OPTICAL AND X-RAY SPECTROSCOPY OF 1E 0449.4—1823: DEMISE OF THE ORIGINAL TYPE 2 QSO

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ABSTRACT

New optical spectra of the original narrow-line quasar 1E 0449.4—1823 show that it now has broad emission lines of considerable strength, eliminating it as a “type 2 QSO” candidate. Although broad emission line components were probably weakly present in 1981 and 1984, they have certainly increased in strength and are accompanied by Balmer continuum emission that makes the spectrum bluer than it was previously. We suggest that the behavior of 1E 0449.4—1823 is the same as that of some Seyfert 1.8 and 1.9 galaxies, in which Goodrich attributed long-term variations of their broad Balmer lines to dynamical motions of obscuring material located in or around the broad-line region. The optical continuum and broad emission line regions of 1E 0449.4—1823 may still be partly covered in our line of sight, which would explain its large forbidden-line equivalent widths and flat $\sigma_{\text{rest}}$ relative to other low-redshift QSOs. Also present are apparent absorption features in the broad Balmer lines and in Mg II, which may be related to the past obscuration and current emergence of the broad-line region. However, it is difficult to distinguish absorption from broad emission line peaks that are displaced in velocity; we consider the latter a plausible competing interpretation of these peculiar line profiles. An ASCA X-ray spectrum of 1E 0449.4—1823 can be fitted with a power law of intrinsic $L_{\text{X}} \sim 10^{44}$ ergs s$^{-1}$; thus, there is no evidence for Seyfert 2 properties in the X-ray emission from 1E 0449.4—1823, which resembles that of an ordinary QSO. With regard to the still hypothetical type 2 QSOs, we argue that there is little evidence for the existence of any among X-ray-selected samples.

Subject headings: galaxies: active — galaxies: individual (1E 0449.4—1823) — galaxies: Seyfert — line: profiles — quasars: general — X-rays: galaxies

1. INTRODUCTION

One basic fact about quasars is not yet understood, namely, why there are virtually no narrow-line or “type 2 QSOs,” the high-luminosity analogs of Seyfert 2 galaxies. Every year or so an X-ray–discovered object is advertised that might fit such a description, but their qualifications are usually found to be lacking for one reason or another. A handful of such cases was described in recent papers by Forster & Halpern (1996) and Halpern & Moran (1998), with generally negative evaluations. In this paper, we present new spectra of the “original” narrow-line QSO, the serendipitous X-ray source 1E 0449.4—1823 at $z = 0.338$ that was the first to be described as such (Stocke et al. 1982). Although Stocke et al. referred to a possible broad component of Hβ in their discovery paper and even presented another spectrum (Stocke et al. 1983) showing a probable weak broad Mg II line in 1E 0449.4—1823 shortly after their original discovery, those observations have generally not been mentioned in subsequent discussions of this object. Instead, 1E 0449.4—1823 is invariably referred to as a Seyfert 2 galaxy or a narrow-line QSO without qualification (e.g., Stephens 1989; Miller & Goodrich 1990; Keel et al. 1994; Elizalde & Steiner 1995; Turner et al. 1997a, 1997b).

A weakness of the original studies of 1E 0449.4—1823 was their lack of coverage at Hα, which is sometimes the only broad emission line that is clearly detectable in X-ray–selected Seyfert galaxies (e.g., Halpern, Helfand, & Moran 1995). Since this deficiency had to our knowledge not yet been remedied, we undertook to obtain spectra covering the Mg II, Hβ, and Hα regions of 1E 0449.4—1823 in order to reassess its qualifications as a narrow-line QSO. We also reanalyzed an archival ASCA X-ray observation of 1E 0449.4—1823, previously published by Turner et al. (1997a, 1997b), in the light of our new optical data. The observations and results of this investigation are reported below together with an interpretation of the broad-line components of substantial strength that we discovered in the optical spectrum. Possible implications of the dearth of type 2 QSOs in general are also discussed.

2. OPTICAL SPECTROSCOPY

Optical spectra of 1E 0449.4—1823 were obtained using the Kast spectrograph (Miller & Stone 1987) on the 3 m Shane reflector of the Lick Observatory and on the Cerro Tololo Inter-American Observatory (CTIO) 1.5 m telescope. A log of the observations is given in Table 1. The spectrograph slit was oriented at the parallactic angle in order to ensure spectrophotometric accuracy. A composite of the spectra is shown in Figure 1, after standard reduction and dereddening by the extinction in this direction, which is estimated to be $E(B-V) = 0.078$ from the neutral hydrogen
column density of Stark et al. (1992). We measure a heliocentric redshift of 0.3387 ± 0.0001 from the narrow emission lines, which is consistent with the systemic galaxy redshift that can be measured from the starlight that is definitely visible in the form of the \( \text{Ca} \ II \) \( \lambda \)3933 absorption line.

Immediately apparent in Figure 1 are broad emission lines of substantial strength, including \( \text{Mg} \ II \), \( \text{H} \beta \), and \( \text{H} \alpha \). The broad \( \text{H} \beta \) line, which here has rest \( \text{EW} \) = 55 Å, was not obvious in the spectra of Stocke et al. (1982), obtained in 1981, or in that of Stephens (1989), obtained in 1984. However, the former authors noted its possible presence, and it can be seen weakly on close inspection of the spectrum of Stephens (1989). In addition to the improved signal-to-noise ratio here, the broad lines have definitely increased in strength since the early 1980s. Another factor that hindered the previous detection and measurement of the broad emission lines is their large velocity width, \( \text{FWHM} \approx 10,000 \text{ km s}^{-1} \) and \( \text{FWZI} \approx 20,000 \text{ km s}^{-1} \). In fact, this large velocity width is still a significant factor limiting the accuracy to which the Balmer lines can be measured; it is difficult to define a continuum blueward of \( \text{H} \beta \) because of blending with the higher order Balmer lines. Accompanying those lines are an increase in the Balmer continuum, which is responsible for the broad bump in the near ultraviolet. This "little blue bump" was not present in the previous spectra, leading Stocke et al. (1982) to describe \( 1 \text{E} \ 0449.4−1823 \) as a red object, with \( U−B = 0.4 \). Although the rest frame \( U−B \) color is now \(-0.8 \) as estimated from our spectrum, there is probably still significant reddening of the continuum as indicated by its steepness in the neighborhood of the \( \text{Mg} \ II \) line. In contrast, Grandi & Phillips (1979) show spectra of QSOs that are rising shortward of the \( \text{Mg} \ II \) line.

Line intensity measurements for both broad and narrow components are given in Table 2. There is not much evidence for reddening in the emission-line spectrum. Both the narrow-line and broad-line Balmer decrements are consistent with those of unreddened QSOs. The broad \( \text{Mg} \ II/\text{H} \beta \) ratio is 0.85, which is within the range 0.5−2.5 that is usually found in QSOs (Grandi & Phillips 1979) and similar to those of other X-ray–selected active galactic nuclei (AGNs) (Puchnarewicz et al. 1997).

There is one noteworthy property of the spectrum of \( 1 \text{E} \ 0449.4−1823 \). A close examination of the broad emission lines shows that their profiles (Fig. 2) all have the same unusual structure, which can be described either as an absorption feature blueshifted by \(-1900 \text{ km s}^{-1} \) from the galaxy rest frame, or else as a well-defined broad emission line peak blueshifted by \(-3500 \text{ km s}^{-1} \). Although narrow absorption lines such as these are common in the resonance lines of Seyfert galaxies, they are virtually unknown in the Balmer lines, which makes us reluctant to adopt the absorption-line hypothesis. Alternatively, displaced broad

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**Table 1**

| Date (UT) | Telescope/Instrument           | Exposure (s) | Wavelength (Å) | Resolution (Å) | Slit Width (arcsec) |
|-----------|--------------------------------|--------------|----------------|----------------|---------------------|
| 1996 Oct 11... | Lick 3 m/Kast Spectrograph | 2 × 2400 | 3180−4526 | 4 | 2.0 |
| 1996 Oct 11... | Lick 3 m/Kast Spectrograph | 2 × 2400 | 4697−7468 | 5 | 2.0 |
| 1997 Jan 5...... | CTIO 1.5 m/RC Spectrograph | 3 × 1500 | 7364−9152 | 3 | 1.8 |

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**Fig. 1.**—Combined spectra of 1E 0449.4−1823 from the Lick 3 m Shane reflector (< 5500 Å) and CTIO 1.5 m telescope (> 5500 Å). The flux scale refers to the lower trace. The upper trace is the same data multiplied by a factor of 10. The gap in the spectrum is due to our choice of dichroic filter for the Kast double spectrograph.
emission line peaks are common in Balmer lines and Mg II, but those are usually found in radio galaxies or Seyferts of moderately high radio luminosity (Eracleous & Halpern 1994), whereas 1E 0449.4—1823 is radio quiet, with flux densities of 1.1 mJy at 6 cm (Feigelson, Maccacaro, & Zamorani 1982) and 3.3 mJy at 20 cm (Condon et al. 1996; NRAO VLA Sky Survey). Although Elingson, Yee, & Green 1991 refer to 1E 0449.4—1823 as radio loud, this is clearly not the case, since its monochromatic power at 20 cm is only $2.2 \times 10^{24}$ W Hz$^{-1}$. Throughout this paper we use $H_0 = 50$ km s$^{-1}$ Mpc$^{-1}$ and $q_0 = 0$.

One reason that it is difficult to decide between these two descriptions of the spectra (absorption vs. displaced emission) is that the contaminating narrow-line components are so strong. Even better spectra would be needed to distinguish between these hypotheses.

3. ASCA X-RAY OBSERVATION

1E 0449.4—1823 was observed by the ASCA satellite on 1994 March 4–5. Data obtained with the four instruments on board ASCA were obtained from the archive and were filtered following the standard procedures described in the ASCA Guide to ASCA Data Reduction (Day et al. 1995). The SIS detectors were operated in 2-CCD mode, with the target placed at the default 1-CCD position. Source counts in the SIS images were extracted using a 3$'$ radius circular region, and background counts were collected from the entire chip, excluding a 4$'$ radius region centered on the target. In the GIS images, source counts were extracted using a region 6$'$ in radius. The GIS background was measured in a source-free part of the image located the same distance off-axis as 1E 0449.4—1823, with an area equal to that used to extract the target. Useful exposure times and average background-subtracted source count rates in the four ASCA detectors are listed in Table 3.

For spectral fitting, the SIS and GIS spectra were rebinned to have at least 20 counts (source plus background) per channel. All four detectors were modeled simultaneously, but for clarity of presentation, the summed SIS and summed GIS spectra are shown in Figure 3. The spectra are modeled with a power law absorbed by a

| Table 2 |
|----------|
| **EMISSION-LINE MEASUREMENTS OF 1E 0449.4—1823** |
| **Line Identification** | **Flux** | **Intensity** | **FWHM** | **EW** |
|-------------------------|---------|-------------|---------|--------|
| Mg II 2795 (narrow)     | 0.32    | 0.37        | 6       |
| Mg II 2802 (narrow)     | 0.17    | 0.20        | 2       |
| Mg II 2798 (broad)      | 1.75    | 2.04        | 47      |
| He I 3203               | 0.21    | 0.24        |         |
| [O II] 2377             | 0.50    | 0.47        | 5       |
| [Ne II] 3369            | 0.72    | 0.77        |         |
| He I 3888, H$\beta$     | 0.29    | 0.31        |         |
| [Ne II] 3368, H$\alpha$ | 0.46    | 0.48        |         |
| H$\alpha$ (narrow)      | 0.35    | 0.36        |         |
| H$\alpha$ (broad)       | 0.86    | 0.89        | 21      |
| [O III] 4658            | 0.44    | 0.47        |         |
| He II 3040              | 0.13    | 0.15        |         |
| H$\beta$ (narrow)       | 1.00    | 1.00        | 27      |
| H$\beta$ (broad)        | 3.41    | 3.41        | 55      |
| [O III] 4363            | 2.43    | 2.42        | 67      |
| [O III] 4959            | 7.42    | 7.17        | 195     |
| [O III] 5007            | 0.07    | 0.06        |         |
| [N II] 5199             | 0.44    | 0.42        |         |
| [N II] 5200             | 0.56    | 0.52        |         |
| H$\alpha$ (narrow)      | 2.63    | 2.46        | 87      |
| H$\alpha$ (broad)       | 10.16   | 9.53        | 285     |
| [N II] 5755             | 1.12    | 1.05        | 37      |
| [S II] 6313             | 0.54    | 0.50        |         |
| [S II] 6364             | 0.24    | 0.22        |         |

*Observed flux relative to $F(H\beta[narrow]) = 3.13 \times 10^{-15}$ ergs cm$^{-2}$ s$^{-1}$.

*Intensity corrected for Galactic $E(B-V) = 0.078$ mag, relative to $I(H\beta[narrow]) = 3.75 \times 10^{-15}$ ergs cm$^{-2}$ s$^{-1}$.

*Rest frame equivalent width.

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**Fig. 2**—Continuum-subtracted spectra of the broad emission lines of 1E 0449.4—1823 in velocity units. Structure in the broad emission lines can be described either as absorption centered at $-1900$ km s$^{-1}$ or as a displaced broad emission line peak at $-3500$ km s$^{-1}$.

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| Table 3 |
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| **ASCA OBSERVATION SUMMARY** |
| **Instrument** | **Exposure Time** | **Count Rate in the Range 0.5–10 keV (counts s$^{-1}$)** |
|-------------|------------------|--------------------------------------------------|
| SIS0        | 33110            | $3.56 \times 10^{-2}$                            |
| SIS1        | 32627            | $2.38 \times 10^{-2}$                            |
| GIS2        | 36669            | $2.06 \times 10^{-2}$                            |
| GIS3        | 36667            | $2.58 \times 10^{-2}$                            |
column of neutral gas fixed at the Galactic value 
\((3.88 \times 10^{20} \text{ cm}^{-2}; \text{Stark et al. 1992})\). The results of the 
fitting are summarized in Table 4. A second absorption 
component was included as a free parameter at the redshift 
of \(1E 0449.4 - 1823\). It was found that this additional intrinsic column did not improve the fit, and only an upper limit 
of \(N_H^\text{int} < 8.8 \times 10^{20} \text{ cm}^{-2}\) (90\% confidence) can be derived 
(see Fig. 4). The photon index is found to be \(\Gamma = 1.63^{+0.09}_{-0.12}\), 
and the observed flux between 0.5 and 10 keV is 
\(1.6 \times 10^{-12} \text{ ergs cm}^{-2} \text{ s}^{-1} \text{ keV}^{-1}\) (the average of the four 
instruments). The intrinsic luminosity of \(1E 0449.4 - 1823\) 
in the rest frame 2–10 keV band is \(6.7 \times 10^{44} \text{ ergs s}^{-1}\).

No emission or absorption features are evident in the 
residuals from the power-law fit; the upper limit to the 
equivalent width of a narrow Fe Kα emission line at rest 
frame energy 6.4 keV is less than 440 eV. The model fit is 
not improved significantly by the addition of such a line 
(\(\Delta \chi^2 = 0.01\)). In this respect, \(1E 0449.4 - 1823\) differs from 
the Seyfert 2 galaxies like NGC 1068, NGC 4945, and NGC 6552 that have fluorescent Fe Kα lines of EW = 1.0–1.5 keV 
(Marshall et al. 1993; Iwasawa et al. 1993; Reynolds et al. 1994). Instead, it is more similar to Seyfert 1 galaxies or QSOs.

The ASCA X-ray spectrum of \(1E 0449.4 - 1823\) is entirely 
consistent with the luminosity measured by \(\text{Einstein}\) in the 
0.3–3.5 keV band, i.e., \(5.6 \times 10^{44} \text{ ergs s}^{-1}\) (Maccacaro et al. 1991), and the UV continuum brightness also has not 
increased since the observation of Stocke et al. (1983). 
Therefore, we do not even have indirect evidence that the 
growth of the broad emission lines that we observe in the 
optical spectrum was caused by an increase in the intrinsic 
ionizing luminosity of the nucleus. However, the non-
simultaneity of the X-ray and optical observations and the 
lack of regular monitoring during the 15 yr since the \(\text{Einstein}\) 
discovery make this inference about the absence of 
causation an unreliable one. Nevertheless, we offer an alter-
native explanation for the emergence of the broad emission 
lines in § 4.

### Table 4

**Power-Law Fit to the ASCA Spectra of \(1E 0449.4 - 1823\)**

| Energy Range (keV) | \(\Gamma\) | \(N_H^\text{int}\) (10\(^{20}\) cm\(^{-2}\)) \(\pm\) \(0.12\) | \(A^b\) | \(\chi^2\) (dof) | Flux (ergs cm\(^{-2}\) s\(^{-1}\)) |
|-------------------|--------|-------------------------|----|-------------|----------------|
| 0.5–10 ........... | 1.63 \(\pm\) 0.12 | < 8.8 | 2.45 | 168.3 (212) | 1.6 \(\times\) 10\(^{-12}\) |

\(\text{a Column density intrinsic to } 1E 0449.4 - 1823, \text{ in addition to the Galactic column of } 3.9 \times 10^{20} \text{ cm}^{-2}.\)

\(\text{b Power-law normalization at 1 keV in the observed frame in units of } 10^{-4} \text{ photons cm}^{-2} \text{ s}^{-1} \text{ keV}^{-1}(\text{average of the four instruments}).\)
We calculate the X-ray to optical slope $x_{\text{opt}}$, defined as $-\log (f_x/f_o)/\log (v_x/v_o)$, where the flux densities $f_x$ and $f_o$ are calculated at frequencies $v_x$ and $v_o$ corresponding to 2 keV and 2500 Å, respectively, in the rest frame. The result is $x_{\text{opt}} = 0.93$, which is smaller than the value of 1.15 quoted by Stocke et al. (1982), perhaps as a result of our more accurate measurement of the continuum at 2500 Å. This value is unusually small for radio-quiet quasars, implying either a deficit of UV emission or an X-ray excess. Typical values are in the range 1.1–1.7 (Stocke et al. 1990; Boroson & Green 1992), indicating, for example, that 1E 0449.4–1823 could be underluminous in the UV by a factor of 4 or more.

4. DISCUSSION

4.1. So, What Is 1E 0449.4–1823 Anyway?

With the discovery of a normal complement of broad emission lines, there is no longer much to distinguish 1E 0449.4–1823 from an ordinary, low-luminosity QSO. Its absolute magnitude $M_V = -23.5$ meets the QSO criteria, and the equivalent widths of its broad lines as listed in Table 2 are also in the normal range. For example, its broad Mg II equivalent width of 47 Å is comparable to the average values for radio-quiet quasars in general, of 67 Å, found by Francis, Hooper, & Impey (1993); 64 Å, found by Zheng et al. (1997); or 34 Å, found by Steidel & Sargent (1991). Furthermore, it is similar to many of the individual objects in Corbin & Boroson (1996). The X-ray luminosity of 1E 0449.4–1823 in the intrinsic 2–10 keV band is $6.7 \times 10^{44}$ ergs s$^{-1}$, which is also typical of low-luminosity QSOs. The upper limit of $9 \times 10^{40}$ cm$^{-2}$ on any intrinsic column density obscuring the X-ray spectrum allows for little equivalent visual extinction: $E(B-V) < 0.18$. Furthermore, there is nothing unusual about the ratio of X-ray (2–10 keV) to broad Hz flux, which is $\approx 30$, very close to the mean value of 40 found for a large sample of Seyfert 1 galaxies by Elvis, Soltan, & Keel (1984). Similarly, the ratio of X-ray to [O III] luminosity of 1E 0449.4–1823 is similar to that of Seyfert 1 and Seyfert 2 galaxies as shown in Figure 5, adapted from Mulchaey et al. (1994). However, the large equivalent widths of its narrow emission lines are somewhat unusual. In Figure 6, we compare several properties of 1E 0449.4–1823 with those of the 87 low-redshift quasars in the Palomar-Green (PG) sample (Boroson & Green 1992). 1E 0449.4–1823 stands out in its [O III] equivalent width, which is larger than that of all the PG quasars. Its FWHM of Hβ is also at the very high end of the distribution, although it would not be unusual among radio-loud quasars (Eracleous & Halpern 1994).

The original optical spectra from Stocke et al. (1982, 1983) and Stephens (1989) appeared redder than ours, with no evidence for a blue bump and with broad lines that were weak at best. The long-term variability of the Balmer lines and Balmer continuum is obvious, although it is difficult to quantify because we do not have the historical spectra in digital form. In this respect, the behavior of 1E 0449.4–1823 resembles that of many Seyfert 1.8 and 1.9 galaxies, in which the broad Balmer line components are highly variable on timescales of years. Goodrich (1989, 1995) has attributed this effect in at least some objects to partial obscuration in and around the broad-line region, which can vary on the dynamical timescale of the clouds containing the dust. The variability can be quite dramatic; some objects originally classified as intermediate Seyferts because of their barely detectable broad-line components appear years later as ordinary Seyfert 1 galaxies. Indeed, if most intermediate-type Seyferts spend only a fraction of their time in a “low state,” then any deliberate survey for them will amass objects that will later change their classification to Seyfert 1. And if the probability of such variable obscuration declines with increasing luminosity, then this can explain why the rare “type 2 QSO” discovered among hundreds of X-ray sources is likely to revert eventually to an ordinary type 1 spectrum.
FIG. 6.—Comparison of the properties of 1E 0449.4—1823 (dark square) with those of the 87 low-redshift PG quasars from Boroson & Green (1992)

We propose, therefore, that 1E 0449.4—1823 is simply a higher luminosity example of these variable intermediate Seyfert galaxies. It is possible that part of the broad-line region of 1E 0449.4—1823 is still covered, which could account for the unusual shape of its emission-line profiles. Furthermore, if the continuum-emitting region is still partly obscured, which would be consistent with the fact that the \( V \) magnitude estimated from our spectrum has not changed significantly from the value of \( V = 18.5 \) measured by Stocke et al. (1982), then this partial obscuration might explain why the \([\text{O} \, \text{III}]\) equivalent width is so large. It is likely that the \([\text{O} \, \text{III}]\) luminosity represents the time-averaged photoionizing flux seen by the narrow-line region. If our present line of sight to the continuum is more obscured than the average one, while the narrow-line region is unobscured, then both the large equivalent width of \([\text{O} \, \text{III}]\) and the relatively flat \( x_{\alpha} = 0.93 \) could be accounted for by a depression of the observed UV/optical continuum by about a factor of 4. Turning now to the X-rays, since the observed X-ray luminosity has not changed significantly from the \( \textit{Einstein} \) value, and in the absence of any evidence for partial covering or reflection in the X-ray spectrum, it is probably the case that our line of sight to the X-ray source is unimpeded and that the observed X-ray luminosity is a fair representation of its intrinsic value.

An important test of these conclusions can be provided by spectropolarimetry. Most intermediate Seyfert galaxies are weakly polarized, but when they do show polarization it is often variable, with the continuum and emission lines having different position angles and wavelength dependence (Goodrich 1989, 1995; Martel 1997). Such complex behavior, or a lack of polarization altogether, would be evidence for our hypothesis that we are getting a direct view of at least parts of the broad-line and continuum-emitting regions. The alternative view of 1E 0449.4—1823 as a type 2 QSO in unified schemes would predict uniform polarization across the broad emission lines and continuum caused by electron scattering of the light from an otherwise hidden AGN, with possible dilution from a second, unpolarized continuum source. In that case, the broad emission lines should be stronger in polarized light than in the direct flux spectrum, in exact analogy with the hidden Seyfert 1 galaxies (Miller & Goodrich 1990; Tran 1995). If it is a hidden QSO, 1E 0449.4—1823 would then be similar to the hidden Seyfert 1 galaxy Wasilewski 49 (Morgan et al. 1992), which is the only one of its class in which broad emission line components are clearly visible in its direct flux spectrum. While we believe that the observed change in the broad emission lines of 1E 0449.4—1823 already argues against the hidden QSO model (e.g., the lines have not been seen to vary in Was 49), the value of independent confirmation via spectropolarimetry is evident.

4.2. Are There Any Type 2 QSOs?

Having stricken 1E 0449.4—1823 from the short list of candidates that are occasionally nominated for the honor of being a type 2 QSO, it remains for us to ask if there are any such objects. That is, are there any high-luminosity counterparts of Seyfert 2 galaxies? Forster & Halpern (1996) and Halpern & Moran (1998) recently addressed this question with regard to the handful of such X-ray–selected objects, offering a generally pessimistic evaluation of the qualifi-
ocations of the proposed candidates and eliminating all but one from active consideration. The reader is referred to those papers for detailed case histories. The only remaining X-ray–selected candidate that is still claimed to be a type 2 QSO is a very faint emission line object, the ASCA source AX J08494 + 4454 at $z = 0.9$ (Ohta et al. 1996). In view of its faintness, we consider this object to be no stronger a candidate than the others, which have since been rejected. At the time of this writing, there is a dearth of evidence for the existence of any type 2 QSOs among X-ray–selected AGNs.

Of course, in the standard unified scheme there are no true Seyfert 2 galaxies, only Seyfert 1 galaxies hidden by molecular tori. We repeat here the discussion of Halpern & Moran (1998) with regard to the possible implications. In the unified scheme, the absence of type 2 QSOs among X-ray–selected samples is natural if either (1) the X-rays from all such objects are hidden from view or (2) all sufficiently luminous QSO nuclei are able to remove any obscuring dust from their vicinity, which allows their broad-line regions to be visible from any direction. Although a number of ultraluminous IRAS galaxies have Seyfert 2 spectra and hidden broad-line regions (e.g., Wills & Hines 1997 and references therein), there is not much evidence that they harbor luminous X-ray sources (e.g., Brandt et al. 1997; Ogasaka et al. 1997). The most luminous X-ray source in the nucleus of an ultraluminous IRAS galaxy is IRAS 23060 + 0505, but its 2–10 keV luminosity is only $1.5 \times 10^{44}$ erg s$^{-1}$ (Brandt et al. 1997), well within the range of Seyfert 1 galaxies as illustrated in Figure 5. While both of the explanations offered above may be responsible to some degree for the dearth of type 2 QSOs, there are counterexamples to both. First, a substantial number of Seyfert 2 galaxies are detected in hard X-rays because their column densities, in the range $10^{23}$–$10^{24}$ cm$^{-2}$, are not so large as to be completely opaque (e.g., Awaki et al. 1991; Salvati et al. 1997). Second, even objects of modest quasar-like luminosity, principally radio galaxies like Cygnus A, are able to retain their obscuring material while permitting their broad Mg II emission lines to be visible in (Rayleigh) scattered light (Antonucci, Hurt, & Kinney 1994). A power-law nuclear X-ray source with 2–10 keV luminosity of $\sim 1 \times 10^{43}$ erg s$^{-1}$ was detected in Cyg A by Ginga (Ueno et al. 1994). So it seems that the obscuring gas and dust that are essential to the unified scheme are neither so substantial as to prevent direct X-ray detection or indirect UV scattering, nor so fragile as to be destroyed in the QSO environment. Thus, the absence of type 2 X-ray sources of higher luminosity and the rarity of type 2 QSOs among ordinary QSOs remain significant facts to be explained, whether in the context of unified models or not. The two commonly offered explanations mentioned at the beginning of this paragraph, while having considerable promise, could both use additional detailed evaluation. In particular, identifications and careful spectroscopy of serendipitous sources in deep AXAF surveys should provide the most sensitive test for hidden QSOs in hard X-rays. Moderate to high redshifts would aid in the detectability of highly absorbed sources by shifting their hard X-rays to lower energy. If no type 2 QSOs are found in these surveys, the simplest interpretation may be that they do not exist.

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