A Deep XMM–Newton Serendipitous Survey of a middle–latitude area

G. Novara1, N. La Palombara1, N. Carangelo1,2, A. De Luca1, P. A. Caraveo1,3, R. P. Mignani4, G. F. Bignami3,5,6

1 INAF/IASF-Milano, via Bassini 15, I–20133 Milano (I)
2 Università di Milano–Bicocca, Piazza della Scienza 3, I–20126 Milano (I)
3 Centre d’Étude Spatiale des Rayonnements (CESR), CNRS–UPS, 9 Avenue du colonel Roche, F–31028 Toulouse (F)
4 European Southern Observatory, Karl Schwarzschild Strasse 2, D–85740 Garching (D)
5 Università di Pavia, Dipartimento di Fisica Teorica e Nucleare, Via Ugo Bassi 6, I–27100 Pavia (I)
6 INFN - Sezione di Pavia, Via Ugo Bassi 6, I–27100 Pavia (I)

Received / Accepted

Abstract. The radio quiet neutron star 1E1207.4-5209 has been the target of a 260 ks XMM–Newton observation, which yielded, as a by product, an harvest of about 200 serendipitous X–ray sources above a limiting flux of $2\times10^{-15}$ erg cm$^{-2}$ sec$^{-1}$, in the 0.3-8 keV energy range. In view of the intermediate latitude of our field ($|b|\simeq10^\circ$), it comes as no surprise that the log$N$–log$S$ distribution of our serendipitous sources is different from those measured either in the Galactic Plane or at high galactic latitudes. Here we shall concentrate on the analysis of the brightest sources in our sample, which unveiled a previously unknown Seyfert–2 galaxy.

Key words. Galaxies: Seyfert – X–rays: general

1. Introduction

The radio quiet neutron star 1E1207.4-5209 has been the target of a 260 ks XMM–Newton observation (De Luca et al. 2004). Such an observation ranges amongst the longest ever performed by XMM–Newton and, as of today, is certainly the longest one at intermediate galactic latitude (i.e. $|b|\simeq10^\circ$).

The deepest X–ray surveys performed, such as the Chandra Deep Field South (Giacconi et al. 2001; Rosati et al. 2002; Giacconi et al. 2002) and North (Brandt et al. 2001), as well as the XMM Lockman Hole survey (Hasinger et al. 2001; Mainieri et al. 2002), encompass only high latitude regions, where serendipitous surveys were also performed (Barcons et al. 2002; Della Ceca et al. 2004). On the other hand, X–ray studies of the galactic population have been performed only along the Galactic Plane: shallow, wide–field surveys were obtained by ROSAT (Motch et al. 1998; Morley et al. 2001) and XMM–Newton (Hands et al. 2004), while deep, pencil–beam observations of the Galactic Center have been performed by CHANDRA (Muno et al. 2003).

Thus, our long observation at intermediate latitude appears to be well suited to address important issues such as the ratio between galactic and extragalactic contributors. The combination of the low flux limit, the wide energy band and the relatively low galactic latitude of this field has the potential for an extremely interesting mix of source types. Owing to the high–energy sensitivity of EPIC, we expect to see through the galactic disk to the distant population of QSOs, AGNs and normal galaxies. On top of such an extragalactic population, however, our field also samples in great depth our Galaxy. Here again the wide energy range allows to sample both hard and soft sources, e.g. population of X–ray binaries and normal stars.

Characterization of the sources’ X–ray spectra, as well as the search for their optical counterparts, are the classical tools to identify, either individually or on a statistical ground, our sample of relatively faint sources. Given the range of $f_x/f_{opt}$ values characteristic for the known classes of X–ray sources (Krautter et al. 1999), we ought to reach $V\simeq25$ in the optical follow–up in order to be able to identify the majority of our serendipitous sources. Thus, although useful for a first filtering, Digital Sky Surveys are not deep enough for our purpose and they do not provide an adequate color coverage.

A proposal for the complete optical coverage of the EPIC field at the 2.2 m ESO telescope has already been accepted. Waiting for its results, here we outline our detection technique as well as the global results of such an analysis. Next we shall focus on the analysis of the brightest sources leading to the spectral characterization of a serendipitously discovered Seyfert–2 galaxy.
While the pn data have been used by Bignami et al. (2003) and De Luca et al. (2004) to study the radio–quiet neutron–star 1E1207.4-5209, here we shall use the MOS data to assess the population of serendipitous sources emerging from this long galactic observation. For both cameras the thin filter was used.

The event files were processed with the version 5.4.1 of the XMM–Newton Science Analysis Software (SAS). After the standard processing pipeline, we looked for periods of high instrument background, due to flares of protons with energies less than a few hundred keV hitting the detector surface. Such soft proton flares enhance the background and the corresponding time intervals have to be rejected, reducing, accordingly, the good integration time. In our case, the effective observing time was $\sim 230$ ks over a total observing time of 260 ks.

2.2. Source detection

In order to maximize the signal–to–noise ratio (S/N) of our serendipitous sources and to reach lower flux limits, we ‘merged’ the data of the two cameras and of the two pointings. We performed the source detection in several energy ranges; first, we considered the two ‘classical’, coarse energy ranges 0.5–2 and 2–10 keV; then, we considered a finer energy division between 0.3 and 8 keV (since above 8 keV the instrument effective area decreases rapidly). For each energy band we generated the field image, the corresponding exposure map (to account for the mirror vignetting) and the relevant background map. The background maps were also corrected pixel by pixel, as described in Baldi et al. (2002), in order to reproduce the local variations.

We had also to take into account that the XMM–Newton image includes a region of diffuse emission characterized by more than 4 events/pixel (Fig. 1), due to the SNR G296.5+10.0. Therefore, we performed the source detection with an ‘ad hoc’ tuning of the parameters inside and outside the SNR area.

The source detection was based on the standard maximum detection likelihood criterium: for each source and each energy range we calculated a detection likelihood $L = -\ln P$, where $P$ is the probability that the source counts originate from a background fluctuation. We considered a threshold value $L_{th}=8.5$, corresponding to a probability $P_{th} = 2 \times 10^{-4}$. The actual sky coverage in the various energy ranges was calculated as described in Baldi et al. (2002): in Fig. 2 we show such a coverage for the two coarse energy ranges.

The number of spurious detections in each energy range, obtained multiplying $P$ times the number of independent (not overlapping) detection cells, is negligible. Indeed, in our detection procedure the area covered by each cell ranges between 0.16 and 0.35 square arcminutes (following the position dependent Point Spread Function size) so that the $\sim 700$ square arcmin EPIC field–of–view contains, at most, $5 \times 10^3$ detection cells. Thus the number of spurious detection is $P_{th} \times N \leq 1$. Since we performed the source detection in 6 independent energy bands, we expect the total number of spurious detected sources to be at most 6. Selecting all the sources with $L > 8.5$ in at least one of our energy ranges and matching those detected in several energy intervals we found a total of 196 sources (with a position accuracy of $\sim 5''$), 35 inside the area covered by the...
diffuse emission and 161 outside it. We detected 135 sources between 0.5 and 2 keV and 89 sources between 2 and 10 keV, at a flux limit of $1.3 \times 10^{-15}$ and $3.4 \times 10^{-15}$ erg cm$^{-2}$ s$^{-1}$, respectively; 68 of them were detected in both energy bands. In order to evaluate the flux of our sources, we assumed a template AGN spectrum, i.e. a power-law with photon–index $\Gamma=1.75$ and an hydrogen column density $N_{\text{H}}$ of $1.28 \times 10^{21}$ cm$^{-2}$, corresponding to the total galactic column density.

2.3. Log$N$–Log$S$ distribution

In Fig. 2 we show the cumulative log$N$–log$S$ distributions for the sources detected in the two energy ranges. For comparison, we have superimposed to our data the lower and upper limits of the log$N$–log$S$ measured by Baldi et al. (2002) for a survey at high galactic latitude ($|b| > 27^\circ$): they obtained the upper limit log$N$–log$S$ by applying the same detection threshold ($P_{\text{th}} = 2 \times 10^{-4}$) but a larger extraction radius, while the lower limit log$N$–log$S$ was obtained with the same extraction radius but a more constraining threshold value ($P_{\text{th}} = 2 \times 10^{-5}$). Moreover, in the same figure we have also reported the log$N$–log$S$ distributions, as well as the 90 % confidence limits, measured by CHANDRA in the galactic plane (Ebisawa et al. 2005).

In the soft energy band, the log$N$–log$S$ distribution of our sources is well above the high–latitude upper limit, especially at low X–ray fluxes. Even if the galactic column density represents an overestimate for the stellar population of our sample, we have checked that not all of such an excess can be ascribable to overcorrection for interstellar absorption arising from the use of the total galactic $N_{\text{H}}$ value. We note also that $\sim$ 60 % of the soft sources were not detected in the hard energy band. In the soft band, the galactic plane log$N$–log$S$ distribution (the red points) is much lower than the one at high latitudes, since a significant fraction of extra–galactic sources is not detected. Moreover, the same log$N$–log$S$ is also lower than the difference between our data and the distribution limits at high latitudes (the blue lines). Since Ebisawa et al. (2005) find that most of their soft sources are nearby X–ray active stars, it is possible that our excess over their distribution is due to additional, more distant galactic sources, which are missed looking at $b \sim 0^\circ$ but can be detected just outside the galactic plane.

In the hard energy band the distribution of our sources is in good agreement with both the high latitude and the galactic plane ones measured by XMM–Newton, CHANDRA and ASCA (Hands et al. 2004; Ebisawa et al. 2005). At energies $> 2$ keV we expect the galactic absorption to be negligible so that the extragalactic sources dominate the log$N$–log$S$ distribution at all galactic latitudes, with just a small contribution of the softer galactic sources.

3. Search for optical counterparts

In order to identify our serendipitous X–ray sources, we cross–correlated their positions with two optical catalogues, namely – the version 2.3 of the Guide Star Catalogue (GSC), not yet published, with limiting magnitudes $B_J \sim 23$ and $F \sim 22$, photometric accuracy of $\sim 0.25$ mag for $B_J$ and $\sim 0.2$ mag for $F$, and position errors $< 0.5^\prime$ (Chieregato et al. 2005).

Fig. 2. Sky coverage of the performed observation (top), in the energy ranges 0.5–2 keV (solid line) and 2–10 keV (dashed line), and log$N$–log$S$ distribution of the detected sources (black open squares) in the energy ranges 0.5–2 keV (middle) and 2–10 keV (bottom). The black solid lines trace the upper and lower limits obtained by Baldi et al. (2002) in the same energy ranges but at higher galactic latitudes; the blue dotted lines are the difference between our data and the Baldi et al. ones. The red filled squares and the red dashed lines represent, respectively, the distributions and the limits measured by CHANDRA in the galactic plane (Ebisawa et al. 2005).
– the United States Naval Observatory (USNO) catalogue \cite{Monet2003}, with limiting magnitudes \( V \sim 21, 0.2'' \) astrometric accuracy and \( 2.33'' \) magnitude to calculate a bremstrahlung model which includes also the element abundances); in all cases we included also the absorption by the interstellar medium, leaving it as a free parameter. For each emission model, we calculated the 90% confidence level error on both the hydrogen column density and the temperature/photon–index. In this way we found that 13 sources were best fitted by a power–law model, 2 by a bremsstrahlung model and 2 by a mekal model (Tab. 1). For 6 of the 7 remaining sources, at least two different models provided an acceptable fit with a comparable \( \chi^2 \); finally, for source #127 all the considered models gave unacceptable results.

The spectral parameters were used to compute the sources’ X–ray flux values, to be compared to the optical ones in the framework of the \( f_X / f_{opt} \) identification tool: for the 23 sources with at least one best–fit model we computed the X–ray flux based on the best–fit values, while for source #127 we assumed a power–law spectrum with photon–index \( \Gamma = 1.75 \) and a galactic hydrogen column density. On the optical side, we considered all the candidate counterparts found within 5'' radius X–ray error circles. In order to minimize the effect of the interstellar extinction, we used the \( F \) magnitude to calculate the source flux; for the X–ray sources with no counterpart, we used \( F=22 \) as the optical upper limit.

On the basis of both the spectral fits (\( N_{\text{H}} \) and best–fit models) and the X–ray–to–optical flux ratios of the possible counterparts, we can propose a firm classification only for 7 sources, i.e. 6 AGNs and 1 star. For 6 additional sources, the suggested classification (i.e. 4 AGNs and 2 stars) is affected by the best–fit value of the interstellar absorption, which is too low (for AGNs) or too high (for stars) in comparison with the galactic \( N_{\text{H}} \) \( 1.28 \times 10^{21} \) cm\(^{-2} \). In view of the large errors on the \( N_{\text{H}} \) best–fit values, however, we accept the proposed identification.
| SRC | RA (J2000) | DEC (J2000) | cts | Model | $N_H$ | $\Gamma/\Delta T$ | $\chi^2_{\nu}$ | $D_{2\sigma}$ | $F$ | $\log(F)$ | SUGGESTED CLAS |
|-----|-----------|-------------|-----|-------|------|-------------|-------------|----------|-----|---------|----------------|
| 1   | -52 30 30.6 | 4229 | 1.8 $^{+0.3}_{-0.2}$ | 1.95 $^{+0.12}_{-0.33}$ | 1.03 | 1.3, 3.1, 3.5 | 20.36, 20.34, 19.35, 19.46 | 1.39, 1.38, 0.99, 1.03 | AGN |
| 2   | -52 24 56.9 | 3848 | 0.7 $^{+0.4}_{-0.3}$ | 1.90 $^{+0.12}_{-0.13}$ | 1.17 | 1.5 | 20.00 | 0.90 | ? |
| 3   | -52 27 26.1 | 2388 | 1.3 $^{+0.5}_{-0.4}$ | 0.61 $^{+0.05}_{-0.03}$ | 1.42 | 1.8 | 10.53 | -3.20 | STAR |
| 4   | -52 28 16.8 | 1499 | 1.3 $^{+0.2}_{-0.1}$ | 2.00 $^{+0.17}_{-0.22}$ | 0.77 | 1.2 | 19.83 | 0.57 | AGN |
| 5   | -52 20 25.2 | 1332 | 0.8 $^{+0.6}_{-0.5}$ | 2.03 $^{+0.22}_{-0.24}$ | 1.47 | - | >22 | >1.49 | AGN (?) |
| 6   | -52 30 10.1 | 1109 | 2.1 $^{+0.2}_{-0.1}$ | 0.33 $^{+0.13}_{-0.13}$ | 1.40 | 1.8 | 13.82 | -2.21 | STAR (?) |
| 7   | -52 35 54.2 | 1056 | 0.9 $^{+0.6}_{-0.3}$ | 2.06 $^{+0.17}_{-0.19}$ | 1.25 | 1.2 | 19.06 | 0.29 | AGN (?) |
| 8   | -52 30 19.8 | 1000 | 0.5 $^{+0.5}_{-0.4}$ | 1.84 $^{+0.07}_{-0.28}$ | 0.91 | - | >22 | >1.26 | ? |
| 9   | -52 30 30.6 | 984 | 3.1 $^{+0.2}_{-0.1}$ | 0.30 $^{+0.14}_{-0.31}$ | 2.35 | 2.9 | 14.22 | -2.02 | ? |
| 10  | -52 21 26.6 | 927 | 0.1 $^{+0.4}_{-0.1}$ | 1.75 $^{+0.22}_{-0.22}$ | 1.01 | 3.1 | 18.9 | 0.14 | ? |
| 11  | -52 36 19.4 | 789 | 1.6 $^{+0.9}_{-0.4}$ | 1.80 $^{+0.24}_{-0.24}$ | 0.93 | 2.9, 3.3 | 17.26, 16.95 | -0.52, -0.64 | AGN |
| 12  | -52 27 06.5 | 769 | 1.8 $^{+1.0}_{-0.9}$ | 0.40 $^{+0.13}_{-0.13}$ | 1.01 | 3.7 | 15.42 | -1.81 | STAR (?) |
| 13  | -52 21 05.4 | 759 | 1.1 $^{+0.9}_{-0.9}$ | 2.02 $^{+0.49}_{-0.49}$ | 0.82 | 2.4, 4.8 | 17.27, 18.91 | -0.90, -0.24 | AGN (?) |
| 14  | -52 19 09.1 | 746 | 3.3 $^{+1.5}_{-1.0}$ | 0.27 $^{+0.12}_{-0.11}$ | 1.46 | 0.7 | 16.56 | -1.40 | ? |
| 15  | -52 30 06.8 | 738 | 6.9 $^{+2.2}_{-1.5}$ | 4.33 $^{+1.26}_{-0.37}$ | 1.03 | 1.6, 2.8, 3.7 | 19.83, 20.43, 18.67 | +0.58, +0.82, +0.11 | ? |
| 16  | -52 21 26.6 | 927 | 7.2 $^{+2.3}_{-1.6}$ | 1.95 $^{+1.23}_{-0.29}$ | 1.15 | 1.6, 2.8, 3.7 | 19.83, 20.43, 18.67 | +0.59, +0.83, +0.12 | ? |
| 17  | -52 36 19.4 | 789 | 5.8 $^{+1.9}_{-1.9}$ | 5.35 $^{+1.98}_{-1.98}$ | 1.15 | 1.6, 2.8, 3.7 | 19.83, 20.43, 18.67 | +0.55, +0.79, +0.09 | ? |
| 18  | -52 30 30.6 | 736 | 1.4 $^{+0.8}_{-0.6}$ | 2.39 $^{+0.40}_{-0.41}$ | 1.71 | - | >22 | >1.11 | AGN (?) |
| 19  | -52 30 10.1 | 736 | 1.4 $^{+0.7}_{-0.7}$ | 1.93 $^{+0.37}_{-0.37}$ | 1.09 | - | >22 | >1.22 | AGN |
| 20  | -52 33 25.2 | 736 | 1.4 $^{+0.8}_{-0.6}$ | 2.39 $^{+0.40}_{-0.41}$ | 1.71 | - | >22 | >0.26 | AGN |
| 21  | -52 35 14.3 | 674 | 3.4 $^{+1.2}_{-0.9}$ | 2.18 $^{+0.39}_{-0.35}$ | 0.54 | 1.2 | 19.72 | +0.26 | AGN |
| 22  | -52 25 24.2 | 749 | 0.8 $^{+0.9}_{-0.6}$ | 2.15 $^{+0.28}_{-0.29}$ | 0.91 | - | >22 | >0.90 | ? |
| 23  | -52 25 24.2 | 669 | 0.0 $^{+0.6}_{-0.4}$ | 3.20 $^{+0.81}_{-0.81}$ | 0.97 | - | >22 | >0.87 | ? |
| 24  | -52 25 24.2 | 669 | 0.2 $^{+0.3}_{-0.2}$ | 4.02 $^{+1.52}_{-1.01}$ | 0.99 | - | >22 | >0.91 | ? |
| 25  | -52 36 19.4 | 789 | 3.7 $^{+2.6}_{-1.2}$ | 3.13 $^{+1.72}_{-1.29}$ | 0.61 | - | >22 | >0.90 | ? |
| 26  | -52 30 30.6 | 650 | 3.7 $^{+2.6}_{-1.2}$ | 3.13 $^{+1.72}_{-1.29}$ | 0.61 | - | >22 | >0.90 | ? |
| 27  | -52 35 14.3 | 674 | 3.4 $^{+1.2}_{-0.9}$ | 2.18 $^{+0.39}_{-0.35}$ | 0.54 | 1.2 | 19.72 | +0.26 | AGN |
| 28  | -52 21 45.7 | 560 | - | - | - | 1.3 | 14.93 | -1.80 | ? |
| 29  | -52 25 36.8 | 548 | 3.8 $^{+1.6}_{-0.9}$ | 0.51 $^{+0.09}_{-0.13}$ | 1.68 | 1.6 | 11.77 | -3.39 | ? |
| 30  | -52 18 26.8 | 532 | 1.7 $^{+1.2}_{-0.7}$ | 1.92 $^{+0.93}_{-0.32}$ | 1.00 | - | >22 | >+1.00 | AGN |
4 additional sources (#190, 72, 198 and 231) are characterized both by a low temperature thermal spectrum and by a low X-ray–to–optical flux ratio, therefore it is probable that they are stars. Unfortunately they have a high $N_{\text{H}}$ value and, in 3 cases, also the emission model is uncertain, therefore the star identification can not be firmly established. For source #72 this classification would be supported also by the observed light curve (Fig. 4), which shows large but short flares and a flux variability with time–scales of a few hundred seconds.

We note that single component fitting can induce further uncertainty on the $N_{\text{H}}$ estimate. Indeed, stars do show two temperature spectra (actually coronal loop distributions) which, if fitted with a single temperature, would result in an overestimate of the $N_{\text{H}}$ values. AGNs, on the other hand, often have additional soft components which, for a pure power–law fit, would yield too low $N_{\text{H}}$ values. In view of the above uncertainties, we underline that the source classification proposed in Tab. 1 is only tentative.

Fig. 4. Light–curve of source #72, with a 1 ksec time binning.

Only the low $N_{\text{H}}$ value prevents to classify as AGNs 3 other sources (#183, 323 and 125), which are best fitted by a power–law spectrum with photon index $\sim2$ and have a rather high X-ray–to–optical flux ratio. The smooth variability observed for source #183, with a time–scale of $\sim 10^4$ s (Fig. 5), would also support an AGN identification.

For 3 sources with hard spectrum (#285, 181 and 294) it is not possible to distinguish between a power–law and a high temperature thermal emission model: with all models sources #285 and 294 show a high $N_{\text{H}}$ value, therefore they are probably extragalactic objects (either AGNs or clusters of galaxies). On the other hand, in all cases source #181 has a very low best–fit value of $N_{\text{H}}$, therefore it should be a galactic object, even if its nature can not be established.

Finally, source #127 has a very unusual spectrum and it will be discussed in detail in Sec. 5.

On the basis of the above results, we conclude that 8 sources over 23 (i.e. $\sim 35\%$) could belong to the Galaxy. Such a percentage is in agreement with the results obtained by previous ROSAT surveys which showed that the stellar content decreases from $\sim 85\%$ to $\sim 30\%$ moving from the galactic plane to the torus of dust around the AGN nucleus, $PL$ is the primary power–law modeling the nuclear component, $RC$ is the cold and optically thick reflection component and $GL$ is the Gaussian component that models the Fe line at 6.4 keV. For the $A_{\text{SP}}$, $A_T$, $R_C$ and $GL$ components the redshift value is fixed at $z=0.032$ (Visvanathan & van den Bergh 1992).

5. Source #127

The X–ray analysis yields 560 counts in the energy band 0.3–8 keV, with a signal–to–noise ratio of 14.64; its count rate in the total energy band is $2.03 \times 10^{-3}$ cts s$^{-1}$. The source spectrum cannot be described by a standard single–component emission model (Fig. 6): it is very hard and highly absorbed; moreover, it is also characterized by a feature at $\sim 6$ keV, ascribable to Fe emission line.

After the astrometric correction, the resulting X–ray position is $\alpha_{2000}=12^h4.8^m28.87^s$, $\delta_{2000}=52^\circ21'45.7''$. Searching the NED (Nasal/IPAC Extragalactic Database) we found the spiral galaxy ESO 217–G29, located at 1.28” from the X–ray source position. The magnitudes of ESO 217–G29 are $B_1=16.74$ and $F=14.93$ and its redshift is $z=0.032$ (Visvanathan & van den Bergh 1992). These parameters, together with the X–ray spectrum and the estimated X–ray–to–optical flux ratio, suggest that source #127 could be an AGN.

The source is located within the region of diffuse emission (Fig. 1), so its spectrum at low energies ($E<1$keV) is polluted by the supernova remnant. Thus we fit the source spectrum only above 1.2 keV. According to the AGN unification model (Antonucci 1993, Mushotzky et al 1993), the source spectrum $S$ has been described by the model

$$S = A_G[A_{\text{SP}}(R_W) + A_T(PL + RC + GL)]$$

where $A_G$ is the galactic absorption ($1.28 \times 10^{21}$ cm$^{-2}$), $A_{\text{SP}}$ is the absorption related to the galaxy hosting the AGN, $R_W$ is the warm and optically thin reflection component, $A_T$ is the absorption acting on the nuclear emission associated to the torus of dust around the AGN nucleus, $PL$ is the primary power–law modeling the nuclear component, $RC$ is the cold and optically thick reflection component and $GL$ is the Gaussian component that models the Fe line at 6.4 keV. For the $A_{\text{SP}}$, $A_T$, $R_C$ and $GL$ components the redshift value is fixed at $z=0.032$ (Visvanathan & van den Bergh 1992).
Table 2. Best-fit parameters for source # 127, for the optical redshift z=0.032 and for its best-fit value z=0.057.

| Component | Parameter | z=0.032 (fix) | z=0.057 |
|-----------|-----------|---------------|---------|
| $A_{SP}$  | $N_{H}^1$ | $2.26^{+1.10}_{-1.14}$ | $2.39^{+0.84}_{-1.14}$ |
| $R_{W}$   | $\Gamma$  | 1.9 (fixed)   | 1.9 (fixed) |
| Flux @ 1 keV$^b$ | $\chi^2$ | $6.4^{+1.81}_{-1.26}$ | $6.4^{+2.00}_{-1.26}$ |
| $A_{G}$   | $N_{G}^1$ | $75.8^{+19.10}_{-24.23}$ | $82.3^{+18.69}_{-24.23}$ |
| $P_{L}$   | $\Gamma$  | 1.9 (fixed)   | 1.9 (fixed) |
| Flux @ 1 keV$^c$ | $\chi^2$ | $1.93^{+0.80}_{-0.80}$ | $1.98^{+0.71}_{-0.71}$ |
| $R_{C}$   | $\Gamma$  | 1.9 (fixed)   | 1.9 (fixed) |
| Flux @ 1 keV$^c$ | $\chi^2$ | $1.93^{+0.80}_{-0.80}$ | $1.98^{+0.71}_{-0.71}$ |
| $G_{L}$   | $E_{line}$ (keV) | $1.26^{+1.26}_{-1.26}$ | $2.33^{+2.42}_{-1.80}$ |
| $x_{line}$ | $\chi^2$ | $185^{+325}_{-205}$ | $311^{+196}_{-322}$ |

$^a$ $10^{22}$ cm$^{-2}$
$^b$ $10^{-6}$ ph cm$^{-2}$ s$^{-1}$ keV$^{-1}$
$^c$ $10^{-4}$ ph cm$^{-2}$ s$^{-1}$ keV$^{-1}$
$^d$ $10^{-6}$ ph cm$^{-2}$ s$^{-1}$

The best-fit parameters, listed in Tab.2, provide an acceptable fit, yielding $\chi^2=1.143$ with 32 d.o.f.; the value of $N_{H_{2}}$ implies that the torus around the AGN is Compton-thin. However, this model does not describe satisfactorily the prominent Fe line, since it assigns an energy of 6.2 keV to the line centroid (red solid line in Fig.6), while in the accumulated spectrum the line is centered around 6.0 keV; moreover, the line significance is marginal.

Leaving the $z$ value as a free parameter, we obtain a better fit ($\chi^2=1.035$ with 31 d.o.f) for $z=0.057^{+0.009}_{-0.016}$ quite different, although consistent at 2 $\sigma$ level, with the optical value; moreover, the line is significant at 90 % confidence level. Using the F-test, the improvement with respect to the previous fit based on the optical redshift is significant at 95% confidence level. In Tab.2 we report the best-fit parameters of both fits. As a further check, we applied also the Cash statistics to the XSPEC fit and we obtained the same results: $z=0.057$ and a normalization of $2.26^{+2.14}_{-1.24}$ for the iron line. If we compare the source spectrum with the best-fit model (blue dotted line in Fig.6), we note that the Fe line is modelled more accurately and is centered around 6.0 keV.

The discrepancy between the X-ray and optical redshift values could be explained by the relativistic broadening of the Fe line. Recently, the rest-frame spectra of several sources detected in the XMM–Newton survey of the Lockman hole showed a relativistically broadened iron line (Streblyanska et al. 2003). Owing to the Compton-thin nature of our source, it is possible that we are observing the same phenomenology. This would explain why the best-fit redshift overcomes the cosmological one. We investigated this possibility by modelling the Fe line with a relativistic line ($RL$) from an accretion disc. To this aim we replaced the Gaussian component of our model with either a laor (Laor 1991) or a diskline (Fabian et al. 1989) component $^4$, leaving $z=0.032$ for the other components. We fixed the emissivity index $\beta$ to 3 and to -2 for the laor and the diskline case, respectively; moreover, in both cases we fixed the line energy to 6.4 keV and the disc inclination angle $i$ to 30$^\circ$, which is near the best-fit value found by Streblyanska et al. (2003).

In both cases the best-fit model traces rather well the Fe line (Fig.6) and provides an acceptable fit, yielding $\chi^2=1.034$ and 1.087 for the laor and the diskline component, respectively. For both models we find that the relativistic component is significant at 90 % confidence level. However, the disc inner and outer radii values are too small (i.e. a few $R_{g}$) and their difference is not significant. Moreover, only for the laor component the line EQW is comparable to the value of $\sim$0.4 keV found by Streblyanska et al. (2003), while it is significantly larger ($\sim$1 keV) for the diskline. Since these parameters are affected by large errors, due to the low count statistics, we conclude that the iron line position can be reconciled with the redshift of the proposed optical counterpart ESO 217-G29.

---

Fig. 6. Top: comparison of the unbinned spectrum of source #127 with the best-fit model, in the case of both redshift fixed at $z=0.032$ (red solid line) and of best-fit value $z=0.057$ (blue dotted line). Bottom: data - model residuals (in $\sigma$) for the two above models.

Fig. 7. Top: comparison of the unbinned spectrum of source #127 with the best-fit model and $z=0.032$, in the case of both a laor (red solid line) and a diskline (blue dotted line) model for the Fe line. Bottom: data - model residuals (in $\sigma$) for the two above models.

$^4$ respectively, laor and diskline in XSPEC
The 2–10 keV unabsorbed flux of the primary nuclear component is $5.79 \pm 1.11 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$ (calculated with XSPEC). Such a flux value, together with the optical magnitude, implies that $f_X/f_{opt}=0.41$, i.e. well within the AGN range (Krautter et al. 1999). The X–ray luminosity of the source in the 2–10 keV energy band, corrected by the absorption and with the redshift at 0.032, is $2.59 \pm 1.07 \times 10^{42}$ erg s$^{-1}$, corresponding to a low luminosity Seyfert galaxy.

Thus, the X–ray spectrum, together with the best–fit value of $N_{H2}$ and the nature of the optical candidate counterpart led us to propose that source #127 could be a new, low–luminosity Seyfert–2 galaxy discovered serendipitously in our field.

6. Summary and conclusions

The longest XMM–Newton observation at low galactic latitude yielded a sample of 135 sources between 0.5 and 2 keV and of 89 sources between 2 and 10 keV, with limiting fluxes of $1.3 \times 10^{-15}$ and $3.4 \times 10^{-15}$ erg cm$^{-2}$ s$^{-1}$, respectively. The log$N$–log$S$ distribution of the hard sources is comparable to that measured at high galactic latitudes, thus suggesting that it is dominated by extragalactic sources. On the other hand, at low fluxes the distribution of the soft sources shows an excess above both the Galactic Plane and the high–latitude distributions: we consider this result as a strong indication that we observed a sample of both galactic and extragalactic sources.

We analysed the 24 brightest sources and proposed an identification for $\sim 80$ % of them. Moreover, the detailed spectral investigation of one unidentified source, characterized by a highly absorbed spectrum and an evident Fe emission line, led us to classify it as a new Seyfert–2 galaxy.

The full X–ray characterization of all the sources, as well as their classification, based on ad hoc optical observations, will be discussed in future papers.

Acknowledgements. We are grateful to K. Ebisawa for providing us the log$N$–log$S$ data of the Chandra observation of the galactic plane. We wish to thank the referee for his useful comments, which improved the presentation of our results. We also thank S. Molendi and A. Tiengo for their suggestions and stimulating discussions. This work is based on observations obtained with XMM–Newton, an ESA science mission with instruments and contributions directly funded by ESA Member States and NASA. The XMM–Newton data analysis is supported by the Italian Space Agency (ASI). ADL acknowledges an ASI fellowship. GN acknowledges a ‘G. Petrocchi’ fellowship of the Osio Sotto (BG) city council. The Guide Star Catalog used in this work was produced at the Space Telescope Science Institute under U.S. Government grant. These data are based on photographic data obtained using the Oschin Schmidt Telescope on Palomar Mountain and the UK Schmidt Telescope. This research has made use of the USNOOF Image and Catalogue Archive operated by the United States Naval Observatory at the Flagstaff Station (http://www.nofs.navy.mi/data/chpix/) and of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

References

Antonucci, R. 1993, ARA&A, 31, 473
Baldis, A., Molendi, S., Comastri, A., et al. 2002, ApJ, 564, 190
Barcons, X., Carrera, F. J., Watson, M. G., et al. 2002, A&A, 382, 522
Bignami, G. F., Caraveo, P. A., Luca, A. D., & Mereghetti, S. 2003, Nature, 423, 725
Brandt, W. N., Alexander, D. M., Hornschemeier, A. E., et al. 2001, AJ, 122, 2810
Chieregato, M., Campana, S., Treves, A., et al. 2005, A&A accepted astro-ph/0505292
De Luca, A., Mereghetti, S., Caraveo, P. A., et al. 2004, A&A, 418, 625
Della Ceca, R., Maccacaro, T., Caccianiga, A., et al. 2004, A&A, 428, 383
Ebisawa, K., Tsujimoto, M., Paizis, A., et al. 2005, ApJ accepted astro-ph/0507185
Fabian, A. C., Rees, M. J., Stella, L., & White, N. E. 1989, MNRAS, 238, 729
Giacconi, R., Rosati, P., Tozzi, P., et al. 2001, ApJ, 551, 624
Giacconi, R., Zirm, A., Wang, J., et al. 2002, ApJS, 139, 369
Hands, A. D. P., Warwick, R. S., Watson, M. G., & Helfand, D. J. 2004, MNRAS, 351, 31
Hasinger, G., Altieri, B., Arnaud, M., et al. 2001, A&A, 365, L45
Krautter, J., Zickgraf, F.-J., Appenzeller, I., et al. 1999, A&A, 350, 743
Laor, A. 1991, ApJ, 376, 90
Mainieri, V., Bergeron, J., Hasinger, G., et al. 2002, A&A, 393, 425
Monet, D. G., Levine, S. E., Canzian, B., et al. 2003, AJ, 125, 984
Morley, J. E., Briggs, K. R., Pye, J. P., et al. 2001, MNRAS, 326, 1161
Motch, C., Guillout, P., Haberl, F., et al. 1998, A&AS, 132, 341
Muno, M. P., Baganoff, F. K., Bautz, M. W., et al. 2003, ApJ, 589, 225
Mushotzky, R. F., Done, C., & Pounds, K. A. 1993, ARA&A, 31, 717
Rosati, P., Tozzi, P., Giacconi, R., et al. 2002, ApJ, 566, 667
Severgnini, P., Della Ceca, R., Baito, V., et al. 2005, A&A, 431, 87
Strüder, L., Briel, U., Dennerl, K., et al. 2001, A&A, 365, L18
Streblyanska, A., Hasinger, G., Finoguenov, A., et al. 2005, A&A, 432, 395
Turner, M. J. L., Abbey, A., Arnaud, M., et al. 2001, A&A, 365, L27
Viswanathan, N. & van den Bergh, S. 1992, AJ, 103, 1057
Zickgraf, F.-J., Engels, D., Hagen, H.-J., Reimers, D., & Voges, W. 2003, A&A, 406, 535