A&A 473, 85–89 (2007)
DOI: 10.1051/0004-6361:20077630

Astronomy & Astrophysics

The XMM-Newton view of IRAS 09104+4109: evidence for a changing-look Type 2 quasar?

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Received 11 April 2007 / Accepted 6 July 2007

ABSTRACT

Aims. We report on a 14 ks *XMM-Newton* observation of the hyperluminous infrared galaxy IRAS 09104+4109, which harbors a type 2 quasar in its nucleus. Our analysis was aimed at studying the properties of the absorbing matter and the Fe K complex at 6–7 keV in this source.
Methods. We analyzed the spectroscopic data from the *PN* and the *MOS* cameras in the 0.4–10 keV band. We also used an archival *BeppoSAX* 1–50 keV observation of IRAS 09104+4109 to investigate possible variations of the quasar emission.
Results. The X-ray emission in the *EPIC* band is dominated by the intra-cluster medium thermal emission. We found that the quasar contributes ~35% of the total flux in the 2–10 keV band. Both a transmission- (through a Compton-thin absorber with a Compton optical depth of $\tau_{\rm C} \sim 0.3$, i.e. $N_{\rm H} \sim 5 \times 10^{23}$ cm^{-2}) and a reflection-dominated ($\tau_{\rm C} > 1$) model provide an excellent fit to the quasar continuum emission. However, the value measured for the *EW* of Fe Kα emission line is only marginally consistent with the presence of a Compton-thick absorber in a reflection-dominated scenario, which had been suggested by a previous, marginal (i.e. 2.5σ) detection with the hard X-ray (15–50 keV), non-imaging *BeppoSAX*/PDS instrument. Moreover, the value of luminosity in the 2–10 keV band measured by the transmission-dominated model is fully consistent with that expected on the basis of the bolometric luminosity of IRAS 09104+4109. From the analysis of the *XMM-Newton* data we therefore suggest the possibility that the absorber along the line of sight to the nucleus of IRAS 09104+4109 is Compton-thin. Alternatively, the absorber column density could have changed from Compton-thick to -thin in the five years elapsed between the observations. If this is the case, then IRAS 09104+4109 is the first "changing-look" quasar ever detected.

Key words. galaxies: individual: IRAS 09104+4109 – galaxies: active – galaxies: nuclei – X-ray: galaxies

1. Introduction

IRAS 09104+4109 is one the most powerful objects in the $z \lesssim 0.5$ Universe. It is a hyperluminous infrared cD galaxy of IR luminosity $>10^{13} L_{\odot}$ at $z = 0.442$, residing in the core of a rich cluster of galaxies (Kleinmann et al. 1988). Its optical spectrum shows only narrow emission lines, but broad Balmer and Mg II emission lines were observed in the polarized light (Hines & Wills 1993; Tran et al. 2000). These pieces of evidence have led to the conclusion that a dust-enshrouded type 2 quasar lies in the nucleus of IRAS 09104+4109.

The X-ray observations of IRAS 09104+4109 collected so far lend support to this suggestion. Franceschini et al. (2000; F00) reported on the analysis of a *BeppoSAX* observation of this source. They found that the X-ray spectrum below 10 keV is dominated by the intra-cluster medium (ICM) thermal ($kT \sim 5.5$ keV) emission. The detection of a weak signal in the 15–60 keV band with the PDS instrument was interpreted by F00 as the primary emission of the buried quasar, which emerges from an absorbing screen of $N_{\rm H} \gtrsim 5 \times 10^{24}$ cm^{-2}. They also reported on the marginal detection of a neutral Fe Kα emission line with an equivalent width (*EW*) of ~1–2 keV, consistent with a reflection-dominated scenario for the quasar emission in the 2–10 keV band. This evidence makes this source the best example of a Compton-thick type 2 quasar found to date. Exploiting the high spatial resolution of *Chandra*, Iwasawa et al. (2001, I01 hereafter) were able to analyze the spectral data of the central source embedded in the extended ICM emission. Although limited by the low statistics (~200 counts in the range 0.6–7 keV), these data allowed to confirm the presence of a heavily obscured quasar and, by the comparison with the *BeppoSAX* PDS flux, I01 concluded that the *Chandra* spectrum is also reflection-dominated.

2. XMM–Newton observation and data reduction

IRAS 09104+4109 was observed with *XMM-Newton* (Jansen et al. 2001, and references therein) on April 27, 2003 for ~14 ks. The *EPIC PN* and *MOS* observations were carried out in the full frame mode using the Medium filter. *XMM-Newton* data were processed with SAS v6.5. We used the EPCHAIN and EMCHAIN tasks for processing the raw *PN* and *MOS* data files, respectively, to generate the relative linearized event files. X-ray events corresponding to patterns 0–12(0–4) for the *MOS*(*PN*) cameras were selected. Hot and bad pixels were removed. The event lists were furthermore filtered to ignore

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Table 1. Best-fit spectral parameters of the *EPIC* spectrum. See Sect. 3 for details. Column: (1) spectral model; (2) temperature of the ICM "cool core" component (keV); (3) ICM metallicity; (4) 2–10 keV flux of the quasar component (10^{-13} erg cm^{-2} s^{-1}); (5) 2–10 keV luminosity of the quasar component (10^{44} erg s^{-1}); (6) column density of the absorber (10^{23} cm^{-2}); (7) energy of the Fe Kα line (keV); (8) intensity of the Fe Kα line (10^{-6} ph/cm^2/s); (9) *EW* of the Fe Kα line (eV); (10) reduced χ^2 and number of degrees of freedom.

Model[a]	kT	$Z/Z_\odot$	F_{2-10}	L_{2-10}	$N_{\rm H}$	$E_{\rm K\alpha}$	$I_{\rm K\alpha}$	$EW_{\rm K\alpha}$	χ^2_ν(d.o.f.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(A)	$3.9^{+0.8}_{-0.9}$	$0.47^{+0.10}_{-0.10}$	4.68	7.95	$4.8^{+2.6}_{-1.5}$	$6.38^{+0.06}_{-0.06}$	$8.7^{+6.2}_{-4.8}$	$390^{+380,b}_{-212}$	0.94(219)
(B)	$3.6^{+0.8}_{-0.7}$	$0.48^{+0.11}_{-0.10}$	5.57	>2.05	–	$6.38^{+0.05}_{-0.05}$	$4.0^{+2.1}_{-1.9}$	$402^{+212,c}_{-193}$	0.96(220)

[a] (A) *transmission* model; (B) *reflection* model; [b] absorption-corrected line against absorption-corrected continuum; [c] with respect to the pure reflection component.

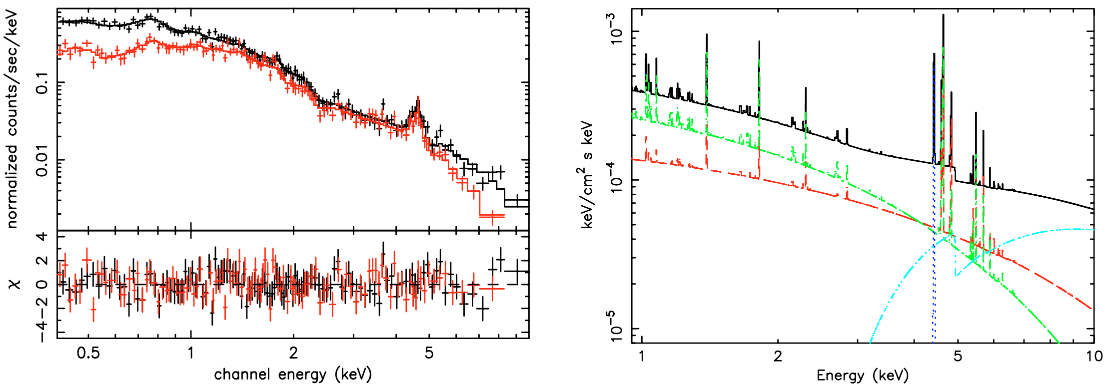

Fig. 1. a) *Left*: *XMM-Newton PN* (top) and *MOS* (bottom) spectra of IRAS 09104+4109 when the *transmission* model is applied. The lower panel shows the deviations of the observed data from the model in unit of standard deviations. **b)** *Right*: best-fit model for the transmission scenario. The different spectral components are also plotted (e.g. Sect. 3 for further details).

periods of high background flaring according to the method presented in Piconcelli et al. (2004) based on the cumulative distribution function of background lightcurve count-rates. Final net exposures of 10.8, 13.4, and 13.4 ks were obtained for *PN*, *MOS1* and *MOS2*, respectively. The source photons were extracted for the *PN*(*MOS*) camera from a circular region with a radius of 37(40) arcsec, while the background counts were estimated from a larger (i.e. ~75 arcsec radius) source-free region on the same chip. Appropriate response and ancillary files for all the *EPIC* cameras were created using respectively RMFGEN and ARFGEN tasks in the SAS. Combined *MOS1+MOS2* spectrum and response matrix were created.

Light-curves in the 0.2–2 keV and 2–15 keV band were extracted. Both light-curves are consistent with a constant flux level over the whole *XMM-Newton* exposure.

3. Spectral modelling

Both *PN* and *MOS* spectra were grouped to have a minimum of 20 counts per bin to allow the use of χ^2 minimization technique and fitted simultaneously. Given the current calibration uncertainties, we discarded events below 0.4 keV and above 10 keV. All fits were performed using the XSPEC package (v11.3) and included the Galactic column density value of $N_{\rm H} = 1.81 \times 10^{20}$ cm^{-2} (Murphy et al. 1996). Best-fit parameter values are given in the source frame, unless otherwise specified. The quoted errors on the model parameters correspond to a 90% confidence level for one interesting parameter ($\Delta\chi^2 = 2.71$; Avni 1976). A cosmology with $(\Omega_{\rm M}, \Omega_\Lambda) = (0.3, 0.7)$ and a $H_0 = 70$ km s^{-1} Mpc^{-1} is assumed throughout.

The high-resolution ($\lesssim 1$ arcsec) *Chandra* observation of IRAS 09104+4109 presented by I01 has definitively established that the emission from the ICM dominates the X-ray spectrum below 10 keV. Furthermore IRAS 09104+4109 is a massive cooling-flow cluster (Fabian & Crawford 1995) showing a large radial temperature gradient, from $kT \approx 3.3$ keV in the bright, cool core up to $kT \approx 7.8$ keV at a distance of 200 kpc, i.e. 36 arcsec (I01). For this reason, we initially fitted the combined *PN+MOS* spectrum with a model consisting of two thermal plasma emission components (i.e. `MEKAL` in `XSPEC`) plus an absorbed power law. We fixed the temperature of one thermal component to 7.8 keV in order not to underestimate the total ICM emission in the hard X-ray band. Since the photon index of the power law was loosely constrained ($\Gamma \approx 1.4 \pm 1$) we fixed it to 1.8, which is the average value typically observed for radio-quiet quasars (e.g. Piconcelli et al. 2005).

This model (*transmission* model hereafter) gave an excellent description of the *EPIC* data with a χ^2_ν(d.o.f.) = 0.94(219) (see Fig. 1). The best-fit values of the spectral parameters are listed in Table 1. The value of $\sim 4.8 \times 10^{23}$ cm^{-2} found for the column density translates in a Compton optical depth $\tau_{\rm C} \sim 0.3$ of the absorbing screen. The value of temperature ($kT = 3.9^{+0.8}_{-0.9}$ keV) in the cluster core and metallicity ($Z/Z_\odot = 0.47^{+0.10}_{-0.10}$) of the ICM are consistent with I01.

Works based on *BeppoSAX* and *Chandra* observations favored an interpretation of the spectrum of IRAS 09104+4109 below 10 keV in terms of reflection-dominated emission. We therefore replaced the absorbed power law in the *transmission* model with a Compton reflection component from neutral matter (i.e. `PEXRAV` model in `XSPEC`). For this spectral component, which is due to the reprocessing of the emission from the obscured primary X-ray source, we assumed a $\Gamma = 1.8$ for the photon index of the incident power law, along with an inclination angle of $i = 50$ deg (Tran et al. 2000) and solar metallicity for the reflector. This model (*reflection* model hereafter) yielded an equally good fit to the *XMM-Newton* spectrum with a final

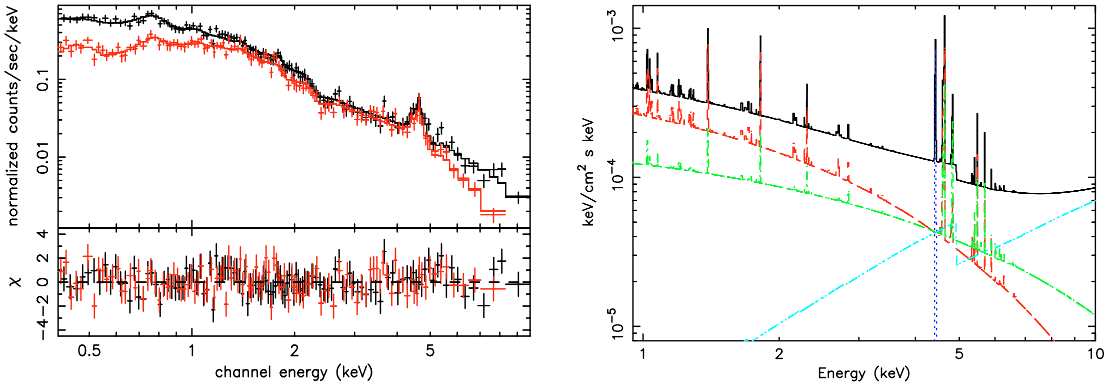

Fig. 2. The same as Fig. 1 for the *reflection* model.

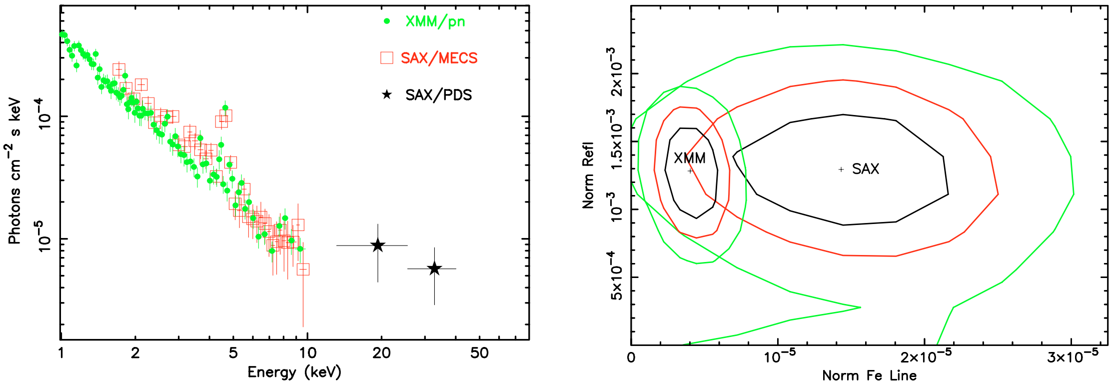

Fig. 3. a) *Left*: unfolded spectra for the 2003 *XMM-Newton* and 1998 *BeppoSAX* observations. **b)** *Right*: confidence contour plot showing the intensity of the Fe Kα emission line (in units of ph/cm^2/s) against the intensity (i.e. photon flux at 1 keV) of the reflection continuum (in units of ph/keV/cm^2/s) obtained using the *XMM-Newton* and *BeppoSAX* (MECS+PDS) data. The contours are at 68%, 90% and 99% confidence levels for two interesting parameters.

χ^2_ν(d.o.f.) = 0.96(220) (see Table 1 and Fig. 2). According to both spectral models, the contribution of the quasar component to the total flux in the 2–10 keV band is ≈30–35%.

As shown in Figs. 1a and 2a, there is a prominent line-like emission feature at 4–5 keV (observer-frame) which is broader than the instrumental resolution at this energy and most likely due to a blend of lines associated with Fe K emission. This complex is partly accounted for by the strong FeXXV Kα emission line at 6.7 keV and the FeXXVI Kα emission line at 6.97 keV (which should be likely blended with a weak Fe Kβ line at 7.06 keV due to the reprocessing of the quasar continuum) from the two-temperature ICM. However, significant (at >99% confidence level) positive residuals are still present. We modelled this excess with an unresolved Gaussian emission line at $6.38^{+0.06}_{-0.06}$ keV. This energy is consistent with a range of ionization states from FeI to FeXVI (Kallman et al. 2004), as typically observed in quasars (Jimenez-Bailon et al. 2005). In the "reflection-dominated" scenario we measure an equivalent width of the Fe Kα line at ~6.4 keV of $EW_{\mathrm{K}\alpha} = 402^{+212}_{-193}$ eV (calculated with respect to the Compton reflection component). For the *transmission* model (i.e. assuming that the line and the continuum are both absorbed) we derive $EW_{\mathrm{K}\alpha} = 390^{+380}_{-212}$ eV (see Table 1).

3.1. A comparison with broadband 1–50 keV BeppoSAX data

To investigate on the possible year-timescale variability of the overall continuum spectral shape, we plot in Fig. 3a the unfolded 2003 *PN* and 1998 *BeppoSAX* MECS+PDS spectra. These data have been unfolded through the instrument response with respect to the best-fit model found by F00 (i.e. ICM thermal emission component + absorbed powerlaw + reflection + narrow Gaussian line at 6.4 keV; model *sax98* hereafter). As expected, the 1–10 keV *XMM-Newton* and *BeppoSAX* spectra have similar shape being dominated by the ICM emission. The different normalizations of the two spectra can be ascribed to the different source extraction regions. In particular, a fraction of ICM emission from the outskirt region of the cluster spreads outside the *PN*/*MOS* extraction radius. Interestingly, the PDS data above 10 keV appear to lie slightly above the extrapolation of the MECS/*PN* continuum level. We calculated a 20–30 keV flux level of $F_{20-30} \sim 6.1\times10^{-13}$ and $\sim1.3\times10^{-12}$ erg cm^{-2} s^{-1} for the *transmission*[1] and *reflection* model, respectively. The 20–30 keV flux of IRAS 09104+4109 measured by *BeppoSAX* is $F_{20-30} = 2.55^{+1.90}_{-1.56}\times10^{-12}$ erg cm^{-2} s^{-1}, whereby the extrapolated *XMM-Newton* flux in this band is fainter by a factor of ~1.6–7.3, if the *transmission* model is assumed. On the other hand, the 20–30 keV flux estimated by *reflection* model is consistent with the *BeppoSAX* value.

Figure 3b shows the iso-χ^2 contour plot of the intensity of the Fe Kα emission line at 6.4 keV ($I_{\mathrm{K}\alpha}$) versus the intensity of the reflection continuum for the 1998 *BeppoSAX* and 2003 *XMM-Newton* observations. The *XMM-Newton* values were derived by the *reflection* model, while for the *BeppoSAX* data we employed the *sax98* model (temperature and abundance of the ICM

[1] In the case of this model, we also added to the model a Compton reflection component with R = 1 (where R is the solid angle in units of 2π subtended by the reflecting material) as commonly observed in the 10–50 keV AGN spectra (e.g. Risaliti 2002; Reeves et al. 2006).

were permitted to vary within the 90% confidence interval measured for these parameters with *XMM-Newton*, e.g. Table 1). These measurements taken at different epochs are consistent within 3σ errors, as expected if Compton hump and cold iron emission arise from distant material. Furthermore, the *XMM-Newton* measurements are also compatible with the values of $I_{\mathrm{K}\alpha} = 7.2^{+6.1}_{-3.3} \times 10^{-6}$ photons cm^{-2} s^{-1} and $EW_{\mathrm{K}\alpha} = 1.1^{+0.9}_{-0.5}$ keV reported by I01 on the basis of a 1999 *Chandra* observation of IRAS 09104+4109. The mean values of $EW_{\mathrm{K}\alpha}$ were significantly larger, but the errors were also very large in the low S/N *BeppoSAX* and *Chandra* spectra.

4. Discussion

The *XMM-Newton* observation presented here has confirmed the presence of a heavily absorbed quasar in the nucleus of the hyperluminous infrared galaxy IRAS 09104+4109. The *EPIC* energy range is dominated by the thermal emission of the ICM and we estimated that the quasar contributes approximately ∼30–35% of the total 2–10 keV flux. We were able to accurately study the Fe K complex at ∼6–7 keV in this source, modelling it with three distinct narrow emission lines from FeI–XVI Kα, FeXXV Kα and FeXXVI Kα transition, respectively. The highly ionized Fe K lines originate in the ICM, while the line from cold iron is likely due to reprocessing of the quasar continuum off the circumnuclear environment. The better quality of *EPIC* data has allowed to overcome the problems of limited spectral resolution and statistics of *BeppoSAX* data (e.g. F00), which prevented a correct estimate of the contribution from the different ions to the Fe emission complex.

The quasar emission can be equally well fitted by either a *transmission* or a *reflection* model. The former implies a Compton-thin absorber with $N_{\mathrm{H}} \approx 5 \times 10^{23}$ cm^{-2}, while the latter suggests a scenario where the primary X-ray continuum is blocked by a Compton-thick ($\tau_{\mathrm{C}} \gtrsim 1$, i.e. $N_{\mathrm{H}} \gtrsim \sigma_t^{-1} \approx 1.6 \times 10^{24}$ cm^{-2}) obscuring screen and the emission observed by *XMM-Newton* is due to indirect radiation scattered into the line of sight (it is generally assumed that the absorber and the reflector are the same material, i.e. the *torus*, e.g. Matt et al. 1996; Molendi et al. 2003). Using the present data these models are statistically indistinguishable. However, an $EW_{\mathrm{K}\alpha} \approx 400 \pm 200$ eV measured assuming the *reflection* model is significantly lower than expected for a truly "reflection-dominated" spectrum with [Fe/H] = 0. In fact, the most prominent feature in the 2–10 keV spectrum of a heavily obscured AGN, as in the case of IRAS 09104+4109 ($2\times10^{24} \lesssim N_{\mathrm{H}} \lesssim 10^{25}$ cm^{-2}, e.g. I01), is a strong Fe Kα emission line with an $EW_{\mathrm{K}\alpha} \gtrsim 1$ keV (Levenson et al. 2002; Guainazzi et al. 2005). This solid observational evidence matches well with the *EW* value predicted by the theoretical calculations (e.g. Leahy & Creighton 1993; Ghisellini et al. 1994; Matt et al. 1996). However, given the uncertainty in the reflection continuum flux due to the presence of the diffuse cluster emission, we also conservatively estimated the $EW_{\mathrm{K}\alpha}$ by using the lowest(highest) value in the 90% confidence interval measured for the normalization of the reflection component(Fe Kα emission line) and vice versa. We obtained a range of $EW_{\mathrm{K}\alpha}$ values spanning from ∼165 to 870 eV, which is marginally consistent with the $EW_{\mathrm{K}\alpha} \approx 1$ keV expected for a reflection-dominated scenario. As the continuum flux estimated for the obscured quasar with the *reflection* model ($F_{2-10} = 4.68^{+1.63}_{-1.08}\times10^{-13}$ erg cm^{-2} s^{-1}) is similar to the value measured with the spatially resolved *Chandra* spectrum ($F_{2-10} \approx 3.9 \times 10^{-13}$ erg cm^{-2} s^{-1}, e.g. I01), the marginal discrepancy in the $EW_{\mathrm{K}\alpha}$ values between the two observations arises from the different best-fit line flux intensity.

On the other hand, the $EW_{\mathrm{K}\alpha} = 390^{+380}_{-212}$ eV (note the large error bars) found in the case of the *transmission* model is in agreement with the expected *EW* value of a Fe Kα line transmitted through an absorbing screen with $N_{\mathrm{H}} \sim 5 \times 10^{23}$ cm^{-2} is (∼200–400 eV; e.g. Awaki et al. 1991; Leahy & Creighton 1993; Ghisellini et al. 1994). A scenario with a Compton-thin absorber along the line of sight to the nucleus of IRAS 09104+4109 is therefore physically plausible. Nonetheless, the flux difference by a factor of ∼1.6–7.3 between the 2003 *XMM-Newton* and 1998 *BeppoSAX* observation (a time interval of 3.5 yr at the source frame after the correction for the time dilation due to the $z = 0.442$) in the 20–30 keV band is puzzling. In fact, given the observed power spectral densities of low black hole mass (i.e. $M_{\mathrm{BH}} \approx 10^7\ M_\odot$) Seyfert galaxies (Markowitz et al. 2003) and scaling linearly with the black hole mass (assuming $M_{\mathrm{BH}} = 2.4 \times 10^9\ M_\odot$ for the nuclear black hole in IRAS 09104+4109[2]), flux variations of a factor of $\gtrsim$2 in 3.5 yr should be considered unlikely (e.g. Fiore et al. 1998). However, the major problem in the interpretation of this mismatch concerns the accuracy of *BeppoSAX*/PDS measurement. According to our analysis, the signal-to-noise ratio of these data is poor (only ∼2.5σ between 15 and 50 keV). This implies that any conclusion based only on the PDS data about the Compton-thick or Compton-thin nature of the absorber in the nucleus of IRAS 09104+4109 could be misleading. The addition of a primary continuum power-law component modified by a Compton-thick absorber (i.e. similarly to the best-fit model proposed by F00 for the *BeppoSAX* broadband spectrum) might easily account for the above flux discrepancy, but, as stressed above, a scenario with a Compton-thick absorber for the *EPIC* spectrum is at odds with the inferred quite small value (i.e. <1 keV) of the Fe Kα *EW*.

Given the large 1.3° *FWHM* PDS field of view (FOV), PDS data might be affected by the contamination of very hard X-ray sources possibly located outside the *XMM-Newton* and *Chandra* 15 arcmin radius FOVs. If a power-law source with $\Gamma = 1.8$ is assumed, the 20–30 keV flux measured for the PDS source ($F_{20-30} \sim 2.55 \times 10^{-12}$ erg cm^{-2} s^{-1}) is translated to $F_{2-10} \sim 7.5 \times 10^{-12}$ erg cm^{-2} s^{-1}. According to the RXTE all-sky slew survey $\log N - \log S$ function in the 2–10 keV band (Revnivtsev et al. 2004), at this flux level 0.025 sources are expected in a 1.5 deg^2 area, which translates into a probability of 2.4%. Moreover, using the NED and SIMBAD catalogs we found a probable contaminating source in the H_2O maser galaxy NGC 2782 ($z = 0.008$), which is located at ∼50 arcmin away from IRAS 09104+4109. The *Chandra* spectrum of this source (with a nuclear X-ray flux of a few times 10^{-13} erg cm^{-2} s^{-1}) strongly suggests the presence of a heavily ($N_{\mathrm{H}} > 10^{24}$ cm^{-2}) absorbed AGN (Zhang et al. 2006), whereby it is likely that NGC 2782 provides a sizable contribution to the 20–30 keV flux measured with the PDS. Assuming a pure reflection model, we estimated a $F_{20-30} \sim 6 \times 10^{-13}$ erg cm^{-2} s^{-1}, which must be considered a lower limit of the 20–30 keV emission from NGC 2782, because of the likely presence of the nuclear continuum emerging after transmission through the absorber.

Alternatively, IRAS 09104+4109 could represent the first example of a "changing-look" quasar (Guainazzi et al. 2002; Matt et al. 2003, and reference therein) ever detected given that the *XMM-Newton* data are better explained by a transmission-dominated model with $N_{\mathrm{H}} \sim 5 \times 10^{23}$ cm^{-2} while, if the

[2] We estimated a mass of $2.4 \times 10^9\ M_\odot$ for the black hole in the nucleus of IRAS 09104+4109 using the measurement of the MgII line width from Hines & Wills (1993), i.e. $FWHM = 10\,000$ km s^{-1}, and the formula in Willott et al. (2003).

PDS emission is entirely due to IRAS 09104+4109, the *BeppoSAX* data are consistent with a reflection-dominated spectral state. In fact, similar spectral transitions from a Compton-thick to a Compton-thin state (or vice-versa) have been observed, but only in Seyfert-like AGNs so far. This scenario implies a dramatic decrease (a factor of $\gtrsim$5–10) in the line-of-sight absorbing column density during a timescale of 5 years and, in turn, suggests the presence of a largely inhomogeneous obscuring circumnuclear gas (Elvis et al. 2004; Elitzur & Shlosman 2006). We estimated the line-of-sight crossing-time of an obscuring cloud in Keplerian motion around the central black hole of 2.4×10^9 $M_\odot$ to explain the possible transition from a reflection-dominated to a transmission-dominated spectrum. We assumed a scenario similar to that described for NGC 1365 in Risaliti et al. (2007) (or NGC 3227, e.g. Lamer et al. 2003) where they found that the Compton-thick obscuring material responsible of the spectral transition is located in the broad line region (BLR) and the size of the X-ray emitting region is $\lesssim$100 R_G. We estimated a distance of the BLR R_{BLR} = 0.14 pc using the empirical relation R_{BLR}–M_{BH} in Kaspi et al. (2000). The redshift-corrected crossing-time (Guainazzi et al. 2002) of a Keplerian cloud covering a region of size 100 R_G around a black hole of 2.4×10^9 $M_\odot$ is ∼1.7 yr. Such a value is therefore consistent with the 3.5 yr (source frame) elapsed between the *BeppoSAX* and *XMM-Newton* observation.

Finally, we calculated a ratio $r_{X,bol} \equiv L_{2-10\,keV} / L_{bol}$ = 0.016 using the 2–10 keV luminosity of $L_{2-10\,keV} = 7.95 \times 10^{44}$ erg s^{-1} measured for the transmission-scenario (see Table 1), and a bolometric luminosity of $L_{bol}(\approx L_{IR}) = 4.7 \times 10^{46}$ erg s^{-1}, which is largely dominated by the obscured quasar (e.g. Hines et al. 1999; Spoon et al. 2007). We also derived the value of $r_{X,bol}$ expected for IRAS 09104+4109 using the value of $\nu l_\nu(2500\,Å)/L_{bol}$ typical for quasars reported in Elvis et al. (1994), correcting the L_{bol} value by a factor of 1/3 as suggested by Fabian & Iwasawa (1999) in order not to count twice the UV emission, and the spectral index α_{OX} between 2500 Å and 2 keV, defined as $\alpha_{OX} = -0.384[l_\nu(2\,keV)/l_\nu(2500\,Å)]$ (e.g. Tananbaum et al. 1979). In particular, we used the relation α_{OX} = 0.137 log(l_ν(2500 Å)) −2.638 reported by Steffen et al. (2006). We converted from the monochromatic value of νl_ν(2 keV) to the $L_{2-10\,keV}$ value by multiplying by a factor of 1.61, applying a photon index of $\Gamma = 2$. We obtained that $r_{X,bol} \equiv L_{2-10\,keV}/L_{bol} = 0.043 \times L_{bol,45}^{-0.357}$ (with $L_{bol,45} = L_{bol}/10^{45}$ erg s^{-1}). This implies that the expected value of $r_{X,bol}$ for IRAS 09104+4109 is 0.011, which is close to the value of $r_{X,bol}$ = 0.016 measured using the $L_{2-10\,keV}$ derived for the transmission scenario. Since the observed luminosity of $L_{2-10\,keV} = 2.05 \times 10^{44}$ erg s^{-1} in the *reflection* model should be just few percent of the intrinsic one (Comastri 2004; I01), this result lends further support to the hypothesis of a Compton-thin absorber along the line of sight to the nucleus of IRAS 09104+4109.

5. Summary

The *XMM-Newton* observation of IRAS 09104+4109 suggests the possibility that the absorber along the line of sight to the nucleus of IRAS 09104+4109 is Compton-thin. If this is the case, it implies a scenario completely different from that reported for this type 2 quasar so far. It is worth stressing, however, that previous X-ray studies of IRAS 09104+4109 inferred a reflection-dominated nature of its 2–10 keV spectrum mainly on the basis of poor signal-to-noise ∼15–50 keV data taken with the non-imaging *BeppoSAX*/PDS detector. Future imaging spectroscopy of IRAS 09104+4109 performed in the 10–50 keV range, say with *Simbol-X* or *XEUS*, is therefore needed to make definitive progress in measuring the exact continuum emission from the quasar and constraining the column density of the nuclear absorber. A deep *Chandra* observation of IRAS 09104+4109 would also be useful to accurately quantify the strength of the Fe Kα emission line at 6.4 keV, which is a proxy for the Compton thickness of the absorber.

Acknowledgements. We thak the referee, Dr. K. Iwasawa, for careful reading and for many useful comments that helped us to improve the manuscript. We are grateful to G. Miniutti, R. Maiolino, S. Colafrancesco and G. Risaliti for helpful discussions. Based on observations obtained with *XMM-Newton*, an ESA science mission with instruments and contributions directly funded by ESA Member States and NASA. This research has made use 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. We acknowledge financial contribution from contract ASI-INAF I/023/05/0.

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