AN OPTICAL AND X-RAY STUDY OF THE PECULIAR NARROW-LINE QUASAR QSO 0117−2837

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ABSTRACT We present an optical and X-ray study of the quasar QSO 0117-2837. It exhibits an interesting combination of optical and X-ray properties: Despite its extremely steep observed X-ray spectrum ($\Gamma_x \approx -4$ when fit by a simple powerlaw), its Balmer lines are fairly broad. A two-component Gaussian fit to Hβ yields FWHM$_{H\beta, broad} \approx 4000$ km/s, and places QSO 0117-2837 in the ‘zone of avoidance’ in the FWHM$_{H\beta}$–$\Gamma_x$ diagram. A time variability analysis shows that QSO 0117-2837 is another case of Narrow-line Sy 1 galaxy (NLSy1 hereafter) which does not show any X-ray variability during the observation. The results are discussed in view of the NLSy1 character of QSO 0117-2837.

KEYWORDS: Galaxies: active, quasars: individual: QSO 0117-2837, quasars: emission lines, X-rays: galaxies

1. INTRODUCTION

QSO 0117-2837 (1E 0117.2-2837) was discovered as an X-ray source by Einstein and is at a redshift of z=0.347 (Stocke et al. 1991). It is serendipitously located in a ROSAT PSPC pointing. Its X-ray spectrum is extremely steep, as was briefly noted by Schwartz et al. (1993). We present here the first detailed analysis of the ROSAT observations of this AGN (see Komossa & Fink 1997b for first results, and Komossa & Meerschweinchen 2000 for the complete ones), and a discussion of a high-quality optical spectrum.

2. OPTICAL PROPERTIES

We have obtained an optical spectrum of QSO 0117-2837 with the ESO 1.52 m telescope at LaSilla in September 1995. The spectrum covers the wavelength range 3900-7800Å with a resolution of 6Å. The optical spectrum reveals several signs of a NLSy1 galaxy (we do not distinguish between NL Seyferts and NL quasars, here): weak [OIII]λ5007 emission and strong FeII complexes (Fig. 1a). After subtraction of the FeII spectrum (see Grupe et al. 1999 for details) we derive FWHM$_{H\beta}=2100\pm100$ km/s, FWHM$_{[OIII]}=820\pm150$ km/s (based upon single-component Gaussian fits to
the emission lines), and [OIII]/Hβ=0.056. Alternatively, Hβ was fit with a two-component Gaussian in which case we obtain FWHM_{Hβ,broad} \simeq 4000 \text{ km/s} and FWHM_{Hβ,narrow} \simeq 1100 \text{ km/s}. Our spectrum also covers the important region around [OII]λ3727, which provides an important discriminant between different models to account for the excitation of the NLR in NLSy1s (Komossa & Janek 1999). [OII] is not detected, implying [OII] to be much weaker than [OIII].

3. X-RAY PROPERTIES

The ROSAT PSPC observation of QSO 0117-2837 was performed in Dec. 1991 with an exposure time of 4.5 ksec. The source is detected with a countrate of 0.44 cts/s (see Komossa & Meerschweinchen 2000 for further details on X-ray data reductions carried out).

Spectral analysis. The ROSAT X-ray spectrum of QSO 0117-2837 is extremely steep. Three models provide a successful spectral fit; we discuss each in turn:

(i) When the X-ray spectrum is fit by a single powerlaw with Galactic cold absorption of N_{Gal} = 1.65 \times 10^{20} \text{ cm}^{-2}, we derive a photon index \Gamma_x \simeq -3.6 \pm 0.1 (-4.3 \pm 0.4, if N_H is treated as free parameter). The overall quality of the fit is good (\chi^2_{\text{red}} = 0.8), but slight systematic residuals remain (Fig. 1b).

(ii) A successful alternative description is a warm-absorbed flat powerlaw of fixed canonical index \Gamma_x = -1.9. The warm absorber models are based on Ferland’s (1993) code Cloudy, and the model assumptions and calculations are described in more detail in Komossa & Fink (e.g., 1997a). We find a very large column density of the warm absorber, and the contribution of emission and reflection is no longer negligible; there is also some contribution to Fe Kα. For the pure absorption model, the best-fit values for ionization parameter and warm column density are log U \simeq 0.8, and log N_w \simeq 23.6 (N_H is now consistent with the Galactic value when treated as free parameter), with \chi^2_{\text{red}}=0.7. Including the contribution of emission and reflection for 50% covering of the warm material as calculated with Cloudy gives log N_w \simeq 23.8 (\chi^2_{\text{red}} = 0.65). Several strong EUV emission lines are predicted to arise from the warm material (e.g., FeXXI\lambda2304/Hβ_wa = 10, NeVIII\lambda774/Hβ_wa = 9, and FeXXII\lambda846/Hβ_wa = 113). No absorption from CIV and NV is expected to show up in the UV. Both elements are more highly ionized.

(iii) Thirdly, the spectrum can be fit with a flat powerlaw (\Gamma_x fixed to –1.9) plus soft excess which was parameterized as black body, or the standard accretion-disk emission model available in EXSAS. We find kT_{bb} \simeq 0.10 \text{ keV} for the black body description (\chi^2_{\text{red}}=0.7). Using the accretion disk description, and fixing the black hole mass to M_{BH} = 0.6 \times 10^4 M_\odot yields \frac{\dot{M}}{\dot{M}_{\text{edd}}} = 0.6.

Temporal analysis. An analysis of the temporal variability reveals constant source flux within the 1σ error during the observation. This makes QSO 0117-2837 another example of a NLSy1 with constant X-ray flux during the time-interval of observation, showing that not all NLSy1s are characterized by permanent rapid variability (see also the discussion and examples in Wisotzki & Bade 1997).
4. DISCUSSION

Given the rather large width of H$\beta$, the X-ray spectrum of QSO 0117-2837 is exceptionally steep; among the steepest observed in NLSy1s. In fact, whereas there is a very large scatter in the X-ray spectral steepness of NLSy1s, with several as flat as ‘normal’ Seyferts (e.g., Xu et al. 1999), broad line objects always tend to show flat X-ray spectra (e.g., Boller et al. 1996, Grupe et al. 1999); the corresponding region in the FWHM$_{H\beta}$–$\Gamma_x$ diagram is occasionally referred to as ‘zone of avoidance’. QSO 0117-2837 appears to be an important transition object: Depending on which representation of the line profile is chosen – a one-component Gaussian with FWHM$_{H\beta}$=2100 km/s, or a two component Gaussian which gives a better fit and FWHM$_{H\beta,broad}$=4000 km/s – QSO 0117-2837 is placed at the border of the ‘zone of avoidance’, or inside it, respectively.

The origin of the steep observed X-ray spectra of NLSy1 galaxies and the relation to their optical properties is still not well understood. In particular, it is interesting to point out the following: Whereas among the early suggestions to explain the X-ray spectral steepness of NLSy1s was the presence of a strong soft excess, in analogy to ‘normal’ Seyferts and quasars that were believed to show a soft excess, there is now growing evidence that many soft excesses in Seyferts were in fact mimicked by the presence of warm absorbers. On the other hand, the soft excesses in NLSy1s, although originally inferred in analogy to Seyferts, turn out to be real, as judged by recent ASCA and SAX observations (e.g., Vaughan et al. 1999). Often, it turns out, several components are simultaneously present that contribute to the spectral steepness in NLSy1s: A steeper-than-usual powerlaw, a soft excess and a
warm absorber pointing to the spectral complexity in these objects (see, e.g., the discussion in Komossa & Fink 1997a,b).

In the case of QSO 0117-2837 the limited ROSAT spectral resolution does not allow us to distinguish between models (i)-(iii) of Sect. 3. It still allows to determine the maximal possible contribution of each component (i)-(iii). In fact, the rather large inferred column density $N_w$ of the warm absorber (model ii) suggests that further mechanisms contribute to, or dominate, the X-ray steepness. Given the very steep rise towards the blue of QSO 0117-2837’s optical spectrum (with $\alpha_{\text{opt}}=0.0$, Grupe et al. 1998), it is tempting to speculate that a giant soft-excess dominates the optical-to-X-ray spectrum. We strongly caution, though, that simultaneous optical-X-ray variability studies in other Seyferts and NLSy1s (e.g., Done et al. 1995) do not favor a common origin of X-ray and optical components. Secondly, one giant optical-to-X-ray bump seems to be inconsistent with the finding of Rodriguez-Pascual et al. (1997) that NLSy1s tend to be underluminous in the UV. The possibility of an indirect relation between optical and X-ray component remains.

Given the abundant presence of warm absorbers in ‘normal Seyferts’, and the additional trend that warm absorbers are more abundant in FeII-strong objects (Wang et al. 1996), combined with QSO 0117-2837’s large FWHM$_{\text{H}\beta}$ and steep X-ray spectrum, it is likely that both, a soft excess and a warm absorber contribute to its spectral steepness in the ROSAT band. Its peculiar optical–X-ray properties make the quasar a good target for (a) follow-up X-ray spectral observations with, e.g., XMM, and (b) high-resolution optical studies of the H$\beta$ profile.

This and related papers can be retrieved from our webpage at http://www.xray.mpe.mpg.de/~skomossa/

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