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 \( L_X \sim 10^{43} \text{erg s}^{-1} \) obscured nucleus with column densities \( N_H \sim 7 \times 10^{22} \text{cm}^{-2} \) and \( N_H \sim 5 \times 10^{21} \text{cm}^{-2} \). 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 \( L_X \sim 10^{43} \text{erg s}^{-1} \) and obscured X-ray source. The optical nuclei of the pair are aligned in the E–W direction at a projected separation of \( \sim 16'' \), with spectroscopic redshifts \( z_E = 0.033223 \pm 0.00003 \) and \( z_W = 0.034307 \pm 0.00014 \) (Sekiguchi & Wolstencroft 1992). The West source was classified as a Seyfert 2 galaxies on the basis of the [NII]λ6583/H\alpha and [OIII]λ5007/H\beta ratios. In the 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 \( \sim 7 \times 10^{-12} \text{erg cm}^{-2} \text{s}^{-1} \) (Polletta et al. 1996). At their redshift, the apparent distance of the pair members translates into a projected physical separation \( R \approx 10.5 \text{kpc} \). The line-of-sight velocity difference is \( \Delta v = 320 \pm 40 \text{ km s}^{-1} \). For comparison, in the Mortlock et al. (1999) sample of binary quasars: \( \langle R \rangle = 32 \pm 9 \text{ kpc} \) and \( \langle \Delta v \rangle = 83 \pm 10 \text{ km s}^{-1} \).
In this paper: energies are quoted in the source’s frame; errors on the count rates are at the 1-σ level; errors on the spectral parameters are at the 90% confidence level for 1 interesting parameter; a flat ΛCDM 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 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 $N_H \approx 7.1 \times 10^{22}$ 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 ($N_{H,Gal} = 6.5 \times 10^{20}$ 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 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.

<table>
<thead>
<tr>
<th>Source</th>
<th>RA (J2000)</th>
<th>Dec (J2000)</th>
<th>EB (″)</th>
<th>CR (s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>13h34m39.7</td>
<td>-23°26'48″</td>
<td>7</td>
<td>0.658 ± 0.018</td>
</tr>
<tr>
<td>E</td>
<td>13h34m40.8</td>
<td>-23°26'45″</td>
<td>10</td>
<td>0.512 ± 0.016</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Source</th>
<th>$N_H$ ($10^{22}$ cm$^{-2}$)</th>
<th>$\Gamma$</th>
<th>$f_s$ (%)</th>
<th>$E_F$ (keV)</th>
<th>EW (eV)</th>
<th>$F$ ($10^{-12}$ erg cm$^{-2}$ s$^{-1}$)</th>
<th>$L$ ($10^{44}$ erg s$^{-1}$)</th>
<th>$\chi^2$/ν</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>7.1±0.6</td>
<td>1.81±0.13</td>
<td>2.3±0.5</td>
<td>6.35±0.05</td>
<td>120±20</td>
<td>0.12/5.2</td>
<td>3.3 ± 0.4</td>
<td>105.8/130</td>
</tr>
<tr>
<td>E</td>
<td>0.51±0.10</td>
<td>1.64±0.72</td>
<td>5.8±2.8</td>
<td>6.4$^a$</td>
<td>&lt;90</td>
<td>0.6/3.0</td>
<td>1.43 ± 0.08</td>
<td>170.2/167</td>
</tr>
</tbody>
</table>

$^a$ Fixed.

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 ($\sim 10^7 M_\odot^{-1}$ yr, where $M_\odot$ 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: $M_{\text{tot}} \approx (R\Delta v^2)/(2G) \approx 2 \times 10^{11} M_\odot$. 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$^{-1}$, 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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References


