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Ejections of Population III Objects Seen as Blueshifted QSOs?

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Abstract. We discuss the origin of the optical jets and the apparently associated cloud of QSOs in NGC 1097. There is a simple explanation for the jets in terms of ejection trails of supermassive black holes. In this interpretation, the trails provide the first direct evidence for the non-conservation of linear momentum in a two black hole collision. The cluster of quasars at the end of the jets is then naturally associated with objects which have been ejected by the merging pair of black holes. It is possible to interpret the spectral lines of these QSOs such that half of them are blueshifted relative to NGC 1097 while the other half is redshifted. We infer that the objects in the QSO cluster are not real QSOs but probably collapsed objects of lower mass. We argue that these objects are likely to represent the hypothetical population III black holes of Carr *et al.*

Key words. Quasars: redshifts of.

1. Introduction

The spiral galaxy NGC 1097 possesses four optical jets which come in two pairs (Wolstencroft & Zealey 1975; Arp 1976; Lorre 1978). The brightest jet is called Rl (Wolstencroft 1981) and its opposite pair R4. The other pair is referred to as R2 and R3. The jets R2 and R3 appear perfectly aligned with each other and the nucleus of the galaxy while the lines of Rl and R4 make a small angle between them. Also it appears that the lines of Rl and R4 do not cross at the centre of NGC 1097 but have a crossing point to the south of the nucleus. In addition to the radial or near radial jets, there is a non-radial jet like feature which may also pass through the crossing points of jet lines Rl and R4. Moreover, at the end of jet Rl there is a dogleg feature, the origin of another jet at nearly 90° angle relative to the line of Rl. The jets are illustrated in Fig. 1 which is adopted from figure 1 of Wolstencroft *et al.* (1983).

Figure 1 also illustrates the positions of the six quasars discussed by Wolstencroft *et al.* (1983). They are actually part of a more extensive quasar complex, a surface density excess of quasars near ends of the jets Rl and R2 (Arp, Wolstencroft & He 1984, see Fig. 2).

Wolstencroft, Tully & Perley (1984) discuss the physical properties of the jets and conclude that the optical emission is thermal bremsstrahlung from gas at about 10^6 K.

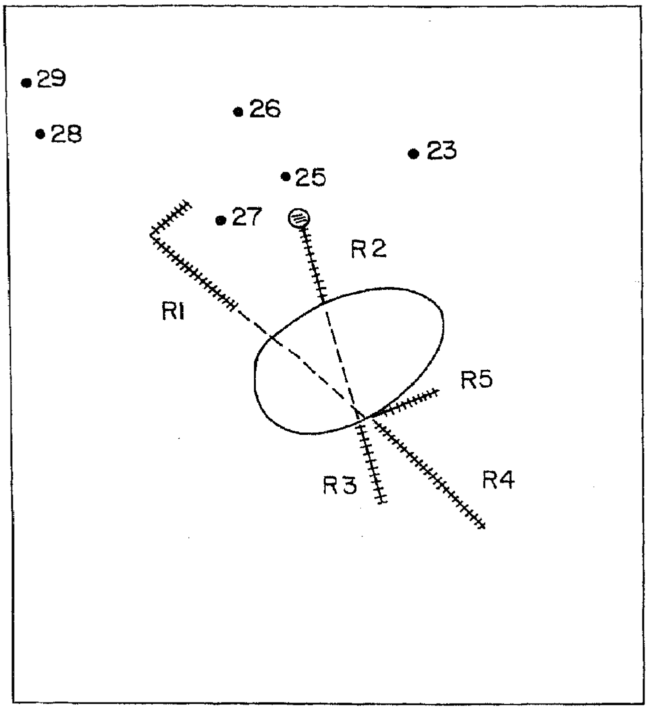

Figure 1. Relative positions of the jets Rl, R2, R3, R4 together with the non-radial jet R5 and QSOs (23, 25, 26, 27, 28 and 29, the numbers correspond to those in Arp *et al.* 1984) around NGC 1097 (adopted from Wolstencroft *et al.* 1983).

The emitting plasma is probably ambient material of NGC 1097, piled up by the passage of some object or particles traveling along the jet. The jets are about $1h^{-1}$ kpc wide and $26h^{-1}$ kpc long ($h = H_0/100$ kms^{-1} Mpc^{-1}) and the upper age limit for them is a few million years both from the cooling time of the jet plasma and the linearity of the pattern.

On the other hand, Carter *et al* (1984) disagree with this and suggest that the jets are tidal remnants or consist of stars formed from cooling plasma in the jets. The latter conclusion was based on the rather steep spectrum between IR and optical which together with the radio upper limit seems to rule out both synchrotron radiation and thermal bremsstrahlung at 10^6 K.

In the following we discuss the types of events which may arise when mergers of galaxies bring large numbers of supermassive black holes together in the centre of the merged galaxy. The resulting disintegration process has features which suggest an application to NGC 1097.

2. Few black hole processes

The process of creating systems of many black holes in multiple mergers of galaxies has been described by Valtaoja, Valtonen & Byrd (1989), Mikkola & Valtonen (1990) and Valtonen *et al.* (1994). In the first stage semi-stable binary black holes form (Roos 1981; Gaskell 1985) and subsequent mergers build up the multiplicity of the

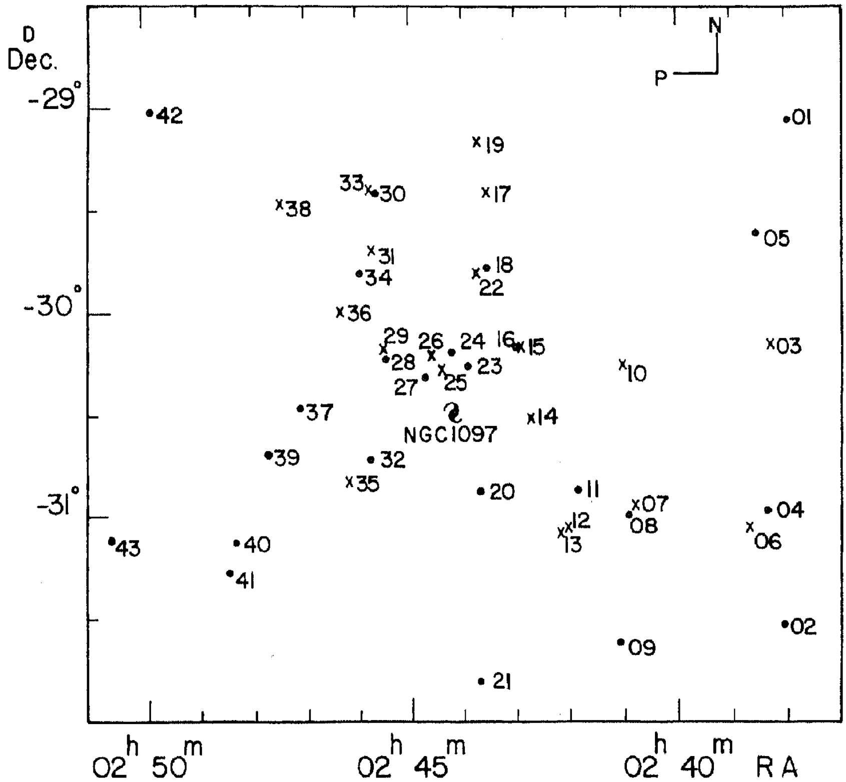

Figure 2. Positions of QSOs in the field of NGC 1097 (adopted from Arp *et al.* 1984). Dots are redshift objects and crosses are possible blueshift objects.

black hole system. Due to the inherent instability of the few body systems many black holes escape from the galaxy with high speed (Saslaw, Valtonen & Aarseth 1974). In addition, many black holes merge together. The end result of the few black hole evolution is a system with many ejections, either one-sided or in opposite pairs, and a emnant black hole in the centre of the galaxy. Occasionally the ejections are effective enough to clear the galaxy completely of the supermassive black holes.

To go to the specific case of NGC 1097, the linearity of the jets suggests an age which is not much greater than a few million years and thus the ejection speeds of black holes should have been about 10^4 km s^{-1}. At much slower speed the trail, whether it is composed of gas or stars, would have been created long ago in the inner parts, and it would have been bent by differential rotation. In the four black hole experiments of Valtonen *et al.* (1994) and Pietilä *et al.* (1995), the median ejection speed of symmetric pairs is 5000 km s^{-1}. This is probably close enough to the case of NGC 1097, but if higher ejection speeds are required they may be obtained by rescaling the four body experiments of Valtonen *et al.* (1994).

In fact, the system of jets Rl and R4, together with the non-radial jet pointing to their crossing point, is like a standard trace of orbits in a four-body break-up (see Pietilä *et al.* 1995, figures 1 and 2). The break-up starts by a slow one-sided ejection (non-radial jet) which causes the rest of the system to recoil in the opposite direction. The remaining three-body system divided itself into binary (jet Rl) and an ejected

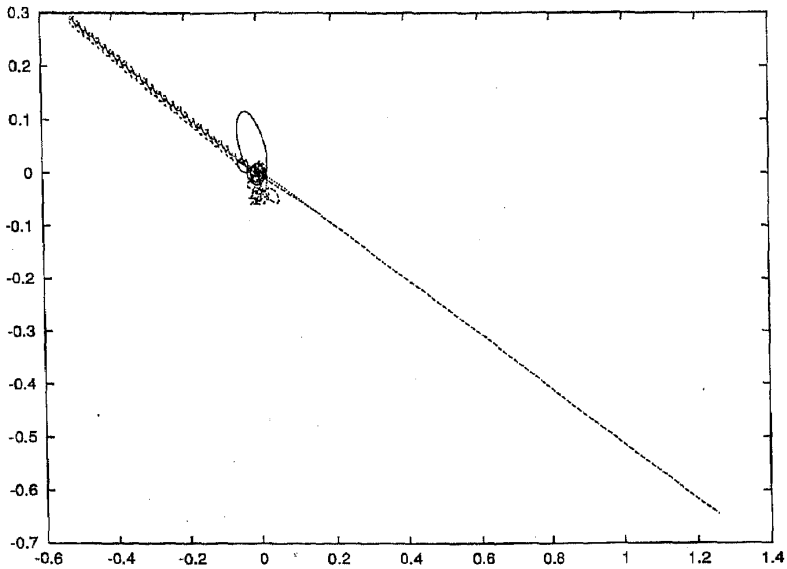

Figure 3. The orbits of initially four black holes in the centre of a galaxy. After one merger, a binary is ejected to the upper left and a single black hole to the lower right. The distance unit is 1 pc.

third body (jet R4). When the binary finally collapses due to energy losses to gravitational radiation its centre of mass obtains an additional momentum to a direction which is generally different from the momentum of the binary itself (Fitchett 1983; Redmount & Rees 1989). This results in a change in the direction of the track which in the case of the Rl jet of NGC 1097 happens to be about 90°. With the identification of the Rl jet as a trail of the binary, the opposite jet R4 is a track of a single black hole which cannot experience similar abrupt changes of course.

To give a concrete example, we illustrate one specific case of Pietilä *et al.* (1995) in Figs. 3 and 4. The nucleus of the galaxy contains four black holes initially. Their mass values were selected from a (α = –3) power law distribution extending from $10^8 M_\odot$ to $10^9 M_\odot$. The approximate mass values in this case were 1.1 . $10^8 M_\odot$, 1.2 $\cdot 10^8 M_\odot$, 1.3 $\cdot$ $10^8 M_\odot$ and 1.3 $\cdot$ $10^8 M_\odot$. In a merger of two black holes the center-of-mass velocity of the merged pair due to anisotropic gravitational radiation was given as

$$V_{CM} = 0.4cf\,(m_1/m_2).f_s, \tag{1}$$

where c is the speed of light and $f(m_1/m_2)$ is a function of the mass ratio m_1/m_2 of the merged black holes. This function is zero for equal masses and its maximum value is f (2.6) = 0.01789. The last factor f_s is an unknown scaling factor for which we use f_s = 1 (see Pietilä *et al.* (1995) for details). The exact value of f_s is not very important in the discussion below as long as we exclude $f_s \ll 1$.

Figure 3 shows the initial orbital tracks of the four black holes in the centre of the galaxy. First a single black hole of approximate mass 1.2 $\cdot$ $10^8 M_\odot$ is ejected to the lower right with the terminal speed of 6315 km s^{-1}. Then one pair of black holes merges and as a result of anisotropic gravitational radiation the whole system obtains

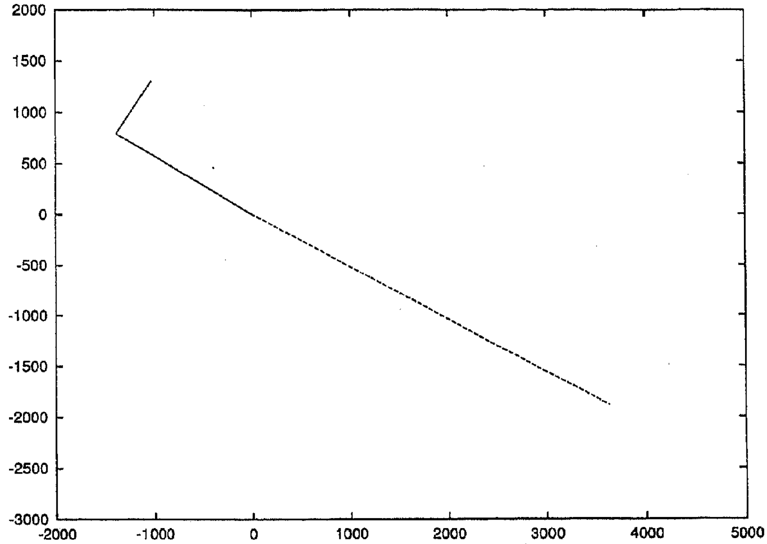

Figure 4. The orbits of Fig. 3 at a later time. The binary black hole collapses after $5.7 \cdot 10^5$ yr and obtains a kick from the anisotropic gravitational radiation. Therefore its motion is redirected to the upper right. The distance unit is 1 pc.

a slow motion towards the upper right. The remaining binary recoils to the upper left with the terminal speed of 2870 km s^{-1}.

Figure 4 illustrates the orbits at a much later time. After $5.7 \cdot 10^5$ yr the binary collapses due to gravitational radiation and the remaining black hole obtains a new direction of motion towards upper right. The mass of this black hole is approximately $3.7 \cdot 10^8 M_\odot$. Accidentally the direction of the gravitational radiation kick was such that a nearly 90° angle is created between the original path of the binary and the path of the merged system. This example, even though it is not meant to match NGC 1097 exactly, illustrates the two relevant properties of the orbits of few black hole systems: (1) the initial ejections are often slightly misaligned from the exactly opposite directions, and (2) a strong sharp bend of the orbital path may result from the collapse of an ejected binary black hole system. Both of these features appear necessary in order to explain the Rl - R4 pair of jets in NGC 1097.

It should be noted that the scale in Figs. 3 and 4 can be freely chosen. Both the distance scale and the time scale are directly proportional to the mass scale. Since the mass scale of the supermassive black hole is unknown, it may be used as a free parameter. Thus one may obtain an exact match with NGC 1097 by raising the mass scale somewhat.

The other pair of jets R2 and R3 is colinear to the extent that it looks like the trace of orbits in a break-up of a three-body system (see figures 5 and 6 in Pietilä *et al.* (1995). As there are no abrupt kinks in these jets, it is not obvious which jet represents the binary orbit. However, the large balloon-like extension at the end of the northern jet R2 suggests to us that here again we may identify the site of a black hole merger. In this case it would become visible by the emission from gas which was expelled from the accretion disks during the merging of black holes (Basu *et al.* 1993)..

Not only are parts of the accretion disks expelled in a black hole merger. Any other close satellites which the black holes must have had will be ejected in the same process. The ejection speeds of the satellites often exceed 0.5c where c is the speed of light (Basu *et al.* 1993). Many of the satellites must be normal stars but they are difficult to detect individually at the distance of NGC 1097. However, what may be seen are compact remnants of very old objects such as the proposed population III black hole remnants (Lahav 1986). If they exist around supermassive cores then they also will be ejected at relativistic speeds during the core mergers.

As the cluster of quasars lies more or less at the extension of the jets Rl and R2, the binary trails in our interpretation, then these quasars are primary candidates for ejected satellite objects. In the next section we consider the available spectroscopic information and how well it fits with this idea.

3. Blueshiftd quasars

If the quasars near the ends of the northern jets are ejected objects then we expect that roughly half of them would come towards us (and be blueshifted in spectrum) and the other half move away from us (and be redshifted). However, all the spectral shifts reported by Wolstencroft *et al.* (1983) are redshifts. Are we somehow missing the blueshifted quasars?

Along similar lines, it should be noted that extensive work of the Doppler hypothesis of quasars has been done by Narlikar and coworkers. Narlikar & Edmunds (1981) examined a hybrid model where in an Arp-Hazard triplet, the quasars at the end are ejected at relativistic speeds from the middle quasar which is assumed to be at the cosmological distance. The quasars' redshifts can be explained by their high speeds of ejection from a centre of explosion (Narlikar & Subramanian 1982), and it is found that a quasar should emit radiation backwards preferentially (Narlikar & Subramanian 1983), accounting for the lack of observed blueshifted quasars. Nevertheless, they predict that there should be a very small but nonzero fraction of blueshifted quasars and they recommend a more thorough search for blueshifted spectral lines. They also suggest that perhaps there has been misidentification of spectral lines in some quasars. The Doppler model can also account for the larger concentration of quasars and the presence of a close pair with nearly equal redshifts in the 1146 + 111 field (Narasimha & Narlikar 1989).

Although it is usually stated that no blueshift has been observed in QSOs, as far as is known to us, no genuine attempt has actually been made as yet to detect a blueshift. The redshifts of as many as a quarter of quasars (23.2%) reported in current literature may actually be blueshifts, the reported redshifts being due to possible misidentification of the observed lines (Basu & Haque-Copilah 1996). Astronomers usually look into the lines in the ultraviolet/blueshifted region of the spectrum to match observed lines to determine redshift. Plenty lines now available at higher wavelengths, including IR region, have so far been ignored and blueshift has never been considered as a possibility. Furthermore, it is often argued that high quality data usually demonstrate redshift without ambiguity. It should be emphasized that it is not the purpose of this paper to propose that all QSOs are blueshifted. Only a small subclass of them are possibly blueshifted for which high quality data may not be available. Literature search would reveal that there are many uncertainties in identification of emission lines used currently for redshift determination. It may be noted in this connection that only 70% of the line identifications in the literature are correct and as many as 50% may be unknown or incorrect (Savage *et al.* 1984), while flux accuracy ranges between 20 and 40% (Osmer & Smith 1982).

We also know that Lyα, CIV, CIII and Mgll, the four standard lines are expected to be broad and strong. However, they have also been reported medium, weak and narrow (Burbidge & Burbidge 1967). The same lines, as well as Hα and [OIII] have been found of highly variable width by Richstone & Smith (1980). Schneider *et al.* (1991) reported "unusual profile" and "extraordinarily weak" CIV lines. Again, it is known that Hα, *Hβ*, Hγ, [OIII] are expected to accompany one another, and FeII should be seen below MgII. But redshift measurements in published literature show that these lines have been seen without their expected followers. Furthermore, lines like [OIII] 4959 and [OIII] 5007, [OIII] 4363 and Hγ 4340, as well as NIII 3869 and NIII 3968 may not be observed separately unless the resolution is good enough (more than 100Å).

It is well known that at least two reasonably strong emission lines must be available within the observing window, 3300 Å to 6900 Å (Basu 1973), for identification and redshift determination. However, the two observed lines can equally be identified with some other pair of lines from the search list at higher wavelengths, the latter having been blueshifted, instead of the pair actually used for identification being redshifted. If the observed spectrum has a third or fourth line they can also be fitted by blueshifting of additional lines from the search list. Prism technique which discovered about 60% of the QSOs in the catalogue of Hewitt & Burbidge (1993) offers resolution of 100 to 150 Å (Savage *et al.* 1984, 1985). An error of ±(100-150) Å in determining observed wavelengths λ_{01} and λ_{02} inside the observing window 3300 Å to 6900 Å (Basu 1973) implies the greatest possible error of 0.02899 to 0.0969 in the ratio of $\lambda_{01}/\lambda_{02}$. Within ±0.02 of the wavelength ratio of the line pairs used in redshift measurements (note, minimum value of greatest possible error in prism technique is 0.029), 100% of these pairs would match (i.e., have same ratio as) some other pairs of lines in the search list at higher wavelengths used for blueshift measurements in our analysis. The same is true for the third and fourth line if seen in the spectrum. Furthermore, lines used in blueshift measurements are found to yield blueshift values within ±0.01 of each other which can be compared to the accuracy of ±0.01 in redshift measurements (Kunth & Sargent 1986). We therefore conclude that the wavelength ratio giving the 'shift' (red or blue) within ±0.01 is the best tool for line identification.

We looked into the spectra of all the quasars in the lists of Wolstencroft *et al.* (1983) and Arp *et al.* (1984) with a view to re-examine the identification of the lines. As far as is known to us, these are the only observations available for these objects in the existing literature.

Re-examination of the spectra of the cloud of QSOs around NGC 1097 (Wolstencroft *et al.* 1983; Arp *et al.* 1984) led us to new identifications of the easily detectable lines. We have used the search lists for redshift determination by Basu (1973) and blueshift determination by Valtonen & Basu (1991), and by Basu & Haque-Copilah (1996). Wolstencroft *et al.* (1983) and Arp *et al.* (1984) fitted the spectra to two of the four major emission lines expected in the quasar spectrum, viz., Lyα 1216, CIV 1549, CIII 1909, and MgII 2798. All of these lines being in the ultraviolet region, for obvious reasons none appears in the search list for possible

Table 1. List of candidates around NGC 1097 showing possible blueshift.

ID. No.	Object	Observed lines Å	Redshift identification lines	Redshift	Blueshifted identification lines	Blueshift	Notes
03	Q 0328-301	4020	Lyα 1216	2.306	Hα 6536	0.387	
		4566 ?	—	—	[ArIII] 7751	0.410	
		5060	CIV 1549	2.267	[OI] 8449	0.401	
		6250 ?	CIII] 1909	2.331	HeI 10830	0.423	
06	Q 0238-310	3687 ?	Lyα 1216*	2.032	Hα 6563	0.438	3687 appears in noisy region and narrow.
		4703	CIV 1549	2.036	[OI] 8449	0.443	
		5600 ?	—	—	—	—	
		5789 ?	CIII] 1909	2.032	HeI 10830	0.465	
07	Q 0241-309	3844	MgII 2798	0.374	HeI 10830	0.645	
		4320 ?	HeII ?	?	Pβ 12818	0.640	
		5100 ?	[OII] 3727	0.368	—	—	
		6000 ?	Hγ 4348	0.380	FeII 16440	0.635	
		6650	Hβ 4861*	0.368	Pα 18751	0.645	
10	Q 0241-302	3801	MgII 2798	0.359	Hα 6563	0.421	
12	Q 0242-3104	3900	—	—	[SIII] 9532	0.591	MgII possibly wrong. Pα out of range.
		4360	—	—	HeI 10830	0.597	
		5242	MgII 2798	0.874	Pβ 12818	0.591	
13	Q 0242.1-3104	3640 ?	Lyα 1216*	1.993	Hα 6563	0.445	
		4185	[SiIV] 1392*	1.996	[ArIII] 7751	0.460	
		4622	CIV 1549	1.984	[OI] 8449	0.453	
		5650 ?	CIII] 1909	1.960	HeI 10830	0.478	
14	Q 0242-305	3905	CIII] 1909	1.046	Pβ 12818	0.695	
		5053 ?	—	—	FeII 16440	0.695	
		5719	MgII 2798	1.044	Pα 18751	0.693	
15	Q 0242.9-3010	3966	Lyα 1216	2.262	Hα 6563	0.396	3966 appears very narrow.
		4450	[SiIV] 1397	2.185	[ArIII] 7751	0.425	
		5068	CIV 1549	2.272	[OI] 8449	0.400	
		6235 ?	CIII]	2.266	HeI 10830	0.424	
17	Q 0243-294	4135	CIV 1549	1.669	[OII] 7324	0.435	
		4395 ?	HeII 1640*	1.680	[ArIII] 7751	0.433	

		5128	CIII] 1909	1.686	[SIII] 9069	0.435	
		6600 ?	—	—	—	—	
19	Q 0243-291	3849	Lyα 1216	2.165	Hα 6563	0.414	
		4445 ?	[OIV] 1406*	2.161	[ArIII] 7751	0.426	
		4895	[IV 1549	2.160	[OI] 8449	0.421	
		6048 ?	CIII] 1909	2.168	HeI 10830	0.442	
22	Q 0243.6-2947	3762	Lyα 1216	2.094	Hα 6563	0.427	
		4294 ?	—	—	[ArIII] 7751	0.446	
		4728	CIV 1549	2.052	[OI] 8449	0.440	3762 appears
		5794 ?	CIII] 1909	2.035	HeI 10830	0.442	very narrow
25	Q 0244.4-3017	4200	Ly continuum	3.102	HeI 10830	0.610	Pα out of
	Q 1097.1	5000	—	—	Pβ 12818	0.612	observing range
26	Q 0244.6-3103	3810	CIII] 1909	0.996	Pβ 12818	0.703	
	Q 1097.3	5600	MgII 2798	1.001	Pα 18751	0.701	
29	Q 0245-301	3987	CIII] 1909	1.089	Pβ 12818	0.687	Redshift is
	Q 1097.6	5876	MgII 2798	1.100	Pα 18751	0.689	uncertain
31	Q 0245-297	3827	CIII] 1909	1.003	Pβ 12818	0.701	
		5605	MgII 2798	1.005	Pα 18751	0.701	
		5880 ?	MgV 2931*	1.006	[SiVI] 19620	0.700	
		6266	[OIII] 3133	1.000	Brγ 21606	0.710	
33	Q 0245.7-2925	3814	Lyα 1216	2.137	Hα 6563	0.419	
		4442	[OIV] 1406*	2.159	[ArIII] 7751	0.427	
		4865	CIV 1549	2.141	[OI] 8449	0.424	
35	Q 0246-308	3992	CIII] 1909	1.091	Pβ 12818	0.689	
		4370 ?	—	—	—	—	
		5864	MgII 2798	1.096	Pα 18751	0.687	
36	Q 0246-300	3850 ?	[SiIV] 1397	1.756	[SIII] 9532	0.596	Pα out of
		4302	CIV 1549	1.777	HeI 10830	0.603	observing
		5293	CIII] 1909	1.773	Pα 12818	0.587	range.
		6512 ?	—	—	FeII 16440	0.604	
38	Q 0247-294	3880	Lyα 1216	2.191	Hα 6563	0.409	
		4468 ?	—	—	—	—	
		4947	CIV 1549	2.194	[OI] 8449	0.414	

? Uncertain; * Our suggestion.

blueshifts of the objects which rightaway eliminates the possibility of even detecting blueshift in the spectra. Secondary predicted features have been indicated in the spectra although in many cases these are doubtful.

Narrowing of the lines is expected as a result of blueshifts, although this may be offset by many other broadening mechanisms present at the seat of origin of the spectra (Burbidge & Burbidge 1967; Osterbrock & Mathews 1986). With these riteria in mind, Table 1 has been prepared consisting of 19 objects out of 32, i.e., 59%, for which spectra are available in Wolstencroft *et al.* (1983) and Arp *et al.* (1984). As would be noticed in Table 1, almost all lines including secondary features in observed spectra of the 19 QSOs, each consisting of 3 to 4 lines, can be explained in terms of blueshift.

Column 1 of the table gives the identification number by Arp *et al.* (1984) in the field surrounding NGC 1097. Column 2 gives the common coordinate name of the quasar. Column 3 lists the observed wavelengths of the lines in the published spectra. The emission line identifications of these lines by Arp *et al.* (1984) and by Wolstencroft *et al.* (1983), supplemented in some cases by our own suggestion, are given in column 4, together with the redshifts (column 5). The alternative identifications and blueshifts are given in columns 6 and 7 respectively, together with notes on the spectra in column 8. The usual spread in redshift values is within ±0.01 (see e.g., Kunth & Sargent 1986). Table 1 would show that the spread in the blueshift values in some objects is larger than ±0.01. However, it would also be found in Table 1 that the spread in redshift values in the same objects as well as in few others is even larger. So, from this point of view, our blueshift identification is better than the published redshift identification. It may be noted in this connection that the spread in redshift values larger than ±0.01 is not uncommon in redshift literature (see e.g., Schneider *et al.* 1991; Maxfield *et al.* 1995). Furthermore, a closer look at Table 1 would show that HeI 10830 line in blueshift identification lies systematically in the blue side of its expected position (with respect to the spread of ±0.01). Such an effect is well recognized in some lines in redshift literature (Corbin 1990; Appenzeller & Wagner 1991; Tytler 1992). If further studies confirm this effect, separate investigation will be needed, as has been done in the redshift case.

Of the 19 objects in Table 1 equivalent width is available for only one, viz., No. 35 (Arp *et al.* 1984). The ratio of the equivalent widths of the two lines at observed wavelengths of 5864 Å and 3922 Å is about 2. This is consistent with the oscillator strengths of Paschen lines with which they have been identified for blueshift measurements, as the width of Pα is much larger than that of Pβ, as expected from oscillator strengths of the two lines. Table 1 thus clearly demonstrates that blueshifts for QSOs can be determined when their spectra are re-examined.

4. Discussion

According to Arp *et al.* (1984) the likely excess number of quasars near NGC 1097 above the expected background is about 7. And it appears that this excess comes mostly from six quasars near the northern jets.

In Table 1 we propose a blueshift interpretation for three of the QSO's (no. 25: z = – 0.61; no. 26: z = – 0.70 and no. 29: z = – 0.69). The remaining three appear truly redshifted (no. 23: z = 0.89; no. 27: z = 0.53 and no. 28: z = 0.34). In terms of ejection speed, these represent velocities in the range 0.28c – 0.56c either towards us or away from us.

If the ejections of quasars have happened isotropically in all directions, we would expect to see the highest values of radial velocity in quasars which are still seen projected near to the original site of ejection. Those quasars which have been ejected closer to the plane of the sky have smaller radial velocity components but are found further away from the ends of the jets. Objects no. 7 (z = 0.374), no. 10 (z = 0.359) and no. 20 (z = 0.088) in the redshift list and objects no. 10 (z = – 0.421), no. 15 (z = – 0.40) and no. 22 (z = – 0.44) in the blueshift list are candidates for the ejections near the plane of the sky.

It may also be significant that the blueshift alternatives are found more often for quasars near NGC 1097 than for quasars at the edge of the fields. We find that altogether somewhat over one-half of the quasars in the field of Arp *et al.* (1984) have blueshift alternatives. In seven cases the radial velocity (redshift) of the quasar is so high that it must almost certainly be a background object.

The six objects of Wolstencroft *et al.* (1983) which are our primary candidates for ejected quasars all have rather equal X-ray fluxes around 2.10^{-13} erg cm^{-2} s^{-1} at 0.5 – 4.5 KeV. In our interpretation this means that all have X-ray luminosities around 10^{40} erg s^{-1}. In the cosmological redshift interpretation the X-ray luminosities vary by more than two orders of magnitude from one quasar to another. The absolute magnitudes of the quasars are around $M_v \simeq -13$ if they are at the distance of NGC 1097.

Objects with these properties do not really fit into the category of quasars. They are much less luminous than quasars but much brighter than individual stars, e.g., X-ray binaries. On the basis of X-ray luminosities their masses appear to be around $10M_\odot$ (Wandel & Mushotzky 1986). As no known category of astronomical objects would seem to fit the description, we are drawn to the earlier suggestion by Valtonen & Basu (1991) that supermassive objects are surrounded by clouds of satellite black holes, typically three orders of magnitude less massive than the standard "central engine" black holes. Black holes of this kind were introduced first as forms of dark matter and as the first generation of stars in galaxies, so called population III stars (Carr 1978; Carr, Bond & Arnett 1984). NGC 1097 may offer the first opportunity to study these objects directly.

The explanation of the kink in jet Rl as a change of momentum due to asymmetric gravitational radiation in a merger of two black holes would provide the first evidence that such momentum changes actually occur. In addition, a concrete case like this can be used to set a lower limit on the magnitude of the centre-of-mass velocity generated during the merger the value of which is very uncertain on theoretical grounds (Redmount & Rees 1989).

It has been shown (Valtonen *et al.* 1994 and Pietilä *et al.* 1995) that ejections of black holes of the kind required to explain the jets of NGC 1097 as ejection trails do occur when binary black holes interact with each other. The initial binaries are wide enough in order that they survive more than 10^9 yr inspite of the gravitational radiation energy losses. After the ejections the remnant binary is more tightly bound than the original binaries and its lifetime is reduced by about two orders of magnitude lower than the lifetime of the original binaries. Thus, the ejected binary can barely escape the confines of the parent galaxy before it collapses due to the gravitational radiation energy losses. This is what seems to have happened in the northern jets of NGC 1097.

The satellites of the supermassive black holes, on the other hand, can have rather stable orbits. If the satellite orbits are initially about an order of magnitude smaller than the relative orbit of the binary, the satellites are stable against gravitational radiation energy losses over the required period (the age of the binary system) and are initially also stable against the tidal forces of the binary components. However, at the last stages of the binary collapse the satellite systems are destabilized and many of the satellites escape with a good fraction of the speed of light (Basu *et al.* 1993).

As was emphasized by Valtonen & Basu (1991), a sufficient number of ejections is produced only if the original number N of satellite black hole in a nucleus of a galaxy is rather large, $N \simeq 10^3$. It would mean that these satellites would not be merely peculiar but otherwise insignificant bodies but would actually make a significant contribution to the mass of the nucleus of a galaxy. And by extrapolation to the rest of a galaxy, they may also make a significant contribution to the so-called dark matter in galaxies (see a recent discussion on observational limits by Rix & Lake 1993).

The nice thing about the proposed model is that one can test it immediately. The new interpretation of the blueshifts in the spectra of some of the objects is easily tested by extending the spectral observations to the UV-region e.g., by the use of the Goddard High Resolution spectrograph (GHRS) abroad the Hubble telescope.

For redshifted quasars, the number of spectral lines used for identifications in the search list outweighs the number of lines available for identification of blueshifted quasars within the observing window 3300 Å – 6900 Å (Basu & Haque-Copilah 1996). In general, there are 17 lines available for blueshifted compared to 27 for redshifted objects, bearing in mind that the region beyond the Lyman continuum at 912 Å is not well known. However, within the UV-band (1100 Å – 3200 Å) the scenario changes. All 31 lines are available for identification in the search list for blueshifted whereas only 13 lines of the search list are available for redshifted objects. Also, the ultraviolet window is richer in the availability of strong lines for blueshifting with 10 candidates as opposed to 4 strong lines available for identification of redshifted objects.

Thus, it should be easier to detect and recognize blueshifting of spectral lines in the UV-region. For every object listed in Table 1, a series of predicted features can be searched for from the blueshift value determined. The presence of such lines, if found, can lead to the confirmation of blueshifts in some of the objects around NGC 1097.

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