THE ASTROPHYSICAL JOURNAL, 415:L13–L16, 1993 September 20

EGRET OBSERVATIONS OF ACTIVE GALACTIC NUCLEI: 0836+710, 0454−234, 0804+499, 0906+430, 1510−089, AND 2356+196

D. J. THOMPSON,[1] D. L. BERTSCH,[1] B. L. DINGUS,[1,2] C. E. FICHTEL,[1] R. C. HARTMAN,[1] S. D. HUNTER,[1] G. KANBACH,[3] D. A. KNIFFEN,[4] Y. C. LIN,[5] J. R. MATTOX,[1,6] H. A. MAYER-HASSELWANDER,[3] P. F. MICHELSON,[5] C. VON MONTIGNY,[3] P. L. NOLAN,[5] E. J. SCHNEID,[7] AND P. SREEKUMAR[1,2]

Received 1993 March 25; accepted 1993 July 2

ABSTRACT

The Energetic Gamma Ray Experiment Telescope (EGRET) on the *Compton Gamma Ray Observatory* observed high-energy gamma rays (50 MeV $\leq E \leq$ 2000 MeV) from quasar 0836+710 ($z = 2.16$) during observations in 1992 January, near the time of an optical flare (von Linde et al. 1993). The gamma-ray spectrum can be fitted with a power law with photon number index 2.4 ± 0.2. EGRET identifies quasars 0454−234, 0804+499, 0906+430, 1510−089, and 2356+196 at a statistical significance of between 4 and 5 standard deviations.

Subject headings: gamma rays: observations — quasars: general

1. INTRODUCTION

The detection of energetic gamma rays from quasar 3C 279 by the Energetic Gamma Ray Experiment Telescope (EGRET) on the *Compton Gamma Ray Observatory* (Hartman et al. 1992) was the first of a growing number of identifications of gamma-ray–loud active galactic nuclei (AGNs). A summary of the properties of 24 identified objects is given by Fichtel et al. (1993a). Collectively, these sources appear to be core-dominated, radio loud, flat-spectrum ($\alpha > -0.5$, where $S_\nu \propto \nu^\alpha$) AGN. At least seven show apparent superluminal motion; seven are identified as optically violent variable (OVV) quasars; and five are BL Lac objects.

Quasar 0836+710 (4C 71.07) is a distant ($z = 2.16$) quasar, with strong radio emission ($S_{1.7\ \mathrm{GHz}} = 3.6$ Jy), flat radio spectrum ($\alpha = -0.33$; Kühr et al. 1981), and both superluminal and stationary components in a bright jet (Krichbaum et al. 1990; Hummel et al. 1992). Some evidence for variability in early 1992 was seen at frequencies of 32 and 90 GHz (Reich et al. 1993). Although the jet shows high radio polarization (Roberts et al. 1990), the quasar optical polarization is low, $1.1 \pm 0.5\%$ (Impey & Tapia 1990). In early 1992, strong optical variability was seen, including a rapid flare on February 16 (von Linde et al. 1993). As noted by von Linde et al., 0836+710 has the properties of a blazar, although it is often classified as a low-polarization quasar (e.g., Wiren et al. 1992). In the *ROSAT* X-ray sky survey, it was seen at a flux of 16.4×10^{-12} ergs cm^{-2} s^{-1} between 0.1 and 2.4 keV (Brinkmann, Boller, & Siebert 1993). This is about one-half the flux of 3C 279 in the same survey.

The EGRET team reported a tentative identification of 0836+710 in an IAU Circular (Fichtel et al. 1992). Details of this detection and spectral analysis are presented here. In addition, analysis of EGRET data shows evidence of detection of quasars 0454−234, 0804+499, 0906+430, 1510−089, and 2356+196 in high-energy gamma rays.

2. THE EGRET OBSERVATIONS

EGRET is the high-energy gamma-ray telescope on the *Compton Observatory*. Descriptions and capabilities of the instrument are given by Hughes et al. (1980), Kanbach et al. (1988, 1989), Nolan et al. (1992), and Thompson et al. (1993). The telescope covers the energy from about 20 MeV to over 20 GeV. EGRET records gamma-ray photons individually as electron-positron pair production events, which are processed automatically (with manual verification) to provide the arrival direction and energy of each photon. Because of the very low flux level of the high-energy gamma rays, observing periods are typically 2–3 weeks.

The principal observations of 0836+710 by EGRET took place 1992 January 10–23 and 1992 March 5–19. During each observation, a source consistent in position with 0836+710 was detected by EGRET with a statistical significance of 5 σ. The detection is based on a maximum likelihood analysis of the region (Mattox et al. 1993b), under the assumption that the background diffuse radiation is a combination of isotropic diffuse radiation plus a component due to cosmic-ray interactions in galactic atomic and molecular hydrogen gas (Bertsch et al. 1993a). Adding the two viewing periods produced a 6 σ excess with a flux above 100 MeV of $(2.1 \pm 0.4) \times 10^{-7}$ photons cm^{-2} s^{-1}.

The source location determined by the likelihood method is R.A. (J2000) = 08^{h}45′, decl.(J2000) = 71°00′, with a 68% confidence uncertainty radius of 0°.5. 0836+710 lies 0°.33 from the center of the distribution. The identification of this gamma-ray source with 0836+710 is based on the similarity of this object to the other identified high-latitude sources seen by EGRET (Fichtel et al. 1993a), all of which are strong radio sources, with all except one (CTA 102; Nolan et al. 1993b) having flat spectra. A search of the NED catalog shows that a 1° circle about the EGRET source direction contains 20 galaxies eight

[1] Code 662, NASA/Goddard Space Flight Center, Greenbelt, MD 20771.
[2] USRA Research Associate.
[3] Max-Planck-Institut für Extraterrestrische Physik, D-85748 Garching, FRG.
[4] Department of Physics, Hampden-Sydney College, Hampden-Sydney, VA 23943.
[5] W. W. Hansen Experimental Physics Laboratory and Department of Physics, Stanford University, Stanford, CA 94305.
[6] Compton Observatory Science Support Center, operated by Astronomy Programs, Computer Sciences Corporation, Greenbelt, MD 20770.
[7] Grumman Aerospace Corporation, Bethpage, NY 11714.

weak radio sources, and three infrared sources, in addition to 0836+710. The high-energy processes needed for gamma-ray production, while naturally associated with a quasar, are not generally associated with galaxies or infrared sources. Of the eight radio sources, only two have a radio flux above 35 mJy at 4.85 GHz (Becker, White, & Edwards 1991). These two, 87GB 085027.7+710053 at 49 mJy and 87GB 084018.8+703813 at 80 mJy, are both weak, steep spectrum sources, different from any of the other EGRET identifications. In the same radio survey, 0836+710 had a 4.85 GHz flux of 2436 mJy. The absence of a likely alternative, coupled with the fact that most of the EGRET sources seen at high latitudes are associated with radio-loud, flat spectrum AGN, argues strongly in favor of 0836+710 as the source of the high energy gamma radiation. It should always be kept in mind that the relatively large error boxes for gamma-ray sources admit the possibility of misidentification and that there may well be other, as yet unidentified, classes of high-energy gamma-ray sources.

The variability seen for 3C 279 in this energy range (Kniffen et al. 1993) and for the next four brightest EGRET AGN sources (Hunter et al. 1993; Bertsch et al. 1993b; Mattox et al. 1993a; Hartman et al. 1993) suggests a search for variability of 0836+710. The 2 week January viewing was divided into three parts, and the $E > 100$ MeV flux was determined for each part. The results were, in units of 10^{-7} photons $\mathrm{cm^{-2}\,s^{-1}}$: January 10–15 (2.4 ± 0.7); January 15–19, <2.1 (95% confidence); and January 19–23 (2.1 ± 0.6). The flux for the more limited 1992 March 5–19 exposure was (4.2 ± 1.1) in the same units. Although larger than the flux values determined in January, this result has sufficiently large uncertainty that evidence for time variability must be considered marginal. What is indicated is that the EGRET detection was not a single, short-duration gamma-ray flare.

3. ENERGY SPECTRUM

The energy spectrum of 0836+710 for the combined observation was derived by applying the maximum likelihood method to individual energy ranges to determine the source flux, assuming a photon spectrum with a power law of 2.2. For energies below 70 MeV, flight data have been used to adjust the instrument response compared to the ground calibrations, which were known to have limitations at low energies. Two were noted by Thompson et al. (1993): (1) the gamma-ray beam, nominally produced by inverse Compton scattering, had a bremsstrahlung component which extended to higher energies; and (2) the calibration measurements were smoothed over a broad energy range. Despite efforts to compensate, both these effects overestimated the EGRET sensitivity at low energies, where the EGRET efficiency is lowest and therefore most sensitive to perturbations. Based primarily on the continuity of the power-law energy spectrum of the Crab pulsar (see results summarized by Strong et al. 1993), the 30–50 MeV flux is increased by a factor of 2.7 ± 0.7 compared to the original calibration, and the 50–70 MeV flux is increased by 1.4 ± 0.2. These corrections, which are the same ones used in previous EGRET publications, were applied, and the uncertainties increased accordingly. The flux values were then fitted to a power-law form as described by Nolan et al. (1993a), using the instrumental response functions for EGRET (Thompson et al. 1993).

Between 50 MeV and 2000 MeV, the spectrum, shown in

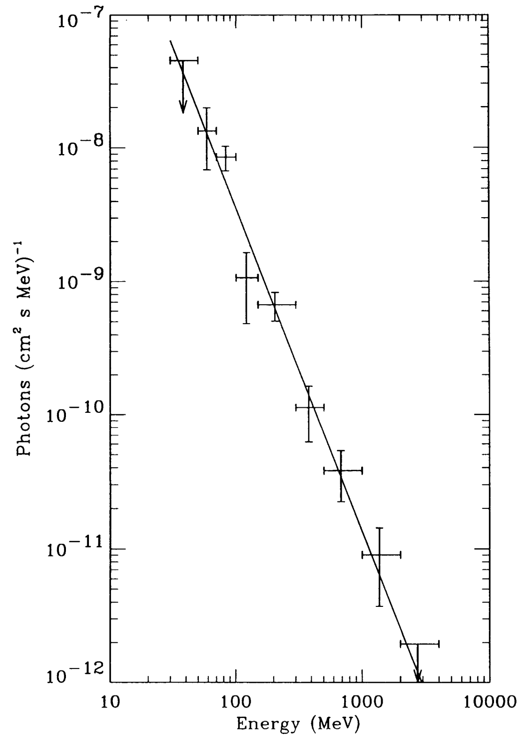

FIG. 1.—High-energy gamma-ray photon spectrum observed for quasar 0836+710 during 1992 January and 1992 March. The upper limits are 1 σ values.

Figure 1, is represented by a power law:

$$dN/dE = (9.3 \pm 1.3) \times 10^{-10} (E/174\ \mathrm{MeV})^{-2.41 \pm 0.18}\ \mathrm{photons\ cm^{-2}\ s^{-1}\ MeV^{-1}}, \quad (1)$$

with E in MeV. Verifications of the fluxes of individual energy bands showed that the assumption of a 2.2 power law differed from the final value of 2.4 by less than 10% of the statistical uncertainty. Flux values given in § 2 were determined with the 2.4 value. The 50 MeV–2000 MeV energy flux is $(1.5 \pm 0.3) \times 10^{-10}$ ergs $\mathrm{cm^{-2}\ s^{-1}}$. The power-law fit for 0836+710 is among the steeper reported for EGRET-detected AGN (3C 273: 2.39 ± 0.13, Montigny et al. 1993; 0528+134: 2.56 ± 0.09, Hunter et al. 1993; CTA 102: 2.6 ± 0.2, Nolan et al. 1993b). Many of the EGRET AGN observations report flatter spectra (Mrk 421: 1.96 ± 0.14, Lin et al. 1992; 3C 279: 1.89 ± 0.06, Kniffen et al. 1993; 0208−512: 1.69 ± 0.05, Bertsch et al. 1993b; 1633+382: 1.86 ± 0.07, Mattox et al. 1993a).

If the emission is assumed to be isotropic, the gamma-ray luminosity of 0836+710 seen by EGRET between 50 MeV and 2000 MeV is about 2.2×10^{48} ergs $\mathrm{s^{-1}}$ for $q_0 = \frac{1}{2}$ and $H_0 = 75$ km $\mathrm{s^{-1}}$ $\mathrm{Mpc^{-1}}$ in a Friedmann universe. As discussed below, however, the gamma radiation is likely to be beamed.

4. OTHER QUASAR IDENTIFICATIONS

A systematic analysis of the EGRET data from the *Compton Observatory* all-sky survey is in progress but will not be complete for some time. During the course of this analysis, several likely quasar identifications have been made which do not have the high statistical significance which have characterized the published EGRET AGN results to date. Previously, EGRET source identifications have been made on the basis of a statistical significance equivalent to 5 σ, i.e., probability that the excess occurred by chance of less than about 10^{-6}. This approach is conservative, as illustrated by the following simplified calculation. The EGRET point spread function above 100 MeV, the range covered by the principal analysis, is sufficiently broad that two weak sources within a 4 deg^2 segment of the sky would not be distinguished. Over the entire sky, then, EGRET can distinguish about 10,000 independent resolution elements near its detection threshold (Note, however, that an isolated source location can be obtained with much greater accuracy). A statistical fluctuation of 4 σ (with probability of about 1 in 15,000) is expected in only one such resolution element, except possibly near the galactic plane, where the structure in the interstellar gas makes the background determination more difficult. Regardless of association with known astrophysical objects, then, any list of 4 σ excesses seen by EGRET will probably contain at most one false detection.

A number of sources with significance between 4 and 5 σ have been seen in the parts of the sky already examined. Several of these are positionally consistent with AGNs of the type already identified. This correspondence strengthens the probability that these are source detections rather than statistical fluctuations. The number of flat-spectrum, radio-loud (flux density ≥ 0.5 Jy) extragalactic sources is less than 900 (based on an extrapolation of the Kühr et al. 1981 catalog). For this number of trials, there is less than a 10% probability that a 4 σ fluctuation will be seen at any of the positions.

Table 1 shows five of these tentative identifications. Because the detections are typically based on an excess of 50 or fewer photons above 100 MeV, derivation of a detailed energy spectrum is not practical. Some information about the spectrum can be seen from the fluxes given in Table 1 for the energy ranges 30 MeV $< E <$ 300 MeV and $E >$ 300 MeV. Despite the large uncertainties for some entries in the table, the spectra of 0454−234 and 0906+430 can be seen to be flatter than those of 0804+499 and 1510−089. For comparison, the 1991 June observation of 3C 279, which has a photon spectral index of 1.89 ± 0.06 (Kniffen et al. 1993), is shown in the table.

Notes on these objects follow.

The quasar 0454−234 is a high-polarization quasar, with measurements of 7.2% (Impey & Tapia 1990) to 27.1% (Wills et al. 1992). It is a core-dominated, flat-spectrum radio source with flux at 5 GHz of 2.06 Jy (Kühr et al. 1981).

The quasar 0804+499 (OJ 508) has polarization ranging from 8.6% (Impey & Tapia 1990) to 11.3% (Wills et al. 1992). Radio flux from this source is variable at 22 and 37 GHz (Wiren et al. 1992). VLBI observations classify it as very compact (Pearson & Readhead 1988).

The quasar 0906+430 (also known as 3C 216) is a quasar with core-dominated radio emission showing a flat spectrum and superluminal motion (Pearson & Readhead 1988, and references therein). Variability at 37 GHz was reported by Wiren et al. (1992). Its optical polarization is variable between 3% and 21% (Angel & Stockman 1980; Impey & Tapia 1990).

The quasar 1510−089 is a member of the Variable Source Survey (Wehrle et al. 1992), as are eight other EGRET-identified AGNs. Polarization measurements show 2.58% (Wills et al. 1992) to 7.8% (Impey & Tapia 1990). Worrall & Wilkes (1990) list its *Einstein* X-ray flux as 0.50 μJy.

The quasar 2356+196 is a core-dominated, flat-spectrum quasar (Preston et al. 1985). Its flux at 4.85 GHz is 705 mJy (Becker et al. 1991).

5. DISCUSSION

Any model for high-energy gamma radiation from AGNs must account for several properties seen in the EGRET detections: (1) a spectrum extending beyond 1 GeV; (2) high gamma-ray luminosity; and (3) variability of the gamma-ray flux. By themselves, the high gamma-ray luminosities required if isotropic emission is assumed ($\geq 10^{48}$ ergs s^{-1} in at least seven of the EGRET identifications) argue in favor of beamed emission (Dermer & Schlickeiser 1992). In the case of 3C 279, Maraschi, Ghisellini, & Celotti (1992) show that in order for the gamma rays to avoid absorption by photon-photon pair production, the gamma rays must be produced in a relativistic jet, independent of the details of the model. Similar constraints arise from 1633+382 (Mattox et al. 1993a).

A variety of models have been developed to interpret the EGRET observations of AGNs, most involving inverse Compton scattering of low-energy photons up to gamma-ray energies by energetic electrons in a relativistic jet (e.g., Marscher & Bloom 1992; Dermer, Schlickeiser, & Mastichiadis 1992; Maraschi, Ghisellini, & Celotti 1992; Blandford 1992). The observation of 0836+710 is consistent with such models, since this quasar has a well-defined jet. The present results, however, do not add new constraints to these models. One key test of models would be the detection of radiation between the soft X-ray and EGRET energy ranges, in order to define the shape of the Compton scattering spectrum, but such observations are generally not available.

The optical variability in 0836+710 starting in 1992 January and including a rapid flare on 1992 February 16 (von Linde et al. 1993) overlaps the period of the EGRET observations. Whether this optical outburst is related to this EGRET observation is problematic—neither the optical nor gamma-ray coverage before and after the event is sufficient to claim a

TABLE 1

EGRET 4 σ Quasar Identifications

Source	Redshift	Dates	Flux >100 MeV ($\times 10^{-7}$)	Flux >300 MeV ($\times 10^{-7}$)	Flux 30–300 MeV ($\times 10^{-7}$)
0454−234	1.009	1992 May 14–Jun 5	(1.4 ± 0.4)	(0.7 ± 0.2)	(3.3 ± 1.5)
0804+499	1.43	1992 Jan 10–23	(2.7 ± 0.8)	(0.3 ± 0.2)	(16.5 ± 3.0)
0906+430	0.67	1991 Jun 28–Jul 12	(3.2 ± 0.9)	(0.9 ± 0.4)	(4.0 ± 2.7)
1510−089	0.361	[a]	(2.7 ± 0.6)	(0.4 ± 0.3)	(8.4 ± 2.2)
2356+196	1.066	[b]	(1.7 ± 0.4)	(0.4 ± 0.2)	(6.7 ± 1.7)
Comparison with 3C 279					
3C 279	0.54	1991 Jun 15–28	(26.8 ± 1.0)	(10.1 ± 0.5)	(62.7 ± 2.7)

[a] 1991 December 12-27 and 1992 April 2–9 combined.
[b] 1992 April 23–28, May 7–14, and August 20–27 combined.

correlation. The fact that the EGRET detection is not concentrated in a small fraction of the observation probably rules out a direct association with the February 16 flare. As noted by Wagner & Witzel (1992), rapid optical variability is a characteristic of all the reported EGRET AGNs. Analogous to the luminosity and time variability discussion for gamma radiation from 3C 279 (Kniffen et al. 1993), the intraday optical variability implies production processes in the quasar jet. These observations reemphasize the need for not only simultaneous, but also contemporaneous, monitoring of potential flare sources. Existing models have no consensus on which other wavelengths should be correlated with the gamma-ray variations and whether there might be any delays.

The new quasar detections reported here also reinforce the basic conclusion of the earlier EGRET detections: the AGNs seen as high-energy gamma-ray sources at any given time represent a small subset ($<10\%$) of the candidate objects. An EGRET field of view typically includes 15–30 radio loud flat-spectrum candidates, most of which are not detected. Upper limits to many of these sources will be included in the EGRET all-sky catalog (Fichtel et al. 1993b). The detected sources span a wide range of redshifts and gamma-ray luminosities, with no obvious features to distinguish them from the many undetected candidates.

An important unanswered question is whether the gamma-ray detections represent a particular subset of AGNs or whether the EGRET results reflect time variability of a larger class. The difference between the brightest AGN detection by EGRET thus far and the limiting sensitivity of the telescope is about a factor of 50. The possibility remains, therefore, that all objects of this radio-loud flat-spectrum class are gamma-ray emitters but that they are only visible when their variable flux exceeds the EGRET threshold. The 3C 279 results (Kniffen et al. 1993) clearly demonstrate that large, rapid time variations (days to weeks) are possible for these gamma-ray sources, and they also suggest persistent emission on a scale of at least months. Quasar 0836+710 does not show strong variability in the EGRET data, and the fact that 2356+196 is only significant with the addition of three separate observations also indicates that at least some of the EGRET sources are probably visible for months. Very long-term, continuous monitoring of some of these sources, although desirable, is not practical with a satellite telescope. One important goal of future EGRET observations will be to revisit certain sky regions of interest regularly in order to examine the visibility of both known and suspected sources.

The EGRET team gratefully acknowledges support from the following: Bundesministerium fur Forschung und Technologie, grant 50 QV 9095 (MPE authors); NASA grant NAG 5-1742 (HSC); NASA grant NAG 5-1605 (SU); and NASA contract NAS 5-31210 (GAC). This work has made use of the NASA/IPAC Extragalactic Database (NED), which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

REFERENCES

Angel, J. R. P., & Stockman, H. S. 1980, ARA&A, 18, 321
Becker, R. H., White, R. L., & Edwards, A. L. 1991, ApJS, 75, 1
Bertsch, D. L., Dame, T. M., Fichtel, C. E., Hunter, S. D., Sreekumar, P., Stacy, J. G., & Thaddeus, P. 1993a, ApJ, in press
Bertsch, D. L., et al. 1993b, ApJ, 405, L21
Blandford, R. 1992, in AIP Conf. Proc. No. 280, Compton Observatory Symposium, ed. N. Gehrels & M. Friedlander (New York: AIP), in press
Brinkmann, W., Boller, Th., & Siebert, J. 1993, A&A, submitted
Dermer, C. D., & Schlickeiser, R. 1992, Science, 257, 1642
Dermer, C. D., Schlickeiser, R., & Mastichiadis, A. 1992, A&A, 256, L27
Fichtel, C. E., et al. 1992, IAU Circ. No. 5460
———. 1993a, Proc. IAU Colloq. No. 142 Particle Acceleration Phenomena in Astrophysical Plasmas, ed. E. L. Chupp (Dordrecht: Kluwer), in press
———. 1993b, in preprint
Hartman, R. C., et al. 1992, ApJ, 385, L1
———. 1993, ApJ, 407, L41
Hughes, E. B., et al. 1980 IEEE Trans. Nucl. Sci., NS-27, 364
Hummel, C. A., Muxlow, T. W. B., Krichbaum, T. P., Quirrenback, A., Schalinski, C. J., Witzel, A., & Johnston, K. J. 1992, A&A, 266, 93
Hunter, S. D., et al. 1993, ApJ, 409, 134
Impey, C. D., & Tapia, S. 1990, ApJ, 354, 124
Kanbach, G. 1989, in Gamma Ray Observatory Science Workshop Proc., ed. W. N. Johnson (NASA: GSFC), 2-1
Kanbach, G., et al. 1988, Space Sci. Rev., 49, 69
Kniffen, D. A., et al. 1993, ApJ, 411, 133
Krichbaum, T. P., et al. 1990, A&A, 230, 271
Kühr, H., Witzel, A. Pauliny-Toth, I. I. K., & Nauber, A. 1981, A&AS, 45, 367
Lin, Y. C., et al. 1992, ApJ, 401, L61
Maraschi, L., Ghisellini, G., & Celotti, A. 1992, ApJ, 397, L5
Marscher, A., & Bloom, S. 1992, in Proc. of the Gamma Ray Observatory Science Workshop, ed. C. R. Shrader, N. Gehrels, & B. Dennis (NASA Conf. Pub. 3137), 346
Mattox, J. R., et al. 1993a, ApJ, 410, 609
———. 1993b, in preparation
Montigny, C. v., et al. 1993, A&AS, 97, 101
Nolan, P. L., et al. 1992, IEEE Trans. Nucl. Sci., 39, 993
———. 1993a, ApJ, 409, 697
———. 1993b, ApJ, in press
Pearson, T. J., & Readhead, A. C. S. 1988, ApJ, 328, 114
Preston, R. A., Morabito, D. D., Williams, J. G., Faulkner, J., Jauncey, D. L., & Nicholson, G. D. 1985, AJ, 90, 1599
Reich, W., Steppe, H., Schlickeiser, R., Reich, P., Pohl, M., Reuter, H. P., Kanbach, G., & Schönfelder, V. 1993, A&A, 273, 65
Roberts, D. H., Wardle, J. F. C., Brown, L. F., Gabuzda, D. C., & Cawthorne, T. V. 1990, in Parsec Scale Radio Jets, ed. J. A. Zensus & T. J. Pearson (Cambridge: Cambridge Univ. Press), 110
Strong, A. W., et al. 1993, A&AS, 97, 133
Thompson, D. J., et al. 1993, ApJS, 86, 629
von Linde, J., Borgeest, U., Schramm, K.-J., Graser, U., Heidt, J., Hopp, U., & Wagner, S. 1993, A&A, in press
Wagner, S. J., & Witzel, A. 1992, in The Nature of Compact Objects in AGN, ed. A. Robinson et al. (Cambridge: Cambridge Univ. Press), in press
Wherle, A. E., Cohen, M. H., Unwin, S. C., Aller, H. D., Aller, M. F., & Nicolson, G. 1992, ApJ, 391, 589
Wills, B. J., Wills, D., Breger, M., Antonucci, R. R. J., & Barvainis, R. 1992, ApJ, 398, 454
Wiren, S., Valtoja, E., Terasranta, H., & Kotilainen, J. 1992, AJ, 104, 1009
Worrall, D., & Wilkes, B. J. 1990, ApJ, 360, 396