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3C 273: a gravitationally lensed quasar?

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Summary. It is suggested that the abnormal brightness of the quasar 3C 273, coupled with the observations of superluminal motions in its radio core B as well as the misalignment of its VLBI jet with the optical jet, can be understood by postulating a faint spheroidal lensing galaxy located about halfway along the line of sight to the quasar. The lens model also helps to understand why the quasar is found slightly off-centre with respect to its nebulosity. The probability for such a lens system to arise for 3C 273 by chance is shown to be no less than that computed on the basis of the relativistic beaming hypothesis. Further tests of the lens model are discussed.

Key words: gravitation – quasars: 3C 273

1. Introduction

The discovery of the twin quasar 0957+561 A and B in 1979 with nearly identical spectra and redshifts led to the hypothesis that the bright objects A and B are the gravitationally lensed images of a single quasar. The imaging agency in this case is believed to be a massive intervening galaxy together with a cluster of galaxies (Young et al, 1981a). This example has been primarily responsible for a revival of interest in the idea of gravitational lensing proposed by others many years earlier (Zwicky, 1937; Barnothy and Barnothy, 1971; Press and Gunn, 1973).

About a year before the discovery of 0957+561 A and B two of us (Chitre and Narlikar, 1979) had invoked the idea of gravitational bending in an altogether different context. The idea is briefly illustrated in Fig. 1, and its objective was to explain the apparent superluminal separation of radio lobes in the cores of some quasars observed with VLBI techniques. In Fig. 1 the radio lobes A and B are seen by the observer O at A′ and B′ because the radio waves from A and B are bent by intervening galaxy G before they reach O. It was shown that under certain circumstances the images A′, B′ appear to O to separate from each other superluminally, even though the sources themselves have subluminal rate of separation.

One important feature of the lensing phenomenon is that under favourable conditions the image can appear considerably brighter than the source. This circumstance was in fact quoted as one of the arguments why in a flux limited sample quasars with superluminal separation would more likely be selected for observations. It was also suggested (Chitre and Narlikar, 1980) that a special search should be made for objects of high mass-to-light ratio along the line of sight to such quasars.

From the above standpoint the quasar 3C 273 presents several features of interest. First, it stands out as an abnormally bright quasar (optical magnitude $12^{m}.8$) in the optical surveys. It is also the brightest quasar in the X-ray and γ-ray wavelengths. Further, its radio core shows superluminal motion of the order of 10c. Do the abnormal brightness and superluminality point to gravitational lensing as the cause?

A prima facie case exists for such a hypothesis on two counts. First, the radio emission in 3C 273 occurs in two components A and B of which the component B coincides with the optical object. The superluminality is seen also in component B, thus suggesting a powerful lensing effect leading to unusual amplification of the core but not so much in the extended radio region; a phenomenon which could not have been invoked if, for example, the superluminality were found in component A.

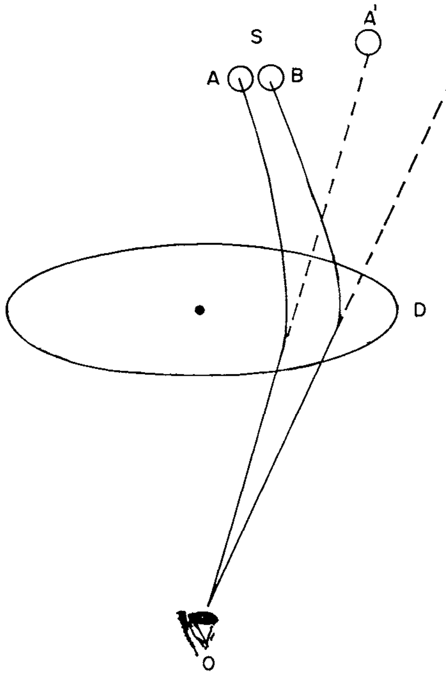

Fig. 1. (*left*) Radio lobes A and B in the source S are separating subluminally and their images A′ and B′ formed by the gravitational deflector D appear to the observer under suitable circumstances to separate at superluminal speeds

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Secondly, the recent studies of 3C 273 by deep CCD photometry by Tyson et al. (1982) reveals a fuzz around it with isophotes akin to that of an elliptical galaxy. Although the measurements of the redshift of the fuzz suggest that it is actually hosting the quasar (Wycoff et al., 1981) two aspects suggest that the interpretation may not be all that simple. First, the quasar is slightly off-centre (by about 0″.5) from the fuzz which is not expected if the quasar is the bright nucleus of the fuzzy galaxy. Second, the absolute luminosity of the fuzz galaxy (if it is assumed to be at the quasar) is considerably higher than for similar galaxies believed to be hosting other quasars. Both these points get explained if we superpose on the system a line of sight lensing galaxy of low luminosity but high mass.

Another consequence of lensing is that an initially linear structure will appear to be progressively bent as a result of the linear amplifications in mutually perpendicular directions being different. Interestingly the position angle of the VLBI structure, differs from the large scale optical jet observed in 3C 273, by ~20° (Pearson et al., 1981). Such bends can be naturally accommodated in a lens scenario.

These qualitative ideas have prompted us to probe the picture in some quantitative detail, with a view to examine its plausibility. We first present the quantitative models and then investigate to what extent they are probable. The probabilities will be compared with that for the scenario of relativistic beaming which is the popular explanation for the observed superluminal separation.

Our lens models of 3C 273 aim at specifying an intervening mass distribution which would reproduce the following observed features of 3C 273:

(i) The superluminal separation at a rate ~10 c in 3C 273B for the VLBI scale components.

(ii) Only one brightened image of 3C 273, other images being absent.

(iii) About 20° difference in the position angles of the VLBI jet and the large scale optical jet.

(iv) Off-centre position of the image with respect to the centre of the lensing galaxy, by at least 0″.5.

We will refer to such solutions as *acceptable* solutions.

The models discussed in the next section are presented in increasing order of complexity starting with the spherical lens. The motivation for seeking more complex models is to make the scenario more realistic.

Throughout this paper we shall assume the Hubble constant to be $H_0 = 60\ \mathrm{km\,s^{-1}\,Mpc^{-1}}$.

2. The lens models of 3C 273

a) The spherically symmetric lens

In this case the images, the source and the centre of the lens all lie in a straight line. This line can be projected onto the deflector plane perpendicular to the line joining the observer to the centre of the lens. Taking (r, θ) as the polar coordinates in this plane with $r=0$ as the direction from the observer to the lens centre, we get for a source located at (r, θ) the following relations for (r_0, θ_0), the image locations:

$$\begin{aligned} r &= r_0 - \mu g(r_0)\,, \qquad \theta_0 = \theta \\ r &= -r_0 + \mu g(r_0)\,, \qquad \theta_0 = \theta + \pi\,, \end{aligned} \tag{1}$$

where, for a lens of mass M

$$\mu = \frac{4GMD}{r_c^2 c^2}\,. \tag{2}$$

We have $D = D_{ds} D_d / D_s$ and r_c = core radius of the lens galaxy and r and r_0 have been expressed in units of r_c. The quantities D_d, D_{ds}, D_s and r_0 are illustrated in Fig. 2.

The function $g(r_0)$ is a real function which depends on the density distribution in the lens galaxy. For model galaxies discussed by King (1972), the density distribution

$$\begin{aligned} \rho &= \rho_0 (1 + r^2/r_c^2)^{-3/2}\,, \qquad r/r_c \leqq n \\ \rho &= 0\,, \qquad r/r_c > n \end{aligned} \tag{3}$$

implies

$$g(r_0) = \frac{1}{r_0}\left[1 - \frac{1}{2\delta} \ln\left(\frac{(n^2+1)^{1/2} + (n^2 - r_0^2)^{1/2}}{(n^2+1)^{1/2} - (n^2 - r_0^2)^{1/2}}\right) + \frac{1}{\delta}\frac{(n^2 - r_0^2)^{1/2}}{(1+n^2)^{1/2}}\right], \tag{4}$$

where

$$\delta = \ln[n + (1+n^2)^{1/2}] - n/(1+n^2)^{1/2}\,.$$

For a spherically symmetric lens the linear scale amplification consists of two parts:

$$\text{radial} \quad a_r = \frac{dr_0}{dr}\,, \tag{5}$$

$$\text{transverse} \quad a_t = \frac{r_0}{r}\,, \tag{6}$$

and the intensity amplification is then given by

$$A = a_r a_t\,. \tag{7}$$

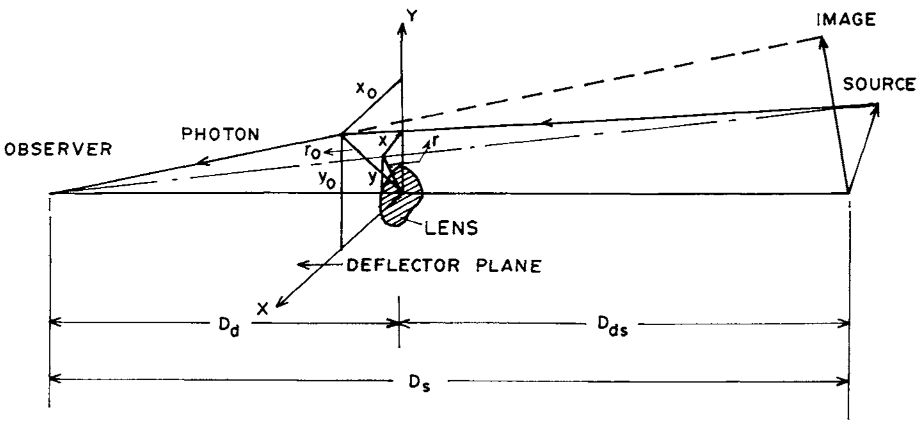

Fig. 2. Positions of observer, source, image and lens are schematically shown with the photon-path close to the z-axis, the origin of the coordinate system being coincident with lens-centre, D_s = observer–source distance, D_d = observer–deflector distance and D_{ds} = deflector–source distance

Table 1. Solutions for a single component lens kept at a redshift $Z_d = 0.07$

Parameters	Spherical lens (a)	Spheroidal lens (b)	Spheroidal lens (c)
Velocity dispersion (σ_g) km s^{-1}	187	225	250
Core radius r_c (kpc)	1.0	1.0	1.35
Eccentricity e	0	0.5	0.5
Cut-off radius $n = R/r_c$	20	10	10
Position angle of major axis θ_g	–	93°	98°
Core-jet angle θ_{cJ}	24°	133°	173°
Source position (arcsec)	(0.000, 0.050)	(0.035, 0.160)	(0.050, 0.173)
Image position (arcsec)	(0.000, 0.536)	(0.386, 0.883)	(0.558, 0.997)
Linear amplification	9.8	10.0	11.9
Amplification	21.830	12.275	16.113
Bend angle θ_b	19.7°	20.0°	20.0°
Mass ($10^{11} M_\odot$)	1.90	1.78	2.19

The solution of (1) is essentially the intersection of the two straight-lines $y = \pm(r_0 - r)$ with the curve $C: y = \mu g(r_0)$ at the two specified values $\theta_0 = \theta$ and $\theta_0 = \theta + \pi$ respectively. Evidently a_r is large where the straight-lines are almost tangential to C, while a_t is large when the source position is close to the origin. For most values of μ it turns out that whenever a_r or a_t is large for one image, there are also other images of comparable brightness, thus violating the requirement (ii) of Sect. 1.

There is, however, a small range of values for μ near a critical value, μ_c given by

$$\mu_c \frac{dg}{dr_0} = 1 \quad \text{at } r = 0, \qquad r_0 = 0, \tag{8}$$

when there is just one bright image and a significant superluminal separation. Solution (a) in Table 1 describes a typical parameter set for such a case. Note that the parameter θ_{cJ} denotes the position angle of the VLBI core jet in the source plane, adjusted to reproduce the observed bend angle of 20°. The solution thus fulfills all the four requirements (i)–(iv) of Sect. 1. The amplification in intensity in this case is by a factor ~22, i.e. by $3^m.3$, thus making the "true" apparent magnitude of 3C 273 ~ 16^m.

This solution suffers, however, in being too contrived. The permitted range of velocity dispersions is only ~ ±5 km s^{-1}, and the source has to be within ~0″.05 of the lens centre. To widen these permitted ranges we next consider spheroidal lenses.

b) Spheroidal lenses

We adopt here a lens model with a single oblate spheroidal mass component. Most galaxies are believed to contain such a component (Schmidt, 1965; Burbidge et al., 1964) and hence the model would have a general validity. We assume the King model to describe the density distribution. For a given source position (r, θ) as in (a) above, the image position is given by (r_0, θ_0) where

$$z^* = z_0^* - \frac{36 D_{ds}}{D_s}\left(\frac{\sigma_g}{c}\right)^2 (1 - e_g^2)^{1/2} \cdot \delta_g\, e^{i\theta_g} f\left(z_0\, e^{i\theta_g} \frac{D_d}{r_c}\right). \tag{9}$$

Here $z = re^{i\theta}$, $z_0 = r_0 e^{i\theta_0}$ expressed in units of arcseconds, δ_g is as defined in Eq. (4), e_g is the eccentricity of the spheroidal lens, σ_g is the velocity dispersion of the lens galaxy defined as in Young et al. (1981) by

$$\sigma = 4\pi G \rho_0 r_c^2/9, \tag{10}$$

and the function f is as derived in Narasimha et al. (1982, for more details see Narasimha, et al., 1984). There is an extra parameter for the spheroidal lens which was absent in the spherical case, viz the angle θ_g between the major axis of the spheroid and the X_0-axis in the deflector plane.

To find acceptable solutions we scan the parameter space of θ_g, the velocity dispersion σ_g and the source position z. For a fixed core radius $r_c = 1$ kpc we find such solutions for a range (180–230) km s^{-1} for σ_g with θ_g lying in the range (90°–120°) and (270°–360°). The source position r lies within ~0″.14 to 0″.21 from the lens centre. The lower limit for r is determined from the requirement that there shall be no multiple images, while the upper limit corresponds to the requirement that the observed superluminal speed should be at least 10c.

Solutions (b, c) of Table 1 outline the parameters of two such models satisfying all the observed requirements (i)–(iv). The intensity amplification in these cases are by a factor ~12–16 (an increase of luminosity by ~3^m).

Clearly the spheroidal model besides being more realistic than the spherical model, has a wider range of possible parameters, thus making it less contrived. As we shall see in the following section, the probability of a suitable lens configuration arising by chance is sensitively dependent on the source position, r, and in fact it increases with the extent of misalignment of the source from the lens centre. Thus, solutions with $r \sim 0''.16$ which we obtain for the spheroidal lens are more probable than those with small r ($\sim 0''.05$) as in the spherical lens.

The extent to which the source can be misaligned from the lens centre, r, can in fact be further enlarged by increasing the core-radius, r_c of the lens galaxy. In this case, to get acceptable solutions, higher values for the velocity dispersion, σ_g, are needed. However, r_c (and also r) cannot be increased arbitrarily. For example, even though a lens galaxy with the core radius $r_c \approx 3$ kpc, can yield acceptable solutions with source position $r = 0''.6$, it requires a velocity dispersion $\sigma_g \sim 400 \text{ km s}^{-1}$ and a lens mass $\sim 2.5\ 10^{12}\ M_\odot$. By the present criteria of galactic masses, a galaxy so massive as this will be considered rare. (However, it may well happen that if the existence of hidden masses becomes established, this mass may not appear to be so high in the future!)

c) Spiral galaxy as a lens

Young et al. (1981b) had earlier used a spiral galaxy to construct lens models to explain the observed properties of the triple quasar Q 1115+080. Basically, a spiral galaxy is a two-component mass system: a central spherical bulge and a disc of which the latter may be approximated by a highly flattened spheroid. We now show that such a system presents an even more probable lens model that the spheroidal case just discussed (by increasing the allowed value of r).

The detailed lens-optics of multiple component systems located at the same redshift have been discussed by Young et al. (1981a) and Narasimha et al. (1984). The relevant formula applicable to the present case is given by modifying the r.h.s. of (9) to

$$z^* = z_0^* - \frac{36 D_{ds}}{D_s}\left(\frac{\sigma_g}{c}\right)^2 (1-e_g^2)^{1/2} \delta_g\, e^{i\theta_g} \cdot f\left(z_0\, e^{i\theta_g} \frac{D_d}{r_c}\right) - \frac{36 D_{ds}}{D_s}(1-e_d^2)^{1/2}\left(\frac{\sigma_d}{c}\right)^2 \cdot \delta_d\, e^{i\theta_d} f\left(e^{i\theta_d} \frac{D_d}{r_d} z_0\right), \quad (11)$$

where the quantities σ_d, σ_a, and θ_d refer respectively to the eccentricity, the velocity dispersion, and the major axis position angle of the disc component (and the corresponding quantities with suffix g refer now to the bulge component), and δ_d is as defined in Eq. (4) with cut-off radius n relevant to the disk component.

Table 2 gives two typical acceptable solutions for a spiral galaxy model. The lensing galaxy is taken at a redshift of $z = 0.07$, with a core radius 1 kpc for the bulge and 2 kpc for the disc. The parameter n is taken to be 20 and 10 for the two components respectively and the spheroidal eccentricity of the disc is taken as $e = 0.95$.

Solution (a) of Table 2, however, violates the requirement (ii) in literal sense if not in spirit. For, it produces three images of which one is much brighter (by about ~80 times; magnitude difference $4^m.75$) than the other two. We give this example to illustrate the fact that it is possible to have multiple images with one dominant image that otherwise satisfies the requirements (i), (iii) and (iv) of Sect. 1. Nevertheless, this solution suffers from the defect of requiring a small range of values of r ($\lesssim 0''.005$) which makes it less probable.

Table 2a. Solution with two component lens model at a redshift of 0.07

		Bulge	Disc
Core radius		1.00 kpc	2.00 kpc
eccentricity		0.35	0.95
n		20	10
Velocity dispersion		300 km s^{-1}	250 km s^{-1}
Position angle of major axis		~37°	−40°
Core-jet angle		113°	
Source position (arcsec)		(0.505, 0.410)	
Image position (arcsec)	A	(1.814, 1.696)	
	B1	(−1.041, −0.840)	
	B2	(−0.216, −0.172)	
Amplifications	A	81.189	
	B1	−1.022	
	B2	0.167	
Linear amplification for A image		89.0	
Bend angle		20°.3	
Total mass of lens		6.17 $10^{11} M_\odot$	

Table 2b. Solution with two component lens model, $z_d = 0.07$

	Bulge	Disc
Core radius	1.0 kpc	2.0 kpc
Eccentricity	0.00	0.95
n	20	10
Velocity dispersion	200 km s^{-1}	240 km s^{-1}
Position angle of major axis	–	91°
Core jet angle	16°	
Source position (arcsec)	(0.020, 0.790)	
Image position (arcsec)	(0.159, 1.885)	
Intensity amplification	15.770	
Linear amplification	15.5	
Bend angle	20°.0	
Mass in lens	2.91 $10^{11} M_\odot$	

The solution (b) is more realistic. It produces only one bright image with an intensity amplification of ~15.77 (~3^m). The source position in solutions of this type can be misaligned as much as $\sim 0''.7$–$0''.9$ without violating acceptability criteria, or without demanding unduly high velocity dispersions. However, the spiral galaxy model suffers on one count: the lens has to be aligned with a position angle of the disc component within a narrow range (~3°). Thus the gain in probability achieved by increasing r is lost by the narrow constraint on alignment, and on the balance the spiral galaxy scenario seems to be less probable than the one involving the spheroidal galaxy.

3. Probability estimates

Skeptics may wonder whether the probability of arriving at a suitable lens configuration by chance, in these scenarios is too small for them to be taken seriously. This criticism can be countered at three different levels, all of which have been used in astronomy in other contexts.

The first level of counter criticism is outright dismissal by arguing that with so few (<10) superluminal cases known so far, any *a*-posteriori calculation of probability would be misleading.

The second level invokes the maxim "What is sauce for the goose is sauce for the gander". Already four or five cases of gravitationally lensed quasars have been proposed and tentatively accepted in spite of the same criticism that the probabilities leading to those configurations are too low. Further, intervening galaxies to account for the absorption line redshifts in quasars have also been widely advocated. The present scenario also requires intervening galaxies.

The third level takes the bull by the horn and attempts to compute the probability of "chance occurrence" of a suitable lens system for 3C 273. This is what we will do now, first for the spheroidal lens model and next for the relativistic beam model.

a) The spheroidal lens model

Let $\phi(L)dL$ denote the luminosity function for galaxies. To fix ideas we will assume that $\phi(L)$ has the form determined by Schechter (1976):

$$\phi(L)dL = \phi_0\left(\frac{L}{L_*}\right)^{-5/4} \exp\left[-\frac{L}{L_*}\right]\frac{dL}{L_*}, \tag{12}$$

where

$\phi_0 = 5\ 10^{-3}\ \mathrm{Mpc}^{-3}, \qquad L_* = 3\ 10^{10} L_\odot.$

We will also assume, following Faber and Jackson (1976) that for a galaxy with velocity dispersion σ, the luminosity varies as

$$L/L_* = \left(\frac{\sigma}{\sigma_*}\right)^4, \qquad \sigma_* = 260\ \mathrm{km\ s^{-1}}. \tag{13}$$

Finally, we will compute the probability in a Friedman universe with deceleration parameter $q_0 = 0$. The answer is expressed by the formula

$$P_g = \int dP = \int \left(\frac{c}{H_0}\right)\left[\frac{(1+z_{\max})^2-(1+z_{\min})^2}{2}\right] \cdot A^{3/2} f(\Delta\theta_g)\Sigma(\sigma)\phi\left[\left(\frac{\sigma}{\sigma_*}\right)^4 L_*\right] 4\left(\frac{\sigma}{\sigma_*}\right)^3 \frac{d\sigma}{\sigma_*}, \tag{14}$$

where the quantities $z_{\min}$, $z_{\max}$, $\Delta\theta_g f$, Σ are given below.

$(z_{\min}, z_{\max})$ = redshift range of the intervening galaxy for an acceptable solution,

$\Delta\theta_g$ = range of position angles of the major axis,

$f(\Delta\theta_g)$ = probability that θ_g lies in the range $\Delta\theta_g$,

Σ = cross section of lensing rays for generating acceptable solution.

The factor $A^{3/2}$ arises because in a flux limited sample an amplified quasar has a greater chance of being picked up. To evaluate dP, we need to know how Σ and f depend on σ. For a lens of fixed eccentricity ($e \approx 0.5$) we find that Σ increases with σ, while f is approximately constant. To evaluate the net probability dP has to be integrated over a specified range of σ which we have taken as (150–400) km s^{-1}.

In practice P_g is numerically evaluated by splitting the above range of σ over several small subranges and then for each subrange computing $\Delta\theta_g$ as well as Σ. With $z_{\min} = 0.02$ and $z_{\max} = 0.12$ we finally get

$$P_g \cong 6.3\ 10^{-5} \tag{15}$$

This probability is based on conservative assumptions and will go up substantially if it becomes established that there is considerable quantity of dark matter in the universe in the form of say, low luminosity galaxies of large M/L or dark supermassive objects.

b) The relativistic beam model

The standard scenario of the beam model is illustrated in Fig. 3. The observer O sees two radio blobs of which A is stationary while B has been ejected towards him with a velocity

$$v = c\frac{\sqrt{\gamma^2-1}}{\gamma}. \tag{16}$$

Let the direction AB make a small angle θ with AO.

Suppose time t has elapsed since ejection so that AB $= vt$ and the projected distance perpendicular to OA is

$$x = vt \sin\theta. \tag{17}$$

If the distance AO $= D$, then light from B will reach O after a time $(D - vt\cos\theta)/c$. Thus by O's reckoning the distance x was achieved in time

$$T = t + \frac{D - vt\cos\theta}{c} - \frac{D}{c} = t\left(1 - \frac{v}{c}\cos\theta\right). \tag{18}$$

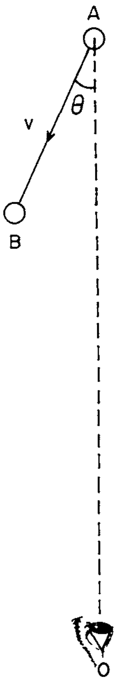

Fig. 3. (right) Schematic representation of the relativistic beam model in which A is the stationary component and component B is beamed towards the observer O; for the manifestation of apparent superluminal motion the angle θ has to be very small

Therefore the apparent transverse speed of separation observed by O is

$$V = \frac{v \sin\theta}{1 - \frac{v}{c}\cos\theta}. \qquad (19)$$

This expression has a maximum value

$$V_{\max} = c\sqrt{\gamma^2 - 1} \quad \text{for} \quad \theta \equiv \theta_c = \sin^{-1}\frac{1}{\gamma}. \qquad (20)$$

Suppose that the observed superluminal speed is $V = Nc$ where $N > 1$. Clearly from (20) we need $\gamma^2 - 1 \geqq N^2$. For a given $\gamma > \sqrt{N^2+1}$ there is a range of values of θ for which the observed transverse speed will lie in the range $(Nc, \sqrt{\gamma^2-1}\, c)$. From (19) this range of θ is $[\theta_1, \theta_2]$ where θ_1 and θ_2 are solutions of the equation

$$\frac{v \sin\theta}{1 - \frac{v}{c}\cos\theta} = Nc. \qquad (21)$$

For a random observer O to lie in the range $[\theta_1, \theta_2]$ the probability is

$$P_b = \tfrac{1}{2}|\cos\theta_1 - \cos\theta_2|. \qquad (22)$$

Since $\cos\theta_1$, $\cos\theta_2$ are the roots of (21), i.e. of the quadratic equation

$$N^2\left(1 - \frac{v}{c}\cos\theta\right)^2 = \frac{v^2}{c^2}(1 - \cos^2\theta) \qquad (23)$$

we get

$$P_b = \frac{1}{(N^2+1)}\left\{\frac{(\gamma^2 - N^2 - 1)}{(\gamma^2 - 1)}\right\}^{1/2}. \qquad (24)$$

This probability vanishes for $\gamma^2 = N^2 + 1$ and tends to the value $(N^2+1)^{-1}$ in the physically unattainable limit of $\gamma \to \infty$. Let us put $\gamma^2 = N^2 + \varepsilon$ where ε is so far arbitrary. Then for $\varepsilon \ll N^2$ and $N^2 \gg 1$, we get

$$P_b \cong \frac{1}{N^3}\varepsilon^{1/2}. \qquad (25)$$

For 3C 273 this probability has to be multiplied by a rarity factor α to account for the fact that it is an abnormally bright object in the optical, X-ray and γ-ray continuum as well as having exceptionally bright emission lines. (Unlike the lens model beaming does not enhance these continuum or line intensities.) Following the arguments due to Rees (1983) we estimate $\alpha \sim 10^{-2}$. Thus putting α into (25) we get for $N \sim 10$,

$$P_b \sim 10^{-5}\varepsilon^{1/2}. \qquad (26)$$

From the energetics of the ejection process small values of ε will be preferred. Taking $\varepsilon \sim 1$ we get

$$P_b \sim 10^{-5} \qquad (27)$$

which is comparable or less than P_g as computed according to (15).

Thus the lens model does not do worse (and may indeed do much better if unseen masses are around) then the beam model, on the probability front. Besides it provides a natural explanation as to why the VLBI jet and the optical jet are misaligned. In the beam model alignment is expected and additional epicycles are necessary to explain why the two are not collimated.

4. Conclusions

To some extent these probability calculations are meaningless if we can point to an actual galaxy lensing the quasar 3C 273. We believe that a closer analysis of the observed nebulosity may indicate a two component system: a fainter galaxy on line of sight lensing the galaxy hosting the quasar. The observed off-centric position of the quasar with respect to the nebulosity suggests this fact.

Two component systems are also indicated in the superluminal object 3C 120. The isophotal ellipses of the optical system in this object as found by Arp (1975) do not have either of their two axes in the direction of the VLBI line of separation (Baldwin et al., 1980). It is likely that here too an intervening galaxy is lensing the VLBI motion of the radio source. Again further studies with CCD detectors are necessary to settle this issue.

We suggest two types of follow-up action by way of testing the lens hypothesis further. We should look for absorption line systems for quasars showing superluminal separation since these will indicate whether an intervening galaxy exists. Tentatively absorption features can be identified in the spectrum of 3C 273 obtained by Ulrich et al. (1980). However, this evidence needs to be further confirmed. [The absence of absorption lines at the redshift of the lens galaxy has not, however, been used as evidence discrediting the lens scenarios of the double quasar 0.0957+561 A, B.]

It would also be worth looking for VLBI motions in quasars for whom reasonable evidence for gravitational lensing exists, as well as for quasars which are at the high luminosity end of the optical luminosity function. Quasars selected according to these criteria may very well show superluminal motion if the lensing hypothesis presented here is correct. It is tempting to speculate in this context that the BL Lac object AO 0235+165 is a possible candidate for gravitational lensing of the general character described in this paper.

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