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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 $L/L_{\rm Edd}$ (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).

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The NLS1 WPVS 007 (1RXS J003916.6−511701, RBS 0088; $\alpha_{\rm J2000.0} = 00^{\rm h}39^{\rm m}15.8^{\rm s}$, $\delta_{\rm J2000.0} = -51°17'03.0''$, $z = 0.029$; Grupe et al. 1995) was discovered in a survey of faint southern galaxies with Hα 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; Maccacaro 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

TABLE 1
Swift XRT Observation Log of WPVS 007

Segment	Start Time[a]	Stop Time[a]	T_{exp}[b]	Upper Limit[c]
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 6, 11:38	917	...[d]
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[d]	2005 Oct 20, 03:21	2007 Jan 11, 05:53	23198[d]	1.04[d]

[a] Start and stop times given in UT.
[b] Observing time given in seconds.
[c] Three σ 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).

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 $\Omega_M = 0.27$, $\Omega_\Lambda = 0.73$, 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 σ 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 σ 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

TABLE 2
Swift UVOT Observation of WPVS 007

	V		*B*		*U*		UV W1		UV M2		UV W2	
Segment	T_{exp}[a]	Mag_{corr}[b]	T_{exp}[a]	Mag_{corr}[b]	T_{exp}[a]	Mag_{corr}[b]	T_{exp}[a]	Mag_{corr}[b]	T_{exp}[a]	Mag_{corr}[b]	T_{exp}[a]	Mag_{corr}[b]
001	...	...	...	...	...	...	656	14.28 ± 0.01	686	14.50 ± 0.01	686	14.53 ± 0.01
002	...	...	...	...	...	...	550	14.31 ± 0.01	588	14.48 ± 0.01	588	14.55 ± 0.01
003	...	...	...	...	...	...	1056	14.27 ± 0.01	1171	14.46 ± 0.01	1171	14.56 ± 0.01
004	155	15.14 ± 0.03	159	15.48 ± 0.02	159	14.44 ± 0.02	319	14.49 ± 0.02	118	14.63 ± 0.04	615	14.82 ± 0.01
005	55	15.01 ± 0.05	170	15.38 ± 0.02	170	14.38 ± 0.02	340	14.27 ± 0.02	144	14.40 ± 0.03	392	14.52 ± 0.02
006	194	15.04 ± 0.03	194	15.37 ± 0.02	194	14.30 ± 0.02	387	14.26 ± 0.01	536	14.42 ± 0.01	777	14.49 ± 0.01
007	344	15.03 ± 0.02	336	15.39 ± 0.01	335	14.33 ± 0.01	686	14.26 ± 0.01	767	14.47 ± 0.01	767	14.49 ± 0.01
009	245	15.12 ± 0.02	245	15.52 ± 0.02	245	14.43 ± 0.02	486	14.44 ± 0.01	621	14.63 ± 0.02	978	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	376	14.64 ± 0.02	534	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	513	14.68 ± 0.02	750	14.81 ± 0.01
012+013	155	15.11 ± 0.03	155	15.40 ± 0.02	155	14.35 ± 0.02	312	14.35 ± 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.

TABLE 3
PREVIOUS UV OBSERVATIONS OF WPVS 007

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

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

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 significantly fainter in the UV by 0.2 mag. In order to investigate this behavior and to get a better estimate of the timescale we initiated an additional ToO for two pointings of 2 ks each, which were executed on 2006 December 12 and 21 (segments 010 and 011). Also note that the 2007 January observation was split into two segments due to scheduling constraints, even though the observations were performed in consecutive orbits.

The XRT was operating in photon-counting mode (Hill et al. 2004), and the data were reduced by the task *xrtpipeline*, version 0.10.4, which is included in the HEASOFT package 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 (2.84×10^{20} cm^{-2}; Dickey & Lockman 1990) and an energy spectra slope $\alpha_X = 3.0$. 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 *uvotmaghist*, 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.

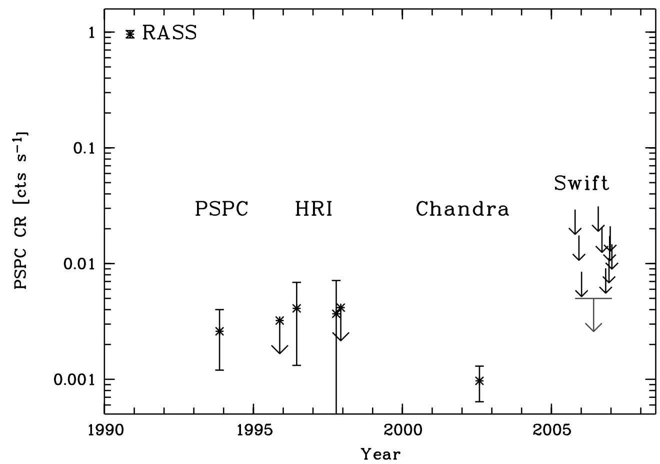

FIG. 1.—Long-term light curve of WPVS 007 containing the *ROSAT* All-Sky Survey and pointed PSPC and HRI observations, the *Chandra* data, and the upper limits derived from the *Swift* XRT observations. The count rates were converted by assuming an absorbed power-law model with $N_H = 2.84 \times 10^{20}$ 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.*]

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 σ 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 σ 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 1.04×10^{-3} counts s^{-1}

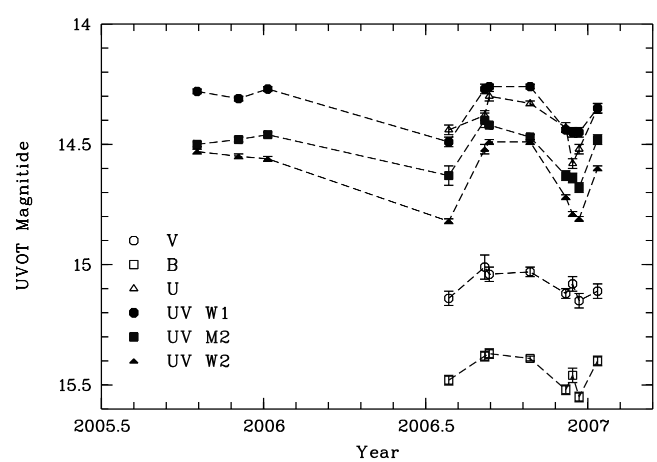

FIG. 2.—*Swift* UVOT light curves of WPVS 007. The values are given in Table 2. [*See the electronic edition of the Journal for a color version of this figure.*]

TABLE 4

List of Reference Stars Used to Determine the Error in the Photometry

Object	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	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	*U*	...	13.21 ± 0.02	13.27 ± 0.02	13.26 ± 0.01	13.21 ± 0.02	13.29 ± 0.02	13.25 ± 0.02	13.21 ± 0.02
			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	*U*	...	13.89 ± 0.02	13.87 ± 0.02	13.88 ± 0.02	13.93 ± 0.02	13.92 ± 0.02	13.96 ± 0.02	13.91 ± 0.02
			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.

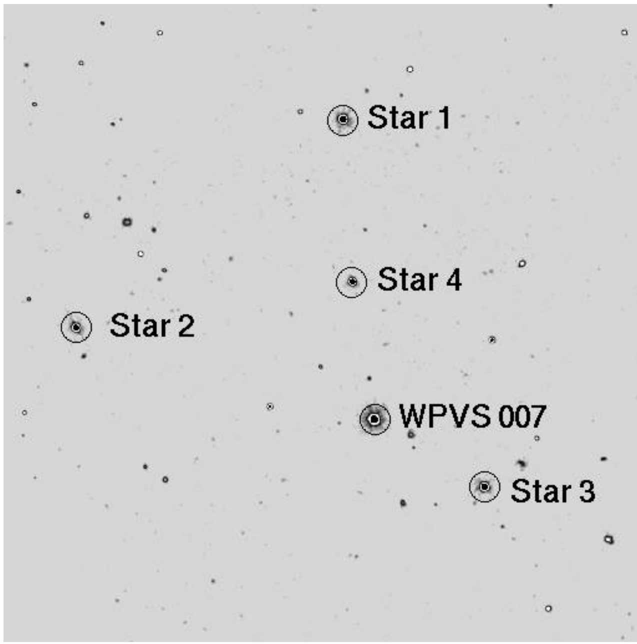

FIG. 3.—*Swift* UVOT W2 image of the 2006 January observation with the reference stars as listed in Table 4 and WPVS 007.

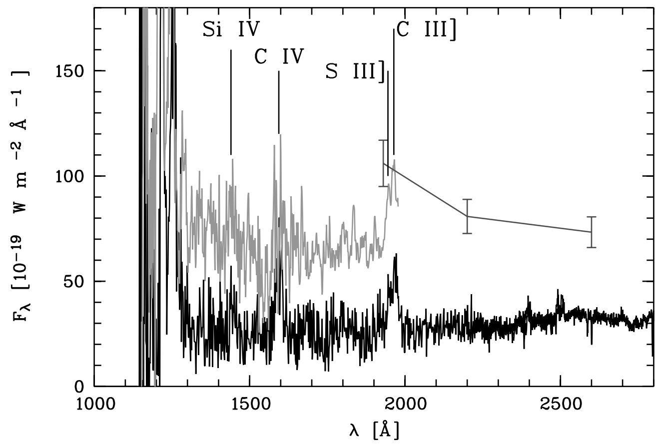

FIG. 4.—UV observations of WPVS 007. The data points show the *Swift* UVOT observations from 2006 January, the black spectrum shows the *HST* observation from 1996, and the gray spectrum shows the average of the *IUE* observations from 1993, 1994, and 1995 December. [*See the electronic edition of the Journal for a color version of this figure*.]

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 2.6×10^{-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* PSPC 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*, UV W1, UV M2, and UV 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[6] 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

[6] See http://www.chara.gsu.edu/PEGA/IUE.

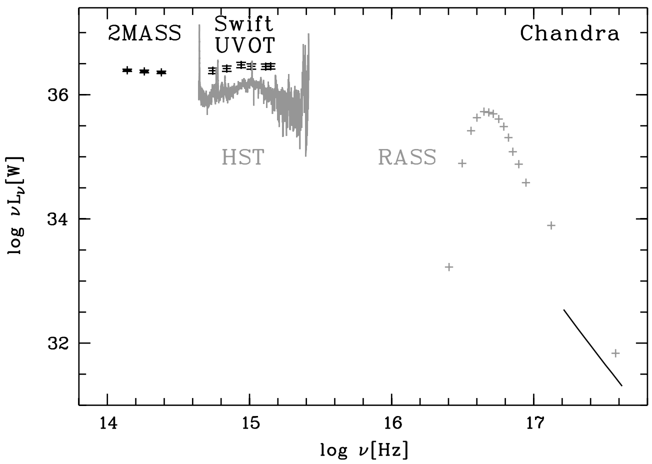

FIG. 5.— Spectral energy distribution of WPVS 007 using the NIR data from 2MASS, optical/UV data from the *Swift* UVOT observation from 2006 January corrected for Galactic reddening, and the X-ray data from the *Chandra* observation from 2002. The *Chandra* data are displayed as a power-law model with $\alpha_X = 3.0$. 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.*]

unabsorbed power-law model with $\alpha_X = 3.0$. The optical to X-ray slope α_{ox}[7] measured from this plot is $\alpha_{ox} = 5.4$. This is an extreme value for an AGN, which typically have values around $\alpha_{ox} = 1.5$ (e.g., Yuan et al. 1998; Strateva et al. 2005). Assuming $\alpha_{ox} = 1.5$ we would expect a flux at 2 keV of $F_{2\,\rm keV} = 6 \times 10^{-16}$ W m^{-2}, or a luminosity at 2 keV of $L_{2\,\rm keV} = 1 \times 10^{35}$ W. However, as shown in Figure 5, this is not the case. During the RASS observation, assuming a UV spectrum such as during the *Swift* observations, α_{ox} was on the order of $\alpha_{ox} = 5.0$. The flattening of the UV spectrum, as shown by the UVOT photometry data, suggests some intrinsic reddening of the AGN. A NLS1 typically has a very blue optical/UV spectrum, as shown, e.g., in Grupe et al. (2006) for the NLS1 RX J0148.3−2758. Assuming that the intrinsic optical/UV spectrum of WPVS 007 is similar to that of RX J0148.3−2758, we can estimate a reddening by 0.6 mag in the UV W2 filter. This results in a lower limit of the intrinsic reddening of $E_{B-V} = 0.073$. Note that this is a rough estimate. Based on the Hα/Hβ flux ratio, Winkler et al. (1992) estimated the extinction to $A_V \approx 1.0$ which is significantly higher than our estimate.

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 3 σ upper limit of 1.04×10^{-3} counts s^{-1}, which converts to an unabsorbed flux in the 0.3–10 keV band of 2.6×10^{-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.

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 *V*, 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_B and L_X for early-type galaxies by O'Sullivan et al. (2001). We use the extinction- corrected blue magnitudes measured with *Swift*, $m_{B,\rm corr} = 15.48$, and a previous USNO measurement, $m_{B,\rm corr} = 14.24$.[8] We then predicted a host galaxy contribution to the X-ray luminosity of $L_X \approx 10^{33}$–7×10^{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.

[7] The X-ray loudness is defined by Tananbaum et al. (1979) as $\alpha_{ox} = -0.384 \log(f_{2\,\rm keV}/f_{2500\,\rm Å})$.

[8] 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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