

# The early stage of a cosmic collision? XMM-Newton unveils two obscured AGN in the galaxy pair ESO509-IG066

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**Abstract.** We report the XMM-Newton discovery of a X-ray bright AGN pair in the interacting galaxy system ESO509-IG066. Both galaxies host an X-ray luminous ( $L_X \sim 10^{43}$  erg s<sup>-1</sup>) obscured nucleus with column densities  $N_H \approx 7 \times 10^{22}$  cm<sup>-2</sup> and  $N_H \approx 5 \times 10^{21}$  cm<sup>-2</sup>. The optical morphology is only mildly disturbed, suggesting a merging system in the early stage of its evolution. Still, the pair is probably gravitationally bound, and might eventually evolve into a compact, fully gas embedded systems such as NGC 6240 (Komossa et al. 2003).

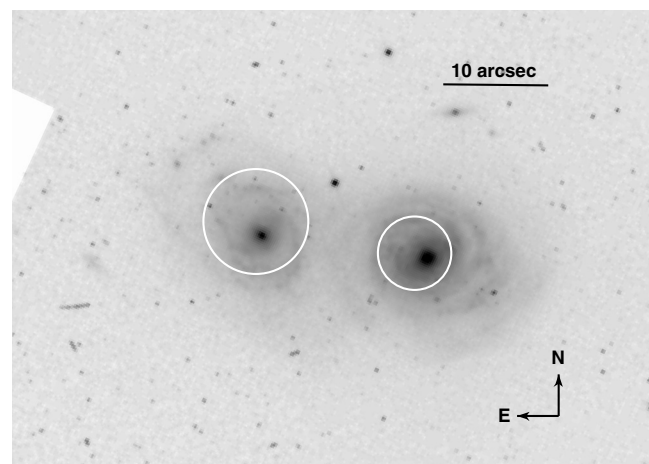
**Key words.** galaxies: interactions – galaxies: Seyfert – galaxies: individual: ESO509-IG066 – X-rays: galaxies

## 1. Introduction

About 20 *bona fide* Active Galactic Nuclei (AGN) pairs are currently known (Kochanek et al. 1999). They represent about 0.1% of QSO optical surveys (Hewett et al. 1998), although this number is dependent on the criteria used to distinguish between “true pairs” and gravitational lenses (Mortlock et al. 1999).

AGN pairs are a potentially interesting laboratory to study the early phases of AGN activity. Gas shock and compression caused by galaxy interactions may lead to feeding otherwise quiescent super-massive black holes, and to enhanced star formation (Rees 1984; Byrd et al. 1986). The possible role of merging and flybys to bring gas to the nuclear region has been examined by means of *N*-body simulations (Barnes & Hernquist 1992; Hernquist & Mihos 1995; Taniguchi & Wada 1996). Observationally, quasars seem indeed to live in denser environment than normal galaxies (Kauffmann et al. 2004), whereas the same evidence for low-luminosity AGN is still controversial (Laurikainen et al. 1994; Rafanelli et al. 1995; de Robertis et al. 1998; Schmitt 2001).

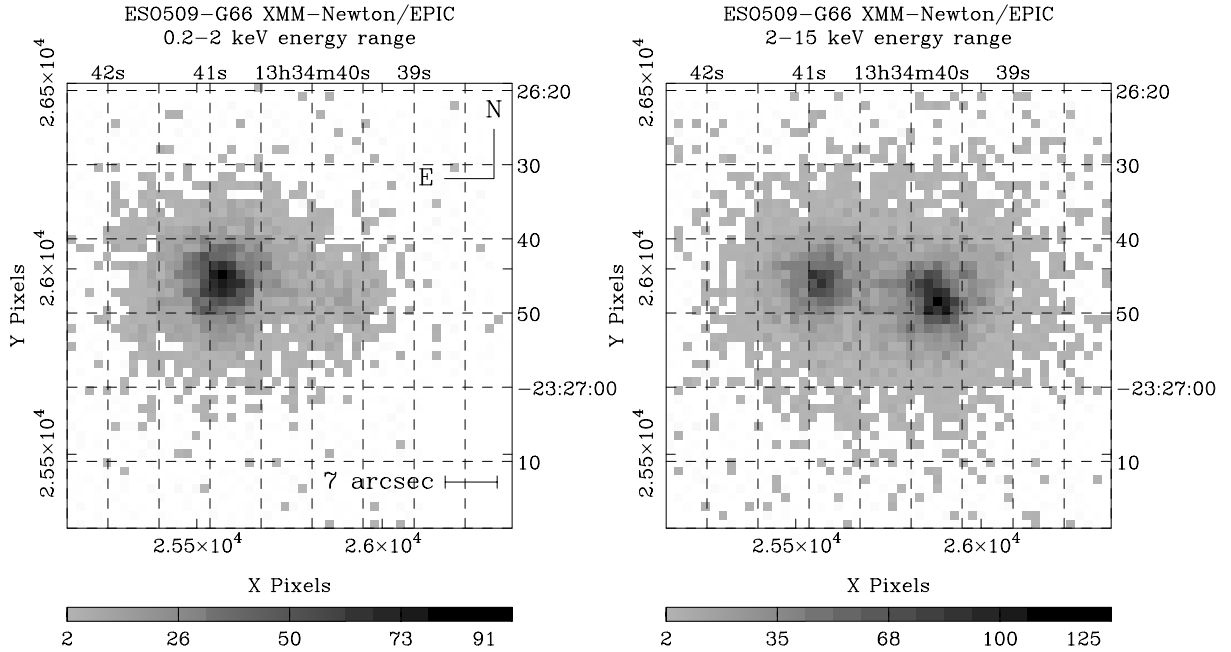
In this paper we present the first X-ray imaging and spectroscopic observation of the interacting galaxy pair ESO509-IG066 (Arp & Madore 1987), and report the discovery that *both* galaxies host a luminous ( $L_X \sim 10^{43}$  erg s<sup>-1</sup>) and obscured X-ray source. The optical nuclei of the pair are aligned in the E–W direction at a projected separation of  $\approx 16''$ , with spectroscopic redshifts  $z_E = 0.033223 \pm 0.00003$  and  $z_W = 0.034307 \pm 0.00014$  (Sekiguchi & Wolstencroft 1992). The W source was classified as a Seyfert 2 galaxies on the basis of the [NII] $\lambda 6583/H\alpha$  and [OIII] $\lambda 5007/H\beta$  ratios. In the



**Fig. 1.** HST/WFC2 image of the ESO509-IG066 field in the *F606W* filter. The circles represent the EPIC/XMM-Newton sources error boxes.

E source, the lack of  $H\beta$  detection favored a H II or LINER classification (Sekiguchi & Wolstencroft 1992). In the X-ray band, only a detection by the *Ginga*/LAC is reported in the literature, with a 2–10 keV flux of  $\approx 7 \times 10^{-12}$  erg cm<sup>-2</sup> s<sup>-1</sup> (Polletta et al. 1996).

At their redshift, the apparent distance of the pair members translates into a projected physical separation  $R \approx 10.5$  kpc. The line-of-sight velocity difference is  $\Delta v_{||} = 320 \pm 40$  km s<sup>-1</sup>. For comparison, in the Mortlock et al. (1999) sample of binary quasars:  $\langle R \rangle = 32 \pm 9$  kpc and  $\langle \Delta v_{||} \rangle = 83 \pm 10$  km s<sup>-1</sup>.



**Fig. 2.** EPIC combined image of the innermost  $1'$  around the ESO509-IG066 galaxy pair centroid in the 0.2–2 keV (*left panel*) and 2–15 keV (*right panel*) energy bands. A constant level of 2 counts per pixel has been subtracted.

In this paper: energies are quoted in the source’s frame; errors on the count rates are at the  $1-\sigma$  level; errors on the spectral parameters are at the 90% confidence level for 1 interesting parameter; a flat  $\Lambda$ CDM cosmology with  $H_0 = 70$  Mpc km s $^{-1}$  and  $(\Omega_M, \Omega_\Lambda) = (0.3, 0.7)$ , (Bennett et al. 2003) is assumed, unless otherwise specified.

## 2. The data

XMM-Newton observed the sky region around ESO509-IG066 on January 24, 2004. The  $\approx 30' \times 30'$  field-of-view EPIC cameras (MOS; Turner et al. 2001; pn, Stüder et al. 2001) were operating in Full Frame Mode with the MEDIUM and THIN optical rejection filter, respectively. Data were reduced with SAS v6.0.0, using the most updated calibration files. Particle background was screened by applying optimized thresholds to the single-event,  $E > 10$  keV, 10-s binned, field-of-view light curve: 0.5 and 3.5 s $^{-1}$  for the MOS and pn, respectively. After screening the exposure times are 9.7 and 8.6 ks for the MOS and the pn, respectively.

In Fig. 2 we show the EPIC images of the innermost  $1'$  around the ESO509-IG066 Galaxy Pair centroid in the soft (0.2–2 keV) and hard (2–15 keV) energy bands. In the soft band, the E source is clearly visible, whereas the W source becomes the brightest in the hard band. Their positions (Table 1) are consistent with the optical nuclei of the galaxy pair members, once the statistical error box, and a residual  $\approx 2''$  systematic uncertainties in the absolute position reconstruction are taken into account.

For such close X-ray sources, point spread function contamination is a potential issue in EPIC. In order to account for this effect, we extracted source scientific products from comparatively small circles of  $7''$  and  $8''$  radius for Source W and E, respectively. We used only single and double (single

**Table 1.** Sources detected by the EPIC camera at a signal-to-noise level  $>3$  in the innermost  $1'$  around the ESO509-IG066 galaxy pair centroid. “E” and “W” refer to the components of the AGN pair. Count Rates (CR) refer to the combined MOS cameras in the 0.2–15 keV band. The Error Box (EB) is purely statistics.

Source	RA (J2000)	Dec (J2000)	EB ( $''$ )	CR (s $^{-1}$ )
W	13 <sup>h</sup> 34 <sup>m</sup> 39 <sup>s</sup> .7	−23°26′48″	7	0.658 ± 0.018
E	13 <sup>h</sup> 34 <sup>m</sup> 40 <sup>s</sup> .8	−23°26′45″	10	0.512 ± 0.016

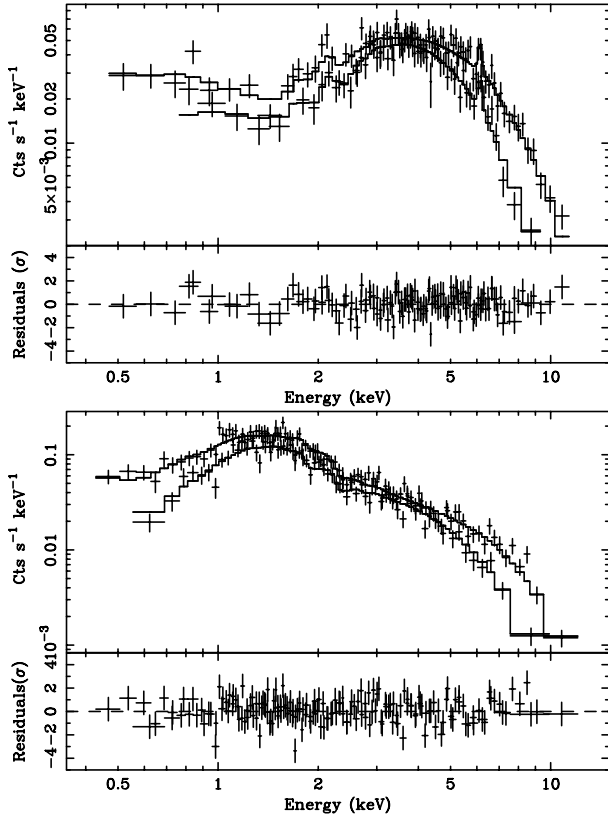
to quadruple) events in the pn (MOS). Background scientific products for each galaxy were generated by combining spectra extracted from standard offset regions on the same chip as the targets, and the appropriate fraction (4%) of the spectrum of the companion. Spectra were rebinned in order to oversample the instrumental resolution by a factor not larger than 3, and to ensure that each background-subtracted spectral channel has 25 counts at least. We have restricted the spectral analysis to the bands 0.5–10 keV and 0.35–15 keV for the MOS and the pn, respectively, where the instrument are best calibrated, and fit the spectra simultaneously with XSPEC v11.3.0.

The spectra of both sources can be reasonably well fit with the combination of two continua. The bulk of the X-ray emission is due to a photoelectrically absorbed power-law. The column densities are  $N_{\text{H}} \approx 7.1 \times 10^{22}$  cm $^{-2}$ , and  $\approx 5.9 \times 10^{21}$  cm $^{-2}$  for Source W and E, respectively. Both are significantly larger than the contribution due to intervening gas in our Galaxy ( $N_{\text{H,Gal}} = 6.5 \times 10^{20}$  cm $^{-2}$ , Dickey & Lockman 1990). A soft excess above the photoelectrically absorbed power-law can be well accounted for by another power-law modified only by Galactic absorption. In Source W an emission line is detected at the 99.95% confidence level according to the

**Table 2.** Best-fit parameters and results for the EPIC spectra of the ESO509-IG066 Galaxy Pair members.  $f_s$  is the scattering fraction ( $1 - f_s$  is the absorber covering fraction in the “leaky absorber” scenario).  $F$  is the observed flux in the 0.5–2/2–10 keV energy bands.  $L$  is the absorption-corrected luminosity in the 0.5–10 keV energy band.

Source	Absorbed power-law		Soft excess	$K_\alpha$ iron line		Fluxes and luminosities		$\chi^2/\nu$
	$N_H$ ( $10^{22}$ cm $^{-2}$ )	$\Gamma$	$f_s$ (%)	$E_c$ (keV)	$EW$ (eV)	$F$ ( $10^{-12}$ erg cm $^{-2}$ s $^{-1}$ )	$L$ ( $10^{43}$ erg s $^{-1}$ )	
W	$7.1^{+0.6}_{-0.5}$	$1.81 \pm 0.13$	$2.3^{+0.5}_{-0.6}$	$6.35 \pm 0.05$	$120^{+60}_{-50}$	0.12/5.2	$3.3 \pm 0.4$	105.8/130
E	$0.51^{+0.46}_{-0.10}$	$1.64^{+0.72}_{-0.07}$	$5.8^{+14.5}_{-5.2}$	$6.4^a$	$< 90$	0.6/3.0	$1.43 \pm 0.08$	170.2/167

<sup>a</sup> Fixed.



**Fig. 3.** Spectra (*upper panels*) and residuals in units of standard deviations (*lower panels*) when the best-fit model is applied to the pn and MOS spectra of source #1 (*top*) and #2 (*bottom*).

F-test (Protassov et al. 2002). Its centroid energy is consistent with  $K_\alpha$  fluorescence from neutral or mildly ionized iron. The Equivalent Width ( $EW \approx 120$  eV) is typical of Compton-thin Seyfert 2 galaxies (Risaliti 2002). Table 2 lists the best-fit parameters and results. Figure 3 shows the spectra, best-fit models, and residuals.

The 0.5–10 keV intrinsic luminosity is  $\sim 10^{43}$  erg s $^{-1}$  for both X-ray sources, typical for luminous Seyfert galaxies, and much larger than observed in LINERS (Ho et al. 2001; Terashima et al. 2002). A substantial contribution by shocked starburst gas, X-ray binaries or supernovae is unlikely. ESO509-IG066 is the X-ray brightest AGN pair ever detected so far. At the flux level observed by XMM-Newton, both AGN should have been detected by the ROSAT All Sky-Survey, with count rates of  $\approx 5.3$  and  $1.4 \times 10^{-2}$  s $^{-1}$  for source E and W, respectively. However, the closest detected RASS source is  $\geq 50'$

away from the AGN pair centroid. Only a count rate  $3\sigma$  upper limit of  $7 \times 10^{-3}$  s $^{-1}$  was measured by the RASS at the AGN pair position.

### 3. Discussion

Once established that most galaxies host a super-massive black hole (Kormendy et al. 1997), the next open issue is the mechanism that triggers gas accretion and ultimately nuclear activity. Galaxy encounters could be one of these triggers (Silk & Rees 1998; Taniguchi 1999). Gravitational torques generated during the encounter can cause gas inflow toward the nucleus (Barnes & Hernquist 1996). Although such inflows are not strong enough to create *new* black holes, they are consistent with the refueling of “quiescent” black holes.

Is the pair in ESO509-IG066 a binary AGN? On a statistical basis, binary quasars become active at projected separations between 50 and 100 kpc, and recover (apparent) quiescence at separations shorter than 10 kpc (Mortlock et al. 1999). If the onset of nuclear activity is indeed related to galaxy interaction, it should “turn on” during galaxy merging, and AGN should be found preferentially in highly disturbed environment, with enhanced star formation. This is, however, *not* the case of ESO509-IG066, whose galaxies exhibit only mild surface brightness disturbances (cf. Fig. 1). An analogous case is MGC 2214+3350 (Muñoz et al. 1998). Morphologically mildly disturbed systems could represent young binaries, in the earliest phase of their encounter (Kochanek et al. 1999). It is tempting to speculate that they might represent the first stage of an evolutionary sequence, at whose end one finds compact, morphologically highly disturbed systems like NGC 6240 (Tecza et al. 2000). This would require that the AGN lifetime is comparable to the time scale for the orbital decay ( $\sim 10^9 M_9^{-1}$  yr, where  $M_9$  is the black hole mass in units of  $10^9 M_\odot$ , Binney & Tremaine 1987).

Whatever its ultimate fate, the AGN pair in ESO509-IG066 is likely to be a gravitationally bound system. The condition on the minimum center-of-mass frame energy being  $\leq 0$  (Mortlock et al. 1999) implies a lower limit on the total mass of the system:  $M_{\text{cr}} \approx (R\Delta v_{\parallel}^2)/(2G) \approx 2 \times 10^{11} M_\odot$ . From the HST image, we estimate a bulge V luminosity of 8.7 and  $3.9 \times 10^{43}$  erg s $^{-1}$  for the E and W source, respectively, corresponding to a total black hole mass  $\sim 1.2 \times 10^9 M_\odot$  (Magorrian et al. 1998). This in turn translates into an estimated dark matter halo mass exceeding  $10^{13} M_\odot$  (Ferrarese 2002). Unfortunately, no other independent estimate of the supermassive black hole mass exists for ESO509-IG066,

such as, for instance, those based on the [OIII] line width or on stellar velocity dispersion measurements. The total AGN bolometric luminosity of the system is  $\sim 8.4 \times 10^{44}$  erg s<sup>-1</sup>, if a standard ratio between the 1–10 keV and the bolometric luminosity is applied (Elvis et al. 1994). Even if one assumes the most conservative prescription for the ratio between the galaxy circular and the halo virial velocities (Seljak 2002), the inferred mass of the latter is sufficient to gravitationally bound the system if the active nuclei are on the average accreting at sub-Eddington rates (Ferrarese 2002).

X-ray observations allow us to accurately probe the nuclear environment. With the caveat of the small sample, it is intriguing that all members of X-ray detected AGN pairs suffer some degrees of absorption, which in at least 50% of cases might be Compton-thick (Komossa et al. 2003; Ballo et al. 2004). This may indicate that galaxy encounters are indeed effective in driving gas to the nuclear environment. If this is generally true, a certain number of AGN pairs might be missed by optical surveys due to obscuration of one of the members (or both), which leads to a wrong classification. These pairs could show up only in hard X-rays. ESO509-IG066 could be the prototype of a larger hidden population of binary QSOs, still to be discovered by deep high-resolution X-ray surveys.

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