

The ultraviolet to soft X-ray bump of Seyfert 1 type active galactic nuclei*

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Abstract. The soft X-ray ($0.1 - 2.4 \text{ keV}$) emission of 58 Seyfert 1 type active galactic nuclei have been studied using the spectra obtained during the *ROSAT* all sky survey. These spectra are well represented by power law models with photon indices ranging between 1.6 and 3.4. The spectra usually do not show intrinsic absorption. A notable exception is Mrk 766 which is probably absorbed by molecular clouds located in the inner part of the Narrow Line Region.

A soft X-ray excess above the extrapolation of the hard X-ray spectrum is detected in 90% of the sources. These soft X-ray excesses are well correlated to the strength of the “big blue bump” observed with *IUE* except for those sources which are highly absorbed in the ultraviolet. The strength of the *ultraviolet to soft X-ray bump* varies by a factor of hundred from object to object and it is not correlated either to the luminosity or to the radio-loudness.

The data are consistent with the assumption that the ultraviolet to soft X-ray bump is similarly shaped in all Seyfert 1 galaxies of our sample. Neither thin nor thick accretion disk models can reproduce the available observations in a natural way.

Key words: galaxies: Seyfert – ultraviolet: galaxies – X-rays: galaxies

1. Introduction

The ultraviolet to X-ray spectra of Seyfert 1 type Active Galactic Nuclei (AGN) can be decomposed in two major distinct components, a non thermal hard X-ray continuum and a broad excess of emission in the ultraviolet, the so-called big blue bump, often interpreted as the prime emission from accreting matter.

In several sources an excess of emission was discovered in the soft X-ray domain by *EXOSAT* (Turner & Pounds 1989). Even if part of this soft X-ray excess can be emitted by an extended source (Elvis et al. 1990), soft X-ray variability observed in several Seyfert 1 type AGN has lead to the conclusion that

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* Tables 1 and 2 of this paper are available in electronic form via an anonymous ftp copy at the Centre de données de Strasbourg.

a major part of the soft X-ray emission is produced in the very central parts of the active nucleus.

Since its discovery (Arnaud et al. 1985), the more widely accepted explanation for the soft X-ray excess has been the emission from the inner edge of the accretion disk which, on the other hand, is thought to be responsible for the ultraviolet big blue bump. The low transmission of galaxies in the far ultraviolet remains, however, a major obstacle to its understanding.

In this paper we use the improved soft X-ray sensitivity and the low instrumental background of the X-ray telescope aboard the *ROSAT* spacecraft (Trümper 1983) to analyse the soft X-ray ($0.1 - 2.4 \text{ keV}$) spectra of a sample of 58 Seyfert 1 type AGN observed during the *ROSAT* all sky survey (Sect. 3). We discuss the absorption in these spectra in Sect. 4 and the spectral components of the soft X-ray excess and its relation to other spectral components in Sect. 5. The main goal of this paper is to establish the relation between the soft X-ray excess and the ultraviolet emission in Seyfert 1 galaxies. In Sect. 6 we determine the spectral shape of the ultraviolet to soft X-ray bump and we compare it to predictions of several emission models.

2. Observations

2.1. The sample

The point sources found by the Standard Processing and Analysis System (SASS) in the *ROSAT* all sky survey have been compared with positions of Active Galactic Nuclei compiled from various catalogues to construct a list of optically well-known AGN detected at X-rays with *ROSAT* (Brinkmann 1992). From it we selected all Seyfert 1 type AGN with more than 300 counts (SASS), which were observed at least once in the ultraviolet with *IUE*.

Four sources were removed from this list. For E 1556+274 the finally extracted net source counts were insufficient to establish a reliable spectrum. NGC 4151 was removed because its soft X-ray emission is extended (Pounds et al. 1986). Finally, Mkn 205 and Mkn 876 are targets of the *ROSAT-IUE* programme (RIASS), for which the data rights do not belong to the

authors. They have been excluded and they will be published elsewhere (Ulrich, *in prep.*).

The remaining sample of 58 Seyfert 1 galaxies are listed in Table 1 together with their redshifts (Véron-Cetty & Véron 1991) and the line of sight equivalent hydrogen column densities as derived from the 21 cm radio measurements. This column density is caused by matter in our Galaxy and it is designated as N_{Hgal} .

For some well-studied X-ray AGN accurate pointed radio measurements by Elvis et al. (1989) are available which we adopted in Table 1 where applicable. For the other sources we used column densities derived from the 21 cm surveys by Dickey et al. (1990) or Stark et al. (1987). These column densities are mean values averaged over areas of $1^\circ \times 1^\circ$ and $2^\circ \times 3^\circ$, respectively, towards the target considered.

2.2. Ultraviolet, infrared and radio data

The ultraviolet fluxes listed in Table 1 have been extracted from the mean spectra observed with *IUE* between 1978 and 1988 or from quasi-simultaneous RIASS observations when available to us.

The given fluxes are continuum fluxes extracted in two windows free of strong emission lines defined in the rest frame of the source at $1375 \pm 25 \text{ \AA}$ and $2675 \pm 25 \text{ \AA}$. They are corrected for galactic reddening in the observer's rest frame by means of the reddening law of Savage & Mathis (1979) using the listed radio column densities (Ryder et al. 1975). The flux errors in Table 1 are standard deviations of the fix pattern noise of *IUE*. The reproducibility of the flux determination in the given windows are usually better than 5% (Walter & Courvoisier 1991) except for faint sources at the limit of detectability at $1375 \text{ \AA}$.

For only 7 objects in our sample quasi-simultaneous *IUE* and *ROSAT* observations are available. According to long-term light curves recorded with *IUE*, typical flux variations are of a factor of three (Courvoisier & Paltani 1992). Therefore we estimate that the uncertainty of the listed ultraviolet fluxes is, on average, not larger than this factor. Since most of the light curves are undersampled, we cannot exclude larger variations in some sources, but a systematic effect on the entire sample is rather unlikely.

The $25 \mu\text{m}$ fluxes are given for those sources detected with *IRAS*. They are compiled from the *IRAS* catalogues and from literature. We estimate that their systematic uncertainties related to the non-simultaneity of the observations is less than a factor 3. Corrections to the *IRAS* fluxes for galactic contributions are usually smaller than a factor of two (Edelson & Malkan 1986) and, therefore, negligible in our discussion.

The 5 GHz fluxes are taken from the Véron-Cetty & Véron (1991) catalogue. They are used to calculate the radio loudness. Although we cannot exclude variations of the radio emission by one order of magnitude, we checked that such uncertainties basically do not have a crucial effect on our conclusions.

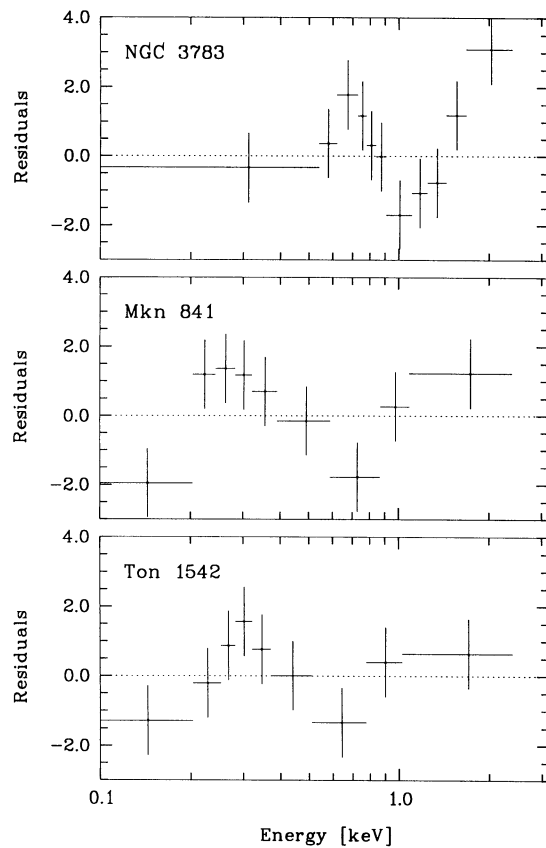


Fig. 1a–c. Residuals (in unit of standard deviations of the count rate) between the observed spectra and the best fit absorbed power law model spectra for **a** NGC 3783 **b** Mrk 841 and **c** Ton 1542

2.3. X-ray observations and analysis

The X-ray observations were performed with the X-ray telescope and PSPC detector (Pfeffermann et al. 1986) aboard the *ROSAT* spacecraft during the *ROSAT* all sky survey (Voges 1992). The survey was performed by scanning the sky along great circles perpendicular to the ecliptic. Therefore, the number of passages of a given source through the detector's field of view (2° in diameter) i.e. the total exposure and the observational period, depends strongly on the ecliptical latitude of the target. Exposure times range from some hundred to some thousand seconds. Sources near the ecliptic are observed for two days, those near the ecliptic poles for weeks to months.

All selected sources are analyzed using the same method. All counts were collected which were registered by the PSPC in a field of view truncated to 57 arcmin in radius to avoid edge effects. Then these counts were reprojected onto the plane of the sky by means of the attitude solution for the telescope axis. By fitting a two-dimensional Gaussian function to the reconstructed X-ray image of the source its centroid is determined. Subsequently, we extracted the source counts contaminated with the local background by cutting out a circular area from the X-ray sky centered on the source's centroid. The extraction radius is

given by that distance from the centroid where the radial profile of the point source meets the background level.

The background photons are collected in an annulus centered on the source during the observation. When detected, other sources were removed from the background field. The gain calibrated source and background counts are then corrected for effects of vignetting, i.e. variation of the off-axis effective area in the field of view of the PSPC, and for the true exposure times at all positions in the sky field considered, and finally binned in pulse height spectra. The spectra are not corrected for the effects of the dead time and of the shadowing of the detector supporting structure. Their common effect is a systematic underestimate of all X-ray fluxes by $(12 \pm 2)\%$.

The first 7 channels ($\lesssim 0.08$ keV) and the last 16 channels ($\gtrsim 2.4$ keV) of the spectra are excluded from the final spectra as the response of the instrument is not well defined at both ends. Finally the background subtraction is performed and the spectrum is compressed to unequally spaced bins containing count numbers with the same S/N ratio, usually between 5 and 9 depending on the total number of counts. Typical compressed pulse height spectra comprise 10 to 20 bins.

The spectral fits described in the following sections always compare the compressed spectra to different models folded with the response matrix of the PSPC detector. The response matrix is the same for all observations, its accuracy is better than 3%. The validity of the χ^2 analysis used to derive the best fit parameters and their uncertainties demands a binning in data points. The optimum choice for the number of bins has been obtained in a Monte Carlo simulation and amounts up to 20 bins (Davelaar 1969).

3. Soft X-ray spectral shape

Observations with the *EXOSAT* and *Einstein* observatories have shown that at least two emission components are merging in the soft X-ray spectra of Seyfert 1 galaxies and quasars: a flat non-thermal hard X-ray power law and a steeper soft X-ray component. In several sources, observations with *EXOSAT* located the spectral break between the two components between 0.3 and 1 keV. This is consistent with the absence of soft X-ray excesses in most of the published hard X-ray ($E > 2$ keV) spectra obtained with *Ginga* and it is confirmed by the results of simultaneous *Ginga* and *ROSAT* observations (Pounds et al., *in prep.*; Turner et al., *in prep.*).

There are a lot of spectral models (including power law, black-body, thermal bremsstrahlung and various disk models) which can be compared to the soft X-ray excesses of active galactic nuclei. However, the poor spectral resolution of the PSPC limits strongly the grade of complexity of models to be compared to the *ROSAT* data. Even for low interstellar absorption, a typical spectrum contains no more than four to five independent energy bands ($\Delta E/E = 0.4 E_{keV}^{-0.5}$).

Therefore, we start with the simplest parametrization, the absorbed power law (pl) model $F_\nu \sim e^{-\sigma N_H} \nu^{1-\Gamma}$, requiring only 3 free parameters. This model is compared to the full (f)

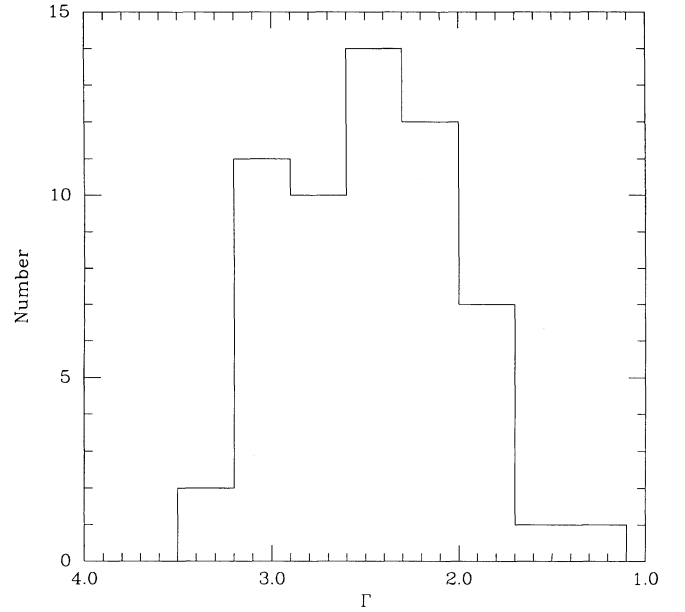


Fig. 2. Distribution of the soft X-ray photon indices

~ 0.08 to ~ 2.4 keV spectra of the sample sources. The best fit photon index Γ , absorbing column density $N_{H(pl,f)}$ and normalization at 2 keV F_{2keV}^{pl} , and their uncertainties (1σ for three free parameters, $\Delta\chi^2 = 3.53$) are given in Table 2 as well as the reduced sum of the square of the residuals $\chi^2_{\nu 1}$.

The distribution of the $\chi^2_{\nu 1}$ meets nicely the theoretical expectation. 62% and 91% of the $\chi^2_{\nu 1}$ values are less than 1.0 and 1.3, respectively. However for Mrk 841 and NGC 3783 the $\chi^2_{\nu 1}$ are 2.3 and 2.6 respectively. The probability to get such large values is less than 1% and 0.4%, respectively, i.e. three to four times less than observed.

A simple power law spectral shape modified by interstellar absorption is, therefore, sufficient to describe all the spectra except those of NGC 3783 and Mrk 841. The residuals obtained in these two cases (Fig. 1) cannot be explained by remaining uncertainties on the response matrix as they correspond to deviations of more than 20% of the observed spectral fluxes. These residuals suggest that an additional low energy component is needed to represent the spectra adequately. This component should merge with the power law below 1 keV. This picture is confirmed by the fact that in both objects the 2 keV flux observed by *ROSAT* and *EXOSAT* (Turner & Pounds 1989; Arnaud

Footnote to Table 1: Quasi-simultaneous observation with ^a*IUE* and/or ^b*Ginga* (Makino, *pers. comm.*) ^cStark et al. (1987) ^dElvis et al. (1989) ^eDickey et al. (1990) ^fVéron et al. (1991) ^g*EXOSAT* archive ^hHalpern (1982) ⁱTurner et al. (1989) ^jTreves et al. (1990) ^kWilliams et al. (1992) ^lWalter et al. (1992) ^mNandra et al. (1991) ⁿBarr et al. (1992) ^o*IRAS* catalogues ^pNeugebauer et al. (1986) ^qEdelson et al. (1987) ^rSanders et al. (1989) ^sThe contribution of the white dwarf K1-16 located at 1.5 arcmin from Q1821+643 has been removed from the spectra of this source following the prescriptions of Ulrich et al. (1992).

Table 1. List of the sample with radio, infrared and ultraviolet fluxes (νF_ν in erg/s cm^2) and hard X-ray power law indices.

Name	Position 1950	z^f	N_{Hgal} 10^{21} cm^{-2}	$\nu F_{2675\text{\AA}}$ 10^{-11}	$\nu F_{1375\text{\AA}}$ 10^{-11}	νF_{5GHz}^f 10^{-14}	$\nu F_{25\mu m}$ 10^{-11}	$\Gamma_{2-10keV}$	Upper channel
1 I ZW 1	0051+1225	0.061	0.507 ^d	5.85 ± 0.26	4.41 ± 2.06	0.015	13.2 ^r		100
2 Mkn 352	0057+3133	0.015	0.555 ^c	3.28 ± 0.63	4.00 ± 1.03			1.70 ± 0.20^g	120
3 Fairall 9 ^{ab}	0122-5904	0.045	0.284 ^c	7.56 ± 0.88	10.7 ± 2.1		7.1 ^p	1.84 ± 0.05^b	80
4 Mkn 359	0125+1855	0.017	0.481 ^c	2.08 ± 0.24	2.76 ± 0.54		5.7 ^o		120
5 3C 48.0	0134+3254	0.367	0.435 ^d		0.92 ± 0.44	26.9	1.9 ^o		
6 Mkn 1018	0203-0031	0.043	0.255 ^e	1.74 ± 0.43	1.83 ± 1.39				
7 Mkn 590 ^a	0212-0100	0.027	0.307 ^d	6.23 ± 0.44	8.36 ± 1.08	0.020	2.7 ^o		80
8 NGC 985	0232-0900	0.043	0.283 ^e	4.41 ± 0.37	5.79 ± 1.40	0.015	6.6 ^o		80
9 NGC 1566	0419-5503	0.004	0.155 ^e	1.81 ± 0.36	0.72 ± 0.39	0.38	10.6 ^o	1.50 ± 0.20^h	
10 Akn 120	0513-0012	0.033	1.130 ^e	20.5 ± 0.5	22.3 ± 3.3	0.015	4.9 ^o	$2.10^{+0.20i}_{-0.30}$	100
11 MCG 8-11-11	0551-0012	0.020	2.238 ^e	7.36 ± 0.62	1.98 ± 2.46	0.415	23.8 ^o	1.70 ± 0.15^j	
12 VII ZW 118	0702+6441	0.079	0.481 ^c	6.66 ± 1.44	5.83 ± 3.66				80
13 Mkn 79	0739+4956	0.022	0.589 ^d	4.26 ± 0.47	5.56 ± 1.19	0.020	9.1 ^o		80
14 Mkn 10	0743+6103	0.030	0.474 ^c	2.73 ± 0.32	2.42 ± 1.41		2.6 ^o		
15 PG 0804+761	0804+7611	0.100	0.312 ^d	6.11 ± 1.29	8.43 ± 2.13	0.010	2.5 ^r	2.00 ± 0.20^k	80
16 Mkn 704	0916+1631	0.029	0.315 ^d	2.74 ± 0.46	1.79 ± 0.46		6.4 ^o		100
17 Mkn 110	0922+5230	0.036	0.157 ^c	2.57 ± 0.49	2.62 ± 1.24	0.010			80
18 Mkn 705	0923+1257	0.028	0.403 ^d		3.35 ± 1.39	0.050	3.6 ^o		80
19 PG 0953+415	0954+4130	0.239	0.118 ^c		6.23 ± 1.38	0.010	1.3 ^p		80
20 Mkn 142	1022+5155	0.045	0.118 ^e		1.70 ± 0.92	0.002			80
21 PG 1116+215	1116+2136	0.177	0.144 ^d	12.3 ± 2.1	10.5 ± 1.1	0.015			80
22 NGC 3783	1136-3727	0.009	0.923 ^c	16.7 ± 0.5	20.2 ± 4.1	0.080	29.2 ^o	1.55 ± 0.15^i	
23 3C 263.0	1137+6604	0.652	0.082 ^d		3.07 ± 1.86	5.20	0.6 ^p		80
24 H 1143-182	1143-1811	0.033	0.348 ^c	5.33 ± 0.42	6.39 ± 2.62		1.4 ^o		80
25 NGC 4051 ^{ab}	1201+4448	0.002	0.131 ^d	3.05 ± 1.80	1.66 ± 0.44	0.225	17.0 ^q	1.65 ± 0.05^b	80
26 PG 1211+143	1211+1420	0.085	0.283 ^d	4.28 ± 0.43	4.86 ± 0.43	0.785	4.3 ^p	$2.10^{+0.20k}_{-0.40}$	80
27 Mkn 766 ^a	1216+3006	0.012	0.176 ^c	1.06 ± 0.30	0.69 ± 1.40	0.075	17.1 ^q		80
28 3C 273 ^{ab}	1226+0220	0.158	0.177 ^c	22.6 ± 1.3	33.1 ± 2.9	217	11.3 ^r	1.50 ± 0.10^b	80
29 TON 1542	1230+2026	0.064	0.258 ^d	3.77 ± 0.33	6.20 ± 1.22	0.005	3.6 ^r		80
30 NGC 4593	1237-0504	0.009	0.197 ^d	5.13 ± 0.27	2.75 ± 0.49	0.010	11.0 ^o	1.90 ± 0.20^l	80
31 IR 1249-1308	1250-1309	0.014	0.361 ^c	2.21 ± 0.30	2.09 ± 0.81				80
32 MCG 6-30-15	1333-3402	0.008	0.406 ^d	0.44 ± 0.50	0.34 ± 0.63	0.005	9.7 ^o	1.70 ± 0.20^i	80
33 IR 1334+2438	1335+2438	0.107	0.112 ^e	1.24 ± 0.16	0.42 ± 0.65	0.035	10.5 ^o		80
34 IC 4329A	1346-3004	0.016	0.455 ^d	0.42 ± 0.16	0.30 ± 0.48	0.120	26.5 ^o	$1.70^{+0.20i}_{-0.10}$	
35 Mkn 279	1352+6933	0.031	0.164 ^d	5.29 ± 0.26	6.58 ± 1.01	0.040	3.5 ^q	$1.85^{+0.25g}_{-0.15}$	80
36 NGC 5548	1416+2522	0.017	0.193 ^e	6.22 ± 0.45	6.49 ± 1.26	0.075	9.2 ^q	1.75 ± 0.15^m	80
37 Mkn 1383	1427+0130	0.086	0.264 ^d	7.46 ± 1.14	11.6 ± 3.9	0.005	2.5 ^o	1.90 ± 0.20^h	80
38 Mkn 478	1440+3539	0.079	0.097 ^c	2.74 ± 0.30	7.47 ± 2.04	0.005	2.2 ^o		80
39 PG 1444+407	1445+4048	0.267	0.131 ^e		2.38 ± 0.69	0.001	1.3 ^r		80
40 PG 1448+273	1449+2722	0.065	0.271 ^e		5.36 ± 6.91		1.4 ^r		80
41 Mkn 841 ^b	1502+1038	0.036	0.223 ^d	5.22 ± 0.37	7.09 ± 1.26	0.030	5.4 ^q	1.80 ± 0.10^b	80
42 Mkn 290	1535+5804	0.029	0.232 ^d	3.77 ± 0.20	4.98 ± 1.13		2.2 ^o	$1.60^{+0.20i}_{-0.30}$	
43 E 1615+061	1615+0611	0.038	0.463 ^e	1.26 ± 0.35	1.54 ± 0.35				80
44 Mkn 506	1721+3055	0.043	0.316 ^c	2.04 ± 0.25	3.21 ± 0.83				80
45 Q 1721+343B	1722+3421	0.206	0.306 ^d	4.92 ± 0.39	4.22 ± 0.82	5.45			80
46 KAZ 163	1747+6838	0.063	0.424 ^e	1.01 ± 0.23	0.57 ± 1.11				80
47 KAZ 102 ^{ab}	1803+6738	0.136	0.500 ^d		2.64 ± 0.49			$2.20^{+0.20b}_{-0.30}$	80
48 Q 1821+643 ^{abs}	1822+6420	0.297	0.410 ^c		5.31 ± 0.46		4.7 ^o	1.80 ± 0.10^b	80
49 3C 382.0	1833+3239	0.059	0.785 ^c	4.31 ± 0.22	6.21 ± 0.72	11.1	1.3 ^p	$1.70^{+0.20n}_{-0.30}$	100
50 3C 390.3	1846+7943	0.057	0.408 ^c	0.74 ± 0.17	0.66 ± 0.29	22.4	3.5 ^o	1.65 ± 0.15^g	100
51 ESO 141-G55	1917-5846	0.037	0.495 ^e	16.3 ± 0.8	26.8 ± 4.6		4.2 ^o		100
52 4C 73.18	1929+7352	0.302	0.824 ^c		2.21 ± 1.04	16.7		2.10 ± 0.20^g	100
53 Mkn 509 ^b	2041-1054	0.035	0.399 ^e	11.4 ± 1.4	21.8 ± 4.7	0.020	8.9 ^o	1.70 ± 0.10^b	80
54 II ZW 136	2130+0956	0.063	0.420 ^d	5.55 ± 0.41	6.48 ± 1.66	0.010	4.6 ^r	$2.40^{+0.20k}_{-0.30}$	80
55 NGC 7213	2206-4725	0.006	0.194 ^e	2.72 ± 0.40	2.39 ± 0.54	11.4	8.9 ^o	1.80 ± 0.20^{hi}	80
56 Akn 564	2240+2928	0.025	0.634 ^c	3.82 ± 0.39	2.62 ± 0.50		6.8 ^o		80
57 NGC 7469	2301+0836	0.017	0.482 ^d	12.4 ± 0.63	13.4 ± 2.1	0.350	65.9 ^q	1.80 ± 0.10^i	80
58 Mkn 926	2302-0857	0.047	0.366 ^c	6.39 ± 0.61	7.50 ± 1.29	0.045			80

Table 2. List of best fit parameters (νF_ν in $10^{-11} \text{ erg/s cm}^2$, N_H in 10^{21} cm^{-2}).

	Γ	$N_{H(pl,f)}$	νF_{2keV}^{pl}	$\chi^2_{\nu 1}$	$N_{H(pl,l)}$	$N_{H(tb,l)}$	νF_{2keV}^{pl+tb}	$Soft_{Excess}$	$\chi^2_{\nu 2}$	$\Gamma_{N_{Hgal}}$	$\chi^2_{\nu 3}$
1	3.18 ± 0.35	0.75 ± 0.21	0.25 ± 0.09	1.04	0.59 ± 0.37	0.47 ± 0.20	$0.13^{+0.20}_{-0.01}$	$10.7^{+8.1}_{-10.1}$	0.93	2.56 ± 0.14	1.35
2	2.10 ± 0.49	0.42 ± 0.22	0.42 ± 0.16	0.35	0.37 ± 0.34	0.31 ± 0.17	0.48 ± 0.01	$2.2^{+1.2}_{-0.5}$	0.55	2.43 ± 0.19	0.49
3	2.21 ± 0.19	0.24 ± 0.07	1.25 ± 0.23	0.62	0.26 ± 0.14	0.21 ± 0.09	1.47 ± 0.02	$1.3^{+0.2}_{-0.2}$	0.70	2.35 ± 0.07	0.64
4	2.99 ± 0.41	0.65 ± 0.24	0.21 ± 0.09	1.13	0.61 ± 0.34	0.45 ± 0.19	0.12 ± 0.01	$7.8^{+6.7}_{-3.6}$	1.00	2.56 ± 0.16	1.23
5	1.97 ± 0.50	0.22 ± 0.16	0.30 ± 0.13	0.76			0.35 ± 0.05	$2.7^{+2.1}_{-1.3}$	0.79	2.67 ± 0.19	1.23
6	1.58 ± 0.47	0.10 ± 0.16	0.24 ± 0.15	0.79			0.22 ± 0.05	$0.7^{+0.9}_{-0.7}$	0.65	2.15 ± 0.21	1.06
7	2.01 ± 0.24	0.20 ± 0.07	1.33 ± 0.28	0.75	0.23 ± 0.14	0.18 ± 0.10	1.51 ± 0.22	$1.4^{+1.5}_{-0.9}$	0.67	2.40 ± 0.08	0.99
8	2.68 ± 0.40	0.31 ± 0.16	0.31 ± 0.14	1.18	0.68 ± 0.52	0.43 ± 0.31	0.48 ± 0.06	$2.5^{+2.3}_{-1.4}$	0.85	2.57 ± 0.13	1.07
9	1.79 ± 0.41	0.07 ± 0.11	0.18 ± 0.10	0.35			0.22 ± 0.03	$1.7^{+1.0}_{-0.7}$	0.23	2.19 ± 0.19	0.55
10	2.63 ± 0.29	1.00 ± 0.22	1.47 ± 0.30	0.58	1.12 ± 0.49	0.87 ± 0.17	1.56 ± 0.06	$0.8^{+0.9}_{-0.4}$	0.57	2.47 ± 0.12	0.63
11	1.37 ± 0.41	1.00 ± 0.90	2.56 ± 1.29	0.73			2.55 ± 0.11	$0.5^{+0.8}_{-0.2}$	0.74	2.12 ± 0.25	0.88
12	2.83 ± 0.37	0.46 ± 0.19	0.26 ± 0.11	0.41	0.27 ± 0.35	0.24 ± 0.35	0.34 ± 0.02	$5.0^{+3.9}_{-2.4}$	0.63	2.88 ± 0.14	0.36
13	2.90 ± 0.24	0.93 ± 0.17	1.08 ± 0.23	0.92	0.86 ± 0.52	0.63 ± 0.77	1.05 ± 0.03	$2.0^{+2.2}_{-1.3}$	1.83	2.18 ± 0.10	2.98
14	3.07 ± 0.45	0.61 ± 0.25	0.15 ± 0.08	0.88			0.19 ± 0.01	$4.6^{+3.6}_{-2.2}$	0.80	2.69 ± 0.16	0.91
15	2.53 ± 0.29	0.37 ± 0.13	0.48 ± 0.15	1.17	0.28 ± 0.24	0.25 ± 0.22	0.50 ± 0.05	$1.1^{+0.9}_{-0.6}$	1.12	2.33 ± 0.10	1.15
16	2.57 ± 0.40	0.35 ± 0.18	0.25 ± 0.11	1.21	0.38 ± 0.32	0.28 ± 0.18	0.30 ± 0.06	$2.4^{+2.4}_{-1.8}$	1.09	2.45 ± 0.13	1.10
17	2.17 ± 0.27	0.13 ± 0.06	0.49 ± 0.13	0.25	0.15 ± 0.10	0.12 ± 0.07	0.60 ± 0.07	$1.2^{+1.5}_{-0.8}$	0.24	2.29 ± 0.08	0.27
18	2.60 ± 0.28	0.39 ± 0.13	0.40 ± 0.12	1.24	0.25 ± 0.23	0.20 ± 0.25	0.46 ± 0.02	$3.6^{+3.5}_{-2.0}$	1.51	2.65 ± 0.11	1.17
19	2.93 ± 0.33	0.17 ± 0.08	0.09 ± 0.04	1.48	0.27 ± 0.18	0.24 ± 0.16	0.16 ± 0.02	$3.5^{+3.2}_{-1.8}$	1.54	2.65 ± 0.12	1.55
20	3.12 ± 0.23	0.16 ± 0.05	0.11 ± 0.03	1.10	0.13 ± 0.06	0.09 ± 0.05	0.09 ± 0.01	$14.7^{+12.3}_{-6.9}$	0.87	2.89 ± 0.09	1.23
21	2.66 ± 0.40	0.14 ± 0.09	0.13 ± 0.06	0.94	0.19 ± 0.16	0.14 ± 0.12	0.21 ± 0.03	$3.2^{+2.8}_{-1.6}$	0.75	2.71 ± 0.15	0.84
22	3.16 ± 0.63	1.22 ± 0.57	0.56 ± 0.25	2.56			0.95 ± 0.06	$3.1^{+1.3}_{-0.6}$	2.16	2.67 ± 0.22	2.44
23	2.66 ± 0.51	0.15 ± 0.12	0.05 ± 0.03	0.66	0.15 ± 0.33	0.13 ± 0.30	0.08 ± 0.01	$1.9^{+2.1}_{-1.2}$	0.76	2.32 ± 0.16	0.77
24	2.59 ± 0.20	0.34 ± 0.09	1.04 ± 0.23	0.93	0.34 ± 0.19	0.27 ± 0.12	1.32 ± 0.09	$3.1^{+3.0}_{-1.7}$	1.04	2.63 ± 0.07	0.88
25	2.88 ± 0.18	0.19 ± 0.05	0.40 ± 0.10	0.67	0.17 ± 0.07	0.13 ± 0.05	0.54 ± 0.03	$5.8^{+0.8}_{-0.5}$	0.52	2.58 ± 0.07	0.94
26	3.12 ± 0.26	0.30 ± 0.10	0.21 ± 0.07	1.19	0.44 ± 0.23	0.34 ± 0.17	0.37 ± 0.05	$3.4^{+4.2}_{-1.2}$	0.90	3.03 ± 0.09	1.13
27	2.75 ± 0.13	0.33 ± 0.05	1.33 ± 0.20	0.74	0.36 ± 0.11	0.28 ± 0.07	1.13 ± 0.23	$2.7^{+2.7}_{-2.0}$	1.51	2.16 ± 0.04	2.71
28	2.16 ± 0.13	0.15 ± 0.03	2.56 ± 0.33	1.12	0.17 ± 0.05	0.13 ± 0.04	3.35 ± 0.08	$2.8^{+0.8}_{-0.6}$	1.13	2.29 ± 0.04	1.16
29	3.43 ± 0.47	0.37 ± 0.19	0.06 ± 0.04	1.31	0.63 ± 0.51	0.38 ± 0.32	0.13 ± 0.01	$4.3^{+2.2}_{-1.5}$	1.42	2.97 ± 0.15	1.40
30	2.49 ± 0.42	0.20 ± 0.13	0.90 ± 0.41	1.07	0.06 ± 0.11	0.06 ± 0.12	0.83 ± 0.04	$2.7^{+1.7}_{-1.2}$	1.02	2.48 ± 0.13	0.93
31	2.50 ± 0.43	0.36 ± 0.19	0.35 ± 0.16	1.12	0.70 ± 0.89	0.38 ± 0.48	0.49 ± 0.06	$2.0^{+1.8}_{-1.1}$	0.74	2.51 ± 0.15	0.90
32	2.33 ± 0.23	0.55 ± 0.12	1.81 ± 0.38	1.07	0.83 ± 0.41	0.65 ± 0.23	1.87 ± 0.03	$0.9^{+0.9}_{-0.6}$	1.34	1.93 ± 0.09	1.35
33	3.20 ± 0.25	0.16 ± 0.06	0.13 ± 0.05	0.86	0.14 ± 0.07	0.10 ± 0.05	0.25 ± 0.03	$6.6^{+5.3}_{-3.1}$	0.76	2.92 ± 0.10	0.99
34	1.71 ± 0.87	3.75 ± 2.47	7.43 ± 1.27	1.20			2.09 ± 0.58		20.2	1.00 ± 0.12	8.25
35	2.15 ± 0.17	0.18 ± 0.05	0.96 ± 0.16	1.27	0.15 ± 0.07	0.13 ± 0.05	1.00 ± 0.05	$0.6^{+1.0}_{-0.6}$	1.23	2.07 ± 0.05	1.24
36	2.21 ± 0.15	0.17 ± 0.04	1.55 ± 0.23	1.00	0.21 ± 0.08	0.17 ± 0.06	1.96 ± 0.11	$1.5^{+0.8}_{-0.6}$	0.68	2.32 ± 0.05	1.03
37	2.33 ± 0.35	0.21 ± 0.11	0.36 ± 0.13	1.04	0.17 ± 0.17	0.14 ± 0.10	0.42 ± 0.03	$1.8^{+1.2}_{-0.8}$	1.05	2.53 ± 0.12	1.02
38	3.18 ± 0.13	0.12 ± 0.03	0.24 ± 0.05	0.71	0.12 ± 0.03	0.08 ± 0.02	0.41 ± 0.04	$8.9^{+7.2}_{-4.2}$	0.74	3.02 ± 0.06	0.85
39	3.41 ± 0.53	0.22 ± 0.15	0.02 ± 0.01	0.97	0.27 ± 0.29	0.29 ± 0.34	0.05 ± 0.01	$6.7^{+4.9}_{-3.0}$	1.14	2.93 ± 0.19	1.20
40	3.17 ± 0.32	0.44 ± 0.16	0.14 ± 0.05	1.00	0.40 ± 0.36	0.32 ± 0.24	0.07 ± 0.01	$13.6^{+12.0}_{-6.4}$	0.81	2.60 ± 0.11	1.48
41	2.65 ± 0.45	0.25 ± 0.16	0.16 ± 0.09	2.28	0.47 ± 0.96	0.35 ± 0.63	0.28 ± 0.01	$2.0^{+0.5}_{-0.4}$	1.84	2.52 ± 0.15	1.98
42	2.17 ± 0.51	0.17 ± 0.14	0.33 ± 0.16	0.62			0.44 ± 0.03	$2.7^{+2.6}_{-1.1}$	0.94	2.44 ± 0.17	0.66
43	2.16 ± 0.40	0.33 ± 0.16	0.36 ± 0.13	0.51	0.42 ± 0.51	0.33 ± 0.30	0.44 ± 0.03	$2.3^{+1.2}_{-0.9}$	0.57	2.57 ± 0.15	0.69
44	2.46 ± 0.20	0.34 ± 0.09	0.57 ± 0.12	0.57	0.34 ± 0.21	0.28 ± 0.13	0.68 ± 0.05	$1.8^{+2.0}_{-1.2}$	0.50	2.37 ± 0.07	0.56
45	2.27 ± 0.25	0.29 ± 0.10	0.41 ± 0.10	0.42	0.19 ± 0.17	0.17 ± 0.22	0.45 ± 0.01	$1.6^{+1.9}_{-1.2}$	0.47	2.33 ± 0.08	0.40
46	2.60 ± 0.19	0.40 ± 0.09	0.08 ± 0.02	1.49	0.57 ± 0.29	0.41 ± 0.16	0.10 ± 0.01	$3.1^{+2.7}_{-1.6}$	1.76	2.66 ± 0.07	1.37
47	2.21 ± 0.11	0.38 ± 0.05	0.17 ± 0.02	0.71	0.24 ± 0.10	0.22 ± 0.19	0.17 ± 0.02	$0.7^{+0.9}_{-0.4}$	0.68	2.54 ± 0.05	1.21
48	1.87 ± 0.11	0.22 ± 0.03	0.76 ± 0.06	0.75	0.17 ± 0.08	0.15 ± 0.10	0.84 ± 0.03	$1.6^{+0.4}_{-0.3}$	1.51	2.43 ± 0.03	6.08
49	2.39 ± 0.24	0.86 ± 0.17	1.36 ± 0.23	0.87	0.76 ± 0.32	0.65 ± 0.27	1.40 ± 0.02	$1.5^{+1.4}_{-0.6}$	0.84	2.28 ± 0.11	0.86
50	1.87 ± 0.45	0.63 ± 0.23	0.44 ± 0.12	0.73	0.82 ± 0.62	0.67 ± 0.29	0.45 ± 0.06	≤ 0.2	1.45	1.44 ± 0.15	0.97
51	2.39 ± 0.38	0.58 ± 0.21	1.39 ± 0.46	1.14	0.43 ± 0.36	0.40 ± 0.38	1.19 ± 0.08	$1.5^{+1.9}_{-1.1}$	1.10	2.18 ± 0.15	1.12
52	2.04 ± 0.69	0.71 ± 0.41	0.21 ± 0.08	0.49	0.64 ± 1.11	0.53 ± 0.94	0.21 ± 0.02	$0.2^{+0.2}_{-0.2}$	0.47	2.19 ± 0.27	0.45
53	2.34 ± 0.16	0.38 ± 0.07	1.89 ± 0.30	1.17	0.47 ± 0.22	0.37 ± 0.13	2.34 ± 0.06	$2.2^{+0.6}_{-0.5}$	0.98	2.39 ± 0.06	1.13
54	2.41 ± 0.29	0.26 ± 0.11	0.44 ± 0.13	0.85	0.17 ± 0.16	0.15 ± 0.16	0.47 ± 0.09	$1.2^{+1.1}_{-0.5}$	0.89	2.95 ± 0.11	1.30
55	1.90 ± 0.19	0.15 ± 0.05	2.01 ± 0.32	0.57	0.15 ± 0.08	0.13 ± 0.05	2.19 ± 0.16	$0.5^{+0.7}_{-0.4}$	0.63	2.06 ± 0.06	0.65
56	2.97 ± 0.12	0.61 ± 0.07	1.69 ± 0.22	0.52	0.55 ± 0.18	0.44 ± 0.10	2.36 ± 0.10	$6.2^{+4.5}_{-2.8}$	1.26	3.07 ± 0.05	0.53
57	2.52 ± 0.24	0.54 ± 0.13	0.80 ± 0.19	0.88	0.39 ± 0.31	0.35 ± 0.48	0.83 ± 0.01	$2.0^{+0.6}_{-0.5}$	0.83	2.36 ± 0.10	0.89
58	2.00 ± 0.31	0.37 ± 0.13	1.12 ± 0.29	0.64	0.29 ± 0.33	0.27 ± 0.74	1.17 ± 0.11	$0.5^{+1.1}_{-0.5}$	0.63	2.01 ± 0.11	0.60

et al.1985) are of the same order, whereas the spectral slopes are significantly different.

Except for these two cases, the total number of counts collected is too low to allow a detection of a break point in the PSPC spectra. The residuals suggest, however, such a break in several other sources, even if the statistic is not good enough to allow a firm detection (see for example Fig. 1c).

The distribution of the power law indices obtained in our sample is displayed in Fig. 2. It is consistent with a constant frequency between indices of 2.0 and 3.2. The mean of the distribution is $\langle\Gamma\rangle = 2.50$. Its standard deviation $\sigma_\Gamma = 0.48$ is significantly larger than the mean of the statistical uncertainties on the individual indices (0.33). The assumption that the spectral index is constant in all 58 spectra gives a χ^2 of 196.7 for 57 degrees of freedom and it is rejected with a confidence level larger than 99.999%.

The hard X-ray spectral indices $\Gamma_{2-10\text{keV}}$ are available for a subsample of 27 sources. They are listed in Table 1. Their mean value $\langle\Gamma_{2-10\text{keV}}\rangle = 1.81$ is slightly larger than the mean of 1.70 found with *EXOSAT* (Turner & Pounds 1989) for Seyfert 1's, with a comparable standard deviation of $\sigma_{\Gamma_{2-10\text{keV}}} = 0.21$. For the non-simultaneous observations the uncertainties given in Table 1 represent the typical variations or uncertainties observed for these sources in the past. The mean of the differences between the soft and hard X-ray slopes is $\langle\Gamma - \Gamma_{2-10\text{keV}}\rangle = 0.46$.

In 17 out of these 27 sources, the difference between the soft and hard X-ray slopes is larger than the statistical uncertainty. If we interpret a statistically significant difference between the hard X-ray slope and the soft X-ray power law index as an indication for the existence of a soft X-ray flux excess, then such an excess is detected in at least 60% of the sources of this subsample.

The standard deviation of the distribution $\Gamma - \Gamma_{2-10\text{keV}}$ is 0.42. It is similar to σ_Γ indicating that the variety of the soft X-ray spectral slope is not reflecting the variety of the slopes measured at hard X-rays. This is confirmed by the fact that $\sigma_{\Gamma_{2-10\text{keV}}}$ is smaller than σ_Γ and, in addition, by a lack of correlation ($r = 0.22$) between Γ and $\Gamma_{2-10\text{keV}}$. The probability to obtain such a correlation by chance for independent slopes is 58%. This suggests that the variation of the soft X-ray index indicates a variable amplitude of the soft X-ray flux excess in the selected objects. This question will be further addressed in Sect. 5.

4. Absorbing column density

In this section we describe the determination of the absorbing column density of cold matter along the line of sight towards the selected AGN. As mentioned in the previous section we must reckon with the fact that a large fraction of the Seyfert 1 galaxies in our sample shows soft X-ray spectra with different slopes at the soft and at the hard end of the telescope's energy band, respectively. Therefore, we evaluated the column densities using only the low energy part of each spectrum.

Five sources (3C 48.0, Mkn 1018, NGC 1566, Mkn 10, Mkn 290) had to be excluded from this study, because the total

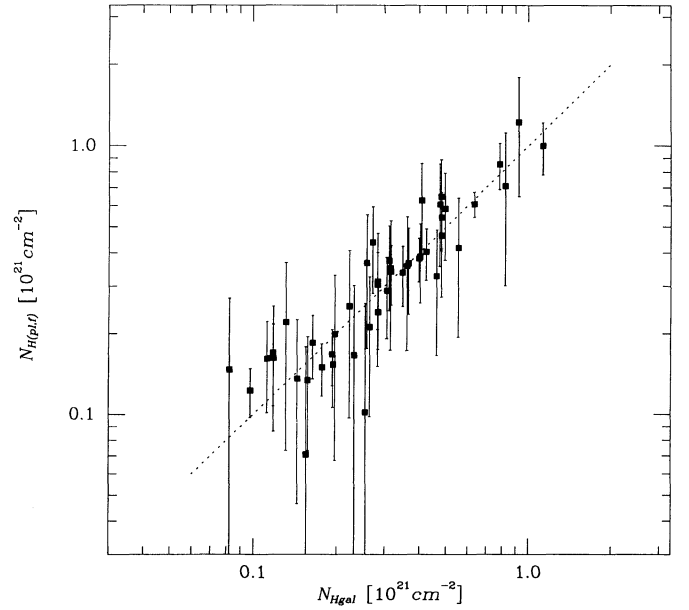


Fig. 3. The fitted absorbing column densities $N_{H(pl,f)}$ compared to the galactic values N_{Hgal} for sources discussed in Sect. 4.1. The dotted line indicates the one to one correlation

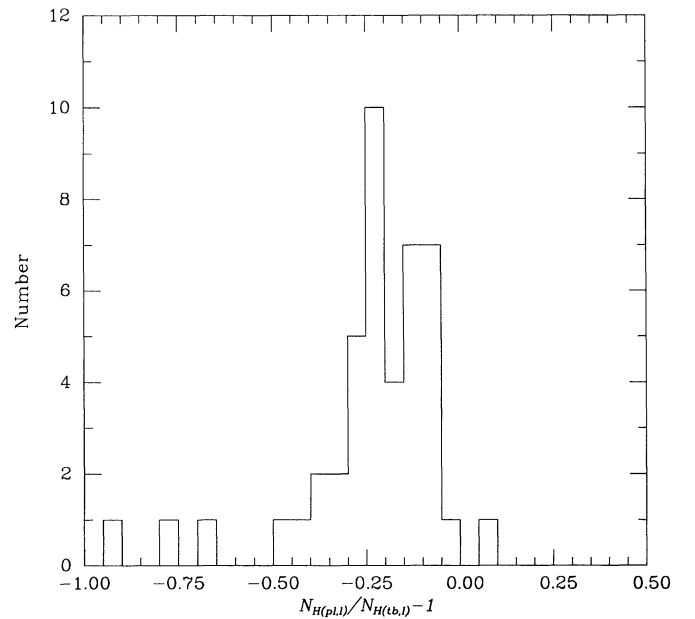


Fig. 4. Distribution of the relative variations of the fitted column density when the power law (pl) continuum is replaced by thermal bremsstrahlung (tb)

number of extracted net source counts is too small to allow to split their spectra into two parts. Furthermore three other sources (IC 4329A, NGC 3783 and MCG-8-11-11) had to be treated separately, because their spectra are completely absorbed below 0.5 keV. For NGC 3783 the best fit absorbing column density $N_{H(pl,f)}$ agrees well with the galactic value (Table 2). IC 4329A and MCG-8-11-11 are peculiar in that their fitted

column densities are significantly different from the Galactic values. They will be discussed separately in Sects. 4.2 and 4.3.

We define the upper boundary of the low energy part of the spectrum by the channel 80 ($E \lesssim 0.8 \text{ keV}$) which yields enough counts to establish a reliable spectrum for most sample members. This boundary has to be shifted slightly to higher channels for some more heavily absorbed or fainter sources to ensure statistical quality. The dividing channel number is given in the last column of Table 1. Table 2 gives the equivalent hydrogen column densities $N_{H(pl,l)}$ derived for power law fits to the low energy parts of the spectra. Table 3 summarizes the means and widths of the distributions of the differences between the fitted N_H and the Galactic value for the different subsamples, for the spectral range for which the fit was performed, and for different spectral shapes.

For the 50 sources studied here, the mean of the difference between the fitted N_H value and the Galactic value, based on 21 cm measurements, is $\Delta N_{H(pl,l)} = \langle N_{H(pl,l)} - N_{Hgal} \rangle = -(0.10 \pm 0.16) 10^{20} \text{ cm}^{-2}$, whereas the width of the $\Delta N_{H(pl,l)}$ distribution is $\sigma_{\Delta N_{H(pl,l)}} = 1.7 10^{20} \text{ cm}^{-2}$ (cf. Table 3). This indicates that the absorbing column densities resulting from power law fits to the low energy data are not systematically larger or smaller than the Galactic values.

Applying the fit to the full energy range of the X-ray spectra results in $N_{H(pl,f)}$ values which are significantly lower than the corresponding Galactic values. The mean of the column density difference is $\Delta N_{H(pl,f)} = \langle N_{H(pl,f)} - N_{Hgal} \rangle = -(0.15 \pm 0.10) 10^{20} \text{ cm}^{-2}$ and the width of the distribution is $\sigma_{\Delta N_{H(pl,f)}} = 1.0 10^{20} \text{ cm}^{-2}$ (cf. Table 3). This is consistent with a systematic steepening of the spectra between 2 and 0.1 keV .

Four individual spectra are not well represented by a power law modified by interstellar absorption even when the fit is restricted to the low energy part of the spectra. For Mrk 766 the fitted absorbing column density is significantly larger than the Galactic one and for Kaz 102, Q1821+643 and II Zw 136 it is the opposite. For the 46 remaining sources, the fitted column densities $N_{H(pl,l)}$ are compatible with the Galactic values.

Our sample can, therefore, be divided in three parts : the fitted column density is larger, approximately equal, or smaller than the Galactic one. The spectra of these subsamples are discussed in the following subsections.

4.1. Measured N_H consistent with galactic N_H

The low energy absorption in the spectra of 46 sources of our sample is well represented by a column density equal to the Galactic one. In these sources, the mean of the differences between the best fit value and the Galactic value is compatible with zero $\Delta N_{H(pl,l)} = \langle N_{H(pl,l)} - N_{Hgal} \rangle = (0.07 \pm 0.17) 10^{20} \text{ cm}^{-2}$ (3rd line of Table 3). The column densities derived from the fit to the low energy part (l) of the spectra and to the full (f) spectra are equivalent without any significant shift (4th line of Table 3). The measured column densities $N_{H(pl,f)}$ are very well correlated to the Galactic values (Fig. 3) with $r = 0.90$.

We conclude that, if the soft X-ray spectra do not steepen towards the very low energies, the contribution of absorbing cold

matter along the line of sight intrinsic to the Seyfert galaxies has to be less than 10^{20} cm^{-2} . This agrees with the fact that there is only a small number of Seyfert 1 galaxies seen edge-on (Keel 1980) and that photoionized gas is found in a radius of several kpc in some nearby Seyfert galaxies (e.g. Ulrich & Pequignot 1980). We cannot exclude, however, that a fraction of Seyferts are heavily absorbed ($N_H > 10^{21} \text{ cm}^{-2}$) and, therefore, show properties different from those of the member galaxies of our sample.

On the other hand, the soft X-ray spectra cannot flatten too much below 0.3 keV . This can invalidate peculiar models. For example, we have tried to fit an absorbed thermal bremsstrahlung (tb) model to the low energy (l) part of each spectrum. The column densities $N_{H(tb,l)}$ and their uncertainties for three free parameters are listed in Table 2.

The center of the distribution of the relative variation of the fitted column density when the power law continuum is replaced by a thermal bremsstrahlung, $N_{H(tb,l)}/N_{H(pl,l)} - 1$, (Fig. 4) shows a systematic decrease of $(23 \pm 5)\%$ of the column density. As the column densities are less than 10^{21} cm^{-1} , the width of this distribution (9%) corresponds to the statistical uncertainty $\sigma_{\Delta N_H}$ (see Table 3).

The column densities determined for a thermal bremsstrahlung model are also systematically smaller than the Galactic values, on average by $(21 \pm 6)\%$ (see also the 5th line of Table 3). As such large systematic uncertainties in the radio measurements (Lockmann et al. 1986) or in the local Helium abundance are not expected, we conclude that the whole data set is not consistent with spectral flattening at low energies inherent to thermal models like bremsstrahlung, even if such models may give good results on individual sources. This indicates that the soft X-ray spectral component is usually wider than a thermal bremsstrahlung peaking at 100 eV and, therefore, also wider than a single black body component.

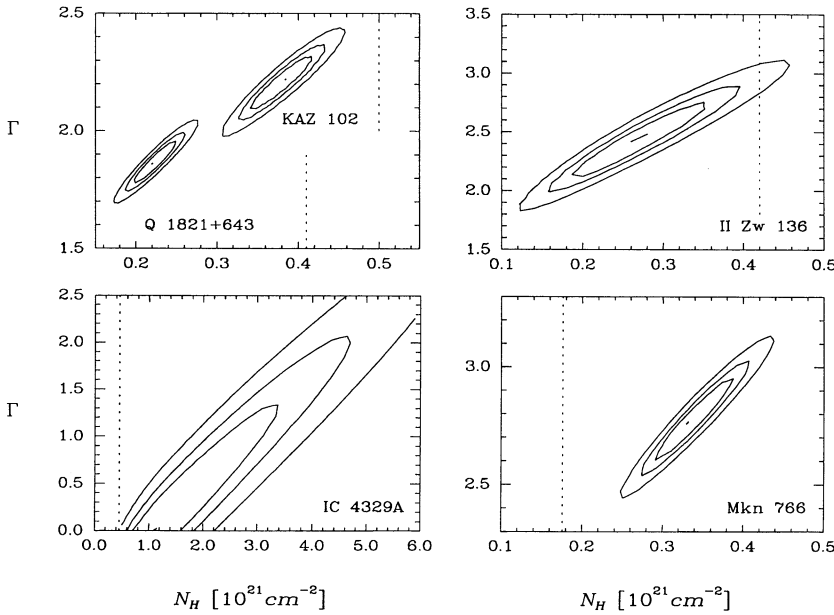
The fact that there is no significant shift between the fitted and Galactic column densities in any of these individual sources and also not in the sample contrasts with the conclusions of Kruper et al. (1990) and Wilkes & Elvis (1987) that a lack of absorption is systematically found in the *Einstein* IPC spectra of Seyfert 1 and quasars. This discrepancy comes probably from the fact that the slope measured with the *Einstein* IPC is slightly affected by the soft X-ray excess. This is supported by the fact that the spectra observed with the *ROSAT* PSPC are systematically steeper than those measured with the *Einstein* IPC.

4.2. $N_{H(pl,l)} < N_{Hgal}$

In four sources (MCG-8-11-11, Kaz 102, Q1821+643 and II Zw 136), the fitted column densities are smaller than the Galactic ones. The case of MCG-8-11-11 is a peculiar one as the Galactic column density is large in this object. The discrepancy between the fitted N_H and the Galactic value indicates that the spectra of MCG-8-11-11 steepens below 0.8 keV . Figure 5 illustrates the discrepancies in the three other sources. Wilkes & Elvis (1987) suggested an additional “ultrasoft” spectral component which should cause this discrepancy in the N_H values.

Table 3. Mean and standard deviation of the differences between couples of hydrogen absorbing column densities derived from the spectral fits or from radio measurements (*pl* = Power law, *tb* = Thermal bremsstrahlung, *f* = Full spectra, *l* = Low energy half).

Selection	Nb of sources	ΔN_H	$\langle \Delta N_H \rangle$ 10^{20} cm^{-2}	$\sigma_{\Delta N_H}$ 10^{20} cm^{-2}
All	50	$N_{H(pl,f)} - N_{Hgal}$	-0.15 ± 0.10	1.0
All	50	$N_{H(pl,l)} - N_{Hgal}$	-0.10 ± 0.16	1.7
$ N_{H(pl,l)} - N_{Hgal} \leq \sigma_{N_{H(pl,l)}}$	46	$N_{H(pl,l)} - N_{Hgal}$	$+0.07 \pm 0.17$	1.6
$ N_{H(pl,l)} - N_{Hgal} \leq \sigma_{N_{H(pl,l)}}$	46	$N_{H(pl,l)} - N_{H(pl,f)}$	-0.07 ± 0.17	1.3
$ N_{H(pl,l)} - N_{Hgal} \leq \sigma_{N_{H(pl,l)}}$	46	$N_{H(tb,l)} - N_{Hgal}$	-0.37 ± 0.12	1.2

**Fig. 5.** χ^2 contour maps in the (Γ, N_H) plane for Kaz 102, Q 1821+643, II Zw 136, IC 4329A and Mkn 766 (contours levels are 68%, 90% and 99%). The dotted lines indicate the corresponding Galactic values

The spectra of the four sources of our sample showing this discrepancy have been measured in the harder X-ray regime with *EXOSAT* and *Ginga* (Makino, *pers. comm.*; Williams et al.1992; Treves et al.1990), KAZ 102 and Q 1821+643 even simultaneously with *ROSAT*.

For all of them, the spectral slopes derived from the PSPC spectra are compatible with those measured with *EXOSAT* and *Ginga* above 2 keV (Table 2). Therefore, we conclude that a fitted N_H , less than the Galactic one, indicates the presence of a peculiarly faint or rather cold soft X-ray component superposed on a uniform power law spectrum ranging from soft X-rays up to higher energies.

4.3. $N_{H(pl,l)} > N_{Hgal}$

For only two objects in our sample (IC 4329A and Mrk 766), the fitted column densities are significantly larger than the Galactic ones assuming a power law shaped continuum. In the case of IC 4329A, the absorber is located in the plane of the associated galaxy, whereas it is probably intrinsic to the active nucleus in Mrk 766.

The best fit column density obtained for IC 4329A is 7 times larger than the Galactic value. The confidence contours in the

(Γ, N_H) plane (Fig. 5) show that the column density of cold matter along the line of sight towards the nucleus is larger than the Galactic value if the photon index is larger than 1. A large column density in this object has also been observed with *Einstein* (Holt et al.1989), *EXOSAT* (Singh et al.1991) and *Ginga* (Piro et al.1989), and a correspondingly large reddening is observed in the optical and ultraviolet (Marziani et al.1992). The optical reddening agrees with the X-ray column density for a gas to dust ratio as in our Galaxy. This extinction is attributed to the edge-on orientation of IC 4329A with its prominent dust lane. IC 4329A has the smallest axes ratio among the galaxies of our sample being one of the rare almost edge-on Seyfert 1 galaxies (Keel 1980).

In Mrk 766 the fitted column density assuming a power law continuum is larger than the Galactic one at a confidence level larger than 99.99% with a best fit value of twice the Galactic value. Molendi et al. (1992) suggested that this large absorbing column density indicates that the unabsorbed soft X-ray continuum is better represented by a black-body emitted by a single temperature hot disk which could explain the soft X-ray variabilities and the very weak ultraviolet continuum observed in this object.

We prefer another explanation based on the comparison of the absorbing column density with the optical reddening using the information yielded by the Balmer decrement, the emission lines and the optical polarization.

The Balmer decrement in Mrk 766 is comparable to that value found for Mrk 359. Both objects are narrow line Seyfert 1 galaxies. The intrinsic reddening of the latter, determined by the ratio of the ultraviolet and optical HeII lines (MacAlpine et al. 1985), is negligible. The ratio of the narrow Balmer lines $H\alpha/H\beta$ is 5.1 ± 0.5 for Mrk 766, 1.6 times larger than the ratio found for Mrk 359 (Veilleux 1991) which equals the ratio predicted by photoionization model of the narrow line region (NLR) (Ferland & Osterbrock 1986). This indicates that at least part of the NLR is absorbed by dust in Mrk 766 and that the corresponding reddening is $E(B-V)=0.4$.

The polarization of the optical continuum of Mrk 766 (2.3% at 5500Å, Goodrich 1989) ranges between the values observed in Seyfert 1 and Seyfert 2 galaxies (Antonucci & Miller 1985). It is at least 5 times larger than that found in Mrk 359 and in typical Seyfert 1's. The enlargement of the polarization in Mrk 766 can be related to an absorption by a factor of 5 of the optical continuum, if the polarized component remains unabsorbed. This also explains, in a natural way, the fact that in this object the polarization increases to the blue (Goodrich 1989). This increase was previously attributed to scattering by dust, but it does not explain the absolute enlargement of the polarization.

In addition, this picture can also naturally explain the weakness of the optical and ultraviolet continua in Mrk 766 in comparison to the soft X-ray flux, and the fact that the [OIII] 5007Å line is less polarized than $H\beta$. This has been interpreted by introducing two distinct polarizers (Goodrich 1989). It can occur in a stratified narrow line region if part of it is not covered by the absorber. This view is supported by the fact that the narrow line ratio $[OIII]/H\beta = 20$ (Veilleux 1991) in Mrk 766 is 2.3 times larger than in Mrk 359, 2.0 times larger than in a typical Seyfert 2, and 2.9 times larger than predicted in photoionisation models of the NLR (Ferland & Osterbrock 1986). This can also explain part of the differences noticed by Veilleux (1991) between the narrow line profile of $H\beta$ and [OIII] in this object.

For a Galactic dust to gas ratio the observed optical reddening corresponds to a column density of $3.5 \cdot 10^{21} \text{cm}^{-2}$ (Netzer 1990) which is ten times larger than the value derived from the *ROSAT* observation. The dust to cold gas ratio in the absorbing matter covering the active nucleus of Mrk 766 is, therefore, 10 times larger than in the interstellar medium. This is comparable to what is observed in molecular clouds (Knacke 1987) and can be compared with the expected properties of the absorbing torus present in Seyfert 2 nuclei (Krolik & Begelman 1988; Krolik & Lepp 1989).

If the increase of the polarization is attributed to the reddening, the absorbing matter must cover only a part of the narrow line region and must not cover the scattering region emitting the polarized light. The absorbing matter is most probably located in molecular clouds located in the inner part of the NLR. This picture is consistent with recent observations of NGC 1068 showing that the scattering region is located at a large distance

from the nucleus (Caganoff et al. 1991) and that the obscuration of the nucleus is probably caused by molecular clouds located in the inner part of the NLR (Genzel et al. 1992). Mrk 766 can therefore be interpreted as an intermediate object between Seyfert 1 and Seyfert 2 in which the absorbing matter is less dense than in NGC 1068.

We consider, therefore, that there is an intrinsic absorber in Mrk 766, and that the unabsorbed soft X-ray continuum is probably wider than a single temperature black-body. In this scenario, there is no basic difference between the unabsorbed optical to X-ray continua emitted by Mrk 766 and by other Seyfert 1 galaxies (see Sect. 5.3 and 5.6).

5. Soft X-ray excesses

The PSPC spectra obtained during the *ROSAT* all sky survey are insensitive to the spectral shape of the soft X-ray component. We tried to fit different models to the spectrum of PG 1211+143 which emits a very strong soft X-ray excess (Bechtold et al. 1987). They are formed with various spectral components added to a power law. Thereby, the power law index is fixed to the value observed with *Ginga* at hard X-rays (Williams et al. 1992) and the absorbing column density is fixed to the Galactic one. All models (thermal bremsstrahlung, black body, broken power law, δ -function) fitted reasonably well the observed excess. To illustrate this, the best reduced chi-square ($\chi^2_\nu = 1.14$) was obtained with the most unlikely δ -function model, centered on the carbon window (0.15 – 0.28 keV) of the detector.

However, as the spectra observed with the PSPC are steeper than those observed at larger energies, it is possible to evaluate the strength of the soft X-ray excesses.

5.1. Measure

A two component model

$$N_\nu = (\text{excess}(\nu) + A \nu^{-\Gamma_{2-10\text{keV}}}) e^{-\sigma N_{H\text{gal}}}$$

folded by the response matrix ϕ of the detector was fitted to the count rate spectra of our sample members. We called *soft X-ray excess* the mean ratio of the count rates of the two unabsorbed components folded by the response ϕ of the PSPC detector, in a window bounded by two channels (ch_p, ch_q) and centered on the carbon window of the detector

$$SE = \frac{1}{q-p} \sum_{p \leq i < q} \frac{\int \text{excess}(\nu) \phi(\nu, ch_i) d\nu}{\int A \nu^{-\Gamma_{2-10\text{keV}}} \phi(\nu, ch_i) d\nu}.$$

The most important parameter in this expression of the soft X-ray excess is the hard X-ray power law index. When available, we fixed it to the value observed simultaneously with *Ginga* or to the mean value observed in the past (Table 1). If no reliable information is available, we fixed it to 1.8. The uncertainties on the soft X-ray excess were evaluated by two supplemental fits for each spectrum for which the power law indices were either fixed to the extreme values observed in the past or to 2.1 and 1.5,

respectively, when no information was available. These extreme values are also listed in Table 1.

This definition of the soft X-ray excess is relatively insensitive to the spectral shape of the excess component and to the exact bounds of the window (ch_p, ch_q) because of the smoothing effect of the response function ϕ . Figures 6a and 6b show the relation between the soft X-ray excesses found for a thermal bremsstrahlung model and for a black body model, and the relation obtained for a thermal bremsstrahlung model but in two differently wide windows. The excesses are always very well correlated.

The effect of the uncertainties of the hard X-ray power law index on the determination of the excesses are always larger than the typical uncertainties associated with the choice of the window or of a (reasonable) spectral model. This ensures that the excesses derived from the data are not affected by large systematic uncertainties linked with the choice of the model or of the spectral window.

Finally, we determined the excesses between 0.1 and 0.4 keV using a thermal bremsstrahlung model for the excess component. The spectral model contains three free parameters: the amplitude of the power law and the amplitude and temperature of the excess component. The mean excess and the normalization of the power law component F_{2keV}^{pl+tb} are listed in Table 2 as well as the reduced $\chi^2_{\nu 2}$. The uncertainties are fixed to the differences between the values found for the extreme and for the mean hard X-ray power law slopes.

The “monochromatic excess” is less than 0.5 above 1 keV, increases sharply near 0.5 keV, and remains flat at smaller energies. A close inspection of these profiles for not too small excesses indicates that the energy of the step is not significantly variable from one object to another, except when simultaneous *Ginga* observations are available. Without discussing these variations in detail we want to note that the soft X-ray excess is peculiarly hot in NGC 4051 and peculiarly cold in Q 1821+643.

For several sources the two components fit is significantly poorer than the single power law fit either because the absorbing column density is fixed to the galactic value (IC 4329A and Mrk 766) or because the hard X-ray power law index is fixed to a non-adequate value when the soft X-ray excess is relatively small (Mrk 79, MCG-6-30-15, Q 1821+643, 3C 390.3). For KAZ 163 and Mrk 705 the poor quality of the fits is related to one bin only. Finally, in Ark 564 the residuals are showing significant unusual trends whose detailed study is out of the scope of this paper. The soft X-ray excess of IC 4329A was not determined as it was not possible to fit this source with an absorbing column density fixed to the galactic value.

The main contributor to the flux detected at 2 keV is the hard X-ray power law. Therefore, the PSPC slope Γ , determined with a simple power law model fitted to the full PSPC spectra as listed in Table 2, is also a measure of the ratio between the flux of the soft X-ray excess component integrated between 200 and 300 eV and the flux of the power law component integrated between 1 and 2.4 keV.

These two measures of the soft X-ray excesses give consistent results. Figure 7 shows the relation between the soft X-ray

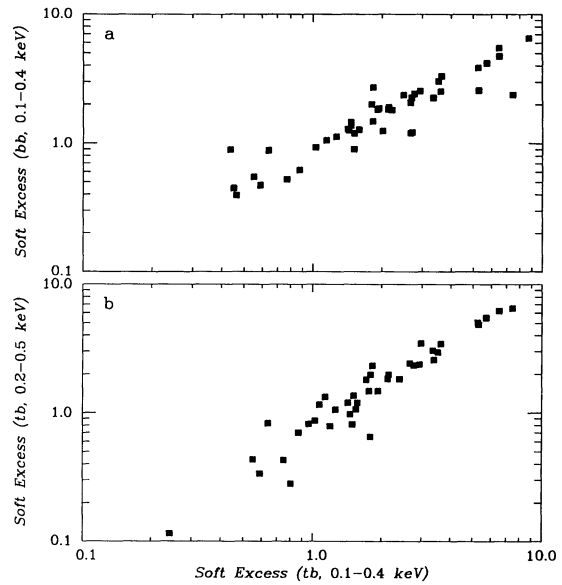


Fig. 6a and b. **a** Relation between the determinations of the soft X-ray excesses assuming thermal bremsstrahlung or black body models for the excess component. **b** Relation between the determinations of the soft X-ray excesses in two different windows assuming a thermal bremsstrahlung model

spectral slope and the logarithm of the excess evaluated from the count rate spectra. Both quantities are well correlated with $r = 0.77$. The probability that this correlation is obtained by chance is less than 0.01%.

We conclude that the extrapolation of the hard X-ray power law has in general only a small effect on the soft X-ray flux, and that Γ is, therefore, a good measure of the strength of the soft X-ray excess in comparison to the 2 keV flux. For $\Gamma < 2$, a significant scatter, however, appears in Fig. 7 resulting from an increasing contribution of the hard X-ray power law at soft X-rays.

Although the normalization at 2 keV of the power law fit to the full spectra is well correlated ($r = 0.98$) to that of the hard X-ray power law in the two components fit, the normalization of the latter is systematically larger by 23% than that one obtained with the single power law model. The width of the distribution of the difference of normalization ($\sigma = 36\%$) gives the uncertainty on the normalization linked with the lack of knowledge of the real spectral shape. A tendency to have larger relative difference between the two normalizations for very large soft X-ray excesses can be clearly noticed in the data. This tendency vanishes when the soft X-ray excess is smaller than 5.

5.2. Statistical properties

The mean of the excesses is 3.0 and the 1σ width of their distribution is 3.0. In 51 sources the excess is larger than 0.2. The assumption that the soft X-ray excess is constant in all the sources is rejected with a confidence larger than 99.999% (χ^2 test) and is rejected with a comparable probability when the best defined ex-

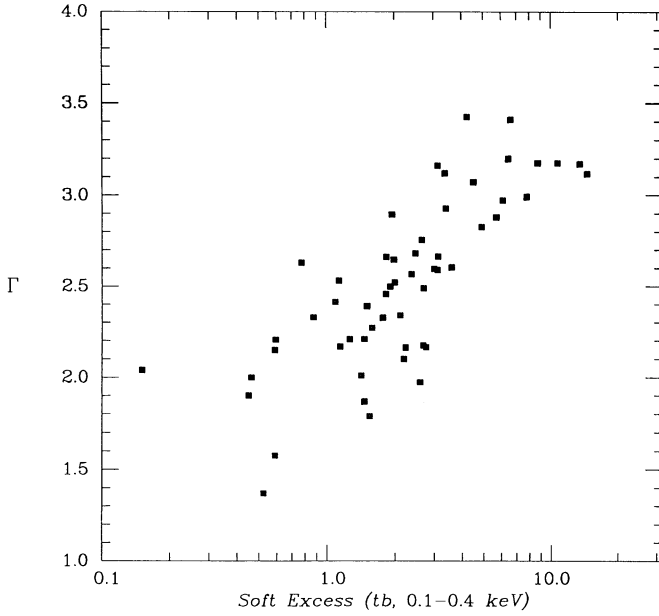


Fig. 7. Relation between the determinations of the soft X-ray excesses assuming a two component spectral model and the mean spectral slope in the PSPC energy band

cesses obtained with simultaneous *ROSAT-Ginga* observations are not taken into account.

The first discovery of a soft X-ray excess was in Mrk 841 observed with *EXOSAT* (Arnaud et al. 1985). Subsequently, soft X-ray excesses were established in about 10 sources (Turner & Pounds 1989). Among their sources the ones which belong to our sample, too, are also showing a strong soft X-ray excess in our data. Furthermore our data confirm soft X-ray excesses suggested by *EXOSAT* observations in Fairall-9, Akn120, NGC 4593, NGC 7213, and NGC 7469. New soft X-ray excesses are finally detected in all the other sources of our sample except in Mrk 1018, Mrk 279, 3C 390.3, 4C 73.18, Mrk 926, and IC 4329A. A soft X-ray excess is, therefore, detected in 90% of the sources.

5.3. Correlation with the ultraviolet

The soft X-ray excesses derived from the PSPC spectra can be compared to spectral components at other wavelengths. In order to study whether the soft X-rays in the *ROSAT* band are connected to the big blue bump component in the spectra of Seyfert 1 galaxies, we investigated the correlation between the soft X-ray excess and the flux in the ultraviolet regime. To label the strength of the bump we use the ratio $\nu F_{1375\text{\AA}}/\nu F_{2\text{keV}}^{pl+tb}$, whereby the flux at 2 keV is thought to be representative for the hard X-ray power law continuum. As the logarithm of this ratio is a measure of the ultraviolet to X-ray mean spectral slope, this ratio can be directly compared to the soft X-ray spectral slope Γ .

Figure 8 shows the spectral index in the PSPC band plotted as a function of the logarithm of the ratio $\nu F_{1375\text{\AA}}/\nu F_{2\text{keV}}^{pl+tb}$. A

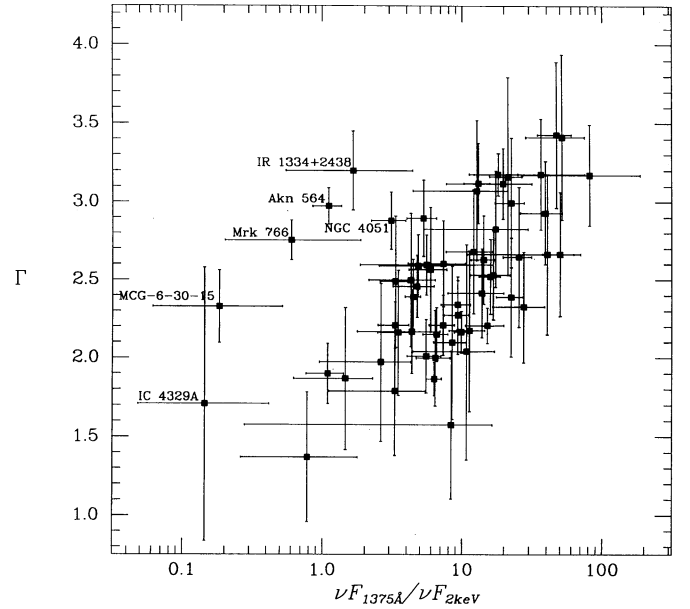


Fig. 8. Relation between the spectral slope Γ measured in the PSPC band and the logarithm of the ratio of the ultraviolet (1375 Å) and the 2 keV flux

significant correlation appears between the soft X-ray spectral slopes and the strengths of the blue bump. The coefficient of correlation, $r = 0.50$, indicates that the probability that this correlation appears by chance is 0.1%. Obviously, the 6 sources located on the left of Fig. 8 are peculiar and they are discussed in the next subsection. If we exclude them, the correlation becomes excellent with $r = 0.72$ for 52 sources indicating that the probability for obtaining it by chance is less than 0.001%.

The best fit linear correlation gives a reduced χ^2 of 1.83. Some significant scatter appears. This scatter is not correlated to the absorbing column density ($r = -0.09$). On the other hand some correlation appears with the redshift z ($r = -0.23$) ($P_{(r>0.23)} < 10\%$) and with the difference ΔN_H between the fitted and Galactic absorbing column densities with $r = 0.47$ ($P_{(r>0.47)} < 0.01\%$). The addition of a linear term in z or in ΔN_H gives improved $\chi^2_\nu = 1.44$ and $\chi^2_\nu = 1.37$, respectively. In both cases, the F-test indicates that the probability that these additional terms are not required is less than 0.1%. The addition of both terms gives a $\chi^2_\nu = 1.19$, and the probability that they are not required is extremely small with $F = 27$. The best multi-dimensional linear fit is

$$\Gamma + (1.2 \pm 0.4)z - (0.10 \pm 0.03) \frac{\Delta N_H}{10^{20} \text{ cm}^{-2}} \\ = (0.68 \pm 0.10) \log \frac{\nu F_{1375\text{\AA}}}{\nu F_{2\text{keV}}} + (1.89 \pm 0.10).$$

The decrease of the spectral slope with the redshift has been discovered by Schartel et al. (1992) in the soft X-ray spectra of quasars observed with *ROSAT*. Its meaning will be discussed in Sect. 6. The dependence on ΔN_H indicates that the real absorbing column density is nearer to the galactic value than

to the best fit value. The results obtained here and in Sect. 4 strengthen, therefore, one another.

5.4. Peculiar sources

Apparently six sources do not match well the correlation found between the soft X-ray excess and the strength of the ultraviolet bump. For IC4329A, Mrk 766, Akn 564, IR1334+2438 and MCG-6-30-15 the large extinction of the optical-ultraviolet continua explains the peculiar location of these sources in Fig. 8. The last one, NGC 4051, is the less luminous Seyfert in our sample and may be a peculiar case.

The absorption of the ultraviolet continua of IC 4329A and Mrk 766 have already been discussed in Sect. 4.3. Akn 564 is, like Mrk 766, a narrow line Seyfert 1 galaxy with a large Balmer decrement of 4.4. Its narrow line $[OIII]/H\beta = 12.5$ (Stirpe 1990) is not unusual suggesting that a large part of the narrow line region is covered by absorbing matter. As the polarization is small or do not exist (Goodrich 1989), a possible scattering region has also to be covered by the same absorber.

Thomson et al. (1987) have noticed a large polarization (9% at 3500Å) in IR 1334+2438 increasing to the blue. They interpreted their observations as evidence for large intrinsic reddening of the nucleus by $E(B - V) = 0.3$ to 0.7 and by an unabsorbed polarized scattered light. This picture is very similar to what we propose for Mrk 766. MCG-6-30-15 is very similar to IR 1334+2438, showing a polarization of 4% increasing to the blue at least in the red (Thomson & Martin 1988) and a narrow line Balmer decrement of 5 (Busko & Steiner 1990).

The reddenings derived from the narrow line Balmer decrement in Mrk 766, Akn 564, IR 1334+2438 and MCG-6-30-15 are consistent with $E(B - V) = 0.4$. The absorption predicted by this reddening at 1375Å is a factor of 30 (Savage & Mathis 1979) corresponding well to the shift of these peculiar sources in comparison to the other Seyferts in Fig. 8. The variety of the narrow emission lines ratios and of the polarization found in these 4 objects indicates that the absorbing matter is not located at the same position in all sources relatively to the NLR and scattering region.

Except for IC 4329A and Mrk 766, the soft X-ray spectra do not show any evidence for intrinsic absorption. The uncertainty on the absorbing column density gives an upper limit of $E(B - V) = 0.02$ for the reddening assuming an interstellar dust to gas ratio. The dust to cold gas ratio is, in these objects, therefore, 15 to 20 times larger than the interstellar ratio, and it is comparable or larger to what is found in molecular clouds.

NGC 4051 is located at an intermediate position in Fig. 8 between the sources showing an absorbed ultraviolet continuum and the other Seyfert 1's. It is not clear from our data whether NGC 4051 is absorbed or it is a peculiar object. It is interesting to note that its soft X-ray excess is peculiarly large and that it is the least luminous Seyfert of our sample. As it has been observed simultaneously with *Ginga*, *ROSAT* and *IUE*, a detailed analysis will be presented separately.

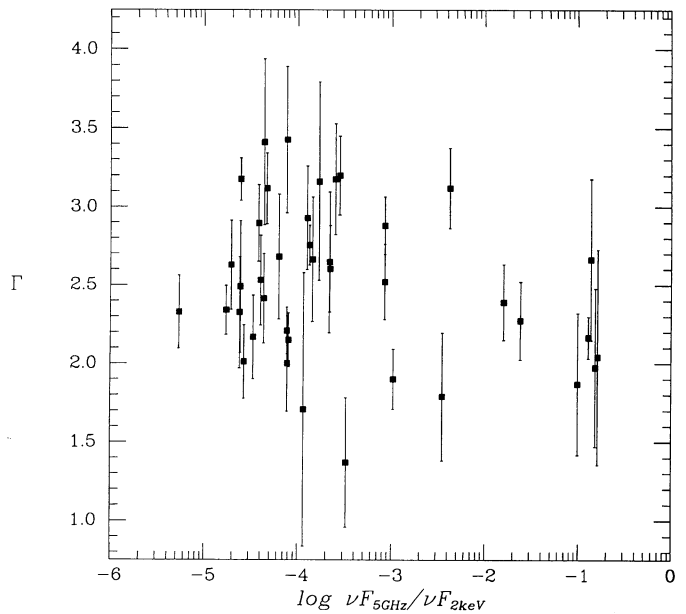


Fig. 9. Relation between the spectral slope Γ measured in the PSPC band and the logarithm of the ratio of the radio (5 GHz) and the 2 keV flux

5.5. Comparison with radio emission

Figure 9 shows that there is no strong correlation between the radio loudness and the soft X-ray spectral slope. Here, the radio loudness is defined as the logarithm of the ratio between the radio 5 GHz flux and the 2 keV X-ray flux. For 40 sources the correlation coefficient is $r = 0.27$. It indicates that a trend exists for radio-loud objects to have a smaller soft X-ray excess.

This trend can, however, be explained by a selection effect as the mean redshift of radio loud objects ($\nu F_{5\text{GHz}}/\nu F_{2\text{keV}} > 0.01$) in our sample is 0.25, whereas the mean redshift of the radio-quiet objects is 0.05. If the soft X-ray spectral slope is corrected for the effect of the redshift, with the relation found in Sect. 5.3, the trend observed in Fig. 9 disappears and the coefficient of correlation obtained above decreases to $r = 0.17$ ($P_{(r>0.17)} > 40\%$).

The redshift effect noticed in the scatter observed in Fig. 8 is not an effect of the radio loudness as no correlation can be noticed between this scatter and the radio loudness ($r = 0.17$ for 35 sources). Furthermore, the addition of a linear term in the radio loudness to the linear correlation observed in Fig. 8 does not decrease the scatter significantly. This point will be further discussed in Sect. 6.

This lack of noticeable correlation between the radio loudness and the soft X-ray spectral slope, apparently, contrasts with the results of Wilkes & Elvis (1987) who showed that there is a dependence of the 0.2 – 3.5 keV spectral index on the radio loudness and it disagrees also with the analogous findings of Comastri et al. (1992) that the soft X-ray excesses are weaker in radio loud QSOs.

Although we cannot exclude that part of this disagreement may be caused by the sample selection, the main difference

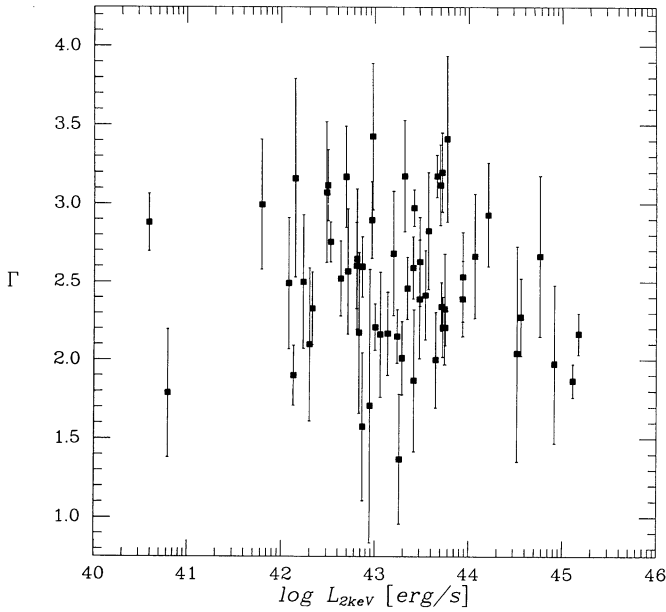


Fig. 10. The soft X-ray spectral slope Γ as a function of the X-ray luminosity at 2 keV

appears in the definition of the radio loudness. Previously, it was defined as the ratio between X-ray and optical fluxes. The correlation observed by Comastri et al. (1992) can, therefore, be interpreted as an analogous correlation we found between the strength of the blue bump and the soft X-ray excess. This interpretation can also be applied to the observations of Wilkes & Elvis (1987). It is supported by the fact that a trend is visible in our sample between the ratio of the radio (5 GHz) flux and ultraviolet (1375Å) flux and Γ with $r = -0.49$ for 40 sources.

5.6. Comparison with luminosity

Figure 10 shows that there is no correlation between the soft X-ray spectral slope and the X-ray luminosity. The probability that the relation between these quantities appears by chance is larger than 48% ($r = -0.11$) and it is larger than 30% ($r = 0.14$) if the ultraviolet luminosity is considered.

6. The ultraviolet to soft X-ray bump

As the main result we conclude that the soft X-ray spectral index is correlated to the strength of the ultraviolet bump in unabsorbed Seyfert 1 nuclei. This correlation indicates that the apparent strengths of both the ultraviolet and the soft X-ray component appear to be strongly linked or, in other words, that *the big blue bump of Seyfert 1 galaxies is an ultraviolet to soft X-ray bump*.

Four different measures of the strength of the bump component are available : on the high energy side, the soft X-ray slope and the ratio of the ultraviolet and 2 keV fluxes (which are discussed in the previous section) and, on the long wavelength side, the ultraviolet spectral slope and the ratio of the

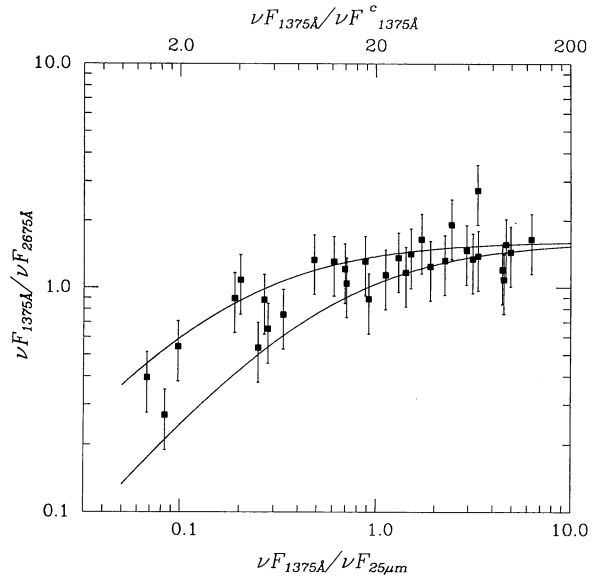


Fig. 11. Ultraviolet spectral slope plotted as a function of the ratio between the ultraviolet and infrared fluxes. The absorbed sources discussed in Sect. 5.4 are excluded. The two continuous lines are the results of the simulations described in the text for $\alpha_c = 2.5$ and 4 where the x-axis (upper scale) is the ratio between the total flux and the contribution of the steep component at 1375Å

ultraviolet and infrared fluxes which are analysed in the following sub-section. The relation between these measures provide some informations about the spectral shape of the bump component which can be compared to the predictions of accretion disk models.

6.1. Ultraviolet spectral slope

A systematic increase of the ultraviolet spectral slope occurs for an increasing ratio of the ultraviolet and infrared fluxes (Fig. 11), even if the absorbed sources (Sect. 5.4) are excluded. This behavior can either be interpreted as the signature of a real change of the ultraviolet spectral slope or it can be due to a reddening effect (Carleton et al. 1987).

If the trend in Fig. 11 is attributed to reddening, the ultraviolet fluxes must be corrected for it by very large factors (10 to 100). The correlation we stated between the strength of the ultraviolet bump and the soft X-ray slope then disappears. As it is difficult to imagine that the amount of dust towards the different sample galaxies is just by chance distributed so that a correlation between the strength of the ultraviolet bump and the soft X-ray slope results, we conclude that most of the variations of the ultraviolet spectral shape over the sample are not caused by reddening.

A more likely model is to explain the variations of the ultraviolet spectral slope by the superposition of the blue bump (bb) component and an underlying continuum (c). If we represent these components by local power law spectra, their slopes are constraint by the measured ultraviolet fluxes to $\alpha_{bb} = 0.3$ and $\alpha_c = 2.5$ to 4 (where $F_\nu \sim \nu^{-\alpha}$). A similar spectral slope

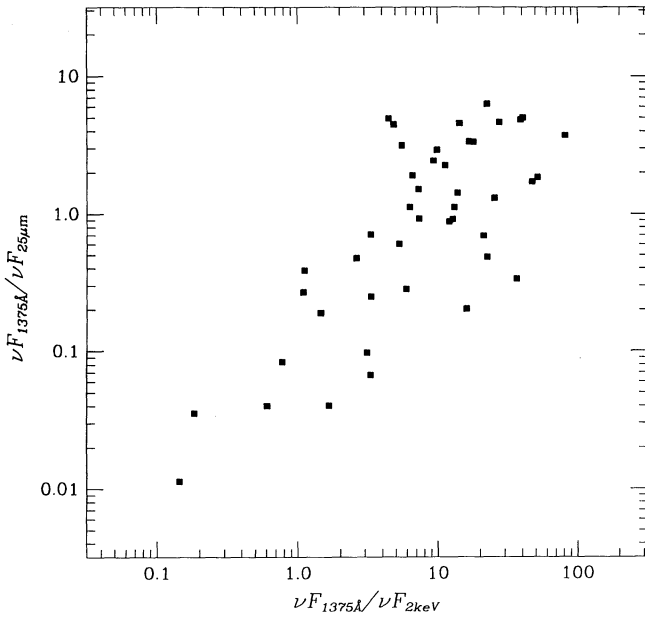


Fig. 12. The relation between the strengths of the ultraviolet bump measured from both infrared and X-ray sides

($\alpha_{bb} = 0.2$) was determined for radio-quiet quasars (Barvainis 1990) and a comparable model was used by Krolik et al. (1991) to fit the spectral variations observed in NGC 5548.

The spectra obtained for different relative normalisations of the two components are located along the two lines drawn in Fig. 11 for $\alpha_c = 2.5$ and 4.0. This model fits the data well if the flux emitted by the steep component at $1375\text{\AA}$ is 20 times smaller than the flux observed at $25\mu\text{m}$, or equivalently, if the flux emitted by this component at $3700\text{\AA}$ is 0.1 to 0.4 time the flux emitted at $25\mu\text{m}$.

A power law shaped infrared to optical component cannot fit the data as the infrared slope ($\alpha = 1.0 - 1.5$) is too flat for the steeper component of the ultraviolet spectra. Galactic emission or thermal emission by cold dust are also not able to reproduce such a component as their characteristic temperatures are too low. An interesting possibility remains that this steep component could be the signature of nuclear hot dust (Barvainis 1990) or of the Balmer continuum emitted by the broad line region.

The latter interpretation is supported by the spectra of Seyfert galaxies given by Edelson & Malkan (1986) for which the ratio between the peak flux of the Balmer continuum and of the $25\mu\text{m}$ flux may be of the order of 0.2 to 1. The mean spectral slope of the Balmer continuum between $3700\text{\AA}$ and $1200\text{\AA}$ corresponding to the optically thin model of Edelson & Malkan (1986) is 3.5. In optically thick models the spectra is flatter (Collin-Souffrin et al. 1986) and can meet the steep component of our model. Furthermore, the flux of the steep component, integrated for $\lambda < 3700\text{\AA}$, is 5 to 15 times larger than the flux emitted in H_β , assuming that the characteristic fluxes emitted in the optical and infrared bands are comparable and that the equivalent width of H_β is of the order of $100\text{\AA}$. This meets quite well the theoretical expectations (Collin-Souffrin et al. 1986).

Table 4. Best fit soft X-ray spectral indices Γ obtained from a power law fit with free absorbing column density to the two spectral components model described in the text. The first part of the table contains the parameters of each models and a characteristic flux ratio.

α_{UV}	-0.3	-0.3	-0.3	-0.3	0.5	0.5	0.5
$e_{cut}[\text{eV}]$	30	40	50	60	60	80	100
$\frac{\nu F_{1375\text{\AA}}}{F_{>150\text{eV}}}$	13	3.0	1.2	0.6	7.5	3.3	1.9
$\frac{\nu F_{1375\text{\AA}}}{\nu F_{2\text{keV}}}$	Γ						
1	1.69	1.65	1.67	1.88	1.67	1.67	1.72
2	1.67	1.65	1.82	2.30	1.66	1.71	1.85
5	1.64	1.71	2.37	3.25	1.67	1.91	2.27
10	1.61	1.99	3.08	4.23	1.77	2.28	2.83
20	1.59	2.51	4.01		2.05	2.86	3.54
50	1.80	3.54	4.72		2.72	3.89	4.54
100	2.21	4.57			3.46	4.75	
200	2.81				4.36		

6.2. Spectral shape

The strengths of the ultraviolet to soft X-ray bump measured from both high and low energy sides are consistent one another. The ratio of the $1375\text{\AA}$ to $25\mu\text{m}$ fluxes is quite well correlated to the ratio of the $1375\text{\AA}$ to 2keV fluxes for the 44 sample sources for which the infrared fluxes are available (Fig. 12, $r = 0.76$, $P_{(r>0.76)} < 0.1\%$). The best linear fit is

$$\log \frac{\nu F_{1375\text{\AA}}}{\nu F_{25\mu\text{m}}} = (0.88 \pm 0.11) \log \frac{\nu F_{1375\text{\AA}}}{\nu F_{2\text{keV}}} - (0.98 \pm 0.17).$$

It indicates that the apparent strength of the ultraviolet bump varies independently of the infrared and X-ray fluxes and that the latter are correlated one with the other.

Both the correlation between the soft X-ray slope and the strength of the ultraviolet bump and that between this strength and the ultraviolet spectral slope suggest, in a first approximation, that the spectral shape of the ultraviolet to soft X-ray bump may be the same in all Seyfert 1 galaxies and that the observed spectral variations are caused by the relative strength of the bump spectral component alone.

A possible spectral shape for the ultraviolet to soft X-ray bump is a power law with an exponential high energy cutoff $F_\nu \approx \nu^{-\alpha_{UV}} e^{-h\nu/e_{cut}}$. We have constructed an array of models, defined as the sum of this bump and of a fixed hard X-ray power law ($\Gamma_{2-10\text{keV}} = 1.7$), absorbed by a column density of $N_H = 3 \cdot 10^{20} \text{cm}^{-2}$ for different α_{UV} , e_{cut} and relative normalisation. These models were folded through the response matrix of the PSPC detector and fitted with a simple power law model absorbed by cold gas to obtain soft X-ray spectral indices which can be compared to those derived from the observations.

The results of these simulations are given in Table 4 for different ultraviolet spectral indices ($\alpha_{UV} = -0.3, 0.5$) and cutoff energies ($e_{cut} = 30 - 100 \text{eV}$). Lines of constant α_{UV} and

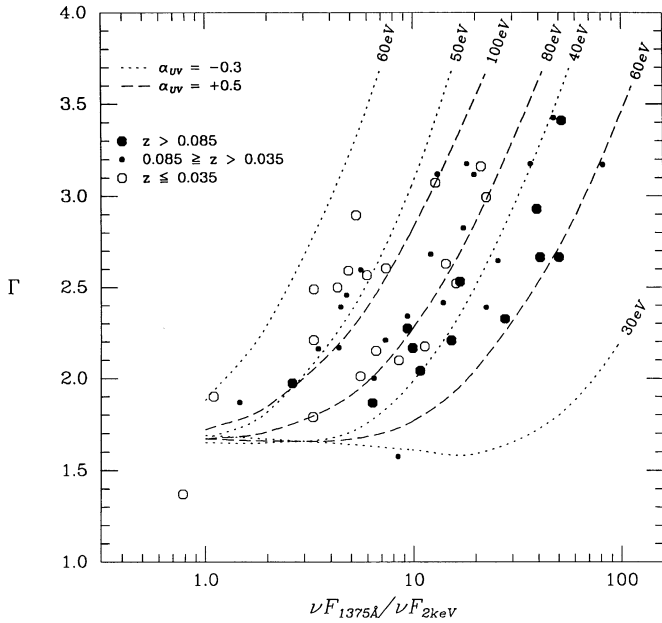


Fig. 13. Results of simulations and observed data (the absorbed sources are excluded). Lines of constant α_{UV} and cutoff energy (labeled by e_{cut}) are showing the relation predicted by bump models between the soft X-ray spectral slope Γ and the ratio of the ultraviolet to X-ray fluxes

e_{cut} are displayed in Fig. 13 with the observed data for a variable relative normalization of both the bump and the hard X-ray spectral component.

Although the observations are compatible with different sets of (α_{UV}, e_{cut}) , the possible models are characterized by a peculiar range of ratios between the ultraviolet and soft X-ray fluxes emitted by the bump $\nu F_{1375\text{\AA}}/F_{>150\text{eV}} \approx 1$ to 7, where $F_{>150\text{eV}}$ is the soft X-ray flux emitted by the model above 150 eV.

The data points in Fig. 13 are coded as a function of increasing redshift. A systematic trend which was already noticed in Sect. 5.3 is clearly present. For a given strength of the ultraviolet bump, “high” redshift objects ($z \approx 0.25$) have smaller soft X-ray excesses.

The effect of a redshift of 0.25 on the spectra observed with *ROSAT* is given by the shift between the lines of constant spectral shape ($\alpha_{UV} = -0.3$) when the cutoff energy decrease from 50 to 40 eV. The predicted effect is of the same order as the systematic shift observed between low and high redshift sources. We conclude, therefore, that the redshift effect is sufficient to explain the peculiar location of the high redshift sources in Fig. 13 and that the effects of the radio loudness or of the luminosity discussed in Sect. 5.5 and 5.6 are small or inexistent. If there is no strong selection effect of the bump’s strength on the limiting detectability with the PSPC, then the mean spectral index must decrease from 2.5 to 2.0 when the redshift increases from 0 to 0.5. Such a trend has been observed by Schartel et al. (1992) in the soft X-ray spectra of quasars observed with *ROSAT*.

If the effect of the redshift is taken into account, most of the available observations can be reproduced by models characterized by

$$\frac{\nu F_{1375\text{\AA}}}{F_{>150\text{eV}}} = 1 \text{ to } 5.$$

This indicates that the variations of the spectral shape of the bump component among sources of our sample are *small* and that a *variation of the relative normalization of the bump and the hard X-ray component is sufficient to explain most of the differences observed in the soft X-ray spectral shape* of our sample members. Larger variations of the spectral shape are not excluded in some sources (NGC 4051, Mrk 841) but cannot be established by comparing the *IUE* and *ROSAT* spectra only.

The comparison of *ROSAT* and *IUE* observations provide two constraints on the emission mechanism in Seyfert 1 nuclei. Firstly, the variations of the ratio of the ultraviolet to soft X-ray fluxes emitted by the bump component are limited to a factor of 5 and, secondly, the ratio of the ultraviolet to hard X-ray fluxes can vary by factors of a hundred. These constraints can be compared with predictions of different emission models.

6.3. Thin accretion disks

Local black body approximation of the thin disk emission (Pringle 1981) have difficulties to explain the soft X-ray excesses observed in Seyfert 1’s (Malkan 1983). The soft X-ray excesses can, however, be reproduced if effects of Compton scattering in the disk are taken into account (Czerny & Elvis 1987). Self-consistent computations of Compton scattering in thin disks have been presented recently (Ross et al. 1992) and they can be confronted to our observations.

An important prediction of thin accretion disk models is that the fraction of the flux emitted at soft X-rays decreases with increasing central mass and with decreasing L/L_{Edd} . For increasing central mass of 10^6 , 10^7 and $10^8 M_{\odot}$ (and constant $L/L_{Edd} = 0.2$), the models of Ross et al. (1992) are characterized by $\nu F_{1375\text{\AA}}/F_{>150\text{eV}}$ of 0.1, 1 and 10, respectively. For intermediate masses these models agree, therefore, quite well with our observations, but they have problems to explain simultaneously the ultraviolet and soft X-ray fluxes of faint ($L < \text{a few } 10^{43} \text{ erg/s}$) and luminous ($L > \text{a few } 10^{45} \text{ erg/s}$) sources. For higher accretion rates the models agree well with luminous sources but disagree with fainter ones ($L < \text{a few } 10^{44} \text{ erg/s}$) and for small accretion rates ($L/L_{Edd} \approx 0.05$) the models agree for faint sources, but do not produce enough soft X-rays in luminous sources.

A possible way to solve these problems is to scale the ratio L/L_{Edd} with the square root of the central mass. Such a scaling provides a relatively constant spectral shape of the disk emission for the full range of luminosities, but it is a rather ad hoc assumption. Inclination effects which are likely to appear in disk geometry (e.g. Laor & Netzer 1989) are also working against a constant spectral shape of the disk emission.

Another possibility is to assume that a large part of the ultraviolet continuum is emitted by reprocessing of hard X-ray

radiation by cold matter in faint sources or/and that a significant part of the soft X-rays are produced by inverse Compton scattering of ultraviolet photons in luminous sources. Such models require, however, a fine-tuning between the relative strength of the reprocessed emission or the Compton y parameter and the luminosity.

6.4. Thick accretion disks

Bare thin disk models cannot explain the constancy of the ultraviolet to soft X-ray spectral shape in our sample members. If the accretion rate exceeds the Eddington limit it is expected that the disk forms a thick torus supported by radiation pressure (Abramowicz et al. 1987). A major fraction of its luminosity is emitted from the surface of the funnel surrounding the rotation axis. In particular, the soft X-rays are emitted from the hottest part of the funnel at a distance less than 10 Schwarzschild radii (R_S) from the central object. As the characteristic radius and height of the torus is about 250 R_S , the soft X-rays can only be observed at small inclination angles. The ratio of the observed ultraviolet to soft X-ray fluxes is, therefore, a strong function of the inclination angle.

The thick disk model of Madau (1988), including reflection effects on the funnel walls, predicts that the face-on disk are emitting soft X-rays excesses 10 times larger than observed and that the apparent ratio of the ultraviolet to soft X-ray fluxes is compatible to the observed value only for disk observed at large inclination angles (50 to 60°). The lack of strong variations of the ratio of the ultraviolet and soft X-ray fluxes in our observations clearly disagree with the inclination effects predicted by thick disk models.

6.5. Relative strength of the bump

Our observations are compatible with very limited variations of the spectral shape of the bump component among Seyfert 1's, although the luminosity varies by 6 orders of magnitude. On the other hand, the relative strength of the bump is highly variable. Taking into account that most of the high energy luminosity may be emitted in the MeV band, the ratio of the luminosities of the bump and the hard X-ray components varies from 0.1 to 10 over the sample without any correlation to the luminosity or to the radio loudness.

Several difficulties arise if this variation is attributed to the emission mechanism. Firstly, it does not agree with the fact that part of the near infrared is believed to be emitted by dust reprocessing the ultraviolet continuum (e.g. Clavel et al. 1989) unless the covering factor of the dust varies with the ratio of the ultraviolet and X-ray continua.

Secondly, it is not compatible with models using reprocessing of X-ray photons at the surface of the accretion disk to explain the simultaneity of the optical and ultraviolet light curves (Courvoisier & Clavel 1991) and the similarities of the ultraviolet and hard X-ray light curves (Clavel et al. 1992) as such models need comparable X-ray and ultraviolet luminosities. Finally, it may be difficult to construct emission models at all

which can predict such large (and continuous) variations in the relative strength of the bump.

Another explanation may be that the ratio of the bump and the X-ray or infrared luminosities is a steep function of the inclination angle of the accretion disk to the line of sight. The apparent disk luminosity varies with the cosine of the viewing angle and the probability to observe it is given by its sine. 10% of the sources should be observed with viewing angles smaller than 6° and, therefore, with an apparent disk luminosity decreased by a factor of 10. This is not sufficient to explain the observed variations, except, if the apparent X-ray luminosity is also a function of the inclination.

Beaming effects are not able to reproduce the observations as they predict a decreasing X-ray luminosity with increasing viewing angle and as the beaming factor decreases steeply with the viewing angle. Another inclination effect is predicted if the hard X-rays are emitted above the accretion disk by anisotropic inverse Comptonization of soft photon emitted from the surface of the disk (Ghisellini et al. 1991). Even if the energy of the electrons is small ($\gamma_e \approx 2 - 10$) the X-ray flux emitted in the direction of the disk is 5 times larger than the flux emitted in the observer's direction. Within this scenario, the ratio of the ultraviolet and X-ray apparent luminosities is 50 times larger when the accretion disk is observed face-on than edge-on. Inclination effects may therefore account for a large part of the variations observed in the relative strength of the bump component.

7. Conclusions

In order to study the interrelation between the ultraviolet and the soft X-ray regions in the spectra of AGN, we investigated the spectra of 58 Seyfert 1 type nuclei measured with the satellites *ROSAT* and *IUE*.

The soft X-ray (0.1 – 2.4 keV) spectra were derived from data obtained with the X-ray telescope and PSPC detector aboard *ROSAT* during the all sky survey. All but two spectra are well represented by a power law model with low energy absorption. The residuals of the model fits resulting for these two peculiar sources and for some other objects, too, suggest that often an additional component is needed for an optimum representation of the spectral data.

The power law indices vary from object to object and they range from 1.6 to 3.4. The mean index is $\langle \Gamma \rangle = 2.50$ and the standard width of the index distribution is $\sigma_\Gamma = 0.48$. The mean value as well as the distribution's width are considerably larger than those found at harder X-rays. This indicates that an additional soft component is found throughout the sample.

In 90% of the sources, the absorbing column density N_H due to cold matter on the line of sight, determined for a power law model continuum, is consistent with the corresponding Galactic value as measured at 21 cm radio wavelength. Furthermore, the mean of the differences between the values resulting from the model fits and the Galactic values is consistent with zero indicating that the Seyfert 1 nuclei in our sample are free of absorbing matter along the line of sight. Since we cannot exclude

that the detection of AGN in the *ROSAT* survey suffers from selection effects, we emphasize that these statements are valid only for the Seyferts of our sample which are chosen to be particularly bright in the all sky survey.

If the column densities are determined by using a thermal bremsstrahlung representation of the very soft X-ray continuum, the N_H values are systematically smaller than the Galactic values by 23% on average. From this we conclude that the spectral data of the sample as a whole are not consistent with a flattening at low energies inherent to thermal models.

In four sources (MCG-8-11-11, KAZ 102, Q1821+643 and II Zw 136) the N_H derived from the model fit are smaller than the Galactic values, whereas the spectral slopes are consistent with the values observed above 2 keV. We interpret this finding as an indication of a probably weak flux excess at very soft X-rays which is completely dominated by the effect of interstellar absorption.

In two other sources the measured column density is larger than the Galactic value. In IC 4329A, the absorbing matter is located in the plane of the galaxy seen edge-on. In Mrk 766 the absorption is most likely caused by molecular clouds located in the inner part of the narrow line region.

Excesses of the soft X-ray flux above the extension of the hard X-ray power law continuum were detected in 90% of the sample sources. The soft X-ray excesses vary from object to object. They are well correlated to the power law index measured in the *ROSAT* energy band.

If these soft X-ray slopes are compared with the ratio of the ultraviolet flux and the flux at 2 keV, which is regarded as a measure of the ultraviolet bump strength, a strong correlation of both quantities is found: objects with a large ultraviolet bump do also show a strong soft X-ray excess. Therefore we conclude that the big blue bump of Seyfert 1 galaxies is an *ultraviolet to soft X-ray bump*.

Six sources do not match this correlation as their spectra show soft X-ray excesses but only faint ultraviolet continua. Five of them (IC 4329A, MCG-6-30-15, Mrk 766, Akn 564, IR 1334+2438) are strongly absorbed by dust in the ultraviolet, explaining their peculiar spectra. The last one (NGC 4051) is the faintest object of our sample and may be a peculiar case.

The soft X-ray spectral indices, as well as the soft X-ray excesses, are neither correlated with the radio loudness nor with the X-ray luminosity of the Seyferts in our sample. On the other hand, we found that the ratio of the ultraviolet to infrared fluxes is correlated with the ultraviolet spectral slope and with the ratio of the ultraviolet to 2 keV fluxes.

These two correlations indicate that most of the variety of spectral shapes observed in the optical to X-ray spectra of Seyfert 1 galaxies is due to the relative strength of the ultraviolet to soft X-ray bump, which varies by factors of 100 when compared to the other spectral components.

If we take the effect of the redshift into account, the spectral data are consistent with the assumption that the ultraviolet to soft X-ray bump is very similarly shaped in almost all Seyferts of our sample. The integrated flux emitted by this component

above 150 eV is 1 to 5 times smaller than the spectral flux emitted in the ultraviolet.

Thick accretion disks models can only reproduce our observations, if the disks are almost all seen with large inclination angle, an assumption which is hardly justified by the data. Emission predicted by thin accretion disk models do not agree with our data without a fine-tuning of the accretion rate with the luminosity. Neither external heating of the disk in faint sources or comptonized soft X-ray excesses in luminous sources can reproduce the observations.

Finally, we note that the large variation of the relative strength of the bump by a factor of 100 over the sample may be difficult to be explained by emission mechanisms only. Inclination effects, however, could account for the major part of this variation, if the hard X-ray source is located above the accretion disk.

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