THE ASTROPHYSICAL JOURNAL, 239:L49–L52, 1980 July 15

LOW-ENERGY GAMMA-RAY EMISSION CLOSE TO CG 135+1

F. PEROTTI, A. DELLA VENTURA, AND G. VILLA
Laboratorio di Fisica Cosmica e Tecnologie Relative, C.N.R., Milan, Italy

G. DI COCCO
Laboratorio T.E.S.R.E., C.N.R., Bologna, Italy

AND

R. C. BUTLER, A. J. DEAN, R. I. HAYLES
University of Southampton, Department of Physics, England
Received 1980 February 15; accepted 1980 April 2

ABSTRACT

A region of the sky close to the *COS B* source CG 135+1 was studied over the photon energy range 20 keV–25 MeV from balloon altitudes on 1978 October 8. A 5 σ excess was measured in the counting rate of the telescope above 120 keV, and the spectrum of the source was evaluated.
Subject headings: gamma rays: general — quasars

I. INTRODUCTION

Results from the *COS B* satellite experiment present evidence for a high-energy γ-ray source in the position $l^{II} = 135\overset{\circ}{.}0$, $b^{II} = 1\overset{\circ}{.}5$. This has been designated CG 135+1 (Wills *et al.* 1979; see also Hermsen *et al.* 1977). Its photon flux above 100 MeV is $(1.0 \pm 0.3) \times 10^{-6}$ photons cm^{-2} s^{-1}. This source is extremely interesting because of its possible identification with the QSO 0241+622 (Apparao *et al.* 1978) which has the second-lowest QSO redshift recorded to date, $z = 0.043$. However, there are good reasons to believe that it is the nearest QSO, because the other object at 1301+375 having $z = 0.036$ has such a low visual magnitude, $M_v = 19$, that it may be a compact subluminous galaxy. Radio observations have identified a strong point source within 2″ of QSO 0241+622 (Apparao *et al.* 1978), and X-ray emission has been observed from the region by the *Uhuru* (Julien and Helmken 1978), *SAS 3* (Apparao *et al.* 1978), and *HEAO 1* (Share *et al.* 1978) telescopes. The *HEAO 1* (A-1) data indicate that there are two weak X-ray sources in this region: H0241+62, whose error box contains the QSO, and H0235+60, whose error box includes the radio source GT 0236+61 (Gregory and Taylor 1978). This radio source has now been identified with a B0 I star (LSI +61°303) at a distance of 2.3 kpc (Gregory *et al.* 1979). Sensitive radio observations show that its radio brightness temperature is about 10^{10} K and that its flux is extremely variable, suggesting synchrotron radiation from relativistic electrons in an emitting region a few AU in size. Recently, X-ray emission in the energy range 1–3 keV using the *Einstein* Observatory has been detected in a region centered on the star LSI +61°303 and 50″ wide (G. F. Bignami, private communication). This star has characteristics that suggest it might belong to the Cyg X-3 class of X-ray emitting binaries. The *OSO 7* results in the energy range 1–40 keV (Maraschi *et al.* 1978) and those of the *Ariel 5* high-energy X-ray telescope between 0.26 and 1.2 MeV (Coe, Quenby, and Engel 1978) have indicated that the photon emission spectrum from this region of the sky is extremely hard in nature, with a power-law spectral index of $\alpha \approx 1.0$. However, the angular resolution of these telescopes makes it uncertain that these fluxes originate from the same celestial object. A search for low-energy γ-ray emission in this region of the sky has been carried out during a balloon flight in 1978 October from Palestine, Texas, using the Milan/Southampton (MISO) telescope. The preliminary analysis of the data (Della Ventura *et al.* 1979) showed an excess in the counting rate above 150 keV from a position compatible with the *COS B* error box. In this *Letter* we present and discuss the photon spectrum for the observed count-rate excess.

II. OBSERVATION AND DATA ANALYSIS

The MISO telescope has been described elsewhere (Baker *et al.* 1979) and consists of two scintillators, S1 (liquid scintillator NE 311) and S2 (sodium iodide), that form the Compton-coincidence detection system S1.S2. The sensitive area is 560 cm^2, and the aperture is 3° FWHM in both the azimuthal and zenithal planes, for "single" and "Compton-coincidence" events. An alt-azimuth orientation system was used to point the telescope with a precision of 20′. A passively shielded hard X-ray detector (20–240 keV) having an effective area of 600 cm^2 was also mounted parallel with the main telescope and had a field of view of 2° × 5° FWHM.

The field containing CG 135+1 was studied with this instrument on 1978 October 8 between 06^h and 10^h UT. Five drift scans were carried out to survey the region contained within the coordinate points 2^{h}16^m and 3^{h}12^m in right ascension and centered on +62° in declination. This region encompasses the error boxes of the X-ray and γ-ray sources seen by the *Uhuru*, *HEAO 1*, *HEAO 2*, *SAS 3*, *OSO 7*, *Ariel 5*, and *COS B* telescopes. The method of observation and the analysis performed on the integral counting rate of the telescope are described in detail in Della Ventura *et al.* (1979). An excess of 5 σ from the general direction of CG 135+1 was observed.

Figure 1 shows the MISO error box in galactic coordinates for the observed γ-ray excess together with other data obtained at different photon energies (the *OSO 7* 1 σ error box is a private communication of L. Maraschi). In this figure the *COS B* error box is taken from the latest *COS B* catalog (Wills *et al.* 1979), in which a decrease of $0.^\circ5$ in galactic longitude for the position of CG 135+1 with respect to the previous one (Hermsen *et al.* 1977) was reported. Since our drift scans were made in one direction only, the limits of our error box are represented by the 1 σ points along the scanning direction, and by the total aperture of the telescope (6°) in the orthogonal direction, which represents the 100% probability of containing the emitting object. The uncertainty due to the pointing system is included. The coordinate points for the corners of the MISO error box are

$$l^{\rm II} = 135.^\circ2,\ 136.^\circ6,\ 134.^\circ1,\ 133.^\circ0;$$

$$b^{\rm II} = -1.^\circ4,\ -0.^\circ9,\ +4.^\circ6,\ +4.^\circ2.$$

The same procedure that had been performed on the integral counting rates of the γ-ray telescope was repeated for the hard X-ray detector. No statistically significant excess was observed between 20 and 240 keV. The same method was used again to evaluate the contribution of the source flux in individual energy-loss channels of the main telescope. A matrix inversion technique which does not make any *a priori* assumptions about the final shape of the spectrum was used to convert the energy-loss spectrum in each of the three individual γ-ray channels (S1, S2, S1.S2) to a photon spectrum at the top of the atmosphere. The absorption of photons in the residual atmosphere, the redistribution of photon energies through Compton interactions and pair-production, and the energy resolution of the telescope were taken into account. The error in this evaluation was estimated to be less than 10%. A statistical combination of all three spectra is shown in Figure 2 and in Table 1, together with the 2 σ upper limits from our X-ray detector. Measurements made at other wavelengths from the same region of the sky have been included. The integral *COS B* flux of 1.0×10^{-6} photons cm^{-2} s^{-1} above 100 MeV has been converted into a differential photon spectrum assuming two different power-law spectral indices (α = 2.0 and 2.5). We note that, because of their angular resolution, the

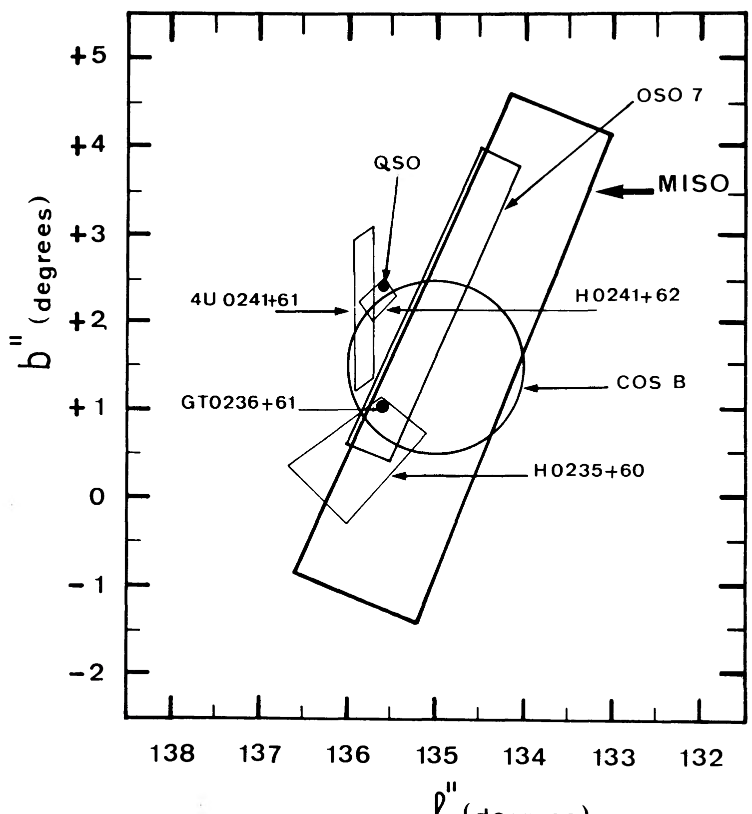

FIG. 1.—The MISO error box in galactic coordinates is shown together with other astronomical data. The MISO error box has 68% probability across the scan direction and 100% across the other. The uncertainty due to the pointing system is included.

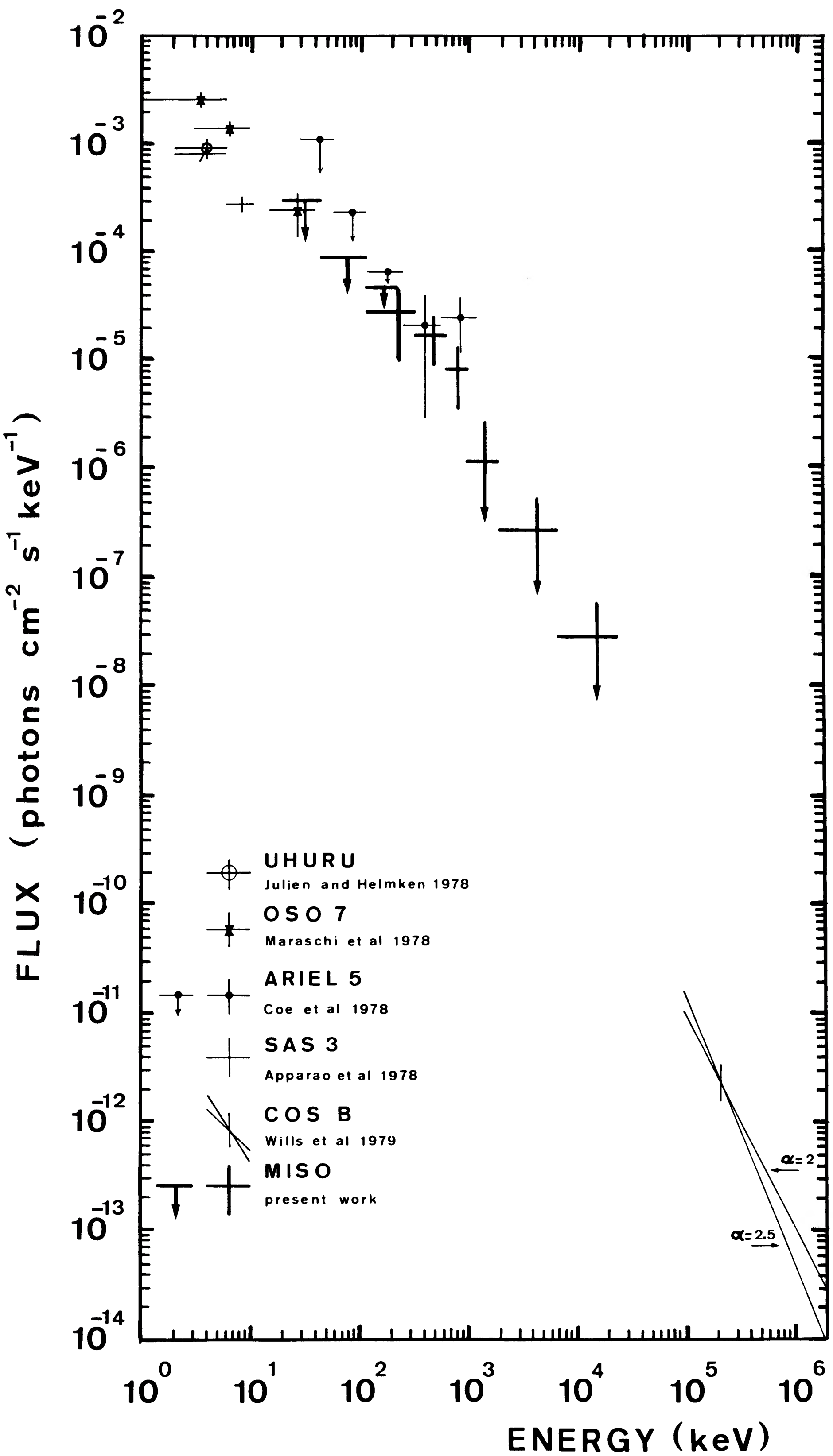

FIG. 2.—The photon spectrum observed by the MISO telescope close to CG 135+1 is shown together with other measurements from the same region of the sky. The integral *COS B* γ-ray flux above 100 MeV is shown converted into a differential photon spectrum assuming two different power-law spectral indices.

TABLE 1

PHOTON SPECTRUM OBSERVED BY THE MISO TELESCOPE CLOSE TO CG 135+1

Energy Range (MeV)	Flux (photons cm^{-2} s^{-1} keV^{-1})
0.020–0.045[a]	3×10^{-4} (2 σ upper limit)
0.045–0.120[a]	9×10^{-5} (2 σ upper limit)
0.120–0.240[a]	4.8×10^{-5} (2 σ upper limit)
0.12–0.34	$(2.9\pm1.9)\times10^{-5}$
0.34–0.67	$(1.8\pm0.9)\times10^{-5}$
0.67–1.05	$(8.5\pm5.0)\times10^{-6}$
1.05–2.0	$(1.2\pm1.6)\times10^{-6}$
2.0–7.0	$(2.8\pm2.8)\times10^{-7}$
7.0–25.0	$(2.9\pm2.9)\times10^{-8}$

[a] From the X-ray detector.

spectral data from the *Uhuru*, *OSO 7*, *Ariel 5*, MISO, and *COS B* telescopes refer to a field containing at least two X-ray sources (the QSO and the star LSI +61°303), while the data from *SAS 3* refer to the QSO only.

III. DISCUSSION

Inspection of Figure 1 suggests that the low-energy (MISO) and the high-energy (*COS B*) γ-ray fluxes originate from the same celestial object. Despite the poor angular resolution (8° FWHM) of the *Ariel 5* experiment, the agreement between their low-energy γ-ray data and that of the MISO telescope (Fig. 2) also suggests a common origin of emission. Our 2 σ upper limits in the energy range 20–120 keV, together with our spectral data between 0.12 and 1 MeV, seem to indicate that the differential photon spectrum of the source has a power-law spectral index $\alpha \sim 1$ in the range 20 keV–1 MeV, in agreement with the 1–40 keV *OSO 7* data. A steepening of the spectrum may exist at energies greater than 1 MeV. The integral γ-ray flux above 100 MeV observed by *COS B* is consistent with a differential power-law photon spectrum having a spectral index $2 \leq \alpha \leq 2.5$ (G. F. Bignami, private communication). If this high-energy γ-ray flux comes from the same object observed at lower energies by the MISO telescope, the compatibility of the two sets of data requires a break at about 500 keV with an $\alpha \sim 2.5$ if we do not wish to consider more complex spectral shapes.

At the moment it is impossible to establish whether the γ-ray emission is associated with the most probable counterparts, which are the radio source and the QSO. On the basis of our error box the radio source GT 0236+61 shows a slight statistical preference. If the X-ray–emitting QSO is also the source of the observed γ-rays, the radiation mechanism may be similar to that recently proposed by Jones (1979) to explain the high-energy emission from the QSO 3C 273. In this model, relativistic electrons producing synchrotron radiation at microwave frequencies Compton-scatter a small fraction of these photons to X-ray wavelengths. The γ-ray flux arises from a second-order inverse-Compton scattering on the X-ray photons.

If the observed γ-ray emission is produced in the radio and possibly X-ray source GT 0236+61 (Share *et al.* 1978; Bignami, private communication), a possible mechanism may be that proposed by Fabian, Blandford, and Hatchett (1977) in the case of Cyg X-3. In this model the hard X-rays come from inverse Compton scattering of the stellar photons and the γ-ray flux from inverse Compton of the soft X-rays. The source of X-rays and relativistic electrons may be a young pulsar (Lamb *et al.* 1977). Gregory *et al.* (1979) have pointed out that the star LSI +61°303 (the optical counterpart of the radio source GT 0236+61) shows some characteristics similar to those of the binary systems. However, at present the evidence for the binary nature of this star is insufficient.

Using the model of spherical turbulent accretion onto black holes proposed by Mészàros (1975), Maraschi and Treves (1977) have shown that electrons and protons are accelerated by the electric field produced by the motion of magnetized turbulence cells in the accretion flow. The synchrotron and Compton radiation from the accelerated electrons is found to be the dominant process of γ-ray emission. The luminosity around 1 MeV is larger than that above 100 MeV. On the basis of our observation, such a picture may be found in the CG 135+1 source.

This project was supported jointly by the Science Research Council (UK) and the Consiglio Nazionale delle Ricerche (Italy). We are grateful for the balloon launch and recovery services provided by the N.S.B.F., Palestine, Texas.

REFERENCES

Apparao, K. M. V., *et al.* 1978, *Nature*, **273**, 450.
Baker, R. E., *et al.* 1979, *Nucl. Instr. Meth.*, **158**, 595.
Coe, M. J., Quenby, J. J., and Engel, A. R. 1978, *Nature*, **274**, 343.
Della Ventura, A., *et al.* 1979, *Nature*, **282**, 486.
Fabian, A. C., Blandford, R. D., and Hatchett, S. P. 1977, *Nature*, **266**, 512.
Gregory, P. C., and Taylor, A. R. 1978, *Nature*, **272**, 704.
Gregory, P. C., *et al.* 1979, *A.J.*, **84**, 1030.
Hermsen, W., *et al.* 1977, *Nature*, **269**, 494.
Jones, T. W. 1979, *Ap. J.*, **233**, 796.
Julien, P. F., and Helmken, H. F. 1978, *Nature*, **272**, 699.
Lamb, R. C., *et al.* 1977, *Ap. J.* (*Letters*), **212**, L63,
Maraschi, L., and Treves, A. 1977, *Ap. J.* (*Letters*), **218**, L113.
Maraschi, L., *et al.* 1978, *Nature*, **272**, 679.
Mészàros, P. 1975, *Astr. Ap.*, **44**, 59.
Share, G. H., *et al.* 1978, *Proc. 21st COSPAR Meeting*, Innsbruck.
Willis, R. D., *et al.* 1979, *Proc. 22d COSPAR Meeting*, Bangalore.

R. C. BUTLER, A. J. DEAN, and R. I. HAYLES: University of Southhampton, Department of Physics, Southampton, England

A. DELLA VENTURA, F. PEROTTI, and G. VILLA: Laboratorio di Fisica Cosmica e Tecnologie Relative, C.N.R., Via Rasini, 15/A Milan, Italy

G. DI COCCO: Laboratorio T. E. S. R. E., C. N. R., Via De' Castagnoli, 1 Bologna, Italy