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# QSO Pairs *across* Active Galaxies: Evidence of Blueshifts?

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**Abstract.** Several QSO pairs have been reported and their redshifts determined, where the two objects in each pair are located *across* an active galaxy. The usually accepted explanation of such occurrences is that the pair is ejected from the parent galaxy. Currently interpreted redshifted spectra for both the QSOs imply that both the objects are receding from the observer. However, ejection can occur towards and away from the observer with equal probability. We argue that for a system with two QSOs lying *across* the parent galaxy, ejection should have occurred in opposite directions, whereby one object will be approaching us and the other will be receding from us. The former would exhibit a blueshifted spectrum. We analyse here a sample of four such pairs and show that the observed spectrum of one QSO in each pair can be interpreted as blueshifted. The other exhibits the usual redshifted spectrum. A scenario based on the 'sling-shot' mechanism of ejection is presented to explain the occurrences of the pairs in opposite sides of the active galaxies moving in opposite directions.

*Key words.* Quasars: emission lines—quasars: absorption lines—cosmology: miscellaneous.

## 1. Introduction

A literature search would reveal that there is a growing number of Quasi Stellar Object (QSO) pairs being observed, where the two objects in the pair are located *across* an active galaxy. We present here a sample of four such pairs and their associated active galaxies (Table 1). In Table 1, column (1) gives the name of the active galaxy and the reference, column (2) gives its redshift, columns (3) and (5) give the names of the two QSOs forming the pair across the active galaxy, and columns (4) and (6) give the redshifts of the two QSOs respectively. In each of these pairs, two QSOs have been identified and their redshifts determined, which are much larger than the redshift of the parent galaxy. Ejection from the parent galaxy is the explanation of such occurrences.

However, the basic mechanism of ejection necessitates that the process can occur in all directions with equal probability for randomly ejected objects. Objects being ejected may therefore move away from us as well as towards us, again, with equal probability. Such a situation is specially important and significant when the two objects are located *across* the parent galaxy, implying that the objects have been ejected by the galaxy to its two opposite sides, and hence, in two *opposite directions*. An ejection

**Table 1.** QSOs across galaxies and redshifts.

| Galaxy (1) | $z_r$ (2) | QSO (3) | $z_r$ (4) | QSO (5) | $z_r$ (6) |
|---|---|---|---|---|---|
| NGC 3628(i) | 0.0028 | 1WGAJ 1120.2 + 1332 | 0.995 | 1WGAJ 1120.4 + 1340 | 0.981 |
| NGC 3842(ii) | 0.0260 | 1141.8 + 2013 (QSO 1) | 0.335 | 1141.4 + 2014 (QSO 2) | 0.946 |
| NGC 5548(iii) | 0.0170 | 1E 1415.1 + 2527 | 0.560 | 1E 1416.7 + 2526 | 0.674 |
| Mark 205(iv) | 0.0700 | 1218.7 + 7522 | 0.645 | 1219 + 7533 | 0.460 |

References: (i) Arp *et al.* (2002); (ii) Arp (1984); (iii) Arp (1997); (iv) Arp (1995).

towards the observer would, of course, exhibit blueshifts in their observed spectra, in at least some cases under suitable conditions. In this respect, the kinematics of the ejection mechanism suggests that at *larger* redshifts ($\geq 3.5$), "randomly directed motions will produce almost an order of magnitude more redshifts than blueshifts", and "as the mean speed of the sources increases, the fraction of blueshifts decreases" (Gordon 1980). This implies that for objects with *smaller* redshifts moving at slower speeds, the fraction of blueshifts to redshifts is higher than that for high redshift objects moving at larger speeds. All QSO pairs in our sample have redshifts smaller than 1.0, much smaller than the redshift of "$\geq 3.5$" (Gordon 1980), and, hence, the probability of some of them being blueshifted is quite high. Furthermore, as commented by Popowski & Weinzeirl (2004), "it is unrealistic to expect that the ejection process would always meet the conditions to produce only redshifts". As such, at least a certain fraction of the vast population of QSOs now known is expected to exhibit blueshifts.

Nevertheless, the spectra of both objects in each pair have been interpreted as redshifted. Ejection has thus been considered away from us for *both* objects, without paying due consideration to the probability of the ejection towards the observer, apparently with the assumption that blueshifts are not observable in QSO spectra. The reality, however, is that no attempt is made in interpreting observed spectra in terms of blueshifts. The line identification program is such oriented as to ensure that all spectra are, almost as a rule, interpreted as redshifted.

We suggest that the two objects in each QSO pair under investigation here have been ejected from the parent active galaxy in opposite directions, resulting in one approaching us and the other receding from us, which would result in one of the objects exhibiting a blueshifted spectrum. The purpose of the present paper is to show that the spectrum of one object in each pair of the QSOs can indeed be interpreted as blueshifted.

## 2. Blueshifted spectra

Putsil'nik (1979) demonstrated that the most frequently used UV lines CIII] 1909 and MgII 2798 for redshift identification of observed emission lines in QSOs may actually be misidentifications, and the IR lines of the Paschen series, *viz.*, P$\beta$ 12818 and P$\alpha$ 18751 respectively, may be better identifications instead, producing 'violet shifts'. Additionally, a literature search reveals many inconsistencies and inadequacies in redshift identifications. Thus, expected strong features are sometimes not seen at expected positions or observed as very weak lines or of unusual profiles, the redshift computed on the basis of observed lines may not be able to interpret additional features seen in subsequent observations, problems appear in energetics based on the calculated redshift values. We are, therefore, concerned about the correctness of the identification process, and, hence, about the possibility of misidentification of observed lines in the redshift determination of QSOs and other extragalactic objects. This necessitates alternative identifications and may lead to blueshifts.

It has been shown in recent years that blueshifts can interpret observed emission lines of QSOs, and, from various considerations, such interpretations in many cases are more convincing than the redshift interpretations (Basu & Haque-Copilah 2001). Very unusual spectra of three additional QSOs, *viz.*, SDSS 1533–00, PG 1407 + 265 and PKS 0635–752, emission and absorption, which cannot be explained properly by the redshift mechanism, have been interpreted in terms of blueshifts (Basu 2004). Spectra of two active galactic nuclei (AGN), *viz.*, PKS 2149–306 and CXOCDFS J033225.3–274219, each exhibiting an X-ray emission feature, which cannot be explained by the redshift determined from its optical spectrum, have been successfully interpreted in terms of blueshifts (Basu 2006a). Blueshifts have also been demonstrated to explain observed spectra of other extragalactic objects, *viz.*, several high redshift galaxies (Basu 1998), the galaxy STIS123627 + 621755 (the redshift interpretation being unable to explain this spectrum) (Basu 2001a), host galaxies of several supernovae Ia (Basu 2000), host galaxies of several gamma ray bursts (Basu 2001b), and also the puzzling spectra of the galactic X-ray source 1E 1207.4–5209 associated with the SNR G296.5 + 10.0 (Basu 2006b). In all the above cases, serious inconsistencies exist in redshift interpretations of the spectra of the objects concerned. It is therefore possible that redshifts have been assigned to spectra of some extragalactic objects due to misidentification of observed lines.

## 3. Results

We re-examined the observed spectra of the eight QSOs of the four pairs in our sample, and found several examples of incompleteness and inadequacy in the redshift identification process of some of the objects, as discussed in section 4. As such, we have interpreted the spectra of one object in each pair as blueshifted by identifying the observed lines with search lines of longer wavelengths, and have determined the blueshift values of each line and, hence, of each such object. We have followed the standard procedure of the identification process for the blueshift determination, *viz.*, at least two observed lines must exhibit the same ‘shift’ (red or blue), whether emission or absorption, when identified with two separate search lines, and the same ‘shift’ must be exhibited for any third or more lines (Basu 1973a, 1973b). Furthermore, when necessary, the higher order line(s) of a series (Balmer or Paschen) has been identified, the lower order line(s) being outside the observed region of the spectrum. Also, in some cases, lower order line(s) of a series has been identified, the higher order line(s) may be too weak to be seen. Results are shown in Table 2.

In Table 2, column (1) is the name of the active galaxy, column (2) gives the name of the QSO, whether the features are emission (EM) or absorption (ABS) and the reference of its spectrum, column (3) is the observed wavelength of the line in the spectrum ($\lambda_o$), column (4) is the wavelength of the search line identified with the observed line for determining the redshift ($\lambda_r$), column (5) is the redshift value of the line ($z_r$), column (6) is spread in redshift ($\Delta z_r$) measured as the difference between the maximum and minimum values of redshifts in the system, column (7) is the wavelength of the search

**Table 2.** Redshifts and blueshifts in observed lines of five QSOs.

| Galaxy (1) | QSO (2) | $\lambda_o$ (3) | $\lambda_r$ (4) | $z_r$ (5) | $\Delta z_r$ (6) | $\lambda_b$ (7) | $z_b$ (8) | $\Delta z_b$ (9) |
|---|---|---|---|---|---|---|---|---|
| NGC 3628 | 1120 + 13 | 3720 | CIII] 1909 | 0.9800 | 0.008 | P$\beta$ 12818 | 0.7098 | 0.0060 |
| | EM (i) | 5565 | MgII 2798 | 0.9880 | | P$\alpha$ 18751 | 0.7032 | |
| NGC 5548 | 1416 + 25 | 4684 | MgII 2798 | 0.6740 | | P$\alpha$ 18751 | 0.7502 | |
| | EM (ii) | | | | | | | |
| Mark 205 | 1218 + 75 | 4600 | MgII 2798 | 0.6440 | 0.012 | H$\beta$ 4861 | 0.0537 | 0.0060 |
| | EM (iii) | 6173 | [OII] 3727 | 0.6564 | | H$\alpha$ 6563 | 0.0594 | |
| | ABS (iii) | 4275 | FeII 2587 | 0.6525 | 0.011 | H2 20338 | 0.7898 | 0.0087 |
| | | 4307 | FeII 2600 | 0.6565 | | H2 20587 | 0.7908 | |
| | | 4600 | MgII 2796 | 0.6452 | | H2 21218 | 0.7832 | |
| | | 4627 | MgII 2803 | 0.6507 | | H2 22233 | 0.7919 | |
| NGC 3842 | 1141 + 20 | 3714 | CIII] 1909 | 0.9460 | 0.003 | H$\beta$ 4861 | 0.2360 | 0.0100 |
| | (QSO 2) | 4050 | ? | ? | | [CaV] 5301 | 0.2370 | |
| | EM (iv) | 4494 | ? | ? | | HeI 5876 | 0.2350 | |
| | | 4804 | [OII] 2470 | 0.9450 | | [OI] 6300 | 0.2375 | |
| | | 5444 | MgII 2798 | 0.9457 | | HeI 7065 | 0.2294 | |
| | | 8455 | H$\gamma$ 4340 | 0.9482 | | P$\gamma$ 10938 | 0.2270 | |
| | ABS (iv) | 3528 | SiII 1808–1817 | 0.9510 | 0.023 | SiII 5454 | 0.3531 | 0.0183 |
| | | | | 0.9420 | 0.019 | | | |
| | | 4300? | ? | ? | | H$\alpha$ 6563 | 0.3348 | |
| | | 8369? | H$\gamma$ 4340? | 0.9280 | | P$\beta$ 12818 | 0.3471 | |

References: (i) Arp *et al.* (2002); (ii) Stocke *et al.* (1983); (iii) Gioia *et al.* (1984); (iv) Arp (1984) (see also Basu & Haque-Copilah 2001).

line identified with the observed line for determining the blueshift ($\lambda_b$), column (8) is the blueshift value of the observed line ($z_b$), column (9) is the spread in blueshift ($\Delta z_b$) measured as the difference between the maximum and minimum values of blueshifts in the system.

The mean blueshifts of the four objects, from Table 2, are 0.7065, 0.7502, 0.0566 and 0.2340, respectively from top downwards. Additionally, two of the QSOs, *viz.*, 1218 + 75 and 1141 + 20 (QSO2), exhibit absorption lines as well, and these have been identified with search lines of longer wavelengths to obtain mean blueshifts 0.7890 and 0.3450 for the two objects respectively.

Absorption lines are known to be formed partly by hydrogen clouds at various stages of evolution to galaxy formation and partly by metals produced in haloes of galaxies.

## 4. Discussion

We have identified the two emission lines at 3720 Å and 5565 Å in the QSO 1120 + 13 with the IR lines P$\beta$ 12818 and P$\alpha$ 18751, instead of the UV lines CIII] 1909 and MgII 2798 respectively. The possibility that these two IR lines are better identifications of some observed lines rather than the UV lines was suggested by Putsil'nik (1979), as mentioned earlier (section 2).

The QSO 1416 + 25 exhibits only one emission line, *viz.*, that at 4684 Å, which has been identified with MgII 2798 in the redshift interpretation. In principle, it can be identified with any search line, and the proper identification needs at least two lines, as explained above. However, in the absence of any other line and any other information of this line, and following Putsil'nik (1979), we have identified the line with P$\alpha$ 18751. The other possible alternative is, of course, H$\alpha$ 6563, but that would require a much stronger line. On the other hand, H$\beta$ 4861 is ruled out in this case as that would bring H$\alpha$ 6563 within the observed region which is not seen.

For the QSO 1218 + 75, the blueshift identification of the line at 4600 Å with H$\beta$ 4681 is justified as the H$\alpha$ 6563 expected within the observing region is seen at 6173 Å. Both are fairly strong lines. The absorption lines are identified in the blueshift interpretation with four of the strongest molecular hydrogen (H2) lines.

The emission lines of the QSO 1141 + 20 (QSO 2) have been shown earlier to be better interpreted as blueshifted (Basu & Haque-Copilah 2001). But the spectrum exhibits absorption lines also, and here we treat the complete spectrum – both emission and absorption. On the other hand, the redshift interpretation of the spectrum of 1141 + 20 (QSO 2) is very confusing. It has been described as "difficult to identify" for the redshift measurement, with "unusual features", and "H$\gamma$ and H$\alpha$ in emission, if present at all, are very weak". Two emission lines at 4050 Å and 4494 Å, and the broad "so strong" absorption line at 4300 Å can not be identified in the redshift interpretation. In addition, the absorption line at 3528 Å has been identified with a multiple of lines *viz.*, SiII 1808–1817. We have identified *all* the observed lines in this object in the blueshift interpretation – the above two emission lines as [CaV] 5301 and HeI 5876 respectively, and the broad absorption line as the H$\alpha$ 6563, the strongest of the search lines.

It should be noted here that the blueshift values presented in this paper are results of superposition of the cosmological redshifts and the Doppler shifts due to the object approaching the observer.

## 5. The 'spread' statistic: Goodness of fit

The quantity spread, $\Delta z$ in Table 2 (columns 6 and 9), is a measure of the goodness of fit for the identification of the observed lines with search lines for computing the 'shift', red or blue, for a system. In principle, $\Delta z$ should be as close to zero as possible. However, in practice, the quantity depends on, and is very sensitive to, the value of the observed wavelength ($\lambda_o$, column 3, Table 2) which is used to evaluate the 'shift'. Unfortunately, the exact determination of $\lambda_o$ is very difficult in practice, even in high $s/n$ and high resolution spectra, as the line profile may be broad, double- or multi-peaked, with complicated structure, blending, etc. Physically, these may involve net flows, screening, gradients, partial absorption, etc. Local velocity drifts, infall or outflow of materials (yet undecided, Penston *et al.* 1990), etc. may also move $\lambda_o$ away from the expected position. Uncertainties in the determination of $\lambda_o$ due to the above reasons may, in some cases, result in somewhat larger values of $\Delta z$, in both redshifts and blueshifts. At least up to a certain extent, this should not be considered as errors in measurement, but may have physical reasons. Having said that, Table 1 would show that, in general, $\Delta z_b$, i.e., spreads in blueshift values, are somewhat smaller, and hence closer to zero, than $\Delta z_r$, i.e., spreads in redshift values.

## 6. A possible scenario: Ejection mechanism

The analysis presented here shows that QSO pairs *across* active galaxies comprise two objects – one approaching us and thus exhibiting blueshifts, the other moving away from us and thus exhibiting redshifts. Such a scenario can be achieved in terms of the ejection mechanism. Merger of black holes is known to lead to their ejections in opposite directions by the so-called 'sling-shot' mechanism when the system becomes unstable (Saslaw *et al.* 1974; Valtonen 1976a, 1976b). Merging of galaxies, each hosting a supermassive black hole at its centre, which are known to be seats of activities (Basu *et al.* 1993; Capetti *et al.* 2005), may produce such a situation. Initially, a binary system is formed by the two central black holes (Valtoja *et al.* 1989), and such a system has been reported to be detected in NGC 6240 (Kommossa *et al.* 2003). As the merger process proceeds further, the supermassive black holes (primaries) are ejected at relavistic or non-relativistic speeds "in two opposite directions" (Mikkola & Valtonen 1990). Evidence of ejection of a supermassive black hole by the 'sling shot' mechanism resulting from merger of galaxies has recently been presented (Haehnelt *et al.* 2006). Additionally, satellite black holes of intermediate masses are also believed to accompany the central supermassive black holes in galaxies (Carr 1978; Carr *et al.* 1984) and are also ejected, some of them assuming eccentric orbits around the primaries (Valtonen & Basu 1991).

It is further known that a black hole at the centre of a galaxy possesses a gaseous accretion disk around it, and this is believed to survive the tidal disruption accompanying the ejection process (Rees & Saslaw 1975; Lin & Saslaw 1977; De Young 1977). A QSO may be formed by the interaction between the disk with the black hole and the surrounding (Rees 1984; Osterbrock & Mathews 1986; Valtonen & Basu 1991; Spriegel 2005). One can further envisage that the same process of interaction would occur between the surroundings and the gaseous disks around the satellite black holes, as in the case of their primary counterparts, although at reduced scales as their masses are smaller, and eventually some of the satellite black holes may end up as faint or nascent or other galaxies.

The merger of two galaxies thus finally gives birth to two QSOs ejected in opposite directions. Each QSO may be accompanied by one or more galaxy-like objects, and the latter act as absorbing clouds when aligned along the line of sight. It may be noted in this connection that absorbing clouds have been shown earlier to be linked with the birth of QSOs themselves (Basu 1982). Moreover, faint, nascent and other galaxies asociated with QSO-like objects have been reported to be observed (Dressler *et al.* 1993; Tripp *et al.* 1998; Tresse *et al.* 1999).

It can therefore be conceived that QSO pairs *across* active galaxies are the results of the ejection process, *viz.*, the 'sling shot' mechanism. One of the pairs is approaching us exhibiting blueshifts in emission and absorption lines, the latter, when observed, being produced by the accompanying absorbing clouds in the form of faint or nascent or other galaxies ejected by the same process but at larger speeds and hence showing larger absorption blueshifts than the corresponding emission blueshifts. The other is receding from us exhibiting the usual redshifted spectra.

## 7. Concluding remarks

We have followed an entirely different path, *viz.*, blueshifts in extragalactic spectra, and not a variant of existing ones, to interpret observational data. We are motivated by the possibility that blueshifts have been ignored by the astronomical community in the modern line identification programs. This, in its turn, has led to wrong approaches. One such example is the assumption that the ejection mechanism would always occur away from the observer, thus obeying all the rules of redshifts only. We have shown here that blueshifts are real possibilities, and observations obey the basic notion of the ejection process, *viz.*, objects should be ejected in all directions with equal probability.

Finally, it should be emphasized that blueshifts and redshifts are complementary and not contradictory. Modern observations would bring in many unusual systems some of which may not be explained by the usual redshift hypothesis, and blueshifts may explain them. Ignoring blueshifts may result in missing some important cosmological scenarios.

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