MedCrave
Step into the World of Research

Physics & Astronomy International Journal

Research Article

Open Access

CrossMark

Analysis of JET component parameters of AGN - brightness, speed, size, distance and acceleration

Abstract

We statistically analysed the jet component parameters of superluminal sources which comprises of radio galaxy (G), radio quasar (Q) and BL Lac (B) objects. Subsamples were formed based on brightness, speed, size, distance D from the assumed stationary core, jet components with positive and negative perpendicular and parallel acceleration. Results show that there is a strong positive correlation between the jet component size and distance away from the core, which supports the self-similarity model of AGN evolution and that jet component accelerations are independent of any size, distance from the core, radio power and speed of the jet component. Moreover, jet components with negative/positive acceleration have similar range in values in the observed parameters.

Keywords: general, miscellaneous, method, data analysis, galaxies, jet, galaxies, active

Volume 4 Issue 5 - 2020

Onuchukwu C Chika
Department of Industrial Physics, Chukwuemeka Odumegwu Ojukwu University, Nigeria

Correspondence: Onuchukwu C Chika, Department of Industrial Physics, Chukwuemeka Odumegwu Ojukwu University, Anambra State, Nigeria,
Email onuchukwu71chika@yahoo.com

Received: July 06, 2020 | **Published:** November 02 2020

Introduction

Several Very Long Baseline Interferometer observation of Active Galactic Nuclei(AGN), have revealed that on pc-scale, the jets of radio sources are not continuous but form blobs of radio-emitting plasma called jet component that speed away from the assumed stationary core with superluminal velocity.[1,2] The jet components observed characteristics are varied with positive or negative acceleration, different speed, different sizes and brightness temperature, beside evolution in size with distance from an assumed stationary core.[3,4] The observed jet component properties include acceleration, apparent speed, size distance from the core have been used to infer the jet dynamics and evolution, yet the origin and properties of these jet components are still poorly understood.[5–7] In this paper, we wish to analyse the statistical behaviour of jet component selected based on radio power, size, speed, distance away from the core and acceleration (jet components with positive or negative acceleration).

Data

The data we used in this analysis were obtained from Lister et al.[2] Monitoring of Jets in Active Galactic Nuclei with VLBA Experiments (MOJAVE) observed at 15 GHz and Piner et al.[1] Radio Reference Frame Image Database (RRFID) observed at 8 GHz. We selected the sources with redshift (z); flux density (S) in Jy converted to radio power (P) in WHz^{-1}; the Full Width at Half Maximum (FWHM) in milliarcsecond (mas) which we converted to pc and used it to indicate the size of the jet component;[8] the projected distance from the assumed stationary core (D); the observed apparent speed $\left(\beta_a\right)$; the observed perpendicular $(\eta\perp)$ and parallel $(\eta\|)$ acceleration. We also estimated the observed apparent brightness temperature T_B. The RRFID sample consists of 85 sources (10 BL Lac Objects (B), 5 Radio Loud Galaxies (G) and 70 Radio Loud Quasars (Q)) with 226 jet components. The MOJAVE sample consists of 296 sources with about 1237 jet components (201 Q, 17 G, 36 B and 5 narrow line radio galaxies-Seyfert I). The narrow line radio galaxies-Seyfert I were subsequently removed from our analysis since there are no counterpart in the RRFID). Each source may have more than one jet components that were observed several times. The MOJAVE sources have been observed since 1994[2] while the RRFID sources have been observed since 1997 (Piner et al.[1] with each jet component a minimum of 20 different epochs of observations). Each observation records different values for the observable source parameters from which we estimated the average values of all the recorded observations which we used in the analysis except for the dynamical properties like acceleration and speed which were calculated by the original authors.

To select the smaller (SM)/bigger (BG) subsamples, each sample (either MOJAVE or RRFID) was divided along the median value of the size, those with sizes less than the median value formed the smaller subsample while those with sizes greater than the median value formed the bigger subsample. This choice though arbitrary, enabled us to include all the jet components in the subsamples as either SM/BG. An alternative choice would be to select for each source, the biggest or smallest jet component, leaving out others, this will lead to none inclusion of all the observed jet components in our analysis. We employed similar procedure to select dimmer (DM)/bigger (BG) subsample (looking at the size), slower (SL)/faster (FS) subsample (looking at the apparent speed) and inner (INs)/outer (OT) subsample (looking at the projected distance from the core).

We also formed subsamples consisting of jet components with positive (+VE) and negative (-VE) perpendicular/parallel accelerations for different classes of radio sources. The MOJAVE sample consists of 320 jet components with -VE $\eta\|$ (comprising 60 BL Lacs (Bs) jet components, 43 radio-loud galaxies (Gs) jet components, 214 radio loud quasars (Qs) jet components and 3 narrow line radio galaxies jet components) and 342 jet components with +VE $\eta\|$ (comprising 60 Bs jet components, 61 Gs jet components, 220 Qs jet components). The MOJAVE jet components associated with perpendicular accelerations consist of 324 jet components having -VE $\eta\perp$ (62 Bs jet components, 53 Gs jet components, 207 Qs jet components) and 338 jet components having +VE $\eta\perp$ (59 Bs jet components, 50 Gs jet components, 227 Qs jet components and 2 narrow line galaxies jet components). The RRFID sample consists 101 jet components with -VE $\eta\|$ (17 Bs jet components, 5 Gs jet components and 79 radio loud quasars Qs) and 117 jet components with +VE $\eta\|$ (21 Bs jet components, 12 Gs jet components and 84 Qs jet components). The RRFID jet components exhibiting perpendicular acceleration consist of 101 jet components with -VE $\eta\perp$ (13 Bs jet components, 8 Gs jet components and 79 radio loud quasars Qs) and 117 jet components with +VE $\eta\perp$ (25Bsjetcomponents, 6 Gs jet components and 86 Qs jet components). Due to low number statistics of Gs in the RRFID sources, we will form only the Qs and Bs subclasses of RRFID sources, but Qs, Gs, and Bs subclasses of MOJAVE sources.

We converted flux density (S) in Jy to radio power (P) in WHz^{-1}, also estimated the observed apparent brightness temperature TB. To obtain the radio power P in WHz^{-1}sr^{-1} at a given frequency of observation (v), the measured flux density (Sv) in Jansky is easily converted into specific radio power by the expression given by Leahy[9]

$$P_v = 8.557 \times 10^{25} h^{-2} Z_q^2 (1+z)^{(1+\alpha)} S_v \qquad (1)$$

where Z_q is the effective redshift and for $q_0 = 0.5, Z_q = 2 - 2(1+z)^{-0.5}$, where z is the observed redshift, α is the spectral index and here is generally assumed $\alpha = 0$ (we are analysing the core components and jet components within few pc from the core), q_0 is the deceleration parameter, h is the Hubble parameter. For simplicity, we adopt H0=71 km/s/Mpc.[10] Sokolovsky et al.[8] had used the FWHM (a) as a representation of the size (R), of the jet component in pc. Thus, we estimate R from the a-data using the expression Leahy[9]

$$R = 14.53 h^{-1} \left(\frac{Z_q}{1+z} \right) a. \qquad (2)$$

Apparently, calculation of both R and P is expected to be world modeldependent due to the tight dependence of radio source size (R) and radio power (P) on the assumed world model. In the Friedman-Robertson-Walker universe, R and P respectively depend on luminosity distance (d_L) as[11]

$$R \sim \theta d_L (1+z)^{-1} \qquad (3)$$

And

$$P \sim 4\pi d_L^2 S_v (1+z)^{\alpha+1} \qquad (4)$$

In the current ΛCDM cosmology

$$d_L = H_0^{-1} \int_0^z \left[(1+z)^2 (1+\Omega_m) - z(2+z)\Omega_\wedge \right]^{-1/2} dz, \qquad (5)$$

where Ω_m and $\Omega_\wedge$ are, respectively, the contributions of baryonic matter and cosmological constant to the energy content of the expanding universe. Planck collaboration (2015) gives $\Omega_m = 0.3$ and $\Omega_\wedge = 0.7$. However, this does not introduce any significant changes in the values of the parameters we have calculated. Onuora et al.[12] pointed out that at low redshift, different cosmologies vary very little and would not have any significant effect on estimated values of radio source parameters. A vast majority of objects in our samples are located at low redshift ($z < 5$, $z_{max} \sim 3.4$ *for MOJAVE sources* & $z_{max} \sim 3.9$) for RRFID sources). It is thus apparent, that for these relatively low redshift sources, the non-zero cosmological constant does not significantly scale up the estimated radio power as would be the case for high redshift sources. The observed flux is also converted into brightness temperature TB (see Piner et al. 2010) using

$$T_B = 1.22 \times 10^{12} \frac{S(1+z)}{a^2 v^2} \qquad (6)$$

Analyses and results

Comparison between Smaller (SM) & Bigger (BG)

The average values of the parameters for SM and BG are shown in Table 1, the large standard error is an indicative of the wide spread in their values. Results from mean values indicate that for quasars, both radio power and brightness temperature are higher for SM than for BG subsamples, while for radio galaxies, while for galaxies, the BG have higher radio power than SM. For BL Lac, the radio power of SM subsample on average is higher than BG for MOJAVE sources, while the reverse is the case for RRFID sources. Generally, the smaller jet components of all classes of radio sources are closer to their core as indicated by D, For quasar and BL Lacs of both samples, the brightness temperature of SM subsamples are higher than BG subsamples. Nevertheless, for radio galaxies, while the brightness temperature is higher for SM objects in the MOJAVE sample, it is higher for BG objects in the RRFID sample. BG jet components are further away from the core than SM sources.

Table 1 Average values of the parameters for different classes of radio sources in our sample for smaller (SM), bigger (BG), jet components (for RRFID and MOJAVE samples)

	P	**R**	**T$_B$**	**D**	**β$_a$**
RR	**(WHz^{-1}sr^{-1})**	**(pc)**	**(K)**	**(pc)**	
Quasars	×10^{22}		×10^{9}		
SM	15.5±6.1	2.2±0.8	62.6±7.6	10.3±7.4	5.7±3.6
BG	5.4±1.9	7.9±3.2	1.7±0.9	23.8±14.6	10.8±7.3
BL Lac	×10^{21}		×10^{9}		
SM	1.8±0.7	0.8±0.3	12.5±17.1	2.5±1.1	2.2±1.1
BG	4.8±0.4	3.8±2.1	2.8±1.6	13.2±8.4	5.6±2.9
Galaxy	×10^{21}				
SM	< 0.1±0.1	0.3±0.2	3.5 ± 2.6	1.3 ± 0.9	0.4±0.1
BG	169.8±20.4	3.8±2.9	29.4±3.3	8.8±5.9	2.9±0.8
MO					
Quasar	×10^{25}		×10^{13}		
SM	11.3 ± 3.4	1.7 ±0.5	6.9 ± 5.8	7.9 ± 4.7	6.3 ± 4.6
BG	3.5 ± 2.3	6.9 ±3.4	0.2 ± 0.1	36.6 ±28.5	9.4 ± 5.6
BL Lac	×10^{24}				
SM	8.4 ± 2.5	0.8± 0.4	6.2 ± 4.9	3.1 ± 1.9	2.5 ± 2.1
BG	5.2 ± 2.8	4.4± 2.2	0.2 ± 0.2	15.7 ± 9.1	4.9 ± 3.6
Galaxy	×10^{23}				
SM	4.1 ± 1.3	0.3± 0.2	1.5 ± 0.2	3.3 ± 0.8	0.3 ± 0.2
BG	38.3 ± 9.2	4.1± 2.4	0.2 ± 0.1	69.2 ± 7.7	0.7 ± 0.5

In Table 2, we display the the results of correlation analyses to check for possible relation between the analysed parameters of the jet components. Generally, the results show that there is fairly strong positive R–D dependence for SM and BG of RRFID/MOJAVE sources with r ranging from 0.4 to 0.9 in the subsamples. However, the SM quasars of RRFID sample show a poor correlation with $r = 0.2$. a fairly significant P-R correlation, with $r \geq 0.3$ which is attributable to strong temporal evolution in the samples.[13] The P–T correlation is fairly negative for most of the subsamples, with BG of RRFID having r~0.1, which might be due to low number statistics. The P–D correlation is strong and positive for only SM of galaxy class of both samples. This result is actually as expected from the strong positive R - D correlation observed for majority of the objects in the samples. In fact, at small scales, a positive P - D correlation would be expected due to the positive temporal evolution in such sources that are usually located at low redshifts. The coefficient results show no $P - \beta_a$ correlation which suggests that the observed radio power is independent of kinetic power of the jet components.

Citation: Chika OC.Analysis of JET component parameters of AGN - brightness, speed, size, distance and acceleration. *Phys Astron Int J.* 2020;4(5):188–196.
DOI: 10.15406/paij.2020.04.00221

Table 2 Correlation coefficient results for smaller (SM), bigger (BG) (for MOJAVE (MO) and RRFID (RR) samples)

	SM	BG	SM	BG	SM	BG
	Q	Q	B	B	G	G
	RR	RR	RR	RR	RR	RR
$P-R$	-0.1	-0.1	0.3	-0.1	0.3	0.2
$P-T_B$	-0.4	-0.9	-0.2	-0.7	-0.9	0.1
$P-D$	-0.2	-0.2	0	-0.2	0.5	-0.4
$P-\beta_a$	0	-0.1	0.1	-0.1	0.9	0.1
$R-T_B$	-0.5	-0.3	-0.3	-0.4	0	-0.5
$R-D$	0.2	0.6	0.9	0.7	0.9	0.9
$R-\beta_a$	0	0.1	0.7	0.3	0.5	-0.3
T_B-D	-0.1	-0.2	-0.4	-0.3	0.1	-0.5
$T_B-\beta_a$	0	0	-0.3	-0.2	0.7	0.3
$D-\beta_a$	0.2	0.1	0.9	0.6	0.7	-0.3
MO	MO	MO	MO	MO	MO	MO
$P-R$	-0.1	-0.1	0	-0.1	0.3	0
$P-T_B$	-0.7	-0.8	-0.6	-0.8	-0.2	-0.4
$P-D$	-0.1	-0.1	0.1	-0.2	0.8	-0.2
$P-\beta_a$	-0.1	-0.1	0	0	0.2	-0.1
$R-T_B$	-0.4	-0.3	-0.2	-0.3	-0.2	-0.4
$R-D$	0.4	0.4	0.7	0.7	0.5	0.5
$R-\beta_a$	0.3	0.1	0.3	0.2	0.6	0.1
T_B-D	-0.2	-0.2	0.1	-0.3	0	-0.2
$T_B-\beta_a$	-0.2	-0.1	0	-0.2	-0.1	-0.1
$D-\beta_a$	0.1	-0.2	0.4	0.3	0.2	-0.2

The R−T correlation is fairly negative for majority of the subsamples with $r \geq -0.3$. For majority of the subsamples, positive $R-\beta_a$ correlation is observed. This is an indication of increased size due to acceleration of the jet plasma. However, for the BG galaxy subsample of RRFID objects, a somewhat anti-correlation is observed. Nevertheless, we note that due the low number statistics of galaxy in RRFID sample, we put little statistical significance on any inference derived form the galaxy subsamples of RRFID. For the MOJAVE sources, there is a fair negative TB−D correlation for the RRFID sample, for the subsamples the SM/BG (r ∼−0.4/−0.3) of BL Lac and BG (r ∼−0.5) of galaxy, other subsamples of MOJAVE sources showed no correlation. TB−β_a shows no correlation. D−β_a shows positive correlation for BL Lac of RRFID and MOJAVE sources with $r \geq 0.3$ suggesting that for these objects, the jet components are accelerated as they propagate out from the core.

Comparison between dimmer (DM) & brighter (BR)

In Table 3, the mean values and the standard errors of the parameters of jet components were shown. For quasars of both samples, the DM and BR subsamples have comparable sizes within the limit of error, while for BL Lac and galaxies of both samples, the BR jet components are larger than the DM jet components. The DM jet components have less average brighter temperature than BR for all the classes of radio sources for both samples. The DM jets components seems further from the core & have similar speed than the BR jet components for quasars of both samples, while BR jets components appear to be further from the core & have higher speed than the DM for both galaxies and BL Lac for the two samples. Several authors[13,14] have argued that in flux density limited radio source samples, there is a steep change in luminosity related effects around a redshift (z), z∼0.3. Apparently, a vast majority of BL Lacs and radio galaxies in current samples are located at low redshifts z≤0.3, while majority of the quasars are located at z≥0.3. Thus the observed differences in trend of relationships between DM and BR objects for quasars and radio galaxies or/and BL Lacs could be interpreted in terms of the differences in their redshift distributions. Actually, Onah et al.[13] argued that there is a positive P −D correlation for sources at z≤0.3, which upturns into an anti-correlation at z≥0.3. Our results can be understood in terms of the turnover of P −D relation between low and high redshift sources. The correlation results between the parameters of DM/BR are shown in Table 4. We note again the significant positive correlation between R−D for all the subsamples of all classes of radio sources of the two samples.

Table 3 Average values of the parameters for different classes of radio sources in our sample for dimmer (DM) brighter (BR), jet components (for RRFID and MOJAVE samples)

	P	R	TB	D	β_a
RR	($WHz^{-1}sr^{-1}$)	(pc)	(K)	(pc)	
Quasars	$\times 10^{22}$		$\times 10^{9}$		
DM	1.3 ± 0.7	5.4 ±3.3	40.5 ± 7.3	24.1 ± 7.7	8.9 ± 3.9
BR	19.9 ±6.3	4.7 ±2.9	55.3 ± 7.2	10.9 ± 4.3	8.1 ± 5.7
BL Lac	$\times 10^{21}$				
DM	0.2 ± 0.1	1.3 ± 0.9	1.7 ± 0.9	4.7 ± 3.3	2.9 ± 1.8
BR	6.4 ± 4.7	3.3 ± 2.2	13.6 ± 8.1	11.3 ± 4.2	4.9 ± 2.7
Galaxy	$\times 10^{21}$				
DM	< 0.4 ± 0.3	0.3 ± 0.2	1.9 ± 0.9	1.7 ± 1.3	1.5 ± 0.8
BR	169.8 ± 20.4	3.8 ± 2.9	30.9 ± 3.3	8.3 ± 4.1	2.8 ± 0.7
MO					
Quasar	$\times 10^{25}$		$\times 10^{13}$		
DM	0.8 ± 0.5	4.5 ± 2.9	0.5 ± 0.1	23.9 ± 8.9	8.3 ± 5.2
BR	14.1 ± 3.4	4.1 ± 2.9	6.8 ± 2.8	19.6 ± 8.1	8.3 ± 5.5
BL Lac	$\times 10^{24}$				
DM	0.2 ± 0.1	1.6 ± 1.3	0.3 ± 0.3	5.9 ± 4.1	3.1 ± 2.5
BR	11.7 ± 7.1	3.4 ± 2.3	5.6 ± 2.9	11.1 ± 7.9	4.7 ± 3.8
Galaxy	$\times 10^{23}$				
DM	0.1 ± 0.1	0.5 ± 0.2	0.6 ± 0.1	2.2 ± 0.9	1.0 ± 0.7
BR	22.9 ± 7.9	3.3 ± 2.6	0.9 ± 0.1	38.1 ± 7.4	1.9 ± 0.9

Table 4 Correlation results for dimmer (DM) brighter (BR) components for (for MOJAVE (MO)and RRFID (RR) samples)

	DM	**BR**	**DM**	**BR**	**DM**	**BR**
	Q	**Q**	**B**	**B**	**G**	**G**
	RR	**RR**	**RR**	**RR**	**RR**	**RR**
P − R	-0.1	-0.3	0.3	-0.1	0.4	0.2
P − T_B	-0.2	-0.4	-0.6	-0.1	-0.7	0.2
P − D	-0.2	-0.2	0.1	-0.2	0.5	-0.3
P − β_a	0	-0.2	0.1	-0.1	0.9	0.3
R − T_B	-0.3	-0.3	-0.4	-0.3	-0.2	-0.5
R − D	0.6	0.7	0.8	0.8	0.9	0.9
R − β_a	0.2	0.4	0.4	0.5	0.7	-0.2
T_B −D	-0.3	-0.2	-0.5	-0.3	-0.1	-0.5
T_B − β_a	-0.2	-0.1	-0.3	-0.3	0.4	0.5
D − β_a	0.2	0.4	0.8	0.7	0.8	-0.3
	MO	MO	MO	MO	MO	MO
P − R	0.1	-0.2	0.2	-0.2	0.4	0.2
P − T_B	-0.2	-0.7	-0.1	-0.6	-0.1	0.1
P − D	0	-0.1	0.1	-0.2	0.6	0.1
P − β_a	0	-0.1	0.2	-0.1	0.8	-0.3
R − T_B	-0.3	-0.2	-0.3	-0.2	-0.2	-0.4
R − D	0.6	0.5	0.9	0.8	0.9	0.6
R − β_a	0.2	0.2	0.1	0.3	0.3	0.2
T_B −D	-0.2	-0.1	-0.2	-0.1	-0.2	-0.3
T_B − β_a	-0.2	-0.2	-0.1	-0.1	-0.1	-0.2

The *P−R* correlation is not significant for all the subsamples, P−T correlation is mildly negative for the BR subsamples of quasars (r ∼−0.7) and BL Lac (r ∼−0.6) of MOJAVE sources as well as the DM subsamples of BL Lac (r∼−0.6) and galaxies (r ∼−0.7) of RRFID sources. The P −D and P−β_a do not show any correlation except for DM of galaxies for both samples, suggestive that the radio brightness of a source does not solely depend of simple conversion of jet kinetic power, but may depend on a number of other effects, such as the density of the ambient medium.[15] R−T coefficient of correlation is mild (∼−0.3) while R−β_a is mild positive for all the subsamples. There is no TB −D correlation except for DM of BL Lac and BR of galaxies for RRFID sources which appears mild and negative. Also, there no T_B−β_a but for RRFID sources of BL Lac which is mildly negative (∼−0.3) and for galaxies which is positive (∼0.4−0.5). D−β_a seems significant for all the subsamples of RRFID sources but only significant for the subsamples of galaxies and BR of BL Lac of MOJAVE sources.

Comparison between slower (SL & faster (FS)

In Table 5, we display the mean values of the parameters we analysed for different classes of radio sources. For the RRFID sources and MOJAVE sources with the exception of the quasar class, jet components that are faster appear to be brighter (higher average values of radio power), but for quasars of MOJAVE sources, slower jet components appear brighter (higher average values of radio power). This can be explained in terms of the differences in density of the ambient medium. For the quasars, the slower jet components may be propagating through denser medium while the faster jet components propagate through less dense medium. This implies that the conversion of jet Kinetic energy into radio emission increases with density of the ambient medium.[15] Generally, slower jet components have lower average values in size and are closer to the core than the faster jet components. The average values of the brightness temperature of slower jet components have higher brightness temperature for all the subsamples.

Table 5 Average values of the parameters for different classes of radio sources in our sample for slower (SL) faster (FS), jet components (for RRFID and MOJAVE samples)

	P	**R**	**TB**	**D**	**β_a**
RR	**(WHz^{-1}sr−1)**	**(pc)**	**(K)**	**(pc)**	
Quasars	×10^{22}		×10^{9}		
SL	1.2 ± 0.4	4.4 ± 2.4	32.2 ± 4.3	14.7 ± 5.4	2.9 ± 1.3
FS	8.1 ± 4.5	5.7 ± 3.3	25.9 ± 9.4	20.4 ± 5.9	14.1 ± 5.9
BL Lac	×10^{21}				
SL	3.5 ± 0.7	2.1 ± 0.9	15.2 ± 10.1	5.2 ± 4.1	1.8 ± 0.9
FS	4.7 ± 2.5	3.1 ± 1.7	3.7 ± 1.2	12.2 ± 3.3	6.5 ± 2.8
Galaxy	×10^{21}				
SL	4.7 ± 2.6	1.8 ± 1.1	2.5 ± 1.3	5.1 ± 2.1	0.7 ± 0.5
FS	15.2 ± 8.8	0.7 ± 0.3	4.6 ± 3.1	3.6 ± 1.5	3.5 ± 0.5
MO					
Quasar	×10^{25}		×10^{13}		
SL	8.9 ± 1.8	3.7 ± 2.6	5.5 ± 1.7	18.3 ± 5.1	3.1 ± 1.8
FS	5.9 ± 3.9	5.1 ± 3.1	1.2 ± 0.7	20.3 ± 5.7	13.6 ± 4.5
BL Lac	×10^{24}				
SL	6.7 ± 3.9	1.8 ± 1.4	3.9 ± 1.3	6.3 ± 4.1	0.6 ± 0.5
FS	5.3 ± 2.3	3.5 ± 2.4	3.6 ± 1.4	10.5 ± 7.2	7.2 ± 3.1
Galaxy	×10^{23}				
SL	82.5 ± 3.6	1.2 ± 0.6	1.1 ± 0.6	15.2 ± 4.5	0.1 ± 0.1
FS	14.8 ± 9.8	3.7 ± 2.5	0.4 ± 0.1	25.2 ± 9.2	2.8 ± 1.9

Table 6 is the correlation coefficient results for different classes of radio sources. We note the strong correlation between R −D which is similar to other subsamples. P−R is not significant for all subsamples of both samples except for galaxies of RRFID sources. The P−T_B correlation is strong and negative for all subsamples except for galaxies of MOJAVE sources, while the P−D and P−β_a correlation coefficients indicate no relation between P−D and P−β_a for all the subsamples except for galaxies of RRFID which showed negative correlation for SL (r ∼−0.3) and positive correlation for FS (r∼0.9) and for galaxy FS subsamples of MOJAVE sources with r ∼−0.4. R−T show correlation, R −β_a show positive correlation for some of the subsamples of RRFID sources,but no correlation for the MOJAVE sources. The correlation coefficient of TB−β_a & T_B−D indicate there in no form of relation between the parameters for all the subsamples. D−β_a correlation coefficient indicates no correlation for MOJAVE samples, but a positive correlation for some RRFID subsamples.

Citation: Chika OC.Analysis of JET component parameters of AGN - brightness, speed, size, distance and acceleration. *Phys Astron Int J.* 2020;4(5):188‒196. DOI: 10.15406/paij.2020.04.00221

Table 6 Correlation results for slower (SL) faster (FS) components for (for MOJAVE (MO) and RRFID (RR) samples)

	SL	**FS**	**SL**	**FS**	**SL**	**FS**
	Q	**Q**	**B**	**B**	**G**	**G**
	RR	**RR**	**RR**	**RR**	**RR**	**RR**
$P-R$	-0.2	-0.2	0.1	0	0.8	0.5
$P-T_B$	-0.6	-0.4	-0.1	-0.7	-1	-0.8
$P-D$	-0.2	-0.3	0.1	-0.1	0.1	0.4
$P-\beta_a$	-0.2	0	0.2	0	-0.3	0.9
$R-T_B$	-0.3	-0.2	-0.2	-0.3	0.6	0
$R-D$	0.6	0.6	0.9	0.9	0.6	1
$R-\beta_a$	0.1	0.3	0.4	0.6	-0.4	0.8
T_B-D	-0.2	-0.2	-0.3	-0.4	0	-0.1
$T_B-\beta_a$	-0.2	-0.1	-0.3	-0.2	-0.1	0.5
$D-\beta_a$	0	0.3	0.5	0.7	-0.1	0.8
	MO	MO	MO	MO	MO	MO
$P-R$	-0.1	-0.1	-0.1	-0.1	0.3	0.2
$P-T_B$	-0.7	-0.7	-0.6	-0.9	0	-0.1
$P-D$	-0.1	-0.1	-0.1	0	0.1	0.2
$P-\beta_a$	0	-0.1	0.2	0	0.1	-0.4
$R-T_B$	-0.2	-0.2	-0.2	-0.1	-0.2	-0.3
$R-D$	0.6	0.7	0.9	0.8	0.9	0.5
$R-\beta_a$	0.1	0.1	0.4	0.1	0.2	0
T_B-D	-0.1	-0.2	-0.2	-0.1	-0.1	-0.2
$TB-\beta_a$	-0.1	-0.1	0	-0.1	-0.2	-0.1

IN/OT

In Table 7, we showed the average values of the inner and outer jet components with associated error. The average values indicate that jet components closer to the core are brighter, higher brightness temperature, smaller in size and are slower in speed than jet components that are further away from the core. The correlation results shown in Table 8 indicate similar significant correlation in the R–D relation though small r∼0.2 for IN subsamples of quasar of RRFID sources and galaxies of MOJAVE sources. The P–T correlation is fair for some subsamples while the P–T correlation is mildly strong and negative except for galaxies of MOJAVE sources. There is no P–D nor $P-\beta_a$ correlation, though OT subsample of galaxies of RRFID subsample suggest strong positive correlation. For R–T, $R-\beta_a$, T_B-D, $T_B-\beta_a$ and $D-\beta_a$, correlation coefficients in Table 8 indicate that some subsamples correlation is strong and positive, some fairly negative, while some subsamples showed no correlation between the pairs of parameters studied.

Table 7 Average values of the parameters for different classes of radio sources in our sample for inner (IN) outer (OT), jet components (for RRFID and MOJAVE samples)

	P	**R**	**TB**	**D**	β_a
RR	**($WHz^{-1}sr^{-1}$)**	**(pc)**	**(K)**	**(pc)**	
Quasars	$\times 10^{22}$		$\times 10^{9}$		
IN	15.1 ± 5.6	3.2 ± 1.5	99.6 ± 6.3	5.8 ± 2.3	6.1 ± 3.9
BL Lac	$\times 10^{21}$				
IN	4.4 ± 0.8	1.1 ± 0.5	17.2 ± 2.1	2.8 ± 1.1	2.7 ± 1.7
OT	3.8 ± 2.3	4.1 ± 2.2	1.5 ± 1.1	14.7 ± 8.6	5.7 ± 3.3
Galaxy	$\times 10^{21}$				
IN	78.8 ± 13.8	0.3 ± 0.2	18.5 ± 2.6	1.1 ± 0.7	1.1 ± 0.3
OT	11.7 ± 8.8	2.3 ± 1.1	16.7 ± 2.9	8.1 ± 5.6	3.1 ± 0.8
MO					
Quasar	$\times 10^{25}$		$\times 10^{13}$		
IN	11.5 ± 3.3	2.2 ± 1.1	6.3 ± 1.9	5.9 ± 2.4	7.2 ± 4.7
OT	3.3 ± 2.3	6.5 ± 3.6	0.7 ± 0.7	37.7 ± 15.1	9.6 ± 5.7
BL Lac	$\times 10^{24}$				
IN	6.3 ± 1.8	0.9 ± 0.5	3.4 ± 2.8	2.5 ± 1.1	2.6 ± 2.8
OT	5.6 ± 3.4	4.1 ± 2.3	2.9 ± 1.8	15.2 ± 8.3	5.3 ± 3.6
Galaxy	$\times 10^{23}$				
IN	3.2 ± 1.2	0.4 ± 0.3	1.9 ± 0.4	0.9 ± 0.6	1.1 ± 0.4
OT	3.8 ± 0.9	3.3 ± 2.5	0.3 ± 0.2	39.5 ± 9.2	1.9 ± 0.9

Table 8 correlation results for inner (IN), outer (OT) components for galaxies (for MOJAVE (MO)and RRFID (RR) samples)

	IN	**OT**	**IN**	**OT**	**IN**	**OT**
	Q	**Q**	**B**	**B**	**G**	**G**
	RR	**RR**	**RR**	**RR**	**RR**	**RR**
$P-R$	-0.2	-0.1	0.6	0.1	0.1	0.9
$P-T_B$	-0.4	-0.8	-0.1	-0.7	-0.8	-1
$P-D$	-0.4	-0.2	0.2	0	-0.1	0.7
$P-\beta_a$	0	-0.1	0.4	-0.1	0.1	0.4
$R-T_B$	-0.3	-0.2	-0.2	-0.3	-0.3	0.9
$R-D$	0.2	0.5	0.8	0.7	1	0.9
$R-\beta_a$	0.2	0.2	0.8	0.3	-0.3	0.5
T_B-D	-0.3	-0.1	-0.4	-0.2	-0.3	0.8
$T_B-\beta_a$	0	-0.2	-0.3	-0.2	0.4	0.5
$D-\beta_a$	0.3	0	0.8	0.6	-0.3	0.7
	MO	MO	MO	MO	MO	MO
$P-R$	-0.1	-0.1	0	-0.1	0.9	0.2
$P-T_B$	-0.7	-0.6	-0.6	-0.9	0	-0.1
$P-D$	-0.1	0	0	-0.1	0.1	0.1
$P-\beta_a$	-0.1	-0.1	0	0	0	-0.3
$R-T_B$	-0.2	-0.2	-0.2	-0.1	-0.1	-0.4
$R-D$	0.4	0.4	0.7	0.7	0.2	0.6
$R-\beta a$	0.3	0.1	0.2	0.1	0.8	0.1
T_B-D	-0.3	-0.1	-0.1	-0.1	-0.3	-0.2
$T_B-\beta_a$	-0.2	-0.1	-0.1	0	0	-0.1

Comparative analyses of jet components with positive and negative acceleration and parallel and perpendicular acceleration

Table 9 showed the average values of the analysed parameters (P, R, TB, D, β_a perpendicular $(\eta \perp)$ parallel acceleration $\eta \parallel$ for jet components with negative (-VE) acceleration and jet components (+VE) acceleration) for the MOJAVE and RRFID sources, for all the classes of radio sources combined (ALL) and for different classes of radio sources (Q - quasars; B - BL Lac; G galaxies). For the G subclass of MOJAVE sources, the average values of the analysed jet components parameters are similar for all the subsamples except the acceleration, which seem to show higher magnitude from the average values for the $|\eta \parallel|$ than $|\eta \perp|$.

Table 9 The average values for p, R ,T_B, D, B_A, H⊥ and $\eta \perp$ for jet component with negative (-ve) and positive (+ve) acceleration respectively for the mojave and rrfid sources (for all the subclasses of radio sources combined (all), bl lac (B), galaxies (G) and radio quasars (Q))

	$\eta \parallel$	$\eta \parallel$	$\eta \perp$	$\eta \perp$	$\eta \parallel$	$\eta \parallel$	$\eta \perp$	$\eta \perp$
	MO	**MO**	**MO**	**MO**	**RR**	**RR**	**RR**	**RR**
ALL	**-VE**	**+VE**	**-VE**	**+VE**	**-VE**	**+VE**	**-VE**	**+VE**
P($WHz^{-1}sr^{-1}$)	1.1×10^{25}	0.9×10^{25}	1.1×10^{25}	2.1×10^{22}	2.1×10^{22}	2.1×10^{22}	2.1×10^{22}	1.8×10^{22}
R (pc)	3.1	2.4	2.7	2.5	3.7	2.5	3.2	3.1
TB (*K*)	0.1×10^{13}	0.2×10^{13}	0.1×10^{13}	0.2×10^{13}	1.4×10^{9}	2.8×10^{9}	2.2×10^{9}	2.1×10^{9}
D(pc)	11.6	7.4	7.9	9.6	9.3	8.6	10.5	7.4
β_a	4.9	4.6	4.3	5.1	5.3	4.2	5.1	4.2
η	-13.1	12.6	-7.3	9.1	-0.6	0.5	-0.5	0.4
B	B	B	B	B	B	B	B	B
P ($WHz^{-1}sr^{-1}$)	1.4×10^{24}	0.4×10^{24}	0.6×10^{24}	0.5×10^{24}	9.4×10^{20}	7.2×10^{20}	7.2×10^{20}	9.9×10^{20}
R (pc)	1.6	1.5	2.1	1.3	1.8	1.5	1.5	1.5
TB (K)	0.1×10^{13}	0.1×10^{13}	0.1×10^{13}	0.2×10^{13}	2.1×10^{9}	0.8×10^{9}	2.3×10^{9}	0.8×10^{9}
D(pc)	6.1	3.5	6	3.2	5.2	4.9	5.2	4.9
βa	1.1	2.7	3.5	1.1	2.7	4.1	2.8	4
η	-16.6	25.5	-21.1	4.6	-0.6	0.5	-0.3	0.3
Q	Q	Q	Q	Q	Q	Q	Q	Q
P ($WHz^{-1}sr^{-1}$)	2.4×10^{25}	2.3×10^{25}	2.3×10^{25}	2.6×10^{25}	3.1×10^{22}	3.8×10^{22}	3.5×10^{22}	3.6×10^{22}
R (pc)	4.2	2.8	3.5	3.3	4.2	3.6	3.7	3.8
TB (*K*)	0.1×10^{13}	0.4×10^{13}	0.2×10^{13}	0.3×10^{13}	1.3×10^{9}	3.4×10^{9}	1.9×10^{9}	3.5×10^{9}
D(pc)	16.4	11.1	13.2	13.9	11.6	9.9	11.8	8.7
βa	7.6	6.7	6.2	8.1	6.7	5.4	6.9	5.4
η	-10.9	10.4	-5.6	10.2	-0.6	0.5	-0.5	0.5
G	G	G	G	G	G	G	G	G
P ($WHz^{-1}sr^{-1}$)	0.4×10^{23}	0.3×10^{23}	0.4×10^{23}	0.3×10^{23}				
R (pc)	0.4	0.3	0.4	0.4				
TB (*K*)	0.1×10^{13}	0.1×10^{13}	0.1×10^{13}	0.1×10^{13}				
D (pc)	1.7	1.5	1.4	1.6				
β^a	0.2	0.3	0.2	0.3				
η	-23.3	18.3	-13	9.2				

For the B subclass of MOJAVE sources using the average values shown in Table 9, the average values P of the jet components showing-VE $\eta \|$ appears to be higher than those showing +VE $\eta \|$ but is similar for both jet components showing -VE and +VE $\eta \perp$. Comparison between $\eta \| / \eta \perp$, jet components with -VE $\eta \|$ have higher average values of P than jet components with -VE $\eta \perp$, while those with +VE acceleration have similar average P. The average R is similar for both subsamples of jet components showing $\eta \|$ but those of VE $\eta \perp$ is higher than that of +VE $\eta \perp$. Average values of T_B are similar for all the subsamples, while the average value of D is generally higher for jet components with -VE acceleration. The average value of β_a for jet components with -VE $\eta \|$ is higher than that of +VE $\eta \|$, while jet components with -VE $\eta \perp$ have lower average value of β_a than the +VE counterpart. Generally, the jet components of B show higher magnitude of -VE $\eta \perp$ than $\eta \|$, but higher +VE $\eta \|$.

The results from the median values of the analysed parameters for the Q subclass of MOJAVE sources indicate that the averages P and β_a of all the subsamples are similar, (though it seems that average values of β_a of -VE $\eta \|$ is higher than +VE $\eta \|$, while average β_a of +VE $\eta \perp$ is higher than that of -VE $\eta \perp$). The median values of R and D suggest that the size and the projected distance of jet components with -VE $\eta \|$ are larger than those with +VE $\eta \|$. The average T_B of +VE $\eta \|$ is higher than those of -VE $\eta \|$ but are similar for both -VE and +VE $\eta \perp$. Generally, jet components display similar average magnitude values of +VE/-VE $\eta \|$. The average values of R for all the subsamples are similar for each class of radio sources. Jet components with +VE $\eta \perp / \eta \|$ show low values of average T_B but higher values of average βa than those with -VE $\eta \perp / \eta \|$. All the subsamples have similar average values of D. The magnitudes of the average acceleration indicate that jet components have show higher parallel acceleration than perpendicular acceleration. For the Q subclass of RRFID, median results from Table 2 suggest that higher values of P for jet component with +VE $\eta \|$ but lower values of R than those with -VE $\eta \|$, but similar values for jet components with +VE/-VE $\eta \perp$. For T_B, jet components with -VE $\eta \perp / \eta \|$ have lower average T_B, higher average D and β_a than jet components with +VE $\eta \perp / \eta \|$. Generally, all the subsamples indicate similar average magnitude of η.

Using the ALL subclass in both Table 9, we compare the jet component parameters of MOJAVE (observed at 15 GHz) and RRFID (observed at 8GHz) sources. Generally, the radio power and the brightness temperature of the MOJAVE sources are higher than those of RRFID being observed at higher radio power may be sampling the inner regions of the radio sources. The average jet component sizes and apparent speeds are similar in range for both MOJAVE and RRFID samples Obviously, the observed physical size of radio sources is independent of frequency of observation (Onuora and Okoye 1983). Jet components with -VE $\eta \|$ of MOJAVE seem to have large average values of D than those of RRFID sources but the reverse is the case for jet components with +VE $\eta \|$. The jet components of RRFID sources -VE $\eta \perp$ appear to have larger values of average D than those of MOJAVE sources but reverses for jet components with +VE $\eta \perp$. Generally, the average values of η of RRFID sources are lower than those of RRFID sources. From our results, both 8 GHz and 15 GHz observations have slightly varying D but with the 8 GHz observation having slightly higher average R across all the subsamples. These results suggest jet components may be composed of different layers/sheaths with the inner layers/sheaths accelerating faster than the outer layer/sheaths (with higher frequency observations sampling the inner layer/sheath).

In Table 10, we display the ratio of median values of the parameters of jet components with negative acceleration to jet components and positive acceleration columns 2 & 3 for MOJAVE sources and columns 6 & 7 for RRFID. Sources for $\eta \|$ and $\eta \perp$ respectively; while in Columns 4 & 5(for MOJAVE sources) and 8& 9 (for RRFID Sources), we present the ratio $\eta \| / \eta \perp$ for jet components with -VE and +VE acceleration respectively. This was done for various subclasses of radio sources (Bs, Gs and Qs). The results indicate that the jet component parameters have similar range of values (the ratio values ∼1) with few parameters of some subclasses at most about 2 factors greater or less (the values in Table 10 ranges from ∼0.5–2.3) except for -VE/+VE∼5 for $(\eta \perp)$ $(\eta \perp), \eta \|$~ 6 for +VE and -VE/+VE~ 3 for $\eta \|$ of MOJAVE Bs. The similarities in values of the jet component parameters for the various subsamples considered indicates that jet components with -VE, +VE, parallel or perpendicular acceleration undergo similar dynamic and kinematic evolution.

Table 10 The ratio of median values of the parameters of jet component with negative acceleration to jet components with positive acceleration a

	MO	**MO**	**MO**	**MO**	**RR**	**RR**	**RR**	**RR**
	$\eta \|$	$\eta \perp$	**−VE**	**+VE**	$\eta \|$	$\eta \perp$	**−VE**	**+VE**
	$\frac{-VE}{+VE}$	$\frac{-VE}{+VE}$	$\frac{\eta \|}{\eta \perp}$	$\frac{\eta \|}{\eta \perp}$	$\frac{-VE}{+VE}$	$\frac{-VE}{+VE}$	$\frac{\eta \|}{\eta \perp}$	$\frac{\eta \|}{\eta \perp}$
B_s								
P	3.4	1.1	2.3	0.8	1.3	0.7	1.3	0.7
R	1	1.7	0.8	1.2	1.2	1	1.2	1
T_B	1.8	0.5	1.7	0.5	2.6	2.8	0.9	1
D	1.7	1.9	1	1.1	1.1	1.1	1	1
β_a	0.4	3.3	0.3	2.6	0.7	0.7	1	1
η	0.7	4.6	0.8	5.5	1.3	1	2.1	1.7
Q_s								
P	1.1	0.9	1.1	0.9	0.8	1	0.9	1.1
R	1.5	1.1	1.2	0.9	1.2	1	1.1	0.9
T_B	0.3	0.7	0.6	1.4	0.4	0.5	0.7	1
D	1.5	0.9	1.2	0.8	1.2	1.4	1	1.1
β_a	1.1	0.8	1.2	0.8	1.2	1.3	1	1
η	1	0.5	1.9	1	1.1	1	1.4	1.1
G_s								
P	1.3	1.1	1.2	1.1	n/a	n/a	n/a	n/a
R	1.2	1	1	0.9	n/a	n/a	n/a	n/a
T_B	0.5	0.9	0.8	1.3	n/a	n/a	n/a	n/a
D	1.1	0.9	1.2	0.9	n/a	n/a	n/a	n/a
β_a	0.9	0.9	1	1.1	n/a	n/a	n/a	n/a
η	1.3	1.4	1.8	2	n/a	n/a	n/a	n/a

The correlation analysis results shown in Table 11 indicate that generally, the acceleration of jet components for the different subsamples, do not depend on the jet component parameters (P, R, T_B, D, & β_a) used in the analyses, though it does seem that for the Bs and Gs subclasses, acceleration shows slight dependence on

Citation: Chika OC.Analysis of JET component parameters of AGN - brightness, speed, size, distance and acceleration. *Phys Astron Int J.* 2020;4(5):188–196.
DOI: 10.15406/paij.2020.04.00221

observed apparent speed. The none dependence of the jet component acceleration on the analysed jet component parameters may be a pointer that other factors like density/pressure gradient can be playing a significant role. Perucho et al.(2019) noted that jets can undergo an acceleration phase as the jet head propagates down the galaxy negative density/pressure gradient, because of the drop in ambient density.

Table 11 the correlation coefficients between η & other jet component parameters (z, P, R, T_B, D, & β_a) for negative (-ve) and positive (+ve) $\eta \parallel$ & $\eta \perp$ for MOJAVE (MO) and RRFID (RR) sources (for all the subclasses of radio sources combined (ALL), bl lac (B) and radio quasars (Q))

	MO	MO	MO	MO	RR	RR	RR	RR
	$\eta \parallel$	$\eta \parallel$	$\eta \perp$	$\eta \perp$	$\eta \parallel$	$\eta \parallel$	$\eta \perp$	$\eta \perp$
	-VE	+VE	-VE	+VE	-VE	+VE	-VE	+VE
B_s								
$\eta - \beta_a$	-0.3	0.6	-0.2	0.5	-0.5	0.6	0.2	0
$\eta - D$	0.1	-0.2	0.1	-0.1	0.1	0.5	-0.6	0
$\eta - T_B$	0.1	-0.1	0.2	-0.1	0.1	-0.2	0.2	0.2
$\eta - R$	0	-0.1	0.1	-0.1	0	0.3	-0.6	-0.1
$\eta - P$	0.1	-0.2	0.2	-0.1	-0.1	-0.2	0.1	0.6
Q_s								
$\eta - \beta_a$	-0.1	0.2	-0.2	0.1	-0.2	0.1	0	0.1
$\eta - D$	0.1	0	0.1	-0.1	0	0	0.1	0
$\eta - T_B$	0.1	-0.1	0.2	0	-0.1	0.3	-0.2	0.1
$\eta - R$	0	0	0	-0.1	0.1	-0.1	0	0
$\eta - P$	0.1	-0.1	0.1	-0.1	-0.4	0.1	-0.2	0.1
G_s								
$\eta - \beta_a$	-0.6	0.7	-0.5	0.5	n/a	n/a	n/a	n/a
$\eta - D$	0	-0.1	0.1	-0.1	n/a	n/a	n/a	n/a
$\eta - T_B$	0.2	-0.1	0.1	-0.1	n/a	n/a	n/a	n/a
$\eta - R$	-0.4	-0.1	-0.1	0.4	n/a	n/a	n/a	n/a

Discussions & summary

The R−D correlation found has been reported by Onuchukwu et al.[3,4] and by Pushkarev et al.[16] who reported a single power-law dependence $D \alpha R^k$ with $k \sim 1$ and indicates that self-similar model;[17,18] applied to large scale jet may work on jet components. The general lack of P−R correlation for all the subsamples of quasars and BL Lac of both samples except for galaxies class of both samples can be attributed to environment within the inner regions of the radio source (the environmental factors responsible for brighter sources is also the factor that limits the growth in size since the mean values suggested that smaller sources are brighter for quasars. $P-T-B$ correlation seems inverse for most of the quasar, BL Lac and galaxy subsamples, but according to equation 6, one would expect some kind of direct relation. The possible explanation is that within the core regions of jet components, other factors (which may include environment-[19,20] play active role in the brightness of the source, not just the intrinsic kinetic power, since there is lack of $P-\beta_a$ correlation. Notice from the average values, that the brighter jet components are smaller, closer to the core where density are expected to be high and there is no difference in the average values of the speed of brighter and dimmer jet components. Similar environmental factors may be slowing down the jets, when they are closer to the core (average values of the speed of jet components closer to the core less than those further away from the core - Table 7).[20–23]

Acknowledgments

We acknowledge the contributions of our colleagues from the Astronomical Society of Nigeria (ASN) and the useful discussion we had with Prof. A. A. Ubachukwu of the Astronomy and Astrophysics Research Lab University of Nigeria Nsukka.

Conflicts of interest

The author declares there is no conflict of interest.

References

1. Piner BG, Pushkarev AB, Kovalev YY, et al. Relativistic Jets in the Radio Reference Frame Image Database II: Blazar Jet Accelerations from the First 10 Years of Data (1994 - 2003). *APJ*. 2012;758:84.
2. Lister MN, Aller MF, Aller HD, et al. Radio observations of active galactic nuclei with mm-VLBI. *AJ*. 2016;152:12.
3. Onuchukwu CC, Ubachukwu AA. On the Lorentz factor of superluminal sources. *Research in Astronomy and Astrophysics*. 2013a;13(5):509.
4. Onuchukwu CC, Ubachukwu AA. *Ap & SS*. 2013b;348:1930.
5. La¨hteem¨aki A, Valtaoja E. *APJ*. 1999;521:493.
6. Jorstad SG, Marscher AP, Lister ML, et al. Polarization structure in the core of 1803+784: a signature of recollimation shocks?. *AJ*. 2005;130:1418.
7. Hovatta T, Valtaoja E, Tornikoski M, et al0 Measurement of the cross section for $t\bar{t}$ production in $p\bar{p}$ collisions using the kinematics of lepton+jets events. *A&A*. 2009;494:527.
8. Sokolovsky KV, Kovalev YY, Pushkarev AB, et al. Identification of *γ*-ray emission from 3C 345 and NRAO 512. *A&A*. 2011;535A:24S.
9. Leahy JP. *Interpretation of Large Scale Extragalactic Jets in Beams and Jets in Astrophysics*. In: PA Hughes editor. Cambridge University Press, Cambridge. 1991. p.585.
10. Komatsu E, Dunkley J, Nolta MR, et al. Five-Year Wilkinson Microwave Anisotropy Probe Observations: Cosmological Interpretation. *APJS*. 2009;180:330.
11. Ubachukwu AA. Relativistic Beaming and Orientation Effects in Lobe-Dominated Quasars. *AP&SS*. 1998;257:23.
12. Onuora LI, Okoye SE. Evolution of extragalactic radio sources andquasar/galaxy unification. *APJ*. 1983;270:360.
13. Onah CI, Ubachukwu AA, Odo FC. Selection effects and structural symmetries in the orientation based unified scheme. *Rev MeX AA*. 2018;54:271.
14. Alhassan JA, Ubachukwu AA, Odo FC. On the Absence of Core Luminosity–Core-Dominance Parameter (P_C - R) Correlation in Radio Galaxies and BL Lacs. *JOAA*. 2013;34:61.
15. Baum, Stefi A, Zirbel, et al. Toward Understanding the Fanaroff-Riley Dichotomy in Radio Source Morphology and Power. *ADS*. 1795;451:88.
16. Pushkarev AB, Kovalev YY, Lister ML, et al. MOJAVE - XIV. Shapes and opening angles of AGN jets. *MNRAS*. 2017;468:4992P.
17. Falle SAEG. Self-similar jets. *MNRAS*. 1991;250:581.
18. Scheuer PAG. On the jet speeds of classical double radio source. *MNRAS*. 1995;277:331.
19. Falcke H, K¨ording E, Nagar NM. Compact radio cores: from the first black holes to the last. *NewAR*. 2004;48:1157.

20. Giacalone J, Jokipii JR. Magnetic field amplification by shocks in turbulent fluids. *The Astrophysical Journal*. 2007;663:L41–L44.

21. Perucho M, Mart´ı JMV, Quilis V. Simulating the dynamics and non-thermal emission of relativistic magnetized jets I. Dynamics. *MNRAS*. 2019;482:3718.

22. Piner BG, Pant N, Edwards PG. The Innermost Regions of Relativistic Jets and Their Magnetic Fields. *APJ.* 2010;723:1150.

23. Planck Collaboration XIII, Planck 2015 results. XIII. Cosmological parameters. *A&A*. 2016;594:A13.

Citation: Chika OC.Analysis of JET component parameters of AGN - brightness, speed, size, distance and acceleration. *Phys Astron Int J.* 2020;4(5):188–196.
DOI: 10.15406/paij.2020.04.00221