

THE COLOURS OF THE X-RAY BACKGROUND

ANDREA COMASTRI

Osservatorio Astronomico di Bologna, via Zamboni 33, 40126 Bologna, Italy

ABSTRACT.

The recent deep X-ray surveys at both soft (0.5–2.0 keV) and hard (2–10 keV) energies have greatly extended our knowledge of the X-ray source density and spectral shapes at relatively faint fluxes adding further evidence on the fact that discrete sources, mainly AGNs, are responsible for the X-ray background (XRB) emission over a broad energy range. In addition the first complete optically identified samples of soft X-ray sources are becoming available allowing to test the XRB AGN synthesis models in the light of recent results. In this paper I will briefly compare the model predictions with some new observational data.

1. AGN models for the XRB

It has been recognized already ten years ago (Setti & Woltjer 1989) that the XRB spectral paradox (i.e. the fact that the source spectra in the 2–10 keV energy range are much steeper than the XRB spectrum) can be solved assuming an important contribution from sources with spectral shapes flattened by absorption.

In the framework of popular AGN unified schemes the 3–100 keV XRB spectrum and the source counts in different energy bands can readily be reproduced by the combined emission of Seyfert galaxies and quasars (type 1) and obscured (type 2) AGNs with a range of column densities and luminosities (Matt & Fabian 1994; Madau et al. 1994; Comastri et al. 1995 hereinafter C95).

All these models rely on several assumptions on the sources spectral shapes, X-ray luminosity function (XLF) and cosmological evolution. Given the large number of “free parameters” is not surprising that the XRB spectrum and intensity can be well reproduced even for rather different choices of the above described parameters. An attempt to reduce the parameter space has been made by C95 who developed a self-consistent approach which simultaneously fit the XRB spectrum and others available constraints: namely the source counts, redshift and absorption distributions observed in the soft (0.5–2 keV) and hard (2–10 keV) bands. Assuming for the spectral and evolutive AGN properties average values consistent with the observations the absorption distribution of type 2 objects is the only “free” parameter which is varied until a global good fit is obtained (see Fig. 1 and figures in C95). According to this model the XRB spectrum is due to sources with a similar range of redshifts and luminosities, but with very different spectral shapes (colours). The optical identifications of faint X-ray sources discovered by ROSAT, ASCA and BeppoSAX surveys open the possibility to test the AGN synthesis model for the XRB. Two examples are briefly discussed in the following.

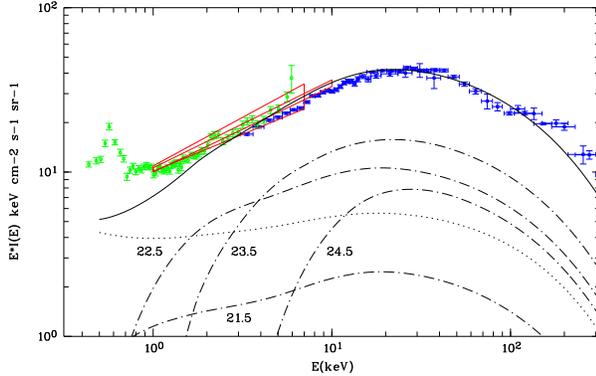


Fig. 1. The AGN synthesis model (solid line) fit to the XRB spectrum. The various curves represent the contribution of unabsorbed (dotted line) and absorbed (dot-dashed lines) objects. There is a clear mismatch between the 0.4–6 keV ASCA data (grey points), the 1–7 keV ASCA plus ROSAT joint fits (dotted bowties) and the HEAO1–A2 data above 3 keV (black points) in the overlapping energy range. The origin of this difference, which is of the order of 20–30 % in the 1–7 keV range, is not yet understood.

2. The AGN content of deep X-ray surveys

The contribution to the XRB of the absorbed objects increases with energy (Fig. 1), as a consequence a significant test for this model would be the comparison of its predictions with the results of optical identifications of complete samples of X-ray sources possibly selected in the hard X-ray band. Programs to optically identify these sources have already started, but the number of identified sources is still low and a detailed comparison will be possible only in the near future. In order to overcome this problem I have considered the complete optically identified sample of the Rosat Deep Survey (RDS) in the Lockman hole (Hasinger et al. 1998). Among the 50 X-ray sources with 0.5–2 keV fluxes $> 5.5 \cdot 10^{-15} \text{ erg cm}^{-2} \text{ s}^{-1}$ the great majority (43) are AGNs (Schmidt et al. 1998). At this limiting flux the model predicts (Fig. 2, left panel) a fraction of absorbed AGN ($N_H = 10^{21-23}$) of the order of 30 % indicating that the bright tail of the absorbed population should be visible in the RDS. X-ray spectral information for the RDS sources is only available in terms of the two hardness ratios HR1 and HR2 (see Hasinger et al. 1998 for the definition) and is reported in Figure 2. Absorbed sources

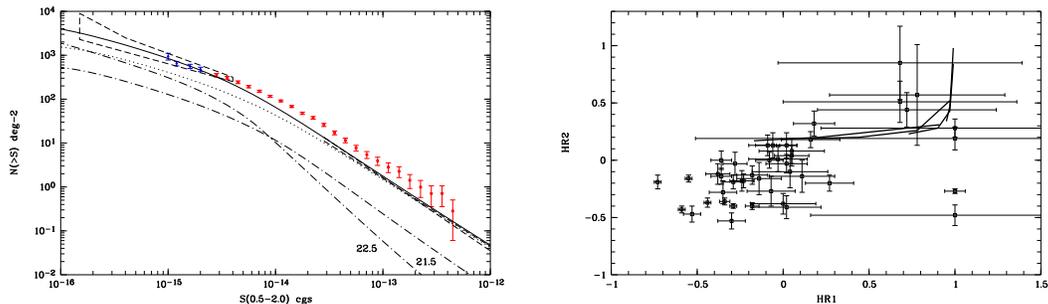


Fig. 2. *Left panel*: the 0.5–2 keV counts compared with model predictions (line types as in Fig. 1). *Right panel*: the colour-colour diagram of the optically identified RDS sources (see text for details). Data points for both panels are from Hasinger et al. 1998

are characterized by hard X-ray spectra and populate the upper right and right parts of the diagram. The hardness ratios of obscured AGNs with a range of column densities ($N_H = 10^{21-23}$) and redshifts ($z = 0 - 3$) assuming a power law spectrum ($\alpha = 1$) lie on the continuous lines. At this limiting flux about 10–12 sources have hardness ratios and redshifts which are consistent with the presence of such column densities, moreover the optical spectra of most of these hard sources show only narrow lines which are typical of type 2 AGNs. Even if the agreement with the model predictions is rather good the number of absorbed sources is still too low preventing from a more detailed analysis. It should be noted that the model predictions, based on the latest response matrix, do not reproduce the HR2 distribution of unabsorbed sources. This discrepancy may be due to either a much steeper, than assumed, 0.5–2.0 keV spectral index, or to residual calibration uncertainties. Given that the fraction of absorbed sources increases at lower fluxes (Fig. 2; left panel) the optical identification of faint sources coupled with the X-ray spectral information is expected to provide further constraints on the model parameters. In particular the comparison of the expected and observed luminosity/redshift distributions of the absorbed sources would provide a key test for the model.

3. Do quasar 2 exist ?

The existence of a population of highly absorbed intrinsically luminous sources, which in analogy with the Seyfert 1/2 classification are named quasars 2, is predicted by the AGN unification schemes at least in their strictest version. Based on these schemes the

C95 model assumes the same XLF and pure luminosity evolution for type 1 and type 2 (obscured) objects, as a consequence several type 2 QSOs are expected in medium–deep X–ray surveys. Even if the discovery of a few type 2 QSO candidates has been reported (e.g. Otha et al. 1996) this population has proved to be elusive and its existence has been recently questioned (Halpern et al. 1998). The surface density (deg^{-2}) of type 2 QSOs according to C95 is reported in Table 1 for two different limiting fluxes (cgs units) and energy ranges (keV units) corresponding to the limits of ASCA and ROSAT deep surveys. As the definition of a type 2 QSO is somewhat ambiguous the calculations have been performed for different choices of the minimum column density and luminosity (log values) required to classify a source as a type 2 QSO. Taking into account the sky coverage of the RDS the number of type 2 quasar ranges from 0.1 to 4. There are 3 RDS sources with hardness ratios and luminosities which meet the above criteria. The comparison with the observations in the 2–10 keV band is not straightforward given the large incompleteness of the optical identifications. Among the 40 X–ray sources in the ASCA Large Sky Survey (Ueda et al. 1998) the expected number of type 2 QSOs (according to Table 1) ranges from 1 to about 10.

Tab. 1 - The space density of quasar 2

	$N_H > 22, L > 44$	$N_H > 22, L > 45$	$N_H > 23, L > 44$	$N_H > 23, L > 45$
$S_{2-10} > 10^{-13}$	4.2	0.9	1.5	0.5
$S_{0.5-2} > 5 \cdot 10^{-15}$	39	17	0.7	0.7

It is concluded that the existence of type 2 QSOs cannot be ruled out on the basis of the present observations. Given that their surface density increases steeply a large number of quasars 2 is expected at faint X–ray fluxes (Comastri 1999 in preparation). Alternatively a large population of lower luminosity Seyfert 2 galaxies, possibly subject to a different cosmological evolution law, may account for the bulk of the XRB at high energies. It is interesting to note that some evidence of a more complex behaviour than pure luminosity evolution is emerging from ROSAT data (Hasinger 1998). If this is the case a revision of the model assumptions will be necessary. Deep observations with AXAF and XMM will clarify some of these issues.

References

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