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A MEDIUM SENSITIVITY X-RAY SURVEY USING THE *EINSTEIN* OBSERVATORY: THE LOG N–LOG S RELATION FOR EXTRAGALACTIC X-RAY SOURCES

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ABSTRACT

Results are presented from an X-ray survey of $\sim$50 deg^2 of the high galactic latitude sky at sensitivities in the range 7×10^{-14} to 5×10^{-12} ergs cm^{-2} s^{-1} (0.3–3.5 keV) carried out with the Imaging Proportional Counter (IPC) aboard the *Einstein* Observatory. The complete sample consists of 63 sources detected at or above the 5 σ level, 48 of which are certainly or most likely of extragalactic origin. The number-flux relation is derived for the extragalactic population, yielding a best-fit power-law slope of 1.53 ± 0.16. The content of the sample is analyzed in terms of types of sources and is found to be significantly different from the content of similar samples selected at higher fluxes. In particular, the *Einstein* Observatory medium sensitivity sample of extragalactic sources is dominated by active galactic nuclei (AGNs—quasars or Seyfert galaxies), while samples selected at higher fluxes and higher energies are dominated by clusters of galaxies. Thus the number-flux relation for extragalactic sources may be interpreted, to a first approximation, as the sum of two different distributions with flatter and steeper slopes describing clusters and AGNs, respectively. This picture agrees well with the fact that in an expanding universe the number-flux relation for a uniformly distributed nonevolving class of sources (as we assume clusters of galaxies are) becomes flatter than the 3/2 power as the flux decreases, and with the fact that QSOs are known to show strong evolutionary behavior at other wavelengths.

Subject headings: galaxies: clusters of — galaxies: nuclei — X-rays: sources

I. INTRODUCTION

The extremely high sensitivity and spatial resolution of the imaging X-ray telescope on the *Einstein* Observatory allow for the first time investigation of the extragalactic source counts at fluxes as low as a few times 10^{-14} ergs cm^{-2} s^{-1}, a factor of 10^3 weaker than detectable by previous instruments. From a deep survey covering $\sim$1 deg^2, Giacconi *et al.* (1979) found $N(>S)=(6.3\pm2.6)\times10^4$ sources sr^{-1} at $S=2.6\times10^{-14}$ ergs cm^{-2} s^{-1} (1–3 keV). This value is in close agreement with the number expected by extrapolating the log N–log S curve derived from the *Uhuru* and *Ariel V* surveys (Warwick and Pye 1978; Schwartz 1979) with a slope of 1.5. However, this agreement could have been fortuitous, and no information was available on the behavior of the source-count relation over two decades of flux density, namely between 10^{-11} and 10^{-13} ergs cm^{-2} s^{-1}.

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Since the shape of the log N–log S distribution gives information on the cosmology and/or evolutionary properties of X-ray sources, a program to study in detail the number-flux relationship for extragalactic X-ray sources at fluxes between the *Uhuru/Ariel V* limit and the *Einstein* deep survey limit has been undertaken.

In this paper the results of a complete survey of serendipitous X-ray sources at intermediate flux levels ($7\times10^{-14}\leq S\leq5\times10^{-12}$ ergs cm^{-2} s^{-1}; 0.3–3.5 keV) covering $\sim$50 deg^2 of sky are presented.

In § II the selection criteria of the survey and the data reduction technique are described. The source sample is examined in § III, paying particular attention to optical classifications. In § IV the shape of the number-flux relationship for extragalactic X-ray sources is analyzed. The relative contribution to the source counts from different classes of objects is discussed in § V.

In the flux range of the present survey, the number-intensity distribution can be described by a power law of the form $N(>S)=KS^{-\alpha}$. As the best estimate of α, the value 1.53 ± 0.16 is derived. Although this value is consistent with that which describes the $\log N(>S)$–$\log S$ at higher fluxes, our data show that the percentage contribution of different classes of objects to the overall population of extragalactic sources varies as a function of S.

II. THE DATA

Among all IPC fields available to us, those outside the galactic plane ($|b^{\mathrm{II}}|>20°$) have been selected to avoid regions characterized by high galactic absorption as well as very high stellar density. Only the central part (32 arcmin^2) of the IPC field of view has been used, to avoid regions of the detector significantly obscured by the window supporting structure and regions in which both source location and background level are poorly known. Observations centered on nearby Abell clusters of galaxies ($D \leq 3$) have also been excluded from the sample due to their extended emission and difficulties in distinguishing between sources related or unrelated to the target itself. The IPC fields are typically centered on previously known or suspected X-ray sources. To avoid biasing this survey, the region of 5′ radius around the target was not included in the analysis. This procedure would, in principle, introduce an opposite bias since we are eliminating *a priori* the possibility of including in the survey those objects chosen to be targets of observation. In particular, all previously known and therefore "strong" X-ray sources have been selected as targets of observation with the *Einstein* Observatory. Consequently, the study of the number-flux relation has been restricted to sources fainter than 5×10^{-12} ergs $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$. For this reason and since the survey covers a small fraction of the high latitude sky (0.18%), it has been estimated that the correction for such bias is negligible (less than one source has to be added to the sample to compensate for the objects eliminated *a priori*).

The nature of the targets of the IPC fields used for the survey is not expected to have any influence on the composition of our sample. About one-third of the fields used were centered on a galactic target: together with a few mispointed fields, they may be regarded as randomly chosen as far as the composition of the extragalactic population is concerned. Quasi-stellar objects are the most numerous (more than one-third) target of the images used in the survey. It has been recently pointed out that they may be associated in superclusters (Oort, Arp, and de Ruiter 1981), and one may thus argue that the use of fields centered on QSOs may bias the sample in the sense that the probability of finding another QSO should be higher in these fields than elsewhere. The fact that serendipitous QSOs with the same redshifts as the target have not been found in our survey makes us confident that the above selection effect, if at all present, is completely negligible.

A computerized detection system was used to establish the existence and location of sources in each of the individual fields. The background was computed by averaging the counts in an annulus of inner and outer radii of 8′ and 15′.5, respectively, around the field center, after removing the sources possibly present. To minimize the number of spurious sources and to satisfy the requirement of the maximum likelihood method used to determine the $\log N$–$\log S$ parameters (see § IV), it is required that the significance of the detection exceeds the (formal) 5 σ level [i.e., source counts/(source counts + background counts)$^{\frac{1}{2}} \geq 5$].

The flux of the sources found with the above technique has been estimated in the 0.3–3.5 keV band assuming a power-law spectrum with energy slope of 0.4 (the slope of the diffuse X-ray background radiation) and an average value of 3.0×10^{20} atoms cm^{-2} for the column density of hydrogen through our own Galaxy. The energy band 0.3–3.5 keV is the largest possible compatible with instrumental background and minimizes the effects on the flux estimate due to gain variations within the IPC field of view. The current uncertainty in the IPC gain, combined with the assumption of a mean spectral index, can introduce errors of about ±20% in the calculation of the X-ray flux. Applying the method discussed by Henry *et al.* (1979), we have also carried out a preliminary analysis of the angular extent of those sources detected in the survey for which there were enough statistics and for which there was no HRI image showing that the X-ray source was pointlike (see § III).

III. THE SAMPLE

To date, data from 189 IPC observations have been analyzed, for a total of 50.3 deg^2 of sky. The exposure times of these observations range from $\sim 10^3$ to $\sim 2.5 \times 10^4$ seconds; their limiting sensitivity is from 5×10^{-12} to 7×10^{-14} ergs $\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$, and the area of each field is typically 0.27 deg^2. There are 63 sources found above the 5 σ significance level, constituting an unbiased sample of randomly selected X-ray sources.

IPC source locations have a 90% confidence error circle of $\sim 1'$ radius. To obtain a more accurate estimate of the X-ray position and therefore reduce the number of candidate objects for optical identification, HRI observations of a large number of sources have been scheduled. These observations, some of which are now available, provide a 10″ radius error circle (90% confidence contour). A spectroscopic study of all objects lying inside or very close to the error circles is still in progress, as well as the analysis of observations at 6 cm made with the VLA. A detailed description of optical identifications and a discussion of the X-ray, optical, and radio properties of the sources detected in the survey will be the subject of subsequent papers.

TABLE 1

THE SAMPLE OF X-RAY SOURCES

Source Name (1)	R. A. Decl. (1950.0) (2)	Error Circle (3)	No. of Sigma (4)	Flux Error (5)	I.D. Code (6)
*1E 0111.9−0132 ...	01 11 54.9 −01 32 25.8	60″	9.8	3.91E(−13) 3.99E(−14)	AGN
*1E 0112.9−0147 ...	01 12 59.7 −01 47 43.7	60″	5.1	1.40E(−13) 2.73E(−14)	class 1
*1E 0126.4+0725 ...	01 26 24.4 +07 25 41.5	60″	5.2	4.82E(−13) 9.21E(−14)	cluster
*1E 0135.0+0339 ...	01 35 00.3 +03 39 29.9	60″	5.4	2.44E(−13) 4.53E(−14)	AGN
*1E 0136.3+0605 ...	01 36 20.2 +06 05 50.1	60″	5.3	2.10E(−13) 3.98E(−14)	AGN
*1E 0144.2−0055 ...	01 44 11.4 −00 55 41.5	10″	12.1	8.09E(−13) 6.69E(−14)	AGN
*1E 0412.4−0803 ...	04 12 28.1 −08 03 08.2	60″	13.3	2.25E(−12) 1.68E(−13)	AGN
*1E 0420.1−3838 ...	04 20 06.1 −38 38 52.4	60″	5.8	1.23E(−13) 2.12E(−14)	class 1
1E 0420.3−3859 ...	04 20 23.7 −38 59 51.9	60″	7.1	1.51E(−13) 2.12E(−14)	class 2
*1E 0420.9−3903 ...	04 20 55.1 −39 03 25.3	60″	8.5	2.01E(−13) 2.36E(−14)	class 1
*1E 0438.6−1049 ...	04 38 39.1 −10 49 48.2	60″	8.9	4.51E(−13) 5.06E(−14)	AGN
*1E 0439.3−1102 ...	04 39 18.2 −11 02 11.6	60″	5.2	2.32E(−13) 4.46E(−14)	cluster
*1E 0440.0−1057 ...	04 40 01.1 −10 57 30.6	60″	5.4	2.60E(−13) 4.82E(−14)	AGN
*1E 0447.1−0916 ...	04 47 09.0 −09 16 18.5	60″	5.0	2.21E(−13) 4.40E(−14)	AGN
*1E 0449.4−1823 ...	04 49 26.3 −18 23 55.0	60″	5.8	7.81E(−13) 1.35E(−13)	AGN
*1E 0450.3−1817 ...	04 50 23.1 −18 17 07.1	60″	5.0	5.37E(−13) 1.07E(−13)	AGN
1E 0536.3−2848 ...	05 36 23.5 −28 48 54.5	60″	7.2	1.74E(−13) 2.42E(−14)	class 2
*1E 0537.1−2834 ...	05 37 11.3 −28 34 19.4	60″	7.7	1.67E(−13) 2.17E(−14)	class 1
*1E 0622.5−5255 ...	06 22 34.4 −52 55 14.0	60″	5.0	6.78E(−13) 1.34E(−13)	class 1
*1E 0648.1−5042 ...	06 48 10.1 −50 42 30.0	60″	6.1	4.55E(−13) 7.41E(−14)	class 1
*1E 0809.8+4809 ...	08 09 52.7 +48 09 32.7	60″	5.8	2.37E(−13) 4.07E(−14)	AGN
1E 0834.7+6512 ...	08 34 47.3 +65 12 29.3	60″	15.8	5.01E(−12) 3.18E(−13)	star
*1E 0838.6+1324 ...	08 38 38.3 +13 24 38.2	60″	5.9	1.80E(−13) 3.08E(−14)	AGN
*1E 0849.0+2844 ...	08 49 04.4 +28 44 23.6	60″	6.2	1.56E(−13) 2.51E(−14)	AGN
*1E 0849.2+2829 ...	08 49 15.9 +28 29 00.6	10″	8.1	1.95E(−13) 2.42E(−14)	AGN
*1E 0849.7+2819 ...	08 49 47.6 +28 19 40.7	60″	8.2	2.13E(−13) 2.59E(−14)	AGN
*1E 0850.0+2827 ...	08 50 00.9 +28 27 53.9	60″	6.2	1.40E(−13) 2.25E(−14)	AGN
*1E 0850.2+2825 ...	08 50 17.9 28 25 17.2	10″	5.7	1.30E(−13) 2.28E(−14)	AGN
1E 0850.9+1401 ...	08 50 54.8 +14 01 26.6	60″	6.0	7.74E(−13) 1.30E(−13)	star
1E 0903.5+1711 ...	09 03 33.0 +17 11 28.3	10″	8.5	3.32E(−13) 3.89E(−14)	star
*1E 0904.5+1650 ...	09 04 30.6 +16 50 56.5	60″	15.9	8.70E(−13) 5.46E(−14)	cluster
*1E 0937.8+1153 ...	09 37 49.4 +11 53 17.9	60″	8.2	2.52E(−13) 3.08E(−14)	AGN

TABLE 1—*Continued*

Source Name (1)	R. A. Decl. (1950.0) (2)	Error Circle (3)	No. of Sigma (4)	Flux Error (5)	I.D. Code (6)
1E 0938.3+1151 ...	09 38 22.7 +11 51 03.6	60″	5.0	1.23E(−13) 2.49E(−14)	class 2
1E 0939.8−2329 ...	09 39 49.9 −23 29 30.3	60″	8.6	1.39E(−13) 1.61E(−14)	star
*1E 1201.5+2823 ...	12 01 32.8 +28 23 50.5	60″	10.3	7.98E(−13) 7.76E(−14)	cluster
*1E 1207.9+3945 ...	12 07 54.8 +39 45 51.0	10″	19.5	1.49E(−12) 7.62E(−14)	AGN
*1E 1208.2+3945 ...	12 08 17.7 +39 45 02.4	10″	7.4	3.16E(−13) 4.29E(−14)	galaxy
*1E 1208.7+3928 ...	12 08 42.5 +39 28 20.1	60″	5.9	2.59E(−13) 4.37E(−14)	cluster
*1E 1223.5+2522 ...	12 23 33.2 +25 22 48.8	60″	7.6	7.48E(−13) 9.90E(−14)	AGN
1E 1240.8+0311 ...	12 40 52.9 +03 11 50.3	60″	7.0	1.71E(−12) 2.44E(−13)	star
1E 1247.0−0548 ...	12 47 03.4 −05 48 25.2	10″	13.2	1.68E(−12) 1.27E(−13)	star
*1E 1327.4+3208 ...	13 27 26.4 +32 08 09.4	60″	5.9	9.83E(−13) 1.66E(−13)	AGN
1E 1339.9+6030 ...	13 39 55.0 +60 30 55.9	60″	7.7	5.10E(−13) 6.63E(−14)	star
*1E 1402.3+0416 ...	14 02 19.8 +04 16 20.9	10″	16.5	1.15E(−12) 6.94E(−14)	BL Lac
*1E 1415.0+2513 ...	14 15 02.3 +25 13 22.8	60″	8.0	1.96E(−13) 2.44E(−14)	AGN
*1E 1415.1+2527 ...	14 15 06.5 +25 27 24.6	10″	7.8	1.80E(−13) 2.33E(−14)	AGN
*1E 1416.2+2525 ...	14 16 14.8 +25 25 04.5	60″	20.0	6.91E(−13) 3.45E(−14)	cluster
*1E 1416.7+2524 ...	14 16 42.2 +25 24 11.3	60″	6.9	1.67E(−13) 2.40E(−14)	AGN
*1E 1454.0+2232 ...	14 54 03.0 +22 32 23.4	60″	5.3	2.33E(−13) 4.35E(−14)	cluster
1E 1457.0+2226 ...	14 57 02.4 +22 26 02.6	10″	10.5	6.69E(−13) 6.39E(−14)	star
*1E 1525.1+1550 ...	15 25 06.5 +15 50 31.1	60″	8.1	1.13E(−12) 1.39E(−13)	AGN
1E 1528.5+0845 ...	15 28 30.7 +08 45 10.0	60″	5.7	8.86E(−13) 1.56E(−13)	star
1E 1532.9+0918 ...	15 32 56.7 +09 18 31.7	60″	5.2	9.38E(−13) 1.80E(−13)	star
*1E 1533.5+1440 ...	15 33 32.9 +14 40 57.4	10″	5.6	6.43E(−13) 1.15E(−13)	AGN
1E 1548.7+1125 ...	15 48 44.1 +11 25 13.3	60″	8.6	9.04E(−13) 1.05E(−13)	class 2
*1E 1549.8+2023 ...	15 49 50.7 +20 23 00.6	60″	12.3	1.65E(−12) 1.34E(−13)	AGN
*1E 1617.9+1731 ...	16 17 56.8 +17 31 40.4	60″	9.9	2.07E(−12) 2.10E(−13)	AGN
*1E 1745.2+2747 ...	17 45 17.1 +27 47 38.2	60″	7.9	3.12E(−13) 3.96E(−14)	AGN
1E 1751.0+7046 ...	17 51 02.8 +70 46 16.5	10″	12.8	3.69E(−12) 2.89E(−13)	star
*1E 1910.5+6736 ...	19 10 32.1 +67 36 38.0	60″	13.9	8.75E(−13) 6.31E(−14)	class 1
*1E 2141.6+0359 ...	21 41 36.9 +03 59 29.7	60″	7.8	3.01E(−13) 3.84E(−14)	AGN
*1E 2204.0−4059 ...	22 04 03.0 −40 59 15.5	10″	14.4	1.24E(−12) 8.66E(−14)	class 1
*1E 2223.6−0517 ...	22 23 39.6 −05 17 22.9	60″	6.0	2.03E(−13) 3.38E(−14)	AGN

NOTE.—Sources marked with an asterisk have been used to compute the log N–log S.

Table 1 lists the relevant parameters of the source sample. Column (1) gives the source name. *Einstein* sources are denoted by 1E followed by right ascension in hours, minutes and truncated fraction of minutes and declination in degrees and minutes. Column (2) gives the position (right ascension and declination) in 1950.0 coordinates; column (3) lists the radius of the 90% confidence error circle; the significance of the detection (No. of sigmas) is given in column (4). Column (5) gives the observed flux ± 1 standard deviation (from photon counting statistics only) in the 0.3–3.5 keV band in ergs cm^{-2} s^{-1}; column (6) contains the optical classification.

So far, 51 of the 63 sources have been positively identified by means of spectroscopic work (40 with extragalactic objects and 11 with stars). Using the number density of quasars as a function of the magnitude (Bonoli *et al.* 1980), we would expect ~ 10 quasars per square degree brighter than 19.5 mag. The *total* number of QSOs expected by chance in our 63 error circles is therefore less than 1 and, consequently, we regard our 31 identifications with AGNs as quite secure on statistical grounds. A similar argument may be used to give confidence in the identification of five X-ray sources with bright (SAO) stars. Very accurate (10″) positioning of the X-ray sources makes four more identifications with fainter stars extremely likely if not certain.

Further support to our identifications comes from the analysis of the angular extent of the X-ray brightness distribution. Twenty sources have been analyzed in this respect (10 AGNs, 3 clusters, 1 star, and 6 unidentified sources). In two cases (1E 0904.5+1650 and 1E 1416.2+2525) we find that the X-ray brightness distribution is not consistent with the sources being pointlike at the IPC resolution. Both sources are identified with clusters of galaxies. The 3 σ lower limit on the diameter of the Gaussian profile fitted to their X-ray brightness distribution is 1′.

In the case of 1E 1201.5+2823, the other source identified with a cluster of galaxies, no evidence of extended emission is found. The 3 σ upper limit (1′.5) to the diameter of the assumed Gaussian profile, however, is consistent with this source having the same size as the previous two.

The unidentified sources have been divided into two major classes: those which are most likely to be associated with extragalactic objects (class 1) and those which are probably associated with galactic stars (class 2). This subdivision has been made on the basis of the ratio of X-ray flux to visual flux of the candidate objects which lie inside or immediately outside the X-ray source error circle. This ratio is defined by

$$\log(f_x/f_v) = \log f_x + \frac{m_v}{2.5} + 5.37,$$

where f_x is the X-ray flux (0.3–3.5 keV), and f_v the visual flux.

Stars exhibit a rather wide range of f_x/f_v which does not normally exceed 0.001 except for late-type (K and M) stars for which f_x/f_v can be as high as 0.01 and 0.1, respectively (Vaiana *et al.* 1981). Eight sources were therefore assigned to class 1 because they did not have an optical counterpart bright enough to make f_x/f_v consistent with the maximum value observed for stars. Four sources have been assigned to class 2.

The analysis of f_x/f_v does not allow us to discriminate against "accretion-type" X-ray emission from galactic sources. For these systems, in fact, f_x/f_v can have any value between 10^{-3} and 10^3 and even more. The fact that only one such source is found among the 51 which have so far been identified, however, makes us confident that not more than one other "accretion-type" galactic source is likely to be hidden among the remaining 12 unidentified sources. Since at the present stage of the survey we are dealing only with statistical properties of extragalactic X-ray sources, a few possible misclassifications are not expected to significantly affect our results. In what follows only the extragalactic content of our sample of X-ray sources is discussed.

IV. THE LOG $N(>S)$–LOG S ANALYSIS

It has been shown that, for the specific problem of estimating the source count slope, the maximum likelihood method gives a minimum variance best estimate with a small correctable bias. Such bias, due to the difference between the true flux density distribution, $P(S)dS$, and the observed distribution, $P(F)dF$, can be calculated provided the lower limit of a survey is chosen to be at least 5 times the rms noise (Crawford, Jauncey, and Murdock 1970; Murdock, Crawford, and Jauncey 1973). We therefore use only those sources detected at ≥ 5 σ confidence level.

With the general assumption that the flux density distribution of the extragalactic X-ray sources can be described by a single power law, $N(>S) = KS^{-\alpha}$, over the range $7\times10^{-14} \leq S \leq 5\times10^{-12}$ ergs cm^{-2} s^{-1}, the best value of α can be estimated maximizing the likelihood function (Murdock, Crawford, and Jauncey 1973):

$$L = N \ln \alpha - N \ln \sum_j A_j \left(S_{lj}{}^{-\alpha} - S_{uj}{}^{-\alpha} \right) + \sum_j n_j \ln A_j - (\alpha+1) \sum_i \sum_j \ln S_{ij},$$

where N is the total number of sources used; n_j is number of sources in the A_j area; A_j is the area of the sky with limiting sensitivity between S_{lj} and S_{uj} ($A_{j+l} > A_j$); and S_{ij} is the flux of the ith source in the jth area. Both the $(N-1)/N$ correction (Crawford, Jauncey, and Murdock 1970) and the correction to account for the difference between the $P(S)dS$ and $P(F)dF$ (cf. Murdock, Crawford, and Jauncey 1973, Table 5) have been applied.

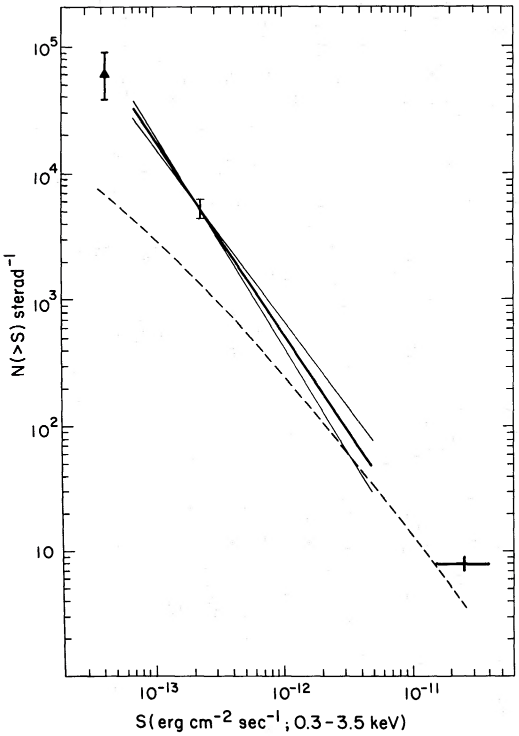

FIG. 1.—The integral log $N(>S)$–log S (best-fit) relation for the extragalactic X-ray sources (*solid line*). The two light lines represent the $\pm 1\ \sigma$ error in the slope of the log $N(>S)$–log S. The data point at high flux level is from the *HEAO 1* A2 study of Piccinotti *et al.* (1982); the horizontal error bar represents the fact that the flux conversion from a 2–10 keV band into a 0.3–3.5 keV band depends on the assumed spectrum. The low flux point is from the *Einstein* deep survey of Giacconi *et al.* (1979). The dashed line represents the expected log N–log S for clusters of galaxies assuming no evolution (see text for details).

The resulting best value of α is 1.53, with an associated normalization $K = 2.7 \times 10^{-16}$ (with S in ergs cm^{-2} s^{-1} in the range 0.3–3.5 keV, and N in number of sources per sterad). The 68% (1 σ) confidence interval for α, obtained by requiring that $L(\alpha \pm 1\ \sigma) = L(\alpha) - 0.5$, is 1.37–1.69. Moreover, our initial assumption of a single power law to describe the distribution has been tested by applying the Kolmogorov-Smirnoff test (Kendall and Stuart 1961). This indicates that a single power law of index $\alpha = 1.53$ is consistent with the observed distribution of fluxes. Figure 1 shows in integral form the best-fit function $N(>S) = 2.7 \times 10^{-16} S^{-1.53}$ (S in ergs cm^{-2} s^{-1}, 0.3–3.5 keV). For ease of comparison with previous results, the best-fit value for the coefficient K with $\alpha = 1.50$ has been computed: $K = 5.5 \times 10^{-16}$ with S in ergs cm^{-2} s^{-1}, 0.3–3.5 keV.

V. DISCUSSION

The value of 1.53 ± 0.16 found for the log $N(>S)$–log S slope of extragalactic X-ray sources with fluxes in the range of the present survey is in good agreement with that found at higher fluxes (Warwick and Pye 1978; Schwartz 1979; Piccinotti *et al.* 1982) and is consistent with the Euclidean model. Yet, the analysis of the difference between the contents of our sample (in terms of classes of sources) and the contents of a sample selected at higher fluxes shows evidence of hidden "features" in the source distribution. In what follows quasars and Seyfert galaxies are classified as AGNs. Recent studies of the properties of X-ray selected QSOs (Grindlay *et al.* 1980; Chanan, Margon, and Downes 1981) indicate in fact that these objects have predominantly low z and low luminosity; their optical properties and correlations with L_x are in good agreement with those of Seyfert galaxies; and they are indeed indistinguishable from Seyfert galaxies except for their stellar appearance on the Palomar prints.

As a comparison sample at higher X-ray fluxes, the extragalactic sample derived from the *HEAO 1* A2 survey experiment is used. This sample is essentially complete down to a flux limit of $\approx 3.1 \times 10^{-11}$ ergs cm^{-2} s^{-1} in the 2–10 keV energy band, and like our sample contains only sources detected at or above 5 σ selected at high galactic ($|b^{\mathrm{II}}| \geq 20°$) latitude (Piccinotti *et al.* 1982). Most of these sources have been identified. The selection criteria for these two samples (*Einstein* and *HEAO 1* A2) are identical, with the only difference arising from the energy ranges of the two instruments. The spectral information available for clusters, Seyferts, and QSOs suggests that the different energy bands (2–10 keV vs. 0.3–3.5 keV) should not produce any significant differences in the observed composition of extragalactic sources.

In the case of the *HEAO 1* A2 survey, the source sample is dominated by rich clusters of galaxies ($\sim$50%), and AGNs account for $\sim$40% of the sources.

A comparison with the composition of the *Einstein* sample is not straightforward because identification for all sources have not yet been made. To date, 80% of the total extragalactic sample (39 out of 48) has extremely likely or certain identifications. Since the only selection effect in the choice of the X-ray positions which have already been studied spectroscopically is the source's declination (8 out of the 12 unidentified sources are in fact at $\delta \leq -25°$), the number of sources of various classes can be estimated for the *Einstein* sample. Table 2 gives a summary of the identifications of the extragalactic subsample. Column (1) gives the optical classification of the sources, column (2) is the present observed distribution of the identifications, and column (3) is the expected final composition of the source sample. Column (4) gives the expected composition if the mix of sources were the same as in the *HEAO 1* A2 sample. It is clear that the two major classes of extragalactic sources (i.e., clusters of galaxies and AGNs) are represented in a different proportion in the two samples under consideration.

TABLE 2

SUMMARY OF THE IDENTIFICATIONS FOR THE EXTRAGALACTIC SUBSAMPLE

Classification	Present Observed Composition	Final Expected Composition	Expected Composition from *HEAO 1* A2 Data
AGNs...........	31	37	19
Cluster..........	7	9	24
Others	2	2	5
Class 1	8	...	...

To compute the significance of this difference (*Einstein* Observatory, estimated; *HEAO 1* A2, observed) a χ^2 test has been applied to the hypothesis that both of these samples originate from the same parent population. The probability for this to be true has been found to be only 1×10^{-3}.

It is thus concluded that the relative contributions of various classes of X-ray objects to the total number of detected sources is changing as one goes to fainter sources. In particular, the number of AGNs increases relative to the number of clusters of galaxies. Our results strongly support the conclusions reached by Giacconi *et al.* (1979) that most of the X-ray sources they found at very low flux density (few times 10^{-14} ergs cm^{-2} s^{-1}) should be Seyfert galaxies and QSOs.

The expected number of nonevolving sources characterized by a luminosity function $f(L)$ in an expanding universe is given by $N(>S)=N(>S)_{\rm E}f(z)$ where $N(>S)_{\rm E}$ is the number-flux relation for Euclidean space and $f(z)$ is a monotonically decreasing function of redshift z [$f(z=0)=1$]. $f(z)$ is also a weak function of q_0. In our computations, it is assumed that $q_0=0$, the assumption of $q_0=1$ does not significantly affect the results. If, on the average, detecting fainter sources is equivalent to detecting more distant objects, fewer sources than predicted by the Euclidean form of the number-flux relation are expected as one moves to fainter fluxes.

Integrating up to $z_{\rm max}=1.5$ the X-ray luminosity function of clusters of galaxies given by Piccinotti *et al.* (1982), ($H_0=50$ km s^{-1} Mpc^{-1}, $L_{\rm min}=3.6\times10^{43}$ ergs s^{-1} and $L_{\rm max}=2.8\times10^{45}$ ergs s^{-1}),[2] the expected number of clusters as a function of the flux S can be computed. (Using for $z_{\rm max}$ the value of 3.5, the total number of clusters increases by only 4% at $S=7\times10^{-14}$ ergs cm^{-2} s^{-1}; with $z_{\rm max}=1.0$, the number decreases by $\sim$12%.)

Since we are dealing with an energy band different from that in which the luminosity function was originally derived, a spectral form to convert luminosities and fluxes must be assumed. The simplifying hypothesis is made that all clusters of galaxies are described by the same spectrum (thermal bremsstrahlung + Gaunt factor, with $kT=6$ keV). The result is shown as the dashed line in Figure 1. (Perrenod and Henry [1981] have recently reported on the possible decrease of the X-ray temperature with redshift in clusters of galaxies. If this effect is confirmed, then it will slightly lower our prediction.) Folding the computed $\log N$–$\log S$ for clusters of galaxies with the sky coverage of our survey, an expected number of 12 clusters is derived, in good agreement with the observed value (see Table 2). It may be argued that the Piccinotti *et al.* (1982) cluster X-ray luminosity function is derived from rich clusters of galaxies while in the present survey most of the detected clusters are poor clusters. For these clusters, an X-ray luminosity function is not yet available. A recent study by Bahcall (1979), however, shows that the expected X-ray luminosity function for poor clusters is the natural extrapolation at low luminosities of the X-ray luminosity function of rich clusters, but with a rather flatter slope. Therefore, a significant underestimate of the total number of clusters in our computation is not expected.

A somewhat surprising result is the almost total absence of BL Lac objects as an optical identification of X-ray sources in our survey. Assuming no evolution and using as a normalization the four BL Lac objects found in the *HEAO 1* A2 survey (Piccinotti *et al.* 1982), $\sim$1 BL Lac is expected, while with the same amount of evolution implied by the AGNs there should have been $\sim$6 BL Lac objects. This result suggests that evolutionary effects in BL Lac objects, if at all present, must be weak. A similar conclusion was reached by Setti (1978) on the basis of a "tentative" optical number count relationship for BL Lac objects.

In summary, our results on the $\log N$–$\log S$ relation for the extragalactic X-ray sources suggest the need for an evolving population of sources to explain the excess of source counts with respect to the expectation value for a nonevolving class of objects. Such a population may be easily identified with QSOs, in agreement with the fact that they show an evolutionary behavior at optical and radio wavelengths. The limited statistics of the present sample does not allow us to make a quantitative analysis of the amount of evolution required to best fit our data. The inclusion of a second set of about 200 more IPC exposures is in progress and will enable

[2] $L_{\rm min}$ and $L_{\rm max}$ have been chosen according to Piccinotti *et al.* (1982) and then converted to the (0.3–3.5) keV energy band.

us to have a more detailed picture of the behavior of the source counts relation of the extragalactic population of X-ray sources.

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Note added in proof.—Seven more sources have been detected with the HRI. In the cases of 1E 0447.1−0916, 1E 0450.3−1817, 1E 1339.9+6030, 1E 1549.8+2023, 1E 1617.9+1731, and 1E 2141.6+0359, the X-ray position is coincident; within the experimental eross (10″), with the proposed identification. In the case of 1E 1548.7+1125, an unidentified source whose nature is suggested to be galactic (class 2), the HRI position indeed confirms our classification. A K3 star is the optical counterpart of this source.

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