Gamma-ray bursts, QSOs and active galaxies

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The similarity of the absorption spectra of gamma-ray burst (GRB) sources or afterglows with the absorption spectra of quasars (QSOs) suggests that QSOs and GRB sources are very closely related. Since most people believe that the redshifts of QSOs are of cosmological origin, it is natural to assume that GRBs or their afterglows also have cosmological redshifts. For some years a few of us have argued that there is much optical evidence suggesting a very different model for QSOs, in which their redshifts have a non-cosmological origin, and are ejected from low-redshift active galaxies. In this paper I extend these ideas to GRBs. In 2003, Burbidge (Burbidge 2003 Astrophys. J. 183, 112–120) showed that the redshift periodicity in the spectra of QSOs appears in the redshift of GRBs. This in turn means that both the QSOs and the GRB sources are similar objects ejected from comparatively low-redshift active galaxies. It is now clear that many of the GRBs of low redshift do appear in, or very near, active galaxies.

A new and powerful result supporting this hypothesis has been produced by Prochter et al. (Prochter et al. 2006 Astrophys. J. Lett. 648, L93–L96). They show that in a survey for strong MgII absorption systems along the sightlines to long-duration GRBs, nearly every sightline shows at least one absorber. If the absorbers are intervening clouds or galaxies, only a small fraction should show absorption of this kind. The number found by Prochter et al. is four times higher than that normally found for the MgII absorption spectra of QSOs. They believe that this result is inconsistent with the intervening hypothesis and would require a statistical fluctuation greater than 99.1% probability.

This is what we expect if the absorption is intrinsic to the GRBs and the redshifts are not associated with their distances. In this case, the absorption must be associated with gas ejected from the QSO. This in turn implies that the GRBs actually originate in comparatively low-redshift active galaxies and are ejected in the same way as are the QSOs. This relates these phenomena to a supernova origin for the GRBs. The current situation based on the latest observational data will be discussed.

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1. Observational data and empirical theory

By now, there are more than 350 gamma-ray bursts (GRBs), most of them listed in the compilation of Greiner, Jochen, GRB Afterglows Catalogue (http://www.mpe.mpg.de/jcg/grb.gen.html) (as of 12 May 2006) with positional error boxes.
approximately 3'. According to his compilation, there are X-ray afterglows (AGs) for 142, optical AGs for 109 and radio AGs for 44.

In the master table of GRBs presented in one of the first reviews of these sources (van Paradijs et al. 2000), it was pointed out that the QSO 4C 49.29 lies in the 3' error box of GRB 960720. This QSO has $z=1.038$ (Piro et al. 1998). For this early GRB no afterglow was ever found and only a steady X-ray source was found many months after the event. Thus, many believe that the identification with a QSO is spurious. This may be the case, but QSOs are very rare.

For more than 90 of approximately 350 GRBs, optical spectra of the source or the afterglow have been obtained. This means that some spectral features have been determined and redshifts are available. The redshifts range from $z=0.0085$, detected in 1998, which is due to an event on the outskirts of a very nearby galaxy related to a supernova outburst, to GRB 050904 with $z=6.29$ detected in 2005. With the launch of Swift, the number of bursts for which there are optical identification and redshifts measured has increased tremendously. Since December 2004, about 150 identifications have been made and about 40% of the redshifts have been determined.

The optical spectra fall into two general categories. Sometimes comparatively strong emission lines due to the Balmer series and [O II] $\lambda\lambda4959, 5007$ are seen with a very weak continuum. For many of the GRBs at much larger redshifts, absorption spectra typical of what we see in QSOs are detected.

When it became clear that the long-duration GRBs are extragalactic with redshifts comparable in range to the QSOs, it was concluded that the transient afterglows could be studied in the same way that the QSO absorption spectra have been investigated. The morphological character of the gas giving rise to either emission or absorption in GRBs is not known in detail. However, the identification of a few low-redshift GRBs with host galaxies, which are clearly active star-forming galaxies, led to the general idea that the largest redshifts detected in the spectrum of a GRB shows that the GRB has taken place either in or very near the host galaxy, or if the optical light fades and the spectrum vanishes, it is due to an explosive event in an intervening galaxy along the sight line. In any case, there appears to be a close connection between QSOs and GRBs.

On the theoretical side, it has been argued that GRBs are results of very high energy interactions involving fireballs (Cavallo & Rees 1978; Mészáros 2002 and other references). With the identification of GRB 970508 with a cosmological redshift $z=0.835$, it became clear that the peak luminosity was of the order of $10^{52}$ erg sec or greater. Assuming isotropic emission, it is clear that the total energy emitted is one or two orders greater than that of the brightest supernova, and for larger redshifts, those energies become much greater. If the event is related to a supernova explosion, for example, if it involves the collapse of a very massive star (cf. Woosley & Heger 2002), this suggests that the energy is strongly beamed. The only alternative is to argue that the redshifts are not good measures of distance, a position that very few have taken seriously.

When I became interested in the nature of GRBs, I noticed that the numerical values of several of the redshifts which had been discovered in the first few years lie very close to redshifts which lie at the peaks of the redshift peak and periodicity distribution found earlier among QSOs associated with active galaxies (Burbidge 1968; Burbidge & Burbidge 1970; Karlsson 1971; Burbidge & Napier 2001).
By the summer of 1999, four of the nine, for which redshifts had been measured, GRBs 970508, 971214, 980703 and 960720 have redshifts almost exactly on the peaks (0.96, 1.41 and 3.44) that have previously been found in earlier samples of QSOs (cf. Burbidge & Napier 2001). The original peak in the QSO redshifts at 1.955 had been found in the 1960s (Burbidge 1968; Burbidge & Burbidge 1970) and as further peaks appeared at 0.061, 0.30, 0.60, 0.96 and 1.41, Karlsson (1971) showed that they form a series with $D \log(1+z) = 0.089$. From this we could predict that the next redshift peaks would appear at $z = 2.63, 3.44, 4.47, 5.71$, etc.

Using the higher redshifts of QSOs, which had been detected up to redshifts 4 or less, Burbidge & Napier (2001) were able to show that the predicted redshift peaks at 2.63 and 3.44 do appear. It is easy to show that the periodicity provides evidence that the bulk of the redshifts of QSOs are intrinsic, and that they are physically associated with comparatively low-redshift galaxies. Their measured redshifts $z_o$ are related to several components, namely cosmological components, $z_c$, $z_d$ and $z_i$, where $z_i$ is the intrinsic redshift component, $z_d$ is the Doppler component associated with the speed of ejection of the QSO from the parent galaxy and $z_c$ is the cosmological redshift of the parent galaxy. Thus,

$$z_o = (1 + z_c)(1 + z_d)(1 + z_i) - 1.$$ \hspace{1cm} (1.1)

Since $z_c$ and $z_d$ are small $z_i \approx z_o$.

While this result has been generally ignored, the data have continued to hold up (cf. Hawkins et al. 2002) and the rebuttal by Napier & Burbidge (2003) and Napier (2006).

In view of this result, in 2002 I carried out an analysis of the redshifts of the GRBs combining them with the redshifts of QSOs which lie very close to some of the GRB positions (Burbidge 2003).

The results are shown in figure 1 (taken from Burbidge 2003) and the conclusion was that the periodicity is present at the 98% confidence level. The derived phase of the gamma-ray periodicity $\Phi \sim 5.69$, which is just outside the 90% confidence region of the original QSO data. Thus, I concluded that there is fairly strong evidence that there is periodicity in the redshift distribution of the GRB sources, and afterglows, but much more evidence is required to make the case stronger.
The model is one in which all of the GRB phenomena arise in objects inside active galaxies, and in many situations (i) they are detected in the galaxies, (ii) they are detected immediately outside the galaxies, and (iii) they are ejected from the galaxies as QSOs and they explode very far from those parent galaxies. The much larger number of bursts which have now been identified shows that there are many comparatively low-redshift active galaxies \( z \leq 0.3 \) in which the GRB originates, or from a position just outside it. Practically all of the high-redshift GRBs have absorption spectra similar to these detected in QSOs and, in a few cases, Ly\( \alpha \) in emission is detected. These are often called host galaxies, but there is no good evidence that they are genuine galaxies at all. Working with QSOs is generally believed that all of absorption is due to intervening matter—clouds, or forming galaxies. These are the objects which I believe are ‘local’ QSOs which have been ejected from the low-redshift host galaxies.

In this case, the absorption must be intrinsic to the QSOs, i.e. gas in the line of sight ejected from the QSO. Such intrinsic absorption with ejection up to 0.1–0.2c is found in a class of QSOs—the broad absorption line QSOs (BAL), but the idea that all absorption is intrinsic is very unpopular with those who use QSOs as probes for cosmological investigation.

The histogram of the redshift distribution of all of the objects at present is shown in figure 2. While there is a slight excess of well-fitting redshifts, including our recent one at \( z = 5.60 \) very close to the predicted peak at 5.71, this histogram is not as significant as the one shown in figure 1. But there is other evidence. Recently, Prochter et al. (2006) have shown that in a survey for strong intervening MgII systems along the sight lines to long-duration GRBs, nearly every sightline shows at least one absorber. If the absorbers are intervening clouds or galaxies, only a small fraction should show absorption of this kind. The number found by Prochter et al. (2006) is four times higher than that normally found for the MgII absorption spectra of QSOs. According to Prochter et al. (2006), this result is inconsistent with the QSO interpretation and requires a statistical fluctuation at greater than 99.1% probability.

Figure 2. A histogram of all of the GRBs and afterglows (87) detected up to September 2006.
However, this of course is what we would expect if the absorption is intrinsic to the GRBs, and the redshifts are not associated with their distances. In this case, the absorption will be associated with gas ejected from the QSOs.

Almost certainly, the Prochter evidence is related to earlier work on the absorption spectra of BL Lac objects by Stocke & Rector (1997), who found that this class of QSOs with smaller redshifts show an excess of MgII absorbers.

In addition, it has now been shown by Lopez-Corredoira & Gutierrez (in press) that there is a clear excess of QSOs near the minor axes with respect to the major axis of nearby edge-on spiral galaxies significant at the 3.9σ level. This suggests that QSOs (and GRBs) are ejected preferentially along the rotation axis of spirals.

Thus, both my original suggestion that there are signs of the redshift periodicity in the spectra of QSOs, and the results of Prochter et al. (2006) and other work suggest that the GRBs are not at great distances but are associated with events taking place in low-redshift active galaxies and objects ejected from those galaxies.

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References


