Extended X-ray emission in the radio loud galaxy 3C382

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ABSTRACT

ROSAT/HRI observations of the powerful radio-loud galaxy 3C382 reveal extended X-ray emission associated with the source. On the basis of this new spatial component, a previous ROSAT/PSPC spectral analysis of the source is revised. Allowing for the presence of an additional thermal component in the PSPC spectrum, the non-thermal component is found to be compatible with the extrapolation of the well defined 3C 382 —2 - 10 keV— power-law spectrum into the soft X-rays. The thermal —extended— component would then account for the soft excess emission previously reported for this source. The origin of this thermal component is not clear. Its luminosity compares with that of rich Abell clusters; yet, the galaxy environment in 3C382 appears of moderate optical richness. An alternative is that it is due to a massive extended gaseous atmosphere sustained by the deep gravitational potential well of 3C382.

Subject headings: radiation mechanism: nonthermal - X-rays: galaxies - galaxies: individual: 3C 382

1. Introduction

Soft X-ray excess emission above a simple extrapolation of the hard energy spectrum is found in a considerable number of AGNs, mainly radio-quiet sources (see Mushotzky,
Done, & Pounds 1993 and references therein). There is a growing body of evidence for its spectral ubiquity below $\sim 2$ keV or so in Seyferts (e.g. Pounds et al. 1994) as in highly luminous quasars (e.g. Saxton et al. 1993). Most previous studies before ROSAT converge toward the idea that the soft excess is a rather common feature among radio-quiet quasars, whereas it is almost absent in their radio-loud counterparts. ROSAT/PSPC data of radio loud sources have shown that a soft excess component is also present in radio loud sources (e.g. Buehler et al. 1995; Prieto 1996; Siebert et al. 1998).

Possible interpretations for the soft X-ray excess in AGNs include thermal emission from the inner regions of an accretion disk, scattering by highly ionized material in its vicinity (Pounds et al. 1986; Ross & Fabian 1993), or thermal emission due to shock-heated gas in the close vicinity of the nucleus (Viegas & Contini 1994). The poor spatial resolution of the ROSAT/PSPC makes difficult the separation between possible components of the observed emission. Indeed, the large PSPC resolution beam, $\sim 25$ arcsec at 1 keV, makes plausible that an important part of the observed emission to be due to an extended gas component surrounding the AGN. In the particular case of radio-loud galaxies which are characterized by large radio sizes, a hot surrounding medium becomes a necessary component for providing the working surface for the radio emission. In the analysis of the 3CRR sample by Prieto, a first attempt to fit the PSPC spectra of sources with extended emission – mostly in Fanaroff & Riley (1974) type I sources (FRI) – with a single power-law leaded to extreme step spectral index, the reason being due to the dominant contribution of the gaseous medium in which those sources usually reside. In the case of FRII, a single power-law fit provided a fair representation of the PSPC spectrum but with average spectral index about -1.1, and so above the extrapolation of the canonical hard-energy spectrum into the soft X-rays. Clustering of galaxies about FRII sources is less common than in FRI, in particular at low redshift; yet, FRII could contain their own extended gaseous atmosphere which may directly translate into a steepening of the PSPC spectrum. This component however may prove to be elusive with present X-ray instrumentation.

This paper presents deep ROSAT/HRI observations of the powerful X-ray radio-loud source 3C 382. This is one of the few nearby broad-line galaxies ($z = 0.0578$) that show extremely bright and broad permitted lines ($FWZI > 25000km s^{-1}$; Tadhunter, Perez & Fosbury 1986) and a strong continuum, with with a X-ray luminosity in 0.2-2.4 keV band of $L_x \sim 7.10^{44}$ erg s$^{-1}$ (Prieto 1996), and a radio power at 178 MHz of $L_{178MHz} \sim 3.10^{33}$ erg s$^{-1}Hz^{-1}$ (Laing et al. 1983).
EXOSAT monitoring of the source (1983–1985) tightly constrains the high-energy (above 2 keV) spectral index of 3C382 to $\alpha = -0.7 \pm 0.1$ (Ghosh & Soundararajaperumal 1992). This is also confirmed by more recent ASCA data (Wozniak et al. 1998). However, the ROSAT/PSPC spectral analysis of the source shows compatible with a power-law model with spectral index $\alpha = -1.2 \pm 0.3$, and absorbed by a column density, $N(H) = 0.78 \times 10^{21} cm^{-2}$, that is in agreement with the Galactic value. Thus, 3C382 shows a soft excess emission below $\sim 2$keV (Prieto 1996). Independently, the presence of a soft excess is also inferred from the analysis of the EXOSAT (Ghosh & Soundararajaperumal), ASCA (Wozniak et al.) and Ginga (Kaastra et al 1991) data.

Extended soft X-ray emission associated with this source is detected in the ROSAT/HRI data. On the basis of that new component a re-evaluation of the PSPC spectrum is presented.

Throughout this work $H_0 = 50$ km s$^{-1}$ Mpc$^{-1}$. 1 arcsecond corresponds to $\sim 1.7$ kpc at the source.

2. Analysis of HRI data

The HRI observations of 3C 382 were conducted in 1996 October and 1997 April (WG900720H and WG900720H-1 datasets respectively) The corresponding total accepted times were 4514 s and 13310 s, respectively. The counts are integrated from channels 1 to 8 which enclose most of the energy accumulated in the ROSAT band, yielding for both dataset count rates of $\sim 1$ cts s$^{-1}$.

The nominal resolution of the ROSAT/HRI is $\sim 5$–6 arcsec (FWHM). Residual errors in the ROSAT aspect solution are known to give rise to elongated images (David et al. 1996), the shape of the surface brightness profile dramatically departing from the expected point response function (PRF). In the case of very bright sources, improvement of the HRI spatial resolution becomes feasible by using speckle interferometric techniques such as the “shift-and-add” method. If one constructs images over short time intervals, the PRF becomes symmetric and therefore the elongation in the image appears as an apparent residual motion of the X-ray source in the sky. Such residual motion can be corrected for by de-speckling.
3C 382 is particularly suitable for that technique as it shows very bright in the ROSAT band, with $\sim 2 \, \text{cts s}^{-1}$ in the PSPC and $\sim 1 \, \text{cts s}^{-1}$ in the HRI.

The procedure used follows the same criteria and approach originally presented in Schmitt, Güdel & Predehl (1994). Basically, each event file is divided into time bins of typically 50 s. For each bin, the apparent X-ray position of the source (i.e., RA and $\delta$) is determined as a function of the observing time. A spline function is fitted to these data points, all recorded photons being then corrected with the appropriate time-dependent correction in RA and $\delta$.

To validate the correction, new measurements of the source centroid are repeated on the corrected event file. The correction is considered as satisfactory if the new centroid positions cluster during the time period of the observation about an average constant value. The uncertainty in the final source centroid is about 2.5 arcsec in RA and 1.5 arcsec in $\delta$.

The X-ray spatial analysis was then performed on the corrected HRI event files. Because of the much higher statistic of the April event file, reliable results from the de-speckle procedure are only found from that dataset. Thus, the following analysis focuses only on this dataset.

3. The extended X-ray component

An X-ray contour image of 3C 382 obtained after the de-speckle procedure is shown in Figure 1a. The image is background-subtracted and smoothed with a Gaussian filter of FWHM $\sim 12$ arcsec. The background level is estimated from different regions in the image within the central 5 arcmin. The emission is dominated by a central peak component, and a surrounding halo slightly more asymmetric towards the North-East side. Some of the morphological features are also apparent in the shortest exposed 1996 October event file -not shown. Overall, the X-ray emission extends out to about 100 arcsec from the center, $\sim 170$ kpc at the distance of the source. This is about the size of the radio structure at 8.3 GHz (Black et al. 1992). The slight North-East asymmetry in the X-ray image is virtually coinciding with the direction of the radio axis and with that of the faint filamentary regions and bright companion galaxy seen in the HST/WFPC2 image (Fig. 1b).

The corresponding surface-brightness profile is presented in Figures 2. For comparison,
the new improved ROSAT/HRI PSF profile by Predhel (1998) —currently upgrade in the EXSAS package— which includes the effect of the ROSAT mirror scattering and has been fit to Capella and Sirius, is shown superimposed. To illustrate the effect of the de-speckle procedure on the data, the surface brightness profile as derived from the original data is shown is Fig 2a, and that after de-speckling in Fig. 2b. The departure from the ROSAT/HRI PRF is clearly evidenced in Fig. 2a, where larger residuals are seen all over the profile. The de-speckle procedure produced a sharper profile which virtually fills the core of the PRF (Fig. 2b). Yet, some systematic residuals still remain at radius beyond \( \sim 10-15 \) arcsec from the center, which we assume to be related to an extended emission component. This component is roughly 10\% of the total emission.

In an attempt to get a better characterization of the observed profile, a combination of an unresolved component represented by the HRI/PSF, and an extended component represented by a \( \beta \)-model are fit to the data. The functional form of the \( \beta \)-model follows King’s approximation (1972) for gas confined in an isothermal sphere: 

\[
S(r) \propto (1 + (r/r_c)^2)^{-3\beta+1/2},
\]

with \( S(r) \) the surface brightness a radius \( r \), \( r_c \) the core radius and \( \beta \) the slope parameter. Given the uncertainty inherent with this approximation for the extended component, a simple addition of the PSF and the beta model is fit to the data.

Figure 2c shows the resulting fit corresponding to the composite model: PRF plus a \( \beta \) model. Fig 2c shows a clear fit improvement to the observed profile as the systematic residual trend seen in Fig 2b is now removed; yet, the composite model still overpredicts the observed emission at radius beyond 10 arcsec. Overall, the \( \beta \)-model does not provide a statistically acceptable fit with reduced \( \chi^2 \) exceeding unity. The main reason for that may reside in the validity of the beta-model for the specific case of the extended gas emission in 3C382. Besides, there is the fact that the dominant contribution of the emission is the unresolved component, which makes the modeling of the extended diffuse emission difficult. Also, there is the rather asymmetric morphology of the emission which may clearly depart from the simple model used here.

Nevertheless, the fit results from the composite model led to a tight range for both the core radius and the \( \beta \) value. The minimum reduced \( \chi^2 \), \(< 1.5 - 2 >\), was obtained for a core radius \( r_c \sim 20-30 \) arcsec \((30 - 50 \text{ kpc at the distance of 3C 382})\) and \( \beta \sim 0.7 - 0.8 \). A much simpler composite model represented by the PRF plus a Gaussian model for the extended component, yielded FWHM for the extended component in the 30 - 40 arcsec
3.1. Re-evaluating the PSPC spectrum

A single power-law model with spectral index -1.2 provides a fair fit of the PSPC spectrum of 3C382, with the derived N(H) in good agreement with the Galactic value. However, the detection of an extended component in the HRI data along with the reported evidence for soft excess emission in this source from EXOSAT and ASCA data besides PSPC (cf. sect. 1) prompt to a re-evaluation of the PSPC data. Because the extended nature of the new component, its association with thermal emission arises as the most natural explanation.

Due to the short energy range and relatively low spectral resolution of the PSPC, a complex analysis of the PSPC spectrum involving a combination of several models is difficult. However, the evidence for extended emission and the fact that the hard X-ray spectral index of this source remains constant about the 0.7 value are additional inputs that can be used for forcing the PSPC fit with a more complex modeling.

Accordingly, a combination of a power-law, with spectral index fixed at $\alpha = -0.7$, and a thermal model are fitted to the PSPC data. In this composite model, N(H) is fixed at the Galactic value following Prieto’s results (1996). Thus, the only parameters that vary freely are the normalizations of the respective thermal and power-law components and the temperature of the thermal component.

The new composite fit (Fig. 3) provides a fair representation of the PSPC spectrum, with a reduced $\chi^2 \sim 1.2$ and constrained values for all the free parameters. A gas temperature of $0.6^{+0.4}_{-0.1}$ keV is derived. Alternative fits, letting free the index of the power-law spectrum or the N(H), lead to larger $\chi^2$ and unconstrained fit parameters. Fitting a single bremsstrahlung model produces also an acceptable fit but the derived N(H) value is found lower than the Galactic value.

The results from the composite model can be compared with those derived from the single power-law model and from the single thermal model in Table 1. Given the PSPC spectral limitations together with the additional complexity of the composite model, the derived fit values may be subjected to larger uncertainties. In this sense, the temperature
could be largely affected whereas integrated fluxes are the least dependent on the adopted model. The total flux contribution from the thermal and power-law components in the composite model compares with that derived from the single power-law model. The reduced $\chi^2$ is slightly better in the case of a simple power-law model; but we consider the difference marginal. The lowest reduced $\chi^2$ is obtained with the thermal model; yet the derived N(H) in this case is inferior than the Galactic value.

3.2. How do the PSPC fluxes compare with those derived from the HRI data?

Fluxes estimate from the HRI data for the extended and unresolved component are primarily derived on the basis of HRI spatial analysis (§3). The total number of counts within the unresolved and extended component leads to count rates of $\sim 1$ cts s$^{-1}$ and about 0.1 cts s$^{-1}$ respectively.

The lack of spectral resolution of the HRI hampers any direct spectral modeling of the X-ray data. Yet, the availability of the PSPC data allows us to use the same model and fit parameters as derived from the PSPC fit (§3.1) to convert the HRI counts to fluxes. These are given in Table 1.

The unresolved HRI component, modeled with a power-law index $\alpha = -0.7$, yields a flux about a factor 2 larger than that measured by the PSPC. 3C 382 is known to be a variable source, with reported maximum-to-minimum variations of up to 120% as measured by EXOSAT (Ghosh & Soundararajaperumal 1992). Regarding the ROSAT observations, previous HRI observations of the source in 1992 March revealed a drop in the total number of counts by a factor 1.8 with respect to the values measured in the present observations taken 5 years later. This drop is thus compatible with the still lower flux measured by the PSPC in 1990. Thus, the difference found between the HRI and PSPC fluxes for the unresolved component appears compatible with the observed variability level of the source.

Regarding the extended component, bremsstrahlung models with temperatures within the range 0.6-3 keV lead to corresponding HRI fluxes $10 - 6. \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ respectively, i.e., a factor 2 to 3.5 smaller than that derived from the PSPC for the same component. We note however that as neither the Gaussian approximation nor the $\beta$-model provide a statically acceptable fit to that component, the corresponding number of HRI counts for the extended component was not derived from the model but from the difference.
between the total integrated number of counts and that integrated within the unresolved component represented by the PRF. Given the simplicity of the method, in particular taking into account that the dominant contribution of the total emission is the unresolved component, the derived PSPC and HRI fluxes can be considered consistent with each other within the order of magnitude. Besides, it is also possible that the emission is more extended than what is detected—at least beyond the radio structure—, but the surface brightness there is too low for being detected with the HRI.

To summarize, the inferred luminosities for the extended and unresolved components estimated from the HRI data appear compatible in order of magnitude with the respective thermal and power-law luminosities derived from PSPC spectrum of the source.

4. Discussion

Extended X-ray emission associated with the very bright, nearby radio-loud galaxy 3C 382 is detected. The analysis of the ROSAT/HRI data shows that about 10% of the total 0.2 -2.4 keV emission is compatible with the presence of an extended component. Assuming that component to be due to hot gas emitting via bremsstrahlung, and allowing for the contribution of such thermal component into the PSPC spectrum, it is found that the non-thermal component of 3C 382 emission becomes consistent with the extrapolation of the “well established” 3C 382 high-energy power-law spectrum —above 2 keV— into the soft X-ray regime.

The temperature of the gas component as formally derived from the PSPC fit is $0.6^{+0.4}_{-0.1}$ keV. This low temperature contrasts with the high luminosity of the gas component, $\sim 3 \times 10^{44} \text{erg sec}^{-1}$. Taken together the spectral limitation of the PSPC and the complexity of the model fit, the uncertainty in the temperature could however be larger. There is furthermore the possibility that a temperature gradient dominates the gas emission — a cooling flow process. In this case, the PSPC spectrum may be mostly sampling the central gas region, where the coolest and more dense gas is located. There are however other factors that could also have lead to an overestimation of the gas luminosity. The analysis by Markevitch (1998) on clusters with strong cooling flows indicates moderate temperature increase of up to 20% but luminosity decrease of up to 40% for the cluster gas after excising the cooling flow regions. On the other hand, if cooling by metals is considered — for sake
of simplicity, pure bremsstrahlung has been assumed – the luminosity of the gas could decrease by about 40%, assuming a Raymond-Smith model with metal abundance Z=0.35.

Still, the derived thermal luminosity in 3C382 is about two order of magnitude larger than that found in isolated, normal elliptical galaxies (Canizares, Fabbiano & Trincheri 1987), and in low-power radio galaxies (Worral & Birkinshaw, 1994) but it is in the range found in powerful radio sources (Worrall et al. 1994; O’Dea et al. 1996; Hardcastle et al. 1999; Crawford et al. 1999). Also, the estimated core radius for 3C382, ~50 kpc, is within the range found by Crawford et al. and Hardcastle et al. in their respective samples of 3CRR radio-loud sources.

Large X-ray halos are often seen in FRI sources, those being associated with the cluster environment in which they often reside (e.g. M 87, Perseus, 3C465). These halos largely dominate the ROSAT emission from these sources. Besides the outstanding case of Cygnus A, evidence for clustering is less obvious in classical double radio sources, particularly at low redshift (cf. Hill & Lilly 1991; Miller et al. 1999). Unambiguous extended X-ray emission in powerful FRII radio galaxies and quasars has mostly being found in sources with redshift larger than 0.1 (Hardcastle and Worall, 1999; Crawford et al 1999; O’Dea et al. 1996); yet, a few low-redshift FRII are reported to show extended X-ray emission (cf. Hardcastle and Worral). In most of these cases, the large X-ray luminosities are found compatible with thermal emission from a moderately rich cluster environment.

Comparing with Cyg A, the archetypal double radio source at z= 0.0574, 3C382 is also one of the few very bright double sources at low redshift with extended X-ray emission. Contrarily to Cyg A which presents an optical narrow line spectrum, 3C382 presents an extreme, in width and strength, broad permitted line spectrum. If this difference is interpreted as due to obscuration of the AGN region in Cyg A, it may explain why the dominant X-ray feature in Cyg A is emission from a hot diffuse gas –the AGN component is obscured at X-ray waves– whereas in 3C382, the unresolved X-ray nuclear component –presumably associated with the AGN– dominates the total X-ray emission, making more difficult the detection of any extended gas component.

The X-ray luminosity of 3C382, of about $10^{44} \text{erg s}^{-1}$, compares with that of rich Abell clusters (this is also the case of Cyg A; yet Cyg A is at the center of a poor cluster of galaxies). Longair & Seldner (1979) derived however a rather poor environment in the vicinity of 3C 382 on the basis of their cross-correlation analysis between the radio position
and galaxy counts. HST/WFPC2 images of 3C382 collected in parallel mode show an elliptical galaxy with a very bright unresolved nucleus and a halo very smooth (Martel et al. 1999). Yet, within the 2.5 arcminutes field of view (Fig 1b), several small galaxies can easily be distinguished in the 300 seconds exposure; the WFPC2 images also show a bright galaxy at 85 arcsec Northeast from 3C382, presenting two at least extended gaseous tails of material in the direction of 3C382; two additional diffuse regions located close to 3C382 and in the direction of the bright galaxy are also apparent. Judging from the HST images, 3C382 may be residing in a relatively poor cluster environment; also, it may be in interaction with that gas-rich galaxy companion. Such interaction could have brought plenty of gas into 3C382.

The luminosity of the halo component in 3C382 would imply a large mass of gas, of about $10^{11}M_{\odot}$, assuming it concentrated in a sphere of about 50 kpc—the estimate core radius derived from the HRI spatial analysis—and a temperature in the 0.6 -1 keV range. An alternative to the cluster environment is that 3C382 it may consist of a self-contained gravitational potential deep enough to restrain such large amount of gas. This could also be the case of the radio-louds 3C48 and 3C273, for which extended X-ray emission is found but the evidence for a cluster environment from optical images is minor (Crawford et al. 1999). Evidence for a massive dark halo in 3C382 comes from the velocity measurements on the extended ionized gas surrounding this galaxy. Tadhunter et al. (1986) detected ionized gas up to 25 kpc from the galaxy center. The gas follow a a rotation curve which extend flat up to those distances with velocities of about 400 km/s relative to the systemic velocity. Assuming a spherical potential, the estimated mass within a 25 kpc radius would be $\sim 8 \times 10^{11}M_{\odot}$. This is about the gravitating mass needed to keep the X-ray gas binded to the galaxy. Following Fornan, Jones and Tucker (1985) formalism, the total gravitating mass within a 50 kpc radius is estimated between $8 - 15 \times 10^{11}M_{\odot}$ for gas temperatures between 0.6 and 1 keV, which is in the order of magnitude of the mass derived from the ionized gas kinematics.

The results so far derived show compatible with a cooling flow process being dominating the gas emission. If the extended gas emission is modeled as that of a uniform sphere of hot gas emitting via bremsstrahlung, for a maximum radius of about 170 kpc (the size of the radio structure) and a temperature in the 0.6 - 1 keV range, the implied density would be $simeq 6 \times 10^{-3}cm^{-3}$. This yields a cooling time of about $4 \times 10^{9}yr$, considerably smaller than the Hubble time. Thus, a cooling flow process could be operating in 3C 382.
A better characterization of the extended X-ray emission in 3C382 would demand much larger spatial resolution but also deeper observations.

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Figure captions

Figure 1a:
HRI contour image of 3C 382 extracted from channels 1 to 8. It is background-subtracted and smoothed with a Gaussian filter with a FWHM $\sim$12 arcsec. Contours are $10^{-3}\text{cts s}^{-1}\text{arcmin}^{-2}\times (2.8, 4.4, 6, 7.6, 9.2, 10, 16, 40, 4000)$; the first contour is about the $2\sigma$ level measured on the background-subtracted image. 1 sky-pixel is 0.5 arcsec.

**Figure 1b:**
Broad band HST/WFPC2 image of 3C382 (data set u27l6w01-2) at 7200 Å an equivalent exposure of 300 seconds. 3C382 is filling the upper left CCD. The bright companion galaxy (upper right CCD) is North-East of 3C382. The image covers 2.5 arcminutes.

**Figure 2a:**
HRI surface brightness profile of 3C 382 before de-speckling. Points with error bars (Poissonian noise) are the data. Dashed line is the HRI PRF; the continuum line is the PRF plus background. The background level is measured in an annulus between 3 to 5 arcmin from the center (flat part of the profile). The residuals between the data and the PRF+background are shown below. Note the large departure from a point source profile due to incorrect attitude reconstruction of the ROSAT data (see text).

**Figure 2b:**
HRI surface brightness profile of 3C 382 after de-speckling. The interpretation of the figure is as in Fig. 2a.

**Figure 2c:** The same as in Fig 2b but in this case the continuum line is the model fit to the surface brightness profile using a combination of an unresolved component represented by the HRI PRF (dash) and an extended component represented by a $\beta$ model (dots). The reduced $\chi^2$ of the fit is 1.7-2 over 35 degrees of freedom (d.o.f.).

**Figure 3:**
Observed and best-model fit to the PSPC spectrum of 3C 382. PSPC data are from Prieto (1996). The dotted line represents the thermal 0.6-keV component; the dashed line, the power-law $\alpha = -0.7$ component. Residuals represent 1-$\sigma$ errors. The first two bins corresponding to energies $\simeq 0.1\text{keV}$ are not included in the fit.
Table 1: ROSAT results for 3C 382

| Data   | Model                  | $\alpha$ | KT (keV) | $N(H)$ $10^{21}$cm$^{-2}$ | $\chi^2$/ndf | Flux $10^{-11}$erg cm$^{-2}$ s$^{-1}$ |
|--------|------------------------|----------|----------|-----------------------------|--------------|-----------------------------------|
| PSPC   | brems                  | -        | 1.4 ± 0.4| 0.59±0.01                  | 1.05/29      | 3.7 ± 0.5                         |
| PSPC   | power-law              | −1.2±0.26| -        | 0.79±0.10                  | 1.16/29      | 4.5 ± 0.2                         |
| PSPC   | power-law+brems        | −0.7     | 0.65$^{+0.4}_{-0.1}$| 0.78                   | 1.23/29      | $2.5^{+1.5}_{-0.8} + 2^{+1.8}_{-0.7}$ |
| HRI    | unresolved+extended    | −0.7     | 0.6      | 0.78                        | -            | $5.8 \pm 0.6 + 1. \pm 0.7$       |

Flux is in the 0.2–2.4 keV range and is absorption corrected. Errors are 1 sigma correlated errors for one interesting parameter. Errors in the HRI fluxes only reflect the uncertainty in the extracted number counts to be about 15% and 50% for the unresolved and extended component respectively. The Galactic column density is 0.78 $10^{21}$ cm$^{-2}$. The PSPC count-rate is $\sim 2$ cts s$^{-1}$ (total PSPC counts= 1743), for the HRI is $\sim 1$ cts s$^{-1}$. Single power-law model results are from Prieto (1996).
