Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 18 May 1998 (MN plain TEX macros v1.6)

Ultrasoft X-ray components in the high-temperature extreme

E. M. Puchnarewicz

Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, Surrey RH5 6NT, UK.

ABSTRACT

A search for high redshift (z >0.5) ultrasoft X-ray AGN in pointed *ROSAT* PSPC observations is made, using the WGACAT catalogue. Evidence for a further three such objects is found, adding to three identified previously (E1346+266, EXO 1346.4+2637 and RX J0947.0+4721). The flux of one new object [1WGA J1342.4+2720; L(0.1-2 keV)$\sim 2 \times 10^{45}$ erg s^{-1})] was found to be variable (a factor of 1.7 over two days) and has relatively narrow permitted line emission. These properties, also seen in E1346+266 and EXO 1346.4+2637, are typical of ultrasoft AGN at all redshifts, in particular the narrow-line Seyfert 1s (NLS1s). The rarity of high-z ultrasoft AGN places limits on the 'temperature' of the soft X-ray component in the rest-frame of AGN in general. It also provides an opportunity to investigate models for the soft component in the high-T extreme, e.g. for accretion disk models, testing the physics at the inner edge of the disk and the effects of Comptonization in a hot, optically-thin corona.

Key words: Galaxies: Seyfert – Galaxies: Active – X-rays: Galaxies – Accretion disks

1 INTRODUCTION

Soft X-ray excesses above an extrapolation of the hard X-ray power-law have been observed in many AGN (e.g. Arnaud et al. 1985; Turner & Pounds 1989; Masnou et al. 1992). 'Ultrasoft' X-ray components, the strongest excesses [e.g. Puchnarewicz et al. 1992; Puchnarewicz, Mason & Córdova 1994 (hereafter P94); Puchnarewicz et al. 1995; Brandt, Pounds & Fink 1995; Boller, Brandt & Fink 1996], provide us with the most extreme conditions in which to test the physics of accretion in AGN. This component is believed to be emitted from the innermost regions of an optically-thick accretion disc (AD) which may be modified by a surrounding hot ($T \sim 10^8$ K), optically-thin corona (Czerny & Elvis 1987; Haardt & Maraschi 1993; Svensson & Zdziarski 1994).

The spectrum emitted by an AD depends basically on the mass and spin of the black hole, the inclination of the disc to our line of sight and the mass accretion rate. Other effects such as electron scattering, relativistic effects, Comptonization and the presence of a hot corona will further modify the spectrum (see e.g. Czerny & Elvis 1987; Siemiginowska et al. 1995). The radius of the innermost stable orbit in simple thin AD models, where the hottest part of the spectrum is emitted, is dependent on the gravitational radius and thus on the mass of the central black hole. The temperature of that inner orbit is inversely dependent on its radius, thus it is hot in low mass black holes (where the AD can form close to the centre) and relatively cool around more massive black holes. Accretion at rates close to the Eddington limit onto a low mass black hole is often put forward as a model for low-z narrow-line Seyfert 1s (NLS1s; Goodrich 1989; Pounds, Done & Osborne 1995; Laor et al. 1997), which are generally ultrasoft X-ray sources (e.g. Puchnarewicz et al. 1992; Boller et al. 1996).

A simple explanation for the ultrasoft X-ray components in AGN would then be that one observes the hottest ADs around relatively low mass black holes. However, reports of two narrow-line *quasars*, E1346+266 (P94) and RX J0947.0+4721 (Molthagen, Bade & Wendker 1998), provide evidence against this explanation, for those objects at least. E1346+266 is a z=0.92 ultrasoft quasar whose luminosity ($L \sim 10^{47}$ erg s^{-1}) implies a (non-rotating) black hole with a mass of at least $10^9 M_\odot$ (P94). The near-IR to X-ray spectrum of E1346+266 is poorly represented by AD models in general which, when normalized to the near-IR/optical spectrum, fail to reproduce the strong soft X-ray component (P94). A simple thermal bremsstrahlung spectrum with a temperature, $T_{\rm brem} \sim 7 \times 10^6$ K gives a better description of the data (Puchnarewicz et al. 1995). RX J0947.0+4721 (z=0.541) is a highly variable source, similar in nature to the narrow-line Seyfert 1 IRAS 13224–3809 (Boller et al. 1993), with a luminosity of up to 10^{46} erg s^{-1} (Molthagen et al. 1998).

E1346+266 thus poses a severe test of AD models and suggests that an alternative origin for the optical to soft X-ray 'big bump' may exist in this object at least. It was originally discovered as part of the *Einstein* Ultrasoft Survey (Córdova et al. 1992; Puchnarewicz et al. 1992) and was the only high-z AGN in that sample. Clearly these objects are rare, but they are important for our understanding of the physics in AGN at the extremes of luminosity and black hole mass, where the order of the AD model may break down.

To look for more objects of this type, the *ROSAT* PSPC archive has been searched for high-z AGN with very soft

Table 1. High-z ultrasoft AGN candidates from WGACAT

WGACAT name	RA (2000)	Dec (2000)	c/r	z	SR1	other name
1WGA J0910.0+5427	09 10 05.0	+54 27 24.0	3.1e-3	0.625	5.83	QSO0906+546
1WGA J1117.9+1808	11 17 57.0	+18 08 23.6	7.7e-3	0.644	4.86	MS1115+1824
1WGA J1234.4+0757	12 34 28.6	+07 57 19.6	4.1e-3	1.190	5.23	QSO1231+0813
1WGA J1342.4+2720	13 42 24.0	+27 20 33.1	1.5e-2	0.704	6.43	EQ1340.1+2735
1WGA J1348.5+2622	13 48 33.9	+26 22 02.2	4.2e-2	0.915	5.61	E1346+266
1WGA J1446.3+1002	14 46 20.3	+10 02 57.8	1.3e-2	0.732	4.69	EQ1443.9+1026
1WGA J1643.5+3953	16 43 33.9	+39 53 51.2	2.0e-2	0.594	4.60	EQ1641.9+3959

c/r is the count rate as given in WGACAT.

0.2-2 keV spectra ($\alpha_{\rm x}\gtrsim 2$; $\alpha_{\rm x}$ and all indices, α, are defined such that $F_\nu \propto \nu^{-\alpha}$). The results of this search and the implications for AGN models at high luminosity are reported in this paper.

2 OBSERVATIONS AND RESULTS

As the source for these high-z ultrasoft AGN, WGACAT, the catalogue of unresolved objects identified from pointed *ROSAT* PSPC observations in the 0.24-2.0 keV band (White, Giommi & Angelini 1995), was searched. The following search criteria were applied:

1. $z \geq 0.5$

2. softness ratio, SR1$\geq$4.6. SR1 is the (0.1-0.4 keV)/(0.4-0.9 keV) ratio, corresponding to channels (11-39)/(40-85). For a Galactic $N_{\rm H}$ of 2×10^{20} cm^{-2}, a softness ratio, SR1$\geq$4.6 corresponds to an energy index, $\alpha_{\rm x}\geq 2.0$.

3. Galactic latitude, $|b| > 30°$, to use only regions of relatively low Galactic column density ($N_{\rm HGal}\lesssim 3\times10^{20}$ cm^{-2}).

4. the source position must lie within 17$'$ of the field centre, to avoid vignetting effects and shadowing by the detector ribs

5. it must have at least 100 background-subtracted counts, to allow fitting of the full PSPC spectrum

6. the source detection quality flag must be 5 or greater.

There are 376 AGN in the WGACAT which satisfy criteria *3* to *6*. Of these, 153 lie at redshifts of 0.5 or higher; only seven of these have a high softness ratio (SR1$\geq$4.6). The seven high-z, ultrasoft candidates, which include E1346+266, are listed in Table 1.

2.1 X-ray spectral reduction

The *ROSAT* PSPC images and spectra of all objects except E1346+266 were extracted to verify the nature of these sources (the spectral reduction and analysis of E1346+266 is given in P94). Using the standard ASTERIX software, the source spectra were extracted using circles with radii of up to 1.5 arcmin (depending on the position of any adjacent sources) and a nearby source-free region was used for background subtraction. Counts were binned to yield at least 10 per energy bin, ignoring channels 1-11 and channels 201-256 where the response is uncertain. The spectra have been corrected for all instrumental effects including vignetting, dead-time and particle contamination.

The reduced PSPC data were fitted using the XSPEC spectral fitting software. The Galactic column density in the direction of each source ($N_{\rm HGal}$) was calculated by interpolating between the 21 cm measurements of Stark et al. (1992). A single power-law model was fitted to each spectrum, first with a column of cold absorbing gas fixed at the Galactic value ($N_{\rm HGal}$), allowing the power-law index ($\alpha_{\rm x}$) and normalization ($norm_{\rm pl}$) to be free. Another cold gas column, which was redshifted into the frame of the AGN and allowed to be free, was then added to the model ($N_{\rm Hint}$). This increased the number of terms to three; the results of these fits are given in Table 2.

For three of the ultrasoft candidates, fitting of the PSPC spectrum was not performed. 1WGA J0910.0+5427 lies close to two other X-ray sources; both lie only 1.3$'$ away. The brightest of these (1WGA J0909.9+5429; PSPC count rate = 0.29 count sec^{-1}) is very soft and has probably contaminated the AGN, making the latter's identification as an ultrasoft source dubious. There is no evidence of significant point source emission at the position of 1WGA J1234.4+0757, thus this is likely to be a spurious detection. 1WGA J1643.5+3953 lies within 30$''$ of four other sources, too close to be able to identify unambiguously the ultrasoft X-ray emission with the AGN using the PSPC data.

2.1.1 *Power-law fits*

For the remaining three AGN, an absorbed power-law model was an acceptable fit in all cases (see Table 2). The addition of the rest-frame absorbing column made no significant improvement to any of the fits. Confidence contour plots for these models are shown in Fig. 1. The PSPC spectra of 1WGA J1117.9+1808 and 1WGA J1446.3+1002 are consistent with rest-frame absorbing gas columns from zero up to 7-8$\times10^{20}$ cm^{-2} (with 68 percent confidence). The 'negative' range for $N_{\rm Hint}$ suggests that, alternatively, the spectra may be relatively hard (with $\alpha_{\rm x}\lesssim 2$) but soften at the lowest energies (i.e. below $\sim$0.5 keV in the AGN rest-frame).

While the RP701063 spectrum of 1WGA J1342.4+2720 shows a similar result, fits to the RP701069 data suggest a slightly softer and more highly absorbed spectrum compared to RP701063. Spectral fits to the two datasets are consistent to within 68 percent confidence (see Fig. 1), with $\alpha_{\rm x}$ between 1.8 and 3.0 and $N_{\rm Hint}$ between 2 and 10 $\times10^{20}$ cm^{-2}. However, the count rates for the two observations, taken only two days apart, are significantly different; the RP701069 count rate is a factor of $\sim$1.7 higher than that measured from the RP701063 dataset. Thus this relatively high-z AGN (z=0.704) which shows evidence for a soft X-ray excess ($\alpha_{\rm x}\gtrsim$ 1.4 with 90 per cent confidence; see Table 2), is also variable on timescales of a few days.

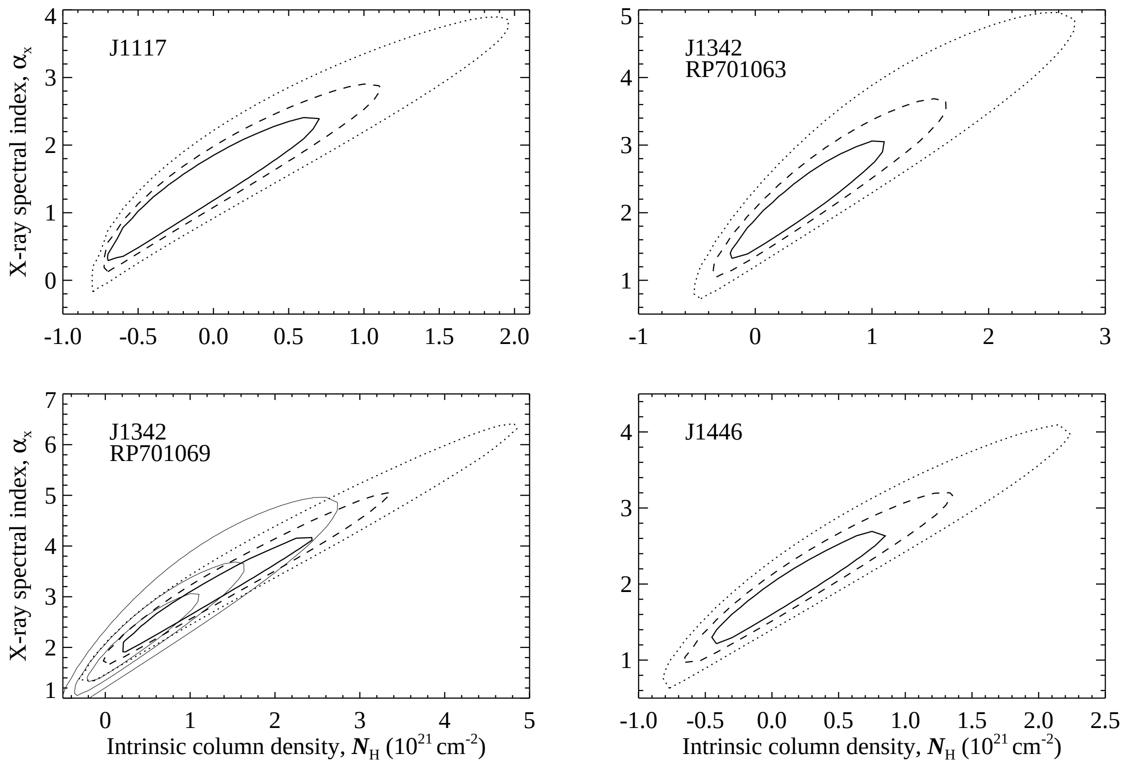

Figure 1. Confidence contours for the ultrasoft candidates. The contours shown are for 68 percent (solid line), 90 percent (dashed line) and 99 percent (dotted line) confidence for two interesting parameters. For the RP701069 dataset, the RP701063 contours are also plotted for comparison as thin lines.

The best-fitting power-law slopes of these soft high-z sources from WGACAT are typical of the mean 0.2-2 keV spectral slopes of $z \leq 0.5$ optically and soft X-ray-selected AGN ($\alpha_x \sim 1.5$-1.7, e.g. Schartel et al. 1996; Laor et al. 1997). However, because the X-ray spectra of AGN tend to flatten to $\alpha_x \sim 1$ at higher energies (e.g. Comastri et al. 1992; Nandra et al. 1997), one would expect the typical slopes of $z > 0.5$ AGN to be harder than those at a lower z. Furthermore, the mean slopes of the *ROSAT* PSPC-selected RIXOS AGN are ~ 1 at $z > 0.5$ (see e.g. Puchnarewicz et al. 1996). Thus the PSPC data suggest that these high-z objects are amongst the softest known.

2.1.2 Bremsstrahlung fits

The data were also fitted with an absorbed bremsstrahlung model, where the absorbing column was fixed at the Galactic value in the observer's frame and the bremsstrahlung spectrum was shifted into the rest-frame of the AGN. The results, listed in Table 2, show that this model also provided an acceptable fit for all objects, giving best-fit temperatures of ~ 600 eV.

2.1.3 E1346+266

E1346+266 was observed by *ROSAT* as the primary target for 20 ksec in 1991 July. The quasar lies close (on the sky) to the Abell cluster A 1795 and was also a serendipitous detection in two long observations of the cluster (26 ksec in 1991 July and 37 ksec in Jan 1992). Model fits to the three AGN spectra were consistent (to within 90 percent confidence) with a power-law with a slope $\alpha_x \sim 2.5$ (P94). Although bremsstrahlung fits to the PSPC data were not made by P94, Puchnarewicz et al. (1995) demonstrated that the overall IR to soft X-ray spectrum did compare well with a 7×10^6 K (600 eV) bremsstrahlung spectrum, i.e. with a similar temperature to the other AGN studied in this paper.

2.1.4 EXO 1346.4+2637

Three arcmin away from E1346+266 lies another ultrasoft X-ray AGN, EXO 1346.4+2637. This also has a spectrum consistent with a power-law with $\alpha_x \sim 2.5$ *and* it has a z greater than 0.5 (z=0.597), thus one would have expected it to have been selected in the search of WGACAT. However, the WGACAT detection algorithm fails in fields which contain very bright, extended sources, therefore in the long observations of E1346+266 and EXO 1346.4+2637, emission from the cluster was probably too strong for these fields to be included. There was a fourth, short (3 ksec) observation of E1346+266 and both AGN were selected for WGACAT from this, but EXO 1346.4+2637 contained only ~ 80 counts, so it was excluded by the selection criteria. However, since P94 confirmed the ultrasoft nature of this $z > 0.5$ object, it will be included in further discussions.

2.1.5 RX J0947.0+4721

The discovery of another $z > 0.5$ ultrasoft quasar has also been reported recently by Molthagen et al. (1998);

Table 2 Results of X-ray spectral fitting

Power-law models - fixed Galactic absorbing column only

Name	Dataset	PSPC count rate[1] 10^{-3} count sec^{-1}	$N_{\rm HGal}$ 10^{20} cm^{-2}	$\alpha_{\rm x}$		$norm_{\rm pl}$ *(2)*	χ^2/dof
1WGA J1117.9+1808	RP600263	8.4±0.9	1.5	$1.5^{+0.3}_{-0.3}$		1.7×10^{-5}	7/14
1WGA J1342.4+2720	RP701063	16.7±1.6	1.1	$1.7^{+0.3}_{-0.3}$		2.1×10^{-5}	19/12
	RP701069	27.9±2.0	1.1	$1.7^{+0.3}_{-0.2}$		3.5×10^{-5}	15/9
1WGA J1446.3+1002	RP701002	17.8±1.5	1.8	$1.8^{+0.4}_{-0.3}$		3.1×10^{-5}	10/10

Power-law models - additional cold gas column in the AGN rest-frame

Name	Dataset		$N_{\rm HGal}$ 10^{20} cm^{-2}	$\alpha_{\rm x}$	$N_{\rm Hint}$ 10^{20} cm^{-2}	$norm_{\rm pl}$ *(2)*	χ^2/dof
1WGA J1117.9+1808	RP600263		1.5	$1.1^{+2.8}_{-1.3}$	-2^{+15}_{-4}	1.8×10^{-5}	7/13
1WGA J1342.4+2720	RP701063		1.1	$2.1^{+1.7}_{-1.0}$	3^{+13}_{-7}	1.9×10^{-5}	19/11
	RP701069		1.1	$2.8^{+2.2}_{-1.2}$	9^{+23}_{-10}	3.2×10^{-5}	11/8
1WGA J1446.3+1002	RP701002		1.8	$1.8^{+1.3}_{-1.0}$	0^{+14}_{-7}	2.9×10^{-5}	9/9

Bremsstrahlung models

Name	Dataset		$N_{\rm HGal}$ 10^{20} cm^{-2}	$kt_{\rm eff}$ eV		$norm_{\rm brem}$ *(3)*	χ^2/dof
1WGA J1117.9+1808	RP600263		1.5	690^{+290}_{-180}		2.0×10^{-4}	11/14
1WGA J1342.4+2720	RP701063		1.1	620^{+200}_{-160}		3.7×10^{-4}	22/12
	RP701069		1.1	590^{+100}_{-90}		7.2×10^{-4}	10/9
1WGA J1446.3+1002	RP701002		1.8	590^{+120}_{-110}		2.7×10^{-4}	15/10

(1) PSPC count rate as measured from the reduced PSPC images; *(2)* Power-law normalization, $norm_{\rm pl}$, in units of photons cm^{-2} s^{-1} keV^{-1} at 1 keV; *(3)* Bremsstrahlung normalization, $norm_{\rm brem} = 3.02\times10^{-15}/(4\pi D^2)\int n_e n_I dV$, where n_e is the electron density (cm^{-3}), n_I is the ion density (cm^{-3}) and D is the distance to the source (cm).

RX J0947.0+4721. This AGN was first discovered in the *ROSAT* All-Sky Survey (Bade et al. 1995), yet was not identified in our search of WGACAT. This is probably because it lies close to the Abell cluster A851 and, like the longer exposures of E1346+266 and EXO 1346.4+2637, the field was excluded by the WGACAT criteria.

2.1.6 *Luminosities*

The logarithms of the 0.1-2 keV luminosities (assuming H_0=50 km s^{-1} Mpc^{-1} and q_0=0) are 44.3, 44.8 and 45.0 erg s^{-1} for 1WGA J1117.9+1808, 1WGA J1342.4+2720 and 1WGA J1446.3+1002 respectively. For EXO 1346.4+2637, $\log L$(0.1-2 keV)=45.4 erg s^{-1} while for RX J0947.0+4721, $\log L$(0.2-3.7 keV)<45 erg s^{-1} (Molthagen et al. 1998). Thus, despite a search of all the PSPC pointed data, no objects with a spectrum as hot *and* as luminous ($L_X \sim 10^{47}$ erg s^{-1}) as E1346+266 were found, which underlines further the extreme nature of E1346+266.

3 DISCUSSION

Most ultrasoft X-ray AGN are found at redshifts below ~0.5. E1346+266, with z=0.92, is a clear exception to this trend. It has a very high luminosity and inferred black hole mass. Consequently its spectrum, which is very hot, is poorly reproduced by simple thin accretion disc (AD) models (P94; Puchnarewicz et al. 1998). Three more z >0.5 AGN have been identified from WGACAT with relatively soft PSPC spectra whose soft X-ray components have a similar rest-frame $T_{\rm brem}$ to that of E1346+266. EXO 1346.4+2637 and RX J0947.0+4721 are other z >0.5 objects with ultrasoft X-ray spectra.

According to the criteria adopted (see Section 2), approximately 1-2 per cent of identified WGACAT AGN at z >0.5 have ultrasoft X-ray components. The WGACAT survey is not complete therefore this statistic should be treated with caution, but it does provide a useful indication of the abundance of these sources. The rarity of high-z ultrasoft AGN suggests either *(1)* that there is an intrinsic upper limit to the temperature of the soft component in the rest-frame, e.g. for a bremsstrahlung model, the upper limit on the temperature, $T_{\rm brem}$~600 eV; or *(2)* that the strength of any high-T soft component may be weak relative to the hard X-ray power law in high-L sources.

In the light of these results, three models for the soft X-ray emission in AGN are investigated; accretion discs, optically-thin emission (e.g. Barvainis 1993; Collin-Souffrin et al. 1996) and reprocessing in cool, dense clouds (Guilbert & Rees 1988; Ferland & Rees 1988; Kuncic, Celotti & Rees 1997). In particular, their ability to reproduce a high-T ultrasoft X-ray component, predictions for the spectrum overall and the consequences of a possible high-T cut-off in the soft X-ray component are examined.

3.1 Accretion discs

For a simple AD where $M \propto T^{-1/4}$, the more massive black holes will have cooler discs, thus the lack of hotter soft excesses in high-z objects (with high luminosity and thus a larger mass) is consistent with simple thin AD predictions. However, AGN with high-L, high-T soft X-ray components are physically possible, as demonstrated by the existence of quasars like E1346+266, EXO 1346.4+2637 and the new objects presented in this paper. The soft components in these AGN may be caused by inverse Compton scattering in a hot, optically-thin corona surrounding the disk (e.g. Czerny & Elvis 1987). The corona upscatters low-energy photons, flattening the high-energy tail of the AD spectrum and boosting the flux at the highest X-ray energies. However, even sophisticated AD models which incorporate the effects of such coronae have failed to reproduce the near-IR to X-ray spectrum of E1346+266, mostly due to the large wavelength coverage of the overall big blue bump component ($\sim 1\mu$m to 5 keV; P94, Puchnarewicz et al. 1998).

3.2 Optically-thin models

While the pure free-free model proposed by Barvainis (1993) was based on a simple analytical description and is not physically self-consistent (Kuncic et al. 1997), Collin-Souffrin et al. (1996) investigated optically-thin models in greater detail. They suggested that clouds optically thick to electron scattering, irradiated by an α=1 primary continuum and with a covering factor $\sim$1 may produce typical quasar spectra. There are four components contributing to the total observed spectrum for this model; the primary, reflected, emitted and transmitted components. An ultrasoft excess is a feature of the reflected component, thus steep soft X-ray spectra are produced when the covering factor is high, increasing the number of reflections and decreasing the fraction of the primary emission. Of the model spectra plotted by Collin-Souffrin et al. (1996), the soft X-ray spectra of the high-z ultrasoft AGN are qualitatively similar to models with a covering factor $\frac{\Omega}{4\pi} \sim 1$ and high ionization parameter (ξ=1000 where $\xi = \frac{L}{nR^2}$). The characteristic features of the reflected component include an FeKα emission line and a dip at around $\sim$1 keV, and the strength of these features gives an indication of the covering factor of the gas. The features cannot be resolved with the present data, but future X-ray observatories, such as *XMM* with high throughput and spectral resolution, can be used to measure them and thus test free-free models.

One drawback of this model is that the gas emits with a low efficiency and must cover a large extent to produce the observed luminosities. This imposes a minimum on variability timescales and is a particular problem for 1WGA J1342.4+2720 ($L_{\rm X} \sim 10^{45}$ erg s^{-1}) whose flux changed by a 70 percent over two days. Collin-Souffrin et al. (1996) find $R_{16} = 0.13\tau_{15}^{-0.5}T_5^{-0.9}L_{UV-46}^{0.5}(\frac{\Omega}{4\pi})^{-0.5}$ where R_{16} is the size of the emitting region in units of 10^{16} cm, τ_{15} is the free-free optical depth at $\nu = 10^{15}$ Hz, T_5 is the temperature in 10^5 K and L_{UV-46} is the UV luminosity in 10^{46} erg s^{-1}. Assuming τ_{15}=1, T_5=50, L_{UV-46}=0.1 and $\frac{\Omega}{4\pi}$=1, the size of an optically-thin emitting region in 1WGA J1342.4+2720 would be $\gtrsim$11 light days, which is not consistent with the observed variability.

3.3 Reprocessing in cool, dense clouds

For this model, ultrasoft X-ray spectra falling at the high energies observed are predicted when the cloud density is relatively low ($n \sim 10^{14}$ cm^{-3}) and the volume filling factor of the clouds is high ($\sim 10^{-4}$; see e.g. Ferland & Rees 1988; Kuncic et al. 1997). However, in order to produce a steep spectrum in soft X-rays, these models predict a sudden, hard upturn at harder energies ($E \gtrsim$1 keV). Such an upturn was not observed in E1346+266, for which only an upper limit could be measured from *ASCA* GIS data (a 3σ upper limit of 2×10^{-13} erg cm^{-2} s^{-1} was measured over 2-10 keV for an $\alpha_{\rm x}$=1 power-law spectrum). Thus, for E1346+266 at least, reprocessing in cool, dense clouds is unlikely to produce the ultrasoft X-ray excess. Deep observations of other high-z ultrasoft AGN in hard X-rays will indicate whether or not E1346+266 is an unusual case.

3.4 Ultrasoft components and the broad line region

Almost all of the ultrasoft X-ray AGN identified to date have Balmer lines with FWHM less than $\sim$2000 km s^{-1} (e.g. Boller et al. 1996). This implies either a direct causal relationship between the soft X-ray spectrum and the velocity of the outer broad line region (BLR), or that the two are linked by a third parameter such as the black hole mass (M) or the orientation of the nuclear regions. It has been suggested that ultrasoft components in NLS1s are produced when matter is accreting at Eddington rates onto a relatively low-M black hole (e.g. Pounds et al. 1995; Laor et al. 1997). If the BLR cloud motions are dominated by the gravitational potential of the black hole, then the velocities will also be low, resulting in the observed relationship. In turn, this might suggest that the BLRs in *high*-luminosity, ultrasoft AGN, which must have a much higher M, would have greater velocities than their low-luminosity counterparts.

However, despite its high-L and high-M ($M \gtrsim 10^9\ M_\odot$; P94), E1346+266 also has relatively narrow Balmer lines (Hβ FWHM $\sim$1800 km s^{-1}). The optical spectra of three other objects (EXO 1346.4+2637, RX J0947.0+4721 and 1WGA J1342.4+2720) also show relatively narrow Balmer lines (FWHM$\lesssim$2500 km s^{-1}), thus it appears that the $\alpha_{\rm x}$-Hβ FWHM correlation holds over a wide range of luminosities, and by implication also over M, i.e. a low-M black hole is *not* required to produce the observed dependence between X-ray spectrum and BLR velocity. For the high-L objects, the Balmer line regions must, therefore, lie much further out from the black hole than in the low-M AGN, to maintain a low cloud velocity. This may be because either *(1).* the outer BLR clouds themselves lie at large radii, perhaps 'pushed-out' by the unusual ionizing continuum; or *(2.)* the Balmer lines are only formed in those clouds which lie relatively far away from the black hole, even though gas may cover a wide range of radii. The latter is supported by Baldwin et al. (1995) who found that, rather than being emitted simply where clouds of gas happen to lie, emission lines in quasars are formed where the conditions of the gas, e.g. density and ionization parameter, are appropriate for that particular species.

4 SUMMARY

A search for high-z (z >0.5) ultrasoft X-ray AGN has been made using the WGACAT list of unresolved sources identified from pointed *ROSAT* PSPC observations. In addition to three such objects already known (E1346+266, EXO 1346.4+2637 and RX J0947.0+4721), a further three candidates have been identified (1WGA J1117.9+1808, 1WGA J1342.4+2720 and 1WGA J1446.3+1002). With typical bremsstrahlung temperatures, $T_{\rm brem}\sim$600 eV, and luminosities between 2×10^{44} and 10^{47} erg s^{-1}, these are the hottest and most luminous soft X-ray components known and are an important test for models of this component in the high-T extreme. Their relative paucity (1-2 per cent of z >0.5 WGACAT sources) suggests a high-T cut-off in the soft X-ray component at about $T_{\rm brem}\sim$600 eV, or that high-T soft components are weak in high-luminosity quasars. These sources have shown evidence for significant variability (E1346+266, 1WGA J1342.4+2720 and RX J0947.0+4721) and low-velocity BLRs (E1346+266, EXO 1346.4+2637, RX J0947.0+4721 and 1WGA J1342.4+2720) and thus appear to be high-luminosity counterparts of the NLS1s, many of which also exhibit these properties. The high central masses implied in some cases demonstrate that a low-M black hole is not required for the production of an ultrasoft X-ray excess. Neither does the link between X-ray spectral slope and BLR velocity require a low-M black hole.

ACKNOWLEDGEMENTS

I am very grateful to David Crampton for providing the spectrum of 1WGA J1342.4+2720 (EQ1340.1+2735), to Keith Mason for his comments and advice and to the referee, Niel Brandt for his considered report. This research has made use of data obtained through the High Energy Astrophysics Science Archive Research Center Online Service, provided by the NASA/Goddard Space Flight Center. It has also made use of data obtained from the Leicester Database and Archive Service at the Department of Physics and Astronomy, Leicester University, UK. 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.

REFERENCES

Arnaud, K. A. et al., 1985, MNRAS, 217, 105 1992, A&A, 253, 35
Bade N., Fink H. H., Engels D., Voges W., Hagen H.-J., Wisotzki L., Reimers D., 1995, A&AS, 110, 469
Baldwin J. A., Ferland G., Korista K., Verner D., 1995, ApJ, 445, L119
Barvainis R., 1993, ApJ, 412, 513
Boller T., Trumper J., Molendi S., Fink H., Schaeidt S., Caulet A., Dennefeld M., 1993, A&A, 279, 53
Boller Th., Brandt W. N. & Fink H., 1996, A&A, 305, 53
Brandt, W. N., Pounds, K. A., Fink H., 1995, MNRAS, 273, 47L
Collin-Souffrin S., Czerny B., Dumont A.M., Zycki P. T., 1996, A&A, 314, 393
Comastri A., Setti, G., Zamorani, G., Elvis M., Wilkes B. J., McDowell J. C., Giommi P., 1992, ApJ, 384, 62
Córdova F. A., Kartje J. F., Thompson R. J., Mason K. O., Puchnarewicz E. M., Harnden F. R., 1992, ApJS, 81, 661
Czerny, B. & Elvis, M., 1987, ApJ, 321, 305
Ferland G. J. & Rees M. J., 1988, ApJ, 332, 131
Goodrich R. W., 1989, ApJ, 342, 224
Guilbert P. W., & Rees M. J., 1988, MNRAS, 233, 475
Haardt F. & Maraschi L., 1993, ApJ, 413, 507
Kuncic Z., Celotti A., Rees M. J., 1997, MNRAS, 284, 717
Laor A., Fiore F., Elvis M., Wilkes B., McDowell J., 1997, ApJ, 477, 93
Masnou, J. L., Wilkes, B. J., Elvis, M., M$^{\rm c}$Dowell, J. C. & Arnaud, K. A., 1992, A&A, 253, 35
Molthagen K., Bade N., Wendker H. J., 1998, A&A, in press (astro-ph/9712306)
Nandra K., George I. M., Mushotzky R. F., Turner T. J., Yaqoob T., 1997, ApJ, 477, 602
Pounds K. A., Done C. & Osborne J., 1995, MNRAS, 277, L5
Puchnarewicz E. M. et al., 1992, MNRAS, 256, 589
Puchnarewicz E. M. et al., 1996, MNRAS, 281, 1243
Puchnarewicz E. M., Mason K. O. & Córdova F. A., 1994, MNRAS, 270, 663
Puchnarewicz E. M., Mason K. O., Siemiginowska A. & Pounds K. A., 1995, MNRAS, 276, 20
Puchnarewicz E. M., Mason K. O., Breeveld A. A., Siemiginowska A., in "Accretion Power in Astrophysics - Some Like it Hot", Proceedings of the 8th Annual October Astrophysics Conference in Maryland, publ. American Institute of Physics, New York, in press
Schartel N., Walter R., Fink H. H., Truemper J., 1996, A&A, 307 33
Siemiginowska A. et al., 1995, ApJ, 454, 77
Stark, A. A., Gammie C. F., Wilson R. W., Bally J., Linke R. A., Heiles C., Hurwitz M., 1992, ApJS, 79, 77
Svensson R. & Zdziarski A. A., 1994, ApJ, 436, 599
Turner, T. J. & Pounds, K. A., 1989, MNRAS, 240, 833
White N. E., Giommi P. & Angelini L., 1994, Bull. American Astron. Soc., 185, 4111

This paper has been produced using the Royal Astronomical Society/Blackwell Science TEX macros.