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A COMPLETE X-RAY SAMPLE OF THE HIGH LATITUDE (|b|>20°)
SKY FROM HEAO-1 A-2: LOG N - LOG S AND LUMINOSITY FUNCTIONS

G. Piccinotti, R.F. Mushotzky, E.A. Boldt, S.S. Holt,
F.E. Marshall, P.J. Serlemitsos and R.A. Shafer

Laboratory for High Energy Astrophysics
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

ABSTRACT

The HEAO-1 experiment A-2 has performed a complete X-ray survey of the 8.2 steradians of the sky at |b| > 20° down to a limiting sensitivity of < 3.1 x 10^{-11} ergs/cm² sec in the 2-10 keV band. Of the 85 detected sources (excluding the LMC and SMC sources) 17 have been identified with galactic objects, 61 have been identified with extragalactic objects and 7 remain unidentified. The log N - log S relation for the non-galactic objects is well fit by the Euclidean relationship. We have used the X-ray spectra of these objects to construct log N - log S in physical units. The complete sample of identified sources has been used to construct X-ray luminosity functions, using the absolute maximum likelihood method, for clusters of galaxies and active galactic nuclei.

Keywords: X-Ray Sources, Luminosity Function, Cosmic X-Ray Background

1NAS/NRC Research Associate

2Also Dept. Physics & Astronomy, Univ. of Maryland
I. INTRODUCTION

The HEAO-1 satellite experiment A-2 (Rothschild et al. 1979) with its extended energy range, complete sky coverage, low and stable internal background and moderate spatial resolution has enabled us to create a complete catalog of X-ray sources at galactic latitudes $|b| > 20^\circ$ down to a limiting sensitivity of $3.1 \times 10^{-11}$ ergs/cm$^2$ sec in the 2-10 keV band. Recent identifications of these sources by modulation collimator experiments on HEAO-1 and SAS-3 as well as imaging detectors on HEAO-2 has resulted in certain identifications of all sources of flux $\geq 4.0 \times 10^{-11}$ ergs/cm$^2$ sec, pending confirmation of two clusters and NGC 7172, and reasonable identifications for 78 out of the 85 (92%) sources in the sample. All but 9 of these identifications are extremely likely or certain. This identification ratio for the extragalactic sources compares to identification of 45 out of 67 (67%) sources in the sample of Warwick and Pye (1979).

The completeness of this sample enables construction of the number-intensity distribution ($\log N - \log S$) for X-ray sources as well as developing X-ray luminosity functions for clusters of galaxies and active galactic nuclei. In addition the body of X-ray spectral data returned by A-2 allows us to cast the $\log N - \log S$ distribution in absolute rather then instrument dependent units which enables comparison with the $\log N - \log S$ relation in different X-ray energy bands (cf. Giacconi et al. 1979).

Analysis of this data shows that the source counts are well fit by a "Euclidean" law with

$$\frac{dN}{dS} = 16.5 \cdot S^{-5/2} \text{ (R15 cts/sec)}^{-1} \text{ sr}^{-1}$$

consistent with previous results despite the quite different samples (Warwick
and Pye 1978; Schwartz 1979). The luminosity functions are well fit by power law representations with

\[ \frac{dN}{dL} \leq 3.5 \times 10^{-7} L_{44}^{-2.15} (10^{44} \text{ erg/sec})^{-1} \text{ Mpc}^{-3} \]

for clusters of galaxies, and

\[ \frac{dN}{dL} \leq 2.7 \times 10^{-7} L_{44}^{-2.75} (10^{44} \text{ erg/sec})^{-1} \text{ Mpc}^{-3} \]

for active galactic nuclei, similar to previous results (McKee et al. 1980; Pye and Warwick 1979). Integration of the luminosity functions over the \( < 10^{42.5} - 10^{45} \) erg/sec range within which they are well determined results in estimates of the contribution of clusters and active galactic nuclei to the integral 2-10 keV unresolved X-ray background of \( < 4\% \) for clusters and \( < 20\% \) for active galaxies. Using these luminosity functions, with no evolution, we estimate that \( < 30\% \) of the sources seen in the Einstein Observatory deep survey (Giacconi et al. 1979) should be relatively low luminosity (\( L < 1 \times 10^{44} \) erg/sec) nearby (\( z \leq 0.5 \)) objects.

II. DATA ANALYSIS AND SOURCE SELECTION

The HEAO-1 A-2 experiment, described in detail by Rothschild et al. (1979), provided two independent, low background, high sensitivity surveys of the entire sky six months apart. We have analyzed the A-2 data in order to obtain a complete flux limited sample of extragalactic X-ray sources. The region between \(-20^\circ\) and \(+20^\circ\) in galactic latitude has been excluded to minimize contamination from galactic sources. A circle of 6 degrees radius around the LMC sources has been also excluded to prevent confusion problems. Therefore, we remain with 65.5% of the sky (8.23 ster). The statistical
significance of the existence of the sources is tested by determining the
decrease in $\chi^2$ when the new source is added to the model. All sources in the
sample give a decrease in $\chi^2$ of at least 30. The probability of having, by
chance, a decrease of 30 in $\chi^2$ with two degrees of freedom (scan angle and
intensity) is $3 \times 10^{-7}$. This probability is almost the same as the one
associated with a deviation of $5\sigma$ in a Gaussian distribution ($6 \times 10^{-7}$).
Therefore, we can also state that the lowest statistical significance for the
existence of the sources included in our sample is $5\sigma$, as required by the
maximum likelihood methods we use to determine the log N - log S parameters
(see Section IV-1). Taking into account this statistical significance
requirement we estimated the completeness level of the first and the second
scan as 1.25 and 1.8 R15 counts/sec respectively, see Figure 1. One R15
count/sec $\leq 2.17$ erg cm$^{-2}$ sec$^{-1}$ in the 2-10 keV energy band for a power law
spectrum with photon index 1.65. R15 is a counting rate derived using the
$1.5^\circ \times 3^\circ$ FWHM fields of view of the second layer of the argon counter and
both layers of a xenon counter. This combination has a FWHM for the quantum

The second pass is less sensitive on average, because much more time was
spent in pointing at sources. We shall be more concerned with the first pass
data in deriving best fit parameters and use the second pass ones mostly as an
independent confirmation.

III. OBSERVATIONS

A. The Sample

Table 1 contains all the relevant data for the 68 sources either
brighter than 1.25 R15 c/s in the first scan which corresponds to days 248-437
of 1977, or brighter than 1.8 in the second scan, days 73-254 of 1978. Source
names are listed in column 1. Column 2 contains previous catalog names.
First pass fluxes and 1σ errors are in column 3, while the second pass ones are in column 4. Some fluxes may differ slightly from previously reported results, as different procedures have been used; e.g., in the recent paper by McKee et al. (1980) fluxes have been obtained fixing the X-ray position at the optical position, instead here we have used the best fit X-ray position to derive the flux. Available identifications are listed in column 5. The type of object is in column 6. One * in column 7 indicates firm identifications (i.e. as provided by the SAS-3 or HEAO-1 modulation collimator, or by the Einstein X-ray telescope), two * indicates possible identification consistent with larger error boxes. Redshift values and references are given in column 8. Spectral information is now available for more than half of our sources (Mushotzky et al. 1980; Worrall et al. 1980; Mushotzky 1979; Holt 1980; Boldt 1980), we quote in column 9 conversion factors between R15 counts/s and ergs cm⁻² s⁻¹. When spectral information is lacking we assumed a 6 keV thermal bremsstrahlung spectrum for all sources identified with clusters and a 1.65 photon index power law for all sources identified with active galaxies. An average conversion factor value of 2.5 × 10⁻¹¹ ergs cm⁻² s⁻¹/R15 counts s⁻¹ was assumed for the few unidentified sources. Columns 10 and 11 contain the first and second pass luminosities in units of 10⁴⁴ erg s⁻¹ calculated for \( H_0 = 50 \text{ km/s/Mpc} \) and \( q_0 = 0.5 \). Column 12 contains notes.

B. Classes of Sources

Sixty of the 82 sources brighter than 1.25 counts s⁻¹ in the first scan and not definitely associated with galactic objects have been associated with extragalactic objects. Only 7 remain unidentified at the present time. These 60 identified sources subdivide almost equally between clusters of galaxies (30) and single galaxies (30). Most of the 30 galaxies are Seyfert galaxies of class 1 or 2, but we have also 1 QSO (3C 273), 4 BL Lac objects, and 1
"normal" galaxy (NGC 7172). Note that M31 and the Magellanic Cloud sources are not included in our extragalactic sample because they represent a local inhomogeneity as part of the local group of galaxies. Table 2 lists the 17 high galactic latitude sources not included in our extragalactic sample because they have been identified with galactic or "local" objects. The second pass sample contains only 37 sources brighter than 1.8 R15 counts/sec, all but one identified. The source classification is consistent with the first pass. Assuming Poisson errors, clusters contribute 50 ± 9% of the identified sources in the first pass and 61 ± 13% in the second. Galaxies contribute 50 ± 9% in the first scan and 39 ± 10% in the second.

C. New Sources and Sample Completeness

H0328+025 and H0917-075 are the only entirely new sources in Table 1. Figure 2 shows their error boxes. All the other sources in Table 1 have been listed somewhere else before. The improvement in our sample, as compared to previously reported ones, is due to a better rejection of non-extragalactic sources, made possible by the recent identifications, and to a uniform sky coverage to a relatively low limiting flux.

As the instrument has a fairly large (1.5° x 3.0°) angular resolution the possibility of source confusion must be considered. The total area of the sky included in this survey is approximately 2.7 x 10^4 square degrees, therefore there are about 6 x 10^3 independent positions on it. As the high galactic latitude X-ray sources bright enough to give confusion problems at our sensitivity level cannot be more than a hundred using the log N-log S relation derived later (taking into account also the possibility that two weaker sources can simulate a source bright enough to be included in our list) we therefore expect negligible confusion. That is using \( \frac{dN}{dS} < 16.5 \ S^{-1.5} \) there are roughly 65 resolution elements per source, of \( S > 1.25 \text{ cts} \), well above the
confusion level of 25 beam areas per source often quoted in the literature. In addition the uniform sky coverage at the chosen sensitivity levels provided by this experiment and the availability of two independent sets of data for cross-checking purposes support our confidence in the completeness of our sample.

D. Space Distribution of Sources

Since the pioneering work of DeVaucouleurs (1958) much attention has been devoted to finding evidence of a supercluster centered in the Virgo cluster of galaxies. We plotted the positions of our sources in supergalactic coordinates looking for some kind of anisotropy. Figure 3 shows the first pass sample. Obviously, no anisotropy is observed as most sources lie beyond the supercluster. If we restrict our attention to the 12 sources with redshifts less than .01 (in boxes in Figure 3), we see that 9 are in the center region of the supercluster while 3 are in the anticenter and that all but one have supergalactic latitude less than 30 degrees in absolute value. This result, which is significant at the few percent level, suggests that close X-ray galaxies may lie preferentially in the supergalactic plane. But no conclusion can safely be made from such a small number of objects at present.

IV. THE NUMBER-FLUX FUNCTION

The usual power law form

\[ N(S) = KS^{-\alpha} \text{ (Rl5 counts/sec)}^{-1} \text{sr}^{-1} \]  

has been assumed for the number-flux relation. The various methods applied to estimate the coefficient K and the differential exponent \( \alpha \) as well as to evaluate the goodness of the fit are outlined in the next section.

A. Statistical Methods
1. Maximum Likelihood

Crawford, Jauncey and Murdoch applied the maximum likelihood method to unbinned data in order to estimate the slope of the number-flux relation of radio sources. In the first paper (Crawford et al. 1970) a solution is worked out for error free data. In the second paper (Murdoch et al. 1973) the method is extended to include errors on the measured fluxes. Numerical corrections to the error free answers were calculated for the special case of Gaussian distributed errors. In the same paper it was pointed out that a minimum signal-to-noise ratio of five is required so that the uncertainty in the correction factor due to weaker sources does not dominate the correction itself. This is why we excluded from our sample sources with statistical significance less than $5\sigma$. In both papers I and II the Kolmogorov-Smirnov test (hereafter: K-S test) was suggested to evaluate the goodness of the fit obtained. In the remainder of this paper we will refer to this method as to the Maximum Likelihood (ML) method.

2. Absolute Maximum Likelihood

The ML method assumes the same underlying error distribution for all the sources in the sample, i.e. it assigns the same $1\sigma$ error to all the sources. As we deal with sources of greater than $5\sigma$ significance the error assumed is one fifth of the minimum flux in the sample, or $0.25 R_{15}$ count s$^{-1}$ in the first scan and $0.36 R_{15}$ count s$^{-1}$ in the second. Table 1 shows that these values are not very far from the actual errors. However Lightman et al. (1980) have developed a refinement of the ML method in connection with the K-S test capable of handling sources with their own experimental error. Following those authors we will call this new statistical method the "Absolute Maximum Likelihood" (AML) method. Lightman et al. (1980) worked out the AML method on general grounds and then applied it to the evaluation of globular cluster
X-ray source masses. As this is the first application of the AMX method to
the number flux function, we give a short outline of the method below.
Assuming the form (1) for the number-flux relation and a Gaussian
form \( \rho(F_i, \sigma_i, S) \) for the error distribution of the measured fluxes we evaluated
numerically the integral probabilities \( P_i(a) \) as

\[
P_i(a) = \frac{\int_{F_{\min}}^{F_i} df \int_{S(a)}^{S} dS N(S, a) \rho(F, \sigma_i, S)}{\int_{F_{\min}}^{F_{\infty}} df \int_{S(a)}^{S} dS N(S, a) \rho(F, \sigma_i, S)}
\]

where \( S \) is the true flux, \( F_i \) and \( \sigma_i \) are the measured flux and error of the
i-th source. \( F_{\infty} \) is a cutoff value used to avoid the apparent divergence at \( F = 0 \). As in Murdoch et al. (1973) the particular choice of the cutoff value
does not affect the value of the integral as long as the statistical
significance of the sources is at least 5\( \sigma \). \( F_{\min} \) is the sensitivity limit
of the sample. For every assumed \( a \) we computed the \( P_i(a) \) for all the
sources. The \( P_i(a) \) should be uniformly distributed between 0 and 1.
Following Lightman et al. we evaluated the maximum deviation from the uniform
distribution:

\[
D_{\text{max}}(a) = \max_{i=1,N} \left( D_i(a) \right) = \max_{i=1,N} \left( \frac{\sum_{i=1}^{N} P_i(a) - \frac{1}{N}}{N} \right)
\]

where \( N \) is the number of sources in the sample and the \( P_i(a) \) have been sorted
in ascending order. Then we calculate the probability \( P(D_{\text{max}}(a)) \) of
observing deviations greater than \( D_{\text{max}}(a) \) from the formula for the K-S
statistic given by Birnbaum and Tingey (1951). The \( (a, P(D_{\text{max}}(a))) \) function is
then plotted. The best fit value of \( a \) is the one corresponding to the maximum
value \( P_{\text{MAX}} \) of the \( P(D_{\text{max}}(\alpha)) \) distribution. Obviously \( P_{\text{MAX}} \) must be greater than some minimum value (say 10%) in order to accept the model. The range in \( \alpha \) for results given below on \( \alpha \) are evaluated from the values \( \alpha_1 \) and \( \alpha_2 \) of \( \alpha \), which reduce \( P(D_{\text{max}}(\alpha)) \) to \( P_{\text{MAX}}/2 \).

3. Chi-Square

Both the ML and the AML methods are independent of the coefficient \( \kappa \) of the number-flux relation, as \( \kappa \) is lost in normalizing the probabilities. Therefore, we used the \( \chi^2 \) method to determine \( \kappa \). Bins with equal expected number of sources for \( \alpha = 2.5 \) have been used for the \( \chi^2 \) calculations. Of course, in calculating confidence bounds, we have assumed that the functional form of the distribution is the "true" one. If better data later shows that this is not true our confidence values are not applicable.

V. LOG N - LOG S RESULTS

The ML method applied to the 60 non-galactic sources brighter than 1.25 \( R_{15} \) counts \( s^{-1} \) in the first pass gives (in this section we use \( R_{15} \) counts \( s^{-1} \) as the unit)

\[
\alpha = 2.67 \pm .23
\]

with a goodness of fit probability (evaluated using the KS test) of 39.5 percent.

For the 37 non-galactic sources brighter than 1.8 \( R_{15} \) counts \( s^{-1} \) in the second pass the ML result is

\[
\alpha = 2.74 \pm .32
\]
with a probability of 17.5 percent.

The AMR results are

\[ \alpha = 2.63 \pm 0.2 \]

in the first pass, see Figure 4a, and

\[ \alpha = 2.74 \pm 0.22 \]

in the second, see Figure 4b.

The 68 and 95 percent probability contours for the 1st pass values of \( \kappa \) and \( \alpha \) evaluated with the \( \chi^2 \) method are plotted in Figure 4c. The \( \chi^2 \) best fit values and 1\( \sigma \) errors for the number-flux function parameters are

\[ \alpha = 2.72^{+0.10}_{-0.10} \]
\[ \kappa = 20^{+4.0}_{-2.6} \quad \text{(Rl5 counts/sec)}^{-1} \text{ sr}^{-1}. \]

The differential number-flux data as well as the best fit function

\[ N(S) = 20 S^{-2.72} \quad \text{(Rl5 counts/sec)}^{-1} \text{ sr}^{-1} \]

are plotted in Figure 5; the \( \chi^2 \) value of the fit is 2.79 for 6 degrees of freedom, corresponding to a probability \( P( > \chi^2) \leq 83\% \). The limited size of the second scan sample does not allow a good estimate of the probability but the results are consistent with the first pass ones.

C. Number Flux Relation in Physical Units

Using the conversions factors listed in column (9) of Table 1 we can
express the fluxes in ergs cm\(^{-2}\) s\(^{-1}\) and evaluate the number-flux relation accordingly. Conversion factors range approximately from 2.0 \(\times\) 10\(^{-11}\) to 2.9 \(\times\) 10\(^{-11}\) ergs cm\(^{-2}\) s\(^{-1}\) (R15 counts s\(^{-1}\))\(^{-1}\), the highest values referring to soft spectra sources whose emission peak lies below our instrument energy window. As a consequence of the different conversions factors the completeness level of the samples when fluxes are in ergs cm\(^{-2}\) s\(^{-1}\) is equal to the former completeness level in R15 counts s\(^{-1}\) times the maximum conversion factor: that is \(<\ 3.6 \times 10^{-11}\) ergs cm\(^{-2}\) s\(^{-1}\) for the first pass and 5.2 \(\times\) 10\(^{-11}\) ergs/cm\(^2\) sec in the second pass. The 1st scan sample with this flux restriction contains 51 sources: 25 clusters, 22 "galaxies" and 4 unidentified sources. The best fit values and 1\(\sigma\) errors for the number-flux function parameters obtained with the three methods agree with

\[
\alpha \leq 2.85 \pm .3 \\
\kappa \leq (5.65^{+1.9}_{-1.3}) \times 10^{-19} \text{ ergs cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1} \tag{5}
\]

The 32 second scan sources brighter than 5.2 \(\times\) 10\(^{-11}\) ergs cm\(^{-2}\) s\(^{-1}\) give us a best fit of slightly steeper slope \(\alpha \leq 3.1 \pm .4\).

VI. DISCUSSION OF THE RESULTS

All the first pass samples, whether fluxes are expressed in R15 counts s\(^{-1}\) or in ergs cm\(^{-2}\) s\(^{-1}\) are consistent with the five halves Euclidean slope (see Figures 6 and 7). The slight preference for a steeper than Euclidian slope is due to the distribution of the brightest few sources in calculating the likelihood functions. It is these sources that are most sensitive to changes in \(\alpha\) by virtue of the relatively small statistical error in their measured intensity. Our Euclidean best fit for the 1st pass data is
\[ N(S) = 16.5^{+3}_{-2} \ S^{-2.5} \ (\text{R15 counts}/s)^{-1} \text{sr}^{-1} \]

with a \( \chi^2 \) of 5.5 for 7 degrees of freedom; \( \rho(\chi^2 > 5.5) \leq 60\% \). The AML probability for \( \alpha = 2.5 \) is 42.4\%. Assuming an average conversion factor of \( 2.4 \times 10^{-11} \text{ergs cm}^{-2}\text{s}^{-1} (\text{R15 counts s}^{-1}) \) the relation (4) becomes

\[ N(S) \leq (1.9^{+0.35}_{-0.25}) \times 10^{-15} \ S^{-2.5} \ (\text{ergs cm}^{-2}\text{s}^{-1})^{-1} \text{sr}^{-1} \]

in agreement with the exact result

\[ N(S) \leq (2.2^{+0.3}_{-0.2}) \times 10^{-15} \ S^{-2.5} \ (\text{ergs cm}^{-2}\text{s}^{-1})^{-1} \text{sr}^{-1} \]

obtained from the last pass complete sample for fluxes in \( \text{ergs cm}^{-2}\text{s}^{-1} \) and using the conversion factors in Table 1.

VII. COMPARISON WITH PREVIOUS EXPERIMENTS

Both the Uhuru (Schwartz 1979) and Ariel 5 data (Warwick and Pye 1978) gave a flux-number function consistent with the Euclidean model. Their best fit values for the coefficient \( \kappa \) with \( \alpha = 2.5 \) and \( S \) in R15 counts s\(^{-1}\) are respectively

\[ \kappa = 16.5 \pm 3.9 \quad \text{using 1 Uhuru ct/s} = 1.0 \text{ R15 ct/sec} \]

and

\[ \kappa = 15.8 \pm 4.2 \quad \text{using 1 Ariel-5 ct/sec} = 2.12 \text{ R15 ct/sec} \]

in agreement with our results at the 10 level. These conversion factors assume a mean R15 conversion factor of \( 2.4 \times 10^{-11} \text{ergs/sec}, 1 \text{ Uhuru ct/sec} = 2.4 \times 10^{-11} \text{erg/sec}, \) and \( 1 \text{ Ariel-5 count/sec} = 5.1 \times 10^{-11} \text{erg/sec}. \) If we use the calibration of Marshall et al. (1979) appropriate for the active galaxies of \( 1 \text{ R15 ct/sec} = 2.17 \times 10^{-11} \text{erg/cm}^{2}\text{sec}, \) we find \( \kappa_{\text{Uhuru}} < 20 \) and
The best fit slope of Warwick and Pye of $2.7 \pm 0.2$ is also consistent with our result.

VIII. LUMINOSITY FUNCTION

A. Method and Data Base

Many authors (Schwartz 1978; Mollardy 1978; McKee et al. 1980; Elvis et al. 1977; Pye and Warwick 1979; Tananbaum et al. 1978; Boldt 1980) have recently considered the problem of evaluating the X-ray luminosity functions for different classes of sources principally, clusters of galaxies and active galaxies. All of them with the exception of Pye and Warwick had to rely upon optical data to select complete samples. We present here X-ray luminosity functions evaluated from X-ray flux limited samples. As we remain with a few unidentified sources, our results have some uncertainty, but we believe that the residual incompleteness should not be very important.

1. The Samples

The first pass sample of clusters of galaxies contains 30 objects. The second pass one includes 22 sources. Thirty "galaxies" are observed in the first pass, but we exclude from our sample the QSO 3C273, the 4 BL Lac objects, the peculiar galaxy M82 and the "normal" galaxy NGC 7172 as they are not homogeneous with the bulk of the sample which consists of Seyfert galaxies. Therefore we remain with 23 active galactic nuclei. The second pass sample contains only 12 objects (after excluding 3C 273 and PKS 2155-304).

The completeness of the sample is checked using the Schmidt $<V/V_M>$ test and with a K-S test on the distribution of the $V_L/V_M$ as suggested by Avni and Bahcall (1980). The results are listed in Table 3.

TABLE 3
### CLASS OF OBJECTS | SCAN # | IN SAMPLE | $<V/V_M>$ | $P(>d)$
--- | --- | --- | --- | ---
Clusters of Galaxies | 1 | 30 | 0.471 ± 0.054 | 18.1
Clusters of Galaxies | 2 | 22 | 0.552 ± 0.062 | 11.8
Active Galaxies | 1 | 24 | 0.523 ± 0.059 | 50.4
Active Galaxies | 2 | 12 | 0.557 ± 0.083 | 56.8

The 1σ error quoted for $<V/V_M>$ is the formal error $1/\sqrt{2N}$, where $N$ is the number of objects in the sample (see Avni and Bahcall). All the 4 samples meet the requirements of the tests. However, we expect a small degree of incompleteness due to the unidentified sources.

#### 2. Methods of Analysis

Of the three methods outlines in Sec (IV-A) only the AML is suited for the determination of the luminosity function parameters. The relatively small sizes of the samples do not allow an efficient use of the $\chi^2$ square method or of any other binned method. Moreover, the ML method in the form developed by Crawford, Jauncy and Murdoch cannot be used because of its assumptions of a single underlying error distribution. This last hypothesis was reasonably satisfied by the flux data in the evaluation of the log N log S parameters, as we already pointed out, but is not satisfied at all by the luminosity data, as the errors are proportional to the square of the redshift of the sources:

$$\sigma_{L_I}^2 = z^2 \sigma_{F_i}^2$$  \hspace{1cm} (6)

On the contrary, the AML method is well suited for the task. The description of Section IV-A still applies. However, instead of calculating the probabilities of eq (2) we evaluated the probabilities:
Eq. (7) gives the integral normalized probabilities of observing a source with measured luminosity less or equal to \( L_i \), assuming a Gaussian error distribution with standard deviation \( \sigma_{L_i} \), and for the differential luminosity function the form \( f(L, q) \) where \( L \) is the true luminosity and \( q \) represents the functional parameters to be determined. \( L_{\text{min}} \) and \( L_{\text{max}} \) are the lower and upper boundaries of the luminosity function. \( V_{\text{MAX}} \) is the maximum volume at which one could detect the source and depends on the sensitivity limit of the sample. For a source of luminosity \( L \) in a sample of minimum sensitivity \( F_{\text{MIN}} \) the maximum visibility volume \( V_{\text{MAX}} \) is proportional to 

\[ (\sqrt{L/F_{\text{MIN}}})^3 \]

Note that Eq. (7) does not take in account errors on the redshift \( z \). The AML method can determine the form of the luminosity function but not its absolute value. Therefore we have used a least squares fit to the unbinned data to evaluate the multiplicative coefficient.

B. Results

1. Clusters of Galaxies Luminosity Function

We considered two different forms for the luminosity function: the power law form

\[ f(L) = KL^{-\gamma} \]

and the exponential form
between the minimum \( L_{44 \text{min}} \) and maximum \( L_{44 \text{max}} \) observed luminosities, expressed in units of \( 10^{44} \text{ ergs sec}^{-1} \). The normalization for a power law luminosity function scales as \( H_0^{-1} \).

Clusters of Galaxies

Figure 9 represents the AML probabilities for the slope of the cluster of galaxies power law luminosity function. The 1st pass best fit values for the power law parameters are

\[
\gamma = 2.15^{+1.12}_{-1.17} \\
K = (3.5 \pm 1.1) \times 10^{-7} (10^{44} \text{ erg/s})^{-1} \text{ Mpc}^{-3}.
\]

K has been evaluated with the least squares method. The error on K has been determined by letting \( \gamma \) assume the 10 extreme values of 2.03 and 2.32. Figure 8a gives a binned representation of the data with the best fit luminosity function. Each bin contains three sources, except for the highest luminosity bin which contains five. The second pass results are

\[
\gamma = 2.13^{+1.16}_{-0.24} \\
K = (3.8 \pm 2) \times 10^{-7} (10^{44} \text{ ergs/s})^{-1} \text{ Mpc}^{-3}.
\]

Figure 8b gives the binned representation. The minimum luminosity object in both the 1st and the 2nd pass at \( 2.4 \times 10^{43} \text{ (ergs/s)} \) is the Virgo cluster. The highest luminosity cluster is Abell 2142 with \( 2.8 \times 10^{45} \text{ (ergs/s)} \).

The exponential form of the luminosity function has also been considered, but the quality of the fit is poorer, see Figure 10.
As the Virgo Cluster of galaxies has a "local" character, we evaluated
the cluster of galaxies luminosity function without the Virgo cluster. The
1st pass sample is reduced to 29 sources, the mean $V/V_{\text{MAX}}$ is $0.486 \pm 0.055$ and
the K-S test on the uniformity of the $V/V_{\text{MAX}}$ distribution gives a probability
of $24.7\%$. The 2nd pass sample contains 21 sources, the mean $V/V_{\text{MAX}}$ is $0.576 \pm
0.063$ and the K-S probability is $6.1\%$. Figure 9 gives the
usual $(Y,P(Y))$ probability curves for the power law slope. The best fit
values for the parameters are

1st scan \[ Y = 2.03 \pm 0.18 \]
\[ K = (2.1^{+1.2}_{-0.8}) \times 10^{-7} \ (10^{44} \text{ ergs/s}) Y^{-1} \text{ Mpc}^{-3} \]

2nd scan \[ Y = 2.07^{+0.25}_{-0.25} \]
\[ K = (3.2 \pm 2) \times 10^{-7} \ (10^{44} \text{ ergs/s}) Y^{-1} \text{ Mpc}^{-3} \]

The minimum luminosity is now $< 3.6 \times 10^{43} \text{ ergs/s}$ (Abell 1060) in both first
and second scan. The exponential fit is again poorer, see Figure 10.

2. Active Galaxies

i. Luminosity Function

The insert in Figure 11 represents the AML probability for the power
law slope of the active galaxies differential luminosity function calculated
from the 1st pass data. The best fit values for the power law parameters are:

\[ Y = 2.75 \pm 0.15 \]
\[ K = (2.7 \pm 0.15) \times 10^{-7} \ (10^{44} \text{ ergs/s}) Y^{-1} \text{ Mpc}^{-3} \]

NGC 3227 is the weakest source in the sample with $1.75 \times 10^{42} \text{ ergs/s}$ and
IIIZw2 is the brightest with $1.3 \times 10^{45}$ ergs/s. Figure 11 shows the binned representation (3 sources/bin). This result is similar to that of Boldt (1980) and Pye and Warwick (1979). The exponential form for the luminosity function is not acceptable as the probabilities are always less than 2%.

The second pass sample is too small for a good determination of the luminosity function, however we find power law slopes steeper but consistent with the first pass ones.

ii. A Lower Limit to the Active Galaxy Luminosity Function

The active galaxies contribution to the cosmic X-ray background depends strongly on the lower luminosity limit of the luminosity function. The lower luminosity limit for which the function can represent the data, $L_{44\text{MIN}}$, can be calculated by noting that the luminosity function must be consistent with the log $N$ - log $S$ observations. Namely, we can set a lower limit on $L_{44\text{MIN}}$ by requiring that the number of active galaxies brighter than 1.25 $R_{15}$ counts/sec expected from the luminosity function does not exceed the observed number plus 1 or 2 times the square root of the expected number.

From eq (14.7.35) of Weinberg (1972), and assuming a power law luminosity function we have (for $\gamma \neq 2.5$ and $\gamma \neq 3$)

$$N(>S) = KA \left[ \frac{1}{2.5-\gamma} \frac{L_{\text{MAX}}}{L_{\text{MIN}}}^{\gamma} \right]^{-3/2} S^{-3/2} - B \left[ \frac{L_{\text{MAX}}}{L_{\text{MIN}}}^{\gamma} \right]^{-2} S^{-2}$$

(8)

where: $S$ is the flux in ergs cm$^{-2}$s$^{-1}$

$K$ and $\gamma$ are the parameters of the differential power law luminosity function in Mpc$^{-3}$ (erg/sec)$^{-(\gamma-1)}$

$L_{\text{MAX}}$ and $L_{\text{MIN}}$ are the upper and lower limit of the luminosity function (actually $N(>S)$ depends strongly on $L_{\text{MIN}}$ and very weakly on $L_{\text{MAX}}$)
all the luminosities are in ergs/s

\[ A = 3.20 \times 10^{-75} \]

\[ B = 4.7 \times 10^{-29} \text{ (assuming } H_0 = 50 \text{ km/s/Mpc)} \]

\( N(S) \) is the total number of sources in the sky uncorrected for sky coverage. The second term of this equation represents a first order cosmological correction to the Euclidean result.\(^{1}\)

\[ \text{Assuming an average conversion factor of } 2.17 \times 10^{-11} \text{ ergs cm}^{-2} \text{s}^{-1} \text{ per R15 counts s}^{-1} \text{ we find that the 1σ lower limit on } L_{\text{MIN}} \text{ is } 4 \times 10^{42} \text{ when } \gamma \text{ is } 2.75 \text{ and } K \text{ is } 2.68 \times 10^{-7} \left(10^{44} \text{ ergs/s}\right)^{-1} \text{ Mpc}^{-3} \text{ and } L_{\text{MAX}} \text{ varies between } 5 \text{ and } 15 \times 10^{44} \text{ ergs/sec.} \]

In Table 4 we show the 1 and 2σ limits on \( L_{\text{MIN}} \) as a function of \( L_{\text{MAX}} \) and \( \gamma \). We note that we have not included in Table 4 the possibility that all (or some) of the unidentified sources could be Seyfert galaxies. However, considering the distribution of identified sources with flux < 3 R15 cts/sec, we would expect, at most, 3 of these unidentified objects to be active galaxies.

**TABLE 4**

**APPROXIMATE \( L_{\text{MIN}} \) FOR VALUES OF \( L_{\text{MAX}} \) AND \( \gamma \)**

\[ L_{\text{MAX}} = 1.5 \times 10^{45} \]

\[ L_{\text{MAX}} = 3 \times 10^{45} \]
C. Discussion

1. Clusters of Galaxies

We note that our luminosity function for clusters of galaxies is very similar to the result of McKee et al. (1980). This indicates that, whatever selection effects are operating in making a X-ray or optically complete sample, they do not strongly bias the result. However there is a strong overlap in the individual objects between this sample and McKee's. The method we have used has allowed us in principle to discriminate between exponential and power law luminosity functions for clusters. It is somewhat surprising that a power law is favored, since it requires a change in form at low luminosities in order not to exceed the space density of all clusters (Bahcall 1979). However, the contribution of clusters to the diffuse X-ray background (DXRB) depends only weakly on the lower limit chosen. We do remind the reader that an exponential form is not excluded. Our data are not capable of rejecting the exponential form. They are also not capable of determining well the three constants in Bahcall's (1979) suggested form of the luminosity function.

Keeping in mind that the mean X-ray spectrum of clusters differs significantly from the diffuse X-ray background we shall, for historical reasons, compare the 2-10 keV volume emissivity of clusters to that of the diffuse X-ray background. For \( q_0 = 1/2, H_0 = 50 \text{ km/sec/Mpc} \) the 2-10 keV background has a volume emissivity of \( \lesssim 2.4 \times 10^{39} \text{ erg/sec/Mpc}^3 \). The
contribution of clusters is

\[ \int_{L_{\text{MIN}}}^{L_{\text{MAX}}} f(L) \, dL = 1 \times 10^{38} \text{ ergs/sec/Mpc}^3 \]

(for \( L_{\text{MAX}} = 3 \times 10^{45} \) ergs/sec, \( L_{\text{MIN}} = 1 \times 10^{43} \) ergs/sec, where we have used the 1st pass cluster power law luminosity function without the Virgo cluster). Therefore, in an average sense, clusters contribute \(< 4\%\) of the 2-10 keV background. (For a more accurate treatment of the problem which includes the effect of the spectral differences of clusters from the background see McKee et al. 1980 and Marshall et al. 1980). We note that the present value agrees well with the estimate made by Marshall et al. (1980) of the maximum possible contribution of clusters if they were not to distort the thermal bremsstrahlung fit to the spectrum of the DXRB in the 3-50 keV band. We note that the relatively soft spectra of clusters should result in an increase in their contribution to the DXRB in the Einstein Observatory energy range.

2. Active Galaxies

The luminosity function derived here is in reasonable agreement with those derived previously by Pye and Warwick (1979) and Boldt (1980) in both slope and normalization. Using a lower bound of \( 3.0 \times 10^{42} \) ergs/sec and a upper bound of \( 1.5 \times 10^{45} \) ergs/sec for our luminosity function results in a volume emissivity of \(< 4.9 \times 10^{38} \) ergs/sec Mpc\(^3\) or a contribution of \(< 20\%\) to the 2-10 keV DXRB. If the lower limit is \( 1.2 \times 10^{42} \) (see Table 4) the contribution to the DXRB is \(< 40\%\). In fact, in order not to exceed the DXRB the luminosity function of AGN's must flatten at \( L > 3 \times 10^{41} \) ergs/sec (De Zotti 1980). There is a strong indication of such a flattening in the optical luminosity function (Huchra and Sargent 1973; Huchra 1977; Huchra 1980) at
\[ M_v < -21.5 \ (H_0 = 50) \] equivalent to an optical bolometric luminosity of \( < 1.2 \times 10^{44} \) ergs/sec. Since the slope of the optical luminosity function, at higher luminosities, is the same, within errors, (Huchra and Sargent 1973; Weedman 1979) as the X-ray function it is tempting to associate the bend in the optical luminosity function with the bend in the X-ray function and therefore derive \( L_{\text{opt}}/L_x \approx 35 \). This value is rather larger than that found by examining individual objects (Kriss et al. 1980; Elvis et al. 1978). This may be due to the fact that most of the optical flux from low luminosity active galaxies does not come from the nucleus but from the stellar population.

The total space density of X-ray emitting active galaxies in the luminosity range \( 3 \times 10^{42} - 1.5 \times 10^{45} \) is \( < 7 \times 10^{-5} \) Mpc\(^{-3} \) which is \( < 1.5\% \) of all galaxies of \( M_p < -19 \) (Huchra 1977). This compares to a space density of active galaxies of \( M_p < -19 \) of \( < 5 \times 10^{-5} \) Mpc\(^{-3} \) (Huchra 1977, 1980). It thus seems, to first order, that all active galaxies of \( M_p < -19 \) emit X-rays at \( L_x > 3 \times 10^{42} \) ergs/sec. For a flat universe there are (assuming no evolution) \( < 4 \times 10^7 \) X-ray emitting active galaxies with \( L_x > 3 \times 10^{42} \) with \( z < 3.5 \).

We can also estimate, the number of sources per square degree expected in the Einstein deep survey if the luminosity function used in this paper does not evolve strongly in either slope or norm and that spectral effects, such as low energy absorption, are not important. With \( q_0 = .5 \), \( L_{\text{min}} = 3 \times 10^{42} \) in the 2-10 keV band and, \( S_{\text{min}} = 5 \times 10^{-14} \) ergs/cm\(^2\)sec in the 2-10 keV band, (which corresponds to the Einstein "deep survey" limit for a \( \alpha = 0.7 \) source) we predict \( < 6 \) active galaxies per square degree and \( < 1.3 \) clusters per square degree, compared to the 19 \( \pm 8 \) total sources per square degree seen by the Einstein Observatory (Giacconi et al. 1979). DeZotti (1980) has performed a similar calculation and finds \( < 5 \) active galaxies per square degree for \( L_{\text{min}} = \)
9.1 \times 10^{41} \text{ and } L_{\text{max}} = 2.9 \times 10^{44} \text{ ergs/sec in the 2-6 keV band and assuming that the slope of the luminosity function is 2.5. Since most of the objects are near } L_{\text{min}} \text{ we would expect many of the Einstein survey objects to be Seyfert galaxies of } L_{\text{x}} \mathrel{\overset{\lower2.5ex\hbox{\&}}{\leq}} 5 \times 10^{42} \text{ erg/sec and } z \geq 0.20. \text{ This is a consequence of the well known fact that if the luminosity function is steeper than 2.5, and barring strong evolution, when one looks at fainter objects one is looking primarily lower in the luminosity function rather than at higher redshift objects.}

A simple way to look at the problem is to examine the number of objects predicted by our best fit luminosity function which would have redshifts \((z) \leq 0.5\) and would have luminosities high enough to have been included in the Einstein Deep Survey. (We shall use } q_0 = 0.5 \text{ or 0 geometry for simplicity). For } S_{\text{min}} = 5 \times 10^{-14} \text{ ergs/cm}^2 \text{ sec in the 2-10 keV band and } q_0 = 0.5 \text{ that we predict } < 1.4 \times 10^4 \text{ sources/ster due to active galaxies and } < 1.4 \times 10^3 \text{ sources/ster due to clusters compared to the } 6.3 \pm 2.6 \times 10^4 \text{ sources/ster seen in the deep survey (Giacconi et al. 1979). We therefore predict that } < 25\% \text{ of the sources in the deep survey are low } (L \leq 4 \times 10^{43}) \text{ close by } (z \leq 0.5) \text{ active galaxies or clusters of galaxies of luminosity } > 1 \times 10^{43} \text{ erg/sec. That this was a likely situation was noted by Fabian and Rees (1978). (If } q_0 = 0 \text{ the number of sources increases to } < 2.1 \times 10^4 \text{ sources/ster and the calculated contribution to the Einstein source counts to } 25^{+24}_{-11} \%).}

Both the contribution of active galaxies to the DXRB and their contribution to the Einstein source counts depend \textbf{sensitively} on the lower limit, \(L_{\text{min}}' \) of the luminosity function used. It is possible that the luminosity where the flattening of the luminosity function takes place could be higher than our calculated value if we allow a two slope model of the luminosity function rather than our simple single slope power law model with a
cutoff. However our data are not good enough to constrain such a model. We therefore strongly caution the reader that these results are model dependent and should be treated as such.

IX. CONCLUSIONS

We have performed an all sky survey of X-ray sources complete to a limiting sensitivity of $3.1 \times 10^{-11}$ ergs/cm$^2$ sec in the 2-10 keV band. Of the 85 detected sources only 7 remain without reasonable identifications. The log $N$- log $S$ relation for extragalactic sources is well fit by a Euclidean law $\frac{dN}{dS} = 16.5 S^{-2.5}$ where $S$ is in R15 ct/sec

or $\frac{dN}{dS} = 2.2 \times 10^{-15} S^{-2.5}$ (erg/cm$^2$sr)$^{-1}$ where $S$ is in erg/cm$^2$s in the 2-10 keV band. This complete sample has allowed construction of luminosity functions based on a flux limited sample for clusters of galaxies and active galactic nuclei. These functions are well represented by power laws of slope 2.05 and 2.75 respectively. The sample enables us to estimate that the luminosity function for active galaxies should flatten at $L \gtrsim 3 \times 10^{42}$ erg/sec in the 2-10 keV band. The space density of X-ray emitting active galaxies is approximately the same as that of optically selected Seyfert galaxies.

Integration of the best fit luminosity functions indicates that clusters of galaxies contribute $< 4\%$ of the 2-10 keV diffuse X-ray background and active galactic nuclei $< 20\%$. The sum of these contributions is very similar to the 26$\pm$11$\%$ contribution due to resolved due to sources seen in the Einstein deep survey. We also predict that many of the objects seen in the deep survey should be local, $(z < 0.5)$, relatively low luminosity active galactic nuclei and clusters of galaxies. In order to determine more accurately the contribution of low luminosity active galaxies to the diffuse X-ray background one would have to sample the luminosity range $10^{41}$-$42.5$ over large solid angles. This would require a complete sky survey with $< 30$ times the...
sensitivity of the present one and a angular resolution $\leq 20$ times better. Such a survey would also extend the luminosity function up to luminosities of $\leq 10^{47}$ ergs/sec. We stress the importance of a complete unbiased X-ray survey with good identifications in determining log N - log S and luminosity functions since there are various classes of sources of widely varying X-ray to optical luminosities. We feel that this strategy rather then deep observations over small solid angles will determine log N - log S and the luminosity functions most accurately for the local epoch since for a given observing time and fixed instrumental parameters the number of observed sources greater than some statistical limit is maximized when the solid angle is maximized at a given completeness level for a photon limited experiment.

ACKNOWLEDGMENTS

We thank J. Swank for extensive discussions and her major contribution to the HEAO-1 analysis program. We thank J. Huchra, D. Schwartz, W.H.M. Ku and C. Forman-Jones for communicating results prior to publication and G. DeZotti and T. Maccacaro for interesting discussion and D. Schwartz for a careful reading of the manuscript.
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**COLUMN CAPTIONS:**

(1) : H NAME

(2) : PREVIOUS NAMES

(3) : 1ST SCAN FLUX AND 1-SIGMA ERROR (R15 COUNTS/SEC)

(4) : 2ND SCAN FLUX AND 1-SIGMA ERROR (R15 COUNTS/SEC)

(5) : IDENTIFICATION

(6) : TYPE OF OBJECT:

1 = Seyfert 1 Galaxy
2 = Seyfert 2, HBL, M or Other Active Galaxy
3 = BL Lacerte Object
4 = Normal Galaxy
5 = QSO
6 = Cluster of Galaxies
7 = Unidentified

(7) : QUALITY OF IDENTIFICATION:

* = Certain: SAS-3 or HEAO-1 Modulation Collimator Position or Einstein Observatory Position
** = Possible

(8) : REDSHIFT VALUE AND REFERENCE:

B = BAHCALL, N.A., SARGENT, W.L.W., 1977, AP.J., 217, L19
B2 = BAHCALL, N.A., AP.J., 217, L77
C1 = CORWIN, H.G.JR., 1971, PUBL.ASTRON.SOC.PACIFIC, 83, 328
CMR = CANIZARES, C.R., MCLINTOCK, J.E., RICKER, G.R., 1978, AP.J., 226, L1
DV = DEVAUCOULEURS, DEVAUCOULEURS AND CORRIGAN, SECOND REFERENCE CATALOG OF BRIGHT GALAXIES 1976
F = FABER, S., DRESSLER, A., 1977, A.J., 82, 167
FD = FOSBURY, R.A.E., DISNEY, M.J., 1976, AP.J., 2#7, L75
FO = FORMAN, W., JONES, C., TANANBAUM, H., 1976, AP.J., 2#6, L29
H = HINTZEN, P., SCOTT, J.S., 1979, AP.J., 232, L145
HSM = HINTZEN,P.,SCOTT,J.S.,MCKEE,J.D. 1980 AP.J. IN PRESS
L = LUGGER,P.,1978,AP.J.,221,745
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N = NOONAN,T.,1973,ASTRON.,78,26
S = SPINRAD,H.,1977,PUB.A.S.P.,89,116
SC = SCHWARTZ,D.,SCHWARZ,J.,TUCKER,W...1980,AP.J.LETT. 238,L59
V = VIDAL,N.V.,1975,PUBL.ASTRON.SOC.PACIFIC,87,625
W1 = WEEDMAN,D.W.,1977,ANN.REV.ASTRON.ASTROPHYS.,15,69
W2 = WEEDMAN,D.W.,1978,MON.NOT.R.ASTR.SOC.,184,115
WF = WEST,R.M.,FRANSDEN,S.,1980,ESO SCIENT. PREPRINT M.119,

(9) : CONVERSION FACTOR (1.E-11 ERGS/CM2 SEC PER R15 COUNTS/SEC)
(19) : 1ST SCAN LUMINOSITY (1.E44 ERGS/SEC)
(11) : 2ND SCAN LUMINOSITY (1.E44 ERGS/SEC)
(12) : NOTES
1. IPC DETECTION BUT NOT IDENTIFIED AT PRESENT
2. MULTIPLE CLUSTER FORMAN ET AL 1981
3. MULTIPLE CLUSTERS PERRENOUD AND HENRY 1981
TABLE 2
HIGH LATITUDE (B > 28 DEG) X-RAY SOURCES EXCLUDED FROM LOG N-LOG S ANALYSIS

<table>
<thead>
<tr>
<th>Source</th>
<th>N</th>
<th>S</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZA039+41</td>
<td>1.95</td>
<td>22</td>
<td>1.47</td>
</tr>
<tr>
<td>H123+75</td>
<td>1.62</td>
<td>26</td>
<td>.73</td>
</tr>
<tr>
<td>ZA311-22</td>
<td>2.64</td>
<td>22</td>
<td>2.23</td>
</tr>
<tr>
<td>H328+05</td>
<td>&lt;.85</td>
<td>2.92</td>
<td>.27</td>
</tr>
<tr>
<td>4U0336+81</td>
<td>1.27</td>
<td>24</td>
<td>1.41</td>
</tr>
<tr>
<td>2S512-39</td>
<td>6.56</td>
<td>&lt;1</td>
<td>5.64</td>
</tr>
<tr>
<td>ZA526-32</td>
<td>1.99</td>
<td>16</td>
<td>2.55</td>
</tr>
<tr>
<td>H8751-22</td>
<td>1.36</td>
<td>21</td>
<td>&lt;.6</td>
</tr>
<tr>
<td>ZA52+60</td>
<td>1.34</td>
<td>21</td>
<td>&lt;.8</td>
</tr>
<tr>
<td>ZA1249-28</td>
<td>4.41</td>
<td>28</td>
<td>5.51</td>
</tr>
<tr>
<td>3U1616-15</td>
<td>&gt;500</td>
<td>&gt;500</td>
<td>3.47</td>
</tr>
<tr>
<td>ZA1274+24</td>
<td>&lt;.8</td>
<td>2.46</td>
<td>.21</td>
</tr>
<tr>
<td>ZA1815+60</td>
<td>4.11</td>
<td>12</td>
<td>3.98</td>
</tr>
<tr>
<td>H2215-80</td>
<td>1.50</td>
<td>23</td>
<td>1.20</td>
</tr>
<tr>
<td>4U2127+14</td>
<td>5.32</td>
<td>22</td>
<td>4.97</td>
</tr>
<tr>
<td>H2252-835</td>
<td>2.36</td>
<td>25</td>
<td>2.43</td>
</tr>
</tbody>
</table>

SOURCES IN AND NEAR THE LMC AND SMC HAVE BEEN OMITTED FROM THIS TABLE AND FROM TABLE 1. THE EXPERIMENT HAS DETECTED FLUX FROM SMX X-1,2,3 LMC X-1,2,3,4,5 AND THE LMC TRANSIENT SOURCE #535-668

REFERENCES:
B1=BRADT,DOXSEY,JERNIGAN 1979
C1=CHRISTENSEN,THORSTENSEN,BOWER,MIDDLEDITCH 1979
D1=DOXSEY,MCCLINTOCK,PETRO,REHILLAR,SCHWARTZ 1979
G1=GRIFFITHS,WARD,BLADES,WILLSON 1979
G2=GARCIA,ALBUNAS,CONROY,JOHNSTON,RALPH,ROBERTS,SMITHWORTH,TONRY 1988
G3=GRIFFITHS,LAMB,WARD,WILLSON,THORSTENSEN,MCHARDY,LAWRENCE 1988
G4=GARCIA,CONROY,DOXSEY,GRIFFITHS,JOHNSTON,RALPH,ROBERTS,SMITHWORTH 1988
M1=MARTIN,BOLDT,MUSHOTZKY,PRAVDO,ROTHSCHILD,SMITHWORTH 1979
S1=SCHWARTZ,BRADT,BRIEL,DOXSEY,FABIANO,GRIFFITHS,JOHNSTON,MARGON 1979
S2=SCHWARTZ 1980 (PRIVATE COMMUNICATION)
S3=SWANK,BOLDT,HOLT,ROTHSCHILD,SMITHWORTH 1978
S4=SWANK,LANPON,BOLDT,SMITHWORTH 1977
T1=TSIKOUSHI,SWANK 1980
V1=VAN SPEYBROECHE,EPSTEIN,FORMAN,GIACCONI,JONES,LEW,LILLER,SWANK 1979
W1=WHITE,SANFORD,WHEELER 1978
REFERENCES

Giacconi, R., Bechtold, J., Branduaradi, G., Forman, W., Henry, J.P., Jones, C., Kellogg, E., van der Laan, H., Lilier, W., Marshall, H., Murray,


Rothschild, R., Boldt, E., Holt, S., Serlemitsos, P., Garmire, G., Agrawal, P., Riegler, G., Bowyer, S., and Lampton, M. 1979, Space Science...
Instrumentation 4, 265.


Weinberg, S. 1972, Gravitation and Cosmology


FIGURE CAPTIONS

Figure 1. The completeness level of the present survey vs ecliptic latitude. The diamonds are for the first pass and the crosses for the second pass. The lower histogram is the sky fraction in each ecliptic latitude bin (right hand scale). The centre of the diamonds and crosses is 5 times the mean error for a source located in that ecliptic latitude bin and the size of the error bar is the standard deviation of this error. Since we truncate at 1.25 R15 counts all of our sources at ecliptic latitude greater than 30° lie well above the 5σ level. We estimate that residual incompleteness of sources at levels less than 1.4 cts is less than 3 sources and zero sources greater than this limit.

Figure 2. The error boxes for H0328+025 and H0917-074. The inner and outer boxes are the 90% confidence boxes as described in Marshall et al. 1979. The inner box assumes that the source was roughly constant during our period of observation.

Figure 3. The distribution of the non-galactic sources detected in this survey in supergalactic coordinates.

Figure 4. The probability distributions for κ and α. The top panel shows the AML probability vs. α in the first pass data, the middle panel shows the AML probability vs. α in the second pass. The bottom panel shows the 66 and 95% joint probability contour for κ and α for the first pass data. The + marks the best fit.
Figure 5. The differential log N - log S distribution for our sample. The best fit is indicated. The highest flux point is indicated by a dashed cross because its upper flux bound is not well defined. (1st pass data)

Figure 6. The AML Kolomogorov-Smirnov test distribution for an $\alpha = 2.5$ model. The 50 and 95% probability bounds are indicated. (1st pass data)

Figure 7. The ratio of the number of observed sources $N_{\text{obs}}$ to the number of expected sources for $\alpha = 2.5 \log N - \log S$ law. (1st pass data)

Figure 8a. The cluster of galaxies differential luminosity function for the first pass data.

8b. The same information for the second pass data. The best fit power law models are indicated on both panels.

Figure 9. the AML probability vs. $\gamma$ the slope of the power law differential luminosity function for clusters of galaxies for the first and second passes including and excluding the Virgo cluster.

Figure 10. Same as Figure 9 but for the exponential luminosity function.

Figure 11. The Seyfert galaxy luminosity function for the first pass data. The best fit power law differential model is indicated. The insert shows the AML probability vs. $\gamma$ the slope of the luminosity function.
2nd PASS COMPLETENESS LEVEL

1st PASS COMPLETENESS LEVEL

5σ SENSITIVITY AND SKY COVERAGE

RI5 COUNTS SEC⁻¹

MOD (ECLIPTIC LAT.)

% SKY COVERAGE IN EACH BAND

1.8 √cos λ

1.25 √cos λ
SUPergalactic CoordinATes

MILKY WAY
<table>
<thead>
<tr>
<th>b</th>
<th>+60°</th>
</tr>
</thead>
<tbody>
<tr>
<td>+30°</td>
<td></td>
</tr>
<tr>
<td>+20°</td>
<td></td>
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<tr>
<td>+10°</td>
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<tr>
<td>-10°</td>
<td></td>
</tr>
<tr>
<td>-20°</td>
<td></td>
</tr>
<tr>
<td>-30°</td>
<td></td>
</tr>
<tr>
<td>-60°</td>
<td></td>
</tr>
</tbody>
</table>

S > 1.25 R15 COUNTS SEC⁻¹

* UNIDENTIFIED SOURCES
○ CLUSTERS
○ GALAXIES
□ Z ≤ 0.01
RATIO OF OBSERVED TO EXPECTED
NUMBER OF SOURCES

\[
\frac{N_{\text{OBS}}}{N_{\text{EXP}}}
\]

R15 COUNTS SEC\(^{-1}\)
AML - KS TEST FOR EUCLIDEAN MODEL:

\[ a = 2.5 \text{ (1st PASS - S \geq 1.25 R15 COUNTS sec}^{-1}) \]
$\log N - \log S$ DISTRIBUTION

HEAO-1 A2

$(\text{R15 COUNTS/SEC})^{-1} \text{SR}^{-1}$

20 $S^{-2.72}$

R15 COUNTS SEC$^{-1}$
POWER LAW MODEL (WITHOUT VIRGO)

FIRST SCAN

FWHM

$\gamma = 2.03 \pm 1.8$

SECOND SCAN

FWHM

$\gamma = 2.07 \pm 0.28$

POWER LAW MODEL (WITH VIRGO)

FIRST SCAN

FWHM

$\gamma = 2.15^{+0.12}_{-0.17}$

SECOND SCAN

FWHM

$\gamma = 2.13^{+0.18}_{-0.24}$
ACTIVE GALAXIES FIRST SCAN

$N(L_{44}) = 2.68 \times 10^{-7} L_{44}^{-2.78}$

FIRST SCAN
$I > 1.25 R15$ COUNTS / S