

A swan song: the disappearance of the nucleus of NGC 4051 and the echo of its past glory

M. Guainazzi,¹ F. Nicastro,^{2,3} F. Fiore,^{3,4} G. Matt,⁵ I. McHardy,⁶ A. Orr,¹ P. Barr,¹
A. Fruscione,⁷ I. Papadakis,⁸ A. N. Parmar,¹ P. Uttley,⁶ G. C. Perola⁵ and L. Piro²

¹*Astrophysics Division, Space Science Department of ESA, ESTEC, Postbus 299, 2200 AG Noordwijk, the Netherlands*

²*Istituto di Astrofisica Spaziale, CNR, Via Fosso del Cavaliere, I-00133 Roma, Italy*

³*Osservatorio Astronomico di Roma, Via dell'Osservatorio 5, I-00040 Monteporzio Catone, Italy*

⁴*BeppoSAX Science Data Center, Via Corcolle 19, I-00131 Roma, Italy*

⁵*Dipartimento di Fisica 'E. Amaldi', Università degli Studi Roma 3, Via della Vasca Navale 84, I-00146 Roma, Italy*

⁶*Department of Physics & Astronomy, University of Southampton, University Road, Southampton SO17 1BJ*

⁷*Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS-70, Cambridge, MA 02138, USA*

⁸*Skinakas Observatory, Physics Department, University of Crete, Heraklion, Crete, Greece*

Accepted 1998 August 10. Received 1998 August 10; in original form 1998 June 19

ABSTRACT

On 1998 May 9–11, *BeppoSAX* observed the low-luminosity Seyfert 1 galaxy NGC 4051 in an ultra-dim X-ray state. The 2–10 keV flux (1.26×10^{-12} erg cm⁻² s⁻¹) was about 20 times fainter than its historical average value, and remained steady along the whole observation (~ 2.3 d). The observed flat spectrum ($\Gamma \approx 0.8$) and intense iron line (EW ≈ 600 eV) are best explained by assuming that the active nucleus has switched off, leaving only a residual reflection component visible.

Key words: galaxies: individual: NGC 4051 – galaxies: Seyfert – X-rays: galaxies.

1 INTRODUCTION

X-ray spectra of Seyfert galaxies above a few keV are dominated by two components: a power law (hereinafter ‘primary’) component emitted very close to the black hole, and a secondary (hereinafter ‘reflection’) component arising from the reprocessing of the primary radiation by neutral, optically thick matter (Pounds et al. 1990; Piro, Yamauchi & Matsuoka 1990). The reflection component, produced by a Compton scattering, forms a broad hump peaking at about 30 keV, and an intense iron K α fluorescent line at 6.4 keV (Lightman & White 1988; George & Fabian 1991; Matt, Perola & Piro 1991). While in many Seyfert 1s at least part of the reprocessing occurs in the inner accretion disc, as indicated by the observed relativistic effects in the iron line profile (Tanaka et al. 1995; Nandra et al. 1997), a further reprocessed component can arise if the nucleus is surrounded by any large amount of distant, optically thick and neutral matter (Krolik, Madau & Zycki 1994; Ghisellini, Haardt & Matt 1994), such as the ‘torus’ expected in the unification scenario (Antonucci & Miller 1985; Antonucci 1993) or the dust lanes visible in the high-resolution optical images of Seyfert galaxies (Malkan, Varoujan & Tam 1998; Maiolino et al. 1998). While the reflection component from the accretion disc should lag the primary emission by minutes or hours at most, the lag introduced by the distant reflector is probably of the order of at least weeks. Indeed there is evidence for a non-varying hard spectral component and iron line flux in *RXTE* observations of a number of Seyfert galaxies, despite variations by a factor of several of the

primary continuum flux (McHardy, Papadakis & Uttley 1998; Uttley et al. 1998). If the active nucleus suddenly switches off, the reflection component would then continue echoing the primary component for some time, remaining for a while the only witness of the past activity of the active nucleus. We have observed what could be precisely this situation in the nearby ($z = 0.0023$), low-luminosity ($\langle L_{2-10 \text{ keV}} \rangle \sim 5 \times 10^{41}$ erg s⁻¹) Seyfert 1 galaxy NGC 4051. *BeppoSAX* observed the source on 1998 May 9–11 and measured a constant flux along the whole observation (≈ 2.3 d), which was a factor of five lower than the faintest state ever observed (which lasted only a few thousand seconds, Uttley et al. 1998). A contemporaneous and longer *EUVE* observation suggests that the faint state lasted for at least one week (Fruscione et al., in preparation). The spectrum above a few keV is completely dominated by a ‘bare’ reflection component and implies a luminosity of the primary nuclear component $L_{\text{nuc}} < 0.14 \times 10^{41}$ erg s⁻¹. This is the first detection of such a dramatic and long-lasting fading in luminosity from NGC 4051, and provides some of the first *direct* evidence for the presence of large amounts of circumnuclear cold, thick matter in the environment of a Seyfert 1.

2 DATA REDUCTION

NGC 4051 was observed by the Italian–Dutch satellite *BeppoSAX* (Boella et al. 1997a) from 1998 May 9 09:56:44 UTC, to 1998 May 11 18:05:06 UTC. In this paper, data from the imaging instruments (Low-Energy Concentrator Spectrometer, LECS, Parmar et al.

Table 1. Best-fitting parameters for the 1998 May observation. Errors correspond to $\Delta\chi^2 = 2.7$. The iron line energy is given in the source rest frame.

#	Model	Γ	E_c^1 (keV)	σ^1 (eV)	EW ¹ (eV)	E_c^2 (keV)	σ^2 (eV)	EW ¹ (eV)	χ^2/dof
1	PO	$0.76^{+0.17}_{-0.15}$							85.0/35
2	PO+BL	$0.75^{+0.21}_{-0.17}$	$6.52^{+0.17}_{-0.09}$	160^{+270}_{-160}	1400 ± 500				44.1/32
3	PO+CR+BL	1.9^\dagger	$6.50^{+0.09}_{-1.46}$	< 6000	600^{+300}_{-200}				43.6/32
4	CR	$1.94^{+0.18}_{-0.14}$							56.8/35
5	CR+NL	$1.92^{+0.19}_{-0.15}$	$6.49^{+0.10}_{-0.09}$	0^\dagger	600^{+300}_{-200}				38.4/33
6	CR+BL	$1.92^{+0.20}_{-0.15}$	$6.50^{+0.12}_{-0.10}$	100^{+220}_{-100}	600^{+300}_{-200}				37.4/32
7	CR+BL+BL	$1.92^{+0.18}_{-0.09}$	6.4^\dagger	< 150	600^{+300}_{-200}	7.1^\dagger	$\equiv \sigma^1$	400 ± 300	33.6/32

[†] fixed

Notes: PO is a power law, CR is the ‘bare’ Compton reflection continuum, NL is a narrow Gaussian emission line, BL a Gaussian emission line in which the intrinsic width is left as a free parameter. Photoelectric absorption with $N_H = N_{H_{\text{Gal}}} \equiv 1.3 \times 10^{20} \text{ cm}^{-2}$ has been added to all the models above, except for model # 3, for which $N_H = (2.9 \pm 0.9) \times 10^{24} \text{ cm}^{-2}$. In model # 3 the relative normalization between the primary and Compton reflected component has been held fixed to 1.

1997; Medium-Energy Concentrator Spectrometer, MECS, Boella et al. 1997b), and from the collimated Phoswich Detector System (PDS, Frontera et al. 1997) are presented. Cleaned and linearized event files have been obtained with the reduction software package SAXDAS (version 1.3.0), using standard screening criteria (see e.g. Matt et al. 1997). The PDS data have been further screened with a temperature-dependent rise-time threshold, which allows a reduction of ≈ 50 per cent in instrumental background. The total net exposure times are 55.9, 69.2 and 33.0 ks for the LECS, MECS and PDS, respectively.

In the following, uncertainties are quoted at the 90 per cent confidence level for one interesting parameter ($\Delta\chi^2 = 2.71$); energies are in the source rest frame; $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ is assumed throughout.

3 SPECTRAL ANALYSIS

LECS (MECS) spectra have been extracted in circular regions of 4 (2) arcmin and rebinned in order to have at least 3 (2) energy channels per resolution element. Background spectra from blank sky fields and response matrices publicly available at the *BeppoSAX* Science Data Center (SDC, 1997 September release) have been employed throughout. PDS spectra have been obtained by subtraction of the ‘off-source’ from the ‘on-source’ intervals. The net count rates are $(1.12 \pm 0.05) \times 10^{-2} \text{ s}^{-1}$ in the LECS (0.1–4 keV), $(1.09 \pm 0.04) \times 10^{-2} \text{ s}^{-1}$ in the MECS (1.8–10.5 keV) and $0.123 \pm 0.027 \text{ s}^{-1}$ in the PDS (13–50 keV). No variability is observed both in the 0.1–3 and 3–10 keV energy bands, contrary to the factors of up to 50 typically observed in various X-ray energy bands (McHardy et al. 1995; Guainazzi et al. 1996; Uttley et al. 1998; Fruscione et al., in preparation).

A fit of the 1.8–10.5 keV MECS spectrum alone with a simple power-law model, absorbed through a column of neutral hydrogen with $N_H = N_{H_{\text{Gal}}} = 1.3 \times 10^{20} \text{ cm}^{-2}$ (Elvis, Lockman & Wilkes 1989), yields a very poor fit [$\chi^2 = 99/36$ degrees of freedom (d.o.f.)]. The main contribution to the residuals is the result of a large emission feature at ≈ 6.4 keV. Adding a Gaussian profile to the continuum significantly improves the quality of the fit ($\Delta\chi^2 = 46$). Best-fitting parameters are: photon index $\Gamma = 0.78^{+0.37}_{-0.13}$, line centroid $E_c = 6.57^{+0.16}_{-0.13}$ keV, line Gaussian dispersion $\sigma = 0.3 \pm 0.3$ keV, line equivalent width $\text{EW} = 1.9^{+0.9}_{-0.5}$ keV. The 2–10 keV flux is $\approx 1.4 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-2}$. Despite the approximate nature of the spectral description, three points are evident: (a) *BeppoSAX* observed NGC 4051 in an ultra-dim state, with a 2–10 keV flux about a factor of 20 fainter than its historical average

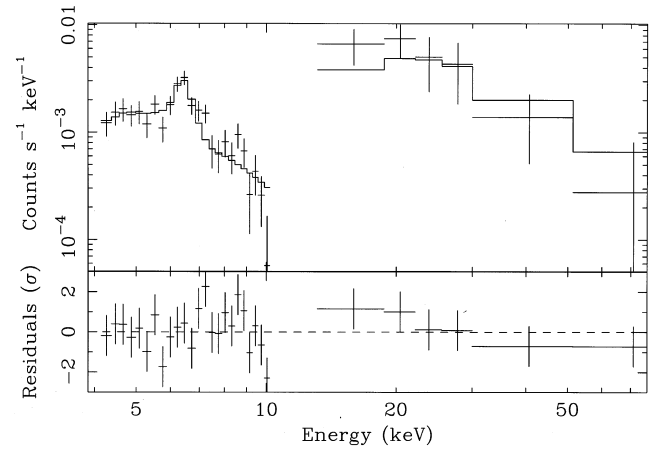


Figure 1. MECS and PDS spectra (upper panel) and residuals in units of standard deviations (lower panel) when a ‘bare’ Compton reflection continuum model + Gaussian line model is applied.

(see Section 4); (b) the intermediate X-ray spectrum is much flatter than in any previously reported observation (see e.g. Fiore et al. 1992; Mihara et al. 1994; Guainazzi et al. 1996) or in any other Seyfert 1 galaxy; (c) the iron line EW is several times higher than typically observed in Seyfert 1s in their ‘normal’ state (Nandra & Pounds 1994; Nandra et al. 1997) and in NGC 4051 in particular (Mihara et al. 1994; Guainazzi et al. 1996).

These pieces of evidence suggest that the primary nuclear emission has switched off, leaving the Compton reflection component (along with the iron fluorescent line) as an echo of past activity. We therefore fitted the MECS (above 4 keV) and PDS spectra with a ‘bare’ reflection component only, plus a Gaussian. We used the XSPEC model PEXRAV, assuming an inclination of 0° , solar abundances, and no high-energy cut-off in the intrinsic power law; such assumptions do not substantially affect the following results.

This model yields a significantly better fit ($\chi^2_\nu = 1.17$) than the ones in which the continuum is fitted with a simple power law ($\chi^2_\nu = 1.38$), or with a strongly absorbed ($N_H \sim 3 \times 10^{24}$) Seyfert-like ($\Gamma \equiv 1.9$) power law + reflection from a plane-parallel infinite slab ($\chi^2_\nu = 1.36$), which both significantly underestimate the PDS counts below 30 keV. Table 1 summarizes the best-fitting results. The spectral index of the illuminating (but now invisible) power law ($\Gamma \approx 1.92$, see Fig. 1) turns out to be perfectly consistent with the typically observed value for NGC 4051 (see Guainazzi et al. 1996 and references therein). The 2–10 keV flux (luminosity) as

inferred from the best fit is $(1.26 \pm 0.06) \times 10^{-12}$ erg cm $^{-2}$ s $^{-1}$ ($[2.84 \pm 0.14] \times 10^{40}$ erg s $^{-1}$). The 90 per cent upper limit on the 1-keV relative normalization between the primary and reflected continua is ≈ 2 per cent. This implies a nuclear flux decrease of at least a factor of 35 in 1.5 yr, if compared with the average measured in the latest *RXTE* long-look pointing (Uttley et al. 1998). Alternatively, a column density of at least 1.4×10^{26} cm $^{-2}$ is needed, if the fading is the result of absorption rather than a switch-off of the primary continuum.

The line centroid energy is consistent with fluorescence from neutral or mildly ionized iron ($E_c = 6.50 \pm_{0.10}^{0.12}$ keV), with an EW ≈ 600 eV. The width of the line is unconstrained, the 90 per cent upper limit on σ being an inconclusive 320 eV. However, some residuals in the blue wing of the line may suggest a line blending. Adding a further narrow emission line improves the quality of the fit only at a 93.7 per cent confidence level. If we assume that an iron K_α/K_β pair is produced in the same medium (and therefore with the same intrinsic width), the best-fitting ratio of the K_β/K_α intensities is $0.5 \pm_{0.4}^{0.2}$, higher than, albeit not formally inconsistent with, the theoretically expected value (≈ 11 per cent). Interestingly enough, the line flux ($I \approx 1.0 \times 10^{-5}$ photon cm $^{-2}$ s $^{-1}$) is only a factor of 3 lower than that observed by *ASCA* (Guainazzi et al. 1996) or *RXTE* (Uttley et al. 1998) in NGC 4051 ‘normal’ states. This shows that a substantial contribution to the iron line is likely *not* to be produced in the immediate vicinity of the black hole, as previously suggested by Guainazzi et al. (1996) and Uttley et al. (1998).

A prominent excess above the extrapolation of the hard X-ray best fit is evident below 4 keV. A detailed spectral description of the soft X-ray spectrum is beyond the scope of this letter, and is deferred to a forthcoming paper. We note only that if a simple power-law model is added to the model CR+BL in Table 1, the soft X-ray spectral index turns out to be $\Gamma_{\text{soft}} = 3.0 \pm_{0.3}^{0.2}$, totally inconsistent with the intrinsic spectral index of the primary nuclear emission ($\Gamma_{\text{primary}} = 1.75 \pm_{0.15}^{0.18}$, $\chi^2 = 116.9/93$ d.o.f.). There is no evidence of absorption edges and/or emission lines, the 90 per cent upper limit on the optical depths of the O VII or O VIII photo-absorption edges being 0.34 and 0.13, respectively. The 0.5–2 keV (0.1–2 keV) *observed* flux is ≈ 7.4 (12.1) $\times 10^{-13}$ erg cm $^{-2}$ s $^{-1}$, corresponding to an *unabsorbed* rest frame luminosity of 1.7 (7.0) $\times 10^{40}$ erg s $^{-1}$.

4 THE GLORIOUS PAST OF NGC 4051 (AND ITS HUMBLE PRESENT)

NGC 4051 is well known for exhibiting large X-ray flux variability on relatively short ($\sim 10^4$ s) time-scales (Lawrence et al. 1987; Matsuoka et al. 1990; Guainazzi et al. 1996; Uttley et al. 1998). *BeppoSAX* instead observed NGC 4051 in an ultra-dim and steady state for the whole ~ 2.3 d of the observation. The measured average 2–10 keV flux is more than one order of magnitude lower than any historical published flux (with the exception of a poorly constrained *EXOSAT* 1985 measure, see Fig. 2). The only comparable example of such a fading is the narrow line emission galaxy NGC 2992, which showed a flux decrease by a factor of ~ 20 in 16 yr (Weaver et al. 1996). This dramatic flux decrease is associated with an equally dramatic spectral change. In Fig. 3, we show the 4–50 keV best-fitting models as observed by *ASCA* (1994, Guainazzi et al. 1996) and *BeppoSAX*. In its ‘normal’ state, the NGC 4051 2–10 keV spectrum is dominated by a continuum with typical intrinsic spectral index of $\Gamma \approx 1.9$, to which a Compton reflection component is superimposed, flattening the spectrum above ≈ 7 –8 keV. This *BeppoSAX* observation is readily explained if the nucleus has

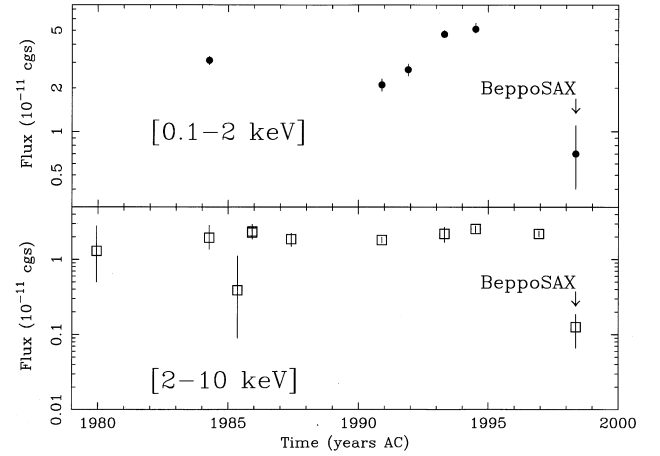


Figure 2. NGC 4051 historical 0.1–2 keV (upper panel) and 2–10 keV (lower panel) flux curves, obtained from the high-energy X-ray spectra catalogue of Malaguti, Bassani & Caroli 1994, except for the 1990 *ROSAT/Ginga* (Walter et al. 1994), 1991 *ROSAT* (McHardy et al. 1995), *ASCA* (1993, Mihara et al. 1994; 1994, Guainazzi et al. 1996) and *RXTE* long-look (Uttley et al. 1998) observations. The error bars represent the 1σ uncertainties on the *average* fluxes.

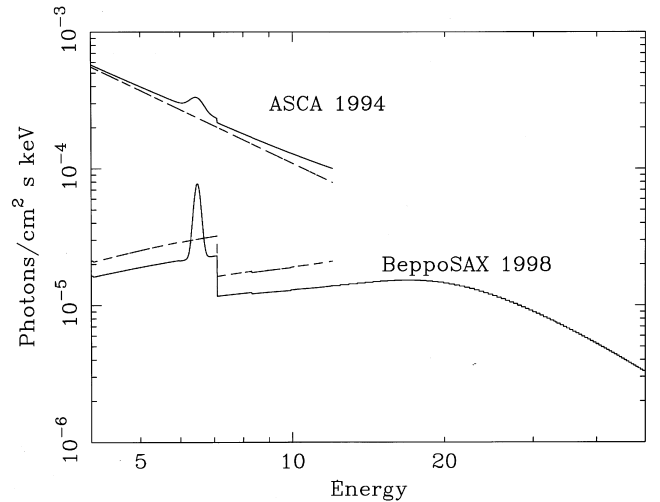


Figure 3. Best-fitting model for the 1996 *ASCA* and 1998 *BeppoSAX* observations. Solid lines mark the total spectra, while dashed lines the spectra components of the *ASCA* best-fitting continuum only (for which reflection from a plane-parallel infinite slab is assumed).

switched off, leaving the reflection component as the only witness of the past brightness. This interpretation is further supported by contemporaneous and even longer (May 8–15) *EUVE* (0.02–0.21 keV) monitoring, which caught NGC 4051 in a much fainter and more constant state than usual (Fruscione et al., in preparation). The implied decrease of the nuclear luminosity ($L_{\text{nuc}} < 0.14 \times 10^{41}$ erg s $^{-1}$) may be explained, if the accretion occurs through a disc, either by a proportional (to the luminosity) change in the accretion rate or by a smaller change, but one still sufficient to trigger a transition of the disc from a radiatively efficient Shakura–Sunayev disc to an inefficient advection-dominated flow. Alternatively, it may provide support for the idea that thermal–viscous hydrogen ionization disc instabilities play a major role in the onset of the AGN phenomenon, which could represent the ‘outburst’ phase of accretion from unstable discs (Burderi, King & Szuszkiewicz 1998).

The present, reflection-dominated X-ray spectrum of NGC 4051 closely resembles those observed in Compton-thick Seyfert 2 galaxies (Iwasawa & Comastri 1998; Iwasawa, Matt & Fabian 1997; Matt et al. 1996, 1997). In those cases, the nucleus is likely to be completely obscured rather than switched off, a possibility which cannot be formally excluded by present data. It requires that a cloud of at least $N_{\text{H}} > 1.4 \times 10^{26} \text{ cm}^{-2}$ has obscured the nuclear region in coincidence with the *BeppoSAX* pointing. It is not easy to imagine that such an amount of absorbing matter could be dynamically active and remain stable under the combined action of the gravitational and radiative pressures in an active nucleus environment. Therefore, the closest similarity occurs with our own Galactic Centre, where the reflection spectrum and the 6.4-keV fluorescent line from the SgrB2 molecular cloud have been interpreted as the signature of past activity in the now-quiet Galactic Centre (Sunayev, Markevitch & Pavlinsky 1993; Koyama et al. 1996; Sunayev & Churazov 1998).

The soft X-rays have undergone a decrease similar to the hard X-rays (see Fig. 2). The steepness of the spectrum, and the lack of any ‘warm absorber’ imprinting, strongly point against a nuclear origin for the soft X-rays. We are therefore likely to observe a ‘remnant’ of the faded nuclear activity, normally underlying the overwhelming primary continuum. The intrinsic 0.1–2 keV luminosity inferred by the present data is $\sim 7 \times 10^{40} \text{ erg s}^{-1}$, a luminosity high but not uncommon for a ‘normal’ galaxy. It is therefore possible that the dimming of the nucleus has left the Galactic components (supernovae winds, hot haloes) as the bulk of the observed soft X-rays. Alternatively, the observed soft X-rays could have the same origin as the extended (spatial scale ~ 100 pc) emission observed by the *ROSAT* HRI in NGC 4151 (Morse et al. 1995) and coinciding with the optical narrow-line emitting clouds. It was interpreted as thermal emission from a hot ($T \sim 10^7$ K) and low density ($n_e < 1 \text{ cm}^{-3}$) gas, in pressure equilibrium with the narrow-line region clouds. High energy and spatial resolution observations with *AXAF* or *XMM* could contribute to settling this issue.

ACKNOWLEDGMENTS

This paper has made use of the cleaned and linearized event files produced at the SDC. The authors acknowledge the whole staff of the SDC for the skillful management of the observations and the prompt and careful reduction of the data. We appreciate valuable suggestions from M. Elvis. MG and AO acknowledge an ESA Research Fellowship. GM and GCP acknowledge financial support from the Agenzia Spaziale Italiana. The *BeppoSAX* satellite is a joint Italian–Dutch programme.

REFERENCES

Antonucci R. R. J., 1993, *ARA&A*, 31, 473
 Antonucci R. R. J., Miller J. S., 1985, *ApJ*, 297, 621

- Boella G., Butler R. C., Perola G. C., 1997a, *A&AS*, 112, 299
 Boella G. et al., 1997b, *A&AS*, 112, 327
 Burderi L., King A. R., Szuszkiewicz E., 1998, *ApJ*, in press (astro-ph/9803224)
 Elvis M., Lockman F. J., Wilkes B. J., 1989, *AJ*, 97, 777
 Fiore F., Perola G. C., Matsuoka M., Yamauchi M., Piro L., 1992, *A&A*, 262, 37
 Frontera F., Costa E., Dal Fiume F., Feroci M., Nicastro L., Orlandini M., Palazzi E., Zavattini G., 1997, *A&AS*, 112, 357
 George I. M., Fabian A. C., 1991, *MNRAS*, 249, 352
 Ghisellini G., Haardt F., Matt G., 1994, *MNRAS*, 267, 743
 Guainazzi M., Mihara T., Otani C., Matusoka M., 1996, *PASJ*, 48, 781
 Koyama K., Maeda Y., Sonobe T., Takeshima T., Tanaka Y., Yamauchi S., 1996, *PASJ*, 48, 249
 Krolik J. H., Madau P., Zycki P. T., 1994, *ApJ*, 420, 57
 Iwasawa K., Comastri A., 1998, *MNRAS*, 297, 1219
 Iwasawa K., Matt G., Fabian A. C., 1997, *MNRAS*, 289, 443
 Lawrence A., Watson M. G., Pounds K. A., Elvis M., 1987, *Nat*, 325, 694
 Lightman A. P., White T. R., 1988, *ApJ*, 335, 57
 McHardy I. M. M., Green A. R., Done C., Puchnarewicz E. M., Mason K. O., Branduardi-Raymond G., Jones M. H., 1995, *MNRAS*, 273, 549
 McHardy I. M. M., Papadakis I. E., Uttley P., 1998, in Scarsi L., Bradt H., Giommi P., Fiore F., eds, *Proc. Symp. The active X-ray sky: first results from BeppoSAX and RXTE*. *Nucl. Phys. B (Proc. Suppl.)*, 69/1–3, 509
 Maiolino R., Krabbe A., Thatte N., Genzel R., 1998, *ApJ*, 493, 650
 Malaguti G., Bassani L., Caroli E., 1994, *ApJS*, 94, 517
 Malkan M. A., Varoujan G., Tam R., 1998, *ApJS*, 117, 25
 Matsuoka M., Piro L., Yamauchi M., Murakami Y., 1990, *ApJ*, 361, 440
 Matt G., Perola G. C., Piro L., 1991, *A&A*, 247, 25
 Matt G. et al., 1996, *MNRAS*, 281, L69
 Matt G. et al., 1997, *A&A*, 325, L13
 Mihara T., Matusoka M., Mushotzky R. F., Kunieda H., Otani C., Miyamoto S., Yamauchi M., 1994, *PASJ*, 46, L137
 Morse J. A., Wilson A. S., Elvis M., Weaver K. A., 1995, *ApJ*, 439, 121
 Nandra K., Pounds K. A., 1994, *MNRAS*, 268, 405
 Nandra K., George I. M., Mushotzky R. F., Turner T. J., Yaqoob T., 1997, *ApJ*, 477, 602
 Parmar A. N. et al., 1997, *A&AS*, 122, 309
 Piro L., Yamauchi M., Matsuoka M., 1990, *ApJ*, 360, L5
 Pounds K., Nandra K., Stewart G. C., George I. M., Fabian A. C., 1990, *Nat*, 344, 132
 Sunayev R. A., Churazov E., 1998, *MNRAS*, 297, 1279
 Sunayev R. A., Markevitch M., Pavlinsky M., 1993, *ApJ*, 407, 606
 Tanaka Y. et al., 1995, *Nat*, 365, 659
 Uttley P., McHardy I. M. M., Papadakis I. E., Cagnoni I., Fruscione A., 1998, in Scarsi L., Bradt H., Giommi P., Fiore F., eds, *Proc. Symp. The active X-ray sky: first results from BeppoSAX and RXTE*. *Nucl. Phys. B (Proc. Suppl.)*, 69/1–3, 490
 Walter R., Orr A., Courvoisier T. J.-T., Fink H. H., 1994, *A&A*, 285, 119
 Weaver K. A., Nousek J., Yaqoob T., Mushotzky R. F., Makino F., 1996, *ApJ*, 458, 160

This paper has been typeset from a $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ file prepared by the author.