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NASA

Technical Memorandum 80239

High Energy X-Ray Observations of BL Lacertae Objects

(NASA-TM-80239) HIGH ENERGY X-RAY OBSERVATIONS OF BL LACERTAE OBJECTS (NASA) 10 p HC A02/MF A01 CSCL 03B

N79-20943

Unclas

G3/89 19632

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FEBRUARY 1979

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

TM 80239

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ABSTRACT

BL Lac objects are of considerable current interest both because they were recently realised to be a new class of objects and because they have been found to be similar in many significant respects to QSOs and Seyfert Galaxies. Since at least one model for the X-ray emission predicts a flattening of the X-ray spectrum above a few keV, several of these sources have been studied using the high energy scintillation telescopes on OSO-8 and Ariel-5. With the possible exception of Markaryan 421, only upper limits were obtained for the X-ray emission in the energy ranges 25-60 and 60-130 keV, thereby imposing constraints on any spectral breaks.

HIGH ENERGY X-RAY OBSERVATIONS OF BL LACERTAE OBJECTS

BL Lac objects are of interest not only because they were recently identified as a new class of objects, but also because they have been found to be similar in many significant respects to QSOs and Seyfert Galaxies. Since at least one model[1] for the X-ray emission predicts a flattening of the X-ray spectrum above a few keV, several of these sources have been studied using the high energy scintillation telescopes on OSO-8 and Ariel-5. With the possible exception of Markaryan 421, only upper limits were obtained for the X-ray emission in the energy ranges 25-60 and 60-130 keV, thereby imposing constraints on spectral hardening.

The prototype of this class of object, the rapid variable BL Lacertae, was established as an unusual object from observations obtained during 1968-69. A review of its discovery and the subsequent realisation that it represented a new class of objects can be found in Stein *et al.*[2] and references therein. X-ray emission in the 2-10 keV band has been established definitely for five of these objects[3], including Mkn 501 (ref. 4) and Mkn 421 (ref. 5), for which the detailed spectra have been measured over the range 2-40 keV[6]. An upper limit of 2.4×10^{-11} erg cm^{-2} s^{-1} in the 2-10 keV range has been set by Mushotzky *et al.*[6] for the remaining members of the list of Stein *et al.*[2], and for the recently discovered[7] new member, 1418+54 (Mushotzky, private communication).

The results presented here were obtained with two high energy scintillation telescopes, one on the OSO-8 satellite and the other on the Ariel-5 satellite. The OSO-8 instrument consists of an actively collimated CsI(Na) detector with an effective area of 28 cm^2 and a field of view (FWHM) of 5°. It has been described in detail by Dennis *et al.*[8]. The Ariel-5 instrument also consists of an actively collimated CsI(Na) crystal, but with an effective area of 8 cm^2 and a field of view (FWHM) of 8°. It has been described by Engel and Coe[9]. Data from both these instruments have been analysed to study a total of nine BL Lac objects, including Mkn 501 and Mkn 421.

Apart from Markaryan 421, which is discussed in the following paragraph, no evidence was found in the OSO-8 and Ariel-5 data for any X-ray emission in the 25-250 keV photon energy range. Two standard deviation upper limits on the flux have been calculated for the photon energy ranges 25-60 and 60-130 keV. These limits are presented in Table 1. The different values obtained arise from the different instrument backgrounds, the length of the observations, and the positions of the sources within the field of view. The upper limits on Mkn 501 do not require any break in the extrapolation of the spectrum observed with HEAO-1 (ref. 6), and serve only to eliminate the possible existence of an extreme hardening above 40 keV. It must be noted, however, that even though there is evidence for little or no variability in Mkn 501 (ref. 4), our measurements and the HEAO-1 spectrum are separated by two years and, as such, may not represent a true composite spectrum at any one time.

Markaryan 421, on the other hand, shows considerable variability above 1 keV. Mushotzky *et al.*[6] observed a factor of 6 change in 6 months in the energy range 2-10 keV, and Ricketts *et al.*[10] observed a 20 fold increase in 10 days in the energy range 2-18 keV. Consequently, it is important to obtain concurrent observations if the overall spectrum is to be considered. This has been done by combining the results from the proportional counter on OSO-8 (Mushotzky *et al.*[6]) with simultaneous high energy observations from the scintillation telescope on the same satellite. The resulting composite spectrum is shown in Figure 1. The low energy data up to 5 keV are well fitted by a power-law photon-number spectrum with a spectral index of −2.5. At higher energies there is an excess flux above an extrapolation of this power law. The upper limits imposed by the high energy detector require that any power-law spectrum in the 10-100 keV range cannot be flatter than $E^{-1.0}$. While our data lend support to a spectral feature at ~25 keV suggested by the proportional counter data, the statistical significance of our data is not sufficient to warrant a more detailed analysis.

A total of nine BL Lac objects have been observed with the high energy X-ray spectrometers on Ariel-5 and OSO-8 including two out of the five known low energy X-ray emitters[3]. Of these nine sources Mkn 501 and Mkn 421 are optically the brightest[2], and are therefore possibly the closest objects in this class. Consequently, the lack of detection of all but Mkn 421 in this search is perhaps not surprising. Nevertheless, the results presented here suggest that these sources are not bright in hard X-rays and hence support the contention by Boldt[11] that they do not contribute significantly to the diffuse cosmic background at these energies. The possibility of a feature in the spectrum of Mkn 421 at $\sim$25 keV, while intriguing at the moment, is in need of further confirmation before it can be considered a constraint on models for these sources.

The work of the OSO-8 Project Scientist, Dr. Roger Thomas is greatly appreciated, as is the assistance in the OSO-8 data analysis by the personnel of Comtech Incorporated. The Ariel-5 satellite project is funded by the Science Research Council of Great Britain and operated by the Appleton Laboratory. MJC acknowledges receipt of an NAS/NRC Resident Research Associateship.

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Table 1

Summary of the Observations

Object	Satellite Used	Date of Observation	2 Sigma Upper Limits (Photons cm^{-2} s^{-1} keV^{-1})	
			25-60 keV	60-130 keV
1101+384 (Mkn 421)	OSO-8	1977 May	6.2×10^{-4}	1.2×10^{-4}
1215+303	Ariel-5	1974 Nov	4.4×10^{-3}	4.6×10^{-5}
1219+285	Ariel-5	1974 Nov	4.2×10^{-3}	4.4×10^{-5}
1225+206	Ariel-5	1974 Nov	5.6×10^{-3}	5.8×10^{-4}
1418+540	OSO-8	1977 June	3.8×10^{-4}	9.2×10^{-5}
1514+197	Ariel-5	1977 June	3.2×10^{-3}	6.6×10^{-4}
1652+398 (Mkn 501)	OSO-8	1975 Aug	4.8×10^{-4}	8.9×10^{-5}
1727+502	Ariel-5	1977 Feb	2.0×10^{-3}	6.4×10^{-5}
2200+420 (BL Lac)	Ariel-5	1974 Oct	3.4×10^{-3}	6.7×10^{-4}

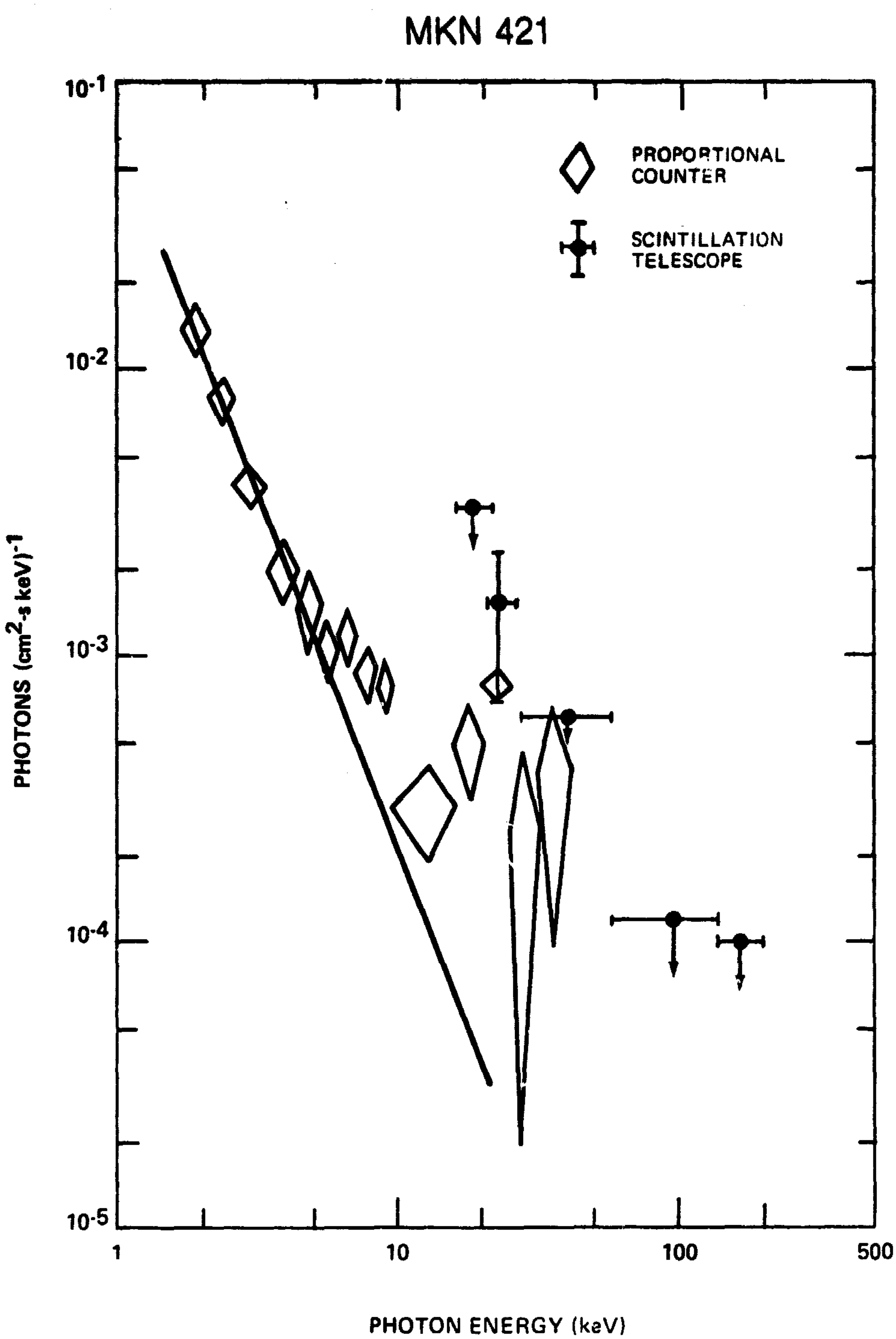

Figure 1. The spectrum of Markaryan 421 observed concurrently with the proportional counter on OSO-8 (ref. 6) and the scintillation spectrometer also on OSO-8 (this work) for the period 1977 May 18-24. The fitted power-law is $dN/dE = 0.06E^{-2.5}$ photons cm^{-2} s^{-1} keV^{-1}. Upper limits are indicated at the two standard deviation level.