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3EG J2016+3657: CONFIRMING AN EGRET BLAZAR BEHIND THE GALACTIC PLANE

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ABSTRACT

We recently identified the blazar-like radio source G74.87+1.22 (B2013+370) as the counterpart of the high-energy γ-ray source 3EG J2016+3657 in the Galactic plane. However, since most blazar identifications of EGRET sources are only probabilistic in quality even at high Galactic latitude, and since there also exists a population of unidentified Galactic EGRET sources, we sought to obtain additional evidence to support our assertion that 3EG J2016+3657 is a blazar. These new observations consist of a complete set of classifications for the 14 brightest *ROSAT* X-ray sources in the error circle, of which B2013+370 remains the most likely source of the γ-rays. We also obtained further optical photometry of B2013+370 itself which shows that it is variable, providing additional evidence of its blazar nature. Interestingly, this field contains, in addition to the blazar, the Crab-like supernova remnant CTB 87, which is too distant to be the EGRET source, and three newly discovered cataclysmic variables, all five of these X-ray sources falling within 16′ of each other. This illustrates the daunting problem of obtaining complete identifications of EGRET sources in the Galactic plane.

Subject headings: gamma rays: observations — novae, cataclysmic variables — stars: Wolf-Rayet — X-rays: general

1. INTRODUCTION

In a recent multiwavelength study of the region in Cygnus containing the unidentified COS–B γ-ray source 2CG 075+00, Mukherjee et al. (2000) noted that two discrete EGRET sources, 3EG J2021+3716 and 3EG J2016+3657, are consistent with the COS–B location (Pollack et al. 1985) and that the weaker of these two, 3EG J2016+3657, is coincident with a blazar-like radio source B2013+370 (G74.87+1.22), which they proposed as its most likely identification. The temporal variability and broadband spectral properties of 3EG J2016+3657 are consistent with those of other EGRET blazars. Leaving aside the novelty of a blazar located behind the Galactic plane, the identification of any particular EGRET source with a blazar is generally a probabilistic claim, since only a small fraction of known blazars were seen to be active in γ-rays during the EGRET survey. Furthermore, there is clearly a Galactic population of γ-ray sources at low latitude that are mostly unidentified. The *a posteriori* probability that the blazar B2013+370 is the correct identification of the EGRET source 3EG J2016+3657 was estimated following the method of Mattox et al. (1997) as $\approx$98.8%, even though the *a priori* probability that EGRET will detect a random radio source having the properties of B2013+370 is only 5.8%. While the distinction between these two types of probability should be clear, they are sometimes confused, causing serious mistakes to be made in diverse fields of inquiry, as was illustrated by Good (1995).

In this particular case, the reliability of the identification of B2013+370 with 3EG J2016+3657 is as good as that of the well-identified EGRET blazars listed by Mattox et al. (1997), but it is slightly diminished by the location of 3EG J2016+3657 in the Galactic plane, where an increased density of γ-ray sources resides that have proven even more difficult to identify than the blazars. One way to further test the association of B2013+370 with 3EG J2016+3657 is to conduct a deep search for plausible, alternative γ-ray source counterparts within the error circle. In the case of 3EG J2016+3657, we report such an investigation here, consisting of complete optical spectroscopic identifications of all soft and hard X-ray sources in the vicinity of 3EG J2016+3657 to faint limits. By process of elimination, this leaves B2013+370 as the most likely counterpart of 3EG J2016+3657.

2. X-RAY OBSERVATIONS

The error circle of 3EG J2016+3657 was covered by several imaging X-ray observations, including the *Einstein* IPC (Wilson 1980), the *ROSAT* PSPC, the *ROSAT* HRI, and the *ASCA* GIS. The results of these observations were described by Mukherjee et al. (2000). In Figures 1 and 2, we show the *ROSAT* PSPC and HRI images with X-ray sources numbered as in that paper. Table 1 gives positions of the brightest sources in the HRI image, or in the PSPC in the case of sources not covered by the HRI. The uncertainties in position are statistical only and do not include any systematic offsets (see below). The limiting HRI count rate of $\approx 1.4 \times 10^{-3}$ s^{-1} corresponds to an unabsorbed 0.1–2.4 keV flux of 6.8×10^{-14} ergs cm^{-2} s^{-1} in the case of a thermal plasma of temperature $T = 3 \times 10^6$ K and $N_{\rm H} = 3 \times 10^{20}$ cm^{-2}, as might be appropriate for stellar coronal sources, or 9.5×10^{-13} ergs cm^{-2} s^{-1} in the case of a $\Gamma = 2$ power law and the total Galactic $N_{\rm H}$ of 1.3×10^{22} cm^{-2}, which might apply to distant Galactic or extragalactic sources.

3. OPTICAL OBSERVATIONS

Of the 14 X-ray sources in Table 1, eight were identified in Mukherjee et al. (2000). We were able to complete the identifications either from positional coincidences with

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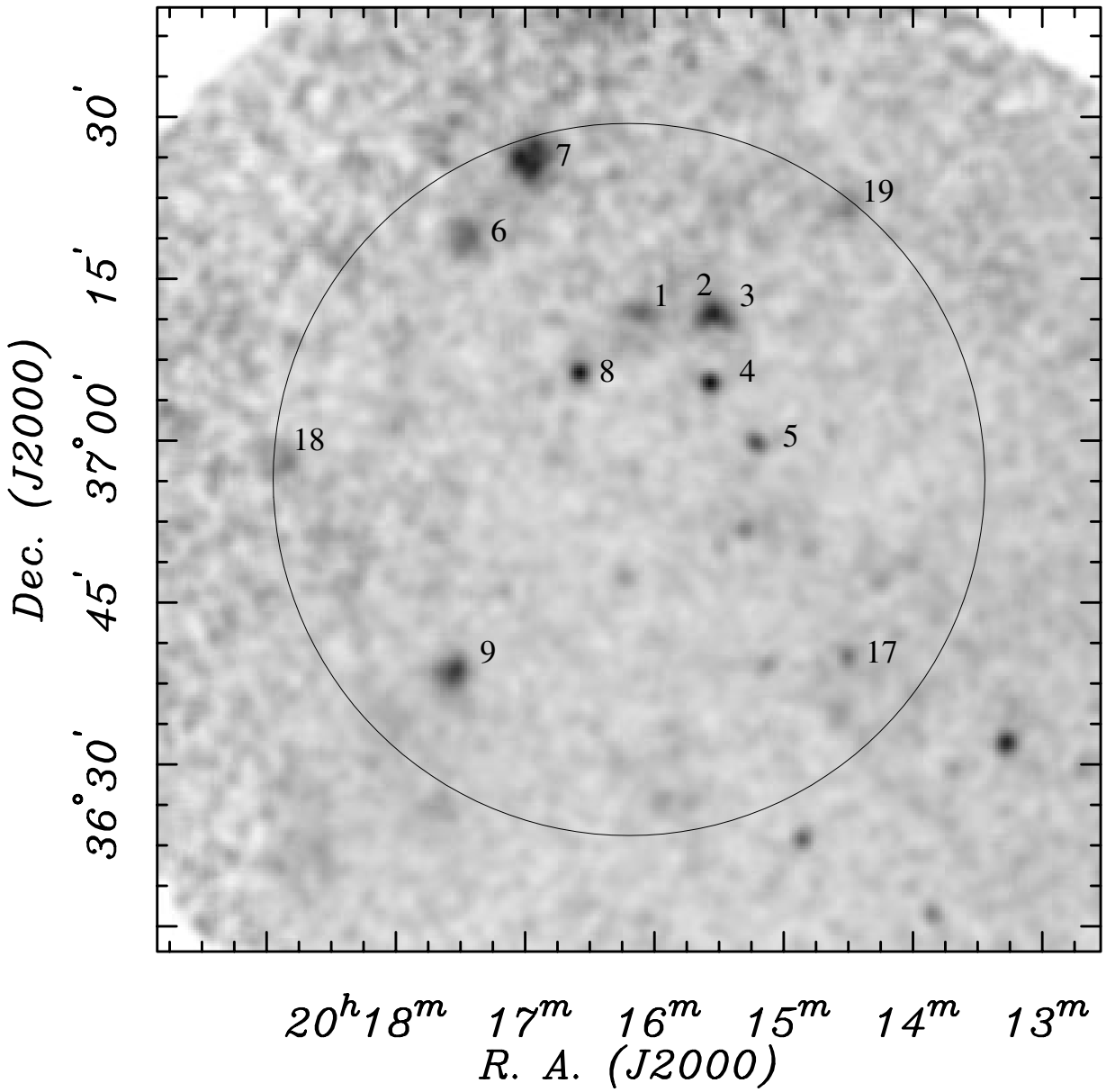

FIG. 1.—*ROSAT* PSPC image and 95% confidence error circle of 3EG J2016+3657, taken from Mukherjee et al. (2000). The X-ray sources are numbered as in that paper and in Table 1. All sources are pointlike except for source 1, which is the SNR CTB 87. The point-spread function radius increases toward the edge.

bright stars (Fig. 3) or by obtaining spectra of the nearest optical object to the X-ray position using CCD spectrographs on either the Michigan-Dartmouth-MIT (MDM) 2.4 m telescope or the Kitt Peak National Observatory (KPNO) 2.1 m telescope in 2000 June. The only source with no optical counterpart is the well-known supernova remnant CTB 87. Figure 4 shows CCD images from the 2.4 m telescope that can serve as finding charts for the fainter counterparts, and Figure 5 shows our collection of optical spectra. Table 1 lists *R* magnitudes measured either from our CCD images for the faint objects, or from the USNO-A2.0 catalog (Monet et al. 1998) for the brighter stars. Optical positions were also taken from the USNO-A2.0 or from the SIMBAD database. The agreement between optical and X-ray positions is excellent. Figure 6 illustrates the offsets between X-ray and optical positions. There is evidently a systematic error in the HRI aspect solution of $\approx 4''$, which accounts for the tight group of sources displaced from the origin with small statistical errors. Such a systematic error is typical for *ROSAT* and not of concern here.

4. COMMENTS ON INDIVIDUAL SOURCES

Entries in Table 1 and in Figures 1 and 2 follow the numbering scheme in Mukherjee et al. (2000). In this section, we give details on each of these sources using the same identifying numbers.

1. *CTB 87.*—This well-studied supernova remnant (SNR), also known as G74.9+1.2, is an extended radio source with a flat spectrum, filled center, and high polarization. It is comparable to the Crab in its radio properties (Duin et al. 1975; Weiler & Shaver 1978; Wilson 1980), but it is characterized as a "non–crab-like plerion" by Woltjer et al. (1997), who enumerate a class that is weak in X-rays

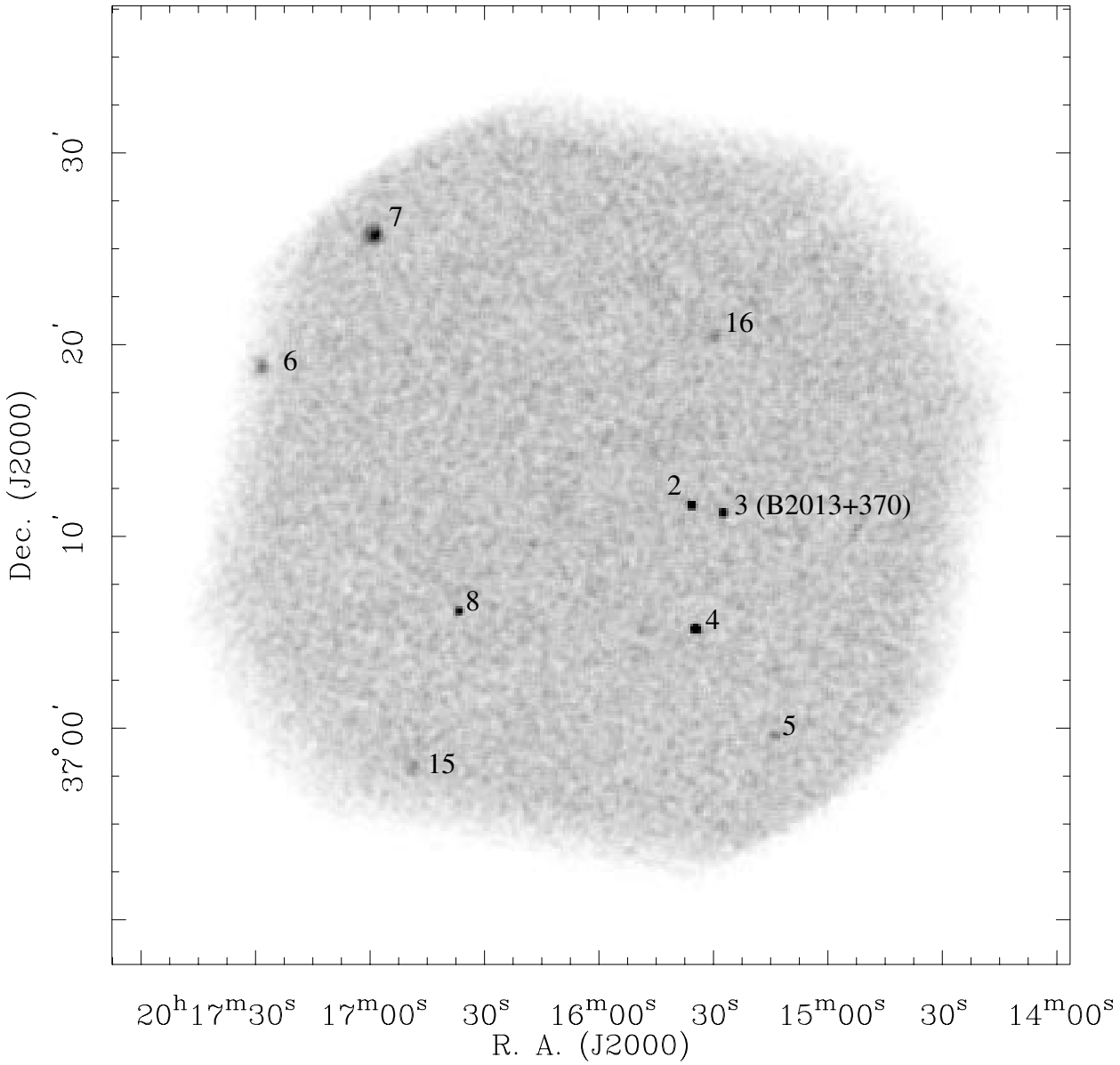

FIG. 2.—*ROSAT* HRI image covering part of the 95% confidence error circle of 3EG J2016+3657, taken from Mukherjee et al. (2000). X-ray sources are numbered as in Fig. 1.

relative to radio and lacks an observed pulsar, at least so far. Its H I absorption spectrum indicates a distance of 12 kpc. An association of an SNR with an EGRET source can be hypothesized as due to either an embedded γ-ray pulsar, of which several are known, or to the decay of π^0s created in the SNR shock (Montmerle 1979; Aharonian, Drury, & Völk 1994), a theory to account for unidentified EGRET sources which has yet to be verified observationally.

Wilson (1980) argued that the X-ray luminosity of CTB 87, which is 100 times less than that of the Crab, implies that the spindown power of the embedded pulsar must be correspondingly less, $I\Omega\dot{\Omega} \sim 4 \times 10^{36}$ $(d/12 \text{ kpc})^2$ ergs s^{-1}. It would require a factor of 2 more power than this to be emitted in the EGRET energy band alone to account for the EGRET measured flux of $\simeq 5 \times 10^{-10}$ ergs cm^{-2} s^{-1} from 3EG J2016+3657. This argument is insensitive to distance as long as the X-ray synchrotron nebula is considered a calorimeter of the present pulsar power. Alternatively, Gaensler, Dickel, & Green (2000) suggested that the spindown power of the pulsar in G74.9+1.2 is much larger, $\sim 1.8 \times 10^{38}$ergs s^{-1}, based on the similarity of its radio luminosity to that of the Crab. These differences of opinion attest to our incomplete understanding of the physics of pulsar synchrotron nebulae. For the purposes of this investigation, it matters little because the Crab pulsar itself channels only about 0.2% of its spindown power into γ-rays. Even the larger power estimate of Gaensler et al. (2000) is less than half the Crab spindown power, and the distance is 6 times greater. The flux from such a pulsar would then be at most 1/70 times that of the Crab. EGRET would not detect such a source, especially in the confusing Cygnus region.

If instead, CTB 87 hosts a Geminga-like pulsar whose energy is no longer trapped by the nebula and which is maximally efficient in the production of γ-rays, then we would expect a spindown power of only $\sim 3 \times 10^{34}$ ergs s^{-1}. Such a pulsar is inadequate to explain the flux of 3EG J2016+3657 unless it were at $d < 500$ pc, which is certainly

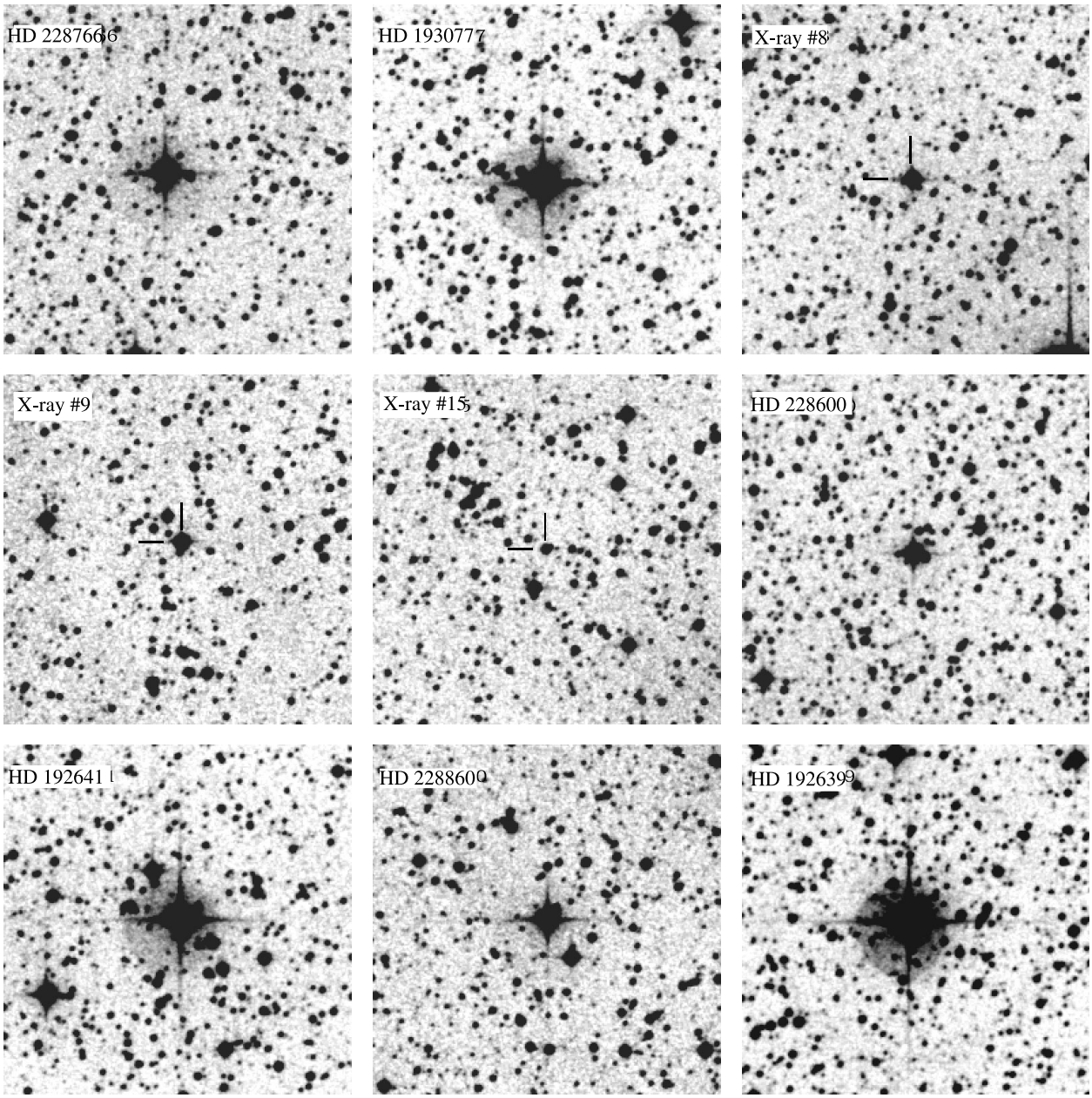

FIG. 3.—Finding charts from the Digitized Palomar Observatory Sky Survey II red plates for the bright stars which are X-ray sources in the field of 3EG J2016+3657. Each chart is 4.′3 × 4.′3. North is up, and east is to the left.

ruled out by the H I and X-ray measured column density to the SNR. Thus, the remnant CTB 87 is unlikely to be responsible for the EGRET source 3EG J2016+3657. It is doubtful that any pulsar at a distance of 12 kpc was detected by EGRET.

2. RX J2015.6+2711.—This source has the optical spectrum of a cataclysmic variable (CV), probably of the magnetic type since its He II λ4686 emission line is as strong as Hβ λ4861 (see Fig. 5). The optical spectrum is clearly reddened, so it may be more distant than 1 kpc. There is no reason to suppose that this, or any other cataclysmic variable, is the source of 3EG J2016+3657, as none of the dozens of nearby CVs have been detected by EGRET (Barrett et al. 1995; Schlegel et al. 1995).

3. B2013+370.—The 2 Jy radio source B2013+370 (G74.87+1.22) is a well-studied, compact, flat-spectrum radio source that was first noticed during the study of the SNR CTB 87 (Duin et al. 1975). Its multiwavelength properties were compiled by Mukherjee et al. (2000), who noted in agreement with previous authors that it has the standard radio properties of a blazar, but now with the addition of optical and X-ray evidence. Although the Galactic extinction in this direction is considerable, $E(B-V) = 1.82$ mag (Schlegel, Finkbeiner, & Davis 1998), we were able to get excellent R-band images of it using the MDM 2.4 m telescope on 2000 April 24 and again on 2000 July 17. The seeing on both occasions was $\approx 0.''75$. An unresolved object appears in these images less than 1″ from the VLBI radio position (Duin et al. 1975), and it is clearly variable, as shown in Figure 4. Using Landolt (1992) standard stars, we measure calibrated magnitudes of $R = 21.40 \pm 0.04$ on April 24 and $R = 21.82 \pm 0.05$ on July 17. (A preliminary magnitude of $R = 21.6 \pm 0.2$ was reported by Mukherjee et al. 2000 for the April image, which at

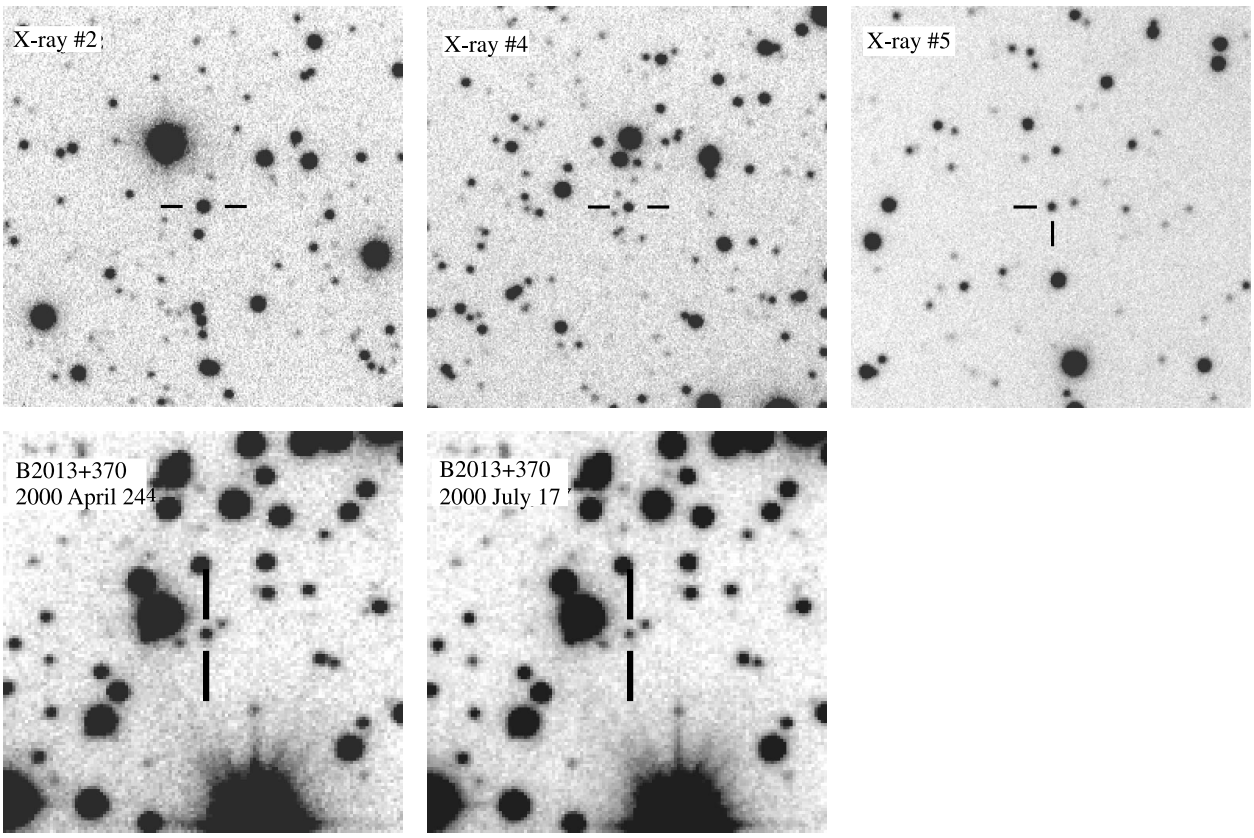

FIG. 4.—*R*-band CCD images of faint objects which are counterparts of X-ray sources in the field of 3EG J2016+3657. The top three images are 70″ × 70″, and the magnitudes of their cataclysmic variable identifications are given in Table 1. The two images of the blazar B2013+370 are each 35″ × 35″ and illustrate its change from $R = 21.40 \pm 0.04$ on 2000 April 24, to $R = 21.81 \pm 0.05$ on 2000 July 17. North is up, and east is to the left.

that time was still uncalibrated). After correcting for Galactic absorption, these magnitudes become $R = 16.53$ and $R = 16.95$, respectively. These results are in accord with the multiwavelength spectral and variability properties of typical blazars.

We note that this object was also probably detected in the *I* band by Geldzahler, Shaffer, & Kühr (1984), who found $I = 19.5 \pm 0.5$, while also noting that it appeared extended. Our *R*-band images show that the object closest to the radio position is unresolved and variable, while a

TABLE 1

ROSAT HRI X-RAY SOURCES IN THE FIELD OF 3EG J2016+3657

	X-RAY POSITION				OPTICAL POSITION			
NUMBER[a]	R.A.	Decl.	UNC.[b] (arcsec)	COUNTS (ks^{-1})	R.A.	Decl.	*R* (mag)	ID
1[c]	20 16 08.44	+37 11 28.0	± 11.	19.2 ± 3.2	...	...	...	CTB 87
2	20 15 36.63	+37 11 25.1	± 0.7	4.7 ± 0.4	20 15 36.98	+37 11 23.2	17.5	CV
3	20 15 28.35	+37 11 01.6	± 0.7	4.0 ± 0.4	20 15 28.76	+37 10 59.9	21.8	B2013+370
4	20 15 35.71	+37 04 59.0	± 0.7	7.3 ± 0.5	20 15 36.10	+37 04 56.5	18.6	CV
5	20 15 14.87	+36 59 22.2	± 2.2	2.4 ± 0.7	20 15 14.73	+36 59 24.4	18.3	CV
6[c]	20 17 28.94	+37 18 27.0	± 10.	31.1 ± 3.6	20 17 29.70	+37 18 31.1	9.3	HD 228766
7	20 16 59.77	+37 25 26.5	± 1.3	14.2 ± 1.1	20 17 00.03	+37 25 23.8	8.1	HD 193077
8	20 16 37.37	+37 05 55.4	± 1.2	3.2 ± 0.4	20 16 37.55	+37 05 55.0	11.3	G star
9[c]	20 17 36.05	+36 37 56.1	± 10.	34.1 ± 2.5	20 17 35.86	+36 38 02.3	11.2	K star
15[c]	20 16 48.94	+36 57 47.1	± 6.8	3.0 ± 1.2	20 16 49.00	+36 57 47.9	14.2	K star
16	20 15 30.62	+37 20 06.6	± 2.0	1.4 ± 0.4	20 15 30.78	+37 20 03.1	10.8	HD 228600
17[c]	20 14 31.94	+36 39 40.1	± 2.0	6.6 ± 0.9	20 14 31.77	+36 39 39.6	8.0	HD 192641
18[c]	20 18 52.50	+36 57 43.0	± 10.	21.7 ± 3.0	20 18 51.55	+36 57 41.4	10.7	HD 228860
19[c]	20 14 30.00	+37 21 15.0	± 10.	15.7 ± 6.3	20 14 30.43	+37 21 13.8	7.2	HD 192639

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

[a] The source numbers follow those of Mukherjee et al. (2000).

[b] 90% confidence uncertainty in each coordinate.

[c] X-ray source data from the *ROSAT* PSPC. We assume a positional uncertainty of 10″ in cases where no value was supplied by the standard analysis.

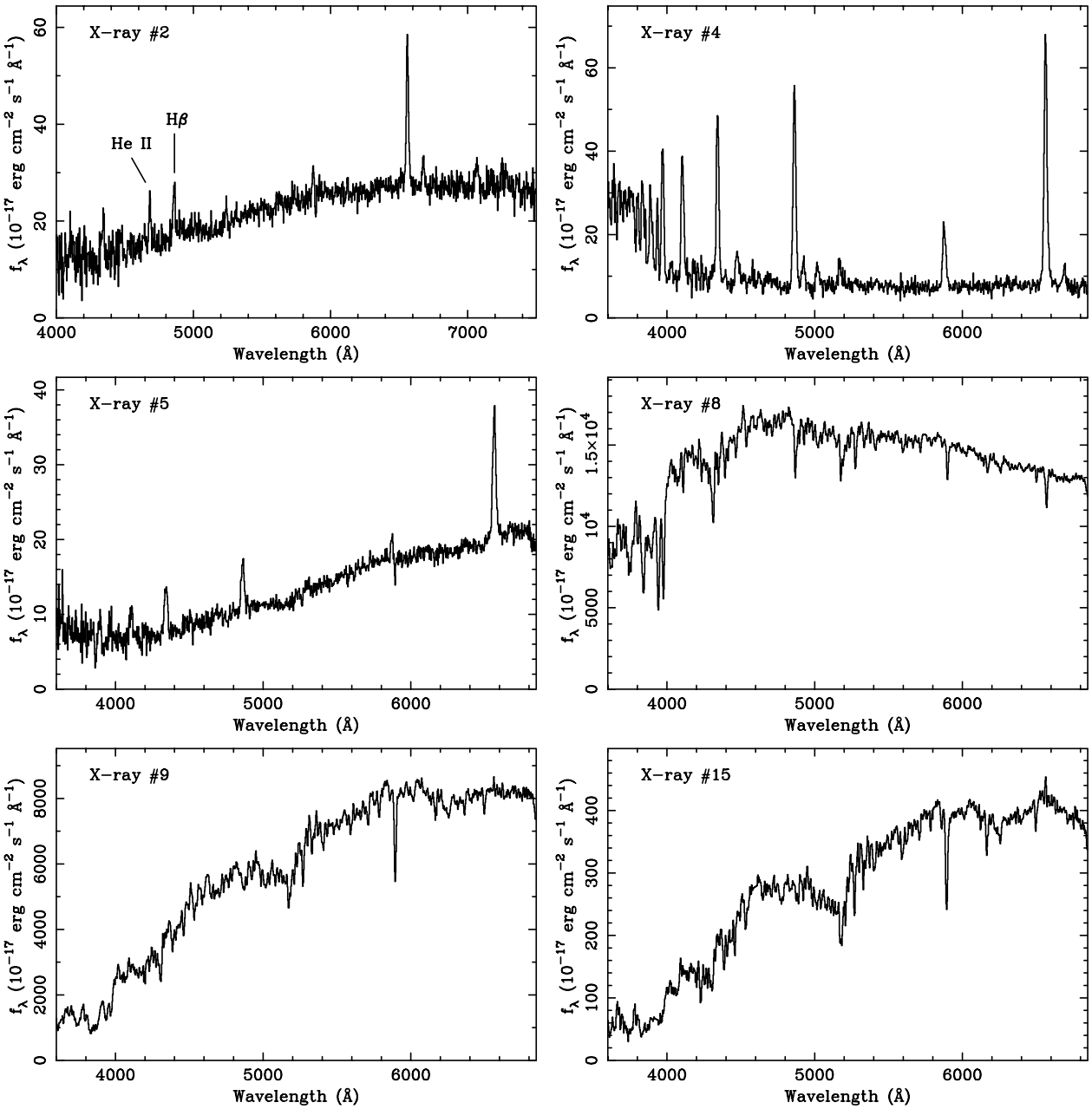

FIG. 5.—Spectra of the six fainter optical counterparts of X-ray sources in the field of 3EG J2016+3657, obtained on either the MDM 2.4 telescope or the KPNO 2.1 m telescope.

faint star 1.″7 to the northwest of it was likely responsible for the extended appearance in the Geldzahler et al. image.

Mukherjee et al. (2000) argued that B2013+370 has all the characteristics of a compact, extragalactic, nonthermal radio source that are typical of the many extragalactic sources seen by EGRET. The reader is referred to that paper for the details. The detection of optical variability reported here bolsters those arguments. Although there is only weak evidence for γ-ray variability from 3EG J2016+3657, the data allow variability by at least a factor of 2, which is greater than the optical amplitude seen so far.

4. RX J2015.4+2711.—This source appears to be a garden-variety CV with strong emission lines of H and He I, and is probably the closest of the three CVs discovered in this study because it is the least reddened.

5. RX J2015.6+2704.—This is another reddened CV, with emission lines of H and weak He I. It is interesting to note that the expected number of CVs in one *ROSAT* HRI field in the Galactic plane is ≈ 1, assuming a local space density of 6×10^{-6} pc^{-3} (Patterson 1984), and that in the Galactic plane *ROSAT* can detect them to a distance of ~ 2 kpc. Therefore, the probability of detecting at least three CVs in one field is not so small, ≈ 0.20. Based on a survey of *Einstein* X-ray sources in the Galactic plane, Hertz et al. (1990) claimed that the space density of CVs is several times higher, $\simeq (2-3) \times 10^{-5}$ pc^{-3}, which would also be consistent with our result.

6. HD 228766.—Originally classified as WN7, this is actually a binary O star system (Hiltner 1951; Walborn 1973) with a period of 10.74 days, consisting of an O7.5

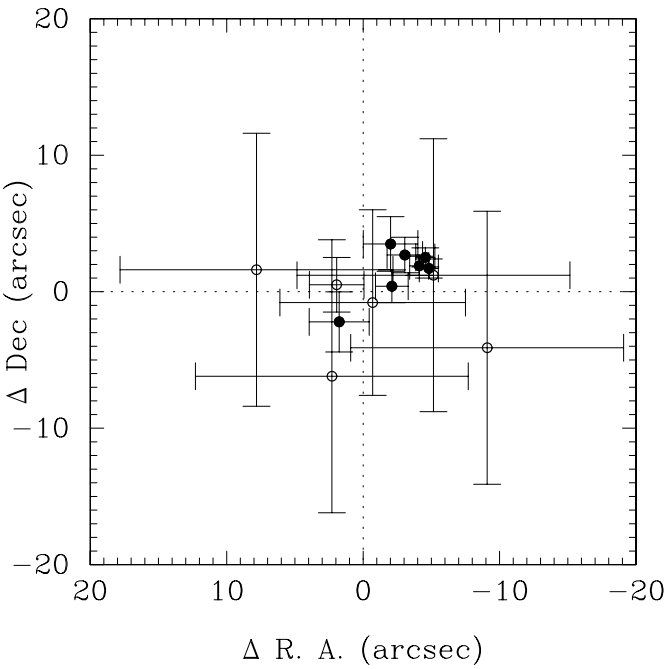

FIG. 6.—Offsets between the X-ray and optical positions of the 13 pointlike X-ray sources in Table 1. Filled circles and their associated 90% confidence error bars are from the *ROSAT* HRI; open circles and their 1 σ error bars are from the *ROSAT* PSPC.

primary and an O5.5f secondary (Massey & Conti 1977). A minimum mass of 16 $M_\odot$ for each star was derived by Massey & Conti, who also estimated a mass-loss rate of 10^{-5} $M_\odot$ yr^{-1} from the Of star. Such high mass-loss rates are of interest in relation to the theory of White & Chen (1992), which predicts π^0-decay γ-rays of as much as 10^{35} ergs s^{-1} from shocks in the densest parts of the stellar wind. However, at the distance of 3.5 kpc (Chlebowski, Harnden, & Sciortino 1989), such a flux from HD 228766 is not likely to be detectable by EGRET. It is variable between two X-ray observations separated by 5 months.

7. HD 193077.—Also cataloged as WR 138 (van der Hucht et al. 1981), this star is of subtype WN5+OB. A probable binary period of $\simeq$4.2 yr was measured by Annuk (1990). It is thought to be a member of the Cyg OB1 association at $d = 1800$ pc (Hamann, Koesterke, & Wessolowski 1993). These authors also derived a mass-loss rate of 2.5 $\times$ 10^{-5} $M_\odot$ yr^{-1} and a terminal wind velocity of 1500 km s^{-1}. The association of WR 138 with 3EG J2016+3657 was suggested by Kaul & Mitra (1997) and by Romero, Benaglia, & Torres (1999). As the brightest *ROSAT* X-ray source in the field of 3EG J2016+3657, this is perhaps the best of the Wolf-Rayet candidates, although it is near the edge of the error circle.

8. RX J2016.6+3705.—This is a G star of magnitudes $R = 11.3$ and $B = 12.4$ that has a typical X-ray flux for its spectral type.

9. RX J2017.6+3637.—This is a K star of magnitude $R = 11.2$ that has a typical X-ray flux for its spectral type.

15. RX J2016.8+3657.—This late K star shows a hint of Hα emission in its spectrum, which may be associated with enhanced coronal X-ray emission.

16. HD 228600.—This is a star of unknown spectral type with magnitudes $B = 10.49$ and $V = 10.12$.

17. HD 192641.—This is WR 137, a binary of type WC7+OB. It is a weak X-ray source, which we list in Table 1 because it was also suggested as a possible WR counterpart of 3EG J2016+3657 by Kaul & Mitra (1997) and Romero et al. (1999).

18. HD 228860.—This member of the Cyg OB1 association is of spectral type B0.5 IV (Humphreys 1978). It is almost certainly the X-ray source at the eastern edge of the EGRET error circle, even though its position is poorly determined this far from the axis. It is variable between two observations separated by 5 months.

19. HD 192639.—The emission lines in this supergiant star of spectral type O8 I(f) vary on time scales of several days (Rauw & Vreux 1998). It is also a variable X-ray source.

5. CONCLUSIONS

As previously concluded by Mukherjee et al. (2000), we still find that the most likely identification for 3EG J2016+3657 is the blazar B2013+370. We have obtained additional identifications of X-ray sources in the field to a flux limit of 6.8×10^{-14} ergs cm^{-2} s^{-1} for nearby, relatively unabsorbed sources, or 9.5×10^{-13} ergs cm^{-2} s^{-1} for extragalactic or very distant hard X-ray sources. The SNR CTB 87 is disfavored because of its extreme distance and the fact that energetic pulsars are known to channel only a small fraction of their power, $<1\%$, into high-energy γ-rays. Cataclysmic variables, which comprise the majority of the newly identified sources in this field, are not known γ-ray emitters. Similarly, while there are several Wolf-Rayet and binary O stars in this field, it remains to be demonstrated that such stars contribute at all to the EGRET source population.

Our complete set of optical identifications also rules out the alternative of a Geminga-like pulsar at a distance less than 500 pc, which would be the maximum distance at which it could be responsible for the γ-ray flux of 3EG J2016+3657. The *ROSAT* PSPC flux limit for identified sources in this field for an assumed blackbody spectrum of $T = 5 \times 10^5$ K and $N_H = 3 \times 10^{20}$ cm^{-2} is 2×10^{-13} ergs cm^{-2} s^{-1}, or 50 times fainter than Geminga. Only if N_H is as high as 10^{21} cm^{-2} could such a pulsar have escaped detection. Even then, the γ-ray properties of 3EG J2016+3657 (steep spectrum, variable) are unlike those of intermediate age pulsars.

Since there is a bona fide blazar available for identification with 3EG J2016+3657, it remains our candidate of choice. The probability of finding an EGRET blazar only 1° from the Galactic equator can be estimated from the total number of relatively well-identified blazars, 66, in the Third EGRET Catalog (Hartman et al. 1999). This implies an expectation of just one blazar within the zone $-1° < b < +1°$. Thus, we should not be surprised to have found this one, but we should not expect that blazars will make a significant contribution to the low-latitude EGRET population.

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REFERENCES

Aharonian, F. A., Drury, L. O'C., & Völk, H. J. 1994, A&A, 285, 645
Annuk, K. 1990, Acta Astron., 40, 267
Barrett, P., Schlegel, E., de Jager, O. C., Chanmugam, G. 1995, ApJ, 450, 334
Chlebowski, T., Harnden, F. R., Jr., & Sciortino, S. 1989, ApJ, 341, 427
Duin, R. M., et al. 1975, A&A, 38, 461
Gaensler, B. M., Dickel, J. R., & Green, A. J. 2000, ApJ, 542, 380
Geldzahler, B. J., Shaffer, D. B., & Kühr, H. 1984, ApJ, 286, 284
Good, I. J. 1995, Nature, 375, 541
Hamann, W.-R., Koesterke, L., & Wessolowski, U. 1993, A&A, 274, 397
Hartman, R. C., et al. 1999, ApJS, 123, 79
Hertz, P., Bailyn, C. D., Grindlay, J. E., Garcia, M. R., Cohn, H., & Lugger, P. M. 1990, ApJ, 364, 251
Hiltner, W. A. 1951, ApJ, 113, 317
Humphreys, R. M. 1978, ApJS, 38, 309
Kaul, R. K., & Mitra, A. K. 1997, in AIP Conf. Proc. 410, Proc. Fourth Compton Symp., ed. C. D. Dermer, M. S. Strickman, & J. D. Kurfess (New York: AIP), 1271
Landolt, A. 1992, AJ, 104, 340
Massey, P., & Conti, P. S. 1977, ApJ, 218, 431
Mattox, J. R., et al. 1997, ApJ, 481, 95
Monet, D., et al. 1998, The USNO-A2.0 Catalog (Washington, DC: US Naval Obs.)
Montmerle, T. 1979, ApJ, 231, 95
Mukherjee, R., Gotthelf, E. V., Halpern, J., & Tavani, M. 2000, ApJ, 542, 740
Patterson, J. 1984, ApJS, 54, 443
Pollock, A. M. T., et al. 1985, A&A, 146, 352
Rauw, G., & Vreux, J.-M. 1998, A&A, 335, 995
Romero, G. E., Benaglia, P., & Torres, D. F. 1999, A&A, 348, 868
Schlegel, D. J., Finkbeiner, D. P., & Davis, M. 1998, ApJ, 500, 525
Schlegel, E., Barrett, P. E., de Jager, O. C., Chanmugam, G., Hunter, S., & Mattox, J. 1995, ApJ, 439, 322
van der Hucht, K. A., et al. 1981, Space Sci. Rev., 28, 307
Walborn, N. R. 1973, ApJ, 186, 611
Weiler, K. W., & Shaver, P. A. 1978, A&A, 70, 389
White, R. L., & Chen, W. 1992, ApJ, 387, L81
Wilson, A. S. 1980, ApJ, 241, L19
Woltjer, L., Salvati, M., Pacini, F., & Bandiera, R. 1997, A&A, 325, 295