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Evidence of a high-velocity ionized outflow in a second narrow-line quasar PG 0844+349

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ABSTRACT

Following the discovery of X-ray absorption in a high-velocity outflow from the bright quasar PG 1211 + 143 we have searched for similar features in *XMM–Newton* archival data of a second (high accretion rate) quasar PG 0844+349. Evidence is found for several faint absorption lines in both the EPIC and RGS spectra, whose most likely identification with resonance transitions in H-like Fe, S and Ne implies an origin in highly ionized matter with an outflow velocity of order ∼0.2c. The line equivalent widths require a line-of-sight column density of $N_{\rm H} \sim 4 \times 10^{23}$ cm^{-2}, at an ionization parameter of log $\xi \sim 3.7$. Assuming a radial outflow being driven by radiation pressure from the inner accretion disc, as suggested previously for PG 1211 + 143, the flow in PG 0844+349 is also likely to be optically thick, in this case within ∼25 Schwarzschild radii. Our analysis suggests that a high-velocity, highly ionized outflow is likely to be a significant component in the mass and energy budgets of active galactic nuclei accreting at or above the Eddington rate.

Key words: galaxies: active – galaxies: individual: PG 0844+149 – galaxies: Seyfert – X-rays: galaxies.

1 INTRODUCTION

The additional sensitivity of *XMM–Newton* and *Chandra*, particularly in the energy band above the Fe K edge at ∼7 keV, has recently provided the first X-ray evidence for high-velocity outflows from quasars (Chartas et al. 2002; Pounds et al. 2003; Reeves, O'Brien & Ward 2003). The deduced ionization parameters and column densities are substantially higher than for the optical/ultraviolet (UV) lines seen in broad absorption line (BAL) quasars, with at least three important consequences. First, the detection of a high-velocity outflow in PG 1211+143 (Pounds et al. 2003), coupled with that reported here for PG 0844+349, imply that this could be a property common to many bright quasars. Second, interpreting the observed absorption as arising in a radial outflow leads inevitably to the prediction that the flow will be optically thick close to the black hole. Third, the outflow is likely to be a significant component in the mass and energy budgets of AGN accreting at or above the Eddington rate.

In this paper we report on the spectral analysis of a ∼25-ks *XMM–Newton* observation of the bright quasar PG 0844+349 taken from the *XMM–Newton* data archive. We assess the results in terms of a recent model describing the characteristics of outflows from black holes accreting at or above the Eddington rate (King & Pounds 2003).

PG 0844+349 is a low-redshift (z = 0.064), optically bright quasar, with strong Fe II emission and relatively narrow permitted optical emission lines (Boroson & Green 1992; Kaspi et al. 2000). It was detected as a strong soft X-ray source in the *ROSAT* sky survey, but had faded by a factor of 6 in a pointed observation six months later (Rachen, Mannheim & Biermann 1996), when it could be described as 'X-ray quiet' by comparison with its optical flux (Yuan et al. 1998). Comparison with earlier soft X-ray detections with *Einstein* (Kriss 1988) and *EXOSAT* (Malaguti, Bassani & Caroli 1994) suggested the 'X-ray quiet' phase is relatively rare. A later *ASCA* observation did indeed find PG 0844+349 to be again in a bright state, with a 2–10 keV power-law index $\Gamma \sim 1.98$ and evidence for Fe K emission with equivalent width EW ∼ 300 eV (Wang et al. 2000). PG 0844+349 has a typical X-ray luminosity (2–10 keV) of 5×10^{43} erg s^{-1}, for H_0 = 75 km s^{-1} Mpc^{-1}, and lies behind a low Galactic column of $N_{\rm H} = 3.32 \times 10^{20}$ cm^{-2} (Murphy et al. 1996).

2 OBSERVATION AND DATA REDUCTION

PG 0844+349 was observed by *XMM–Newton* on 2000 November 5 for ∼25 ks. An analysis of the EPIC spectrum (Brinkmann et al. 2003) reported a strong soft X-ray excess, which the authors discuss in terms of Comptonization of thermal accretion disc photons. Given the recent detection of 'blueshifted' absorption lines in a very similar PG quasar (Pounds et al. 2003), we have re-examined the *XMM–Newton* observation of PG 0844+349 to search for further evidence of such features. We use the full *XMM–Newton* X-ray data, including the EPIC pn camera (Strüder et al. 2001),

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which has the best sensitivity of any instrument flown to date in the ~7–10 keV spectral band above the Fe K absorption edge, the combined EPIC MOS cameras (Turner et al. 2001), and the Reflection Grating Spectrometer/RGS (den Herder et al. 2001). The X-ray data were first screened with the latest XMM SAS v5.4 software and events corresponding to patterns 0–4 (single and double pixel events) were selected for the pn data and patterns 0–12 for MOS1 and MOS2, the latter then being combined. We considered using only pattern 0 data from the pn camera, since at a mean count rate of 7 s^{-1} there was some evidence of pile-up. However, given that our target was to search for narrow spectral features, we chose to retain the maximum high-energy count rate at the expense of some (minor) loss of energy resolution. A low-energy cut of 300 eV was applied to all X-ray data and known hot or bad pixels were removed. We extracted source counts within a circular region of 45 arcsec radius defined around the centroid position of PG 0844+349, with the background being taken from a similar region, offset from but close to the source. Particular care was taken to locate the background region for the pn camera well inside the 'shadow' caused by Cu K fluorescence in a circuit board at the base of the camera. The nett exposures used for subsequent spectral analysis were 20.2 ks (pn), 46.7 ks (MOS1 + MOS2) and 25 ks (each RGS). Individual spectra were binned to a minimum of 20 counts per bin, to facilitate use of the χ^2 minimalization technique in spectral fitting. Spectral fitting was based on the XSPEC package (Arnaud 1996) and used a grid of ionized absorber models calculated with the XSTAR code (Kallman et al. 1996). All spectral fits include absorption due to the line-of-sight Galactic column of $N_H = 3.32 \times 10^{20}$ cm^{-2}. Errors are quoted at the 90 per cent confidence level ($\Delta\chi^2 = 2.7$ for one interesting parameter).

3 2–11 keV SPECTRUM

3.1 Power-law continuum

We began our analysis of PG 0844+349 by confirming there were no obvious spectral changes with varying source flux and then proceeded to fit the *XMM–Newton* pn and MOS data integrated over the full ~25-ks observation. A simple power-law fit over the 2–11 keV band yielded a relatively steep photon index of $\Gamma \sim 2.13$ (pn) and $\Gamma \sim 2.08$ (MOS), with a combined χ^2/dof (degrees of freedom) of 546/586. The statistical quality of this fit indicated that any discrete spectral features were less strong than in the case of PG 1211+143 (Pounds et al. 2003). However, visual examination of the data:power-law-model ratio (Fig. 1) does suggest some excess emission at ~6 keV, and – most interestingly – shows evidence of absorption near ~8 keV in both data sets. When extrapolated to 0.3 keV, the 2–11 keV power-law fits to both pn and MOS data reveal the previously reported strong 'soft excess' (Fig. 2).

3.2 Fe K emission and absorption features

We then added further spectral components to match the features seen in the data, beginning with a Gaussian emission line with energy, width and equivalent width (EW) as free parameters. This addition improved the 2–11 keV fit, to χ^2/dof of 526/583, with a line energy (in the active galactic nucleus (AGN) rest frame) at 6.5 ± 0.1 keV, rms width σ = 0.35 ± 0.15 keV and EW = 0.25 ± 0.11 keV.

Next, we fitted the narrow absorption feature visible in Fig. 1 with a Gaussian-shaped absorption line, again with energy, width and equivalent width free. The best-fitting observed line energy was

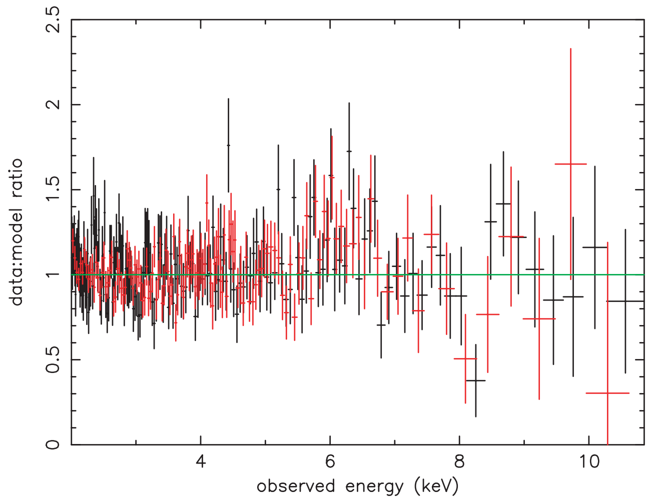

Figure 1. Ratio of the EPIC pn (black) and MOS (red) spectral data to a simple power-law model fitted between 2 and 11 keV for PG 0844+349. The plot shows a broad excess near 6 keV and a narrow absorption feature at ~8 keV.

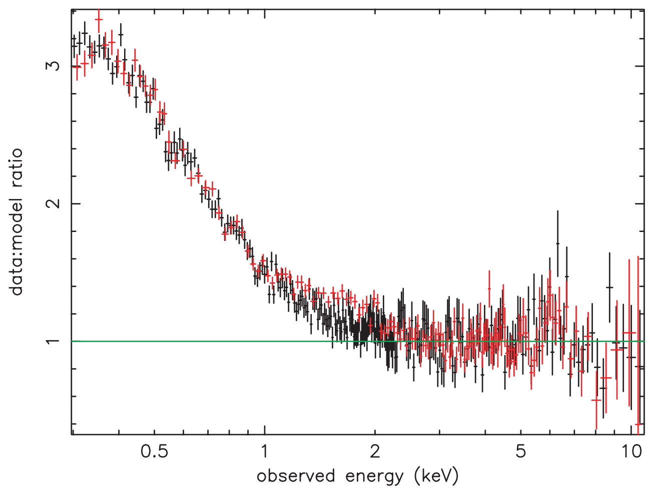

Figure 2. Extension to 0.3 keV of the 2–11 keV power-law model fits for the pn (black) and MOS (red) spectral data, showing the strong soft excess in PG 0844+349.

8.18 ± 0.10 keV, with an rms width of ⩽100 eV, and an EW of 170 ± 60 eV. The addition of this Gaussian absorption line improved the overall fit to χ^2/dof = 515/580, an improvement at 99.3 per cent confidence by the F-test (Bevington & Robinson 1992). We then examined the EPIC data for other spectral features, excluding the region ~1.8–2.3 keV where calibration residuals associated with the Si K and Au M edges remain. The strongest feature is a possible absorption line at ~3.0 keV; fitting this with a Gaussian line, again with energy and equivalent width free, further improved the 2–11 keV fit, to χ^2/dof of 508/578 (98 per cent confidence). A note of caution is appropriate here, since the ~3 keV feature is only significant in the pn data. We reject a second feature of similar depth, apparent near 3.3 keV, where a Gaussian fit (Fig. 3) shows this 'absorption line' to be marginally too narrow to match the EPIC resolution.

Finally, we retain only the most convincing absorption features, at ~8.18 keV and ~3.02 keV, in Table 1, which lists the observed and AGN rest-frame energy of each line, together with their most likely

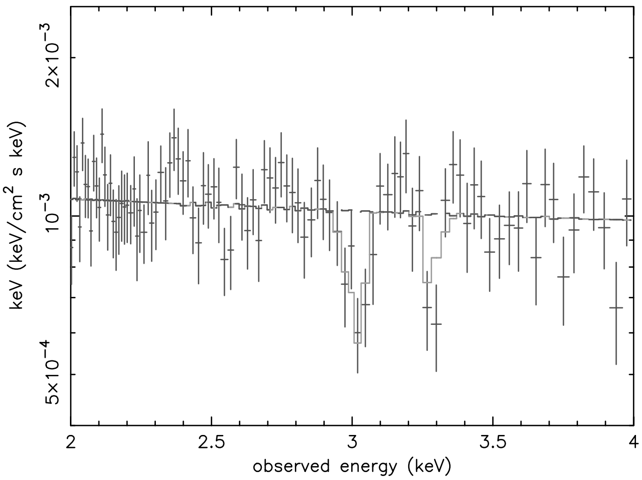

Figure 3. Fit to spectral features in the pn data between 2 and 5 keV. Possible identifications with S K lines are detailed in Table 1.

Table 1. Candidate line identifications and corresponding outflow velocities in the parametric fit to the EPIC spectrum of PG 0844+349. Line energies are in keV.

Line	E_{obs}	E_{source}	E_{lab}	Outflow velocity	EW (eV)
Fe XXVI Lyα	8.18 ± 0.1	8.70	6.96	∼0.22c	170 ± 60
Fe XXV 1s-2p	8.18 ± 0.1	8.70	6.70	∼0.26c	170 ± 60
S XVI Lyα	3.02 ± 0.1	3.21	2.62	∼0.20c	35 ± 16
S XV 1s-2p	3.02 ± 0.1	3.21	2.46	∼0.26c	35 ± 16

identifications and corresponding outflow velocities. Since the Fe K-shell dominates X-ray absorption above ∼7 keV, with a series of resonance and weaker satellite lines (e.g. Palmeri et al. 2002) leading up to the absorption edges of He-like Fe XXV at 8.76 keV and H-like Fe XXVI at 9.28 keV, the most likely interpretion of the ∼8.18 keV feature, where the narrow profile indicates a line rather than an edge, is with the primary resonance absorption line in H- or He-like Fe. These alternative identifications indicate an outflow velocity of ∼0.22c or ∼0.26c, respectively. The absorption feature at ∼3.02 keV has a most probable association with the primary resonance absorption line of He- or H-like S (as S K-shell absorption is likely to to be dominant in a highly ionized absorber in this energy range). We note that the implied outflow velocities from these alternatives are consistent with the values deduced for the ionized Fe line, lending support to the overall interpretation.

In summary, the detection of absorption lines in the EPIC spectra of PG 0844+349 provides intriguing evidence of an ionized outflow, with a velocity, depending on the line identifications, in the range ∼0.20–0.26c. To attempt to reduce this uncertainty, and find supporting evidence for this conclusion, we extend our search in Section 5 to the simultaneous RGS observation of PG 0844+349.

4 SOFT EXCESS

Extending the 2–11 keV power-law fits for both pn and MOS spectral data to 0.3 keV shows very clearly (Fig. 2) the strong soft excess indicated in earlier observations. In the EPIC data this can be adequately modelled with the addition of three black-body emission components, at $kT = \sim 70$ eV, ∼130 eV and ∼330 eV, fitting the 'gradual soft excess' seen in PG 0844+349 and which is apparently typical of higher-luminosity AGN (Pounds & Reeves 2002). Based on this fit we obtain an average 0.3–10 keV flux for PG 0844+349 of 1.1×10^{-11} erg s^{-1} cm^{-2}, corresponding to a luminosity of $\sim 10^{44}$ erg s^{-1} ($H_0 = 75$ km s^{-1} Mpc^{-1}). The 2–10 keV flux was 3.8×10^{-12} erg s^{-1} cm^{-2}, with a corresponding luminosity of 3×10^{43} erg s^{-1}. Compared with the *XMM–Newton* observation of PG 1211 + 143, the soft excess in PG 0844+349 is found to be significantly 'hotter', as is evident from a comparison of Fig. 2 here with the similar plot for PG 1211+143 (fig. 3 in Pounds et al. 2003).

5 SPECTRAL LINES IN THE RGS DATA

In Section 3.2 absorption lines in the EPIC spectrum have been identified alternatively with resonance transitions in He-like Fe XXV and S XV or H-like Fe XXVI and S XVI. The ambiguity in these identifications leaves the deduced outflow velocity uncertain within the range ∼0.20–0.26c. To attempt to clarify the situation we then examined the simultaneous *XMM–Newton* grating spectra. We began by jointly fitting the RGS-1 and RGS-2 data with a power law and black-body continuum (from the EPIC 0.3–11 keV fit) and examining the data:model residuals by eye. Only a few, weak spectral features were found, with the most significant at the shortest wavelengths (consistent with a high ionization parameter). Fig. 4 reproduces a section of the combined RGS data in the 8–15 Å band, showing narrow absorption lines at ∼10.85 Å and ∼9.18 Å, and a resolved emission line at ∼12.53 Å. The observed wavelength and EW of each line was determined by adding individual Gaussian lines to the power-law plus black-body continuum fit from EPIC. The statistical quality of the fit was improved by the addition of the three lines, from $\chi^2/\mathrm{dof} = 90/102$ to $\chi^2/\mathrm{dof} = 68/93$ (99.8 per cent confidence by the F-test). To attempt an initial identification of the absorption lines we noted that He- and H-like Ne (and possibly several Fe L lines) dominate photoionized spectra at 8–15 Å. Table 2 lists the line energies, for the primary resonance line of Ne X and Ne IX, and it is encouraging that the pair of absorption lines are separated by the correct wavelength ratio to fit the first two lines of either the Ne X Lyman series or the 1s–2p and 1s–3p transitions of Ne IX. While this adds strength to the evidence for a high-velocity outflow in PG 0844+349, the ambiguity relating to the He- or H-like identifications remains. However, the apparent absence of Fe L absorption suggests a high ionization parameter, while a fit to the He-like lines would leave the absence of the Ne X Lyα line (which should then

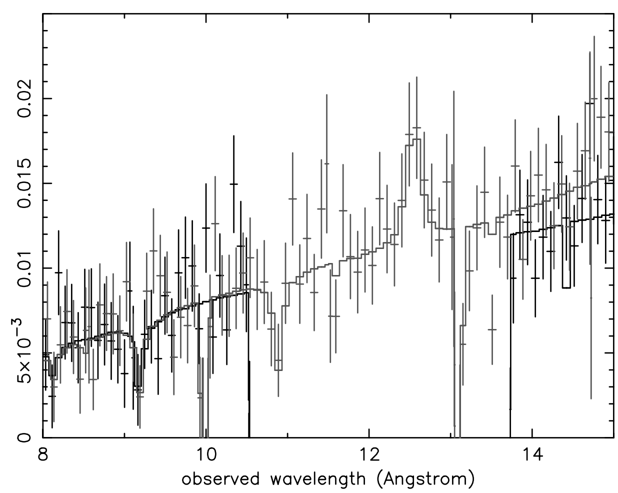

Figure 4. Fit to spectral features in the RGS data between 8 and 14 Å. Possible identifications with Ne K lines are detailed in Table 2. Data dropouts near 10, 10.5, 13.1 and 13.7 Å are due to chip gaps in the RGS CCDs.

Table 2. Ne K emission and absorption lines identified in the RGS spectrum of PG 0844+349. All wavelengths in angstroms.

Line	λ_{obs}	λ_{source}	λ_{lab}	Outflow velocity	EW (mA)
Ne X Lyα	12.53 ± 0.1	11.78	12.13	∼0.03c	125 ± 30
Ne IX-f 1s-2p	12.53 ± 0.1	11.78	13.65	∼0.15c	125 ± 30
Ne X Lyα	10.85 ± 0.1	10.20	12.13	∼0.17c	110 ± 35
Ne IX 1s-2p	10.85 ± 0.1	10.20	13.45	∼0.27c	110 ± 35
Ne X Lyβ	9.18 ± 0.1	8.63	10.24	∼0.17c	90 ± 45
Ne IX 1s-3p	9.18 ± 0.1	8.63	11.55	∼0.28c	90 ± 45

appear at ∼10 Å) a problem. We provisionally conclude, subject to testing with the XSTAR modelling in Section 6, that the H-like line identifications give a physically more compatible description of the ionized outflow in PG 0844+349. Comparison of Tables 1 and 2 then require an outflow velocity in the range ∼0.17–0.22c, with an indication of a positive correlation of velocity with ionization energy. That interpretation would then suggest the emission observed at ∼12.53 Å, and resolved by the RGS, is primarily due to Ne X Lyα, corresponding to emission from matter moving at a mean velocity (to the line of sight) of ∼0.03c. The strength and relatively low 'blueshift' of this component indicates the outflow has a wide cone angle, a point taken up again in Section 7.1, where we note that a broad outflow can be important in limiting sideways leakage of the radiation flux responsible for accelerating the outflow.

As in our observation of PG 1211+143, the absorption line profiles are unresolved, again suggesting the absorbing material is streaming outward with relatively little turbulence, and that we are viewing down (rather than across) the flow. The narrow line widths also suggest the high column density inferred from the XSTAR model fitting (see Section 6) may be an underestimate since no account is taken of saturation in the narrow line cores. Indeed, the comparable strengths of the Ne X Lyα and β absorption lines suggest the former is strongly saturated.

6 AN IONIZED ABSORBER MODEL

To quantify the highly ionized matter responsible for the observed absorption features, and check for physical consistency of the candidate line identifications, we replaced the Gaussian absorption lines in the above fits with a model comprising a grid of photoionized absorbers based on the XSTAR code. These model absorbers cover a wide range of column density and ionization parameter $\xi (=L/nr^2)$, with outflow (or inflow) velocities as a variable parameter. All abundant elements from C to Fe are included with the relative abundances as a variable input parameter. To limit processing time the XSTAR models assume a fixed width for each absorption line of 1000 km s^{-1} FWHM. Given the paucity of data from the PG 0844+349 spectral analysis we included only one absorbing column in the fit, assumed to fully cover the underlying continuum, recognising this would probably 'average out' the optimal parameters for ions as disparate as Fe XXVI and Ne X. Assuming solar abundances, a best-fitting ionization parameter of log ξ of 3.7 ± 0.2, with a column density of $N_H = 4 \times 10^{23}$ cm^{-2}, was found to reproduce the observed absorption line strengths of Fe XXVI, S XVI and Ne X, with a nett blueshift of 0.15 (or ∼0.21c, in the AGN rest frame). Apart from a minor contribution from Fe XXV, the main absorption lines produced by this highly ionized column were all of hydrogenic ions. An alternative fit, at an ionization parameter of log $\xi = 3.2 \pm 0.15$, was obtained by assuming line identifications with He-like Fe, S and Ne. However, at this lower ionization level, significant Fe L absorption lines are predicted in the 10–15 Å band, which are not seen. We therefore conclude that the XSTAR fitting favours the high ionization parameter solution, and an outflow velocity of ∼0.2c.

7 DISCUSSION

The *XMM–Newton* observation of PG 0844+349 has revealed an X-ray spectrum with intriguingly similar (albeit weaker) features to those recently reported for another bright, narrow-line quasar PG 1211 + 143 (Pounds et al. 2003). The soft X-ray excess reported in previous observations is confirmed, being somewhat 'hotter' and less strong than for PG 1211 + 143. Fe K emission is again detected and modelled by a broad, but non-relativistic Gaussian line. Of most interest is finding further evidence of an absorption line structure, in both EPIC and RGS data, indicating a high-column, high-ionization absorber, outflowing at an even higher velocity (than found for PG 1211+143) of ∼0.2c. We attribute the relatively faint absorption lines to the higher ionization (lower opacity) of the outflow, despite the best-fitting column density again being remarkably high. As for PG 1211+143 we note that most of the uncertainty in the derived column densities is on the upside, since partial covering and accounting for saturation in the relatively narrow line profiles would both increase the above values.

PG 0844+349 adds to a growing list of AGN showing X-ray evidence for high-velocity ionized outflows, also including PG 1211+143 (Pounds et al. 2003), the ultra-luminous quasar PDS456 (Reeves et al. 2003) and the BAL quasar, APM 08279+5255, reported to have strongly blueshifted resonance absorption lines of Fe XXV or XXVI by Chartas et al. (2002). The most important implication of finding such absorption in the hard X-ray band is that the required column densities are higher (cf. with those seen in the UV), and the mass and kinetic energy in the outflows are correspondingly more significant. It appears that highly ionized, high-velocity gas, capable of imparting Fe K absorption features, may be a major component of (at least some) AGN that has remained undetected prior to the improved sensitivity of observations in the ∼7–10 keV band.

7.1 A massive ionized outflow

As in the case of PG 1211+143, the high column density of ionized matter in the line-of-sight to PG 0844+349 implies – for the simplest assumption of a radial outflow – that the flow will be optically thick at small radii. We show below that the hot 'photosphere' provides a major part of the energetically dominant thermal continuum (BBB) emission for PG 0844+349. Other important implications of the observed high-velocity outflow, which we assess below in terms of a physical model of winds from black holes accreting at or above the Eddington limit (King & Pounds 2003, hereafter KP03), are a significant mass loss and substantial kinetic energy associated with the outflow.

As shown in the analysis of PG 1211+143 (Pounds et al. 2003), for a radial outflow with constant (coasting) speed v, occupying a solid angle of $4\pi b$ steradians, mass conservation implies the outflow is optically thick at a radius R_{ph}, where

$$\frac{R_{ph}}{R_s} = \frac{1}{2\eta b}\frac{c}{v}\frac{\dot{M}_{out}}{\dot{M}_{Edd}}. \quad (1)$$

Here $\dot{M}_{out}$ is the outflow mass rate and $\dot{M}_{Edd}$ the Eddington accretion rate. $R_s = 2GM/c^2$ is the Schwarzschild radius for mass M and $\eta \sim 0.1$ is the assumed accretion efficiency. Since the outflow is optically thick, most of the photons have scattered and given up at least their original momentum. This will be assured if photon leakage from the sides of the outflow cone is small, i.e. the collimation of the outflow is not too extreme.

As in KP03 we assume that the outflow is launched from the photosphere at the local escape velocity, i.e.

$$R_{\rm ph} \simeq R_{\rm esc} = \frac{c^2}{v^2} R_{\rm s}. \tag{2}$$

With $\dot{M}_{\rm Edd} = 0.7\,{\rm M}_{\odot}\,{\rm yr}^{-1}$, appropriate to a black hole mass of $M \sim 3 \times 10^7\ {\rm M}_{\odot}$, we then find $\dot{M}_{\rm out} = 0.7b\,{\rm M}_{\odot}\,{\rm yr}^{-1}$. Assuming the measured outflow velocity is the same as the launch velocity, the associated kinetic energy is $8b \times 10^{44}$ erg s^{-1}.

Since the outflow is optically thick for $\dot{M}_{\rm out} \sim \dot{M}_{\rm Edd}$, much of the accretion luminosity generated deep in the potential well near $R_{\rm s}$ must emerge as black-body-like emission from it. The quasi-spherical radiating area is

$$A_{\rm phot} = 4\pi b R_{\rm ph}^2 \tag{3}$$

with an effective black-body temperature (KP03, equation 18) of

$$T_{\rm eff} = 10^5 b^{1/4} \dot{M}_1^{-1} M_8^{3/4}\ {\rm K}. \tag{4}$$

where $\dot{M}_1 = \dot{M}_{\rm out}/(1\ {\rm M}_{\odot}\ {\rm yr}^{-1})$ and $M_8 = M/10^8\ {\rm M}_{\odot}$.

Assuming $b \sim 1$ in PG 0844+349 this gives $T_{\rm eff} = 6 \times 10^4$ K, consistent with the optically thick flow being a major component of the BBB (and bolometric luminosity) of PG 0844+349.

Confirmation of the physical consistency of the above analysis can be made by noting that, for a Compton thick wind driven by radiation pressure, the momentum in the outflow must be of the same order as that in the Eddington-limited radiation field (KP03, equation 12), as is indeed the case for PG 0844+349.

Furthermore, the kinetic energy in the outflow should be lower than that of the radiation field by a factor of order v/c (equation 13 in KP03), a requirement which again is met by the outflow parameters of PG 0844+349.

In summary, we conclude that the radiation-driven, optically thick wind described in KP03 represents a physically consistent model by which to assess the high-velocity, highly ionized outflows detected in PG 0844+349 and several other AGN. A question remains as to how common are these phenomena, and – in turn – how common is supercritical accretion?

7.2 How common are massive outflows in AGN?

As noted earlier the bolometric luminosity of PG 0844+349 is of order 3×10^{45} erg s^{-1}, which for a reverberation mass of $M \sim 3 \times 10^7\ {\rm M}_{\odot}$ (Kaspi et al. 2000) implies accretion at close to the Eddington rate. PG 1211+143 has a very similar luminosity and black-hole mass (Kaspi et al. 2000) and – taken together – the *XMM–Newton* observations suggest that a high-velocity, highly ionized outflow may be a new signature of a high (super-Eddington?) accretion rate in AGN. A strong soft X-ray excess (seen in earlier data as a steep soft X-ray spectrum) then follows naturally from the physical model sketched in Section 7.1. It is interesting to note that the detailed differences in the observed properties of PG 0844+349 and PG 1211+143 are also broadly consistent with the physical model described in KP03. In particular, we associate the more highly ionized/higher-velocity outflow for PG 0844+349 with a smaller launch radius. The smaller and hotter photosphere matches in a general way the lower UV flux ($m \sim 14$ compared $m \sim 13.3$ from the simultaneous OM data), but 'hotter' soft X-ray excess in PG 0844+349 compared with PG 1211+143 (compare Fig. 2 in this paper with fig. 3 in Pounds et al. 2003). Another interesting difference evident in the simple power-law fits to the EPIC data of PG 0844+349 and PG 1211+143 is the absence of any evidence of an extreme broad Fe K emission line in the former case. While, if truly a relativistic Fe K line, this could relate to a difference in reflection from the innermost accretion disc, a simpler alternative is that the partial covering by a column of moderately ionized gas (proposed to explain the extreme Fe K 'line' in PG 1211+143) is simply absent from the more highly ionized flow in PG 0844+349. In summary, the *XMM–Newton* observations of PG 0844+349 and PG 1211+143 provide strong evidence of a massive outflow of ionized gas, which may well be a characteristic of AGN accreting at or above the Eddington limit. The question of how common are these outflows might then be transposed to the more fundamental question of how common is Eddington or super-Eddington accretion in AGN?

Until recently the evidence for high-velocity outflows in AGN has come from UV studies of BAL quasars, where a variety of, mainly high-ionization, UV resonance transitions exhibit velocity widths up to ∼30 000 km s^{-1} (e.g. Weymann et al. 1991). The BAL property, involving some 10 per cent of optically selected quasars, is usually interpreted as viewing the central continuum source along a particular line-of-sight tangential to the accretion disc. At X-ray energies most BAL quasars are 'X-ray weak', a property explained by line-of-sight absorption in moderately ionized gas with column densities up to $N_{\rm H} = 10^{23}$ cm^{-2} (e.g. Hamann 1998; Sabra, & Hamann 2001; Gallagher et al. 2002). Crucially, these observations have not revealed whether the X-ray absorbing column is moving or stationary. The extended *Chandra* observation of the gravitationally lensed high-redshift BAL quasar APM 08279+5255 (Chartas et al. 2002) was an exception, showing components of the absorbing column to be highly ionized and outflowing at ∼0.2c and ∼0.4c. Taken together with the evidence reported here (and for PG 1211+143 and PDS456) it seems a reasonable speculation that a high column density and high-velocity (hence massive) outflow may be a common property of luminous AGN. This invites the further intriguing speculation that accretion at (or above) the Eddington rate is equally common, extending the suggestion by Becker et al. (2000) who proposed that BAL objects may be young or have recently been fuelled.

Observationally, the detection of highly ionized outflows remains challenging since the gas is largely transparent, showing its most unambiguous features in the X-ray band above ∼7 keV where current in-orbit instruments have low sensitivity. Nevertheless, future longer exposures with *XMM–Newton* and *Chandra* should provide a better assessment of this important new component of (at least high accretion rate) AGN.

8 CONCLUSIONS

(1) Archival *XMM–Newton* data of the bright quasar PG 0844+349 has revealed further evidence of a high-velocity ionized outflow in a PG quasar.

(2) An implication of the observed high column density is that the inner flow will be optically thick, providing a natural explanation for the dominant BBB (and strong soft X-ray emission) in PG 0844+349.

(3) Efficient acceleration requires the outflow in PG 0844+349 to be only weakly collimated, which then leads to estimates of the mass and kinetic energy of the flow representing a significant fraction of the accretion mass rate and energy budget.

(4) We suggest the above properties may be common in AGN accreting at or above the Eddington limit.

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