Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY LETTERS

Mon. Not. R. Astron. Soc. **403,** L6–L10 (2010) doi:10.1111/j.1745-3933.2009.00801.x

Gamma-ray halo around 3C 279: looking through the Sun on the 8th of October

Malcolm Fairbairn,[1,2]⋆ Timur Rashba[3,4,5] and Sergey Troitsky[6]⋆

[1]*Department of Physics, King's College London, Strand WC2R 2LS, London*
[2]*CERN Theory Division, CH-1211 Geneva 23, Switzerland*
[3]*Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Str. 2, D-37191 Katlenburg-Lindau, Germany*
[4]*Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), Föhringer Ring 6, D-80805 München, Germany*
[5]*Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation (IZMIRAN), Troitsk, Moscow Region, 142190, Russia*
[6]*Institute for Nuclear Research of the Russian Academy of Sciences, 60th October Anniversary prosp. 7a, 117312, Moscow, Russia*

Accepted 2009 December 6. Received 2009 December 6; in original form 2008 October 3

ABSTRACT

We discuss how the solar occultations of bright sources of energetic gamma-rays can be used to extract non-trivial physical and astrophysical information, including the angular size of the image when it is significantly smaller than the experiment's angular resolution. We analyse the EGRET data and discuss prospects for other instruments. The *Fermi Gamma-ray Space Telescope* will be able to constrain the size of a possible halo around 3C 279 from observations it makes on October 8 each year.

Key words: gamma-rays: theory.

1 INTRODUCTION

The brightest source in the sky almost at any wavelength, the Sun, is very weak in high-energy ($E \gtrsim 100\,\mathrm{MeV}$) gamma-rays. This property can be used to study solar occultations of gamma-ray sources.

The width of the point spread function (PSF) of telescopes detecting photons at these energies is quite large, of the order of several degrees. The enormous exposure of the *Fermi Gamma-ray Space Telescope* (the telescope previously known as *GLAST*) would partially compensate for the poor resolution; however, it would be almost impossible to directly measure the angular size of the image which may be smaller than the PSF width. On the other hand, energetic gamma-ray images of distant sources may indeed have a significant angular size due to the cascading of photons on the background radiation and magnetic deflections of the cascade electrons and positrons. It has long been known that one can obtain the angular size of stars from lunar occultations; we suggest that one may determine the image size of gamma-ray sources screened by the Sun. [1]

The current collection of known energetic gamma-ray point sources is scarce (∼300 sources detected by EGRET), so only a few are expected to be on the strip on the sky such that they are screened by the Sun. Fortunately, the brightest EGRET source identified with an extragalactic object, 3C 279, has an ecliptic latitude of $0\overset{\circ}{.}2$ and is screened by the Sun on October 8 each year. It is 3C 279 which is the main subject of our discussion because, as we will see in Section 2, it represents a perfect target for this kind of study.

The simplest and most direct effect of an extended image size would be the detection of flux from the source during occultation. Such a result could also be the signal of the transparency of the Sun to gamma-rays possible in several scenarios of new physics (Fairbairn, Rashba & Troitsky 2007); however the parameter space of particular models is strongly disfavoured by results of other experiments (e.g. Andriamonje et al. 2007).

In Section 3, we review our analysis of archival EGRET data of the 1991 occultation of 3C 279 during which a non-zero flux was indeed observed, although at a very low statistical significance.

With a sensitive enough telescope, a more detailed study of the light curve during ingress and egress would be possible. In Section 4, we discuss the potential of *Fermi* for this kind of a study and mention sources other than 3C 279, while Section 5 summarizes our conclusions.

2 POSSIBLE MECHANISMS FOR EXTENDED EMISSION

Very high energy photons interact with other photons in the source, with photons along the path between the source and the Earth and with photons near to the Sun. These interactions result in the production of electrons and positrons which themselves consequently interact with the gamma-ray background leading to the development of electromagnetic cascades which result in a gradual decrease of the average energies of propagating photons. Ambient magnetic fields deflect the electrons and positrons and, as a result, the image of

⋆E-mail: malcolm.fairbairn@kcl.ac.uk (MF); st@ms2.inr.ac.ru (ST)

[1] Interestingly, we note that the Moon is much brighter than the Sun in this energy band because of secondary emission from cosmic rays hitting the lunar surface (see e.g. Thompson et al. 1997; Brigida 2009).

the source seen in gamma-rays becomes extended. This kind of extended image may be observed for distant sources which emit very energetic photons (both the Universe and typical source environments are transparent for gamma-rays below ∼1 GeV). Recently, the MAGIC collaboration has reported (Teshima et al. 2007) the detection of $E > 200$ eV emission from 3C 279. Given the expected absorption on the cosmic infrared background, this corresponds to an extremely high luminosity of the quasar at very high energies (Albert et al. 2008). Moreover, according to both the Hillas criterion (Hillas 1984) and bounds on the source parameters from energy losses (see e.g. Ptitsyna & Troitsky 2008), the jets of 3C 279 might provide the necessary conditions for the acceleration of cosmic rays up to ultra-high energies (UHE), $E \gtrsim 10^{19}$ eV. 3C 279 therefore seems to be an ideal candidate to search for an extended halo due to the production of secondary photons.

Let us briefly summarize a few different scenarios which could lead to the formation of an extended image.

Inverse Compton effect in the source environment (≲GeV). It has been pointed out some time ago (Aharonian, Coppi & Volk 1994) that a halo of (sub-)GeV inverse-Compton photons may form around the source of very high energy gamma-rays. The estimates of Aharonian et al. (1994) for the case of 3C 279 give rise to an expected angular size of the halo of ∼0°.2 and a flux from the halo approximately equal to the flux coming from the central point source.

Synchrotron halo of UHECR sources (∼GeV). For reasonable values of the magnetic field ($\gtrsim 10^{-9}$ G) around a source of UHECR, synchrotron photons contribute to a halo of angular size of a fraction of degree potentially detectable by *Fermi* (Gabici & Aharonian 2007; Atoyan & Dermer 2008).

Electromagnetic cascades on the intergalactic magnetic fields (∼10^3 GeV). Energetic photons from distant sources undergo electromagnetic cascades when scattering off extragalactic background light, resulting in extended images for TeV sources (Neronov & Semikoz 2007). Even stronger cascading is expected for secondary photons from UHECR sources (see e.g. Ferrigno, Blasi & De Marco 2005): because of their higher energies, they can scatter on cosmic microwave background (CMB) photons as well as the infrared background, and the number density of CMB photons is much higher. However, extended emission of this kind is too weak at GeV energies to lead to a detectable effect.

Electromagnetic cascades on the solar radiation (∼10^2 GeV). The solar radiation is strongly concentrated in the optical band, corresponding to the thermal emission of 5800 K, that is $\omega_{\rm Sun} \sim 1$ eV. The pair production threshold is determined by $E = m_{\rm e}^2/\omega_{\rm Sun} \approx 260$ GeV. The optical depth of the solar radiation with respect to the pair production for 260 GeV photons tangent to the solar surface is $\tau \sim 0.1$, and any secondary electrons and positrons produced in this way would be isotropized by the ∼1 G magnetic field of the Sun. Because of this, the extended halo as viewed from the Earth would be too weak to be observable (one may hope to detect such a halo when the Sun passes in front of the regions with significant diffuse emission at 260 GeV if such regions exist, but without the timing signature, this emission would be hard to detect).

Formation of the halo is a random process and therefore one expects that the variability time-scale of the halo should be determined by its physical size (light minutes for the solar neighbourhood but millions of light years for all other scenarios).

We see that one might expect a halo around 3C 279 in the energy band detectable by EGRET and *Fermi* (above 100 MeV). This halo is of angular size ∼0°.1 while the PSF of these instruments extends to several degrees. However, the halo could be detected when the Sun screens the bright central source. Study of the shape and spectrum of this halo would help to distinguish between various scenarios of its formation and therefore contribute to our understanding of the source engine, the source environment and the extragalactic background radiation. The extended halo would reveal itself in a smooth falling of the flux when the Sun approaches the source and in a non-zero flux from the source while it is screened by the Sun. In Fig. 1, we present examples of the light curves for various source extensions.

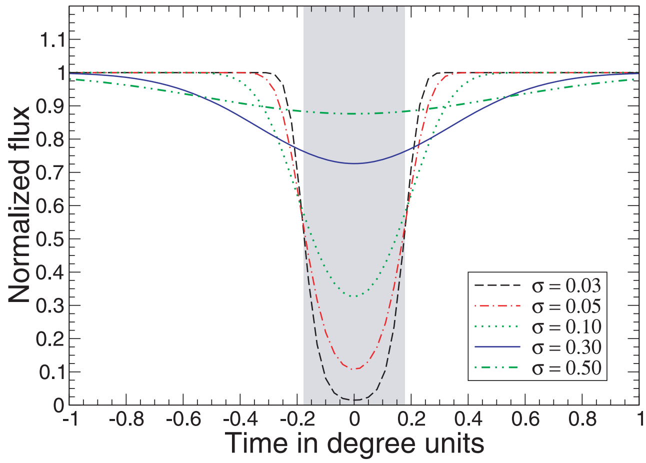

Figure 1. Normalized light curves of an extended source occulted by the Sun, assuming Gaussian model for the extended image. Different values of the radial source variance σ are taken in units of degree. The time corresponds to the angle (in degree) between source centre and the point of its minimal separation from the centre of the solar disc, for the minimal separation of 0°.20. The shadow region represents the occultation of the point-like source.

3 EGRET OBSERVATIONS

In 1991, the solar occultation of 3C 279 occurred within the field of view of EGRET. We have analysed publicly available EGRET data to test the conjecture that the flux from the quasar was non-zero when the source was screened by the Sun (Fairbairn et al. 2007); here we present more details and discussions related to the study.

Given the coordinates of 3C 279 taken from the NASA/IPAC Extragalactic Database (NED) (http://nedwww.ipac.caltech.edu) and the coordinates of the Sun calculated with the program PLANEPH (Chapront & Francou 1998), we are able to establish that the source was screened by the Sun for 8 h and 34 min. The minimal separation between the quasar and the centre of the solar disc was 0°.20 while the angular radius of the Sun at that period during the Earth's orbit was 0°.2675 (Kulikovsky 2004). At that time (viewing period 11.0), EGRET was pointed in the direction of 3C 273, some 5° away from 3C 279. The quasar was in a moderate state and was firmly detected in gamma-rays during that viewing period (Hartman et al. 1999).

The actual distribution of observed photons with their coordinates, energies and arrival times, as well as a record of the instrument's viewing modes, is available from the EGRET ftp site (ftp://cossc.gsfc.nasa.gov/compton/data/egret). To calculate the exposure map for the period of occultation, we made use of the EGRET software (Blackburn 1995; Laubenthal et al. 1993).

To determine the source flux, one compares the distribution of arrival directions of detected gamma-rays with the sum of background and point-source fluxes using a particular model for the former and the instrument PSF for the latter, both convolved with time- and direction-dependent experimental exposure. We denote the diffuse background flux of gamma-rays from a given direction (α, δ) as $B(\alpha, \delta)$. This flux was determined by Cillis & Hartman (2005) from the analysis of the EGRET data. From $B(\alpha, \delta)$, we calculate $B(\psi)$, the expected flux of background photons within the angular distance ψ from the source we study [it is the integral over the corresponding circle on the sky, of $B(\alpha, \delta)$ weighted by exposure]. The PSF of EGRET, obtained by its careful calibration (Thompson et al. 1993), is energy-dependent; one has to assume some spectral index α for the source. We use the PSF for $E > 100$ MeV and $\alpha = 2$ [the EGRET-measured spectral index of 3C279 is 1.96 ± 0.04 (Hartman et al. 1999)] from Cillis & Hartman (2005) and denote it as $p(\psi)$.

The number $n(\psi)$ of observed photons from the circle of angular radius ψ centred at the source (a ladder-like function of a single variable ψ) is fitted by the sum of a slowly varying background and a sharp PSF,

$$n(\psi) = bB(\psi) + N_{\mathrm{s}}p(\psi) + \sum_i s_i(\psi),$$

where b and N_{s} are parameters of the fit (determined by the standard least-squares method). Following the original 3EG procedure (Mattox et al. 1996), we keep the coefficient b free, motivated by possible temporal variations of the background while s_i are contributions of known nearby sources (for which we use the 3EG values for this viewing period). The best-fitting number of source photons N_{s} divided by the exposure determines the source flux. In the same way as the authors of the 3EG catalogue, we select events with energies $E > 100$ MeV, TASC in coincidence at 6 MeV and distance to the source not exceeding 15°. These cuts correspond also to the PSF we use.

Our approach is very similar to that used for the construction of the 3EG catalogue [see Mattox et al. (1996) for more details of the method] apart from some details.

(i) We use the updated maps of EGRET-observed diffuse background (Cillis & Hartman 2005) while Hartman et al. (1999) used a theoretical model for the distribution of the background flux.

(ii) The catalogue construction used the counts distribution binned in two celestial coordinates; we use the unbinned distribution in one coordinate – distance from the source [both approaches were discussed by Mattox et al. (1996)]. This is more appropriate in the case of small number of observed events.

(iii) The 3EG procedure subtracts all 3σ sources (in the catalogue, they list only 4σ ones). We subtract only the sources listed in the catalogue, even if they are fainter than 4σ for this particular viewing period (in this way, we potentially exclude some sources which did not pass the 4σ cut for this viewing period, or for any other viewing period or their sum, but were brighter than 3σ in this period).

We performed the fit for the occultation period and for the rest of the viewing period. The best fits give the signal of $N_{\mathrm{s}} = 4.82$ photons for the occultation and $N_{\mathrm{s}} = 284.5$ for the rest of the viewing period. Within the 68 per cent containment angle of the PSF, the numbers of signal and background photons are roughly equal. Therefore, we found some weak evidence for a non-zero point-source flux from the location of 3C 279 during the occultation, $(6.2^{+3.7}_{-2.7}) \times 10^{-7}$ cm^{-2} s^{-1}, to be compared with the value obtained from the analysis of the rest of the same viewing period, $(8.6 \pm 0.5) \times 10^{-7}$ cm^{-2} s^{-1} [the value quoted in the 3EG catalogue for this period is $(7.94 \pm 0.75) \times 10^{-7}$ cm^{-2} s^{-1}]. The zero flux (point-like source) is excluded at $\approx$

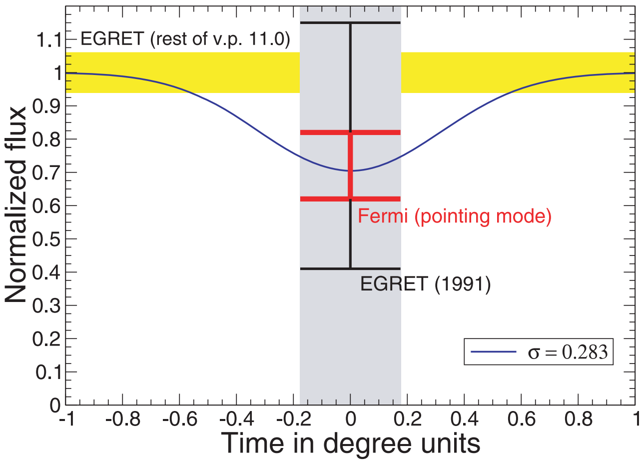

Figure 2. The normalized light curve (blue line) for the Gaussian extended source with the extension providing the best fit to the EGRET data on 3C 279 occultation in 1991. The time is determined as in Fig. 1. The horizontal band represents the 68 per cent CL EGRET off-occultation flux determined from the two week period. Black (thin) error bars give the average flux during the occultation seen by EGRET; red (thick) error bars are expected for a *Fermi* observation, in the pointing mode, of one occultation with the same parameters.

98 per cent confidence level (CL); no upper limit can be placed on the source extension because unsuppressed flux is well within the 68 per cent CL error bars. Assuming a Gaussian extended image, the best fit for the radial extension is $\sigma \approx 0.283°$. The error bars in Fig. 2 give an idea of the size of statistical uncertainties, both of this result and of potential future studies.

Here, we mention some possible subtleties which one should be aware of when trying to understand this result or similar future observations.

Other nearby 3EG sources. The numbers quoted above were obtained with the subtraction of the expected contribution of a single nearby source detected at 3σ in the viewing period 11.0 (3EG J1235+0233, see the list of nearby sources in Table 1).The result can in principle be confused by contribution of other sources. As a test, we changed the 3σ threshold adopted by EGRET to both 2σ and 4σ without any significant change in the result. The procedure described above assumed that the flux of the sources being subtracted was constant during the viewing period. Clearly, an extreme flare of 3EG J1246−0651, or 3EG J1310−0517, or both, exactly at the

Table 1. Potential confusing sources: 3EG sources within 15° of 3C 279. θ is the angular offset from 3C 279; F_{-7} is the flux during viewing period 11.0 in 10^{-7} [cm^{-2} s^{-1}], $(TS)^{1/2}$ is the significance of detection in the viewing period 11.0. Data from Hartman et al. (1999).

3EG name	Other name	θ	F_{-7}	$(TS)^{1/2}$
1219−1520		13°.2	<0.89	0.0
1229+0210	3C 273	10°.5	<0.95	0.4
1230−0247	1229−021	7°.0	1.13±0.43	2.9
1234−1318		9°.3	<0.89	0.0
1235+0233		9°.9	1.24±0.41	3.5
1236+0457		11°.9	<0.90	0.3
1246−0651	1243−072	2°.5	1.29±0.54	2.7
1310−0517		3°.6	1.05±0.51	2.2
1339−1419	1334−127	13°.6	<1.08	0.0
1255−0549	3C 279	0°.0	7.94±0.75	15.1

Table 2. Solar flares during the occultation.

Start (UT)	End (UT)	EGRET photons (separation from the Sun)
$20^{h}14^{m}$	$20^{h}15^{m}$	27°.2, 32°.3, 21°.7, 19°.4, 17°.8
$20^{h}48^{m}$	$20^{h}49^{m}$	–
$21^{h}59^{m}$	$22^{h}00^{m}$	10°.8
$22^{h}07^{m}$	$22^{h}08^{m}$	–

occultation time, could explain our result without 3C 279. Note, however, that on the time-scale between one viewing period and another, these sources do not demonstrate significant variability, so such a flare seems unlikely.

The Sun. The solar surface could be a gamma-ray source due to its interaction with cosmic rays. Early EGRET studies put a 95 per cent CL upper limit of 2.0×10^{-7} cm^{-2} s^{-1} on the flux of the quiet Sun (Thompson et al. 1997). A marginal detection of solar disc flux $\sim 4 \times 10^{-8}$ cm^{-2} s^{-1} has been reported by Orlando & Strong (2008). The theoretical expectation of the flux of the disc of the quiet Sun is about 2×10^{-8} cm^{-2} s^{-1} (Orlando, Petry & Strong 2007).

The extended emission of the Sun (Moskalenko, Porter & Digel 2006; Orlando & Strong 2007, 2008) cannot explain the observed excess: within the 68 per cent containment width of the EGRET PSF the expected flux from the extended solar emission is about $\sim 1.5 \times 10^{-7}$ cm^{-2} s^{-1} assuming the model for the solar extended flux and the total flux of 4.44×10^{-7} cm^{-2} s^{-1} obtained by Orlando & Strong (2008) in the 10° circle around the Sun. We would like to note that the recent unpublished *Fermi* observations have been used to extract the solar flux from the 10° region around the Sun which is $(4.59 \pm 0.89) \times 10^{-7}$ cm^{-2} s^{-1} (Brigida 2009), in good agreement with Orlando & Strong (2008). This flux is low compared to that of 3C 379 and may be neglected within our current poor precision.

Solar flares. Solar flares are sources of gamma-rays; the BATSE records (http://umbra.nascom.nasa.gov/batse/batseyears.html) list four weak flares in the occultation time (see Table 2).The photons detected by EGRET during these flares were separated from the Sun by at least 10°.8, so they most probably do not contribute to the point-source flux (the 68 per cent width of the EGRET PSF at $E >$ 100 MeV is 3°.3).

The Moon. One more gamma-ray source was nearby during the time of these EGRET observations: the Moon was in 6° to 9° from the Sun during the period of interest. The gamma-ray ($E >$ 100 MeV) flux of the Moon in 1991 was $(3.6 \pm 0.9) \times 10^{-7}$ cm^{-2} s^{-1} [see fig. 2 of Thompson et al. (1997)]. Given the separation, the PSF width and the flux we conclude that the lunar contribution cannot explain the observed excess.

Possibility of misidentification. Though 3C 279 is considered as one of the best EGRET identifications, one still cannot exclude the possibility that the gamma-ray excess is due to a source misidentified with 3C 279. This would be actual source, if located just 20 arc-min away, would not be screened by the Sun. The best-fitting position of the EGRET source associated with 3C 279 is indeed displaced from the position of the quasar as seen in other wavelengths, but this position is evenly more deeply screened by the Sun during an occultation.

4 PROSPECTS OF FUTURE OBSERVATIONS

Let us estimate the ability of new experiments to observe the solar occultations of gamma-ray sources, notably that of 3C 279. AGILE cannot be pointed to the Sun because of configuration of its solar

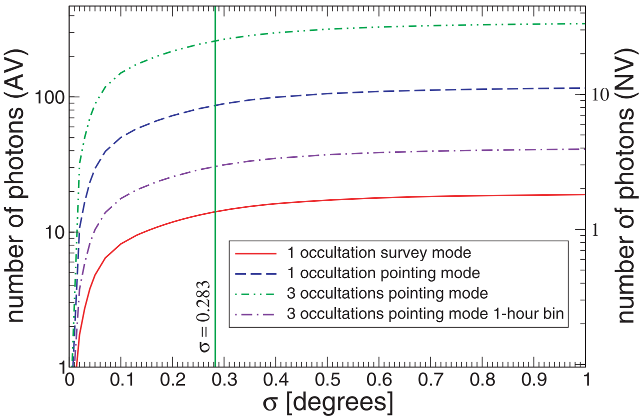

Figure 3. The expected number of source photons from 3C 279 during the occultation, seen by *Fermi*, versus the radial extent of the Gaussian image, for 8.5-h observations in the survey mode (full line), pointing mode (dashed line), combination of three observations in the pointing mode (dash-dot-dotted line) and for 1-h bin of the latter combination (dash–dotted line). The vertical line indicates the best-fitting value of the extension from the EGRET data. The left and right scales are described in the text.

panels (M. Tavani, private communication). Atmospheric Cerenkov telescopes cannot be pointed at the Sun as they would be destroyed. The sensitivity of MILAGRO is insufficient to detect the source in 8.5 h. The Large Area Telescope (LAT) of *Fermi* may, however, be used to observe the occultation successfully.

In the survey mode, *Fermi* will scan the sky rotating continuously, so the short-period exposure to a given point in the sky is not too large. The sensitivity may be estimated using the *Fermi* web service (http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm). For the pointing mode, the average on-axis effective area for $E >$ 100 MeV, weighted with the $\sim E^{-2}$ spectrum, is $\sim$4700 cm^{2}. Further precision may be gained by repeating the observation each year.

To estimate the ability of the instrument to detect non-zero flux during the occultation, we have to assume a particular value of the total flux of the source. 3C 279 is strongly variable; however the extended image should not be variable unless it is formed near the Earth and not near the quasar. While the formation of the halo near the quasar is better motivated physically (cf. Section 2), the opposite is in better agreement with the EGRET result (Section 3) because the non-variable flux of 3C 279, roughly estimated as a minimal flux over EGRET viewing periods, is $\sim 8 \times 10^{-8}$ cm^{-2} s^{-1} (Hartman et al. 1999), much lower than the best-fitting flux during the occultation. Fig. 3 shows the expected number of photons from the source during the occultation as a function of the source extension for various *Fermi* observations for both scenarios. The left-handed scale (AV) corresponds to the total flux of the Gaussian image of 83.7×10^{-8} cm^{-2} s^{-1}, the average flux of 3C 279 over nine viewing periods (Casandjian & Grenier 2008); the right-handed scale (NV) corresponds to the non-variable flux. The number of background photons within the 68 per cent containment width of PSF is approximately equal to the number of source photons in the latter scenario.

Two more EGRET sources with ecliptic latitudes $b_e <$ 0°.25 (see Table 3) had been classified as unidentified in the 3EG catalogue. Further studies suggested potential identifications; they also have been detected by *Fermi* (Abdo et al. 2009). The study of the solar occultation may help to determine their coordinates with higher precision, testing the identification. We expect that these (and maybe

Table 3. EGRET and *Fermi* gamma-ray sources potentially eclipsed by the Sun. b_e gives the ecliptic latitude calculated from the *Fermi* bright source list (Abdo et al. 2009), 'GEV' means $E > 1$ GeV detection by EGRET (Lamb & Macomb 1997), 'VHE' means $E > 100$ GeV detection.

Name	b_e	3EG	GEV	VHE
AX J1809.8−2333	−0.099	J1809−2328	Yes	No
3C 279	+0.186	J1255−0549	Yes	MAGIC
W28 = M20 (?)	−0.020	J1800−2338	Yes	HESS

other) sources will become potential targets for angular-size measurements.

5 CONCLUSION

It will be interesting to try and measure the angular sizes of images of energetic gamma-ray sources by means of observation of their solar occultations. The best target is 3C 279, whose occultation happens each year on October 8. EGRET observations made during such a period did not exclude the unsuppressed flux of the quasar, when it was screened by the Sun. The sensitivity of the *Fermi* telescope is high enough that if the flux was unsuppressed during occultation, it could be observed more definitively than with EGRET. *Fermi* can also constrain the angular size of the image even in the survey mode, and is capable of obtaining a light curve by the combination of several observations in the pointing mode. This would help to constrain models of particle acceleration and magnetic fields in and around the quasar. If the flux during the occultation exceeds the non-variable flux of the source (as it is slightly favoured by the EGRET data), it would mean that either the extended image is formed relatively nearby or the Sun is partially transparent for the point-like gamma-ray emission (both options would mean a discovery of some unconventional physical or astrophysical phenomenon). The same method may be applied to refine the coordinates and/or to estimate the angular size of images of other gamma-ray sources screened by the Sun.

ACKNOWLEDGMENTS

We are grateful for discussions with J. Conrad, V. Rubakov and M. Tavani. This work was supported in part by DFG (Germany) and CONACYT (Mexico) (TR), by the grants RFBR 07-02-00820, RFBR 09-07-00388, NS-1616.2008.2 and by FASI under state contracts 02.740.11.0244 and 02.740.11.5092 (ST). We made use of NED which is operated by the Jet Propulsion Laboratory, CalTech, under contract with NASA.

REFERENCES

Abdo A. A. et al., 2009, ApJS, 183, 46
Aharonian F. A., Coppi P. S., Volk H. J., 1994, ApJ, 423, L5
Albert J. et al., 2008, Sci, 320, 1752
Andriamonje S. et al., 2007, J. Cosmol. Astropart. Phys., 0704, 010
Atoyan A., Dermer C. D., 2008, ApJ, 687, 75
Blackburn J. K., 1995, in Shaw R. A., Payne H. E., Hayes J. J. E., eds, ASP Conf. Ser. Vol. 77, Astronomical Data Analysis Software and Systems IV. Astron. Soc. Pac., San Francisco, p. 367
Brigida M., 2009, Moon And Quiet Sun Detection With Fermi-lat Observatory (http://ricap09.roma2.infn.it/slides/Brigida_RICAP09.pdf)
Casandjian J. M., Grenier I. A., 2008, A&A, 489, 849
Chapront J., Francou G., 1998, Ephemerides of Planets between 1900 and 2100 (1998 update), ftp://cdsarc.u-strasbg.fr/pub/cats/VI/87
Cillis A. N., Hartman R. C., 2005, ApJ, 621, 291
Fairbairn M., Rashba T., Troitsky S., 2007, Phys. Rev. Lett., 98, 201801
Ferrigno C., Blasi P., De Marco D., 2005, Astropart. Phys., 23, 211
Gabici S., Aharonian F. A., 2007, Ap&SS, 309, 465
Hartman R. C. et al., 1999, ApJS, 123, 79
Hillas A. M., 1984, ARA&A, 22, 425
Kulikovsky P. G. ed., 2004, Reference Book for Amateur Astronomers. URSS publishers, Moscow
Lamb R. C., Macomb D. J., 1997, ApJ, 488, 872
Laubenthal N. A. et al., 1993, in Hanisch R. J., Brissenden R. J. V., Barnes J., eds, ASP Conf. Ser. Vol. 52. Astron. Soc. Pac., San Francisco, p. 249
Mattox J. R. et al., 1996, ApJ, 461, 396
Moskalenko I. V., Porter T. A., Digel S. W., 2006, ApJ, 652, L65 [Erratum-ibid., 2007, 664, L143]
Neronov A., Semikoz D. V., 2007, JETP Lett., 85, 473
Orlando E., Strong A., 2007, Ap&SS, 309, 359
Orlando E., Strong A. W., 2008, A&A, 480, 847
Orlando E., Petry D., Strong A., 2007, in Ritz S., Michelson P., Meegan C. A., eds, AIP Conf. Proc. Vol. 921, the first GLAST symposium. Am. Inst. Phys., New York, p. 502
Ptitsyna K., Troitsky S., 2008, preprint (arXiv:0808.0367)
Teshima M. et al., 2007, in Caballero R., D'Olivo J. C., Medina-Tanco G., Nellen L., Sánchez F. A., Valdés-Galicia J. F., eds, Proc. 30th ICRC, Vol. 3. UNAM, Mexico, p. 1045
Thompson D. J. et al., 1993, ApJS, 86, 629
Thompson D. J. et al., 1997, J. Geophys. Res., 102, 14735