains the luminosity data of the sample in terms of relativistic beaming effect. One can therefore assume that relativistic beaming and source orientation effects may play very significant roles in the overall distributions of observed radio properties of the sample.

Figure 5 shows the scatter plot of fractional separation difference (x) as a function of projected linear size (D) for the non-symmetric sample. The plot shows an obvious general trend in which sources observed at larger angles are more symmetric than those observed end-on. Furthermore, there is a well defined upper envelope $x - D$ function, where relativistic beaming effects are expected to predominate. Perhaps, the structural asymmetry, characterized by x, among those objects observed at close angles to the line-of-sight substantially results from relativistic beaming effect at such small viewing angles.

Linear regression analysis of the $x - D$ data yields: $x = 0.35 - 0.0006D$ with a correlation coefficient $r \sim -0.5$ and chance probability $\rho \sim 10^{-10}$. Using $x_m = 0.35$

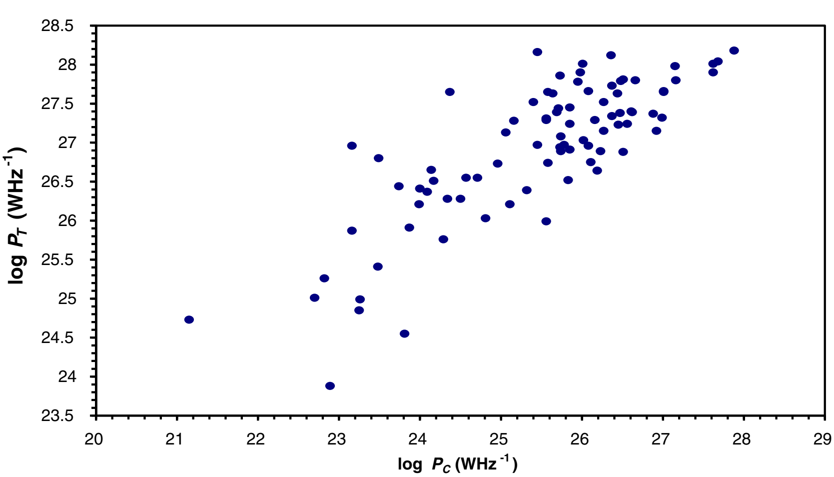

Figure 4. Scatter plot of total radio luminosity (P_T) against core luminosity (P_C) for the 86 sources.

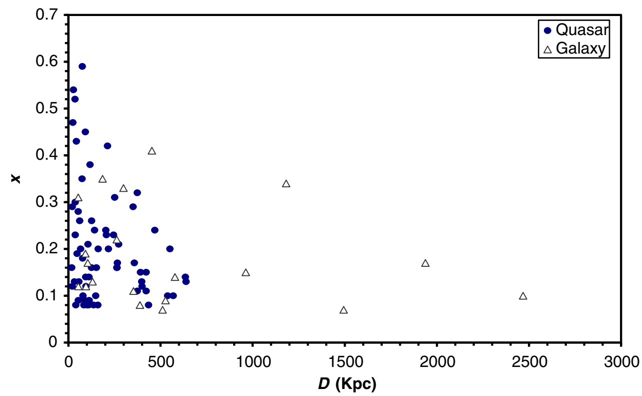

Figure 5. Scatter plot of the fractional separation difference (χ) as a function of projected linear size (D) for the 86 sources: 66 quasars (●) and 20 radio galaxies (▲).

in equation (10) gives $\phi \approx 70°$, which corresponds to $\gamma = 1.1$. Similar analysis of the upper envelope function yields a correlation coefficient $r \sim 0.9$, $x_m = 0.66$, corresponding to $\phi_c \approx 48°$ and $\gamma = 1.3$. Separating the sample into quasar and radio galaxy sub-samples, analyses of upper envelope functions yield $x_m = 0.52$; $\phi_c \approx 59°$; $\gamma = 1.2$ and $x_m = 0.84$; $\phi_c \approx 33°$; $\gamma = 1.8$, for radio galaxies and quasars, respectively. The results correspond to angular separation (ϕ_{sep}) of $\sim 26°$, based on the upper envelope functions.

However, if relativistic beaming at small viewing angles is the main driver, an outcome of equations (2) and (5b) is a correlation between x and R, especially for beamed sources that are presumably observed at small viewing angles to the line-of-sight. Thus, we examine the $x - R$ data of the sample to study the dependence of x on relativistic beaming and orientation. The $x - R$ plot is shown in Fig. 6. It is obvious from the figure that there is no general trend on the $x - R$ plane, for all the objects in the sample. Simple regression analysis applied to the plot yields log $x = (0.007 \pm 0.002)$ log $R - (0.76 \pm 0.05)$, with a correlation coefficient $r \sim 0.02$ and chance probability $\rho \sim 10^{-15}$. This result does not completely show that x is

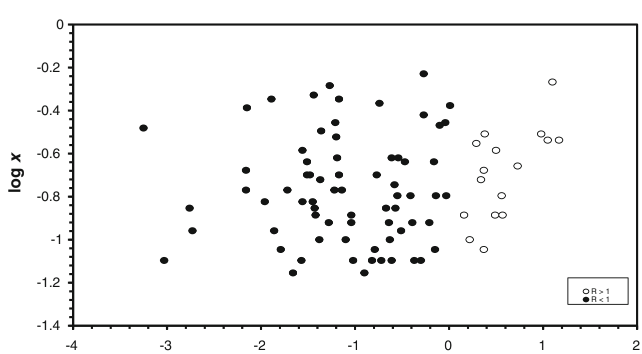

Figure 6. Scatter plot of x as a function of R on logarithmic scales for the 86 radio sources.

fully orientation-dependent. Furthermore, several researchers (Nilsson 1998; Gopal-Krishna & Wiita 2004) have suggested that the jet misalignment (bending) angle (θ) is an asymmetry parameter known to be sensitive to orientation of the radio source, with little environmental dependence. Hence, a simple linear regression analysis of the $x - \theta$ data of the 86 objects was carried out in the sample to determine any possible correlation of x with θ. The result yields: $\log x = (0.003\pm 0.001) \log \theta + (0.21\pm 0.04)$, with a correlation coefficient $r \sim 0.2$ and chance probability $\rho \sim 10^{-9}$. This also seems to suggest that x is not fully orientation-dependent.

4. Effects of redshift

Following the absence of $x - R$ and $x - \theta$ correlations in the current sample, which are expected in the relativistic beaming and source orientation scenario, it could be argued that the $x - D$ and $P_T - P_C$ correlations may have emerged as a secondary result of redshift effects on these parameters. Hence, the fractional separation difference (x) was tested for any possible dependence on redshift (z). The scatter plot of x as a function of z for the sample is shown in Fig. 7. It can be observed clearly from the figure that there is no obvious trend on the $x - z$ plane. Linear regression analysis of the $x - z$ data yields: $\log x = (0.012\pm 0.006) \log (1 + z) - (0.77\pm 0.09)$, with a correlation coefficient $r \sim 0.01$ and chance probability $\rho \sim 10^{-15}$. However, while several researchers (Ubachukwu & Ogwo 1998; Alhassan *et al*. 2013) have noted that the slope of luminosity – redshift ($P - z$) relation of extragalactic radio sources shows a steep change around $z = 0.3$, some others (Kollgaard *et al*. 1992) argued that the steep change occurs around $z = 1$ (see also Nilsson 1998, Fig. 2). This observation has been explained in terms of luminosity selection effect due to Malmquist bias in flux density limited samples (Ubachukwu & Ogwo 1998). This steep change in $P - z$ relation may possibly have contributed to the absence of $x - z$ correlation, especially, as x has been widely suggested (Kharb *et al*. 2008) to be strongly sensitive to asymmetries in the local environments of the radio sources. In order to examine the $x - z$ data for possible luminosity selection effect, regression analysis of the $x - z$ data was repeated for four different redshift bins, namely $z \leq 0.3, z > 0.3, 0.3 \leq z \leq 1$ and $z > 1$. However, none of the redshift bins

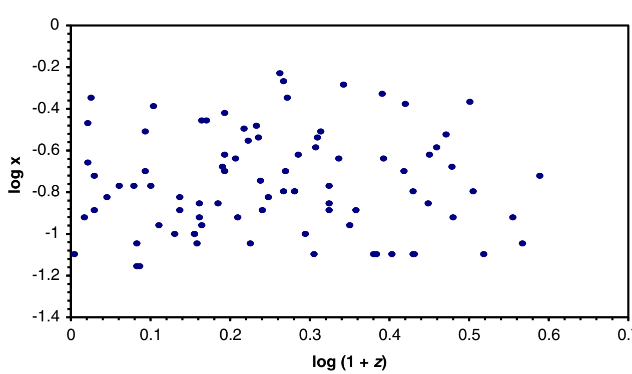

Figure 7. Scatter plot of the fractional separation difference, x against redshift, z for the 86 sources.

yielded any significantly different result. Hence, x does not still seem to show strong dependence on environment of the sample, which suggests that the observed $x - D$ anti-correlation may actually be an orientation effect rather than a secondary effect of redshift.

Similarly, it is possible that the strong $P_{\rm T} - P_{\rm C}$ correlation ($r \sim 0.85$), with slope $\approx$ 1, obtained in Fig. 4 may also be a secondary effect of the strong dependence of both $P_{\rm T}$ and $P_{\rm C}$ on z: in flux density limited samples, there is a tight correlation between luminosity and redshift due to luminosity selection effect (Singal 1993). We have tested this effect by withholding out the common dependence of both parameters on z using Spearman-partial correlation statistic, which is a non-parametric statistic involving a cross-correlation matrix of the parameters. The partial correlation coefficient between $P_{\rm T}$ and $P_{\rm C}$ when z is fixed is given (Aalen 1978) by

$$r_{P_{\rm T}P_{\rm C},z} = \frac{r_{P_{\rm T}P_C} - r_{P_{\rm T}z}r_{P_{\rm C}z}}{[(1 - r^2_{P_{\rm T}z})(1 - r^2_{P_{\rm C}z})]^{1/2}}, \qquad (11)$$

Analyses of $P_{\rm T} - z$ and $P_{\rm C} - z$ data of the current sample give correlation coefficients of 0.75 and 0.61, respectively at 95% confidence. The strong correlation of each $P_{\rm T}$ and $P_{\rm C}$ with z is an indication that luminosities of radio sources are very sensitive to any asymmetry in the local environment of the sources. However, the correlations yield $P_{\rm T} - P_{\rm C}$ partial correlation coefficient of 0.76 from equation (11). Thus, there is little or no significant effect of redshift on the observed $P_{\rm T} - P_{\rm C}$ correlation. The correlation, thus, may be intrinsic, rather than a secondary effect of redshift in the current sample of radio sources.

5. Discussion

Many research works on active galactic nuclei have focussed on the development of a unified scheme in which the observed properties of different classes of extragalactic radio sources could be understood as similar objects seen at different orientation angles to the line-of-sight. In the context of the unified hypothesis, all extragalactic radio sources are presumed to intrinsically possess the same morphological features, and exhibit similar physical phenomena, observations of which at different orientation angles give rise to different classes/subclasses that are shown in previous works. Relativistic beaming paradigm predicts that relativistic enhancement/Doppler boosting and geometric projection effects are expected to be more pronounced in sources whose radio axes are inclined at smaller angles to the line-of-sight than those that are observed at the plane of the sky. Therefore, the relativistic beam from the jets of AGNs is expected to be narrow and extremely characterized, for a particular class of the AGN, by the Lorentz factor (γ) and geometric projection angle (ϕ). The ability of any AGN phenomenon model to predict the Lorentz factor and viewing angle of any class/subclass of the AGN is assumed to be an easy method to validate the model.

The results presented in this paper show a strong $P_{\rm T} - P_{\rm C}$ correlation ($r > 0.8$), with slope $\sim$1, in the current sample of non-symmetric sources, which is consistent with relativistic beaming model as predicted earlier in this paper. Furthermore, the entanglement between orientation and structural asymmetry results in a fairly strong anti-correlation ($r \sim -0.5$) between the fractional separation index (x) and projected linear size (D). We have also shown in the results that the observed $x - D$ anti-correlation in the combined sample is consistent with a viewing angle of $\sim 48°$ and Lorentz factor of 1.3. Furthermore, the angular separation (ϕ_{sep}) between the radio galaxies and quasars is in the range $\phi_{\text{sep}} \geq 26^{\text{o}}$. These results suggest that the jets in these non-symmetric sources must be relativistic and are actually observed at small orientation angles to the line-of-sight. This is consistent with the hypothesis that the jets of large asymmetric sources should be oriented at smaller angles to the line-of-sight. Thus, it could be deduced from the results that relativistic beaming and source orientation effects may have contributed significantly to the observed asymmetries in the sample. This is quite consistent with many previous results (Arshakian & Longair 2000; Onuchukwu & Ubachukwu 2013).

It can also be observed in Fig. 5 that the radio galaxies occupy the low x, high D end of the $x - D$ plot, suggesting that the radio galaxies appear more symmetric and are observed at relatively larger angles to the line-of-sight than radio quasars. This is, however, as expected if radio galaxies form the less beamed parent population of the quasars. Ubachukwu (1998) earlier used a beaming model to find $5 \leq \gamma \leq 12$ and $24° \leq \phi \leq 40°$, in terms of the quasar – galaxy unification, for the lobe dominated quasars. Best *et al.* (1995) used angular asymmetries and relative separations of hotspots to obtain a viewing angle $\phi \geq 6°$ for FR II sources in the 3CR sample. Similarly, Ubachukwu & Chukwude (2002) used a pure beaming model to obtain a critical cone angle of $4°-10°$ and optimum Lorentz factor of 6–16 for a sample of core-dominated quasars. Wardle & Aaron (1996) suggested a quasar – galaxy unification hypothesis with angular separation of less than 70°.

Arshakian & Longair (2000) also reported a maximum quasar – galaxy angular separation of $\sim 45°$. More recently, Hocuk & Barthel (2010) in a test for orientation based unifications argued that an intrinsically symmetric two-sided jet axes may be at least 33° away from the plane of the sky. All these are in good agreement with the results presented in this paper and suggest that the present data is consistent with an orientation-based quasar – galaxy unification.

On the other hand, the symmetric relativistic beaming and source orientation effects observed in the present analysis has been complicated by the apparent lack of $x - R$ correlation, as shown in Fig. 6. This is further strengthened by yet another loss of $x - \theta$ correlation. Both R and θ have been independently suggested by many researchers (Nilsson 1998; Fan & Zhang 2003; Gopal-Krishna & Wiita 2004) to be strong indicators of relativistic beaming and source orientation, so that both $x - R$ and $x - \theta$ correlations would be expected in the beaming and orientation scenario. The results do not apparently suggest that x is fully orientation-dependent, but rather seem to indicate that intrinsic/asymmetries in the local environment may be playing a significant role. Actually, the analysis shown in Fig. 4 (c.f. equation (3)) and its consequences are expected to be valid only for core-dominated sources in which the core-to-lobe luminosity ratio $R >> 1$. On the contrary, it can be observed from the distribution of R in Fig. 6 that a vast majority of the sources (70 objects, representing over 81% of the sample) are lobe-dominated with $R < 1$. Possibly, for such sources, relativistic beaming effect may be less important and intrinsic asymmetries may be more prominent, leading to the apparent lack of $x - R$ correlation. Nevertheless, there is a clear $x - R$ correlation with correlation coefficient $r \sim 0.7$ and chance probability of $\sim 10^{-11}$ for the 16 sources ($\sim$19% of the sample) with $R > 1$, shown with open circles in Fig. 6, which suggests that x is actually sensitive to relativistic beaming for these few sources. Thus, the lobe-dominated sources may show a much stronger dependence on intrinsic/environmental asymmetries compared to their core-dominated counterparts. In other words, for sources with $R < 1$, intrinsic asymmetry is expected to easily swamp any $x - R$ correlation, which is based on relativistic beaming. For objects with $R > 1$, the luminosities are primarily affected by relativistic beaming at small orientation angles, leading to the strong $x - R$ correlation. It is important to observe that all the FR II radio galaxies in the sample have $R < 1$, which implies that for FR II radio galaxies the fractional separation difference (x) is more sensitive to intrinsic/environmental asymmetries than relativistic beaming. This is actually in agreement with recent works (Kharb *et al*. 2008) on powerful FR II radio galaxies in which the arm-length ratio (Q) was also observed to be more sensitive to asymmetries in the local environments than relativistic beaming. However, the sample size with $R > 1$ is small and a larger sample would be required to confirm the results.

6. Conclusion

We have used the fractional separation difference (x) and projected linear size (D) to examine a simple consequence of radio source orientation and relativistic beaming in the quasar/galaxy unification, using a sample of non-symmetric radio sources. The results suggest that the large scale structural asymmetries observed among powerful extragalactic radio sources can be attributed largely to relativistic beaming and source orientation effects, which, perhaps become more pronounced in core-dominated sources with large core-to-lobe luminosity ratio. There is a significant $x - D$ anti-correlation which is consistent with a maximum viewing angle of 48°, Lorentz factor of 1.3 and angular separation of at least 26° between non-symmetric radio quasars and galaxies. There is little or no correlation between the fractional separation difference (x) and either of core dominance parameter (R) or jet misalignment angle (θ). The results are consistent with quasar/galaxy unification via orientation with fractional separation difference (x) also being sensitive to intrinsic/asymmetries in local environments of the sample.

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