AN UPDATE ON THE X-RAY TRANSIENT NARROW-LINE SEYFERT 1 GALAXY WPVS 007: SWIFT OBSERVATIONS OF UV VARIABILITY AND PERSISTENCE OF X-RAY FAINTNESS

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ABSTRACT

We report on the detection of UV variability and the persistence of X-ray faintness of the X-ray transient narrow-line Seyfert 1 galaxy WPVS 007 based on the first year of monitoring with Swift between 2005 October and 2007 January. WPVS 007 has been an unusual source. Although it was X-ray-bright in the ROSAT All-Sky Survey, it has been extremely faint in all following X-ray observations. Swift also finds this NLS1 to be X-ray-faint, not detected at a 3 σ upper limit of 2.6 × 10^{-17} W m^{-2} in the 0.3–10.0 keV band, confirming that the AGN is still in a low state. During the 2006 July and December observations with the Swift UV-Optical Telescope (UVOT) the AGN became fainter by about 0.2 mag in the UV filters and by about 0.1 mag in V, B, and U compared with the 2005 October to 2006 January and 2006 September to October observations, followed by a rebrightening in the 2007 January observation. This variability can be caused either by a change in the absorption column density, and therefore the reddening in the UV, or by flux variations of the central engine. We also noticed that the flux in the UVOT filters agrees with earlier measurements by the International Ultraviolet Explorer taken between 1993 and 1995, but spectra taken by the Hubble Space Telescope Faint Object Spectrograph show that WPVS 007 was fainter in the UV by a factor of at least 2 in 1996. The flat optical/UV spectrum suggests that some UV extinction is present in the spectrum, but that alone cannot at all account for the dramatic fading in the X-ray flux. Most likely we see a partially covering absorber in the X-ray. Alternatively, the current X-ray emission seen from WPVS 007 may also be the emission from the host galaxy.

Key words: galaxies: active — galaxies: individual (WPVS 007)

Online material: color figures

1. INTRODUCTION

When observed at optical or lower energies, radio-quiet AGNs appear to be rather stable and not highly variable. However, this picture changes dramatically when AGNs are observed in the X-ray. Flux variability by factors of 2–3 on timescales of days to months is quite common among low- and high-luminosity AGNs. An increasing number that vary by factors of 10–30 have emerged in the last decade, including those in intermediate-type Seyfert and narrow-line Seyfert 1 galaxies (NLS1s), and there is good evidence that a substantial part of that variability is caused by (cold) absorption, in terms of complete or partial covering. Interestingly, the highest amplitudes of variability have been detected from the cores of nonactive galaxies in terms of transient flares, interpreted as tidal disruptions of stars by the black holes at the centers of these galaxies (e.g., Komossa et al. 2004 and references therein).

NLS1s are objects with extreme properties: they show the steepest X-ray spectra, strongest optical Fe II emission, and weakest [O iii] emission (e.g., Boller et al. 1996; Boroson & Green 1992; Laor et al. 1997; Grupe et al. 2004b). The most common explanation for their extreme properties is that they have a relatively small black hole mass and a high Eddington ratio $L/L_{\text{Edd}}$ (e.g., Boroson 2002; Grupe 2004; Sulentic et al. 2000). NLS1s are also known to be objects with very strong X-ray variability (e.g., Leighly 1999).

The NLS1 WPVS 007 (1RXS J003916.6–511701, RBS 0088; $\alpha_{J2000,0} = 0^h39^m15.8^s$, $\delta_{J2000,0} = 51^\circ17'03.0''$, $z = 0.029$; Grupe et al. 1995) was discovered in a survey of faint southern galaxies with H_0 emission by Wamsteker et al. (1985) and is a unique X-ray transient AGN. While X-ray transience is typically associated with an X-ray outburst caused by a dramatic increase in the accretion rate or the very onset of accretion, the situation is very different in WPVS 007. During the ROSAT All-Sky Survey (RASS; Voges et al. 1999), when the source was X-ray bright, the optical to X-ray flux ratio was in a normal range for an AGN (e.g., Beuermann et al. 1999; Maccarico et al. 1988). However, all follow-up X-ray observations between 1994 and 2002 using ROSAT and Chandra found it to have almost vanished from the X-ray sky (Grupe et al. 2001; Vaughan et al. 2004).

Until recently the cause for the transient behavior of WPVS 007 had been a mystery. Grupe et al. (1995) suggested that this transience could be due to a temperature change in the accretion disk that would shift the soft X-ray spectrum out of the ROSAT PSPC energy observing window. However, in recent years it became clear that the cause of the transience is absorption. In 1996 July, WPVS 007 was observed by HST (Goodrich 2000; Constantin & Shields 2003); a 2003 FUSE observation revealed the emergence of a broad absorption line (BAL) flow (Leighly et al. 2005; K. M. Leighly et al. 2007, in preparation). A discovery of a rebrightening and a following rise in the X-ray luminosity, and in spectral changes, will set tight constraints on the movement and location of the absorber and on the nature of the absorption. The high amplitude of the variability makes WPVS 007 exceptional among the known cases of absorption variability. In order to detect a possible rebrightening, and therefore the disappearance of the absorber, we began a monitoring campaign using Swift in 2005 October.

The Swift mission (Gehrels et al. 2004) was launched on 2004 November 20. The main purpose is to hunt and observe gamma-ray
bursts (GRBs). However, part of the observing time is used for fill-in targets and targets of opportunity when no GRB can be observed. Due to its multiwavelength capacities and its flexible scheduling, Swift is an ideal observatory of all types of AGNs, as demonstrated by, e.g., Grupe et al. (2006) for the NLS1 RX J0148.3−2758 and Markwardt et al. (2005) in the search for obscured AGNs in the BAT survey. Swift is equipped with three telescopes: at the high-energy end is the Burst Alert Telescope (BAT; Barthelmy 2005) operating in the 15−150 keV energy range, then the X-Ray Telescope (XRT; Burrows et al. 2005), which covers the soft X-ray range between 0.3 and 10.0 keV, and at the long-wavelength end, the UV-Optical Telescope (UVOT; Roming et al. 2005). The XRT uses a CCD detector identical to the EPIC MOS on board XMM (Turner et al. 2001). The UVOT covers the range between 1700 and 6500 Å and is a sister instrument of XMM’s Optical Monitor (OM; Mason et al. 2001). The UVOT has a similar set of filters to that of the OM (Mason et al. 2001; Roming et al. 2005). However, the UVOT UV throughput is about a factor of 10 higher than that of the OM.

The outline of this paper is as follows: in § 2 we describe the Swift observations and the data reduction, in § 3 we present the results of the Swift XRT and UVOT data analysis and compare the UVOT data with earlier IUE and HST spectra, and in § 4 we discuss the results. Throughout the paper spectral indices are denoted as energy spectral indices with $F_{\nu} \propto \nu^{-\alpha}$. Luminosities are calculated assuming a ΛCDM cosmology with $\Omega_{\Lambda} = 0.73$, and a Hubble constant of $H_0 = 75$ km s$^{-1}$ Mpc$^{-1}$, using the luminosity distance of $D = 118$ Mpc given by Hogg (1999). All errors are 1 $\sigma$ unless stated otherwise.

2. OBSERVATIONS AND DATA REDUCTION

WPVS 007 was monitored by Swift between 2005 October and 2007 January. Table 1 lists the Swift XRT observations, including the start and end times, the total exposure times, and the 3 $\sigma$ upper limits. Note that we do not include the segment 005 data (2006 September 6) in the XRT analysis because during the time of that observation the XRT detector was rather warm, resulting in an enhanced detector background. However, the UVOT data from that time period were not affected. The Swift UVOT observations are summarized in Table 2. Also note that segment 008 does not exist. WPVS 007 was originally scheduled for 2006 December 3, but the observations were superseded by the detections of GRBs 061201 and 061202 (Marshall et al. 2006 and Sakamoto et al. 2006, respectively) before the start of the

| Segment | Start Time | Stop Time | $T_{\text{exp}}$ | Upper Limit |
|---------|------------|-----------|-----------------|-------------|
| 001...... | 2005 Oct 20, 03:21 | 2005 Oct 20, 03:54 | 2025 | 5.78 |
| 002...... | 2005 Dec 7, 13:29 | 2005 Dec 7, 13:58 | 1696 | 3.42 |
| 003...... | 2006 Jan 5, 00:48 | 2006 Jan 5, 05:41 | 3466 | 1.67 |
| 004...... | 2006 Jul 31, 04:39 | 2006 Jul 31, 06:30 | 1610 | 6.16 |
| 005...... | 2006 Sep 6, 08:19 | 2006 Sep 9, 11:38 | 917 | |
| 006...... | 2006 Sep 11, 05:40 | 2006 Sep 11, 07:37 | 2335 | 5.02 |
| 007...... | 2006 Oct 27, 02:34 | 2006 Oct 27, 23:33 | 3228 | 1.80 |
| 009...... | 2006 Dec 6, 00:02 | 2006 Dec 6, 06:36 | 2964 | 2.70 |
| 010...... | 2006 Dec 12, 00:33 | 2006 Dec 12, 01:01 | 1611 | 3.60 |
| 011...... | 2006 Dec 21, 06:19 | 2006 Dec 21, 08:15 | 2273 | 4.36 |
| 012+013... | 2007 Jan 10, 21:21 | 2007 Jan 11, 00:53 | 1905 | 3.05 |
| 001−013... | 2005 Oct 20, 03:21 | 2007 Jan 11, 00:53 | 23198 | 1.04 |

$^a$ Start and stop times given in UT.
$b$ Observing time given in seconds.
$c$ Three $\sigma$ upper limits in units of $10^{-3}$ XRT counts s$^{-1}$.
$d$ Due to high background during the observation, the segment 005 XRT data were not included in the analysis. Segment 008 does not exist (see text).

### Table 2

| Segment | $V_{\text{exp}}$ | $B_{\text{exp}}$ | $U_{\text{exp}}$ | UV W1 | UV M2 | UV W2 |
|---------|-----------------|-----------------|-----------------|-------|-------|-------|
| 001...... | ... | ... | ... | ... | ... | ... |
| 002...... | ... | ... | ... | ... | ... | ... |
| 003...... | ... | ... | ... | ... | ... | ... |
| 004...... | 155 | 15.14 ± 0.03 | 159 | 15.48 ± 0.02 | 159 | 14.44 ± 0.02 | 656 | 14.28 ± 0.01 | 686 | 14.50 ± 0.01 | 686 | 14.53 ± 0.01 |
| 005...... | 55 | 15.01 ± 0.05 | 170 | 15.38 ± 0.02 | 170 | 14.38 ± 0.02 | 319 | 14.49 ± 0.02 | 319 | 14.49 ± 0.02 | 319 | 14.49 ± 0.02 |
| 006...... | 194 | 15.04 ± 0.03 | 194 | 15.37 ± 0.02 | 194 | 14.30 ± 0.02 | 340 | 14.27 ± 0.02 | 340 | 14.40 ± 0.03 | 340 | 14.52 ± 0.02 |
| 007...... | 344 | 15.03 ± 0.02 | 336 | 15.39 ± 0.01 | 335 | 14.33 ± 0.01 | 387 | 14.26 ± 0.01 | 387 | 14.42 ± 0.01 | 387 | 14.49 ± 0.01 |
| 009...... | 245 | 15.12 ± 0.02 | 245 | 15.52 ± 0.02 | 245 | 14.43 ± 0.02 | 686 | 14.44 ± 0.01 | 686 | 14.63 ± 0.02 | 686 | 14.72 ± 0.01 |
| 010...... | 134 | 15.08 ± 0.03 | 134 | 15.46 ± 0.03 | 134 | 14.58 ± 0.02 | 267 | 14.45 ± 0.01 | 267 | 14.64 ± 0.02 | 267 | 14.79 ± 0.01 |
| 011...... | 187 | 15.15 ± 0.02 | 187 | 15.55 ± 0.02 | 187 | 14.52 ± 0.02 | 374 | 14.45 ± 0.02 | 374 | 14.68 ± 0.02 | 374 | 14.81 ± 0.01 |
| 012+013... | 155 | 15.11 ± 0.03 | 155 | 15.40 ± 0.02 | 155 | 14.35 ± 0.02 | 312 | 14.35 ± 0.002 | 373 | 14.48 ± 0.02 | 625 | 14.60 ± 0.01 |

$^a$ Observing time given in seconds.
$^b$ Magnitude corrected for reddening with $E_{B-V} = 0.012$ given by Schlegel et al. (1998). The errors given in this table are statistical errors.
WPVS 007 observations. Segment numbers, however, can only be used once by the Swift scheduling tool. The segment numbers in both tables refer to the days Swift observed WPVS 007 (see the description in Grupe et al. 2006). In the first observation of 2006 December (segment 009) we noticed that the AGN became significant fainter in the UV by 0.2 mag. In order to investigate this behavior and to get a better estimate of the timescale we compared the observations from different missions we used the HEASARC tool PIMMS, version 3.8. For the conversion we assumed an absorbed power-law model with an absorption column of 6.1. Photons were collected in the 0.3–10.0 keV energy range. The upper limits were determined from the background in the XRT. The photons were extracted with XSELECT, version 2.4. In order to compare the observations from different missions we used the HEASARC tool PIMMS, version 3.8. For the conversion we assumed an absorbed power-law model with an absorption column density at the Galactic value (2.84 \times 10^{20} \text{ cm}^{-2}) and $\alpha_{X} = 3.0$. Note, however, that this is just an estimate, since we do not know what the low-state X-ray spectrum of WPVS 007 really looks like. For all observations the counts were corrected with exposure maps.

As listed in Table 2, the UVOT observations were performed in all filters, except that during the 2005 October and December and 2006 January observations only the UV filters were used. Photometry on all UVOT individual and co-added exposures was performed with the tool uotmaghist, version 0.1. Extraction regions of 6'' and 12'' radius were used centered on WPVS 007 for the optical ($V, B,$ and $U$) and UV filters (UV W1, UV M2, and UV W2), respectively, and the background count rate was measured with a 20'' radius aperture in a nearby source-free region. All reported magnitudes have been corrected for Galactic extinction, where the reddening in the line of sight to the object is $E(B-V) = 0.012$ mag (Schlegel et al. 1998). All data were aspect-corrected and co-added before measuring the magnitudes and fluxes. The UVOT uses Vega-based magnitudes with the following zero points: $V = 17.88 \pm 0.09, B = 19.16 \pm 0.12, U = 18.38 \pm 0.23, UV W1 = 17.69 \pm 0.20, UV M2 = 17.29 \pm 0.23,$ and $UV W2 = 17.77 \pm 0.20$ (Brown et al. 2007).

Prior to the Swift observations WPVS 007 was observed in the UV by IUE four times between 1993 and 1995, by HST in 1996 July, and by FUSE in 2003 November. In this paper we make use of the IUE and HST data. Table 3 lists these observations. The FUSE data will be presented by K. M. Leighly et al. (2007, in preparation) in a future paper, which will also contain a spectral analysis of the mini-BALs present in the HST data.

### Table 3: Previous UV Observations of WPVS 007

| Mission | ObsID | Grating | Start Timea | $T_{\text{exp}}$b |
|---------|-------|---------|-------------|-------------------|
| IUE...... | SWP 48542 | ...... | 1993 Sep 5, 15:58 | 16800 |
| IUE...... | SWP 52369 | ...... | 1994 Oct 10, 15:30 | 18900 |
| IUE...... | SWP 56215 | ...... | 1995 Nov 19, 22:00 | 20000 |
| IUE...... | SWP 56318 | ...... | 1995 Dec 20, 12:47 | 18000 |
| HST...... | FOS Y3790102T | G130H | 1996 Jul 30, 13:30 | 1730 |
| HST...... | FOS Y3790103T | G130H | 1996 Jul 30, 14:46 | 2110 |
| HST...... | FOS Y3790104T | G160L | 1996 Jul 30, 15:30 | 240 |
| HST...... | FOS Y3790105T | G190H | 1996 Jul 30, 16:29 | 1500 |
| HST...... | FOS Y3790107T | G270H | 1996 Jul 30, 18:02 | 1280 |

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a Start time given in UT.
b Observing time given in seconds.
A complete listing of all HST FOS observations is given in Constantin & Shields (2003).

### Fig. 1 — Long-term light curve of WPVS 007 containing the ROSAT All-Sky Survey and pointed PSPC and HRI observations, the Chandra data, and the upper limits derived from the Swift XRT observations. The count rates were converted by assuming an absorbed power-law model with $N_H = 2.84 \times 10^{20} \text{ cm}^{-2}$ and $\alpha_{X} = 3.0$. The arrow on the bottom under Swift displays the upper limit of the co-added exposures of the Swift XRT observations (23.2 ks). [See the electronic edition of the Journal for a color version of this figure.]

### Fig. 2 — Swift UVOT light curves of WPVS 007. The values are given in Table 2. [See the electronic edition of the Journal for a color version of this figure.]

### 3. Results

#### 3.1. X-Rays
We have not detected WPVS 007 in the X-ray in any of the monitoring observations performed by Swift so far, as listed in Table 1. To determine the $3 \sigma$ upper limits we applied the method by Kraft et al. (1991). This method determines the confidence levels for low numbers of counts using the Bayesian method for Poisson-distributed data. The background in all observations was measured in a circular region with $r = 235''$ around the position of WPVS 007. For the source itself we assumed an extraction radius of 23.5''. The $3 \sigma$ upper limits are listed in Table 1. We co-added all XRT observations together, except for the 2006 September 6 observation (segment 005), when the background was too high. From these co-added data with a total exposure time of 23.2 ks we measured an upper limit of $1.04 \times 10^{-3}$ counts s$^{-1}$.
Table 4
List of Reference Stars Used to Determine the Error in the Photometry

| Object       | α_{2000.0} | δ_{2000.0} | Filter | Segment 003 | Segment 004 | Segment 006 | Segment 007 | Segment 009 | Segment 010 | Segment 011 | Segment 012+013 |
|--------------|------------|------------|--------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|----------------|----------------|
| Star 1..............| 00 39 20.0 | −51 10 53.2 |        |             |             |             |             |             |             |             |                 |                 |
|               |            |            | UV W1  | 13.50 ± 0.01 | ...         | ...         | 13.50 ± 0.01 | 13.51 ± 0.01 | 13.53 ± 0.01 | 13.52 ± 0.01 | 13.50 ± 0.01     |                 |
|               |            |            | UV M2  | 16.27 ± 0.02 | ...         | ...         | 16.26 ± 0.03 | 16.24 ± 0.03 | 16.30 ± 0.04 | 16.20 ± 0.03 | 16.22 ± 0.04     |                 |
|               |            |            | UV W2  | 15.32 ± 0.02 | ...         | ...         | 15.26 ± 0.01 | 15.02 ± 0.01 | 15.10 ± 0.02 | 15.29 ± 0.01 | 15.32 ± 0.02     |                 |
| Star 2..............| 00 39 54.2 | −51 15 04.7 |        |             |             |             |             |             |             |             |                 |                 |
|               |            |            | UV W1  | 14.38 ± 0.01 | 14.40 ± 0.02 | 14.40 ± 0.01 | ...         | ...         | 14.39 ± 0.02 | 14.44 ± 0.02 | ...           |                 |
|               |            |            | UV M2  | 15.77 ± 0.02 | 15.78 ± 0.06 | 15.80 ± 0.03 | ...         | ...         | 15.79 ± 0.03 | 15.77 ± 0.03 | ...           |                 |
|               |            |            | UV W2  | 15.93 ± 0.02 | 15.98 ± 0.02 | 15.95 ± 0.02 | ...         | ...         | 15.98 ± 0.02 | 15.99 ± 0.02 | ...           |                 |
| Star 3..............| 00 39 01.8 | −51 18 17.6 |        |             |             |             |             |             |             |             |                 |                 |
|               |            |            | UV W1  | 14.30 ± 0.01 | 14.32 ± 0.02 | 14.37 ± 0.01 | 14.33 ± 0.01 | 14.30 ± 0.01 | 14.35 ± 0.02 | 14.33 ± 0.02 | 14.32 ± 0.02 |                 |
|               |            |            | UV M2  | 15.25 ± 0.01 | 15.24 ± 0.04 | 15.35 ± 0.02 | 15.36 ± 0.02 | 15.29 ± 0.01 | 15.38 ± 0.03 | 15.31 ± 0.02 | 15.27 ± 0.02 |                 |
|               |            |            | UV W2  | 15.50 ± 0.01 | 15.55 ± 0.02 | 15.65 ± 0.02 | 15.54 ± 0.01 | 15.55 ± 0.01 | 15.64 ± 0.02 | 15.53 ± 0.02 | 15.54 ± 0.02 |                 |
| Star 4..............| 00 39 18.7 | −51 14 14.0 |        |             |             |             |             |             |             |             |                 |                 |
|               |            |            | UV W1  | 15.06 ± 0.01 | 15.04 ± 0.02 | 15.04 ± 0.02 | 15.04 ± 0.01 | 15.08 ± 0.02 | 15.05 ± 0.02 | 15.04 ± 0.02 | 15.09 ± 0.03 |                 |
|               |            |            | UV M2  | 16.17 ± 0.02 | 16.07 ± 0.06 | 16.08 ± 0.03 | 16.12 ± 0.02 | 16.07 ± 0.03 | 16.14 ± 0.04 | 16.14 ± 0.03 | 16.07 ± 0.03 |                 |
|               |            |            | UV W2  | 16.50 ± 0.02 | 16.41 ± 0.03 | 16.43 ± 0.02 | 16.46 ± 0.02 | 16.48 ± 0.02 | 16.43 ± 0.03 | 16.47 ± 0.03 | 16.55 ± 0.03 |                 |

Notes.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. The magnitudes are the uncorrected, directly measured values. The positions relative to WPVS 007 are shown in Fig. 3.
in the Swift XRT. Assuming a power-law model spectrum with $\alpha_X = 3.0$ and $N_H$ at the Galactic value, this upper limit count rate converts to an upper limit in unabsorbed flux in the 0.3–10 keV band of $2.6 \times 10^{-17}$ W m$^{-2}$.

Figure 1 displays the long-term light curve of WPVS 007. The ROSAT values were taken from Grupe et al. (2001), and the Chandra data point from Vaughan et al. (2004). The light curve shows that WPVS 007 is still in a low state, and the upper limit of the co-added Swift observations is consistent with the ROSAT PSCP and HRI detections. Note that Figure 1 uses PSPC counts, which were converted by PIMMS assuming a power-law spectrum with $\alpha_X = 3.0$ and $N_H$ at the Galactic value.

### 3.2. UVOT Photometry

The magnitudes in the UVOT filters are given in Table 2, and previous UV observations by IUE and HST are listed in Table 3. The errors quoted in Table 2 are statistical errors. As listed in Table 2 and shown in Figure 2, WPVS 007 became fainter in the optical filters by about 0.1 mag and by about 0.2 mag in the UV filters in the 2006 July and December observations, respectively, compared with the observations obtained in 2005 and 2006 January and 2006 September and October. The AGN became brighter again by about 0.2 mag in the 2007 January observation, which was about 3 weeks after the last observation in 2006 December. From the current light curve as shown in Figure 2, the AGN seems to be variable in the optical/UV on timescales of a few weeks to several months.

In order to determine whether this variability is real or just within the uncertainties, we picked four field stars of similar magnitude to that of WPVS 007 as reference stars and compared their magnitudes segment by segment. Table 4 lists these four stars with their coordinates and magnitudes in $U$, $U$ V1, $U$ M2, and $U$ W2 with statistical errors. Figure 3 displays where these stars are located relative to WPVS 007. Note that during some of the observations not all four stars were in the field of view of the UVOT. $U$ magnitudes could only be given for stars 3 and 4, because stars 1 and 2 were too bright in the $U$ filter, so they suffered significantly from coincident losses. Also note that stars 1 and 2 were not in the field of view during some of the observations. As shown in Table 4, the variance in the field stars is small compared with the variability observed in WPVS 007. Therefore, we consider the UV variability found in WPVS 007 to be real. The change by 0.2 mag in the UV filters observed during the 2006 July and December observations is larger than the uncertainties between the measurements in the field stars.

WPVS 007 has shown variability on timescales of months before between the IUE and HST observations from 1993 to 1996. Figure 4 displays the Swift UVOT measurements from 2006 January, the HST spectrum from 1996 (Goodrich 2000; Constantin & Shields 2003), and the IUE spectrum averaging three spectra taken between 1993 and 1995. We excluded the 1995 November observation due to strong cosmic-ray events during that observation. The data shown in Figure 4 are the observed data, uncorrected for reddening. The IUE spectra and the Swift UVOT data seem to agree. However, the HST spectra show a significantly lower flux than the IUE and Swift data. Dunn et al. (2006) have presented an online database of UV continuum light curves of Seyfert galaxies, which also shows that WPVS 007 displayed significant variability in the UV between the IUE and HST observations. One possible reason for the lower flux in the HST data is a misalignment of the source in the 1$''$ aperture in the HST FOS. However, as listed in Table 3, the AGN was observed during several orbits, and the fluxes in all these spectra agree with each other. A 1$''$ aperture is also rather large compared to the 0.1$''$ resolution. Therefore, we exclude a misalignment as the cause of the lower flux in WPVS 007 during the HST observation in 1996 July. Note that Winkler et al. (1992) report $V = 15.28 \pm 0.03$, $B = 15.77 \pm 0.03$, and $U = 15.15 \pm 0.03$. While the small differences in $V$ and $B$ can be explained by the different central wavelength between the filters used by Winkler et al. (1992) and the UVOT, the difference in $U$ suggests that WPVS 007 is variable in $U$.

### 3.3. Spectral Energy Distribution

Figure 5 displays the spectral energy distribution of WPVS 007 using 2MASS NIR data derived from the NASA/IPAC Extragalactic Database, optical/UV data from Swift’s UVOT from 2006 July, and X-ray data from the Chandra observation in 2002 (Vaughan et al. 2004). The Chandra data are displayed as an

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6 See [http://www.chara.gsu.edu/PEGA/IUE](http://www.chara.gsu.edu/PEGA/IUE).
Our UVOT observations suggest that the AGN is variable in the UV bands by about 0.2 mag within timescales of a few months. UV variability, however, is not uncommon in AGNs and has been reported for various AGNs such as NGC 4151 (Edelson et al. 1996; Crenshaw et al. 1996), NGC 5548 (Clavel et al. 1991; Korista et al. 1995),Ark 564 (Collier et al. 2001), and 3C 390.3 (O’Brien et al. 1998), but only a few NLS1s have repeated UV coverage as good as that for WPVS 007. In the case of WPVS 007 we can speculate that the UV variability is likely to be caused by a change in the absorption column density, and therefore the reddening in the UV. Using the change in the UV W1 magnitude by 0.2 mag, we can derive an additional $E_{B-V} = 0.032$. This would cause an additional reddening by 0.10 mag in $I$, 0.17 in $U$, and 0.28 in UV W2, which is consistent with the changes we observe during the 2006 July and December observations. However, a change in luminosity of the central engine cannot completely be excluded based on the current data set.

The variability we observed in the UV between the $IUE$, $HST$, and Swift UVOT observations was previously also noticed by Dunn et al. (2006) between the $IUE$ and $HST$ observations. This is not a calibration issue. There are no problems reported on the $HST$ FOS and $IUE$ observations either. Also, the light curves presented in the UV continuum light-curve database by Dunn et al. (2006) suggest that the UV flux was already decaying in the $IUE$ observation from 1994 to 1995 and that the 1996 $HST$ observation is consistent with this decay.

WPVS 007 may be one of the most extreme cases of X-ray-weak NLS1s, such as those found by Williams et al. (2002, 2004). The reddened optical/UV spectrum also suggests that the X-ray weakness of WPVS 007 is caused by absorption. However, of the 10 photons detected at the position of WPVS 007 in the $Chandra$ ACIS-S data (Vaughan et al. 2004), eight have energies below 1 keV. A simple cold absorber would have absorbed all these photons. The solution could be a partially covering absorber that would allow some of the soft X-ray photons to escape. Such partially covering absorbers have been found in several NLS1s, such as Mrk 1239 (Grupe et al. 2004a) or 1H 0707-495 (Gallo et al. 2004; Tanaka et al. 2004; Boller et al. 2002).

Alternatively, the low-state X-ray emission detected with $Chandra$ may actually represent the X-ray emission from the host galaxy, with the AGN being completely absorbed. In order to check this, we used the blue magnitude of the galaxy to predict the expected X-ray flux from the host galaxy, using the correlation between $L_X$ and $L_Y$ for early-type galaxies by O’Sullivan et al. (2001). We use the extinction- corrected blue magnitudes measured with $Swift$, $m_{B,corr} = 15.48$, and a previous USNO measurement, $m_{B,corr} = 14.24$. We then predicted a host galaxy contribution to the X-ray luminosity of $L_X \approx 10^{33} - 10^{33} W$, which may well account for all of the observed low-state emission. Indeed, host galaxies typically show such soft, thermal spectra. However, as shown in Figure 1 in Vaughan et al. (2004), the 10 photons found at the position of WPVS 007 seem to be consistent with a point source. In order to verify this statement, a much longer observation by $Chandra$ is needed. We will continue monitoring WPVS 007 every 4–6 weeks with $Swift$ as long as the AGN is not Sun-constrained. In particular, more observations in the UV will give us a better handle on the timescales of the variability in the UV.

4. DISCUSSION

Our main results are that WPVS 007 is still in a low state in the X-ray and that it shows significant variability in the UV on timescales of months. Adding all $Swift$ observations together (except for the segment 005 data of 2006 September 6) we determine a 3σ upper limit of $1.04 \times 10^{-3}$ counts s$^{-1}$, which converts to an unabsorbed flux in the 0.3–10 keV band of $2.6 \times 10^{-17}$ W m$^{-2}$. This upper limit is at a similar level to the $ROSAT$ pointed PSPC and HRI observations. Note that $Chandra$, with its superb point-spread function, was able to detect WPVS 007 at an even lower level (Vaughan et al. 2004) within an exposure time of 10 ks. Even though we could not detect a rebrightening of WPVS 007 in the X-ray, it is still an exciting AGN. Note that the purpose of the $Swift$ observations is not to obtain a deep detection but to monitor the AGN in order to detect when it rebrightens again.

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* Both measurements have to be taken with some caution, since we did not correct for any possible AGN contribution to $m_B$ on the one hand and since the short $Swift$ observation may have missed part of the host galaxy contribution on the other hand. Therefore, the estimate should only be regarded as order of magnitude.

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7 The X-ray loudness is defined by Tananbaum et al. (1979) as $\alpha_{ox} = -0.384 \log (F_2 / F_{2500})$. 

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Fig. 5.—Spectral energy distribution of WPVS 007 using the NIR data from 2MASS, optical/UV data from the Swift UVOT observation from 2006 January corrected for Galactic reddening, and the X-ray data from the $Chandra$ observation from 2002. The $Chandra$ data are displayed as a power-law model with $\alpha_X = 3.0$. Note that all these observations were not performed simultaneously. The $HST$ spectra and the observed RASS data are displayed in gray for comparison purposes. [See the electronic edition of the Journal for a color version of this figure.]
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