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X-ray variability of Seyfert 1.8/1.9 galaxies

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ABSTRACT

Context. Seyfert 1.8/1.9 are sources showing weak broad Hα components in their optical spectra. According to unification schemes, they are seen with an edge-on inclination, similar to type 2 Seyfert galaxies, but with slightly lower inclination angles.

Aims. We aim to test whether Seyfert 1.8/1.9 have similar properties at UV and X-ray wavelengths.

Methods. We used the 15 Seyfert 1.8/1.9 in the Véron Cetty and Véron catalog with public data available from the *Chandra* and/or *XMM–Newton* archives at different dates, with timescales between observations ranging from days to years. All the spectra of the same source were simultaneously fit with the same model and different parameters were left free to vary in order to select the variable parameter(s). Whenever possible, short-term variations from the analysis of the X-ray light curves and long-term UV variations from the optical monitor onboard *XMM–Newton* were studied. Our results are homogeneously compared with a previous work using the same methodology applied to a sample of Seyfert 2.

Results. X-ray variability is found in all 15 nuclei over the aforementioned ranges of timescales. The main variability pattern is related to intrinsic changes in the sources, which are observed in ten nuclei. Changes in the column density are also frequent, as they are observed in six nuclei, and variations at soft energies, possibly related to scattered nuclear emission, are detected in six sources. X-ray intra-day variations are detected in six out of the eight studied sources. Variations at UV frequencies are detected in seven out of nine sources.

Conclusions. A comparison between the samples of Seyfert 1.8/1.9 and 2 shows that, even if the main variability pattern is due to intrinsic changes of the sources in the two families, these nuclei exhibit different variability properties in the UV and X-ray domains. In particular, variations in the broad X-ray band on short timescales (days to weeks), and variations in the soft X-rays and UV on long timescales (months to years) are detected in Seyfert 1.8/1.9 but not in Seyfert 2. Overall, we suggest that optically classified Seyfert 1.8/1.9 should be kept separated from Seyfert 2 galaxies in UV/X-ray studies of the obscured AGN population because their intrinsic properties might be different.

Key words. X-rays: galaxies – galaxies: active – ultraviolet: galaxies

1. Introduction

Active galactic nuclei (AGN) are thought to be powered by accretion of matter onto the supermassive black hole (SMBH) that resides in the center of the galaxies (Rees 1984). Historically, these nuclei have been classified as type 1 when broad Balmer permitted lines (full-width at half maximum (*FWHM*) $\sim$ 1000–20 000 km s^{-1}) are detected in their optical spectra, while they are classified as type 2 when detecting only narrow lines (*FWHM* $\sim$ 300–1000 km s^{-1}). Using the relative intensity of broad and narrow lines, the nuclei can also be classified as type 1.2, 1.5, 1.8, or 1.9 AGN (intermediate Seyferts), the latter having the weaker broad component (e.g., Osterbrock 1977; Osterbrock & Martel 1993). In particular, the optical spectra of Seyfert 1.8 are characterized by strong narrow emission lines combined with weak broad Hα and H$_\beta$ emission lines, whereas Seyfert 1.9 present the narrow lines but only a weak broad Hα emission line (Osterbrock 1981).

The detection of broad components in polarized light of type 2 sources set the unified model of AGN (Lawrence et al. 1987; Antonucci 1993; Urry & Padovani 1995; Moran et al. 2000). Under this scenario, the different properties observed in AGN can be explained by orientation effects, that is, they are the same kind of source observed at different angles. The cornerstone of this model is a dusty structure (often simplified as a torus) that surrounds the SMBH, which plays a fundamental role as it is responsible for obscuring the broad line region (BLR) where the broad lines are created. In support of this model, X-ray observations have shown that type 2 sources are more obscured than type 1s, whereas type 1.8 and 1.9 AGN are less absorbed than strictly type 2s (Risaliti et al. 1999).

X-rays are indeed a powerful tool for the comprehension of AGN as they are capable of reaching closer to the SMBH than other wavelengths. At these energies the absorbing column density, N_H, is used to classify sources as unobscured (type 1) when N_H is below $\sim 10^{22}$ cm^{-2} and obscured (type 2) sources for larger values. For N_H values larger than 1.5×10^{24} cm^{-2}, the sources are classified as Compton-thick (Maiolino et al. 1998). Sometimes transitions from Compton-thick to Compton-thin (or vice versa) have been observed; these are known as changing-look sources according to the original nomenclature by Matt et al. (2003).

Variability is one of the properties characterizing AGN, a highly valuable tool for the comprehension of their physical structure (Peterson 1997; Netzer 2013). The first systematic studies of AGN showed that short-term X-ray variability (from hours to days) is common in type 1s, but not in type 2s, while long-term (from months to years) variations are common in both (e.g., Nandra et al. 1997; Turner et al. 1997; Vaughan et al. 2005). Currently, we believe that the X-ray variations might be related to intrinsic changes of the nuclear source (e.g., Uttley et al. 2005; Uttley 2007; Parker et al. 2015), or to absorbing clouds that intersect the line of sight to the observer (e.g., Risaliti et al. 2007). These changes can be studied by modeling the X-ray spectrum of AGN, whose continuum is dominated by a power-law component extending up to a cut-off at energies ≥100 keV (e.g., Zdziarski et al. 1995; Guainazzi et al. 2005; Fabian et al. 2015). Changes in the power law might indicate a change in the accretion disk or the X-ray corona, while changes in the absorption may be related to clouds in our line of sight, more likely in the BLR, the torus, or the boundary between them (Risaliti et al. 2002, 2005a, 2011; Braito et al. 2013; Markowitz et al. 2014).

Because of their similar optical and X-ray spectra, it is usually assumed that optically classified Seyfert 1.2 and 1.5 behave more like type 1 sources, whereas types 1.8 and 1.9 behave as type 2. Indeed, many studies aiming to analyze the properties of type 2 sources have included Seyfert 1.8/1.9 in their samples (e.g., Guainazzi et al. 2001; Risaliti 2002; Akylas & Georgantopoulos 2009).

However, it is not clear whether the properties of Seyfert 1.8/1.9 are directly related to differences in the nuclear continuum or to an obscurer in our line of sight, since weaker broad lines may be produced by a lower ionizing continuum flux or by reddening from the BLR or the host galaxy (Osterbrock 1981; Goodrich 1995; Trippe et al. 2011). Through the analysis of variability, we are able to differentiate between changes in the accretion state and the configuration of the clouds. The main purpose of the present work is to homogeneously compare the variability properties of optically classified Seyfert 1.8/1.9 and Seyfert 2. The ultimate goal of our study is to understand the physical origin of the phenomenological differences between Seyfert 1.8/1.9 and Seyfert 2 in the optical, UV, and X-ray. We employ X-ray variability as gauge in this paper. This study is part of a systematic analysis of the variability properties of nearby AGN; by now we have analyzed the properties of a sample of optically classified low ionization nuclear emission line regions (LINERs, Hernández-García et al. 2013, 2014), and a sample of Seyfert 2 (Hernández-García et al. 2015). A comparison between the properties of LINERs and Seyfert 2 was carried out in Hernández-García et al. (2016).

The paper is organized as follows. The sample selection is presented in Sect. 2. The data reduction and the methodology are explained in Sects. 3 and 4. The results of the analysis are presented in Sect. 5, which are discussed in Sect. 6. Finally, the conclusions of this study are summarized in Sect. 7.

2. Sample and data

We used the 13th edition of the Véron-Cetty and Véron catalog (Véron-Cetty & Véron 2010), which contains quasars and AGN. We selected nearby sources located at redshifts below 0.05[1] that were classified as Seyfert type 1.8 and 1.9. In this way we selected 142 Seyfert 1.8 and 189 Seyfert 1.9.

We used the HEASARC database[2] to search for public data in the *Chandra* and/or *XMM–Newton* archives of these sources. To study X-ray variability, we selected those sources with more than one observation with these satellites. This included 12 Seyfert 1.8 and another 12 Seyfert 1.9.

We further restricted our sample to sources whose spectra have a minimum of 400 number counts in the 0.5–10 keV energy band (to use χ^2-statistics) and to not be affected by a pileup fraction larger than 10%. This leaves us with nine Seyfert 1.8 and seven Seyfert 1.9. We removed MARK 1018 from the sample because, although being classified as a Seyfert 1.9 by Osterbrock (1981) using optical data, Cohen et al. (1986) reported variations from Seyfert 1.9 to Seyfert 1 also using optical data, and remained as a Seyfert 1 at least up to 2007 (Trippe et al. 2010). Therefore, the final sample includes nine Seyfert 1.8 and six Seyfert 1.9. The sample properties are presented in Table 1.

We note that a caveat in the analysis could be related to the non simultaneity of the X-ray data with the optical spectroscopic data used for the optical classification of the sources. Unfortunately, the only case in our sample where the X-ray and optical data were obtained at close epochs is NGC 2617, where the X-ray data were taken in 2013, while it was reclassified as a Seyfert 1 using optical spectroscopy gathered in 2014, confirming that variability might be an important issue.

3. Data reduction

3.1. Chandra data

Chandra observations were obtained from the ACIS instrument (Garmire et al. 2003). Data reduction and analysis were carried out in a systematic, uniform way using CXC *Chandra* Interactive Analysis of Observations (CIAO[3]), version 4.6. Level 2 event data were extracted by using the task ACIS-PROCESS-EVENTS. Background flares were cleaned using the task LC_CLEAN.SL[4], which calculates a mean rate from which it deduces a minimum and maximum valid count rate and creates a good time intervals file.

Nuclear spectra were extracted from a circular region centered on the positions given by NED[5]. We chose circular radii, aiming to include all possible photons, while excluding other sources or background effects. The radii are in the range between 2–4″ (see Table A.1). The background was extracted from circular regions in the same chip that are free of sources and close to the object.

For the source and background spectral extractions, the DMEXTRACT task was used. The response matrix file (RMF) and ancillary reference file (ARF) were generated for each source region using the MKACISRMF and MKWARF tasks, respectively. Finally, the spectra were binned to have a minimum of 20 counts per spectral bin using the GRPPHA task (included in FTOOLS), to be able to use the χ^2-statistics, as customary in X-ray spectroscopy.

3.2. XMM-Newton data

XMM-Newton observations were obtained with the EPIC pn camera (Strüder et al. 2001). The data were reduced in a systematic, uniform way using the Science Analysis Software (SAS[6]),

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[1] The redshift of 0.05 corresponds to a distance of d = 214.3 Mpc (using H_0 = 70 km s^{-1}). The limit on distance was chosen to be the same as in Hernández-García et al. (2015) for Seyfert 2.

[2] http://heasarc.gsfc.nasa.gov/

[3] http://cxc.harvard.edu/ciao4.4/

[4] http://cxc.harvard.edu/ciao/ahelp/lc_clean.html

[5] http://ned.ipac.caltech.edu/

[6] http://xmm.esa.int/sas/

Table 1. General properties of the sample galaxies.

Name (1)	RA (J2000) (2)	Dec (J2000) (3)	Dist.^{1} (Mpc) (4)	$N_{\rm Gal}$ (10^{20} cm ^{2}) (5)	m_V (6)	Morph. type (7)	Seyfert type (8)	log $M_{\rm BH}$ $M_\odot$ (9)
ESO 540-G01	00 34 13.8	–21 26 20	110.5	1.62	13.7	SBc	1.8	–
ESO 195-IG21	01 00 36.5	–47 52 03	201.8	1.65	16.7	–	1.8	–
ESO 113-G10	01 05 17.0	–58 26 13	104.1	2.95	14.6	SBa	1.8	6.85
NGC 526A	01 23 54.4	–35 03 56	77.8	2.19	14.6	S0	1.9	7.90
MARK 609	03 25 25.4	–06 08 39	141.1	4.42	14.1	S0	1.8	–
NGC 1365	03 33 36.4	–36 08 24	18.0	1.35	13.0	Sb	1.8	7.54
NGC 2617	08 35 38.8	–04 05 19	56.1	3.65	14.0	SBc	1.8	7.60
MARK 1218	08 38 11.1	24 53 45	116.6	3.54	14.1	Sb	1.8	–
NGC 2992	09 45 42.0	–14 19 35	30.5	4.99	13.8	Sa	1.9	7.73
POX 52	12 02 56.8	–20 56 03	87.3	4.03	17.2	–	1.8	5.14
NGC 4138	12 09 29.9	43 41 06	16.0	1.36	12.2	S0-a	1.9	7.30
NGC 4395	12 25 48.9	33 32 48	4.5	1.35	10.3	Sm	1.8	4.82
NGC 4565	12 36 20.6	25 59 11	12.1	1.30	12.4	Sb	1.9	6.30
MARK 883	16 29 52.8	24 26 39	155.7	3.97	14.4	I	1.9	7.28
IRAS 20051-1117	20 07 51.4	–11 08 35	128.9	6.57	14.0	–	1.9	7.11

Notes. (Column 1) Name, (Col. 2) right ascension, (Col. 3) declination, (Col. 4) distance, (Col. 5) galactic absorption, (Col. 6) aparent magnitude in the Johnson filter V from Véron-Cetty & Véron (2010), (Col. 7) galaxy morphological type from Hyperleda, (Col. 8) AGN type as in Véron-Cetty & Véron (2010), and (Col. 9) black-hole mass on logarithmical scale, determined using the correlation between stellar velocity dispersion (from HyperLeda) and black-hole mass (Tremaine et al. 2002), or obtained from the literature otherwise (ESO 113-G10 from Cackett et al. 2013, NGC 526A from Vasudevan & Fabian 2009, NGC 2617 from Shappee et al. 2014, MARK 883 from Benítez et al. 2013, and IRAS 20051-1117 from Wang & Zhang 2007). $^{(1)}$ All distances are taken from the NED and correspond to the average redshift-independent distance estimates.

version 14.0.0. First, good time intervals were selected using a method that maximizes the signal-to-noise (S/N) of the net source spectrum by applying a different constant count rate threshold on the single events, $E > 10$ keV field-of-view background light curve. We extracted the spectra of the nuclei from circles of 20–35″ radius centered on the positions given by NED, while the background spectra were extracted from circular regions using an algorithm that automatically selects the best area – and the closest to the source – that is free of sources. This selection was manually checked to ensure the best selection for the backgrounds.

Source and background spectra were extracted with the EVSELECT task. The response matrix files (RMF) and the ancillary response files (ARF) were generated using the RMFGEN and ARFGEN tasks, respectively. To be able to use the χ^2 statistics, the spectra were binned to obtain at least 20 counts per spectral bin using the GRPPHA task.

3.3. Light curves

Light curves in three energy bands (0.5–2.0 keV, 2.0–10.0 keV, and 0.5–10 keV) for the source and background regions as defined above were extracted using the DMEXTRACT task (for *XMM–Newton*) and EVSELECT task (for *Chandra*) with a 1000s bin. To be able to compare the variability amplitudes in different light curves of the same object, only those observations with a net exposure time longer than 30 ks were taken into account. For observations longer than 40 ks, the light curves were divided into segments of 40 ks, so in some cases more than one segment of the same light curve can be extracted. Our light curves are occasionally affected by high particle background events ("flares"), whose flux dominates the observed count rates. We decided to remove these intervals from the source background-subtracted light curves due to their poor S/N that could affect the estimate of the normalized effect variance (cf. Sect. 4.4). High particle background flux intervals were identified using the same algorithm described in Sect. 3.2. As the fraction of high-particle background intervals is small, our procedure does not significantly affect the results discussed in this paper (Vaughan et al. 2003). We notice that after excluding these events, the exposure time of the light curve could be shorter, thus we recall that only observations with a net exposure time longer than 30 ks were used for the analysis. The light curves are shown in Appendix D. We recall that the values of the continuum (median value of the count rate) and dashed (1σ standard deviation) lines are used only for visual inspection of the data and not as estimators of the variability (as in Hernández-García et al. 2014).

4. Method

The method used in this work is presented in Hernández-García et al. (2013). Here we review the most important aspects but we refer the reader to this paper for further details of the analysis.

4.1. Individual spectral analysis

The first step is to select a model to fit all the data of the same source simultaneously. For that purpose, we used five different models that were fitted to each spectrum individually. We note that more complex models were also tested but they were not required by the data. The models are as follows:

- PL: a single power law representing the continuum of a non-stellar source. The empirical model is $e^{N_{\rm Gal}\sigma(E)} \cdot e^{N_{\rm H}\sigma(E(1+z))}[N_{\rm H}] \cdot {\rm Norm}\, e \quad [\;\;, {\rm Norm}]$.
- ME: the emission is dominated by hot diffuse gas, that is, a thermal plasma. A MEKAL (in XSPEC) model is used to fit the spectrum. The model is $e^{N_{\rm Gal}\sigma(E)} \cdot e^{N_{\rm H}\sigma(E(1+z))}[N_{\rm H}] \cdot {\rm MEKAL}[kT, {\rm Norm}]$.

- 2PL: in this model the primary continuum is an absorbed power law representing the non stellar source, while the soft energies are due to a scattering component that is represented by another power law. Mathematically the model is explained as $e^{N_{\rm Gal}\sigma(E)}\ e^{N_{\rm H1}\sigma(E(1+z))}[N_{\rm H1}] \cdot \mathrm{Norm}_1 e\ [\ ,\mathrm{Norm}_1] + e^{N_{\rm H2}\sigma(E(1+z))}[N_{\rm H2}] \cdot \mathrm{Norm}_2 e\ [\ ,\mathrm{Norm}_2])$.
- MEPL: the primary continuum is represented by an absorbed power law, but at soft energies a thermal plasma dominates the spectrum. Empirically it can be described as $e^{N_{\rm Gal}\sigma(E)}\ e^{N_{\rm H1}\sigma(E(1+z))}[N_{\rm H1}] \cdot \mathrm{MEKAL}[kT,\mathrm{Norm}_1] + e^{N_{\rm H2}\sigma(E(1+z))}[N_{\rm H2}] \cdot \mathrm{Norm}_2 e\ [\ ,\mathrm{Norm}_2])$.
- ME2PL: same model as MEPL, but an additional power law is required to explain the scattered component at soft energies, so mathematically it is $e^{N_{\rm Gal}\sigma(E)}\ e^{N_{\rm H1}\sigma(E(1+z))}[N_{\rm H1}] \cdot \mathrm{Norm}_1 e\ [\ ,\mathrm{Norm}_1] + \mathrm{MEKAL}[kT] + e^{N_{\rm H2}\sigma(E(1+z))}[N_{\rm H2}] \cdot \mathrm{Norm}_2 e\ [\ ,\mathrm{Norm}_2])$.

In the equations above, $\sigma(E)$ is the photo-electric cross-section, z is the redshift, and Norm_i are the normalizations of the power law and/or the thermal component. For each model, the parameters that vary are written in brackets. The Galactic absoption, $N_{\rm Gal}$, is included in each model and fixed to the predicted value (Col. 5 in Table 1) using the tool NH within FTOOLS (Dickey & Lockman 1990; Kalberla et al. 2005). Even if not included in the mathematical expressions above, all the models include three narrow Gaussian lines to take the iron lines at 6.4 keV (FeK), 6.7 keV (FeXXV), and 6.95 keV (FeXXVI) into account.

The χ^2/d.o.f. and F-test were used to select the simplest model that represents the data best. We considered an improvement of the spectral fit significant when the F-test results in a value lower than 10 ^{5}.

4.2. Simultaneous spectral analysis

We determined the best-fit model for each individual observation using the procedure described in Sect. 4.1. As a baseline model we used the one corresponding to the individual observation with the largest count number, and we checked that it matches the best fit model of the remaining spectra of the same source[7]. This model was applied to all the observations of the same source simultaneously with its parameters linked amongst them – we note that the values of the parameters are able to change from the initial values given in the baseline model. If this fit (SMF0) resulted in a good fit (see below), we considered the source as non-variable.

When SMF0 did not give a good result, the next step was to let different parameters in the model vary one-by-one (SMF1). These parameters are the column densities at soft ($N_{\rm H1}$) and hard ($N_{\rm H2}$) energies, the temperature (kT), the spectral index ( ), and the normalizations at soft (Norm_1) and hard (Norm_2) energies.

When SMF1 failed to be a good fit, we also tested to vary two parameters at the same time (SMF2), and also three parameters (SMF3) were needed in one case.

Each "next step" (e.g., SMF1 versus SMF0) was always tested in order to confirm an improvement of the spectral fit. A χ^2_r in the range between 0.9–1.5 – and as close as possible to the unity and an F-test value lower than 10 ^{5} were the criteria to accept a new step. If different models at a given step yielded a significant improvement with respect to the previous step, we chose the model corresponding to the lowest χ^2_r.

Whenever possible, this analysis was applied to observations of the same satellite. However, in some cases there was only one observation per instrument available. In order to compare the data extracted from different apertures, we fit the extranuclear emission in the annular region in the *Chandra* image between the *Chandra* aperture around the nucleus and the *XMM–Newton* aperture (see Table A.1) using the same procedure described in Sect. 4.1. This allowed us to define the best-fit model of the *Chandra* extranuclear emission. This model was included in the spectral analysis of the *XMM–Newton* data, when comparing with *Chandra* data. This procedure was applied whenever *XMM–Newton* and *Chandra* data were available.

4.3. Flux variability

The luminosities in the soft and hard X-ray energy bands were computed using XSPEC for both the fits of the individual observations, as well as for the simultaneous fit of all the observations together. The distances were taken from NED, corresponding to the average redshift-independent distance estimate for each object, when available, or to the redshift-estimated distance otherwise; distances are listed in Table 1.

When data from the optical monitor (OM) onboard *XMM–Newton* were available, UV luminosities (simultaneously to X-ray data) were estimated in the available filters. We recall that *UVW2* is centered at 1894 (1805–2454) , *UVM2* at 2205 (1970–2675) , and *UVW1* at 2675 (2410–3565) . We used the OM observation FITS source lists (OBSMLI)[8] to obtain the photometry. When OM data were not available, we searched for UV information in the literature. We note that in this case, the X-ray and UV data might not be simultaneous (see Appendix B).

We assumed an object to be variable when the square root of the squared errors was at least three times smaller than the dynamical range covered by the luminosities (see Hernández-García et al. 2014, for details).

4.4. Short-term variability

Initially, we assumed a constant count rate for segments of 30–40 ks of the observation in each energy band and calculated the χ^2/degrees of freedom (d.o.f.). We considered the source as a variable candidate if the count rate differed from the average by more than 3σ (or 99.7% probability).

Secondly, we calculated the normalized excess variance, $\sigma^2_{\rm NXS}$, for each light curve segment with 30–40 ks following prescriptions in Vaughan et al. (2003, see also González-Martín et al. 2011; Hernández-García et al. 2014). We recall that $\sigma^2_{\rm NXS}$ is related to the area below the power spectral density (PSD) shape.

When $\sigma^2_{\rm NXS}$ was negative or compatible with zero within the errors, we estimated the 90% upper limits using Table 1 in Vaughan et al. (2003). We assumed a PSD slope of –1, the upper limit from Vaughan et al. (2003), and we added the value of $1.282\mathrm{err}(\sigma^2_{\rm NXS})$ to the limit to account for Poisson noise. For a number of segments, N, obtained from an individual light curve, an upper limit for the normalized excess variance was calculated. When N segments were obtained for the same light curve and at least one was consistent with being variable, we calculated the

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[7] We note that for NGC 4138 we used the PL model because the *Chandra* spectrum did not have counts below 2 KeV, therefore the analysis was performed in the 2–10 keV band.

[8] `ftp://xmm2.esac.esa.int/pub/odf/data/docs/XMM SOC GEN ICD 0024.pdf`

Table 2. Results of the variability analysis.

Name (1)	log ($L_{\rm soft}$) (0.5–2 keV) (2)	log ($L_{\rm hard}$) (2–10 keV) (3)	log ($R_{\rm Edd}$) (4)	Long-term variability			$\Delta T_{\rm max}$ (years) (8)	Short term (9)	UV Variab. (10)
				SMF0 (5)	SMF1 (6)	SMF2/3 (7)			
ESO 540-G01 (X, C)	41.53 ± 0.13	41.72 ± 0.13	–	MEPL	Norm$_2$		1	–	–
	40%	38%			74%				
ESO 195-IG21 (X, C)	42.54 ± 0.37	43.03 ± 0.37	–	MEPL	Norm$_2$	Norm$_1$	4	–	–
	98%	97%			91%	98%			
ESO 113-G10 (X)	43.07 ± 0.05	42.70 ± 0.05	–0.74	ME2PL	Norm$_1$		4	TSH	W2
	17%	17%			40%				
NGC 526A (X)	42.91 ± 0.10	43.32 ± 0.09	–1.16	2PL	Norm$_2$	–	11	TSH	W1
	48%	46%			48%				
MARK 609 (X)	42.55 ± 0.04	42.69 ± 0.04	–	2PL	Norm$_1$		5	–	–
	13%	13%			22%				
NGC 1365 (X)$^{\rm CL}$	41.15 ± 0.35	42.18 ± 0.42	–1.95	ME2PL	$N_{\rm H2}$	$N2/N1^{*}$	10	TSH	W1, M2
	81%	24%			68%	33/35%			
(X, C)	41.80 ± 0.38	41.73 ± 0.27		ME2PL	$N_{\rm H2}$	Norm$_2$	2	–	–
	99%	77%			37%	30%			
NGC 2617 (X)	43.24 ± 0.15	43.25 ± 0.15	–0.94	2PL	Norm$_1$	$N_{\rm H2}$	0.1	TS	W1
	46%	45%			59%	30%			
MARK 1218 (X)	41.87 ± 0.22	42.56 ± 0.21	–	PL	Norm		0.08	–	No
	64%	64%			63%				
NGC 2992 (X)$^{\rm CL}$	41.57 ± 0.23	42.03 ± 0.22	–2.30	2PL	$N_{\rm H2}$	Norm$_2$	3	TH	M2
	19%	19%			5%	21%			
POX 52 (X, C)	41.89 ± 0.01	41.75 ± 0.02	0.18	ME2PL	$N_{\rm H2}$	$N_{\rm H1}$	1	No	–
	2%	7%			44%	100%			
NGC 4138 (X, C)	–	41.53 ± 0.07	–2.42	PL**	Norm		2	–	–
		21%			98%				
NGC 4395 (C)	39.50	39.94	–1.15	ME2PL	$N_{\rm H2}$		0.003	–	W1
	0%	0%			31%				
(X)	39.69 ± 0.06	40.28 ± 0.40		ME2PL	$N_{\rm H2}$	Norm$_2$	12	TSH	–
	15%	13%			20%	88%			
(X, C)	39.78 ± 0.21	40.21 ± 0.22		ME2PL	Norm$_2$		2	–	–
	61%	65%			93%				
NGC 4565 (X, C)	39.51 ± 0.03	39.65 ± 0.07	–4.63	PL	$N_{\rm H}$		2	No	–
	11%	21%			48%				
MARK 883 (X)	42.42 ± 0.09	42.71 ± 0.08	–1.15	PL	Norm		4	–	W1, W2
	28%	28%			28%				
IRAS 20051-1117 (X)	42.39 ± 0.09	42.53 ± 0.09	–1.16	PL	Norm		0.5	–	No
	29%	29%			29%				

Notes. (Column 1) name, and the instrument (C: *Chandra* and/or X: *XMM–Newton*) in parenthesis ($^{\rm CL}$ refer to changing-look candidates); (Cols. 2 and 3) logarithm of the soft (0.5–2 keV) and hard (2–10 keV) X-ray luminosities, where the mean was calculated for variable objects, and percentages in flux variations; (Col. 4) Eddington ratio, $L_{\rm bol}/L_{\rm Edd}$, calculated from Eracleous et al. (2010) using $L_{\rm bol} = 33 L_{2\ \ 10\ \rm keV}$; (Col. 5) best fit for SMF0; (Col. 6) parameter varying in SMF1, with the percentage of variation; (Col. 7) parameter varying in SMF2 and SMF3 (for NGC 1365, $^{(*)}$ N1 = Norm$_1$, and N2 = Norm$_2$), with the percentage of variation; (Col. 8) the sampling timescale, corresponding to the difference between the first and the last observation. The percentages correspond to this $\Delta T_{\rm max}$; (Col. 9) short-term variations in the total (T), soft (S), and/or hard (H) energy bands; and (Col. 10) filters where variations are detected at UV frequencies with the OM. A "–" means that data were not available, while "No" means that variations were not detected. $^{(**)}$ We note that the *XMM–Newton* data of NGC 4138 is best fitted by the ME2PL model, but *Chandra* data does not have counts below 2 keV, thus the PL model is used for the simultaneous fit.

normalized weighted mean and its error as the weighted variance. We considered short-term variations for $\sigma^2_{\rm NXS}$ detections above 3σ of the confidence level.

4.5. Compton thickness

We tested the possibility of some sources being so heavily absorbed that their spectra can be completely reflected below 10 keV, i.e., Compton-thick sources. Since the Compton-thick column densities cannot be directly measured at the energies analyzed here, the following indirect indicators (using X-ray and [O III] data) are taken to classify these sources: $\ \ < 1$, EW(FeK) > 500 eV, and $F(2\ \ 10\ \rm keV)/F_{[OIII]} < 1$ (Ghisellini et al. 1994; Bassani et al. 1999; Panessa & Bassani 2002). Where   and EW(FeK) were obtained from individual spectral fits in the 3–10 keV energy band using the PL model, the extinction-corrected [O III] fluxes were obtained from the

Table 3. Median values and 25% and 75% percentiles of the spectral parameters of Seyfert 1.8/1.9 presented in this work (Col. 2) and the Seyfert 2 sample (Col. 3) presented in Hernández-García et al. (2015).

(1)	Seyfert 1.8/1.9 (2)	Seyfert 2 (3)
log (L(0.5–2 keV) [erg s $^{\ 1}$])	$41.9^{42.6}_{41.2}$	$42.1^{42.6}_{41.3}$
log (L(2–10 keV) [erg s $^{\ 1}$])	$42.5^{42.7}_{41.7}$	$42.7^{42.8}_{42.5}$
N_{H2} ($\times10^{22}$ [cm $^{\ 2}$])	$3.00^{8.34}_{0.06}$	$22.2^{38.4}_{9.8}$
	$1.7^{1.9}_{1.4}$	$1.7^{2.0}_{1.5}$
kT [keV]	$0.19^{0.38}_{0.09}$	$0.71^{0.81}_{0.67}/0.15^{0.18}_{0.12}$
S/N(0.5–2 KeV)	$5.3^{7.7}_{4.9}$	$5.2^{6.4}_{3.8}$
S/N(2–10 KeV)	$5.4^{6.6}_{4.7}$	$3.8^{5.2}_{2.3}$

Notes. (Column 1) spectral parameter, (Col. 2) average values for Seyfert 1.8/1.9, and (Col. 3) average values of Seyfert 2 from Hernández-García et al. (2015). The two temperatures represent the two thermal components in the model.

literature (and corrected when needed following Bassani et al. 1999), and the hard X-ray luminosities, L(2 10 keV), from the individual fits were used (see Table A.3) for the calculation.

We considered that a source is a *Compton*-thick candidate when at least two of the three criteria above were met. Otherwise, the source is considered to be a *Compton*-thin candidate. When different observations of the same source result in different classifications, the object was considered to be a changing-look candidate.

5. Results

In this section we present the results of the spectral characteristics and variability patterns of the Seyfert 1.8/1.9 in the sample. For results on individual sources we refer the reader to Appendix B, as well as for notes and comparison with previous studies.

5.1. Spectral characteristics

We used five different models to fit each spectrum individually. The best model for each source resulted to be the same in all the individual observations from the same satellite. When comparing data from different instruments, different best fit models were selected for two sources (NGC 1365, and NGC 4138), most probably because of the low count-rate in the *Chandra* data, which required the simplest model. It is worth noticing that the *XMM–Newton* spectrum of NGC 4138 is best fitted with the ME2PL model, but the lack of counts in the *Chandra* spectrum below 2 keV forced us to perform the analysis only above 2 KeV and thus using the PL model (see Appendix B.11). The ME model was not the best-fit for any of the spectra.

The median (25% and 75% percentiles) values of the spectral parameters are presented in Table 3. Absorption at soft energies is usually compatible with the Galactic one (see Table A.2). Absorption at high energies is common in these sources, being obscured in the range of 10^{21} 10^{23} cm $^{\ 2}$, with median of N_{H2} = 3.00[0.06 8.34] $\times$ 10^{22} cm $^{\ 2}$. The median value of the spectral indices is   = 1.7[1.4 1.9], completely compatible with other AGN (see e.g., Brightman & Nandra 2011a). The thermal component has a median of $kT = 0.19[0.09–0.62]$ keV.

The X-ray luminosity medians in our sample are log L(0.5–2.0 keV) = 41.9[41.2–42.6] and log L(2–10 keV) = 42.5[41.7–42.7].

5.2. Compton-thickness

We recall that a source was classified as a Compton-thick candidate within an observation when at least two out of the three criteria explained in Sect. 4.5 were met. None of the sources are classified as Compton-thick. Two of the sources are classified as changing-look candidates (NGC 1365, and NGC 2992), as already reported in the literature (Gilli et al. 2000; Risaliti et al. 2009). Another two sources have been classified as changing-look candidates in the literature (MARK 609, Trippe et al. 2010, and NGC 2617; Shappee et al. 2014), but the present work does not detect these changes. It is worth noticing that we did not find the flux of the [OIII] in the literature for four sources (ESO 540-G01, ESO 195-IG21, ESO 113-G10, and NGC 2617), but the two other criteria were compatible with them being Compton-thin.

5.3. Long-term X-ray spectral variability

From the 15 nuclei in our sample, we compare spectra obtained from the same instrument in 10 cases, all of them observed by *XMM–Newton*, and in one case (NGC 4395) *Chandra* data are also available. In the remaining five sources only one observation per instrument was available.

Chandra and *XMM–Newton* data are available for the same source in eight cases (note that this analysis is independent of the one mentioned above, see Table A.1), thus the simultaneous analysis was carried out by using the methodology explained in Sect. 4.2.

Long-term X-ray spectral variability is detected in all the 15 nuclei. Variations are detected in four parameters (Norm$_1$, Norm$_2$, N_{H1}, and N_{H2}). In nine objects the observed variability can be explained by varying only one parameter; in five nuclei varying two parameters is required (ESO 195-IG21, NGC 2617, NGC 2992, POX 52, and NGC 4395), and in NGC 1365 varying three parameters is required. The most frequent variations are found in Norm$_2$, which are observed in ten nuclei (ESO 540-G01, ESO 195-IG21, NGC 526A, NGC 1365, MARK 1218, NGC 2992, NGC 4138, NGC 4395, MARK 883, and IRAS 20051-1117). Changes in N_{H2} are also frequent, as they are observed in six nuclei (NGC 1365, NGC 2617, NGC 2992, POX 52, NGC 4395, and NGC 4565). Variations at soft energies are detected in six sources (ESO 195-IG21, ESO 113-G01, MARK 609, NGC 1365, NGC 2617, and POX 52). Among them, only in two objects (ESO 195-IG21 and POX 52) these variations are reported for a simultaneous fit using *Chandra* and *XMM–Newton* together, thus these variations cannot be ascribed to the comparison of data obtained from different instruments.

5.4. Short-term X-ray variability

Short-term X-ray variations are analyzed in eight nuclei (Table A.4). We recall that only light curves longer than 30 ks were analyzed (see Sect. 4.4). Two sources do not show variations (POX 52 and NGC 4565) according to the χ^2/d.o.f. and σ^2_{NXS}, whereas the remaining six are variable in at least one energy band. Four sources show variations in the total, soft, and hard energy bands (ESO 113-G10, NGC 526A, NGC 1365,