LOW-LATITUDE GAMMA-RAY SOURCES: CORRELATIONS AND VARIABILITY

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Abstract
A review of the main characteristics of low-latitude sources in the third EGRET catalog is presented. There are 75 unidentified gamma-ray sources detected by EGRET at $|b| < 10^\circ$. About a half of these sources are spatially correlated with potential galactic gamma-ray emitters such as supernova remnants, OB associations and early-type stars with very strong stellar winds. The other half is formed by sources without positional correlation with known galactic objects capable to generate a gamma ray flux significant enough as to be detected by EGRET. A variability analysis shows that this second group of sources contains several objects with high levels of gamma-ray variability. These variable sources resemble very much the AGNs detected by EGRET, but without their typical strong radio emission. To establish the nature of these sources is one of the most urgent problems of high-energy astrophysics.

1. INTRODUCTION
The existence of a galactic population of gamma-ray sources is a well-known fact since the early days of the COS-B experiment (Bignami & Hermens 1983). The ESA COS-B satellite was launched on August 9, 1975, and was operational until April 25, 1982. The second COS-B catalog contains 25 sources, most of which are located very close to the galactic plane (Swanenburg et al. 1981). Although two low-latitude sources were soon identified with pulsars (Crab and Vela), the nature
of the remaining, presumably galactic sources, stood uncertain. Montmerle (1979) presented the first correlation study for these high-energy sources. He found that about 50% of the unidentified COS-B detections lie in regions containing young objects like massive stars and supernova remnants. He estimated that the chance probability of these associations was as low as $\sim 10^{-4}$ and suggested that the gamma-rays could be the result of $\pi^0$-decays originated in hadronic interactions between locally accelerated cosmic rays and ambient gas. The cosmic rays would be produced by a two-step process: low-energy protons or nuclei are firstly accelerated by OB stars and injected at supernova shock fronts where they are subsequently re-accelerated up to high-energies by Fermi mechanism. This scenario predicted by first time the positional correlation between low-latitude gamma-ray sources and star forming regions, a correlation that would be tested by several authors, using increasingly improved data, in the years to come.

A major breakthrough in the study of galactic gamma-ray sources was achieved with the advent of NASA’s Compton Gamma-Ray Observatory (CGRO) in 1991. During its lifetime, the Energetic Gamma-Ray Experiment Telescope (EGRET) detected 271 point sources, 170 of which have not been clearly identified yet (Hartman et al. 1999). About a half of these unidentified sources are located at low galactic latitudes and many studies looking for correlations with known galactic populations have been performed in recent years. For instance, Sturmer & Dermer (1995) and Sturmer et al. (1996) have investigated the correlation between gamma-ray sources in the first two EGRET catalogs (Thompson et al. 1995, 1996) and supernova remnants, finding statistical support for the idea that some remnants could be gamma-ray emitters. This idea is also supported by several particular cases studied in detail by Esposito et al. (1996) and Combi et al. (1998, 1999, 2001), where the gamma-ray emission seems to come from molecular clouds overtaken by the expanding shell of nearby remnants.

The correlation between EGRET sources and star forming regions was confirmed by Kaaret & Cottam (1996) and Yadigaroglu & Romani (1997), using data from the second EGRET catalog. Contrary to the original hypothesis of Montmerle, these authors suggested that most of the low-latitude sources could be pulsars. This suggestion is supported by the discovery of several new gamma-ray pulsars since the COS-B original identifications (there are at least seven pulsars detected so far, see Thompson 1996) as well as by population studies (e.g. Yadigaroglu & Romani 1995, Zhang et al. 2000, McLaughlin & Cordes 2000). The high level of variability and peculiar spectral features presented by some low-latitude unidentified sources, however, is quite at odds with the hy-
pothesis of a unique population of galactic gamma-ray emitters and seem to open the possibility that our Galaxy could contain yet unknown types of high-energy sources (McLaughlin et al. 1996, Merck et al. 1996, Tavani et al. 1998, Tompkins 1999, Romero et al. 2000, Punsly et al. 2000, Torres et al. 2000).

In this paper we shall review the main correlational properties of the sample of low-latitude unidentified gamma-ray sources in the third and final EGRET catalog. We shall discuss which objects in our Galaxy are expected to generate strong enough gamma-ray emission as to have been detected by EGRET and what are the prospects for future space missions like INTEGRAL and GLAST regarding the identification of galactic gamma-ray sources.

2. LOW-LATITUDE SOURCES AND THE SPIRAL STRUCTURE OF THE GALAXY

There are 81 unidentified gamma-ray sources in the third EGRET catalog located at less than 10° from the galactic plane. Six of these sources are thought to be artifacts associated with the proximity of the very bright Vela pulsar. These sources do not show up in a map which excludes the Vela pulsation intervals and will not be taken into account in the present discussion. We have, consequently, a sample of 75 unidentified low-latitude sources, whose distribution with galactic latitude is shown in Figure 1. A strong concentration around zero degrees can be clearly seen in this histogram, indicating that most of the sources belong to our Galaxy.

One of the first things that we could ask about the group of low-latitude gamma-ray sources is whether they are correlated with the spiral arms of the Galaxy. The arms are where most stars are formed and the regions where the galactic gas storage is concentrated. In order to test the correlation, we need a tracer for the spiral structure of the Galaxy. The usual tracers, in this sense, are giant and bright HII regions. We can use, then, Georgelin & Georgelin’s (1976) catalog of the 100 brightest HII regions to perform a correlation analysis with the sample of low-latitude sources in the third EGRET catalog. When this is done, we find that 32 out of 75 sources are positionally overlapping HII regions. In order to quantify the statistical significance of this number we can make numerical simulations of random populations of galactic gamma-ray sources (subject to adequate boundary conditions) using the code developed by Romero et al. (1999) to produce synthetic gamma-ray source populations. Through thousands of simulations, we find that the expected number of chance coincidences is $13.2 \pm 2.9$. This implies a Pois-
Figure 1  Distribution with galactic latitude of those unidentified gamma-ray sources in the 3EG catalog located at $|b| < 10^\circ$.

3. CORRELATIONS WITH GALACTIC OBJECTS

The main mechanisms for gamma-ray production in a galactic scenario are inverse Compton (IC) scattering of lower frequency photons, relativistic bremsstrahlung and $\pi^0$-decays from hadronic interactions. The common feature of all these mechanisms is that they require the presence of a population of relativistic particles (electrons or positrons in the first two cases, protons or ions in the latter). Consequently, if we look for gamma-ray production sites in the Galaxy, we should look

son probability of chance correlation of $5 \times 10^{-6}$, i.e. the correlation is reflecting a physical relation with a confidence of $\sim 7\sigma$. The conclusion, consequently, seems to be that there is a significant number of extreme Population I objects in the parent population of low-latitude gamma-ray sources. This result was already suggested by previous correlation studies using former gamma-ray catalogs presented by Montmerle (1979) and Yadigaroglu & Romani (1997), but the confidence only reaches overwhelming levels when data from the third EGRET catalog are used.
at sites where charged particles can be efficiently accelerated up to high energies.

Basically, we have two types of scenarios where particles can be accelerated up to the required relativistic energies: 1) large sites where the acceleration is mediated by strong shock fronts in a first order, diffusive process, and 2) compact objects with very strong electromagnetic fields where the acceleration occurs in a single step. The first type of acceleration is expected to occur in supernova remnants (SNRs) and also at the strong shock that could be formed near very massive stars endowed with strong supersonic winds. The second type of acceleration should operate in pulsars and accreting black holes, where strong magnetic fields should be anchored in the surrounding accretion disks.

It is natural, then, to look for positional correlations between gamma-ray sources and galactic objects like SNRs, early-type stars, and OB associations (which are considered as pulsar tracers), and this has been done in the past as we have briefly mentioned in the Introduction. Regarding the sources in the third EGRET catalog, Romero et al. (1999) have performed a correlation analysis finding out that there is a suggestive number of spatial coincidences with Wolf-Rayet and Of stars, SNRs and OB associations. The probabilities of pure chance superposition are moderate ($< 10^{-2}$) for stars and quite negligible for remnants and star forming regions ($< 10^{-5}$). In the next sections we shall discuss these potential gamma-ray emitters in more detail, with emphasis in the case of stars.

4. STARS

Wolf-Rayet (WR) stars are very massive objects that have burnt their hydrogen and have entered in the final phases of their evolution. These stars present very strong supersonic winds with velocities of several thousands of km/s. The mass loss rate is as high as $10^{-4} \, M_\odot$/yr. Of stars are also early-type stars with strong winds; they are thought to be the progenitors of WR stars and, although their winds are not so strong, they have mass loss rates that can be $10^9$ times higher than those presented by stars like the Sun.

The energy losses experienced by all these stars through their winds have a great impact in the surrounding interstellar medium. The winds swept up the ambient gas creating low-density cavities around the stars (e.g. Benaglia & Cappa 1999). A strong shock front is formed at the contact layer between the wind and the outer, colder ISM. These shocks are expected to accelerate particles up to high-energies through Fermi mechanism (e.g. Völk & Forman 1982). If a source of UV photons or
a cloud are present near the acceleration site, significant amounts of gamma-rays could be produced through IC scattering, bremsstrahlung or hadronic interactions (Benaglia et al. 2000).

Figure 2 Sketch illustrating the different regions where gamma-rays can be produced in a stellar system. Top panel: Terminal shock region. Middle panel: The unstable base of the wind. Lower panel: Colliding winds region in a binary system.

The winds of early-type stars are radiatively driven by absorption in spectral lines and are prone to undergo instabilities that can grow up to form strong shocks at the base of the outflow (Lucy & White 1980, Lucy 1982). These shocks can efficiently accelerate both electrons and protons up to energies of about a few GeV (White 1985), and these
particles, through interactions with stellar photons and ions, could yield gamma-ray emission in EGRET’s energy range (Benaglia et al. 2000).

Another site where stellar high-energy emission can be generated is the colliding winds region in binary systems formed by two massive stars (Eichler & Usov 1993). Electrons are accelerated at the strong shock formed by the winds collision, as evidenced by the clear detection of non-thermal radio emission from the region between stars in several systems (e.g. Contreras et al. 1997). Gamma-rays should be produced by Comptonization of stellar photons in this region.

| γ-source (3EG J) | Star | Δθ (deg) | r (kpc) | v∞ (km s⁻¹) | logM (M⊙ yr⁻¹) | NT emission |
|------------------|------|----------|---------|-------------|----------------|-------------|
| 0747 – 3412      | WR 9 (B) | 0.37     | 2.35    | 2200        | -4.2           |             |
| 1102 – 6103      | WR 34  | 0.48     | 9.50    | 1200        | -4.5           |             |
|                  | WR 35  | 0.40     | 9.58    | 1100        | -4.3           |             |
|                  | WR 37  | 0.45     | 2.49    | 2150        | < -4.1         |             |
|                  | WR 38  | 0.45     | 1.97    | 2400        | < -4.2         |             |
|                  | WR 39  | 0.51     | 1.61    | 3600        | < -4.0         | Yes         |
| 1655 – 4554      | WR 80  | 0.59     | 4.40    | 2000        | -4.1           |             |
| 2016 + 3657      | WR 137 (B) | 0.44   | 1.82    | 1900        | -4.5           |             |
|                  | WR 138 | 0.50     | 1.82    | 1500        | -4.7           |             |
| 2021 + 3716      | WR 142 | 0.15     | 0.95    | 5200        | < -4.7         |             |
| 2022 + 4317      | WR 140 (B) | 0.64  | 1.34    | 2900        | -4.1           | Yes         |

In Tables 1 and 2 we list those unidentified gamma-ray sources that are positionally coincident with WR and Of stars, respectively. A “B” letter marks those stellar systems that are confirmed binaries. From left to right we provide the name of the gamma-ray source in the 3EG catalog, the star name, angular separation between the star and the best estimated position of the 3EG source, distance to the star, terminal wind velocity and mass loss rate. We also indicate (in the last column) whether non-thermal (NT) radio emission has been detected. The presence of synchrotron radiation is important because it reveals the existence of a population of relativistic electrons that could be also responsible for the gamma-ray emission. In Figure 3 we show the non-thermal radio contours of the southern Of star HD 124314 observed.
Table 2 Of stars spatially correlated with 3EG sources.

| γ-Source (3EG J) | Star     | ∆θ (deg) | r (kpc) | v_∞ (km s^{-1}) | logM (M_⊙ yr^{-1}) | NT emission |
|------------------|----------|----------|---------|-----------------|---------------------|-------------|
| 0229 + 6151      | HD 15629 | 0.30     | 1.9     | 2900            | -5.8                |             |
| 0634 + 0521      | HD 46150 | 0.64     | 1.3     | 2900            | < -5.9              |             |
|                  | HD 46223 | 0.63     | 1.6     | 2800            | -5.8                |             |
| 1410 – 6147      | HD 124314| 0.25     | 1.0     | 2400            | -4.7                | Yes         |
| 2033 + 4118      | Cyg OB2 5 (B) | 0.27   | 1.8     | 1500            | -4.43               | Yes         |
|                  | Cyg OB2 11 | 0.24   | 1.8     | 2500            | -5.2                |             |

with the Australia Telescope Compact Array (ATCA) by Benaglia et al. (2001). Similar observations for the remaining sources listed in Tables 1 and 2 are in progress. The source 3EG 2016+3657, positionally coincident with WR 138, has been recently studied by Mukherjee et al. (2000) who suggest that the counterpart is the blazar B2013+370.

The information on the relativistic electronic population obtained with interferometric radio observations can be used, along with the available information on the stellar parameters, to estimate the expected gamma-ray luminosity of individual, well-studied, stellar systems. Such work has been recently made by Benaglia et al. (2000) for the particularly interesting case of Cyg. OB 2 No. 5. This system is formed by three stars: an O7 Ia + Ofpe/WN9 contact binary and a B0 V star in a larger orbit. Benaglia et al. estimated the gamma-ray production in the colliding winds region, the terminal shock of the dominant wind, and the unstable zone at the base of the wind. Their results indicate that the high-energy emission is dominated by IC radiation from the colliding winds and π^0-decays from the inner wind region near the primary star. The expected luminosities are shown in Table 3 and can be considered as representative for similar systems.

Both INTEGRAL and GLAST missions will provide new and valuable elements to test our ideas about how gamma-rays can be generated in stars. In particular, the Imager on Board INTEGRAL Satellite (IBIS), a coded masked detector designed to produce sky images in the 20 KeV – 10 MeV band with an angular resolution of 12 arcminutes, is expected to detect the IC flux density in a few, nearby stars that have been already found to be non-thermal radio sources. This instrument will also have a
good spectral capability that could be used to differentiate stars where the high-energy emission comes from particles accelerated at a single shock (e.g. the shock formed by winds collision) from those where the emission is produced by particles accelerated at multiple shocks at the base of the wind (e.g. Chen & White 1991). The main limitations of IBIS are the sensitivity (long integrations of $\sim 10^6$ seconds will be necessary to detect even the nearest stars) and the fact that $\pi^0$-decays produce gamma-rays of energy well above instrument’s energy range. GLAST, on the contrary, will detect this latter emission. Its improved sensitivity will allow to observe thousands of sources, including hundreds of stars. The determination of the spectral features and variability characteristics of these stars, along with new and more accurate measurements of their radio properties, will lead to a radical advancement in our understanding of high-energy stellar processes.

5. SUPERNOVA REMNANTS

Torres et al. (these proceedings) discuss in detail the case for the association of SNR and 3EG sources. If we exclude sources that are
Table 3  Expected gamma-ray production in Cygnus OB2 No. 5 in the EGRET energy range (from Benaglia et al. 2000)

| Region             | Mechanism          | Expected luminosity (erg/s) | Observed luminosity (erg/s) |
|--------------------|--------------------|-----------------------------|-----------------------------|
| Winds collision    | IC scattering      | $\sim 8 \times 10^{34}$    |                             |
|                    | Bremsstrahlung     | $\sim 3.4 \times 10^{30}$  |                             |
|                    | $\pi^0$-decay       | $\sim 5.2 \times 10^{24}$  | $\sim 2.4 \times 10^{35}$  |
| Terminal shock     | $\pi^0$-decay       | $\sim 2.3 \times 10^{32}$  |                             |
| Base of the wind   | IC scattering      | –                           |                             |
|                    | $\pi^0$-decay$^1$   | $\sim 5 \times 10^{34}$    |                             |

1: See also White & Chen (1992)

suspected to be artifacts, we have that 19 out 75 low-latitude EGRET detections are positionally coincident with SNR in Green's (2000) catalog (see also Romero et al. 1999). The probability of all these associations being the mere effect of chance is quite negligible: $\sim 10^{-5}$. However, the possibility that many sources result from the compact object left by the supernova explosion and not from the remnant itself cannot be ruled out.

In several cases, however, the gamma-ray emitter seems to be the SNR. This occurs when the remnant is interacting with nearby and dense molecular clouds. In these cases, as discussed by Aharonian et al. (1994) and Aharonian & Atoyan (1996), the probability of detection
is dramatically increased. Some particular cases have been studied in
detail by Esposito et al. (1996) and Combi et al. (1998, 2001). Cosmic
rays are accelerated at the remnant shock front and transported into
the cloud by convection. There, gamma-rays are produced by $\pi^0$-decays
from $pp$ interactions and relativistic bremsstrahlung. Additional contri-
butions from IC scattering can be also important. The spectral shape
at low and high energies can be used to infer the energy distributions
of both hadrons and leptons in the remnant. Multifrequency studies of
these SNRs can shed light on the details of the acceleration process of
galactic cosmic rays at large, strong shock fronts (see Gaisser et al. 1998
for further details).

6. OB ASSOCIATIONS

OB associations are considered as tracers of young pulsar concentra-
tions (Kaaret & Cottam 1996). Taking into account the distribution of
pulsar transverse speeds derived by Lyne & Lorimer (1994), it has been
estimated that a fraction of $0.25 - 0.4$ of all young pulsars (ages less
than $10^5$ yr) can be found within $1^\circ$ from the center of OB associations
(Kaaret & Cottam 1996).

A correlation analysis using the 3EG catalog and Mel’nik & Efremov’s
(1995) OB associations catalog indicates that 26 low-latitude gamma-ray
sources are superposed to OB associations. This result is about $5\sigma$ away
from what is expected by chance (probability of all coincidences being
the effect of chance $\sim 10^{-5}$).

The idea that most of the gamma-ray sources in this group are pul-
sars is supported by the particularly hard spectra presented by them.
All known gamma-ray pulsars are young objects with spectral indices
smaller than 2.15 (Crab’s) and a trend for spectral hardening with char-
acteristic age (Fierro et al. 1993). In Figure 4 we show a plot of the
expected luminosity of the gamma-ray sources (assuming for them the
distance to the corresponding OB associations) versus the spectral in-
dex $\Gamma$ of the high-energy emission ($F(E) \propto E^{-\Gamma}$). In this plot pulsars
should be located towards the left side of the panel, precisely where most
sources are concentrated. Three sources differentiate from the rest, with
high luminosities, similar to the luminosity of Vela pulsar.

Recent modeling of gamma-ray pulsar populations by Zhang et al.
(2000) also corroborates that most sources positionally associated with
OB star forming regions are probably pulsars. The simulations made
by these authors, based on the outer gap model proposed by Zhang &
Cheng (1997), shows that a mixed population of radio-quiet and young
radio pulsars can account for most (although not all) associations found by Romero et al. (1999) using the 3EG catalog.

7. **UNCORRELATED SOURCES**

The correlation analysis made by Romero et al. (1999) showed that there is a significant number of low-latitude gamma-ray sources for which there is no positional superposition with any known galactic object thought to be capable of producing high-energy gamma rays. To clarify the nature of this group of sources is, perhaps, one of the most interesting problems aroused by EGRET.

A comparative analysis of the gamma-ray variability properties of these sources could provide some clues on their origin. Gamma-ray pulsars are expected not to vary over relatively short timescales, so the identification of clearly variable galactic sources could lead to the discovery of a new population of gamma-ray emitters in the Galaxy (Tavani et al. 1997).

A variability analysis for the group of sources without positional correlation has been performed by Romero et al. (2000) and Torres et al. (2000). They have used a statistical method widely applied to blazar studies (Romero et al. 1994). Although this method is applied to the
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catalog data, it is free of several problems that affect similar methods (see Reimer, this proceedings, and Tompkins 1999). Basically, a variability index \( I = \mu_s / \langle \mu \rangle_p \) is introduced, where \( \mu_s = \sigma / \langle F \rangle \) is the fluctuation index of the gamma-ray source and \( \langle \mu \rangle_p \) is the averaged fluctuation index of all known gamma-ray pulsars (which are usually considered as a non-variable population). Sources with \( I > 1 \) at 3\( \sigma \) or more are considered as possibly variable ones (1\( \sigma = 0.5 \)). In the estimate of the fluctuation index of known gamma-ray pulsars only data from the 3EG catalog are considered. In the limits of very variable and non-variable sources this method yields similar results to the most comprehensive method applied by Tompkins (1999), who worked with the raw data and took into account background fluctuations, source contamination, and other sources of systematic error.

![Plot of variability index \( I \) versus high-energy spectral index \( \Gamma \) for low-latitude 3EG sources without positional correlation with potential galactic gamma-ray emitters. Known gamma-ray pulsars are contained between the horizontal lines. Gamma-ray AGNs are shown for comparison.](image)

Figure 5 Plot of variability index \( I \) versus high-energy spectral index \( \Gamma \) for low-latitude 3EG sources without positional correlation with potential galactic gamma-ray emitters. Known gamma-ray pulsars are contained between the horizontal lines. Gamma-ray AGNs are shown for comparison.

The basic results of the variability analysis of the low-latitude, uncorrelated gamma-ray sources in the 3EG catalog are shown in Figure 5 as a plot of variability index \( I \) versus the high-energy spectral index \( \Gamma \). AGNs and pulsars are also shown in this plot for comparison. Known pulsars are located between the two solid lines at the bottom of the panel. Since they also have hard spectra, they are concentrated towards the left side of the frame. AGNs, on the contrary, mostly display high variability levels and in many occasions steep spectra. It can be clearly seen from the plot that there is a group of unidentified sources with
a behaviour similar to that presented by AGNs. The surface density of these sources is, however, much higher than what could be expected through an extrapolation of the high-latitude AGN density towards the galactic plane. Actually, there seems to be a trend among these sources in the sense that those with the highest variability levels also present the steepest spectral indices. These sources seems to form a population of galactic, variable sources, of which GRO J1838-04 (Tavani et al. 1997) and 3EG J1828+0142 (Punsly et al. 2000) are extreme examples.

8. VARIABLE GAMMA-RAY SOURCES IN THE GALAXY

The nature of the variable low-latitude sources remains a mystery. The large error boxes of the EGRET detections make very difficult the identification of potential lower frequency counterparts. A single radio field of 1° around the centre of the EGRET 95% probability location contour can contain as many as 50 point-like weak radio sources, most of which are also of unknown nature (Torres et al. 2000). Although only the improved angular resolution of GLAST will allow to isolate the more promising candidates for counterparts and lead to a final identification, we can speculate about some possibilities on the nature of these sources. Among the main ones, we can mention:

- **Early-type stars with strong winds.** In our study of the positional correlation of sources in the 3EG catalog with massive stars we have only included extreme stars like WR and Of stars. However, other O and B stars can also be sources of gamma-ray emission strong enough as to be detected by EGRET, especially if they are forming binary systems (Eichler & Usov 1993, Benaglia et al. 2000) or are located in a very rich environment. The luminosity of these stars should not be very high, say around a few times $10^{34}$ erg s$^{-1}$ (Benaglia et al. 2000), so only nearby sources would be detected. Variability is naturally expected in these stars due to geometric changes during the orbital evolution of the binaries and also due to the effect of wind instabilities. Stars are interesting candidates to explain mid-latitude sources probably linked to the nearby Gould belt (Gehrels et al. 2000).

- **Pulsars.** Pulsars, under certain circumstances, can be variable sources. For instance, when a pulsar forms a non-accreting binary system with a massive star, it could be subjected to a changing UV photon bath from the star (e.g. Tavani & Arons 1997). Isolated pulsars also could be variable through some kind of quake-driven activity.
Faint microquasars. This hypothesis is supported by the recent discovery of a persistent and faint microquasar (LS 5039) by Paredes et al. (2000, also these proceedings) positionally correlated with the source 3EG 1824-1514. Other, yet undetected microquasars could switch between high and low states due to periodic accretion instabilities. Recent evidence seems to show that LS 5039 displays short-term radio variability. If IC gamma-ray emission is associated with the radio emission, it should also be variable.

Isolated black holes accreting from the interstellar medium. Bondi-Hoyle accretion of diffuse matter onto black holes of several solar masses can yield moderate gamma-ray luminosities (Dermer 1997). If the hole is moving through an inhomogeneous medium, variable emission could be observed.

Non-pulsating (NP) black holes. Maximally rotating Kerr-Newman black holes (see Punsly, these proceedings, and references therein) can support a magnetosphere and, if they are located in a low-density medium, could, in principle, be gamma-ray sources (Punsly 1998a, b). Variability naturally results from jet instabilities. A model of this kind has been recently applied to the source 3EG J1828+0142 (Punsly et al. 2000).

Although this list does not exhaust all possibilities, it is enough to show that a variety of candidates can be postulated and that new observations of improved quality are required.

9. FINAL REMARKS

EGRET has confirmed the finding made by COS-B of a galactic population of gamma-ray sources and has shown that this population is not formed by a unique class of objects. Pulsars, supernova remnants, and early-type stars seem to be capable, under certain circumstances, to emit detectable gamma-rays. The possibility of other, more strange, gamma-ray emitting objects in the Galaxy remains open. The search for these objects will be one of the most interesting and challenging tasks of high-energy astrophysics in GLAST era.

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