CHAPTER X

THE DISTRIBUTION OF X-RAY SOURCES AND THE X-RAY BACKGROUND

THE DISTRIBUTION OF X-RAY EMITTING QUASARS IN SPACE

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ABSTRACT

This review is mainly concerned with the discussion of the statistical properties of X-ray and optically selected samples of quasars and Sy 1 nuclei and their intercomparison. The inconsistencies which have been found are clearly exemplified by the discrepancy between the observed and the predicted X-ray source counts. It is shown that a satisfactory understanding of these problems has not yet been reached. The last section deals with the long debated contribution of AGNs to the extragalactic X-ray background (XRB), which is still uncertain within a factor of 2, although a lower bound of 30% at the (now convenient) energy of 2 keV can be set.

INTRODUCTION

It is well known that a big step forward in the study of the X-ray properties of large samples of objects has been provided by the enhanced sensitivity of the Einstein Observatory. The optical identifications of several hundred sources detected by the Einstein Observatory have led to the discovery of a substantial number of X-ray selected AGNs. The published observational material can be conveniently subdivided into two groups: on the one side the "surveys" such as the High Sensitivity Survey (HSS) (Giacconi et al., 1979; Griffiths et al., 1983) and the Medium Sensitivity Survey (MSS) (Maccacaro et al., 1982; Stocke et al., 1983; Gioia et al., 1984), where the derived samples are complete down to precisely defined X-ray flux limits, and on the other side statistical samples of serendipitous sources found in Einstein IPC and HRI fields (Chanan, Margon and Downes, 1981; Kriss and Canizares, 1982; Reichert et al., 1982; Margon, Chanan and Downes, 1982; Margon, Downes and Chanan, 1985). In addition, a large number of previously known quasars have been observed either in preselected

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heterogeneous samples (Tananbaum et al., 1979; Zamorani et al., 1981; Ku, Helfand and Lucy, 1980) or as members of samples complete down to well defined optical and/or radio limits (Tananbaum et al., 1983; Marshall et al., 1984; Tananbaum et al., 1986). Observations of Seyfert galaxies have also established the continuity of X-ray properties between Sy 1 galaxies (nuclei) and quasars (Kriss, Canizares and Ricker, 1980).

Studies of optically selected samples have led to some important conclusions which are relevant to the subject of this review. These can be summarized as follows:

a) The X-ray to optical luminosity ratios appear to be predominantly dependent on the optical luminosities of the objects, such that on average $L_x/L_{opt} \propto L_{opt}^{-0.2}$, although some dependence on the redshift cannot be excluded (Kriss and Canizares, 1985; Avni and Tananbaum, 1986).

b) Contrary to what happens in the radio domain, no more than a few percent of optically selected quasars (and Sy 1 nuclei) can be X-ray quiet - probably all are X-ray loud (Avni and Tananbaum, 1986).

Among other things, these findings tell us that it should be possible, at least in principle, to make precise predictions about the properties (counts, composition, evolution, etc.) of X-ray selected samples based on the knowledge accumulated in optical samples. These issues and the question of the contribution of quasars and Sy 1 nuclei* to the extragalactic XRB will be the subject of the following discussion.

THE X-RAY NUMBER COUNTS RELATIONSHIP

Direct information is being obtained from the optical identification content of three surveys which are believed to be complete down to different, but well defined X-ray flux limits. For the sake of clarity, let us briefly summarize the results so far obtained.

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*) The adoption of this terminology is only meant to provide a convenient separation of the quasar phenomenology in two luminosity domains, and it has been preferred to the term AGNs which comprises a wider class of objects not discussed in this paper. The luminosity separating the two classes falls in the range $M_B = -23 \div -24$ (depending on authors), but its precise definition is not critical for the present discussion.

Whenever needed, cosmological parameters $H_o = 50$ km s^{-1} Mpc^{-1} and $q_o = 0$ have been adopted throughout this paper.

The intermediate X-ray fluxes are covered by the Einstein Medium Sensitivity Survey (MSS). This survey is composed of serendipitous sources from a mosaic of Einstein IPC fields (~ 340) with different sensitivities ranging from 7×10^{-14} to 2×10^{-12} erg cm^{-2} s^{-1} in the energy band 0.3-3.5 keV. The area of the sky covered is ~ 90 deg^2 of which only 0.3 deg^2 have been covered with the highest sensitivity mentioned above, so that from the sky coverage table provided by Gioia et al. (1984) it appears that only sources brighter than 1.6×10^{-13} ergs cm^{-2} s^{-1} may effectively be represented in the survey. By applying well defined selection criteria 112 sources have been detected above the 5σ level, all of which have been identified in the POSS with the result that almost exactly 50% are associated with quasars and Sy 1 nuclei, for which redshift and colours are also available. Thus, for the first time it has been possible to derive an observed X-ray number count relationship for this class of objects with the result that over a factor of about 30 in flux the integral counts can be represented by a power law of the form $N(>S) \propto S^n$ with $n = -1.71 \pm 0.15$ (Fig. 1). Although a steep Log N - Log S was expected on the basis of the optical source counts and of the strong correlation

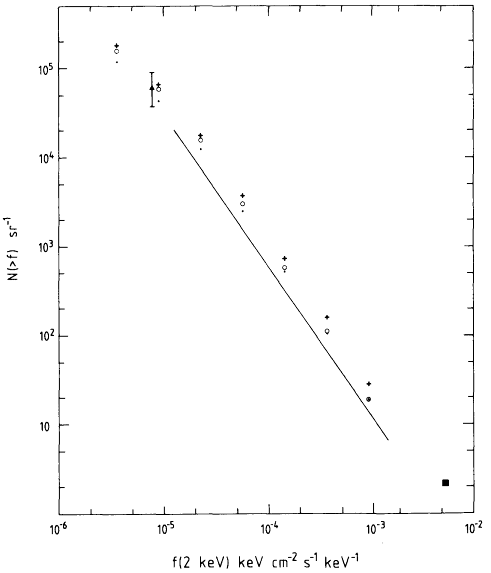

Fig. 1 - The integral source counts versus the observed fluxes at 2 keV. The straight line corresponds to the MSS counts for AGNs, the filled square to the surface density of Sy 1 galaxies detected at the limit of the HEAO 1 survey, and the filled triangle to the HSS limit of Giacconi et al. (1979). The open circles correspond to the predicted integral counts from the optical Log N - B relationship given in the text, while the crosses refer to the same with the inclusion of object A in Fig. 2. The filled dots outline the modifications in the predicted counts after inclusion of a possible K-correction term as explained in the text.

between X-ray and optical luminosities, as emphasized by Gioia et al. (1984) this result is an important independent observational evidence of the existence of strong cosmological evolution for the combined sample of quasars and Sy type 1 nuclei free from the optical selection effects which could have biased the optical source counts (see Wampler and Ponz (1985) for a recent discussion of these effects). The slope of the X-ray counts appears to be significantly less steep than the slopes derived from optical counts for which values of the exponent $n = -2 \div -2.3$ are normally quoted, which seems to indicate that the cosmological evolution as measured at X-rays is less dramatic than at optical wavelengths. Maccacaro, Gioia and Stocke (1984) analyzed the MSS data by adopting a pure luminosity evolution model whereby the X-ray luminosity of the objects is assumed to increase exponentially as a function of the look-back time, and consistently derived a cosmological evolution coefficient much lower than those derived in the corresponding models applied to optical samples.

It should be noted that if luminosity evolution plays an important rôle in describing the spatial distribution of quasars, as it appears to be the case (e.g. Koo, 1986; Boyle et al., 1986; Schmidt, 1987), then the slope of the X-ray source counts should be less steep than that of the optical counts because of the inverse correlation between L_x/L_{opt} and L_{opt} (Avni and Tananbaum, 1982). However, care should be exerted when making a closer comparison between the source count slopes: since a substantial fraction of the objects in the MSS sample tend to have quite reddish colours (~ 30%, showing a $B-V \gtrsim 0.8$) and frequently, but not always, associated extended images (Gioia et al., 1984), they would be underrepresented or completely excluded in optically selected quasar samples based on colour criteria (UVX). Since on average these objects are intrinsically faint and of low redshift (Sy type 1 nuclei with $M_B > -22$), it is likely (but it should be proven observationally) that their effect is to flatten the overall X-ray Log N - Log S with respect to that which would be obtained by including only objects which meet the colour (and images) selection criteria of the optical quasar searches.

At the faintest fluxes the X-ray source counts are bound by the limits derived from the studies of the Einstein High Sensitivity Survey (HSS) fields. From the Draco and Eridanus fields Giacconi et al. (1979) derived an absolute limit of 19.2 ± 7.9 deg^{-2} to the total number of extragalactic sources ($> 5\sigma$) down to a flux limit of 2.6×10^{-14} ergs cm^{-2} s^{-1} in the energy range 1-3 keV. Primini et al. (1986) have analyzed available deep IPC exposures of 8 HSS fields (including a reanalysis of previously reported fields) to cover a sky area of ~ 2,3 deg^2. From the optical identification work on the sources detected above a 4.5σ level, 8 have been positively identified with quasars (with absolute magnitudes ranging around $M_B = -24$) and 10 others are "probable extragalactic objects", leading to a surface density of X-ray selected quasars and Sy 1 nuclei $\lesssim 8^{+3}_{-2}$ deg^{-2} down to a flux limit approximately equal to that of Giacconi et al. reported above. Although this result is in agreement within the statistical errors with the Giacconi et al. limit, the central value is smaller by a factor 2.4 and it provides a much stronger constraint on the X-ray source counts.

At the very bright end of the flux scale information is provided by the HEAO 1 X-ray survey of Piccinotti et al. (1982), which covers ~ 27,000 deg^2 of the sky and is claimed to be complete down to a limiting sensitivity of 3.1×10^{-11} ergs cm^{-2} s^{-1} in the 2-10 keV energy band. It contains 19 Sy 1 galaxies and 1 quasar.

These results have been plotted in Fig. 1 as a function of the monochromatic 2 keV fluxes by converting the broad-band spectra with the corresponding power-law photon distributions assumed in the data analysis of the various surveys, i.e. photon spectral indices of 1.4, 1.5 and 1.65 for the MSS, HSS and HEAO 1 surveys, respectively. It should be noted that a downward extrapolation of the MSS source counts falls about a factor 3 below the HEAO 1 point. Since the MSS source counts are ill defined at the bright band, it is not clear to me whether the counts would tend to flatten to meet the HEAO 1 point or whether this discrepancy is due, at least in part, to a genuine scale difference between the Einstein Observatory and HEAO 1 fluxes, as recently suggested by Danese et al. (1986).

COMPARISON BETWEEN X-RAY AND OPTICALLY SELECTED SAMPLES

When the complete results of the MSS became available it was immediately realized (Setti, 1984; Zamorani, 1984) that there was a striking contradiction, an excess of a factor 2-3, between the number of quasars and Sy 1 nuclei predicted on the basis of the optical source counts and of the X-ray emission properties of optically (and radio) selected samples and the number actually found in the MSS. Similarly, one finds contradictory predictions with regard to the slope of the X-ray source counts, the redshift distributions, and so on. It should be stressed that these contradictions persist independently of the methods, evolution models, reference optical samples, luminosity and colour constraints which have been adopted in making the predictions (Setti and Woltjer, 1962; Maccacaro, 1984; Kriss and Canizares, 1985; Zamorani, 1985; Schmidt and Green, 1986; Avni and Tananbaum, 1986).

In particular, Schmidt and Green (1986) have made a study of a homogeneous set of data obtained for the Bright Quasar Survey (BQS), a sample of which has been observed with the Einstein Observatory (Tananbaum et al., 1986). X-ray fluxes have been derived by assuming a 1.5 power-law photon spectral index, and therefore are directly comparable to the MSS results; in order to minimize the intervention of optical selection effects their analysis has been confined to the quasar sample ($M_B < -23$). In the framework of the evolution models (luminosity-dependent density evolution) utilized to fit the BQS data, an overprediction of a factor 2, or so, in the number of quasars and a higher average redshift with respect to the MSS results are again found. By forcing agreement with the MSS quasar sample these authors introduced a negative cosmological evolution of the X-ray luminosity (at a given optical luminosity).

This has prompted Maccacaro and Gioia (1986) to analyze possible causes of incompleteness of the MSS, with the conclusion that the MSS AGNs sample is statistically complete. Franceschini, Gioia and Maccacaro (1986) find that most of the discrepancies could be greatly reduced, if not completely eliminated, if the intrinsic distribution of the residuals in the L_x, L_{opt} correlation is narrower (and more skewed at large L_x/L_{opt}) than the observed one, and discuss a number of effects which could have artificially broadened the observed distribution, among which the temporal variability represents a clear-cut case since X-ray and optical data have usually been acquired at very different epochs (see also Avni and Tananbaum, 1986, and Zamorani, 1985).

In order to have a somewhat clearer and more qualitative perception of the various issues, without entering into the whole alchemy of luminosity functions, evolution models, α_{ox}, etc., I have derived X-ray source counts by making use only of the observed Log N - B relationship(s) and of the observed ratios of X-ray to optical flux for a well defined unbiased sample of optically selected objects, such as the sub-sample of BQS observed with the Einstein Observatory (Tananbaum et al., 1986). Of the 66 objects observed, 57 have been detected and their 2 keV fluxes versus B magnitudes are plotted in Fig. 2. A posteriori I have verified that the upper limits available

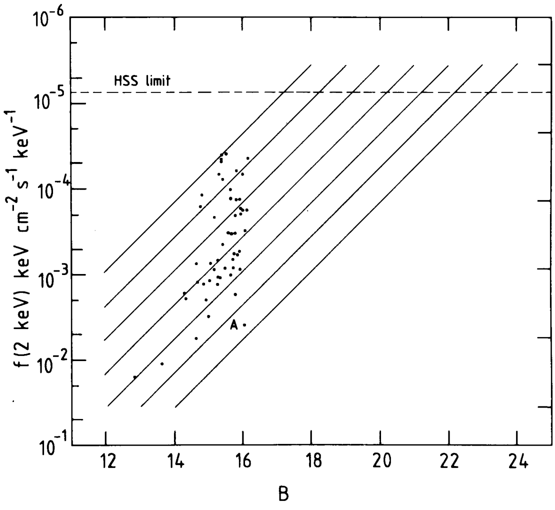

Fig. 2 - The observed fluxes at 2 keV from the BQS X-ray sub-sample versus B magnitudes corrected for galactic absorption. The straight lines correspond to loci of constant intrinsic X-ray to optical ratios.

for the remaining objects are such that these objects can be neglected without substantially modifying the results of the present analysis. It is seen that most of the objects fall within one magnitude in B, while they are spread over more than two orders of magnitude along the X-ray flux axis. If for any given object the intrinsic ratio of X-ray to optical flux were preserved as a function of distance, then in the Log f_X - B diagram the objects would move along trajectories parallel to the diagonal lines shown in Fig. 2. It is seen that objects from a wide range of B magnitudes will contribute to any given X-ray flux interval and it is now a simple matter to derive the corresponding X-ray source counts by summation over the contributions obtained by drawing out objects from the optical Log N - B according to the percentage found in the reference sample per bin of B magnitudes. However, because of the inverse proportionality of L_X/L_{opt} with L_{opt}, and because the percentage of objects in any given absolute magnitude interval in the Log N - B relationship changes with B, the procedure described above must be qualified per luminosity bins. The percentages of objects per luminosity bin in the Log N - B relationship have been derived from the contents of the BQS (Schmidt and Green, 1983), BFG (Braccesi et al., 1970) and BF (Formiggini et al., 1980; Marshall et al., 1984) samples. Beyond B ≃ 20 percentages have been calculated by assuming a quasar redshift cutoff z = 3, so that at B = 24 only nuclei with $M_B \gtrsim -24$ would be present in the optical counts.

Several qualitative conclusions can be drawn immediately from the inspection of Fig. 2:

(a) According to the scheme outlined above, it is clear that the precise distribution of the objects at bright X-ray fluxes plays a key-rôle because of the coupling with the fainter B magnitudes where the surface density of quasars increases dramatically due to the very steep slope of the optical source counts. For instance, the contribution of the object marked A, found in the last bin, to the derived X-ray source counts is of the order of 25% (Fig. 1). This is precisely the effect discussed by Franceschini, Gioia and Maccacaro (1986). It is hard to believe that the estimate should depend so strongly on the inclusion (or exclusion) of just one object, and accordingly we shall ignore it in what follows. It should be noted, however, that to remove it from its position in the diagram of Fig. 2 would require that it be at least 0.6 magnitudes brighter at the time of the X-ray measurement. [Object A is the nucleus of the Sy 1 galaxy III Zw 2 and, since its absolute magnitude $M_B = -22.7$, it has been excluded from the quasar sample discussed by Schmidt and Green (1986). Evidence for cosmological evolution of Sy 1 nuclei of this luminosity has been discussed by Setti (1984).]

(b) A flattening of the X-ray source counts is predicted to take place well before the HSS limit when one begins to include objects with B $\gtrsim$ 20, the magnitude beyond which the optical source counts are known to flatten dramatically.

(c) Objects with magnitudes up to B ~ 23 contribute to the X-ray source counts down to the HSS sensitivity.

The adopted optical source count can be described as follows: Log N(<B) = 0.53 + 0.85 (B-19) for B < 19, consistent with the BQS and BFG samples corrected for selection effects (Woltjer and Setti, 1982; Setti, 1984); Log N(<B) = 1.57 + 0.38 (B-21) for B > 21, consistent with Koo (1986) and Marano, Zamorani and Zitelli (1986), while in the interval 19 < B < 21 the counts have been smoothly interpolated so that at B = 19.8 an integral surface density of ≃ 13 obj. deg^{-2} is obtained, a factor ~ 1.5 below the surface density of the BF sample which appears to be in excess of the findings in other quasar surveys (Marano, Zamorani and Zitelli, 1986; Boyle et al., 1986). The integral X-ray source counts can now be derived and the results are plotted in Fig. 1. It is seen that the predicted counts (excluding object A) exceed by a factor from 1.5 to 2.1 the MSS counts and have a steeper slope. As can be immediately guessed from a quick glance at Fig. 2, the predicted X-ray counts are very sensitive to the precise value of the optical counts in the magnitude range 19 < B < 21 (Woltjer and Setti, 1982; Anderson and Margon, 1986). A surface density of a full factor 2 below the value of the BF sample would flatten the predicted counts and the discrepancy with the MSS counts would not exceed a factor 1.8. In addition, if the average X-ray spectrum of quasars and Sy 1 nuclei in the BQS sample is as steep as indicated by the findings of Elvis et al. (1986), and if a spectral index ≃ -0.5 is representative of the average optical continuum (Richestone and Schmidt, 1988), then an important K-correction term must be taken into account (see also Schmidt and Green, 1986). In the diagram of Fig. 2 this is equivalent to saying that the (hypothetical) trajectories of the objects are curving upwards and a stretching of the source counts along the X-ray flux axis is inferred. Assuming that the difference between the average X-ray and optical continuum spectral indices is 0.5, the predicted source counts change as shown in Fig. 1 (filled dots)*. It is worth noting that the slope of the counts is now almost exactly equal (by coincidence?) to that of the MSS, but an excess of a factor 1.6 can still be registered**. A further flattening of the counts at the fainter fluxes would be introduced by another K-correction term (not considered here) because of the brightening of the objects at $z \gtrsim 2$ caused by the strong emission lines entering the B filter.

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*) As discussed later, a much steeper X-ray spectrum implies a sizeable reduction in the 2 keV fluxes. This has not been taken into account since we are interested here only in the relative comparison with the MSS results.

**) The detailed analysis also shows that at the HSS limit most objects are comprised in the luminosity range $-22 > M_B > -26$, almost equally positioned around $M_B \simeq -24$.

Based on the above discussion, it should be noted that because of the steep slopes involved the difference between the predicted and observed number counts can be completely eliminated by a horizontal shift of only a factor 1.25-1.30 in the relative flux scale. This could be a genuine difference, but one may wonder if it could at least in part be explained by the presence of systematic effects such as, for instance, the different procedures (background subtraction) followed to derive the source fluxes for the MSS and for the BQS X-ray sub-sample as described in Maccacaro et al. (1982) and in Tananbaum et al. (1986), respectively. Moreover, if the steep X-ray spectra derived by Elvis et al. (1986) for 8 X-ray bright quasars of the BQS sample are representative of the optical as well as X-ray samples surveyed by the Einstein Observatory, then, by direct comparison with the data shown in Tananbaum et al. (1986), one finds that an average reduction of ~ 40% in the 2 keV fluxes displayed in Figs. 1 and 2 should be applied. While this would not modify the intercomparisons within the samples studied by the Einstein Observatory, it would further enhance by a large factor (~ 2.3) the difference between the HEAO 1 point and the downward extrapolated MSS counts. Equivalently, the number of Sy 1 nuclei predicted on the basis of the HEAO 1 data and a uniform space distribution would greatly exceed the one found in the MSS. Although this may certainly contribute to solving a selection problem pointed out by Schmidt and Green (1986), it seems to me that the general situation would be eased by a substantial upward scaling of the MSS fluxes. In addition, this may also contribute to the solution of another apparent discrepancy between the number and mean luminosity of clusters of galaxies predicted on the basis of the HEAO 1 survey and the findings of the MSS (Schmidt and Green, 1986).

In conclusion, I believe that at this stage the observational situation is so tight that it is important to make sure first that the X-ray fluxes have been calibrated exactly on the same scale.

THE CONTRIBUTION TO XRB

The question of the contribution of quasars and Sy 1 nuclei to the XRB has been the subject of many investigations over the past fifteen years. Despite the vast increase in the number of objects detected in the X-rays and the great advance in the understanding of their emission properties, this subject remains open to a great deal of incertitude as shown by the wide range of estimates arrived at by different authors (Cavaliere et al., 1981; Setti and Woltjer, 1982; Zamorani, 1982; Maccacaro, Gioia and Stocke, 1984; Anderson and Margon, 1986; Schmidt and Green, 1986). Obviously, in the discussion of this problem a key rôle is also played by the spectral shape of the sources. The differential energy spectra of a close-by sample of Sy 1 galaxies selected at hard X-ray energies can be fitted by power laws in the 2-20 keV interval, such that the sample shows a mean spectral index ≃ -0.65 with a small dispersion around the mean (Mushotzky, 1984). Very little information is available on the hard X-ray spectra of quasars. Recently, results from the Einstein Observatory IPC (0.1-4 keV) have become available (Elvis, Wilkes and Tananbaum, 1985; Elvis et al., 1986) for a small sample of optically selected quasars and Sy 1 nuclei at relatively small redshifts ($z < 0.3$). Single power-law fits to the spectra are obtained with slopes on average much steeper (mean spectral index $\lesssim -1.00$) than the previously quoted value for the hard X-ray domain. The reason for this difference is not yet fully understood, although the hard and soft X-ray selection of the samples may play an important part (Elvis et al., 1986; also for references to previous work on the subject). The important point as far as the present discussion is concerned is that the spectra of the sources appear to be at variance with the spectrum of the XRB, which in the 2-20 keV interval can be represented by a power law with a spectral index -0.4 and an intensity at 2 keV of $\simeq 5.83$ keV cm^{-2} s^{-1} $ster^{-1}$ keV^{-1}. Consequently, unless the X-ray spectra of quasars and Sy 1 nuclei undergo a strong cosmological evolution (become flatter at large z), these objects cannot explain the bulk of the XRB. In fact, the high precision measurements of the XRB in the 3-50 keV interval made with the HEAO 1-A2 (which can be accurately fitted by a 40 keV thermal bremsstrahlung) have been used to set a limit of $\lesssim 30\%$ in the 2-10 keV energy interval to the integrated contribution from sources having power-law spectra with mean spectral index $\simeq -0.7$ and a high energy cutoff (De Zotti et al., 1982). As a corollary, the same authors noted that any population of sources substantially contributing to the XRB in addition to AGNs must have a mean spectral index $\gtrsim -0.4$.

With the above considerations in mind, the contribution of quasars and Sy 1 nuclei to the XRB can be better discussed with reference to a fixed observed energy of 2 keV which represents a convenient compromise between the soft X-ray sensitivity of the IPC, where most of the statistical information on these objects has been obtained, and the hard X-ray where the extra-galactic XRB has been accurately measured. The most recent estimate of the quasar contribution to the XRB has been made by Schmidt and Green (1986). On the basis of the X-ray source counts derived from the BQS sample by forcing agreement with the number of quasars found in the MSS (as discussed in the preceding section), they estimate a contribution to the 2 keV background of 13% down to 8% if the steep spectral index found by Elvis et al. (1986) is considered typical of all quasars. Estimates, and in fact lower bounds, can be obtained by integration over the X-ray source counts derived from the optical counts independent of the particular choice of evolution models. With the specifications described in the previous sections with regard to the optical counts and their content, it is found that quasars down to $B = 23$ would contribute 19-21% of the 2 keV background depending on the adopted value of the counts around $B = 20$. If agreement with the MSS counts is forced and/or a steep slope for the X-ray spectra of a typical quasar is adopted, then contributions ranging from 7 to 11% are found, in good agreement with the findings of Schmidt and Green (1986).

A "minimal" contribution of 29% to the 2 keV background can be obtained from the HEAO 1 (local) sample of Sy 1, assuming a uniform spatial density and a mean spectral index -0.65 (Piccinotti et al., 1982; Schmidt and Green, 1986), with a statistical error of ± 6.5% due to the small size of the sample. Since two Sy 1 nuclei in the Elvis et al. (1986) sample show a very steep spectral index, a possible additional contribution from steep spectra Sy 1 nuclei should be considered. Moreover, a further contribution may result from evolution possibly present at the bright end of the Sy 1 luminosity function (Setti, 1984). A direct estimate of the Sy 1 contribution to the XRB via the counts cannot be done at present, not only because of the selection effects affecting both the X-rays and optical source counts at the bright end, but, even more importantly, because it would require the knowledge of the optical counts down to and deeper than B = 24, where the counts should be fully dominated by Sy 1 nuclei.

Therefore, while it appears ascertained that the combined contribution of Sy 1 nuclei and quasars to the 2 keV background must be $\gtrsim 30\%$, it may also exceed 50%. A more precise value for this contribution, together with an appropriate knowledge of the corresponding X-ray spectra not yet available and of the contributions from other classes of sources, are needed to properly derive the residual XRB above 3 keV, a prerequisite to the discussion, beyond the scope of the present review, of the nature of the source (or sources) which saturate the XRB. A recent discussion of these issues has been made by Giacconi and Zamorani (1986).

CONCLUSIONS

The apparent inconsistencies between the statistical properties of X-ray selected samples of quasars and Sy 1 nuclei and those predicted on the basis of X-ray observations of optical samples have not yet been satisfactorily understood. Although possible solutions have been proposed, further investigations are required including a verification that the X-ray flux measurements in different samples are calibrated on the same scale.

The problem has become even more complicated, if one may say so, after the discovery that the Einstein IPC spectra of optically selected X-ray bright quasars and Sy 1 nuclei are on average much steeper than the often quoted "canonical" value for AGNs, which indicates a widely spread distribution in the spectral indices. Because of the interplay between the spectral shapes and the corresponding X-ray fluxes, a proper intercomparison of different samples should be based on an adequate knowledge (not achievable at this moment) of the spectral characteristics of the corresponding populations of objects. To assume, for instance, that the IPC spectra of the optically selected X-ray bright quasars are representative of all optically selected quasars, or that the X-ray and optically selected samples have similar average spectra, may turn out to be a gross oversimplification leading to contradictory results.

These uncertainties are fully reflected in the estimates of the combined quasar and Sy 1 nuclei contribution to the XRB which span a factor of 2, although a lower bound of 30% at the monochromatic energy of 2 keV seems well established. It should be noted that the additional estimated contributions from different objects (such as galaxies and clusters of galaxies) make it likely that the integrated contribution of known classes of sources to the 2 keV XRB exceeds 50%. This, together with the poor knowledge of the X-ray spectra applicable to the various classes of objects (with the exception of clusters), renders very uncertain any extrapolation of the contribution to the background above 3 keV.

It has become customary to terminate papers dealing with this subject by deferring the solution of all these difficult problems to the launch of future X-ray observatories such as ROSAT, AXAF and XMM. While this will certainly be the case, I believe that in the meantime a tremendous amount of important work can be done with the data already acquired. In particular, the extension of the MSS now under way is of the greatest importance since it will provide a much larger sample of X-ray selected AGNs, thereby allowing a much closer comparison with the optically selected samples. The MSS probes the quasar distribution down to B ~ 21 (Fig. 2) and it is hoped that the increased size of the sample will permit to achieve statistically meaningful results at this faint end not affected by well known optical selection biases. Similar considerations apply to the HSS, for which it would obviously be of greatest importance to complete the optical identifications. This is clearly not an easy task because objects down to B ~ 23 may be involved. But it is worth trying since, at least in principle, the identification content of the HSS, together with the corresponding surface density of the objects, can provide extremely important constraints on the evolution of quasars.

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DISCUSSION

PECKER: When evaluating the counts of X-ray sources, in relation to optical counts, you use the relation $L_X = L_O^{\beta}$ ($\beta \sim 0.7$-0.8). But, I understood that some data indicated that indeed β is a function of the X-ray energy; this effect should definitely affect the z-dependence of the predicted counts for sources observed in a well-defined energy range. What could be said now about it?

SETTI: I am not aware of data proving the existence of such an effect. If it existed, it would simply mean that the slope of the X-ray spectra would depend on the optical luminosity, and this cannot be excluded at present.