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NO EVIDENCE FOR GAMMA-RAY BURST/ABELL CLUSTER OR GAMMA-RAY BURST/RADIO-QUIET QUASAR CORRELATIONS

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ABSTRACT

We examine the recent claims that cosmic gamma-ray bursts are associated with either radio-quiet quasars or Abell clusters. These associations were based on positional coincidences between cataloged quasars or Abell clusters and selected events from the BATSE 3B catalog of gamma-ray bursts. We use a larger sample of gamma-ray bursts with more accurate positions, obtained by the Third Interplanetary Network, to reevaluate these possible associations. We find no evidence for either.

Subject headings: galaxies: active — galaxies: clusters: general — gamma rays: bursts — quasars: general

1. INTRODUCTION

The discovery of optical counterparts to gamma-ray burst (GRB) sources has finally given an indication of the burster distance scale. Three bursts, GRB 970508 (Metzger et al. 1997), GRB 971214 (Kulkarni et al. 1998), and GRB 980326 (Djorgovski et al. 1998) have been demonstrated to lie at cosmological distances, and all appear to be associated with faint galaxies. With the possible exception of GRB 980425, which may be associated with a supernova in a nearby galaxy (Galama et al. 1998), no optical transient definitely associated with a GRB has yet been found to coincide with a cataloged object, and the precise type of GRB host galaxy is not known. Prior to the detection of optical counterparts, suggestions were made that GRBs were associated with Abell clusters (Kolatt & Piran 1996, hereafter KP96) and with radio-quiet quasars (RQQs; Schartel, Andernach, & Greiner 1997, hereafter SAG97). The fact that none of the counterparts discovered to date appear either to lie in an Abell cluster or to be a quasar does not disprove either idea, however, since both relied on the statistics of many GRBs.

Specifically, KP96 selected 136 bursts from the Burst and Transient Source Experiment (BATSE) 3B catalog (Meegan et al. 1996) with a 68% confidence error circle radii $\leq 2\overset{\circ}{.}26$, and 3616 Abell clusters (Abell, Corwin, & Olowin 1989) with galactic latitude $|b| > 30^\circ$. They calculated the number of burst cluster pairs, $N(\theta)$, whose separation was smaller than a given angle θ, and found that the number for $\theta = 4^\circ$ was larger than the numbers found for randomly generated catalogs. The excess was significant at the 95% confidence level.

SAG97 selected 134 bursts from the 3B catalog with error circle radii $\leq 1\overset{\circ}{.}8$ and examined positional coincidences between these bursts and radio-loud and RQQs, BL Lac objects, and active galactic nuclei, among others, in the Véron-Cetty & Véron (1996) catalog.[1] They created an "optimized" sample of 967 bright, RQQs and found a probability of greater than 99.7% that they were associated with GRBs.

We reexamine each of these claims using more bursts and more precise burst location data.

2. BATSE AND IPN3 DATA

For the period covered by the BATSE 3B catalog, the Third Interplanetary Network (IPN3) of GRB detectors consisted of the *Ulysses* spacecraft (at distances from Earth of up to 6 AU; Hurley et al. 1992), BATSE, and until late 1992, *Pioneer Venus Orbiter* (*PVO*). For the period between the end of the 3B catalog and the end of the 4B catalog (Paciesas et al. 1998), *PVO* was replaced for a short period by *Mars Observer* (*MO*). When only *Ulysses* and BATSE observed a burst, the resulting localization was an annulus generally crossing the BATSE error circle. The widths of the annuli ranged from $7''$ to $2\overset{\circ}{.}3$, and the average reduction in area from the BATSE error circles to the BATSE/IPN3 error boxes is a factor of 25. These data may be found in Hurley et al. (1998a, 1998b). When a third distant spacecraft such as *PVO* or *MO* also observed an event, the result was a

[1] Available as CDS catalog 188 by anonymous ftp to adc.gsfc.nasa.gov.

TABLE 1

ABELL CLUSTER/GRB ASSOCIATIONS

Instrument/Study	Abell Clusters	Abell Clusters at $\|b\| > 30°$ (deg^{-2})	BATSE Error Circles	BATSE/IPN Error Boxes	Abell Clusters in BATSE/IPN Boxes	Number Expected by Chance
KP96	3616	0.175	136	...	...	...
3B/IPN.....	3616	0.175	104	104	17	14.2
4B/IPN.....	3616	0.175	157	156	27	21.3
4B/IPN (0°.2).....	3616	0.175	157	156	98	95
4B/IPN (0°.4).....	3616	0.175	157	156	178	166

small error box. The *PVO* events may be found in Laros et al. (1998), and the *MO* events in Laros et al. (1997).[2]

The BATSE 3B locations used in the KP96 and SAG97 studies have in some cases been revised, and the sample has been expanded in the 4B catalog.[3] Similarly, the IPN3 data have recently been finalized through the 4B catalog and beyond. Thus a complete reconsideration of the proposed associations is in order.

3. THE ABELL CLUSTER/GRB ASSOCIATION

In an earlier paper (Hurley et al. 1997), we attempted to confirm the KP96 claim. We first verified the number of Abell clusters (3616) and bursts (134) after galactic latitude and size cuts were applied. For each cluster, we checked each BATSE error circle to see whether their positions were consistent. If it was, we finally checked for consistency with any IPN3 location information. If the 3 σ IPN3 annulus did not pass through the BATSE error circle, the Abell cluster was considered to be inconsistent with the burst position. If the annulus intersected the error circle and the cluster center lay within the annulus, the cluster's position was taken to be consistent with the burst position. Since KP96 counted Abell clusters within 4° of a BATSE error circle as correlated with the burst, we assigned an error radius of 4° to the BATSE bursts, and we also used this to define the BATSE/IPN3 error box. The addition of the IPN3 data to this subset of bursts reduces the BATSE error circle areas by a factor of 56, which results in a more accurate test. This study did not confirm the Abell cluster/GRB association. However, Struble & Rood (1997) pointed out two problems. The first was that the positions used for the Abell clusters were for J2050 equinox, while the BATSE/IPN3 positions used were J2000. This came about owing to the accidental application of a precession routine to the Abell cluster data. (However, when corrected, a null result was again obtained.) The second was that the Abell clusters were treated as point sources in our comparison (cluster diameters are not given in the Abell catalog), whereas in fact they have angular diameters of up to several tenths of a degree. This fact was unimportant for the KP96 study because the sizes of the BATSE error circles exceed these diameters by 1 order of magnitude or more. However, they are comparable to the widths of IPN3 annuli, so the fact that the center of a cluster does not lie within an annulus does not necessarily mean that its position is inconsistent with it.

As a first step, we corrected the precession error and performed the test using the revised BATSE 3B and IPN3 data. As a second step, we extended the test to cover the BATSE 4B and IPN3 data; in this case, the 4B/IPN3 error boxes have a total area that is smaller by a factor of 57 than the BATSE error circles alone. In both cases, we proceeded under the assumption that Abell clusters were point sources. Finally, we took cluster radii to be either a constant 0°.2 or 0°.4 (see, e.g., Gorosabel & Castro-Tirado 1997), and we tested their association with the BATSE 4B and IPN3 data. This was done by increasing the half-widths of the IPN3 annuli by 0°.2 or 0°.4 before checking for intersections with BATSE error circles and proceeding as explained above. In all cases, we also calculated the number of random associations based on the number of Abell clusters per square degree at latitudes $|b| > 30°$ and the total area of the BATSE/IPN3 error boxes; no clustering was assumed. The results are shown in Table 1. The number of clusters found in BATSE/IPN3 error boxes is always within $\sim 1\,\sigma$ of the expected value, in contrast with the KP96 result.

4. THE QSO/GRB ASSOCIATION

To examine the SAG97 QSO/GRB association, we began by duplicating their data cuts. We first selected 134 bursts from the 3B catalog with error circle radii $\leq 1°.8$ and 967 bright RQQs from the Véron-Cetty & Véron (1996) catalog. We tested the position of each RQQ to determine whether it was within the BATSE error circle. If it was, we also tested its position with respect to the corresponding IPN3 annulus. If its position lay within the annulus, it was counted as a coincidence and removed from the set of selected RQQs so that it could not be counted a second time if it happened to lie within in another annulus. This duplicates the "singular" coincidences in SAG97. Since RQQs are

[2] Data may also be found on the World Wide Web at http://ssl.berkeley.edu/ipn3/index.html.

[3] Updated data are available on the World Wide Web at http://www.batse.msfc.nasa.gov/data/grb/catalog/basic.html.

TABLE 2

QSO/GRB ASSOCIATIONS

Instrument/Study	RQQs	RQQ (deg^{-2})	BATSE Error Circles	BATSE/IPN Error Boxes	RQQs in BATSE/IPN Boxes	Number Expected by Chance
SAG97.....	967	0.0234	134	...	...	...
3B/IPN	967	0.0234	126	126	0	0.41
4B/IPN	967	0.0234	192	192	0	0.72

point sources, no further assumptions were made. We carried out this test for the revised 3B catalog as well as for the 4B catalog. In the latter case, the 4B/IPN3 error boxes again have a total area that is smaller than the BATSE error circles alone by a factor of 57. The number of random coincidences was calculated using the number of quasars per square degree and the total area of the BATSE/IPN3 error boxes. The results are given in Table 2. Using the Poisson distribution, the probabilities of finding 0 when the means are 0.41 and 0.72 are 0.64 and 0.47, respectively; thus our results are consistent with expectations.

5. CONCLUSION

Neither the Abell cluster/GRB correlation nor the QSO/GRB correlation is confirmed when the error box sizes are reduced using the IPN3 data and the number of error boxes tested is increased. This can probably be attributed to the fact that the KP96 and SAG97 studies employed two or more of the following procedures, which led to an apparent correlation:

1. A rather small sample was considered and large error circles were used, which led to a relatively insensitive test.
2. Marginal statistical significance was obtained for the proposed association.
3. Numerous data cuts were used; although physically well motivated, they were not counted as independent trials that reduce the statistical significance.
4. Various distances between bursts and error circles were tested to optimize results; again, although physically well motivated, they were not counted as independent trials.

This nonconfirmation is in keeping with previous results (Webber et al. 1995; Hurley et al. 1997; Marani et al. 1997; Gorosabel & Castro-Tirado 1997). Nevertheless, the limitations of studies such as this should be kept in mind. The distance scale that appears to be emerging for GRBs is approximately in the range $z \geq 1$ (but see Lidman et al. 1998). The Abell cluster data is limited to $z \leq 0.37$, and the RQQ study by design examines only quasars with $z < 1$. In addition, the best located BATSE bursts, as well as the IPN3 bursts, tend to be the brightest ones and are thus probably also the closest. Finally, more sophisticated BATSE error models can be used, resulting in a better definition of the error circles. Work is underway that will remedy the last two limitations and result in a still stronger test of any possible associations.

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