OPTICAL VARIABILITY OF THE STRONG-LINED AND X-RAY-BRIGHT SOURCE 1WGA J0447.9—0322

R. Nesci, M. Mandalari, and S. Gaudenzi

Department of Physics, University of Roma La Sapienza, Rome, Italy; roberto.nesci@uniroma1.it

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ABSTRACT

We present the historic light curve of 1WGA J0447.9—0322, spanning the time interval from 1962 to 1991, built using the Asiago archive plates. The source shows small fluctuations of about 0.3 mag around $B = 16$ until 1986 and a fast dimming of its average level by about 0.5 mag after that date, again with small short-term variations. The variability pattern is within the values shown by other QSOs with long-term monitoring, notwithstanding its high X-ray/optical ratio. We also present its overall spectral energy distribution using literature data and recent UV-optical Swift observations.

Key words: galaxies: active — quasars: general — quasars: individual (1WGA J0447.9—0322)

Online material: machine-readable table

1. INTRODUCTION

The Deep X-Ray Radio Blazar Survey and ROSAT All-Sky Survey—Green Bank samples of blazars (Perlman et al. 1998; Laurent-Muehleisen et al. 1999) discovered a number of flat-spectrum radio quasars (FSRQs) with strong X-ray fluxes (Padovani et al. 2003). This finding was in contrast to the previous expectation that strong-lined quasars should not be bright X-ray emitters.

The so-called blazar sequence, proposed by Fossati et al. (1998), indeed showed a marked correlation between the peak frequency of the spectral energy distribution (SED) in the radio to soft-X-ray range and the X-ray/optical flux ratio. According to that sequence, the peak frequency of the low-energy branch of the SED is inversely correlated with the bolometric power of the source, so that only intrinsically faint sources should be capable of accelerating electrons to the high energies required to push the synchrotron emission up to the X-ray band; these sources are the so-called HBL objects.

Very little information is currently available on these X-ray-strong FSRQs, as they were discovered relatively recently. One of these is the radio source PMN J0447—0322 (Griffith et al. 1995), identified as an X-ray source in the WGA catalog. It is present as a bright source in the ROSAT All-Sky Survey (Voges et al. 1999), and as such it was included in ROSAT-based catalogs of active galactic nuclei (AGNs) like the Radio Emitting X-Ray Sources survey (Caccianiga et al. 2000). On the basis of its optical and radio spectrum it was classified as a bright FSRQ by Caccianiga et al. (2000), with a redshift of $z = 0.773$. It is also present in the Two Micron All Sky Survey (2MASS) (Barkhouse & Hall 2001).

Despite its relative brightness ($B \sim 16$), the optical variability of 1WGA J0447.9—0322 was not studied in any detail; therefore, we performed a search in the Asiago plate archive for historical images and found a large number of useful Schmidt plates, covering the period from 1961 to 1985.

In this paper we present the first optical historic light curve of 1WGA J0447.9—0322 and compare it with long-term light curves of QSOs taken from the literature to see whether it is statistically different from those of X-ray-faint sources. We also report the results of a recent Swift observation of this source in the optical and X-ray bands and an updated SED.

2. THE 67/92 cm PHOTOGRAPHIC MATERIAL AND DATA ANALYSIS

We found 266 useful plates in the Asiago Observatory archive containing our source; 205 of them were obtained with the 50/40/120 cm Schmidt telescope (S40) and 61 with the 92/67/245 cm telescope (S67). Several filter-emulsion combinations were used over the years, characterized by different effective wavelengths: 103a-O+GG13 (closely matching the Johnson’s B filter), 103a-O (3600–5000 Å), TriX (3600–6700 Å), and Pancho Royal (3800–6400 Å). All these plates were taken as part of the supernova sky patrol of the Asiago Observatory ($\mu$ Eri field) and were never used before for the study of 1WGA J0447.9—0322. The covered time interval is from 1962 September to 1991 January but with a highly uneven sampling. Indeed, the source can be properly observed from Asiago only during the winter because of its low declination.

The plates were digitized at the Asiago Observatory with an Epson 1680 Plus scanner as part of a national program of digitization of astronomical plate archives (Barbieri et al. 2003). A sampling step of 16 $\mu$m (1600 dpi) was used in gray-scale/transparency mode and with 16 bit resolution. Plate scanning also included the unexposed borders in order to measure the plate fog level ($F$).

Due to the presence of residual scattered light in the scanner, we evaluated the instrumental zero value for each plate ($Z$) using the central pixels of the most overexposed stars. The transformation of the recorded plate transparency $T$ of each pixel into a relative intensity $I$ was obtained by applying the simple relation $I = (F - Z)/(T - Z)$.

As there is no photometric sequence in the sky near 1WGA J0447.9—0322, we used the $B$ magnitudes of the GSC2 (Guide Star Catalog 2) for our measurements of 1WGA J0447.9—0322. For this purpose we select 18 stars around the source covering the range $14.3 \leq B \leq 16.8$; the faint extreme is nearly the limit of detection for the small Schmidt telescope.

We checked that the selected stars were not variable and that their $B - R$ color indices were similar in order to minimize any possible color effect. In this respect 1WGA J0447.9—0322 is remarkably bluer ($B - R \sim 0.5$) than all our reference stars ($B - R \sim 1.0$). A finding chart of the reference stars is given in Figure 1, where 1WGA J0447.9—0322 is marked “W.” For each star Table 1 gives right ascension and declination (J2000.0) taken from

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1 VizieR Online Data Catalog, IX/31 (N. E. White, P. Giommi, & L. Angelini, 2000).
the GSC2 (cols. [1] and [2]), the GSC2 identification (col. [3]), the $R$ and $B$ magnitudes (cols. [4] and [5]), our adopted $B$ magnitude and internal error (col. [6], discussed below), and its flag on the finding chart (col. [7]).

We started our search with the plates of the 67 cm Schmidt telescope, which allows a higher photometric accuracy; nearly all the plates were taken with the 103a-O emulsion without a filter and had a limiting magnitude of $B \sim 18$. Instrumental magnitudes were obtained with the IRAF task apphot using a photometric aperture of 3 pixels (4.5$''$). The scatter plot between these magnitudes and those of the GSC2 for each plate showed that a linear fit was quite satisfactory. The slopes of the fitting lines were always between 0.7 and 1.4, as expected for the linearized response of a photographic plate. The formal error of the $B$ magnitudes in the GSC2 is 0.4 mag, mainly due to the uncertainty of the zero-point calibration. Having 67 plates of the field, we performed an intercalibration of the magnitudes of our reference stars and obtained the data listed in column (6) of Table 1. The differences with respect to the GSC2 $B$ values are in all cases smaller than 0.1 mag, indicating that the GSC2 can be very useful for the construction of historical photographic light curves.

The magnitudes of column (6) (which we call $B_{\text{Asiago}}$) were then used to rebuild the calibration curve for each plate, which was again well fitted by a linear relation with an appreciably smaller scatter. The $B$ magnitude of 1WGA J0447.9–0322 in each plate was then derived from the instrumental magnitude using the relevant calibration curve. These magnitudes and the rms deviation of the fit are reported in columns (3) and (4) of Table 2. In several cases, due to statistical fluctuations and different plate quality, the rms deviation is smaller than the errors of the individual reference stars given in Table 1, which are derived from the whole plate set. The typical value is 0.1 mag and is representative, in our opinion, of the actual photometric accuracy even for good plates with smaller formal errors. The plate number and JD $−$ 2,400,000 are reported in columns (1) and (2) of Table 2.

We checked whether the color difference between 1WGA J0447.9–0322 and the reference stars might produce systematic effects in our photometry. We performed a numerical simulation, assuming a spectral shape $F_{\nu} = A\nu^{-\alpha}$ and integrating the flux with the $B$ filter passband, normalized at the central wavelength. The $\alpha$-values corresponding to the color index of our source ($B − R = 0.5$) and of our average reference stars ($B − R = 1.0$) are 0.4 and 1.5, respectively. Changing the spectral slope $\alpha$ by this amount gives a magnitude variation of just 0.03 mag, which is below our typical photometric uncertainty.

Actually, many BL Lac objects are “bluer when brighter,” with a spectral slope variation range of $\sim$0.5 (see, e.g., Vagetti et al. 2003; Fiorucci et al. 2004). Also, if we consider 1WGA J0447.9–0322 to be a QSO rather than a BL Lac object, the spectral index

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**TABLE 1**

**REFERENCE STARS IN THE FIELD OF 1WGA J0447.9–0322**

| R.A. (J2000.0) | Decl. (J2000.0) | GSC2   | $R$ (GSC2) | $B$ (GSC2) | $B$ (Asiago) | Flag |
|----------------|----------------|--------|------------|------------|--------------|------|
| 04 47 29.672   | −03 18 29.99   | S020101354 | 14.65      | 15.56      | 15.44 ± 0.06 | O    |
| 04 47 39.666   | −03 18 27.48   | S020101353 | 14.52      | 15.56      | 15.48 ± 0.05 | N    |
| 04 47 42.546   | −03 17 14.97   | S020101350 | 14.87      | 15.81      | 15.85 ± 0.06 | Y    |
| 04 47 44.998   | −03 21 21.27   | S02010137258 | 15.67     | 16.62      | 16.58 ± 0.08 | P    |
| 04 47 45.326   | −03 22 41.42   | S020101366 | 13.71      | 14.76      | 14.86 ± 0.06 | K    |
| 04 47 46.044   | −03 24 14.78   | S02010137110 | 15.19    | 16.09      | 16.00 ± 0.07 | R    |
| 04 47 47.440   | −03 23 50.83   | S020101372 | 14.36      | 15.46      | 15.49 ± 0.06 | Q    |
| 04 47 56.038   | −03 26 15.88   | S020101381 | 14.37      | 15.32      | 15.28 ± 0.06 | J    |
| 04 47 59.699   | −03 16 37.23   | S02010119203 | 15.81   | 16.74      | 16.68 ± 0.10 | B    |
| 04 48 03.515   | −03 17 31.13   | S02010119142 | 16.08    | 16.78      | 16.69 ± 0.10 | Z    |
| 04 48 04.352   | −03 26 32.06   | S020101385 | 13.27      | 14.31      | 14.40 ± 0.05 | S    |
| 04 48 08.896   | −03 27 36.46   | S020101393 | 13.90      | 15.03      | 15.03 ± 0.06 | V    |
| 04 48 08.973   | −03 28 07.46   | S020101394 | 13.86      | 14.84      | 14.92 ± 0.05 | X    |
| 04 48 11.340   | −03 22 11.41   | S0201011270 | 13.69    | 14.72      | 14.68 ± 0.05 | E    |
| 04 48 11.703   | −03 27 17.69   | S02010136903 | 15.45   | 16.29      | 16.30 ± 0.07 | T    |
| 04 48 14.386   | −03 21 59.36   | S0201013266 | 14.07     | 15.09      | 15.06 ± 0.04 | F    |
| 04 48 14.481   | −03 27 39.03   | S02010136876 | 14.93   | 16.09      | 16.31 ± 0.08 | U    |
| 04 48 16.103   | −03 21 11.37   | S02010118906 | 14.90    | 16.10      | 16.29 ± 0.12 | G    |

**Note:** Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.
variability has a limited range (~0.5; Trevese & Vagnetti 2002). From our simulation such a variation has a negligible effect (0.01 mag) on the observed magnitude of our source, so we can ignore the effect of a possible color change with luminosity of 1WGA J0447.9–0322.

In no case was 1WGA J0447.9–0322 fainter than our faintest reference stars, so our magnitudes are always derived by interpolation in the calibration curve. The resulting light curve is plotted in Figure 2, together with the light curve of the reference star R (from Fig. 1; $B = 16.0$) shifted 0.5 mag upward for clarity.

3. DIGITAL SKY SURVEY DATA

Two additional historical points were obtained from the digitized POSS I (1955 December 14, JD 2,435,455) and United Kingdom Schmidt Telescope (UKST) DSS-II (1982 December 12, JD 2,445,315) blue plates retrieved from the Space Telescope Science Institute (STScI) archive, using the same reference stars and data reduction procedure used for the 67 cm Schmidt plates.

The POSS I plate gave a good linear fit for the instrumental magnitudes of the reference stars (rms = 0.09) with $B = 15.85$ for 1WGA J0447.9–0322 (circle at JD 35,455 in Fig. 2). The UKST plate was that used for the construction of the GSC2. In our $B$ Asiago magnitude scale we measured 1WGA J0447.9–0322 at $B = 16.03$ (circle at JD 45,315 in Fig. 2); we have a nearly simultaneous observation in our database (plate S67-11792) at $B = 15.86$, in reasonable agreement.

We also found two red plates in the STScI archive, a POSS I plate (103a-E emulsion) made the same day as the blue plate and a UK Schmidt (Illa-F emulsion) plate taken on 1995 November 14. We measured the instrumental magnitudes of our reference stars for these plates too (with IRAF apphot) and made calibration curves using the GSC2 red magnitudes. A linear fit in the magnitude range 15.4–16.0 was quite satisfactory with rms scatter of ~0.1. For both plates we got $R = 15.60$, very close to the value $R = 15.63$ given by the GSC2. From the simultaneous 1955 $B$ and $R$ plates, the $B - R$ color index of 1WGA J0447.9–0322 was 0.27. Assuming that this value is also valid for 1995, we found that the source in 1995 was as bright as in 1955 ($B = 15.85$, star at JD 50,036 in Fig. 2), appreciably brighter than the last S67 Asiago point in 1991 at $B = 16.3$.

4. SWIFT UVOT OBSERVATION OF 1WGA J0447.9–0322

The quasar 1WGA J0447.9–0322 was observed several times by Swift (Gehrels et al. 2004) in the framework of a program of blazar monitoring, but UV-Optical Telescope (UVOT) data were obtained in only one pointing (2005 April 15). The observing strategy of the satellite was to get several short exposures in each of the six filters ($V, B, U, UW1, UM2, and UW2$). To improve the signal-to-noise ratio we summed all the frames relative to each filter and performed aperture photometry of our reference stars (and 1WGA J0447.9–0322) with the task wotsource in the UVOT data analysis package using a 6$''$ radius for the $V, B, U$ filters and 12$''$ for the remaining filters, as recommended in the most recent cookbook (Breeveld et al. 2005). The resulting magnitudes for each filter, not corrected for Galactic reddening, are collected in column (2) of Table 3; in the same table we also show the $\nu F_\nu$ values (in ergs s$^{-1}$ cm$^{-2}$), corrected for Galactic extinction assuming $E(B - V) = 0.05$, which we use in §6 to build the SED of the source.

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**TABLE 3**

PHOTOMETRY OF 1WGA J0447.9–0322 WITH UVOT

| Filter | Mag     | $\nu F_\nu$ |
|--------|---------|-------------|
| $V$    | 16.53 ± 0.04 | -11.310    |
| $B$    | 16.91 ± 0.03 | -11.259    |
| $U$    | 15.97 ± 0.02 | -11.223    |
| UW1    | 15.65 ± 0.02 | -11.089    |
| UM2    | 15.63 ± 0.01 | -10.962    |
| UW2    | 15.84 ± 0.01 | -10.997    |

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Notes.—Data from the STScI plate archive, Swift UVOT, and Cima Ekar are also shown. Table 2 is published in its entirety in the electronic edition of the Astronomical Journal. A portion is shown here for guidance regarding its form and content.

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2 See http://archive.stsci.edu/cgi-bin/dss_plate_finder.
We did a consistency check for the B filter between the UVOT and our B Asiago magnitudes. For this purpose we performed aperture photometry with *uvotsource* of 13 reference stars that fall within the UVOT field of view (star S [Fig. 1] was excluded because it was very near the saturation limit of UVOT). The comparison of the UVOT and B Asiago magnitudes gave a best-fit slope of 1.10 with an rms of 0.04. The magnitude differences between the reference stars, due to the different zero points and slope, are not large: 0.1 at $B = 14.7$ and 0.3 at $B = 16.7$, in any case within the formal error of the GSC2 absolute calibration.

We tried to further check this point by observing the field of 1WGA J0447.9–0322 at the 182 cm telescope at Cima Ekar (Asiago) on 2006 January 4 with the CCD camera of the AFOSC instrument, but the night was not photometric, so we could not check the zero point of the GSC2 magnitude scale. Due to the limited field of view (8.8'), the observation included only five reference stars (excluding star S, as above), but we were able to cover the magnitude range of the 1WGA J0447.9–0322 light curve. A comparison of the AFOSC instrumental magnitudes with those of UVOT showed that the linearity of the UVOT magnitude scale is rather good (slope = 1.034, rms = 0.018); a small nonlinearity of the UVOT instrument at the 5% level was also found by Li et al. (2006) in the analysis of the stars in two supernova fields and by some of us in the analysis of the reference stars in the fields of BL Lac (G. Tosti et al. 2007, in preparation). We conclude, therefore, that the GSC2 scale is somewhat compressed. However, this small compression has little effect on the light curve of 1WGA J0447.9–0322, which has a maximum amplitude of only 1 mag; the peak-to-peak systematic difference is 0.1 mag, comparable with the statistical error of our photographic magnitudes. Therefore, we did not correct our light curve for this effect.

The magnitude of 1WGA J0447.9–0322 observed by UVOT was $B = 16.60$ on the B Asiago scale (Fig. 2, open square); the same value was given by the AFOSC observation 8 months later (Fig. 2, filled square). Therefore, the source was recently at a flux level similar to that of the Asiago historic light curve in the low state of the years 1987–1989.

5. THE SMALL SCHMIDT PLATES

Finally, we also performed photometry of our source on the S40 plates, using our B Asiago values for the reference stars; due to the smaller plate scale (206' mm$^{-1}$) we adopted a photometric aperture radius of 2 pixels (6.6”). The rms deviation of the linear fit between the nominal and instrumental magnitudes of the reference stars was higher than for the 67 cm Schmidt telescope, as expected for a smaller instrument. The scatter of the reference star magnitudes around their nominal value is, however, well-behaved; i.e., it increases monotonically from 0.08 mag at $B \sim 14.5$ to 0.26 mag at $B \sim 16.5$. In these plates the fainter stars of the sequence were rather close to the plate limit. We decided to use these lower quality plates just to look for possible large-amplitude flares of 1WGA J0447.9–0322. The S40 plates are indeed much more numerous than the S67 plates and therefore allow a better time coverage of the light curve, although with a worse photometric accuracy.

In a large number of nights, two consecutive plates were taken at the S40 with different emulsions. No systematic differences in the magnitudes of 1WGA J0447.9–0322 were found between Pancho Royal and 103a-O, while a systematic difference of 0.23 mag was found between TriX and 103a-O, the TriX magnitudes being fainter. This is probably due to the better violet sensitivity of the 103a-O emulsion, which is relevant for an object definitely bluer than the reference stars. We reported all the.

6. THE SPECTRAL ENERGY DISTRIBUTION

A SED of 1WGA J0447.9–0322 was published by Padovani et al. (2003) using literature data. An enhanced version, including *JHK* magnitudes taken from 2MASS (Cutri et al. 2003) and preliminary X-ray and optical data from *XMM-Newton*, was published by Landt et al. (2005). The source was not detected by the *Extreme Ultraviolet Explorer*.

The SED of the source is shown in Figure 4, including literature radio, *JHK*, and GSC2 data and our optical and UV data from *Swift*. The radio point at 4.8 GHz is from the Parkes-MIT-NRAO (PMN) survey of 1990 November (Griffith et al. 1995) and is nearly simultaneous with the *ROSAT* observation used in the WGA catalog. The X-ray flux is taken from the NASA/IPAC Extragalactic Database (NED), and we checked the result by converting the WGA count rate to flux using the PIMMS tool at HEASARC. The observation at 1.4 GHz is given by the NRAO VLA Sky Survey (NVSS; Condon et al. 1998; 87 ± 3 mJy) and shows no precipice polarization. From our light curve the B magnitude at the epoch of the *ROSAT* and PMN observations was about 16.3, only 0.2 mag fainter than the GSC2 point. The high X-ray/optical flux ratio of this source is therefore real and not a spurious result of using nonsimultaneous data of a variable object.

It is apparent that 1WGA J0447.9–0322 looks like a high-energy peaked source, with an apparent peak around $10^{15.5}$ – $10^{16.5}$ Hz. The optical part of the SED at the epoch of the *Swift*
observation looks parallel to that obtained from historical data (2MASS + GSC2). We derived a $B - R$ color index from the published optical spectra in Caccianiga et al. (2000) and Perlman et al. (1998), in both cases obtaining $B - R \approx 0.47$. This value is in fair agreement with that derived by extrapolating the $UBV$ slope of the Swift data to the $R$ frequency ($B - R = 0.6$).

7. DISCUSSION

At a redshift of 0.774, the absolute $B$ magnitude of 1WGA J0447.9–0322 is $-26.6$ ($H_0 = 70$ km $s^{-1}$ Mpc$^{-1}$, $q_0 = 0.5$), and the radio power at 1.4 GHz, $K$-corrected assuming a slope for the radio flux density of $-0.34$, is $26.0$ (log W Hz$^{-1}$). Therefore, the source has a radio power intermediate between those of FR I and FR II sources and is moderately radio-loud ($F_{\text{radio}}/F_{\text{opt}} \sim 40$). It is reported as unresolved with the VLA (Landt et al. 2006).

We compared the rms amplitude of the optical variability of 1WGA J0447.9–0322 (0.27 mag) with the corresponding value reported for the Palomar-Green (PG) QSO sample (Giveon et al. 1999), derived from light curves covering a time interval of about 7 yr. No systematic difference between radio-loud and radio-quiet QSOs was found by Giveon et al. (1999) for this value, which ranges from 0.05 to 0.34 mag; the detected variability of 1WGA J0447.9–0322 is therefore within the range of the PG QSOs.

A much wider sample of optically selected QSOs from the Sloan Digital Sky Survey that was monitored over a time base of a few years by Vanden Berk et al. (2004) also shows no definite statistical difference between radio-loud and radio-quiet sources, while the typical rms variability is 0.13 ($b$-band) mag.

A comparison with longer light curves can be made using the Rosemary Hill Observatory data (Pica et al. 1988) monitoring 144 AGNs (26 BL Lac objects, 18 radio-quiet QSOs, 85 radio-loud QSOs, and a few miscellaneous AGNs) over 19 yr. Also, in this case the rms variability of 1WGA J0447.9–0322 is within the range of the monitored sources, and the peak-to-peak variability amplitude (1.1 mag) is at an intermediate level. The X-ray brightness of 1WGA J0447.9–0322 has, therefore, no apparent impact on its optical variability.

In our opinion the historic light curve of 1WGA J0447.9–0322 can be seen as characterized by flat behavior around $B = 16.0$ with small-amplitude (0.3 mag) oscillations until JD 46,500, when a fast jump down to 16.6 occurred (see Fig. 2). This vision is suggested by the fact that the POSS I point at JD 35,455 is at the average level of the light curve between JD 38,000 and 46,000, while the UVOT and Cima Ekar points are at the level of the second part of the light curve (JD 46,500–48,000). However, a simpler interpretation of a slow monotonic decreasing trend with small-amplitude oscillations cannot be ruled out.

The light-curve shapes shown by Pica et al. (1988) are broadly classified by them into three classes: (1) fast flickering with a nearly stable base level, (2) small flickering above a long-term (possibly oscillating) trend, and (3) significant flickering over much slower long-term changes of similar amplitude. These classes are not sharply separated, and they report some cases of sources changing from one class to another. Two cases of “ bistable” sources are also reported by them, i.e., flickering for some years above a given level and then, after a sharp transition, above a different level. One is GC 0109+220, a well-established BL Lac object; the other is PKS 0723–080, which is currently classified as a narrow-line radio galaxy (Eracleous & Halpern 2004). The recent behavior (1992–2002) of GC 0109+224 has been extensively monitored by Ciprini et al. (2004). Its behavior can still be classified as class 1 in the previous scheme but with a higher base level than in the 1970s. Based on all the available data, 1WGA J0447.9–0322 might belong to this “bistable” class; clearly, longer monitoring would be necessary to check this result.

8. CONCLUSIONS

Old photographic archives still contain a lot of unexplored data that can be very useful for complementing recent multiwavelength observations of variable sources (Nesci et al. 2005). The optical light curve of 1WGA J0447.9–0322, spanning about 29 years, showed a moderate variability, typical for a QSO, without strong flares (it is not an optically violent variable object). Therefore, the high X-ray/optical flux ratio seems to be real, and not a spurious result due to the use of nonsimultaneous data.

A moderate level of variability is also often found in BL Lac objects of the high-energy peak type; 1WGA J0447.9–0322 is not a BL Lac object, given its strong Mg II 2890 emission line with about 200 Å of equivalent width, but it is a high-energy peak object.

If a strong and fast variability is due to the fast cooling of relativistic electrons emitted by the synchrotron process, then it is expected to be observed mainly at energies higher than the peak of the SED (see, e.g., Perlman et al. 2005); the mild behavior of 1WGA J0447.9–0322 at optical frequencies would therefore be quite within the current model expectations.

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