Are there any Type 2 QSOs? The case of AXJ0341.4–4453

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ABSTRACT
The X-ray source AXJ0341.4–4453 was described by Boyle et al. as a Type 2 AGN at z = 0.672 based on the absence of broad emission lines in the observed wavelength range 4000–7000 Å. We obtained a new spectrum of AXJ0341.4–4453 extending to 9600 Å which reveals broad Balmer lines and other characteristics of Seyfert 1 galaxies. The FWHM of broad Hβ is at least 1600 km s⁻¹, while [O iii] λ5007 has FWHM = 730 km s⁻¹. The flux ratio [O iii] λ5007/Hβ = 1. Thus, AXJ0341.4–4453 is by definition a narrow-line Seyfert 1 galaxy, or perhaps a moderately reddened Seyfert 1 galaxy, but it is not a Type 2 QSO. Although examples of the latter have long been sought, particularly in connection with the problem of the X-ray background, there is still virtually no evidence for the existence of any Type 2 QSO among X-ray selected samples.

Key words: galaxies: active – galaxies: individual: AXJ0341.4–4453 – quasars: general – X-rays: general.

1 INTRODUCTION
The X-ray source AXJ0341.4–4453 was discovered in a deep exposure by the ASCA satellite, and was noted to have an exceptionally hard X-ray spectrum (Boyle et al. 1998). It was only weakly detected in a deep ROSAT survey of the same field (Georgantopoulos et al. 1996). An optical identification was made with an emission-line object at z = 0.672 that has high-ionization forbidden lines, most notably [Ne v] λ3426 (Boyle et al. 1998). The absence of broad Mg II λ2798 and broad Balmer lines led those authors to classify AXJ0341.4–4453 as a Type 2 (obscured) AGN with a 2–10 keV X-ray luminosity of 1.8 × 10⁴⁴ erg s⁻¹.

It has long been postulated that highly absorbed AGNs are the source of most of the hard X-ray background. The search for Type 2 QSOs among X-ray survey identifications is therefore a natural test of this hypothesis, but there is little, if any, evidence for such high-luminosity analogues of Seyfert 2 galaxies (see Halpern, Eracleous & Forster 1998; Halpern & Moran 1998; and references therein). Because they are rare (possibly nonexistent) and easily mimicked by other types of AGNs, considerable care must be taken in the search for true Type 2 QSOs. In particular, the classification of AXJ0341.4–4453 as Type 2 AGN was made on the basis of an optical spectrum extending to a maximum wavelength of 4200 Å in the rest frame, thus excluding the lower order Balmer lines from examination. Since these lines are sometimes the only broad lines that are detected in X-ray selected AGNs, we sought to remedy this deficiency by obtaining a spectrum of AXJ0341.4–4453 extending at least to the Hβ and [O iii] λ5007 emission lines.

2 OBSERVATIONS
Optical spectra of AXJ0341.4–4453 were obtained on UT 1998 October 19 using the RC Spectrograph and Loral 3K CCD on the CTIO 4m telescope. The wavelength range 3600–9600 Å was covered at a resolution of 6.3 Å. Wavelength calibration using a helium-argon spectrum achieved an rms accuracy of 0.3 Å. Both object and standard star LTT 1788 (Baldwin & Stone 1983,1984) were observed near zenith under photometric conditions through a slit of width 1′.5. A total of 3000 s of exposure was obtained on AXJ0341.4–4453. The spectral images were reduced using standard methods and extracted using an optimal extraction technique (Horne 1986). The reduced spectrum is shown in Figure 1. Although a WG360 blocking filter was used, there is still the possibility of second-order overlap at wavelengths longer than 7200 Å. However, both object and standard star are relatively red, and we see no specific evidence for second-order contamination in either spectrum. The standard star was also used as a template for the removal of atmospheric absorption bands in the red. Instrumental artefacts are apparent near wavelengths 6860 Å and 8870 Å. These are due to charge traps in the CCD that are approximately 10 columns (20 Å) wide.

Our spectrum resembles that of Boyle et al. (1998) shortward of 7000 Å, but we also cover the redshifted emis-
Figure 1. Spectrum of AXJ0341.4–4453 from the CTIO 4m telescope on UT 1998 October 19.

Figure 2. Continuum subtracted spectrum of AXJ0341.4–4453 in velocity units. A feature possibly due to Fe $\text{ii} \lambda 4923$ is marked.

Emission lines of $H\gamma$, $H\beta$, and $[O \text{ iii}]$ in the near infrared. The Balmer lines contain components that are broader than the forbidden lines, immediately requiring a Seyfert 1 classification. Details of the profiles can be seen in Figures 2 and 3, which show the regions around the Balmer lines in velocity units, after continuum subtraction. The $[O \text{ iii}]$ line has FWHM = 730 km s$^{-1}$, while the FWHM of the total $H\beta$ profile is 1620 km s$^{-1}$, more than twice that of $[O \text{ iii}]$. The signal-to-noise ratio is not sufficient to decompose $H\beta$ into narrow and broad components, but it is clear that the $H\beta$ line extends to $\pm 3000$ km s$^{-1}$, whereas the $[O \text{ iii}]$ lines have no such component. In Figure 1 there is a hint of the presence of the usual complexes of permitted Fe $\text{ii}$ multiplets on either side of $H\beta$ and $[O \text{ iii}]$. Although these are too noisy to measure, it is possible, for example, that Fe $\text{ii} \lambda 4923$ contributes to an apparent emission bump at 3000–4000 km s$^{-1}$ in the rest frame of $H\beta$ as indicated in Figure 2. Note that $H\delta$ in our spectrum falls on the charge trap at 6860 Å, and is therefore not detected. $H\delta$ was the only Balmer line visible in the spectrum of Boyle et al. (1998), and its blue side in fact looks somewhat broad there. However, the red side of the $H\delta$ profile is absorbed by the atmospheric B band at 6867 Å, which was evidently not corrected in their spectrum, and is responsible for their discrepant redshift measurement from this line.

Details of our emission-line measurements are given in Table 1. We measure a redshift of $z = 0.6723 \pm 0.0002$ from the stronger narrow emission lines, in agreement with Boyle et al. (1998). We do not list dereddened fluxes, as Galactic extinction is negligible in this direction. Although it is not possible to decompose the $H\beta$ line uniquely into broad and narrow components, the $H\gamma$ line has a narrow peak which is more readily measured (see Figure 3), thus providing evidence that the narrow-line region is less reddened than the region emitting the broad lines. We give only the total $H\beta$ flux in Table 1, but we list the broad and narrow components of $H\gamma$ separately. If we assume that the narrow-line ratio $H\gamma/H\beta$ has the recombination value 0.47, then the broad $H\gamma/H\beta$ ratio is 0.17. Such a decomposition of the $H\beta$ flux is plausible, since it would require $[O \text{ iii}] \lambda 5007/H\beta = 8$ for the narrow-line region, a value which is typical. According to the standard Galactic reddening law, $H\gamma/H\beta = 0.17$ would correspond to 7 magnitudes of visual absorption intrinsic to
Table 1. Emission-line measurements of AXJ0341.4–4453.

| Line       | Flux (erg cm\(^{-2}\) s\(^{-1}\)) | FWHM (km s\(^{-1}\)) | z  |
|------------|----------------------------------|-----------------------|----|
| Mg \(\text{II}\) A2798 | \(\leq 2 \times 10^{-16}\) | ... | ... |
| \[Ne \text{III}\] A3426 | \(1.3 \times 10^{-16}\) | 1060 | 0.6709 |
| \[O \text{II}\] \(\lambda 3727\) | \(4.7 \times 10^{-16}\) | 630 | 0.6725 |
| \[Ne \text{III}\] A3869 | \(1.9 \times 10^{-16}\) | 860 | 0.6718 |
| \[Ne \text{II}\], \(\text{He}\) | \(6.8 \times 10^{-17}\) | ... | ... |
| H\(\gamma\) (narrow) | \(2.0 \times 10^{-16}\) | 740 | 0.6724 |
| H\(\gamma\) (broad) | \(4.6 \times 10^{-16}\) | ... | ... |
| \[O \text{III}\] \(\lambda 4363\) | \(1.0 \times 10^{-16}\) | ... | ... |
| H\(\beta\) (total) | \(3.1 \times 10^{-15}\) | 1620 | 0.6719 |
| \[O \text{III}\] A4959 | \(1.2 \times 10^{-15}\) | 720 | 0.6718 |
| \[O \text{III}\] \(\lambda 5007\) | \(3.3 \times 10^{-15}\) | 730 | 0.6723 |

3 CONCLUSIONS AND SPECULATIONS

The optical spectrum of AXJ0341.4–4453 is most naturally interpreted as that of a narrow-line Seyfert 1 galaxy (NLS1). It fits the standard definition of this class (Osterbrock & Pogge 1985; Goodrich 1989), namely \([O \text{III}] \lambda 5007/H\beta < 3\) and FWHM H\(\beta < 2000\) km s\(^{-1}\). There is also possible evidence for permitted Fe II emission lines, which are common in NLS1s. The only uncertainty in classification involves the extent of the broad component of H\(\beta\), which could be larger than we have detected. If the narrow and broad components could be separated in spectra of higher signal-to-noise ratio, then the FWHM of the broad component alone could be larger, which might require revision to an ordinary Seyfert 1 classification. In NLS1s, however, these components are normally not separable. In any case, AXJ0341.4–4453 certainly does not have a Seyfert 2 spectrum, and is therefore not a candidate for the high-luminosity Seyfert 2 analogue, the Type 2 QSO. It is easy to mistake a NLS1 for a Type 2 QSO. Another such case was IRAS 20181–2244 (Halpern & Moran 1998), a NLS1 that also suffers from moderate absorption, and lacks a Mg II emission line.

Moderate obscuration of the broad-line and continuum emitting regions can probably account for the optical and X-ray properties of AXJ0341.4–4453. A column density of \(\sim 10^{22}\) cm\(^{-2}\), which severely attenuates soft X-rays, could be responsible for the apparent hard X-ray spectrum, as well as for several magnitudes of visual extinction if the dust and gas properties are similar to Galactic. Although Boyle et al. (1998) dismissed the NLS1 possibility on the basis of a hard X-ray spectrum, it is now evident from their deep X-ray survey, as well as others, that the types of AGNs found at faint flux levels in hard X-ray surveys with ASCA and BeppoSAX (Akiyama et al. 1998; Fiore et al. 1999; Giommi, Fiore & Perri 1998) are basically the same as had been found previously in soft X-rays with ROSAT. Therefore, it should not be surprising that moderately obscured but otherwise representative AGNs are found when X-ray sources are singled out on the basis of their flat X-ray spectra. We also caution that, since even highly luminous NLS1s can vary by more than order of magnitude in X-ray flux (e.g., Forster & Halpern 1996), it is not safe to draw conclusions about X-ray spectral shape by comparing noncontemporaneous ROSAT and ASCA observations of these objects.

As to the question of whether or not such moderately reddened objects are Type 2 AGNs, we remark that reddening alone is not sufficient to make a Type 2 AGN. It depends on where the obscuring material is located and how thick it is. In the currently popular unified model of Seyfert classification, the obscuring material must be in a position to obscure the broad-line emitting region from our view, but not the narrow-line region, in order to produce a Type 2 AGN. A visual absorption of 3.5–7 magnitudes, as estimated above, is vanishingly small compared to the amount of extinction in the so-called Compton-thick Seyfert 2 galaxies, for which equivalent visual absorption of 1000 magnitudes or more is inferred from their X-ray measured column densities. An absorption of 3.5–7 magnitudes could easily be due to the interstellar medium in the disk of the host galaxy, especially if viewed at high inclination, or to a single molecular cloud. Indeed, a certain fraction of Seyferts must suffer just such galaxian obscuration. Therefore, isolated cases like AXJ0341.4–4453 cannot be interpreted in the unified model as Type 2, especially since Compton-thick absorption is now found to be ubiquitous among Seyfert 2 samples that are selected by their \([O \text{III}]\) flux alone (Maiolino et al. 1998). AXJ0341.4–4453 shows no evidence of being Compton thick. In particular, its ratio \(L_X/L([O \text{III}])\) of 33 is much larger than those of the Compton-thick Seyferts in Maiolino et al. (1998), for which this ratio is less than 1.

It would also be unpalatable to regard a NLS1 as an “intermediate” type AGN. The recently acquired wealth of data on NLS1s eludes explanation within the Seyfert unification paradigm. In particular, the fact that the permitted emission lines are narrow in NLS1s is not understood in terms of any orientation-dependent unification scheme. Rather, it is likely to be due to some intrinsic physical property. Similarly, the rapid and large amplitude X-ray variability, and soft X-ray spectra which characterise NLS1s as a class, are antithetical to obscuration.

The absence of Type 2 QSOs, the high-luminosity analogues of Seyfert 2 galaxies, remains a significant fact to be explained whether in the context of unified models or not. Broad optical emission lines are detectable in most Seyfert galaxies with X-ray luminosity \(\gtrsim 10^{42}\) erg s\(^{-1}\) (Halpern, Helfand & Moran 1995; Moran, Halpern & Helfand 1996), and, as far as we know, in every non-blazar AGN whose X-ray luminosity exceeds \(3 \times 10^{44}\) erg s\(^{-1}\) (Halpern et al. 1998). In the context of the unified scheme, the absence of Type 2 QSOs among X-ray selected samples is natural if either (1) all such objects are perfectly Compton thick or (2) all sufficiently luminous QSO nuclei are able to remove any obscuring material from their vicinity, affording their broad-line regions 4\(\pi\) steradians of visibility. But we do not have
much confidence that either of these idealizations will hold strictly true. Therefore, it is possible that Type 2 QSOs may yet be found at the lower X-ray flux thresholds of AXAF and XMM. However, it is not clear that such a new population is needed to account for the hard X-ray background. Indeed, the ideal Compton-thick AGN can make little or no contribution to the X-ray background unless such a source is at high redshift. Whether or not Type 2 QSOs exist, it might turn out that moderately obscured AGNs of the types that are well known will prove sufficient to comprise the X-ray background (Fiore et al. 1999; Giommi et al. 1998).

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