

THE OBSERVATION OF COUNTERJETS OF QUASARS AND GALAXIES

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ABSTRACT: The purpose of this paper is to point out the importance of the observation of the counterjet of subluminals, for it will settle up the question whether quasars redshifts are cosmological or not. If so, from the observed wavelength of the counterjet, one is able to find out the value of Hubble constant H_0 . What we observe as an apparent superluminal or subluminal motion is the resultant velocity of Hubble flow and a local ejection. Taking Hubble flow into account, one can explain problems posed for the relativistic beaming model, such as the one-sidedness problem and the intolerable extension of the deprojected structure of some superluminal sources. Our method is applied to two superluminals, 4C73.18 and 3C179, and two subluminals, M87 and 3C84. Our method can also be applied to investigate the problem of the ejection of the quasar from the galaxy in the framework of kinematics. Two quasar-galaxy pairs, Markarian 205-NGC4319 and 3C455-NGC7413, are studied.

1. INTRODUCTION

In the past few years a great progress has been made in the VLBI images, such as the "WORLD ARRAY" images of M87 made by Biretta and Owen (1990) and 3C48 obtained by Wilkinson et al.(1990), showing structural complexity that rivals that seen in VLA. However, the theory to interpret these valuable data lags behind. The most generally accepted explanation appears to be the relativistic beaming model, first suggested by Rees (1966, 1967) and elaborated for relativistic jet by Behr et al. (1976) and Blandford and Konigl (1979). Problems posed for the relativistic model, such as the one-sidedness problem and the uncommonly largely intrinsic size of some superluminal sources, are still challenging current workers at the recent workshops (Superluminal Radio Sources, 1987; Parsec-scale Radio Jet, 1990) and IAU Symposium 129 (Impact of VLBI on Astrophysics and Geophysics, 1988).

Rees' formula, $v_{app} = v \sin \theta / (1 - v \cos \theta)$ (the velocity of light $c=1$), relates the apparent transverse velocity v_{app} with the ejection velocity v , where θ is the angle between v and the line of sight. Rees' formula is good only for the ejecting body, relatively at rest with respect

to an observer. Now the ejecting body, a quasar, usually has large receding velocity. We have to take the velocity of Hubble flow into consideration.

In the literature a few works (Dishon & Weber, 1977; Horak, 1978; Li, 1980) tried to solve the problem of superluminal motion with the consideration of Hubble flow. In addition to the unsound assumption about the quasar to have the transverse velocity of the ejecta in the first two works and the introduction of unconfirmed proper motions of quasars in the third, all three works said nothing about the radial component of the velocity of the ejecta. They had not really solved the problem, nevertheless, it is helpful to point out the need of the consideration of Hubble flow.

In the simple case of a quasar ejecting materials in the direction of line of sight, Bahcall et al. (1967) and Weymann et al. (1977) had successively derived the relative velocity, v_{rel} , between the absorption and emission regions by taking the velocity of Hubble flow into account. The relative velocity is no other than the velocity of local ejection seen from the quasar. An observer on the Earth will see velocity of the absorption material, not the velocity of local ejection.

2. THE SOLUTION FOR THE OBSERVATION OF COUNTERJET OF QUASAR

The solution of the subluminal motion is the same as that of the superluminal one which we have given elsewhere (Gong, 1991). The observed apparent transverse velocity v_{app} of a separation of a blob from the core of a quasar is related to the resultant velocity V made of the velocity v_h of Hubble flow and the velocity u of local ejection through the expression,

$$v_{app} = \frac{V \sin \alpha}{1 + V \cos \alpha} \quad , \quad c = 1 \tag{1}$$

where α is the angle between V and v_h . Let the ejection velocity u make an angle ϕ with v_h , then according to the formulae of the composition of velocity given by special relativity, we have the V_H component of the resultant velocity V in the v_h direction,

$$V_H = \frac{v_h + u \cos \phi}{1 + v_h u \cos \phi} \quad , \tag{2}$$

$$V = \frac{\{(v_h^2 + u^2 + 2v_h u \cos \phi) - (v_h u \sin \phi)^2\}^{1/2}}{1 + v_h u \cos \phi} \quad , \tag{3}$$

where v_h is uniquely given by the redshift z_q of the quasar in question,

$$v_h = \frac{(1 + z_q)^2 - 1}{(1 + z_q)^2 + 1} \quad . \tag{4}$$

By solving the above equations, we can obtain values of v_h , u , ϕ , α , V and V_H . By definition the Doppler factor of a moving source is given by,

$$\delta = \frac{1}{1 + z_q} = \frac{(1 - V^2)^{1/2}}{1 + V_H} = \frac{\nu_m}{\nu_r} = \frac{\lambda_r}{\lambda_m} \quad . \tag{5}$$

Subscripts m and r indicate, respectively, the frequency and the wavelength of the emission sources in motion and at rest.

So far we have obtained the solution for the jet. By putting $u' = u$, $\phi' = \phi + 180^\circ$ in the above equations, we can obtain values of corresponding quantities α' , V' , V'_H and δ' of the counterjet. From Eq.(5), the rest wavelength of the jet will be $\lambda_{rj} = \delta \lambda_{ob}$, where λ_{ob} is the observed wavelength of the jet and the corresponding wavelength of the counterjet will be

$$\lambda_{cj} = \lambda_{rj} / \delta' = \delta \lambda_{ob} / \delta' . \quad (6)$$

The wavelength of the counterjet λ_{cj} is derived from three quantities, z_q , λ_{ob} and v_{app} . Both z_q and λ_{ob} are observed quantities. v_{app} is given by

$$v_{app} = \mu D_L / (1 + z_q) \propto D_L , \quad (7)$$

where μ is the observed proper motion. The luminosity distance is expressed by

$$D_L = \{z_q q_0 + (1 - q_0)(1 - \sqrt{2q_0 z_q + 1})\} / H_0 q_0^2 \propto 1 / H_0 . \quad (8)$$

Numerically D_L changes very little when the deceleration parameter q_0 varies from 0.1 to 1.0. Thus, λ_{cj} is mainly determined by the value of Hubble constant H_0 . We, therefore, are able to find out the value of H_0 reversely from the observed value of λ_{cj} .

3. NUMERICAL RESULTS FOR SUPERLUMINALS AND SUBLUMINALS

3.1. Numerical Results for Superluminals 1928+738 and 3C179

A few numerical results are quoted here from the paper (Gong, 1991) for illustration. For quasar 1928 + 738 ($v_{app} = 7.0c/h$, $z = 0.302$), the allowed values of the solution for ϕ , the angle between the local ejection and the radial direction are in the range of $169^\circ - 175^\circ$, the corresponding values of their speed, u , are in the range of $0.9940 - 0.9972c$ and those of δ/δ' are in the range of $95 - 238$. For 3C179 ($v_{app} = 4.8c/h$, $z = 0.846$), the corresponding values of ϕ , u and δ/δ' are, respectively, in the range of $168^\circ - 176^\circ$, $0.9943 - 0.9980c$ and $86 - 233$. As the value of δ/δ' is the ratio of the wavelength of the counterjet to λ_{ob} , the wavelength of the observed jet, obviously one is unable to observe the counterjet of superluminals with the wavelength as λ_{ob} .

As to the problem of the intolerable extension of the deprojected structure of some superluminal sources, we solve it satisfactorily. For quasar 1928+738, the deprojected size given in Table 1 of the paper by Simon et al. (1987) is $1090 \text{ kpc}/h$, it reduces to $472 - 255 \text{ kpc}/h$ if the ejection velocity decreases to $0.50 - 0.30c$ with the ejection angle kept constant.

3.2. Numerical Results of Subluminals M87 and 3C84 and the Way for the Determination of Hubble constant H_0 .

We put $H_0 = 100h \text{ km/s/Mpc}$ with $h=1.0, 0.75$ and 0.5 and proceed to compute the values of λ_{cj} 's. Up to now we have found only two well-behaved subluminals with known redshift and proper motion as follows:

- 1) M87 = Virgo A = 3C274 (Procas, 1987; Birett et al., 1988)
 $z_q = 0.004$, $\mu = 1.1 \text{ mas/yr}$, $v_{app} = 0.21 \text{ c}/h$;
- 2) 3C84 = NGC1275 (Marr et al., 1988)

$$z_q = 0.018, \mu = 0.55 \text{ mas/yr}, v_{app} = 0.46 \text{ c/h}$$

The calculated values of various quantities solved for M87 and 3C84 are tabulated separately, shown here only for 3C84 in Table 1. From the tabulated values we plot λ_{cj} , the wavelength of the counterjet against u' , the speed of local ejection, in Figure 1 for 3C84.

In the figure, these $\lambda_{cj} - u$ curves are located separately from each other. The top one is for $h=0.5$, the middle one for $h=0.75$ and the bottom one for $h=1.0$. On each curve there is a lowest point, i.e., the least ejection velocity u'_{min} , denoted by B, B' and B'', respectively, on the top, middle and bottom curves. Points L, L' and L'' denote the longest expected wavelength of the counterjet for the respective cases of $h=0.5, 0.75$ and 1.0 . Similarly points S, S' and S'' denote the shortest expected wavelength of the counterjet for three cases.

Table 1. Numerical Results for Subluminal 3C84, $\lambda_{ob} = 1.3 \text{ cm}$

$V(c)$	$V_H(c)$	$u(c)$	δ	$V'_H(c)$	$V'(c)$	δ'	$\lambda_{cj}(cm)$
$h=1.0$							
.44078	-.30196	.45072	1.2859	.33402	.46083	.66527	2.513
.41791	-.17465	.42429	1.1007	.20901	.43112	.74631	1.917
.43482	-.06555	.43728	.9637	.10098	.14031	.81550	1.536
$h=0.75$							
.55148	-.42991	.56101	1.4455	.45176	.57074	.56571	3.322
.52283	-.27335	.52793	1.1731	.30603	.53686	.64598	2.361
.54213	-.15114	.54582	.9899	.18581	.54986	.7043	1.827
.60083	-.20890	.60145	.8164	.05651	.60235	.75554	1.409
$h=0.5$							
.70996	-.61562	.71757	1.8321	.63729	.72507	.42062	5.663
.67706	-.45841	.68361	1.3588	.48612	.69019	.48693	3.628
.69621	-.33905	.70075	1.0861	.37024	.70540	.51729	2.729
.74914	-.22245	.75154	.8519	.25608	.75408	.52288	2.118
.84203	-.08999	.84264	.5928	.12525	.84335	.47755	1.614

We are able to determine Hubble constant H_0 in the following way. The observed wavelength of the jet is 1.3 cm. The longest expected wavelength are 5.64, 3.32 and 2.51 cm, respectively for the cases $h=0.5, 0.75$ and 1.0 . Now, if the observed wavelength of the counterjet $\lambda_{cj} = 4.0 \text{ cm}$ is longer than those at L' and L'', then the value of h must be less than 0.75 and lies between 0.5 and 0.75. We put the new value of h in the range $0.5 \sim 0.75$ and derive the new longest value of λ_{cj} for the new value of h . The new one, say, h_m which gives $\lambda_{cj} = 4.0 \text{ cm}$, is the upper bound of h values for 3C84, i.e., $0.5 < h < h_m < 0.75$. Looking closely into the problem, one will find out λ_{cj} is also effected by the direction of the ejection. The longer the wavelength λ_{cj} , the smaller the ejection angle between the radial direction and the ejection. Therefore, we need subluminals to make smaller angle with the radial direction.

In the figure the wavelength λ_{cj} for three curves overlaps each other on the left side. It is impossible to differentiate to which curve the observed λ_{cj} belongs. However, the curves show that for each soluble value of u' , there are always two solutions of λ_{cj} , one at the left side and the other at the right side of the lowest points B, B' and B'', respectively for each of three curves. It can be shown that there is pretty chance to get the observed λ_{cj} at the right side of B (B' or B''), if more subluminals are observed.

4. THE SOLUTION FOR THE OBSERVATION OF COUNTERJET OF GALAXY

Arp et al. (1987a) claimed the ejection of a quasar from a galaxy as a result of the bipolar flow. As before we adopt a kinematic model involving twin processing jets in opposite direction. Thus, we can apply equations in Section 2 to solve the problem. Let u be the velocity of the quasar ejected from a galaxy and ϕ , the angle between u and v_h , the velocity of Hubble flow, then Eq.(2) gives the component V_H of the resultant velocity made of u and v_h in the direction of v_h . Eq.(5) can be rewritten as,

$$V = \{1 - (1 + V_H)^2 / (1 + z_q)^2\}^{1/2} \quad (5')$$

in which z_q , the redshift of the observed quasar, is a known quantity. The value of V_H derived from any value of $u \cos \phi$ in Eq.(2) will be allowable solutions for the resultant velocity V provided $V_H \leq z_q$.

We apply the above method to two close associations of the galaxy and the quasar for illustration:

- 1) Markarian 205, $z_q = 0.07$; NGC4319, $z_g = 0.006$,
- 2) 3C455, $z_q = 0.543$; NGC7413, $z_g = 0.0332$.

Both of them have been described by Arp et al., (1975) as the example of the ejection of quasar by the nearby galaxy. The numerical results for the two examples are shown in Table 2, in which values of u and ϕ are, respectively, the speed and the ejection angle of the jet making with the radial direction so as to render the redshift of the ejecta equal to that of the observed quasar. Values of z'_q are the red (positive) and blue (negative) shift of the counterjet, a quasar in the present case. In case Mark.205 is ejected from NGC4319 in the process of bipolar flow, we should observe another quasar with one of the values z'_q in the opposite direction to Mark.205 with respect to NGC4319 as a center body. None of them has been observed. Neither for the case of 3C455 and NGC7413. Therefore, in the standpoint of kinematics and existing physical principles, both Mark.205 and 3C455 are not ejected from their respective galaxy.

Table 2. Numerical Results for the Solution of Mark.205 and NGC4319 pair
(Those for 3C455-NGC7413 deleted due to space)

ϕ ($^\circ$)	0.000	43.7	71.6	79.1	86.0	100.1	124.5	136.9
u (c)	.615	.0830	.159	.211	.284	.533	.882	.958
z'_q	-.054	-.051	-.032	-.012	+.028	+.308	+2.20	+4.97

The above conclusion for the two galaxy-quasar pairs might be extended to the problem of the ejection of quasars in the universe in general. Although an approaching source

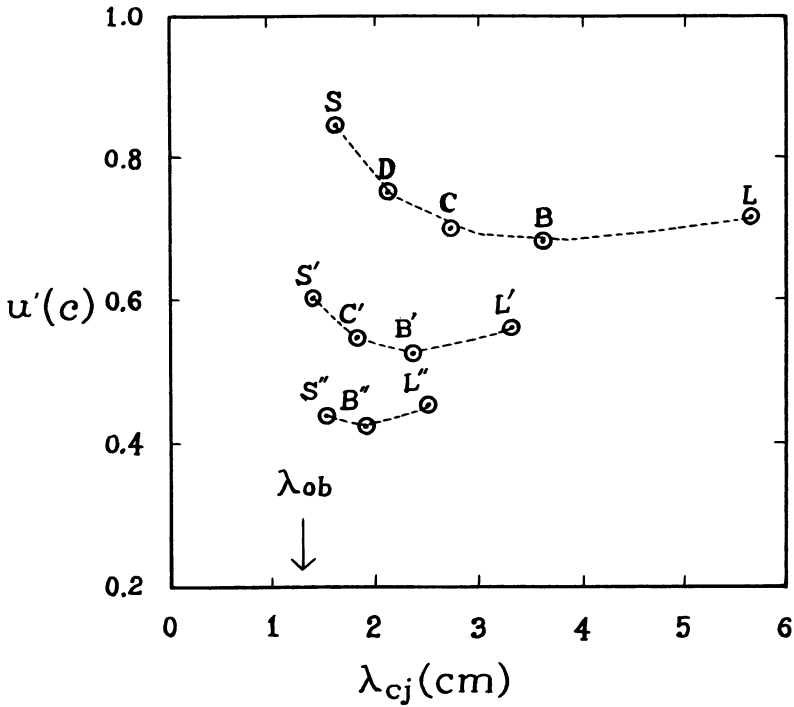


Fig.1. The expected wavelength λ_{cj} of the counterjet vs the ejection velocity u' for subluminal 3C 84. The top curve is for $h=0.5$, the middle one for $h=0.75$ and the bottom one for $h=1.0$.

does not always show blue shift due to the time dilation factor, there are still quite a few approaching sources to have blue shift as shown in Table 2. Up to now the number of the observed quasars is over 4000, none of them shows blue shift. Why? The only answer to it is that the quasar is not ejected from galaxy.

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