An X-ray and optical study of the cluster A33

S. Colafrancesco, C.R. Mullis, A. Wolter, I.M. Gioia, T. Maccacaro, A. Antonelli, F. Fiore, J. Kaastra, R. Mewe, Y. Rephaeli, R. Fusco-Femiano, V. Antonuccio-Delogu, F. Matteucci and P. Mazzotta

1 Osservatorio Astronomico di Roma via dell’Osservatorio 2, I-00040 Monteporzio, Italy
Email: cola@coma.mporzio.astro.it
2 Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA
3 Osservatorio Astronomico di Brera, Via Brera 26, Milano, Italy
4 SRON, Sorbonnelaan 2, 3584 CA Utrecht, The Netherlands
5 School of Physics and Astronomy, Tel Aviv University, Israel 69978
6 IAS - CNR, Via Fosso del CaVALiere, 100133, Roma, Italy
7 Osservatorio Astrofisico di Catania, Via A. Doria, Catania, Italy
8 Osservatorio Astronomico di Trieste, Via dell’Osservatorio, Trieste, Italy
9 Dipartimento di Fisica, Università di Roma “Tor Vergata”, Via della Ricerca Scientifica 1, I-00133 Roma, Italy
10 Home institution: Istituto di Radioastronomia del CNR, Via Gobetti 101, I-40129, Bologna - Italy
11 Visiting Astronomer at the W. M. Keck Observatory, jointly operated by the California Institute of Technology, the University of California and the National Aeronautics and Space Administration

Abstract. We report the first detailed X-ray and optical observations of the medium-distant cluster A33 obtained with the Beppo-SAX satellite and with the UH 2.2m and Keck II telescopes at Mauna Kea. The information deduced from X-ray and optical imaging and spectroscopic data allowed us to identify the X-ray source 1SAXJ0027.2-1930 as the X-ray counterpart of the A33 cluster. The faint, \( F_{2-10\ keV} \approx 2.4 \times 10^{-13} \ erg\ s^{-1} \ cm^{-2} \), X-ray source 1SAXJ0027.2-1930, \( \sim 2\) arcmin away from the optical position of the cluster as given in the Abell catalogue, is identified with the central region of A33. Based on six cluster galaxy redshifts, we determine the redshift of A33, \( z = 0.2409 \); this is lower than the value derived by Leir and Van Den Bergh (1977). The source X-ray luminosity, \( L_{2-10\ keV} = 7.7 \times 10^{41} \ erg\ s^{-1} \), and intracluster gas temperature, \( T = 2.9\ keV \), make this cluster interesting for cosmological studies of the cluster \( L_X - T \) relation at intermediate redshifts. Two other X-ray sources in the A33 field are identified. An AGN at \( z = 0.2274 \), and an M-type star, whose emission are blended to form an extended X-ray emission \( \sim 4 \) arcmin north of the A33 cluster. A third possibly point-like X-ray source detected \( \sim 3 \) arcmin north-west of A33 lies close to a spiral galaxy at \( z=0.2863 \) and to an elliptical galaxy at the same redshift as the cluster.

Key words: Cosmology: clusters of galaxies: individual: A33, observations: X-rays

1. Introduction

A33 is a medium-distant Abell cluster of galaxies with very few and sparse information in both the X-ray and the optical bands. This cluster was claimed to have been detected by the HEAO1-A1 all sky survey (Johnson et al. 1983, Kowalski et al. 1984) with a count rate of \( 3.77 \pm 0.47 \) counts \( cm^{-2} \ s^{-1} \) in the \( 2 - 6\) keV energy band. Its luminosity was estimated, with large uncertainties, to be \( L_{2-6\ keV} \approx 2.34 \times 10^{45} \ erg\ s^{-1} \).

A33 was also observed with the GINGA LAC detector from December 9 to December 10, 1988 (Arnaud et al. 1991), but no X-ray emission was found at the optical position of the cluster. From such a non-imaging observation, Arnaud et al. (1991) were able to put an upper limit on the luminosity of A33, \( L_{2-10\ keV} < 6 \times 10^{44} \ erg\ s^{-1} \), assuming a temperature \( T = 8.4\ keV \). The value of the X-ray luminosity derived from GINGA data is inconsistent with the one derived from the HEAO1-A1 observation (note, however, that A33 lies at the edge of the error box for the position of the HEAO1 source).

The source 1RXSJ002709.5-192616 in the ROSAT Bright Source Catalog (BSC: Voges et al., 1996), at coordinates \( \alpha_{2000} = 00^h\ 27^m\ 09.50^s \) and \( \delta_{2000} = -19^\circ\ 26'\ 16" \),
has been observed for 317 sec with a count rate of
0.062 ± 0.017 cts/s. This source has 19.6 net counts in
the 0.1 − 2.4 keV energy band corresponding to a flux
F_{0.1-2.4} = (9.3 ± 2.6) \times 10^{-13} \text{ erg s}^{-1} \text{ cm}^{-2} \ (\text{assuming a nominal conversion factor of } 1.5 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ cts}^{-1}) \text{ and does not appear to be extended. This source is}
unrelated to the cluster and most probably associated
with an AGN which is only 5.4'' away (see Table 1, source
1SAXJ0027.1-1926, and Table 2, source A).

In the optical band there is no detailed information except from that derived from the extensive study of Leir & Van Den Bergh (1977), who classified A33 as a distance
class $D = 6$, richness $R = 1$, Bautz-Morgan-class-III cluster.
In the Abell (1958) catalog, A33 has 69 galaxies which
lie within one Abell radius ($2.7 \times 10^{-1} \text{ arcmin}$) and which
are not more than 2 mag fainter than the third brightest
galaxy. Its photometrically estimated redshift, $z = 0.28$,
was derived by Leir & Van Den Bergh (1977) from the
cluster optical diameter and the magnitude of the bright-
est and tenth-brightest cluster galaxies.

In this paper we present a new X-ray observation of
A33 obtained with Beppo-SAX. This observation enables
us to derive detailed information on the X-ray source,
on its morphology and thermal properties. The complex
appearance of the X-ray emission in the field of A33
prompted us to obtain optical images and spectroscopic
information for several objects in the field.

The plan of the paper is the following. In Section 2 we
present the basic information on the Beppo-SAX obser-
vation and data reduction. In Section 3 we describe the
optical data and in Section 4 we discuss the X-ray spec-
troscopy of the various sources in the A33 field. We sum-
marize our results for A33 and discuss their implications
in Section 5.

Throughout the paper $H_0=50 \text{ km sec}^{-1} \text{ Mpc}^{-1}$ and
$\Omega_0 = 1$ are used unless otherwise noted.

2. Beppo-SAX Observation

The A33 field was observed with the Narrow Field In-
struments (NFI) of the Beppo-SAX satellite from Novem-
ber 23$^{th}$ to 25$^{th}$, 1996. The total effective exposure time
is $t_{\text{exp}} = 3.8417 \times 10^4 \text{ s}$ for the LECS instrument and
$t_{\text{exp}} = 7.7610 \times 10^4 \text{ s}$ for the MECS instrument (see e.g.
Boella et al. 1997a and 1997b for a technical description of
the Beppo-SAX mission and instrumentation).

Data preparation and linearization was performed us-
ing the SAXDAS v.1.3 package under the FTOOLS envi-
ronment. The imaging analysis was performed using the
XIMAGE package (Giommi et al. 1991). The extraction
of the source and background spectra was done within the
XSELECT package. The spectral analysis was performed
using XSPEC v.9.0.

The only previous claimed X-ray detection of A33
was done with the HEAO1 satellite (Johnson et al.
1983; Kowalski et al. 1984). Due to the large error box
of the HEAO1 detectors, the coordinates of the X-ray
source were associated with the optical coordinates of
the A33 cluster. Thus the Beppo-SAX observation was
centered on the optical coordinates $\alpha_{2000} = 00^h 26^m 52.7^s$
and $\delta_{2000} = -19^\circ 32^\prime 29^\prime\prime$. The MECS 2 − 10 keV X-ray
image of the field is shown in Fig.1, where three dif-
ferent subsystems are evident: a bright and apparently
extended source, 1SAXJ0027.1-1926, an extended but
smaller source, 1SAXJ0027.2-1930, located to the south of
the brightest source and an apparently point-like source,
1SAXJ0027.0-1928, located to the west. Positions, count
rates and extraction region radii, $R_{\text{extr}}$, are listed in Table 1.
The sources have sufficient count rates to be detected in-
dividually at more than 4 sigma level by the MECS instru-
ments. The poorer spatial resolution of the LECS instead
allows only to determine the count rate of the brightest
source 1SAXJ0027.1-1926. In the following we describe the
spatial structure of each source detected in the A33 field
as derived from the MECS data.

The MECS PSF is $\approx 1 \text{ arcmin}$ Half Energy Width,
and this spatial resolution allows us to detect the sources
1SAXJ0027.1-1926 and 1SAXJ0027.2-1930 as extended in the
MECS image of Fig.1.

The source 1SAXJ0027.1-1926 has an extension of $\approx 2
\text{ arcmin}$ (radius). As discussed in Sections 3 and 4, this
source is most probably the result of the blending of two
point-like sources not resolved by the MECS PSF. The
X-ray MECS image contours superposed onto the POSS
II image of the field plotted in Fig.2 show that there
is no clear galaxy excess associated to the X-ray source
1SAXJ0027.1-1926.

The source 1SAXJ0027.2-1930, located $\approx 4.5 \text{ arcmin}
south of the brightest source (see Fig. 1), has an exten-
sion of $\gtrsim 1.5 \text{ arcmin}$ radius. Using a $\beta$-model with values
$\beta = 0.75$ and $r_e = 260 \text{ kpc}$ ($H_0 = 50, \Omega_0 = 1$) chosen
as representative of such low luminosity objects, and con-
volved with the MECS PSF we find a central density of
$\approx 3.9 \times 10^{-3} \text{ cm}^{-3}$. Moreover, an extended, low surface
brightness X-ray emission is visible in the southern part of
the image (see Fig. 1 and Fig. 2). Such a low surface
brightness source extends for a few arcminutes at levels of
$\approx 10^{-4} \text{ cts s}^{-1} \text{ cm}^{-2} \text{ arcmin}^{-2}$. The extended source
1SAXJ0027.2-1930 is associated with A33 as shown in the
POSS II image of the field (see Fig.2 and Section 3).

The third source 1SAXJ0027.0-1928, located $\approx 4 \text{ arc-
min}$ south-west of the brightest source, has a point-like
appearance. Two faint objects in the POSS II are posi-
tionally consistent with 1SAXJ0027.0-1928.

3. Optical Imaging and Spectroscopy

Due to the lack of detailed optical information in the lit-
erature for A33, we took I and B images of the cluster re-
region on November 23 and 24 1997 at the Keck II telescope.
The images were obtained using the Low-Resolution and
Imaging Spectrograph (LRIS) (Oke et al. 1995) in imag-
Table 1. LECS (0.1 - 2 keV) and MECS (2 - 10 keV) count rates

| Source        | α_{2000}  | δ_{2000}  | t_{exp} | Count rate | Count rate | R_{extr} |
|---------------|-----------|-----------|---------|------------|------------|----------|
|               | (h m s)   | (° ′ ″)   | (s)     | (10^{-3}s^{-1}) | (10^{-3}s^{-1}) | arcmin   |
| 1SAXJ0027.1-1926 | 00 27 08  | −19 26 38 | 77609   | 7.6 ± 0.7  | 7.8 ± 0.6  | 2        |
| 1SAXJ0027.2-1930 | 00 27 12  | −19 30 32 | 77609   | −          | 1.76 ± 0.23 | 2        |
| 1SAXJ0027.0-1928 | 00 27 01  | −19 28 30 | 77609   | −          | 1.14 ± 0.19 | 1        |

**Fig. 1.** The Beppo-SAX image of A33 in the 2 - 10 keV energy band. The three different components of the emission are labeled according to the text. The circles indicate the extraction area for each X-ray source. Note that 1SAXJ0027.2-1930 has also a diffuse, low-surface brightness distribution which appears to be extended in the southern part of the image. The image has been deconvolved with a wavelet transform using a smoothing length of 3.5 pixels (1 pixel = 8 arcsecs). North is up and East to the left.

ing mode, resulting in a scale of 0.215″ pixel^{-1} and a field of view of 6′×7.3′. The I (B) images were taken in 0.4″ - 0.5″ seeing on the first night and consist of 3×300s (4×120s) dithered exposures centered at α=00\(^h\)27\(^m\)10.5\(^s\) and δ = −19°29′18″ (J2000), the southern region of the X-ray emission complex. On the second night (0.8″ seeing) we took 2×120s I (2×300s B) exposures centered at α=00\(^h\)27\(^m\)09.8\(^s\) and δ = −19°26′12.″4 (J2000), the northern region of the X-ray emission system. The optical position of A33 (Fig.2) is close to an open stellar cluster. Fig.3 shows the B images for both North (Fig.3a) and South (Fig.3b) regions. No excess of galaxies is present in the northern region at the position of 1SAXJ0027.1-1926 (Fig.3a), while Fig.3b reveals an overdensity of galaxies in the region of the X-ray source 1SAXJ0027.2-1930.

Spectroscopic observations for several objects in the field were carried out on August 16, 17 and 19, 1998, with the Wide Field Grism Spectrograph and the Tek2048×2048 CCD attached to the University of Hawaii 2.2m telescope on Mauna Kea. We used the 420 l/mm grating which provided a ~3990-9900 Å coverage and a pixel size of 3.6 Å/pix, and a long-slit of 2.4″ which gives
Table 2. Optical results

| Name | \( \alpha_{2000} \) \((^h^m^s)\) | \( \delta_{2000} \) \((^\circ^\prime^\prime)\) | z   | Identification and Comments                                      |
|------|------------------|------------------|-----|---------------------------------------------------------------|
| A    | 00 27 09.8       | −19 26 12.6      | 0.2274 ± 0.0006 | AGN ([OII], [OIII], [Ne III], broad Balmer)                  |
| B    | 00 27 07.3       | −19 26 36.4      | 0.2420 ± 0.0005 | galaxy (G-band, H\(\beta\), Mgb, NaI d)                     |
| C    | 00 27 00.5       | −19 28 16.8      | 0.2863 ± 0.0015 | galaxy (H+K, G-band, H\(\beta\), Mgb)                       |
| D    | 00 26 59.5       | −19 30 45.5      | 0.2406 ± 0.0008 | galaxy (H+K, G-band, H\(\beta\), Mgb, NaI d)                |
| g1   | 00 27 12.3       | −19 30 40.1      | 0.2380 ± 0.0012 | galaxy (CaII-break, G-band, H\(\beta\), Mgb, NaI d)         |
| g2   | 00 27 12.6       | −19 30 34.7      | 0.2395 ± 0.0017 | galaxy (CaII-break, G-band, H\(\beta\), Mgb, NaI d)         |
| g3   | 00 27 12.5       | −19 30 29.4      | 0.2445 ± 0.0004 | galaxy (H+K, G-band, H\(\beta\), Mgb, NaI d)                |
| g4   | 00 27 13.1       | −19 30 45.5      | 0.2406 ± 0.0005 | galaxy (H+K, G-band, H\(\beta\), Mgb, NaI d)                |

Fig. 2. The optical image of A33 taken from the POSS II plate and the X-ray contours of the Beppo-SAX image obtained with the MECS detector in the 2 – 10 keV energy band. Contours are taken from the image shown in Fig.1 and are logarithmically spaced. The image has been deconvolved with a wavelet transform using a smoothing length of 3.5 pixels (1 pixel = 8 arcsecs). The white cross indicates the position of A33 from the Abell catalogue. The first X-ray contour is at 3\(\sigma\) from the background level. North is up and East to the left.

In the region of the southern X-ray emission we obtained spectra for five galaxies which turned out to be members of the cluster. These galaxies are labeled g1 through g5 in Fig.3b. Table 2 gives the results of the observations:

Based on our imaging and spectroscopic results, we conclude that a blend of the AGN (A) and M-type star (B) X-ray emissions contribute to the extended source 1SAXJ0027.1-1926 to the north. The Abell cluster A33 is the source of the southern X-ray emission 1SAXJ0027.2-1930, while the identification of the source of the western X-ray emission, 1SAXJ0027.0-1928, remains unknown. The two galaxies for which we measured the spectra, and which are the two brightest optical sources in the region, might be responsible for part of the emission of 1SAXJ0027.0-1928, but we need spectroscopic data for more objects to help in the identification. One of the sources (C) is consistent with being part of A33. From the six cluster members listed in Table 2 we obtain for A33 an average <\(z\)> = 0.2409 ± 0.0009, and a very tentative velocity dispersion, given the few cluster galaxies, \(\sigma_{los} = 472^{+295}_{-148}\) km s\(^{-1}\). This estimate includes the 1 + \(z\) correction.

4. X-Ray Spectroscopy

The Beppo-SAX concentrator/spectrometer system consists of four separated concentrator mirrors, three of them covering the 1.6 – 10 keV range (Medium Energy Concentrator Spectrometer, or MECS) and the fourth extending to lower energies down to 0.1 keV (Low Energy Concentrator Spectrometer, or LECS). The concentrators are designed to have a large effective area around the iron K\(\alpha\) line complex: 150 and 50 cm\(^2\) for MECS and LECS, at 6 keV. Also, Beppo-SAX is able to provide spatially resolved spectra: its energy and angular resolution are \(\Delta E/E = 8\%\) at 6 keV and \(\theta_{FWHM} \approx 40''\), respectively.

In order to obtain the emission weighted spectral information of the three main sources in the A33 field, we have extracted the photons from circular regions drawn around each source (see Fig.1). The extraction radius,
smaller than the suggested 4 arcmin radius region since the sources are separated by a small angular distance, might introduce a systematic uncertainty. We have used the appropriate Ancillary Response File to correct for this effect. We fitted the source spectra using both a Raymond-Smith code (1977; hereafter RS) or a MEKAL code (Mewe, Kaastra & Liedahl 1995) to model the thermal intracluster gas emissivity and a simple absorbed power-law, non-thermal model. Background spectra have been extracted from library blank-sky images in the same circular regions as the sources.

a) 1SAXJ0027.1-1926

The spectrum of the brightest source in the field was extracted, both for the LECS and the MECS instruments, from a circular region of 2 arcmin radius centered on the X-ray position of Table 1. The combined LECS-MECS spectrum is shown in Fig.4: we do not observe any low energy absorption in the spectrum, thus we keep $N_H$ fixed at the galactic value of $1.86 \times 10^{20}$ cm$^{-2}$ (Dickey & Lockman, 1990) relative to the source position.

The best fit spectral parameters for the MECS spectrum are listed in Table 3 together with their uncertainties at 68.3% (and 90% in parentheses) confidence level. We use 605 source photons in this spectral fit.

Within 2 arcmin from its center, the source has a flux of $F_{2-10keV} = (4.20 \pm 0.32) \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$, evaluated using the MEKAL best fit parameters. The other models give similar fluxes. This flux is also consistent, within the errors, with the flux of the X-ray source 1RXSJ002709.5-192616 in the ROSAT band.

The optical magnitude of the M-star if $m_V \approx 19$. Assuming that the X-ray flux of the M-star contributes to 50% of the total flux of 1SAXJ0027.1-1926, we obtain $F_{2-10}/F_V \approx 2$. In the 2–10 keV band and $F_{0.3-3.5}/F_V \approx 6$ in the 0.3–3.5 energy band (assuming a thermal emission at $T = 1$ keV). This ratio is almost one order of magnitude higher than the values of $F_{0.3-3.5}/F_V$ for X-ray selected stars in the EMSS (see Fig.1 in Maccacaro et al. 1988). This means that the contribution of the M-star to the X-ray flux of 1SAXJ0027.1-1926 should be $\lesssim 8\%$ to be consistent with the values of $F_X/F_V$ for normal stars. If this is the case, then more than half of the X-ray emission of 1SAXJ0027.1-1926 is due to the AGN (listed as A in Table 2) at $z = 0.2274$ with a luminosity $L_{2-10 keV} \lesssim 4.5 \times 10^{43}$ erg s$^{-1}$. Otherwise, the source 1SAXJ0027.1-1926 should result from the blend of the AGN and of a different unknown X-ray source.

b) 1SAXJ0027.2-1930

The average spectrum of 1SAXJ0027.2-1930 was extracted from a circular region of 2 arcmin radius centered on the X-ray position of Table 1 (see also Fig.5). In this region there is a clear excess of galaxies (see Fig. 3) which is $\sim 1.5$ arcmin away from the Abell catalog position of A33. Fitting the spectrum (which contains 140 source photons) with a RS thermal model with temperature, abundance and redshift as free parameters, the fit gives $\chi^2_{red} = 1.22$. Fixing the value of $N_H$ to the galactic value ($1.86 \times 10^{20}$ cm$^{-2}$) we obtain an average temperature $T = 3.1 \pm 0.9$ keV and a redshift $z_X = 0.72 \pm 0.04$. The abundance is only marginally constrained at $Fe/H = 0.98 \pm 0.71$ of the solar value. However, the fit results are mainly due to a marginally significant spectral feature at $E \sim 4$ keV.

Therefore, we fixed the redshift of the X-ray source at $z = 0.2409$, as measured from the optical spectra (see Section 3), and we fitted the spectrum again, fixing the abundance to a value $Fe/H = 0.3$ solar. The results of the fit are shown in Table 4. Uncertainties in the temperature of 1SAXJ0027.2-1930 are given at 68.3% (and 90% in parentheses) confidence level. The low count rate of the source does not allow a more accurate description of the X-ray emission.

Assuming the MEKAL best fit parameters we obtain an integrated flux of $F_{2-10keV} = (2.4 \pm 0.3) \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$ in the 2 arcmin radius extraction region (which corresponds to a linear size of $\approx 1$ h$^{-1}$ Mpc). The other models give consistent fluxes. At the red-shift of the cluster this flux corresponds to a luminosity $L_{2-10 keV} = (7.7 \pm 0.9) \times 10^{43}h^{-2}_{50}$ erg s$^{-1}$ and to a bolometric luminosity $L_{bol} = (2.2 \pm 0.3) \times 10^{44}h^{-2}_{50}$ erg s$^{-1}$.

c) 1SAXJ0027.0-1928

We extracted the spectrum of 1SAXJ0027.0-1928 from a circular region of 1 arcmin radius centered on the X-ray position of Table 1 (see Fig.6). Results of the fit are shown in Table 5 (uncertainties on the best fit values are given here at 68.3 % confidence level. Note that the spectrum of this source contains 90 source photons). Assuming an

| Model  | pho. index | $z$  | $T$  | bins | $\chi^2$ | $\chi^2_{red}$ |
|--------|------------|-----|------|------|---------|----------------|
| RS     | –          | 0.245 ± 0.023 | 3.99±0.96(1.83) | – | 61 | 56.12 | 0.97 |
| MEKAL  | –          | 0.245 ± 0.024 | 3.90±0.99(1.88) | – | 61 | 55.98 | 0.97 |
| PL     | 2.05±0.17(0.41) | – | – | – | 61 | 62.55 | 1.06 |

Table 3. 1SAXJ0027.1-1926
absorbed power–law non–thermal model, we derived a flux of $F_{2-10keV} = (4.74 \pm 0.8) \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$. There are two galaxies, a spiral (C) at the same $z$ of A33, and an elliptical (D) in the region for which we took an optical spectrum.

The identification of the source is not certain at the moment. Assuming that the galaxy D at $z = 0.2863$ is the X-ray emitter, its X-ray luminosity would be $L_{2-10 \text{ keV}} = 1.9 \times 10^{43}$ erg s$^{-1}$. Such an X-ray luminosity seems to be sensibly higher than the X-ray luminosity of a “normal” galaxy. The possibility that the X-ray emission is due to a more distant, unidentified object cannot be excluded at present.

5. Discussion

In this paper we presented the first detailed X-ray observation of the distant Abell cluster A33, obtained with the Beppo-SAX satellite. We have closely examined and clarified the complex X-ray emission in the direction of A33. The analysis of the X-ray data revealed the presence of three different X-ray sources in the field of A33. The X-ray counterpart of the cluster is 1SAXJ0027.2-1930. We present a spectroscopic redshift for A33, applying a $\sim 20\%$ correction to the previous photometric estimate. From optical spectra of six cluster galaxies we measure a redshift $z = 0.2409 \pm 0.0009$ and a velocity dispersion along the line of sight $\sigma_{\text{los}}=472_{-148}^{+295}$ km s$^{-1}$. The dominant X-ray component (incorrectly linked with A33 in the past) is associated with a blend of an AGN and M star, while the X-ray emission from A33 is $\sim 4$ times fainter. Using the proper X-ray flux and measured redshift, we determine a more realistic cluster luminosity of $L_{2-10 \text{ keV}} = (7.7 \pm 0.93) \times 10^{43} h_{50}^{-2}$ erg s$^{-1}$, one to two orders of magnitude lower than previous attempts. The MECS spectral resolution also allows us to determine that the intracluster gas temperature is $T = 2.91^{+1.25}_{-0.54}$ keV. No useful information on the cluster abundance is given due to the low count rate of the source in the MECS detector.

In the following we will focus on measured quantities such as the low temperature and low velocity dispersion. We are dealing here with a moderately rich (R=1) and distant (D=3) Abell cluster but with X-ray luminosity and temperature more typical of nearby ($z < 0.1$) poor clusters. The temperature of A33 is commensurate with the predictions from its X-ray luminosity from the $L_X - T$ relation by David et al. (1993) and Arnaud and Evrard (1999). There is an extensive literature on the correlation between these two basic and measurable quantities (Edge & Stewart 1991, Ebeling 1993, David et al. 1993, Fabian et al. 1994, Mushotzky & Scharf 1997, Markevitch 1998, Arnaud and Evrard, 1999). Comparing the bolometric luminosity of A33 with the best fit relation, $\log(L_X)=(2.88\pm0.15) \log(T/6\text{keV})+(45.06\pm0.03)$ obtained by Arnaud and Evrard (1999), analyzing a sample of 24 low-$z$ clusters with accurate temperature measurements and absence of strong cooling flows, we would expect for the A33 a temperature of 3.4 keV, as compared with our deduced value $2.91^{+1.25}_{-0.54}$. The $L_X - T$ relation does not seem to evolve much with redshift since $z=0.4$ (Mushotzky & Scharf 1997). Note however that the ASCA data that they use show a strong bias at the low-luminosity end of the distribution due to the absence of objects in the lower luminosity range in the ASCA database. The present data on a cluster at about 0.2 are thus important to fill in the gap in the $L_X - T$ relationship found among rich clusters and groups (see Mushotzky & Scharf 1997).

The measured velocity dispersion of A33 is also commensurate with the predictions from the $\sigma - T_X$ relation.
ship. A large number of authors (see Table 5 in Girardi et al., 1996, or Table 2 in Wu, Fang and Xu, 1998, for an exhaustive list of papers on the subject) have attempted to determine the $\sigma - T$ using different cluster samples in order to test the dynamical properties of clusters. Girardi et al. (1996) have derived a best fit relation between the velocity dispersion and the X-ray temperature, with more than 30% reduced scatter with respect to previous work (Edge and Stewart 1991; Lubin and Bahcall 1993; Bird, Mushotzky and Metzler, 1995; Wu, Fang and Xu 1998, among others). If we substitute the temperature of 1SAXJ0027.2-1930 in the best fit relation $\log(\sigma)=(2.53\pm0.04)+(0.61\pm0.05)\log(T)$, derived by Girardi et al. (1996) a value of 650 km s$^{-1}$ would be expected for the 1-D velocity dispersion, somewhat higher but within the uncertainties of the measured value from six cluster members of A33. If we assume energy equipartition between the galaxies and the gas in the cluster ($\beta=1$) and we use the measured temperature of 2.9 keV from the SAX data in the equation $\beta = \mu m_p \sigma_v^2 / kT_{\text{gas}}$ (where $\mu m_p = 0.62$, for solar abundance), we obtain a velocity dispersion of 665 km/s.

The data for A33 are also consistent with the relation $\sigma_{\text{los}} \propto (T/\text{keV})^{0.6\pm0.1}$ found by Lubin & Bahcall (1993) and increase its statistical significance in the low temperature ($T \lesssim 3$ keV) range and at intermediate redshifts ($z \sim 0.2$) where only a few clusters have measured values of $\beta$. This issue will be discussed in a forthcoming paper.

We have also found that the bright source 1SAXJ0027.1-1926 has an extended appearance which is due to the blending of two different sources: an AGN at $z = 0.227$ and approximate B magnitude $M_B \approx -23.9$ (derived from the apparent B magnitude as given in the APM scans) and an M-type star. The X-ray spectrum does not show any line.

Fig. 3. The two images are 1024x1024 (3.7x3.7 arcmin) subarrays extracted from two B-band exposures taken at the Keck II telescope. The image to the top shows the field around 1SAXJ0027.1-1926 and 1SAXJ0027.0-1928 and the image to the botton shows the field around 1SAXJ0027.2-1930. North is up and East to the left.

Fig. 4. The combined LECS and MECS spectrum of the source 1SAXJ0027.1-1926 extracted from a 2 arcmin radius regions. The spectrum shown in figure has been rebinned so that the significance of each bin is at least 3$\sigma$. The best fit model is a MEKAL thermal model (see text for details). The spectrum has been further rebinned using XSPEC for graphical purposes.
The SAX MECS spectra of 1SAXJ0027.2-1930 fitted with a thermal MEKAL model (upper panel) and with an absorbed power-law model (lower panel). Details of the spectral analysis are given in Table 4. The spectrum has been further rebinned using XSPEC for graphical purposes.

Fig. 6. The SAX MECS spectrum of 1SAXJ0027.0-1928 fitted with a non-thermal power-law model (see Table 4 for details). The spectrum has been further rebinned using XSPEC for graphical purposes.

features, and it is contaminated by the emission of the M star. Given the low statistics we did not try to disentangle the two contributions but we consider an upper limit to the AGN emission using the $F_X/F_V$ for the M star. The ROSAT BSC source found at a position consistent with the coordinates of 1SAXJ0027.1-1926 is most probably associated with the AGN. The distance between the foreground AGN and the cluster is $\Delta d_L \approx 89.2 h_{70}^{-1} \text{Mpc}$. At the redshift of the AGN, the observed total flux corresponds to a luminosity $L_X \lesssim 4.5 \times 10^{43} \text{erg/s}$, which can be considered as an upper limit to the AGN luminosity.

We also detected a point-like faint source, 1SAXJ0027.0-1928, for which no X-ray spectroscopic identification was possible. The $2-10 \text{keV}$ spectrum of this source can be fitted by both thermal and non-thermal models (see Table 5) but we do not elaborate further given the poor statistics.

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