X-RAY EMISSION FROM THE REGION OF γ 195+5

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The number of discrete celestial gamma-ray sources now stands at nearly 30, two-thirds of which are not firmly identified at other wavelengths. Figure 1 gives a breakdown of these sources, There are seven sources identified with our own galaxy — six of which are radio pulsars and Cygnus X-3, which seem to be the most luminous gamma-ray source in our galaxy by almost two orders of magnitude. There are three extragalactic sources — a quasar, a Seyfert galaxy, and a radio galaxy — all quite bright at other wavelengths and relatively close to us. Therefore as the sensitivity of new gamma-ray detectors increases, this number will surely grow dramatically as a larger volume of space is sampled.

My talk will concentrate on one of these 19 unidentified sources and our efforts to observe X-rays from it. My collaborator in this work was Diana Worrall of Goddard. I am indebted to the much larger group of people connected with the entire A-2 effort.

Our results are that we have seen some indication of X-rays from the gamma-ray source region. If that is real and if these X-rays are indeed physically associated with the gamma-ray source, then we now have a source error box about seven times smaller than it was.

Figure 2 shows the galactic plane, our milky way, in gamma-rays whose energies are greater than 70 MeV. Many of the unidentified sources are located along this plane and therefore are presumably galactic. The positions of these sources are located by arrows along this one-dimensional view below. The Cygnus region is a galactic longitude of 80 degrees. In the galactic anticenter region are the Crab pulsar and the source 195 + 5. This latter source is the one whose X-rays we are looking for. This source was first seen by the SAS-2 gamma-ray satellite. This beautiful map is from a preprint by the European Caravane Collaboration based on results from their COS-B satellite.

Figure 3 shows a close-up of 195 + 5 in the anticenter region. The SAS-2 and COS-B error boxes are shown. The other coordinate system shown here is appropriate to the satellite during late september and early October of 1977. As you know, in the scanning mode, the

HEAO-1 detectors sweep through a great circle, perpendicular to the Earth-Sun line every 30 min. For a source near the ecliptic, located at 180 degrees scan angle, the field of view moves over about 1 degree/day, moving eastward. The 1-1/2 × 3 degree field of view of the X-ray detectors is also represented in Figure 3. Our plan was to locate any new source within a strip of 10 degrees in scan angle, roughly 180 to 190 degrees, and within 5 degrees in day angle, roughly day 272 to 277 centered on the gamma-ray source region. We do claim one new source within the 50 square degrees covered by this search and it is located at l = 195 degrees, b = 5 degrees. What is the evidence?

Figure 4 shows the accumulation of 2 days data for days 270 to 272, well away from the gamma-ray region.

Figure 5 shows two well known sources, 4U061+09 at a scan angle of 193 degrees and IC443 very near the ecliptic. As we move later in time 4U061+09 decreases considerably and we get the scan data for a 3 day interval which is centered on the gamma-ray region. Please note there has been a considerable scale change. Actually IC443 is getting weaker; you can see the probable vestiges of 4U061 in this region, but there is also another small enhancement in this region. What is its significance?

The procedure is to fit the data in this region with only IC443 and determine a χ^2. Then allow an additional source, free to wander anywhere in scan angle and determine a new χ^2. The position shown maximizes the χ^2 change. In this particular case the change in χ^2 is nine units, equivalent approximately to a 2.7σ result. We have data on this region of the sky 6 months later and there is an enhancement at this identical scan angle,and therefore we believe the case is strong enough to think there may be a new source in this region, in that we see the source on two different occasions. The statistics are summarized in Figure 6. The overall probability that the effect is only a statistical fluctuation is 2×10^{-3}, about equivalent to a 3.1σ result.

Figure 7 shows the intensity of the source as a function of the observing day for the 1977 data. The points are the observed intensity. The staircase is the collimator response fitted to the points. The fit is certainly acceptable. There is no gross evidence for either strong variability or for a source which is extended in this angular dimension.

The error box determined from the 2 observations is shown in Figure 8. Its area is 1.4 square degrees approximately seven times smaller than the size of the gamma-ray error region. The significance of the COS-B error box has not been stated; however, I think it is reasonable to assume that its significance is comparable to the SAS-2 result. Therefore we claim the position of the X-ray source is consistent with both gamma-ray error boxes.

Figure 9 gives the parameters relating to the source's intensity and spectrum. The energy flux from 2-6 Kev is 1.5×10^{-11} ergs $cm^{-2}5^{-1}$ or approximately 0.9 Uhuru counts/sec. You can calculate the probability of seeing by chance, an unrelated X-ray source, of this intensity or stronger anywhere within the immediate 10-square degree vicinity of the gamma-ray error boxes, based on what is already known about the density of X-ray sources of a given strength. That chance probability is calculated to be 9 percent. This number is small enough to indicate that the X-ray source may well be associated with the gamma-ray source.

The spectrum of the source was determined from data when the detectors were pointed at the source for 6 hr. The spectrum is fit equally well by either a power law or by simple thermal bremsstrahlung with the parameters shown in the slide.

Figure 10 shows a comparison of the X-ray source spectrum with the gamma-ray spectrum. To make this comparison I have taken the SAS-2 integral flux value and assumed a power law exponent for the number spectrum of -1.5. If one makes the assumption that the X-ray source and the gamma-ray source are indeed related, then the following observations are relevant. The best fit power law of the X-ray source falls below the gamma-ray by about four orders of magnitude; that is, there does not seem to be a simple extrapolation to the gamma-ray point. Also the level of hard X-ray emission and low energy gamma-rays suggested by this slide are not very encouraging to experimenters seeking to fill in the gap. For example at 100 keV the energy flux density of 10^{-4} keV/cm^2-sec-keV is less 1/100 of the total emission from the Crab at the same energy. On the plus side we believe that this detection may represent an important first step in identifying γ195+5.

Certainly, the smaller error box will guide future identification efforts with the Einstein Observatory and at other wavelengths. The region will be studied with the Einstein Observatory in August or September of this year.

DISCRETE γ RAY SOURCES

TYPE	NUMBER
1. GALACTIC	
PULSARS	6
CYGNUS X-3	1
2. EXTRAGALACTIC	3
3. UNIDENTIFIED	19
TOTAL	29

Figure 1

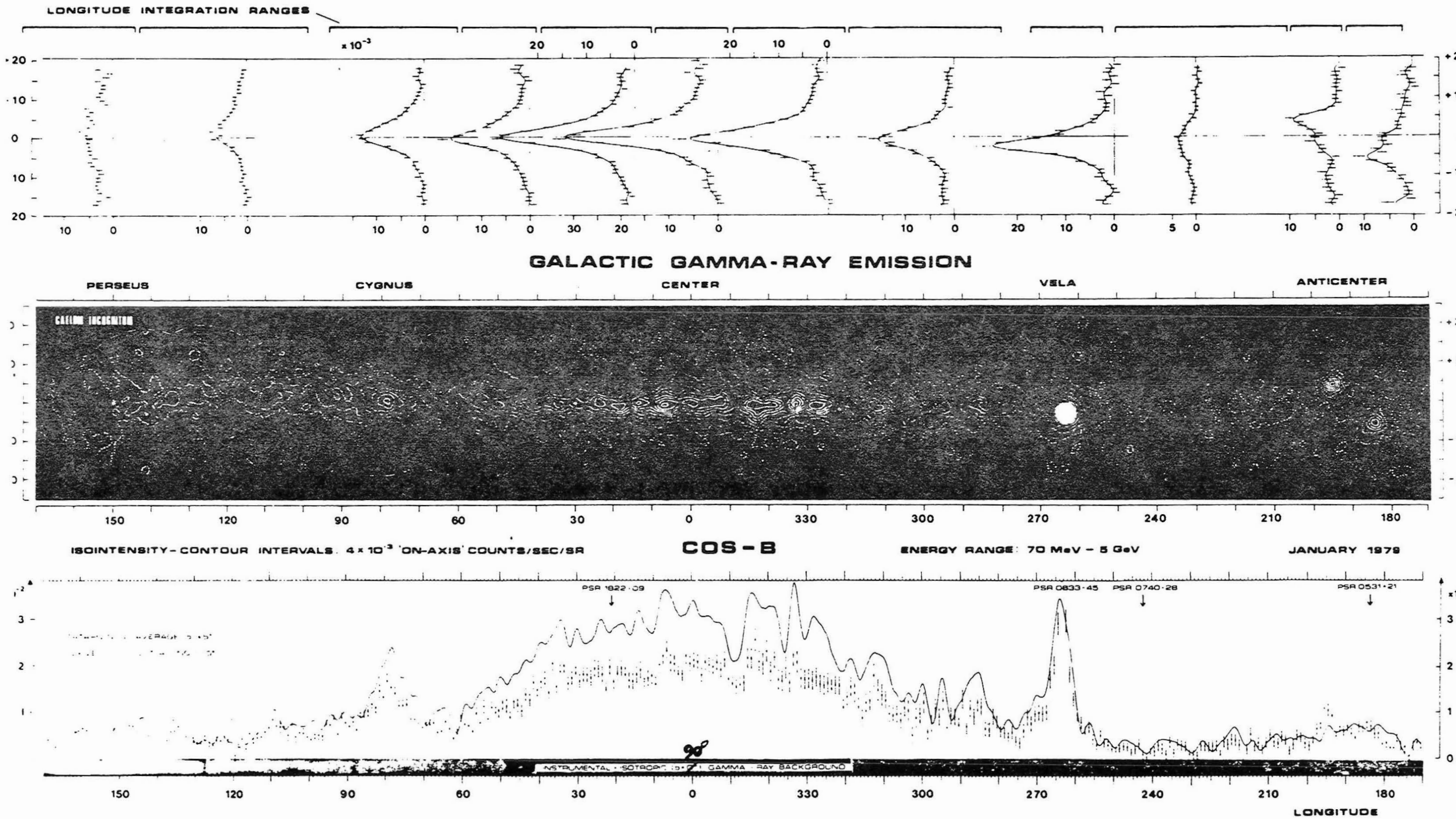
LONGITUDE INTEGRATION RANGES
GALACTIC GAMMA-RAY EMISSION
PERSEUS
CYGNUS
CENTER
VELA
ANTICENTER
ISOINTENSITY-CONTOUR INTERVALS: 4 × 10^{-3} 'ON-AXIS' COUNTS/SEC/SR
COS-B
ENERGY RANGE: 70 MeV – 5 GeV
JANUARY 1979
PSR 1822-09
PSR 0833-45
PSR 0740-28
PSR 0531+21
150 120 90 60 30 0 330 300 270 240 210 180
LONGITUDE

Figure 2

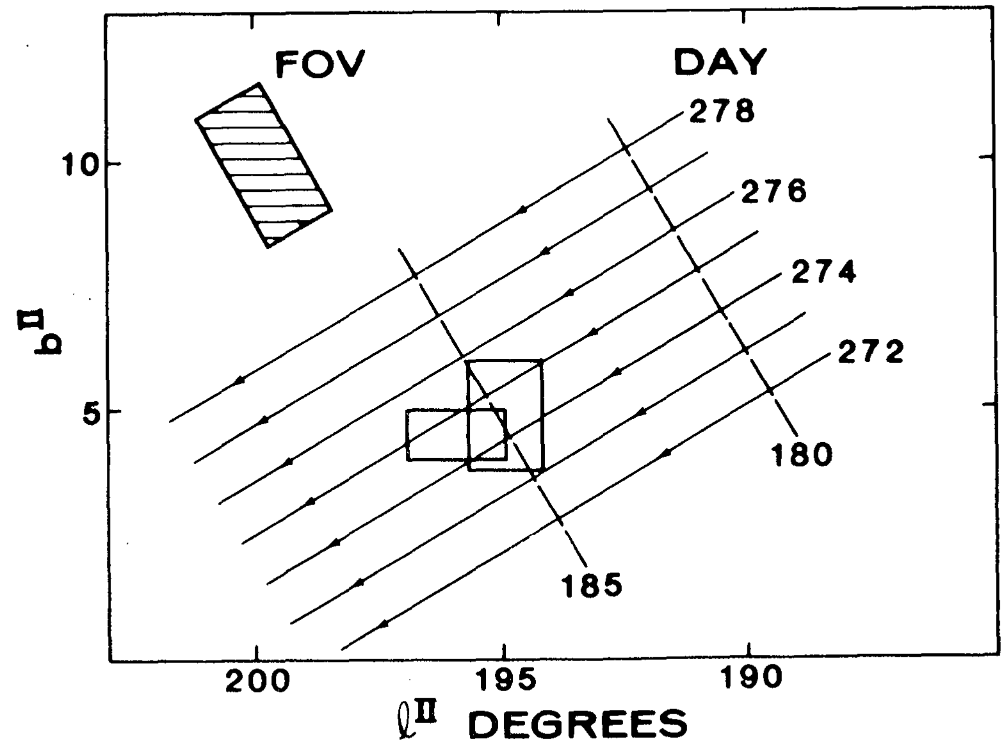

Figure 3

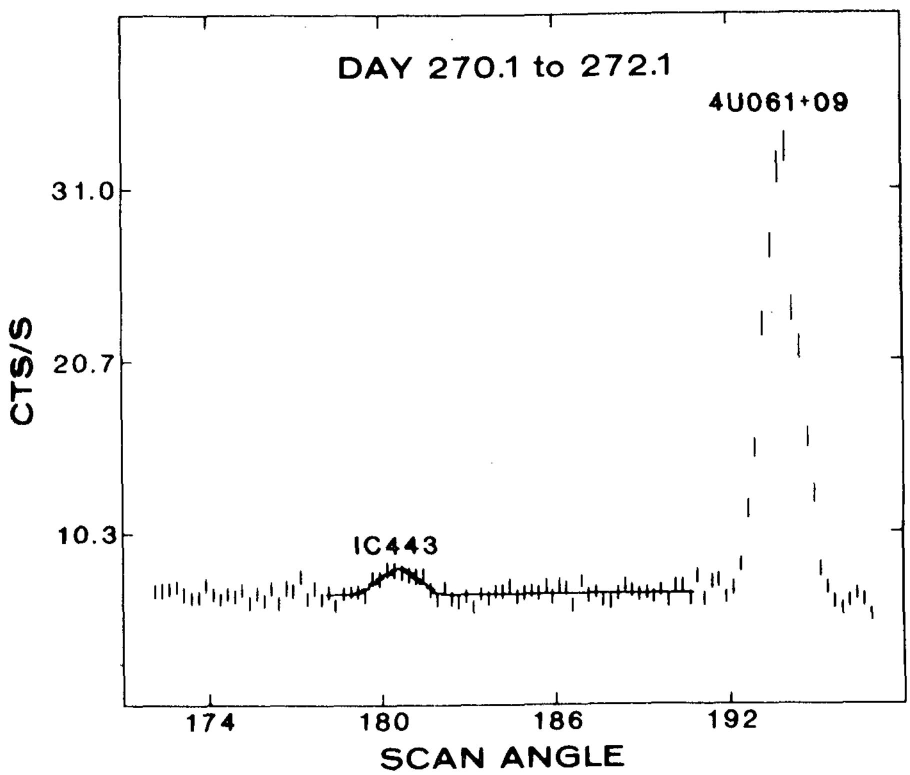

Figure 4

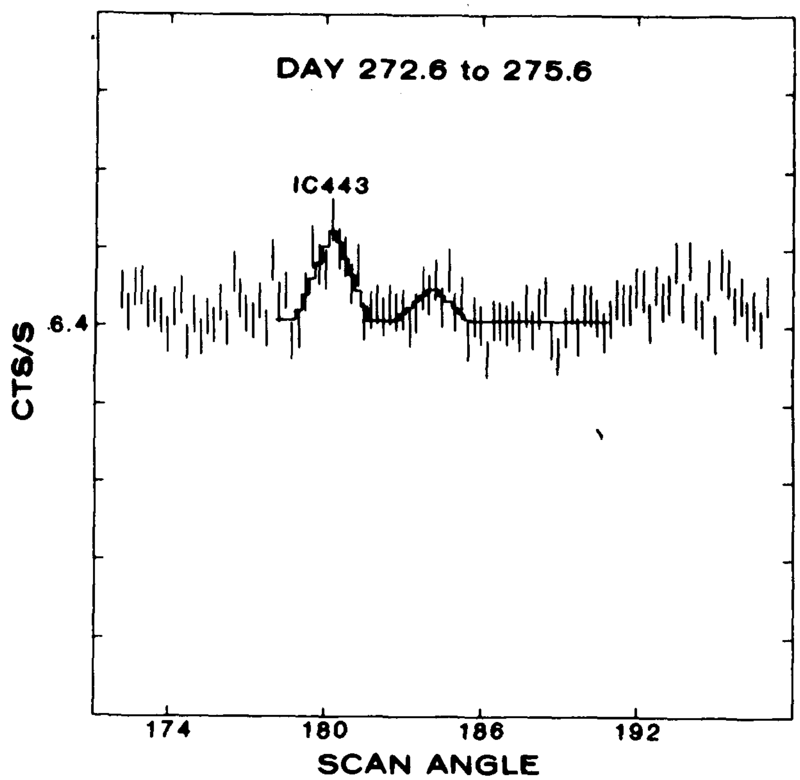

Figure 5

STATISTICAL SIGNIFICANCE

DATA SET	$\Delta\chi^2$	PROBABILITY THAT THE EFFECT IS A FLUCTUATION
October 1977	8.9	0.8×10^{-2}
March 1978	5.0	5×10^{-2}

The positions of the two source determinations are in good agreement:

$$\Delta(\text{scan angle}) = 0^\circ\!.02 \pm 0.38$$

$$\Delta(\text{day angle}) = 0^\circ\!.65 \pm 0.61$$

The combined probability that the effect is a fluctuation is: $(0.8 \times 10^{-2})(5 \times 10^{-2}) = 4 \times 10^{-4}$.

The number of resovable positions in the immediate vicinity of the γ-ray error boxes is ≈ 5. Therefore, the overall significance is:

$$5 \times 4 \times 10^{-4} = 2 \times 10^{-3} \qquad (3.1\sigma)$$

Figure 6

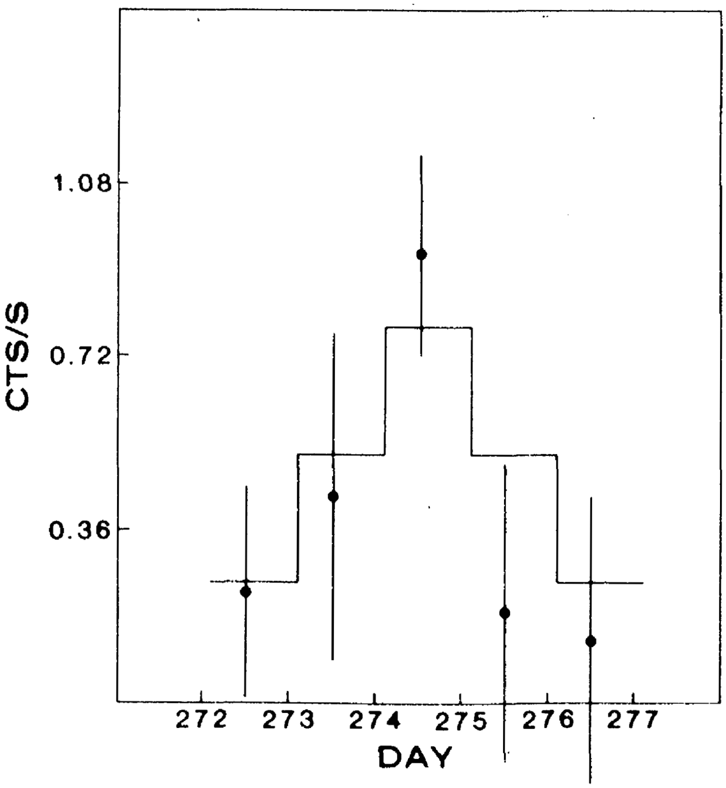

Figure 7

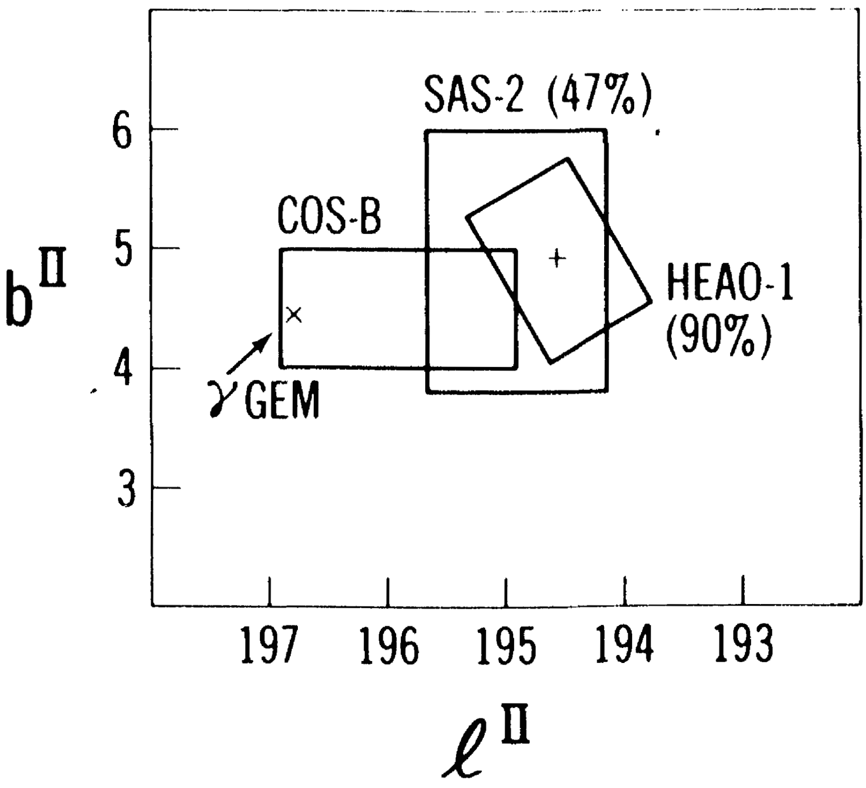

Figure 8

SOURCE INTENSITY (2-10 KeV)

PHOTON FLUX (CM^{-2} S^{-1})	ENERGY FLUX (ERGS CM^{-2} S^{-1})
$(3.2 \pm 1.0) \times 10^{-3}$	$(2.1 \pm 0.7) \times 10^{-11}$

SPECTRUM

POWER LAW

DN/DE α $E^{-\alpha}$: $\alpha = 2.6^{+0.7}_{-0.6}$

ABSORPTION $< 7 \times 10^{22}$ (H ATOMS CM^{-2})

THERMAL BREMSSTRAHLUNG

$kT = 6 \pm 3$ KeV

ABSORPTION $< 4 \times 10^{22}$ (H ATOMS CM^{-2})

Figure 9

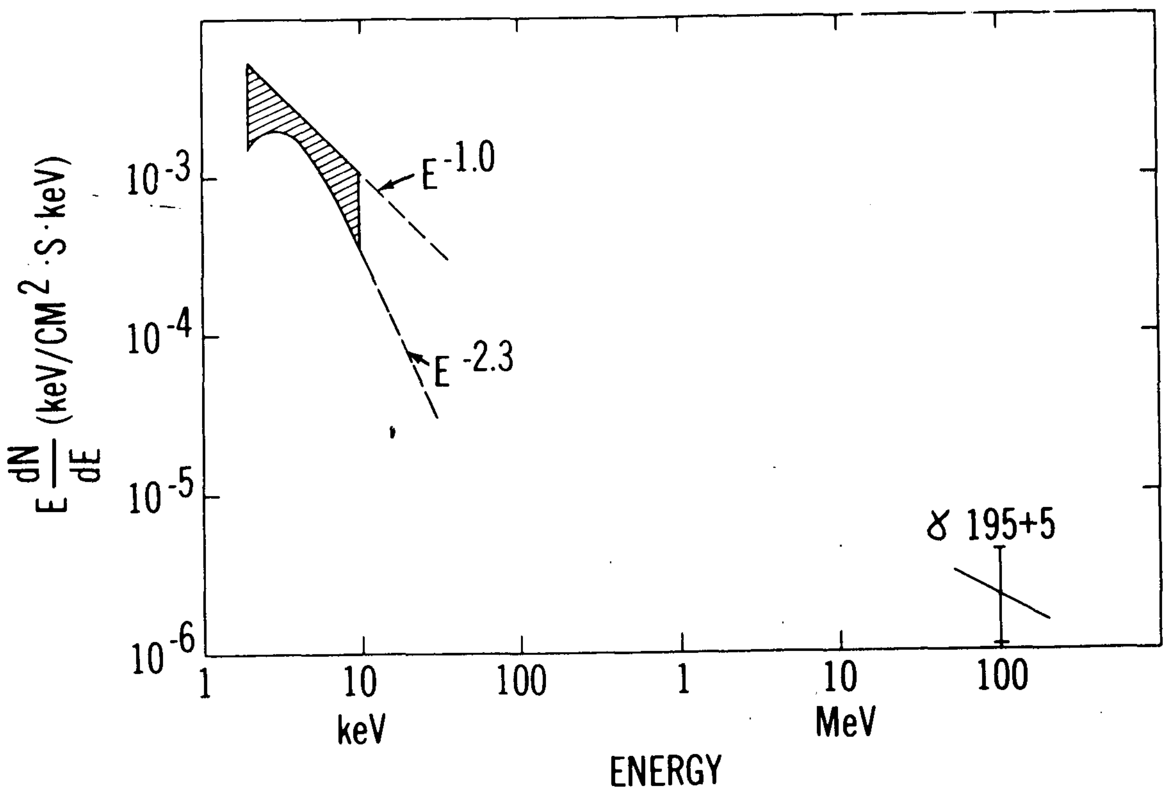

Figure 10