EGRET Observations of Gamma Rays from Point Sources with Galactic Latitude $+10^\circ < b < +40^\circ$

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ABSTRACT

The EGRET instrument aboard the Compton Gamma Ray Observatory (CGRO) has completed the first all-sky survey in high-energy gamma rays and has repeatedly viewed selected portions of the sky. Analysis of the region with galactic latitude $+10^\circ < b < +40^\circ$ indicates the presence of nineteen point sources, including nine which can be identified as active galactic nuclei, some of which have been reported previously, as well as ten other sources with no definite counterparts. Using the combined exposures from Phase 1 and Phase 2 of the CGRO viewing program, the spectra, time variability, and positions of all detected sources in this region are determined. It is tentatively suggested that one of the unidentified sources might be associated with the radio galaxy Centaurus A.

Subject headings: gamma rays: observations – galaxies: nuclei – galaxies: active

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1. Introduction

The all-sky survey by the Compton Gamma Ray Observatory has led to the detection of a number of high-energy gamma ray sources with the Energetic Gamma Ray Experiment Telescope (EGRET). EGRET covers the high-energy gamma ray range from about 30 MeV to over 20 GeV. It produces an image of a circular region of the sky with maximum sensitivity at the center of the field of view, falling to half at about 18° from the center and to one-sixth at 30°. Individual photons are detected with an angular accuracy which varies with the photon energy from about 0.5 degrees at the highest energy to 10 degrees at the lowest. The properties of the instrument are discussed by Kanbach et al. (1988, 1989) and by Thompson et al. (1993a). The full sky survey provided for the first time an opportunity to study in detail high-energy gamma ray emission from point sources as well as from extended regions of diffuse emission. Individual observations, typically one to three weeks long, provided an opportunity to examine the emission from potential point sources while adding all the observations during the survey allowed weak, steady sources to be enhanced. This analysis covers Phase 1 and Phase 2 of the CGRO observing plan, from the spacecraft’s launch in April 1991 to August 1993.

This paper covers the detected point sources whose galactic latitude is between +10° and +40°. Sixty-five separate observations contributed useful data for this region. Other portions of the sky are discussed in other papers (Dingus et al. 1995; Lin et al. 1995b; Sreekumar et al. 1995; Bertsch et al. 1995). The sky is divided into zones of different galactic latitude for two reasons. First, different types of point sources are found in different parts of the sky. The pulsars which EGRET has detected are all within a few degrees of the galactic plane (Thompson et al. 1994), and it is possible that many other point sources belong to other galactic populations. Above 10 degrees of latitude, it is likely that the sources are predominantly extragalactic. Second, the galactic diffuse emission has a strong influence on the ability to distinguish point sources. Within 10 degrees of the Galactic plane, most point sources are weak “bumps” on a strong, structured background. At higher latitudes, the diffuse emission is much weaker and more uniform. The statistical criteria used in the data analysis are necessarily different at different latitudes.

The first EGRET catalog (Fichtel et al. 1994a) contains all the EGRET point sources detected in the Phase 1 observations. This paper covers many of the same sources, but there are some differences. With more data, positions and fluxes are known more precisely, and some marginal sources are now detected significantly. Information on spectra and time variation are included here. Some variable sources not detectable in Phase 1 flared in Phase 2 and became detectable. With an improved model of the Galactic diffuse emission, a number of spurious sources have been removed from the list. Point sources can now be
studied in the zone with $0^\circ < \ell < 30^\circ$, $10^\circ < b < 20^\circ$, which was omitted from the first catalog because of shortcomings in the old diffuse model. The second EGRET catalog (Thompson et al. 1995) will use the same data used here, but the point sources are not discussed in the same detail.

This paper will not discuss the Ophiuchus Cloud, an extended gamma-ray source covered in detail by Hunter et al. (1994).

2. Observations and Analysis

The standard EGRET processing operations were applied to the data (Bertsch et al. 1989). Maps were made of the number of photons detected in $0.5^\circ$ pixels and the instrument exposure was calculated for each pixel. Photons out to $30^\circ$ from the center of the instrument field of view were accepted. Maps were made for each individual viewing period as well as for the whole of Phase 1 and 2. A list of the viewing periods in Phase 1 is contained in Fichtel et al. (1994a). The Phase 1 and 2 viewing periods will be listed in the second EGRET catalog (Thompson et al. 1995).

Source fluxes are derived by a maximum-likelihood analysis (Mattox et al. 1996) which uses the detector point spread function to model any excess above a predicted map of the diffuse Galactic emission (Bertsch et al. 1993, Hunter et al. 1995) and a (presumed extragalactic) isotropic component. Recent improvements in this prediction have made it possible to resolve point sources in the region $0^\circ < \ell < 30^\circ$, $10^\circ < b < 20^\circ$, which formerly had an implausible number of deviations from the diffuse model (Fichtel et al. 1994a). The levels of the predicted Galactic and isotropic diffuse emission are allowed to vary over limited regions in order to allow for local inaccuracies of the model. The statistical significance of a detected point source at a fixed position is estimated from its test statistic $T_s \equiv 2 \log(L_1/L_0)$, where $L_1$ and $L_0$ are the likelihoods of the models with the source present and absent. The strengths of the source and the diffuse components are adjusted to maximize $T_s$. If no real point source is present, $T_s$ at any chosen point on the sky will be a random variable distributed as $\chi^2(1)$ (Mattox et al. 1996). Thus $\sqrt{T_s}$ is approximately the significance of a detection, expressed in Gaussian “sigmas.”

To search for possible point sources we first examined a map of the whole observation containing photons with energy $> 100$ MeV. This choice has proven to be a useful compromise between the better angular resolution that could be obtained by using only higher-energy photons and the larger number of photons that could be obtained by admitting lower energies. A source is accepted for further analysis if $\sqrt{T_s} > 4$. Monte-Carlo
simulations show that there should be about 2 spurious sources in the whole sky with \( \sqrt{T_s} > 4 \) (Mattox et al. 1996), in agreement with a approximately Gaussian distribution of \( \sqrt{T_s} \). Thus there should be less than one spurious detection in this region. To look for other sources with unusual spectra we also searched maps in other energy bands: 30–100 MeV, 100–300 MeV, 300–1000 MeV, and \( >1000 \) MeV. There were no new detections with \( \sqrt{T_s} > 4 \). We also searched the individual viewing period maps and found no new sources.

Positions for point sources are estimated by mapping the value of \( T_s \). A trial point source is placed in many different locations; a different \( T_s \) value is obtained at each. The maximum point is the most likely location of the source. Confidence regions are chosen to be areas in which \( T_s \) is greater than a cutoff value. The cutoff is equal to the maximum \( T_s \) less the appropriate critical value of the \( \chi^2(2) \) distribution. The positions estimated here were derived in two different ways. First, the single E \( >100 \) MeV map was examined. Second, \( T_s \) maps for three energy bands (100–300 MeV, 300–1000 MeV, and \( >1000 \) MeV) were added. The 30–100 MeV band was omitted because of its poor angular resolution in comparison with the others. For the objects studied here, the second procedure usually produces better results because it takes better advantage of the narrower point spread function at high energy. The smaller of the two confidence regions is reported here. There are still a few regions in which there are possible difficulties in the diffuse model, as shown by large, unsymmetric error regions, suspicious variation between energy bands, or concentrations of weak flux excesses. Such cases will be noted for individual source detections.

The positions of the detected point sources are compared with a list of candidate sources. The extreme AGN portion of this list includes radio-loud (\( >1 \) Jy) quasars, OVV quasars, high-polarization quasars, superluminal objects, and BL Lac objects (Fichtel et al. 1994a). In addition a selection of prominent Seyfert galaxies and radio-quiet quasars was added. Many Galactic objects were also included, such as pulsars, X-ray binaries, globular clusters, X-ray bursters, supernova remnants, and COS-B gamma-ray sources. The total number of candidates is slightly more than 1000, of which roughly 200 fall between Galactic latitudes \(+10^\circ \) and \(+40^\circ \). The probability of even one chance coincidence with an object from this list is less than 10% for a typical error circle of radius \(<1 \) degree. Approximately half of our detected sources can be identified with objects from this list, which indicates that most of the identifications are probably correct.

Spectra of the detected sources can be determined from the fluxes measured in the different energy bands. A power law form without breaks is assumed for the spectrum. A model spectrum is propagated through a model of the detector response function (Thompson et al. 1993a) and compared with the detected flux by a \( \chi^2 \) test. The normalization and spectral index are adjusted to obtain the best agreement with the data (Fichtel et al.
1994b). The uncertainty in the spectral index is based on the size of the region in parameter space in which \( \chi^2 < \chi^2_{\text{min}} + 2.3 \). This is appropriate if there are two interesting parameters, the spectral index and the normalization (Lampton, Margon, & Bowyer 1976). It might be argued that the index is the only interesting parameter in this situation. In that case the appropriate confidence region would be \( \chi^2 < \chi^2_{\text{min}} + 1 \), so the uncertainty could be decreased by a factor \((2.3)^{-\frac{1}{2}}\). Spectra for all the sources can be determined in the four energy bands described above. For strong sources these can be checked by dividing the 30 MeV – 10 GeV range into ten narrow bands. Empirical corrections are applied to the flux for energy less than 70 MeV (Thompson et al. 1993b).

3. Results

The main results for the combined data are found in Tables 1 and 2. There were 19 point sources which met the criteria described above. These are all presented together in the Tables, abandoning the distinctions (Fichtel et al. 1994a) between identified and unidentified sources and between significant detections \((\sqrt{T_s} > 5)\) and marginal ones \((4 < \sqrt{T_s} < 5)\). Each source has been assigned a name based on the celestial (J2000) coordinates of its most likely position, for instance J0009+73. In some cases the numerical portions of these names differ slightly from those which have been used to identify these sources in previous publications because of more data and the improved diffuse model.

Table 1 contains information about the flux, position, and identification of the sources. The photon flux for energy \(>100\) MeV is presented, along with the value of \(\sqrt{T_s}\) in this band. The Galactic coordinates of the most likely position are given, as well as the radius of the 95% confidence error circle in arcminutes. For the identified sources, the counterpart is named and its distance from the most likely position is given. The redshifts of the counterparts are shown, if known, and the gamma ray luminosity in the range 100 MeV – 10 GeV is calculated. The luminosity calculation assumes isotropic emission, \(q_0 = \frac{1}{2}\), and \(H_0 = 75\) km s\(^{-1}\) Mpc\(^{-1}\). The photon number spectral index \(\alpha\) is taken from Table 2. A \(K\) correction factor of \((1 + z)^{-(\alpha+2)}\) has been applied so the luminosities can be compared for the same emitted energy band.

Table 2 contains information about the spectra of the sources in broad energy bands. Photon fluxes are presented for the four standard energy bands: 30–100 MeV, 100–300 MeV, 300–1000 MeV, and >1000 MeV. From these values a photon number spectral index is produced, assuming a spectrum of the form \(\frac{dN}{dE} \propto E^\alpha\). All of the energy spectra were consistent with the simple power law model according to a \(\chi^2\) test. There is no compelling evidence for a spectral break or cutoff. Most of the spectra, however, are of such low quality
that no meaningful individual limits on the shape of the spectrum can be derived. In such cases the spectral index is just a rough guide to the hardness of the spectrum. The average energy spectra in 10 narrower energy bands are displayed in Figure 1.

To search for possible variability, the source fluxes were examined in each of the individual viewing periods. A fairly stringent criterion was used: a $\chi^2$ test must show less than 5% probability that the source flux is constant. On this basis only five sources showed definite evidence for variation, J0009+73 (2.6% probability of not being variable), J0720+21 (1.7%), J0744+54 (2.3%), J0826+70 (4.5%), and J1835+59 (1.9%). Figure 2 shows the $>100$ MeV light curves for three of these objects. The other two are not presented here because they have been discussed fully elsewhere (J0720+71 identified as 0716+714 in von Montigny et al. 1995 and Lin et al. 1995a; J0744+54 in Mukherjee et al. 1995). Some other sources have been described as variable (J1626-24 in Hunter et al. 1994; J0826+70 in Michelson et al. 1994), but they do not pass our $\chi^2$ test. It is possible that all of the detected sources may be variable to some degree, but the measurements are not precise enough to detect small changes in the weaker ones.

In a few cases some sources were bright enough to be detected with $\sqrt{T_s} > 4$ in individual viewing periods. In these cases, it is possible to derive spectra for the individual observations. The resulting fluxes and spectral indices are shown in Table 3. Note that the five objects listed here are the same ones with significant variability. The spectra of two objects, J0721+71 and J1835+59, show significant variation in spectral index. There is no obvious correlation between spectral index and flux. The individual spectra of J1835+59, the brightest and most often observed source, are shown in Figure 3.

Because of the recent report (Quinn et al. 1995) of the detection of 0.3 TeV gamma rays from the nearby BL Lac object Markarian 501 with a flux of $8 \times 10^{-12}$ photons cm$^{-2}$ s$^{-1}$, we searched for emission in the EGRET energy range. None was detected, and the 95% confidence upper limit is $1.0 \times 10^{-7}$ photons cm$^{-2}$ s$^{-1}$ for $E > 100$ MeV. If the spectrum spanning the two energy bands is assumed to be a single power law, then it must be flatter than $E^{-2.2}$.

4. Discussion

This list cannot be considered a complete, flux-limited survey in a strict sense. The limiting flux is a function of the local diffuse emission. A source could appear on the list either by having steady emission for the whole survey period or by having a relatively brief flare. Nevertheless it is possible to say that the minimum average flux detected is about
10^{-7} \text{ photons cm}^{-2} \text{ s}^{-1} \text{ for energy} > 100 \text{ MeV.}

There is marginal evidence for a difference in the spectra of the identified and unidentified objects. The mean spectral index of the identified sources is $-2.46$, with a standard deviation of 0.51; the mean and deviation for the unidentified sources is $-2.16$ and 0.39. A Student-t test shows that the hypothesis that the two sets are drawn from the same parent population can be rejected with only 83% confidence. It remains possible that the unidentified sources may not be a homogeneous class.

4.1. Identified Sources

The gamma source counterparts are blazars, that is BL Lac objects or radio-loud quasars with a flat radio spectrum, high optical polarization, or rapid variability (Angel & Stockman 1980; Burbidge & Hewitt 1992). Our confidence in these identifications is based on a statistical argument: there are not many blazars, and many of them fall in the EGRET error circles (von Montigny et al. 1995). In these objects, the apparent gamma-ray luminosity dominates all other wavelength bands if the emission is assumed to be isotropic. This gamma-ray brightness is seen as evidence for beaming by a relativistic jet. Von Montigny et al. (1995) describe many of the specific models which have been proposed to explain the gamma-ray emission.

Most of the identified sources in this region have been discussed in some detail by von Montigny et al. (1995). Because of improvements in the model of Galactic diffuse gamma ray production (Hunter et al. 1995), the significance of some of these detections has changed. Also some source positions have shifted enough to affect identifications. The sources 0829+046 and 1741−038 in von Montigny et al. (1995) do not appear in this paper because their detections no longer pass the $\sqrt{T_s} > 4$ test. Conversely, J0740+18 and J1734−13 don’t appear in von Montigny et al. (1995), but they are in the present list. Other published possible blazar identifications from the EGRET data are noted below. Unless otherwise noted, redshifts and basic characterizations are taken from the compilation of Hewitt & Burbidge (1993) and the NASA Extragalactic Database (NED) (Helou et al. 1991). Following are the identified sources.

J0720+71 = 0716+714. This is a BL Lac object with a flat radio spectrum. Its redshift is unknown, but it is probably more than 0.3 (Witzel et al. 1988). The EGRET observations of this object have also been discussed in detail by Lin et al. (1995a). Its gamma ray flux is variable.

J0740+18 = 0735+178. This is a BL Lac object. According to Stevens et al. (1994),
its high-frequency radio emission underwent a smooth decrease during the entire period of
the EGRET observation after outbursts in 1989 and early 1991.

J0808+49 = 0804+499 = OJ 508. This is a highly-polarized QSO. The EGRET
observations of this object have also been discussed by Thompson et al. (1993b).

J0826+70 = 0836+710 = 4C +71.07. This is a flat-spectrum QSO. The EGRET
observations of this object have also been discussed by Thompson et al. (1993b). This
source is variable with confidence > 95%. Its light curve is presented in Figure 2(b). It is
the most luminous of all the identified sources in this section of the sky.

J0831+24 = 0827+243 = OJ 248. This is a flat-spectrum QSO. The EGRET
observations of this object have also been discussed by Michelson et al. (1994). There is
some uncertainty about its redshift. We adopt the value 0.941 of Steidel & Sargent (1991)
rather than 2.046 as listed in the NED database.

J1315−34 = 1313−333. This is a flat-spectrum QSO.

J1626–24 = PKS 1622–253. The EGRET observations of this object have also been
discussed in detail by Hunter et al. (1994). This is located behind the Ophiuchus Cloud,
a strong, compact, diffuse gamma ray source. Although it is not listed in the Hewitt &
Burbidge (1993) catalog, Impey & Tapia (1990) identify it as a quasar. The radio spectrum
is bright and flat enough to qualify it as a blazar candidate. No redshift value is known.

J1734–13 = 1730–130. This is a flat-spectrum, variable QSO. This is the only source
in this list for which a better position was obtained by using the E > 100 MeV band. It is
located in a region where the galactic diffuse region is strong and difficult to model.

J1738+51 = 1739+522 = 4C +51.37. This is a flat-spectrum QSO.

4.2. Unidentified Sources

Ten point sources are not identified with AGN counterparts. At such high galactic
latitudes, it is probable that most of these are AGN of types similar to the identified sources.
Some, however, might be unidentified Geminga-like pulsars or other nearby galactic objects.
However, most of the unidentified sources have steeper spectra than the EGRET-detected
pulsars (Thompson et al. 1994). Most of the error circles are so large that the NED or
SIMBAD databases will contain several possible counterparts. Most of those are weak radio
sources or IRAS infrared sources, which are so numerous that several chance coincidences
are expected. We will comment on the brightest gamma sources and the ones with bright
 (> 0.25 Jy) potential radio counterparts.

J0009+73. This source is variable with confidence > 95%. The light curve is shown in Figure 2(a). It is coincident in position with the supernova remnant CTA 1, a plerion with a central point X-ray source (Seward 1990), 1.2 \times 10^4 years old (Sieber, Salter, & Mayer 1981), at a distance of 1.1 kpc (Milne 1979). At this distance, the gamma luminosity would be about 10^{34} \text{ erg s}^{-1}. This luminosity and the flat spectrum are appropriate for a pulsar, but the variability is not. Sturmer & Dermer (1995) have proposed that several other EGRET sources are remnants, and they describe several mechanisms by which gamma rays might be produced. It is possible for the emission from a remnant to vary in a few months (de Jager & Harding 1992), so this identification can’t be ruled out. The flat-spectrum QSO 0016+731 is also less than a degree away, although the position is not formally consistent.

J0445+62. This might be identified with the extragalactic radio sources 4C +61.11 (27' away, 2.4 Jy at 178 MHz) or 0437+6139 (29' away, 0.4 Jy at 1.4 GHz).

J0500+59. This might be identified with the extragalactic radio sources 4C +59.05 (41' away, 2.5 Jy at 178 MHz), 0500+5935 (49' away, 2.6 Jy at 1.4 GHz), or 0451+5945 (61' away, 0.57 Jy at 1.4 GHz). The position of this source should perhaps be regarded with a certain degree of caution. The error circle is elongated, it is detected in only two of the four broad energy bands, and the two best positions don’t agree within their formal uncertainties. These factors might indicate remaining problems in the diffuse model.

J0744+54. This source is variable (Mukherjee et al. 1995). It could plausibly be identified with the radio source 0738+5451, 14' away, which has a radio flux of 0.27 Jy at 4.85 GHz and a flat spectrum.

J1326−43. This error circle contains no known blazars, but 31' from the center is Centaurus A = NGC 5128, an unusual radio galaxy with an X-ray jet (Feigelson et al. 1981) and large radio lobes (Meier et al. 1989) located only 3.5 Mpc away (Hui et al. 1993). This identification must be tentative with such a large error circle. Also, the diffuse emission in this region shows some low-level structure not found in the model. Such irregularities might disturb the position estimate or the significance of the detection. This possible identification has not been mentioned in any previous list because recent revisions of the galactic diffuse model caused the source position to shift. Other catalogued objects in the circle include several normal stars, several normal galaxies, several IRAS infrared sources, the pulsar PSR 1325-43, and the supernova SN 1986G. None of these shows any characteristics that would make it likely to be a strong emitter of high-energy gamma rays. Nice, Sayer, and Taylor (1994) searched part of the error circle for new pulsars, but found none.

It is plausible that Cen A could be a high-energy gamma ray source. It is the brightest
extragalactic source of hard X-rays near 100 keV and its spectrum doesn’t show the sharp high-energy cutoff typical of Seyfert galaxies (Kinzer et al. 1995). The EGRET spectrum extrapolates to match fairly well with the contemporaneous COMPTEL measurements of Collmar et al. (1993) around 1 MeV. The spectral index would have to steepen by about 1 between 100 keV and the EGRET energy range. This gradual steepening is consistent with a nonthermal synchrotron/Compton model of the emission (Grindlay 1975; Mushotzky et al. 1978; Beall & Rose 1980), probably not with the Compton reflection model (Zdziarski et al. 1990; Skibo, Dermer, & Kinzer 1994). The gamma ray luminosity of $8.3 \times 10^{40}$ erg s$^{-1}$ is only a few hundred times our own galaxy’s.

J1835+59. This is the brightest of the EGRET unidentified sources. It was discussed by Nolan et al. (1994). Since then the error circle has been refined to a smaller size, so the list of possible counterparts in the standard catalogs has been reduced to one: IRAS F18342+5913. This is is a faint point source in the IRAS wavelength bands, and nothing else is known about it. No radio source in the Green Bank survey (Becker, White, & Edwards 1991) is consistent with the error circle. Nice, Sayer, and Taylor (1994) searched for pulsars in the error circle, and found none. This source is variable on a time scale of weeks. Its light curve is shown in Figure 2(c). There is also some evidence that the spectral index varies.

5. Summary

Nineteen point sources of $>100$ MeV gamma rays can be identified in this region of the sky. Nine of them can be identified with blazars. This identification can be made confidently because of the relative rarity of blazars. Five of the brightest sources, both identified and unidentified, are variable in flux. One of the bright unidentified sources is coincident with the plerion supernova remnant CTA 1, and another is consistent with the position of the radio galaxy Centaurus A. The brightest of the unidentified sources has a 9' radius error circle containing no prominent identification candidates in other wavelength bands.

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database, operated at CDS, Strasbourg, France.
Table 1. Gamma Ray Sources

| EGRET Position | $F_{>100}$ (photons cm$^{-2}$ s$^{-1}$) | $\sqrt{T}$ (rad.) | $\ell$ (deg) | $b$ (deg) | 95%$^{c}$ | ID$^{f}$ | $\Delta$ (arcmin) | Z$^{h}$ | $L_{48}^{i}$ |
|----------------|---------------------------------|-----------------|-------------|----------|---------|--------|--------------|--------|-----------|
| J0009+73       | 55.2 ± 8.0                      | 8.6             | 119.81      | 10.47    | 28      | ?      | -            | -      | -         |
| J0445+62       | 17.8 ± 5.0                      | 4.0             | 146.89      | 10.65    | 36      | ?      | -            | -      | -         |
| J0500+59       | 17.1 ± 4.6                      | 4.2             | 150.52      | 10.25    | 62      | ?      | -            | -      | -         |
| J0720+71       | 17.2 ± 2.4                      | 8.7             | 143.90      | 27.94    | 25      | 0716+714| 6            | > 0.3  | > 0.029   |
| J0740+18       | 15.2 ± 4.2                      | 4.2             | 201.35      | 17.87    | 110     | 0735+178| 51           | 0.424  | 0.040     |
| J0744+54       | 16.4 ± 2.9                      | 6.8             | 162.98      | 29.32    | 44      | ?      | -            | -      | -         |
| J0808+49       | 14.9 ± 2.9                      | 6.0             | 169.06      | 32.56    | 74      | 0804+499| 5            | 1.43   | 1.5       |
| J0811−07       | 26.2 ± 6.2                      | 5.2             | 228.86      | 14.33    | 47      | ?      | -            | -      | -         |
| J0826+70       | 8.1 ± 2.0                       | 4.7             | 144.19      | 33.33    | 74      | 0836+710| 73           | 2.172  | 4.2       |
| J0831+24       | 24.6 ± 6.0                      | 5.2             | 200.23      | 31.89    | 56      | 0827+243| 11           | 2.046  | 0.79      |
| J1315−34       | 18.0 ± 3.3                      | 6.4             | 308.46      | 28.14    | 39      | 1313−333| 51           | 1.21   | 1.3       |
| J1326−43       | 17.5 ± 3.5                      | 5.7             | 309.56      | 18.90    | 41      | Cen A? | -            | -      | -         |
| J1626−24       | 25.0 ± 4.2                      | 6.7             | 352.63      | 16.60    | 25      | 1622−253| 33           | ?      | -         |
| J1629−28       | 18.5 ± 3.7                      | 5.5             | 350.42      | 13.81    | 67      | ?      | -            | -      | -         |
| J1635−14       | 13.4 ± 3.6                      | 4.2             | 2.57        | 21.68    | 28      | ?      | -            | -      | -         |
| J1719−04       | 18.8 ± 4.7                      | 4.5             | 17.84       | 18.10    | 65      | ?      | -            | -      | -         |
| J1734−13       | 21.8 ± 4.2                      | 5.7             | 12.07       | 10.38    | 33      | 1730−130| 26           | 0.902  | 0.53      |
| J1738+51       | 23.8 ± 4.1                      | 7.2             | 79.09       | 31.98    | 36      | 1739+522| 28           | 1.375  | 2.0       |
| J1835+59       | 65.2 ± 5.1                      | 17.9            | 88.77       | 25.09    | 9       | ?      | -            | -      | -         |

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$^{a}$Right ascension and declination (epoch 2000) of the point source in the format hhmm±dd.

$^{b}$Flux of photons with energy > 100 MeV in units of $10^{-8}$ photons cm$^{-2}$ s$^{-1}$. The uncertainty is 1σ, statistical only.

$^{c}$A measure of the statistical significance of the detection, as described in the text.

$^{d}$Galactic longitude and latitude in degrees.

$^{e}$Radius, in arcminutes, of the 95% confidence error circle.

$^{f}$The name of the radio source with which this gamma source can be identified.

$^{g}$Distance, in arcminutes, between the radio source position and the best position of the gamma source.

$^{h}$Redshift of identified radio source, if known.

$^{i}$Gamma ray luminosity in the 100 MeV to 10 GeV range, in units of $10^{48}$ erg s$^{-1}$, assuming isotropic emission, $q_0 = \frac{1}{2}$, and $H_0 = 75$ km s$^{-1}$ Mpc$^{-1}$. A $K$ correction factor of $(1 + z)^{-\frac{1}{2}}$ has been applied.
Table 2. Fluxes in different energy bands

| EGRET Position | $F_{30-100}$ | $F_{100-300}$ | $F_{300-1000}$ | $F_{>1000}$ | Spectral Index |
|----------------|--------------|---------------|----------------|------------|---------------|
| J0009+73       | 49 ± 39      | 18.8 ± 6.3    | 17.8 ± 3.5     | 8.6 ± 2.4  | −1.58 ± 0.20  |
| J0445+62       | 43 ± 29      | 16.1 ± 4.8    | 2.5 ± 1.6      | 1.4 ± 0.8  | −2.31 ± 0.39  |
| J0500+59       | < 48         | 6.5 ± 4.1     | 6.4 ± 1.8      | < 1.6      | −1.99 ± 0.52  |
| J0720+71       | < 39         | 12.0 ± 2.3    | 3.8 ± 0.9      | 1.2 ± 0.5  | −2.12 ± 0.24  |
| J0740+18       | 104 ± 28     | 13.3 ± 3.9    | < 4.0          | < 1.3      | −3.54 ± 0.83  |
| J0744+54       | < 31         | 8.5 ± 2.5     | 4.9 ± 1.2      | 0.7 ± 0.5  | −2.06 ± 0.29  |
| J0808+49       | 71 ± 17      | 11.1 ± 2.6    | 3.0 ± 1.0      | < 0.6      | −2.72 ± 0.38  |
| J0811–07       | 46 ± 35      | 21.5 ± 5.7    | 3.4 ± 2.1      | 1.7 ± 1.2  | −2.35 ± 0.55  |
| J0826+70       | 53 ± 13      | 8.6 ± 2.0     | 1.3 ± 0.6      | < 0.6      | −2.86 ± 0.36  |
| J0831+24       | < 63         | 19.8 ± 5.5    | 3.9 ± 2.0      | 1.0 ± 1.2  | −2.21 ± 0.47  |
| J1315–34       | < 37         | 7.6 ± 2.8     | 4.3 ± 1.2      | 1.4 ± 0.7  | −1.84 ± 0.30  |
| J1326–43       | 110 ± 24     | 15.5 ± 3.3    | 2.1 ± 1.1      | 0.7 ± 0.5  | −2.85 ± 0.38  |
| J1626–24       | 46 ± 22      | 12.2 ± 3.8    | 8.2 ± 1.6      | 0.5 ± 0.5  | −2.27 ± 0.24  |
| J1629–28       | < 41         | 12.2 ± 3.5    | 3.7 ± 1.3      | 0.7 ± 0.5  | −2.20 ± 0.32  |
| J1635–14       | 39 ± 22      | 5.4 ± 3.3     | 3.4 ± 1.3      | 1.1 ± 0.6  | −1.87 ± 0.49  |
| J1719–04       | 112 ± 28     | 14.6 ± 4.5    | 5.5 ± 1.7      | < 1.5      | −2.61 ± 0.42  |
| J1734–13       | 60 ± 25      | 13.4 ± 3.9    | 6.3 ± 1.6      | < 1.5      | −2.39 ± 0.27  |
| J1738+51       | 34 ± 24      | 20.3 ± 3.9    | 3.4 ± 1.2      | 1.6 ± 0.9  | −2.23 ± 0.38  |
| J1835+59       | 70 ± 25      | 32.1 ± 4.1    | 20.3 ± 2.3     | 8.1 ± 1.5  | −1.75 ± 0.11  |

\(^a\)Celestial position, as in Table 1.

\(^b\)Photon flux in four different energy bands, in units of $10^{-8}$ photons cm$^{-2}$ s$^{-1}$. Uncertainties are 1σ, statistical only. Upper limits are 95% confidence.

\(^c\)Photon number index defined by $\frac{dN}{dE} \propto E^\alpha$, based on fitting the fluxes in columns 2–5. Uncertainties are derived from $\chi^2_{\text{min}} + 2.3$. 
Table 3. Significant individual detections

| EGRET position | date                | F$_{>100}$   | spectral index |
|----------------|---------------------|--------------|----------------|
| J0009+73       | 1992 Jul 16 – Aug 6 | 72.7 ± 13.4  | −1.58 ± 0.24   |
|                | 1993 Feb 25 – Mar 9 | 36.7 ± 9.9   | −1.47 ± 0.47   |
| J0720+71       | 1992 Jan 10–23      | 22.0 ± 4.7   | −2.31 ± 0.33   |
|                | 1992 Mar 5–19       | 52.4 ± 13.2  | −2.57 ± 0.49   |
|                | 1993 Jul 13–27      | 18.7 ± 5.2   | −1.63 ± 0.47   |
| J0744+54       | 1993 Jun 29 – Jul 13| 38.1 ± 7.7   | −1.96 ± 0.29   |
|                | 1993 Jul 13–27      | 17.8 ± 5.4   | −1.78 ± 0.65   |
| J0826+70       | 1992 Jan 10–23      | 14.1 ± 3.9   | −2.62 ± 0.36   |
|                | 1992 Mar 5–19       | 37.6 ± 10.8  | −2.47 ± 0.49   |
| J1835+59       | 1991 May 30 – Jun 8 | 82.5 ± 15.4  | −1.96 ± 0.32   |
|                | 1991 Sep 12–19      | 43.2 ± 13.9  | −1.52 ± 0.47   |
|                | 1992 Mar 5–19       | 42.8 ± 13.0  | −2.22 ± 0.53   |
|                | 1992 Nov 17–24      | 92.5 ± 26.0  | −2.04 ± 0.53   |
|                | 1992 Nov 24 – Dec 1 | 94.4 ± 21.6  | −1.88 ± 0.39   |
|                | 1992 Dec 1–22       | 92.2 ± 13.7  | −1.91 ± 0.24   |
|                | 1993 Mar 9–23       | 54.0 ± 8.1   | −1.46 ± 0.21   |
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Figure Captions

Fig. 1.— Average spectra of the nineteen detected point sources with the best-fitting power-law models. The dotted lines represent $2\sigma$ upper limits.

Fig. 2.— Light curves ($E > 100$ MeV) for three of the variable sources. Each data point represents an entire CGRO viewing period.

Fig. 3.— Energy spectra of J1835+59 in individual viewing periods, with the best-fitting power-law models. The dotted lines represent $2\sigma$ upper limits.
1991 May 30 - Jun 8

1991 Sep 12-19

1992 Mar 5-19

1992 Nov 17-24

1992 Nov 24 - Dec 1

1992 Dec 1-22

1993 Mar 9-23

- Photons cm\(^{-2}\) s\(^{-1}\) MeV\(^{-1}\)