SPECTRA AND POSITIONS OF GALACTIC GAMMA-RAY SOURCES

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ABSTRACT

The UCSD/MIT Hard X-Ray and Low Energy Gamma-Ray Experiment aboard HEAO-1 scanned the galactic center region during three epochs in 1977 and 1978 from 13-180 keV. We present the results from the scanning epoch of 1978 September. Twenty-two known 2-10 keV source positions were necessary for an acceptable fit to the data. The spectra of the 16 strongest, least confused sources are all consistent with power laws with photon spectral indices ranging from 2.1 to 7.2. Acceptable fits to thermal bremsstrahlung models are also possible for most sources. No one source in this survey can be extrapolated to higher energy to match the intensity of the gamma-ray continuum as measured by HEAO-1 large field of view detectors, which implies that the continuum is a composite of contributions from a number of sources.

INTRODUCTION

The galactic center region (i.e. within about 20° of the galactic center) contains more than 30 2-10 keV x-ray sources brighter than about 10 UFU[1]. Observations of this region between 10 and 200 keV are hampered by coarse angular resolution and its attendent problems of source confusion. Previous observations did, however, continually find bright source(s) near the galactic center[2,3]. The HEAO-1 UCSD/MIT Sky Map[4] provided a sensitive survey of this region in four broad energy bands covering 13-180 keV. This Sky Map obtained close to 30 sources within 20° of the galactic center at a typical sensitivity of 20 UFU.

Wide field of view ($\geq$10° FWHM) observations extending to 1 MeV and above have detected variable continuum emission from a region centered on the galactic center, as well as variable 511 keV emission[5,6]. Between the Fall of 1979 and the spring of 1980 both components varied by a factor of two or more[7] as seen by HEAO-3. This variability implies that the dominant source(s) must be $\leq$3" in extent at a distance of 10 kpc. The source(s), however, of this emission have yet to be localized above 200 keV, and it is unclear which, if any, of the 1 keV EINSTEIN sources[8] are associated with the gamma-ray emission.

We present here further analysis of the HEAO-1 UCSD/MIT data base using a finer binning structure retaining full spectral resolution. By applying this analysis to the region within 40° of the galactic center only, we can achieve slightly better sensitivity than the HEAO-1 Sky Map and can measure the detailed spectrum of each source along with its six-month variability. We compare each spectra, or group of spectra, to that measured at the same time by the higher energy HEAO-1 instruments, with the goal of associating the flux from individual sources with the variable gamma-ray flux.

INSTRUMENT AND OBSERVATIONS

The detectors used in this analysis are the 13-180 keV Low Energy Detectors (LEDs) of the Hard X-Ray and Low Energy Gamma-Ray Experiment aboard HEAO-1[9]. They were 100 cm^2 NaI/CsI phoswich scintillation detectors, oriented perpendicular to the spin axis, which pointed within 0.5° of the Earth-Sun line. Their fields of view were defined by passive and active shielding to be 1.6°x20° FWHM with the planes of the slat collimators inclined at +60° (LED 1) and -60° (LED 2) to the scan plane. During the 16 month lifetime of HEAO-1, the galactic center was within the LED fields of view for three, 30 day epochs in the Fall of 1977, Spring of 1978, and again in the Fall of 1978.

ANALYSIS

The scanning data were accumulated into 1-day sums for each LED binned along the scan plane of the satellite. The bins were 0.4° wide spanning ±40° from the galactic center. The photons in any one bin, thus, came from a region on the sky with the width of the bin and ±20° along the detector's instantaneous slat direction. In order to maximize sensitivity, many of these 1-day accumulations were summed to produce a time-averaged counting rate versus scan angle for each epoch for each LED.

In order to determine which sources were contributing a significant amount to the data, the data were summed from 13-80 keV in each bin. Using the known positions of each source and the aperture response, the source intensities and overall background rates were fit to both detector data sets simultaneously.

In order to extract spectra of these sources, the results of the fitting were used to determine those angle bins that contain events from a single source, and less than 20% contamination from other sources on the list. Similarly, regions devoid of response to any source on the list were selected for background determination. The full 64 channel spectra of source and background regions were used with standard spectral deconvolution programs to determine various spectral parameters. If spectra from both detectors were available, a simultaneous fitting of both spectra took place; otherwise, a single detector spectrum was fit. The results presented in Table 1 assume a power law model only.

RESULTS AND DISCUSSION

Twenty-two, known, 2-10 keV source positions were necessary to fit the LED data, and are listed in Table 1. This list of source positions used to fit the present data agrees with the HEAO-1 Sky Map list with a few exceptions. The present list contains the SAS-3 and Cos-B source 1715-321, the Ariel-5 source 1712-337, and the HEAO-1 A-1 source 1815-121, which are not in the Sky Map. On the other hand, all Sky Map sources not in the present list were either highly confused or not significant[4].

The spectral indices shown in Table 1 are the result of fitting individual sources to a power law model. All fits were acceptable, except for GX 17+2 and GX 9+9, and most sources could also be fit acceptably by a thermal bremsstrahlung model.

No one source in this survey is intense enough to equal the gamma-ray flux from this region, which was also measured by the HEAO-1 Medium Energy Detectors[5] in the Fall of 1978. The "galactic center" source, 1742-294, is brightest at 100 keV, but is at least a factor of three below the 100 keV gamma-ray flux.

Extrapolating the 13-165 keV fit to 1742-294 to higher energies reveals that its power law index must decrease to less than -3 above ≈250 keV in order not to exceed observations (see Figure 1). This may indicate that a high temperature thermal model or a Comptonization model would be more appropriate for 1742-294. If we sum the spectra of the three brightest sources within 5° of the galactic center (1742-294, GX 1+4, and GX 5-1), as shown in Figure 1, nearly all of the gamma-ray flux above 100 keV can be accounted for. This may not apply at other times, however, when the gamma-ray flux was brighter and 1742-294 was weaker at 100 keV[5].

ACKNOWLEDGEMENTS

This work was supported by the Office of Naval Research and NASA Grant NAG 8-499. The authors wish to thank Frank Primini, Duane Gruber, and Ken Kalata for useful discussions and insight.

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Table 1. Galactic Center Source List

Source Name		Spectral Index
1642-455	GX 340+0	4.99±1.31
1657-415	38s plsr	2.70±0.25
1658-298		3.61±0.39
1700-377		2.77±0.18
1702-363	GX 349+2	3.76±0.27
1702-437		----
1705-250	Nova Oph	----
1712-337		3.20±0.83
1715-321		3.46±0.39
1728-169	GX 9+9	3.67±0.25
1728-247	GX 1+4	2.30±0.07
1735-444		----
1742-294	GCX	2.12±0.04
1743-322		----
1744-265	GX 3+1	----
1758-250	GX 5-1	3.91±0.13
1758-205	GX 9+1	4.94±0.24
1811-171	GX 13+1	7.19±1.73
1813-140	GX 17+2	4.16±0.11
1820-303	NGC 6624	3.66±0.19
1815-121		4.61±1.05
1822-371		----

Figure 1: Galactic Center Spectra