BL Lacertae objects beyond redshift 1.3 – UV-to-NIR photometry and photometric redshift for *Fermi*/LAT blazars

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ABSTRACT

Context. Observations of the γ -ray sky with *Fermi* led to significant advances towards understanding blazars, the most extreme class of active galactic nuclei. A large fraction of the population detected by *Fermi* is formed by BL Lacertae (BL Lac) objects, whose sample has always suffered from a severe redshift incompleteness due to the quasi-featureless optical spectra.

Aims. Our goal is to provide a significant increase of the number of confirmed high-redshift BL Lac objects contained in the 2 LAC *Fermi*/LAT catalogue.

Methods. For 103 *Fermi*/LAT blazars, photometric redshifts using spectral energy distribution fitting have been obtained. The photometry includes 13 broad-band filters from the far ultraviolet to the near-IR observed with *Swift*/UVOT and the multi-channel imager GROND at the MPG/ESO 2.2 m telescope. Data have been taken quasi-simultaneously and the remaining source-intrinsic variability has been corrected for.

Results. We release the UV-to-near-IR 13-band photometry for all 103 sources and provide redshift constraints for 75 sources without previously known redshift. Out of those, eight have reliable photometric redshifts at $z \gtrsim 1.3$, while for the other 67 sources we provide upper limits. Six of the former eight are BL Lac objects, which quadruples the sample of confirmed high-redshift BL Lac. This includes three sources with redshifts higher than the previous record for BL Lac, including CRATES J0402-2615, with the best-fit solution at $z \approx 1.9$.

Key words. galaxies: distances and redshifts – techniques: photometric – BL Lacertae objects: general

1. Introduction

Since its launch in 2008, the *Fermi* Space Laboratory has dramatically extended our view of the high-energy sky. The recently released 24-month catalog (2LAC) of active galactic nuclei (AGN) detected by the Large Area Telescope (LAT; [Atwood et al. 2009](#)) revealed 885 high-significance sources, the large majority of them being blazars ([Ackermann et al. 2012](#)). The latter form the most extreme class of AGN with their observational characteristics governed by the small angle between their relativistic jets and the observer's sight line ([Blandford & Rees 1978](#)). The resulting Doppler boosting makes blazars exceptionally bright sources at nearly all wavelengths and therefore visible out to high redshift.

The scientific relevance of blazars is very broad, ranging from laboratories for the physics and structure of relativistic jets (and thus the extraction of energy from the central massive black hole) (e.g., [Abdo et al. 2010d](#)) to probes of the extra-galactic background light (EBL) through attenuation of γ -ray photons (e.g., [Abdo et al. 2010c](#)). One of the crucial parameters for these applications is the distance to the objects, which unfortunately is not easy to obtain in most cases.

Two classes of blazars dominate the 2LAC population. These are the flat-spectrum radio quasars (FSRQs, 310 sources) and BL Lac objects (395), named after the prototype BL Lacertae ([Hoffmeister 1929](#)). While for the former redshift measurements are routinely performed using their strong emission lines at UV-optical wavelengths, the featureless, power-law optical

spectra of BL Lac objects have proven to be a challenge (e.g., Shaw et al. 2009). Indeed, 220 of the 395 BL Lacs in the 2LAC (55%) lack redshift estimates. Until this incompleteness is resolved, conclusions about the EBL, the blazar sequence (e.g., Fossati et al. 1998; Ghisellini et al. 1998), and the blazar population in general remain tentative at best.

Several methods have been exploited to increase the BL Lac redshift sample. At low distance, one can utilize the remarkably uniform absolute brightness of the giant elliptical BL Lac host galaxies (Sbarufatti et al. 2005; Meisner & Romani 2010) and very-high signal-to-noise optical spectroscopy to help to identify weak emission or absorption features in a few other cases (e.g., Shaw et al. 2009). An alternative method, applicable to the more distant sources, is the photometric redshift technique, which consists of fitting spectral energy distribution (SED) templates to multi-band photometry. Neutral hydrogen along the line of sight to the blazar will imprint a clear attenuation signature at the Lyman limit and thus allows an accurate estimate of the redshift of the absorber. Even though the absorber will be located somewhere along the line of sight and its redshift will thus not necessarily correspond to that of the blazar, photometric redshifts, z_{phot} , will provide a reliable lower limit on the blazar redshift.

In this paper we explore the use of ultra-violet to near-infrared quasi-simultaneous photometry to measure the redshift of 103 2LAC blazars, 86 of them without previous redshift constraints. The sample selection is described in Sect. 2 while the observations and data reduction are detailed in Sects. 3 and 4. The results and their discussion are presented in Sects. 5 and 6, respectively.

2. Sample selection

The sample is selected mainly from the clean sample of the 24-month catalog of AGN detected by *Fermi*/LAT (Ackermann et al. 2012) which includes 885 high-significance γ -ray sources which are statistically associated with AGNs and located at high Galactic latitudes ($|b| > 10$ deg). To accommodate the location of one of our follow-up instruments in the southern hemisphere, we applied a cut in declination ($\delta_{J2000} < +25$ deg). Furthermore, the importance of the ultra-violet bands for the z_{phot} estimates lead us to discard all sources with Galactic foreground reddening of $E_{B-V} > 0.2$ mag, as derived from the Schlegel et al. (1998) maps. The final sample is composed of 80 sources without known redshift but with optical or radio counterpart associations from Bayesian statistics (Abdo et al. 2010a,b), Likelihood Ratio, or $\log N - \log S$ methods (Ackermann et al. 2012) and was further extended by eight sources that do not belong to the clean 2LAC sample¹. In addition, observations for 16 2LAC sources with existing redshift measurements are included for verification. We emphasize here that our sample is not statistically complete, but biased by selection. The final list of 104 targets is presented in Table 1. Of those, 82 have been classified as BL Lac objects, three as FSRQ, and the remaining 19 are of unknown type (Ackermann et al. 2012).

3. Observations

The observations were performed with the Ultraviolet and Optical Telescope (UVOT; Roming et al. 2005) onboard the *Swift* satellite (Gehrels et al. 2004) and the Gamma-Ray Optical/Near-infrared Detector (GROND; Greiner et al. 2008)

Fig. 1. Cumulative distribution of the (absolute) time between the mid-points of the GROND and *Swift*/UVOT observations. The median offset is 1.5 d. For longer UVOT observations, which were spread over several satellite orbits, the mid-time of the *uvw2*-exposure was taken as reference.

mounted on the MPI/ESO 2.2 m telescope at La Silla, Chile. Each source has been observed at least once with both instruments, although for some targets several epochs had been acquired.

The UVOT pointings have been obtained as part of the *Swift* fill-in program from January 2010 to October 2011. With few exceptions, they comprise observations in three optical (*u*, *b*, *v*) and three UV (*uvw2*, *uvm2*, *uvw1*) lenticular filters, covering the wavelength range between 160 nm and 600 nm (Poole et al. 2008). The exposure times vary from source to source depending on visibility and brightness of the optical counterpart. Approximate values are 100 s each in *u*, *b*, *v* and 200, 250, 400 s in *uvw1*, *uvm2*, *uvw2*, respectively. For a few sources multiple consecutive orbits, and thus longer exposures, were obtained.

While UVOT needs to cycle through all filters in sequence, GROND observes in its four optical *g'*, *r'*, *i'*, *z'* and three near-IR *J*, *H*, *K_s* bands simultaneously. This capability is particularly important for studies of fast-varying sources such as blazars as it allows the construction of a reliable spectral energy distribution (SED) without the need to correct for source-intrinsic variability. Unfortunately, scheduling limitations rarely allowed simultaneous observations with both instruments, UVOT from space and GROND from the ground. However, in order to minimize the impact of variability on the combined SED, GROND observations were executed as close as possible in time to the *Swift* pointings. Except in a few cases where visibility or weather constraints lead to offsets of more than 10 d, observations were typically achieved within 1–2 d of each other (see Fig. 1). The z_{phot} uncertainties associated with these offsets will be discussed in Sect. 4.3.

A typical GROND observation had an integration time of 2.4 min in (*g'*, *r'*, *i'*, *z'*) and 4.0 min in (*J*, *H*, *K_s*).

4. Data and analysis

4.1. *Swift*/UVOT and GROND

UVOT photometry was carried out on pipeline processed sky images downloaded from the *Swift* data center², following the standard UVOT procedure (Poole et al. 2008). Source photometric measurements were extracted from the UVOT imaging

¹ Flagged due to analysis issues by the LAT team.

² http://www.swift.ac.uk/swift_portal

data using the tool UVOTMAGHIST (v1.1) with a circular source extraction region that ranged from $3''.5$ – $5''$ radius to maximise the signal-to-noise. In order to remain compatible with the effective area calibrations, which are based on $5''$ aperture photometry (Poole et al. 2008), an aperture correction was applied where necessary. This correction was at maximum 5–6% of the flux, depending on the filter. For the further analysis, all magnitudes were converted into the AB system and are presented in Table 2. Typically achieved $3\text{-}\sigma$ limiting magnitudes are $uvw2_{AB} \approx 22.4$ and $b_{AB} \approx 19.6$.

The GROND data (Table 3) were reduced and analyzed with the standard tools and methods described in Krühler et al. (2008). The g' , r' , i' , z' photometry was obtained using point-spread-function (PSF) fitting and calibrated against observations of fields covered by the SDSS Data Release 8 (Aihara et al. 2011). Due to the undersampled PSF in the near-infrared, the J , H , K_s photometry was measured from apertures with the sizes corresponding to the full-width at half maximum (FWHM) of field stars and calibrated against selected 2MASS stars (Skrutskie et al. 2006). This resulted in 1σ accuracies of 0.04 mag (g' , z'), 0.03 mag (r' , i'), 0.05 mag (J , H), and 0.07 mag (K_s) for the absolute calibration. While the SDSS calibration directly provides magnitudes in the AB system, the near-IR photometry required further transformation from the 2MASS-native Vega system into AB. Typically achieved $3\text{-}\sigma$ limiting magnitudes are $r'_{AB} \approx 23.5$ and $K_{s,AB} \approx 19.8$.

Correction for Galactic foreground extinction was performed following the procedure described in Cardelli et al. (1989) with E_{B-V} from Schlegel et al. (1998). For the UVOT bands, the correction factors presented in Kataoka et al. (2008) were used. Uncertainties in E_{B-V} (10%; Schlegel et al. 1998) and in the reddening law produce an additional contribution to the photometric error budget. As this systematic uncertainty is coupled between the photometric bands for a given position in the sky, its impact on the SED fitting is smaller than the contribution to the photometry in each individual filter. An exact calculation is very complex. Thus, we adopt a conservative 5% of the reddening value in each band which is added in quadrature to the photometric uncertainties.

4.2. Counterpart selection and morphology

Astrometric solutions for the GROND optical bands have been obtained through comparison with USNO or, if available, with SDSS measurements, achieving a typical rms of $0''.3$ in both coordinates. For the large majority of our targets (91) only a single optical source was found within $2''$ radius of the location given in the 2LAC catalog. For an additional twelve objects isolated candidate counterparts were detected at offsets of up to $6''$. In one case (CGRaBS 1407-4302), several blended sources made a reliable identification impossible. Counterpart coordinates and offsets for the 103 sources with identification are given in Table 1. Most of the identified optical sources are bright and point-like with typical magnitudes in the GROND r' -band of 16–18 mag (Fig. 2).

The source morphology can be used as a prior for the selection of the SED template library (see Sect. 4.4) and redshift range, i.e., clearly extended sources will have a contribution from the host galaxy emission to the observed SED and are likely located at low redshift. A simple morphological distinction in point-like and extended has been performed on the GROND images and will be used for discussing the reliability of the z_{phot} estimates.

Fig. 2. Observed GROND r' -band magnitude distribution of the optical counterparts.

4.3. Variability correction

The optical emission of blazars is known to vary on a wide range of time scales. Brightness variations range from a few tenths of a magnitude within minutes to days (e.g., Racine 1970; Miller et al. 1989; Carini et al. 1991; Urry et al. 1993) to several magnitudes over weeks to years (e.g., Ciprini et al. 2003; Raiteri et al. 2005). This variability contributes significantly to the uncertainties when constructing an SED from non-simultaneous multi-band, multi-instrument observations.

As GROND observes in all seven bands at the same time, the g' to K_s photometry can be considered as a snapshot of the SED and is thus unaffected by variability on time scales longer than the exposure of an individual observation. This leaves two areas where a proper treatment of variability has to be performed, i) between the exposures in the individual UVOT filters and ii) between the GROND and UVOT pointings.

UVOT observes in each band separately and, for our program, typically cycled through its filters in a specific order ($uvw1$, u , b , $uvw2$, v , $uvm2$). A complete sequence in all six bands took ≈ 12 min, during which time the target may vary in brightness. Without a priori knowledge of the spectral shape, this variability can only be accounted for statistically, i.e., by including an additional contribution to the systematic uncertainties. For this purpose we analyzed the photometry for those blazars for which multiple UVOT exposures in a single band were available. Here, we focused on the bluest filter ($uvw2$) which would be least affected by a potential host galaxy contribution and should thus give a good representation of the maximum variability. In Fig. 3 the distribution of variability as function of time between two $uvw2$ exposures is shown for 25 targets with accurate photometry ($\delta m_{uvw2} < 0.1$ mag) in each image. While variability as large as $\Delta m_{uvw2} \approx 0.4$ mag can be seen for some sources also on time scales of $\Delta t < 0.1$ d, the median variation for $\Delta t < 50$ d is ≈ 0.1 mag, comparable to the photometric uncertainty.

The shortest time sampled between two $uvw2$ exposures in this sample is one satellite orbit (≈ 90 min) and therefore longer than it takes to cycle through the six filters. However, it is reasonable to assume that the median variation on a 12 min time scale is not much larger than the one over 96 min. Thus, we conservatively adopted $\Delta m = 0.1$ mag as an additional contribution to the systematic uncertainties for all UVOT filters.

In order to correct between GROND and UVOT we made use of the spectral overlap provided by the two instruments (Krühler et al. 2011). Under the assumption that the SED

Fig. 3. Absolute brightness changes in the *uvw2* filter as function of time between two UVOT pointings for all 25 sources with multiple observations. The black crosses show the median values (and median absolute deviation) and the grey dots mark all 174 pairs of observations. While micro-variability ($\Delta m_{uvw2} \approx 0.1$ mag) dominates on time scales shorter than 50 d, significantly larger variability ($\Delta m_{uvw2} > 0.3$ mag) is observed at $\Delta t > 50$ d.

Fig. 4. Absolute brightness offset as function of time between the GROND and *Swift*/UVOT observations. The black crosses show the median values (and median absolute deviation) and the grey dots mark all 90 sources for which the offset was determined (excluding eleven sources with large photometric uncertainties, missing *b*, *g'*, or *r'* photometry, or strong host galaxy contribution).

remains unchanged and can be approximated by a power law and thus, that the GROND and *b*, *v* photometry follow the same spectral slope³, color-terms can be used to derive the normalization offset. Here we used the calibration with the largest spectral overlap, namely the one between *b*, *g'*, and *r'*:

$$b - g' = 0.17(g' - r') + 0.03(g' - r')^2 \quad (1)$$

which is valid for $-1 \leq (g' - r') \leq 2$ (Krühler et al. 2011). These corrections, $\Delta \text{mag}_{GR \rightarrow UV}$ (Table 2), were calculated for all sources with accurate photometry in *b*, *g'*, and *r'* ($\delta m < 0.2$ mag). They were computed for each object individually and applied to the GROND photometry, shifting it in line with UVOT. Typically values are of the order of ± 0.1 mag (Fig. 4). In cases where multiple epochs were available, we used the closest pair of GROND and UVOT observations. The final SED for each source corresponds to the best possible reconstruction between 160–2200 nm at the time of the UVOT observation. No correction was performed for sources where the photometric uncertainty ($\delta m \geq 0.2$ mag in *b*, *g'*, and/or *r'*) was larger than the typical $\Delta \text{mag}_{GR \rightarrow UV}$.

For a few sources, the emission from the underlying host galaxy contributes significantly to the overall SED (see Sect. 4.4). While the blazar emission can still vary, the host contribution naturally remains unchanged, violating the assumption of a constant SED slope. Thus, no variability correction was performed in those cases where the UV to optical SED clearly deviates from a power law.

4.4. SED fitting

The photometric redshift computation was performed with the publicly available LEPHARE code v.2.2 (Arnouts et al. 1999; Ibert et al. 2006). The program uses the simple χ^2 fitting method to differentiate between a theoretical and an observed photometric catalogue. We used three custom template libraries for comparison with our GROND and UVOT photometry. The first

was composed of 40 power law SEDs of the form $F_\lambda \propto \lambda^{-\beta}$ with β ranging from 0 to 2 in steps of 0.05 and describes primarily the central-engine dominated blazars. Here, the source-intrinsic extinction was assumed to be zero and the luminosity prior was chosen to cover the expected range of absolute magnitudes ($-20 < M_{g'} < -30$; Véron-Cetty & Véron 2010). Such a simple model is a good approximation for the UV-near-IR SEDs of BL Lacs, which form the bulk of our sample. Also FSRQs, if their emission lines are not dominant, can be modeled with a power law to first order. The second library contains templates of normal (inactive) galaxies and galaxy/AGN hybrids (Salvato et al. 2009, 2011) and has been implemented in order to model host galaxy dominated objects. If the host contribution is significant, the 4000 Å break can emerge and potentially be misinterpreted as a Lyman-limit. While for the galaxy models intrinsic extinction was again neglected, a different luminosity prior of $-8 < M_{g'} < -30$ was chosen to allow for the expected fainter host magnitudes. The third library consists of a wide range of stellar templates (Pickles 1998; Bohlin et al. 1995; Chabrier et al. 2000), included to test against potential false associations. For each source in our sample, all three libraries were fit independently.

The most prominent spectral feature used to measure z_{phot} for blazars is caused by the absorption through neutral hydrogen along the line of sight. At $z \approx 0.8$ the Lyman-limit moves into the wavelength covered by the UVOT and starts to suppress the flux in the *uvw2* filter. While this is the theoretical lower limit on z_{phot} for the combined GROND and UVOT coverage, uncertainties associated with the photometry and modeling will shift it to a higher redshift. Usually one would use a spectroscopic training sample to evaluate the redshift range and accuracy which is accessible with our SEDs. As the majority of the sources with known redshift in our sample are located at $z < 1$, they alone do not suffice to provide a statistically meaningful test of the method. Instead we assess the reliability in our photometric redshift computation with a Monte-Carlo approach.

Here, we simulated 27 000 test power-law SEDs with spectral slopes ranging from 0.5 to 2, redshifts from 0 to 4, and at three apparent magnitudes, $r' = 17$ –19 mag. For each source, the photometry in the individual bands was scattered around the model magnitudes with a brightness-dependent statistical

³ This is reasonable for redshift $z < 3.5$ and for sources where the host galaxy contribution to the emission is negligible. See Sect. 4.4 for further discussion.

contribution and with a component representing the systematic uncertainties from the photometric calibration and variability correction. The resulting SEDs were fed back into LEPHARE and the output z_{phot} was compared to the input value.

As can be seen in Fig. 5, there is a good correspondence between the input and the recovered redshift for $z_{\text{sim}} > 1.2$. In particular for bright sources ($r' < 18$ mag) the number of outliers η , defined as the number of sources with $|\Delta z(1+z_{\text{sim}})| > 0.15$, drops steeply above this redshift. For fainter sources ($r' \approx 19$ mag), the increasingly less constrained UV photometry causes the outlier fraction to remain high ($\approx 20\%$) out to $z_{\text{sim}} \approx 2$. A more quantitative selection can be made when using P_z , the integral of the probability distribution function $\int f(z)dz$ at $z_{\text{phot}} \pm 0.1(1+z_{\text{phot}})$, which describes the probability that the redshift of a source is within $0.1(1+z)$ of the best fit value. When choosing a cut at $P_z > 90\%$, the majority of the outliers at $z_{\text{phot}} > 1.2$, as well as nearly all the solutions with $z_{\text{phot}} < 1.2$ disappear (inset Fig. 5). This confirms that for power-law sources with $z < 1.2$ the available photometry can only place an upper limit, and suggests that $P_z > 90\%$ can be used as a criterion to identify reliable photometric redshift solutions. Selecting a higher P_z threshold, e.g., 99%, can further reduce the outlier fraction but will also shift the lower constrainable redshift bound to higher values. In order to reach such a very tightly peaked redshift probability distribution function more than one photometric band has to be affected by the Lyman-limit, limiting the redshift range to $z \gtrsim 1.5$.

5. Results

The fit results for all 103 sources with identified counterparts are presented in Table 4. Here we give the photometric redshifts (and their 90% confidence errors), the P_z values, and the best fit models for the power law and galaxy templates. No source requires a stellar template.

As discussed in the previous section, $P_z > 90\%$ can be used as a good reliability criterion for the photometric redshift solution. Applying this cut to the power law model fits results in a sample of 15 sources with $\chi^2 < 30$. Next, we also require that a source can not be fit well with a galaxy/AGN-hybrid template at low redshift ($z < 1.2$). This step is required in order to identify those sources for which a degeneracy in the photometric redshift solution does not allow a distinction between a low-redshift galaxy/AGN-hybrid and a blazar at higher redshift. In analogy with our selection for a good redshift constraint ($P_z > 90\%$), we consider $P_{z,\text{gal}} < 90\%$ as a reliable criterion that no adequate low-redshift galaxy/AGN-hybrid solution was found. This removes further seven sources from the sample and leaves eight candidates, all unresolved in the GROND images and with $z_{\text{phot,pl}} > 1.2$.

For three additional sources the power law and galaxy models fit similarly well ($P_{z,\text{pl}} \sim P_{z,\text{gal}} > 90\%$) and give comparable high-redshift solutions, indicating that the Lyman-limit was fit by power law and galaxy templates alike. Including those, we end up with a sample of eleven sources with reliable photometric redshift computation, all, with z_{phot} ranging from $z_{\text{phot}} \approx 1.28$ to $z_{\text{phot}} \approx 1.92$. This encompasses eight sources without previous redshift measurements and three blazars with known redshift. For the latter, the photometric redshifts are within $3\text{-}\sigma$ of the known value (see Fig. 5), indicating an accuracy of $|\Delta z|/(1+z_{\text{spec}}) < 0.12$ for our z_{phot} method described in Sect. 4.4. The fit results and SEDs for the eleven sources are presented in Table 4 and Fig. 6, respectively.

For 21 sources, the galaxy library provides the better fit with $P_{z,\text{gal}} > 90\%$, $P_{z,\text{pl}} < 90\%$, and $\chi^2_{\text{gal}} < 30$. All of these are

Fig. 5. Recovered best-fit photometric vs. input redshift (*top*), accuracy (*middle*), and outlier fraction (*bottom*) for 27 000 simulated sources with spectral slope of $0.05 \leq \beta \leq 2$ and optical brightness of $r' = 17\text{--}19$ mag. The pink circles indicate the location of three blazars in our sample with known redshift, PKS 0332-403 ($z_{\text{spec}} = 1.351$, Bergeron et al. 2011), OM 235 ($z_{\text{spec}} = 1.549$), and CRATES J1312-2156 ($z_{\text{spec}} = 1.491$, Ackermann et al. 2012), as well as that of PKS 0537-286 ($z_{\text{spec}} = 3.104$, Wright et al. 1978), a LAT-non-detected blazar with available GROND and UVOT photometry. The green area in the *middle panel* corresponds to the forbidden parameter space where $z_{\text{phot}} > 0$. Systematics are visible at $z_{\text{phot}} < 0.8$. The large majority of the fits have $\chi^2 < 30$ (for typically 10 d.o.f.) with the exceptions shown in light grey. The inset in the *top panel* displays the results if only solutions with $P_z > 90\%$ are selected.

best described by starburst/QSO hybrid templates at $z < 1.3$ and none require an elliptical galaxy, i.e., a strong 4000 Å break. The most significant difference between the starburst/QSO hybrid templates and the power-law models is that the former exhibit strong emission lines originating from star-formation (see Salvato et al. 2009, for more details on the templates). These lines can be fit to small deviations in the photometry from a power-law and thus provide low χ^2 values and apparently well-constrained z_{phot} solutions. However, as described in Sect. 4.3, the variability correction is not reliable when applied to non-power-law sources, as the color terms, and thus the correction factors, will be erroneous. Also, 18 of these sources have previously been classified as BL Lac objects and are therefore unlikely to show strong emission lines in their optical spectra. Given these considerations, we do not regard their galaxy-template photometric redshifts to be reliable.

There are 79 sources which are well-fit by power-law templates ($\chi^2 < 30$) but have a low P_z . In other words, the spectral slope is well defined but the photometric redshift cannot be unambiguously determined. As expected, the best solutions are predominantly at low redshift ($z < 1.2$) with typical redshift

Fig. 6. SEDs for the eleven sources for which photometric redshifts larger than 1.2 were estimated (see Table 4) and one example for $z_{\text{phot}} < 1.2$. From bottom to top: CRATES J0402-2615, CRATES J1312-2156, OM 235, CRATES J0630-2406, SUMSS J053748-571828, PKS 0600-749, PKS 0332-403, CLASS J2352+1749, PKS 0047+023, PKS 0055-328, RX J0035.2+1515, and BZB J0543-5532.

probability distributions that are flat down to $z = 0$. For those we give the 90% upper limit of the photometric redshift. This subsample also includes eleven sources with a previously known redshift from spectroscopy or imaging, all in agreement with our limits.

We also provide the 90% upper limit for four sources for which the power-law and galaxy libraries give similarly good constraints ($P_{z,\text{pl}} \approx P_{z,\text{gal}} > 90\%$) but with very different redshift solutions. This degeneracy can occur, e.g., when a break in the SED is similarly well fit by the Lyman limit of a power-law model and with the 4000 Å break of a galaxy template. No $z_{\text{phot,best}}$ is given for ten sources for which no satisfactory fit ($\chi^2 > 30$) was obtained.

6. Discussion and conclusion

In this paper we presented redshift constraints for 103 blazars from the 2LAC catalog using UV-to-near-IR multi-band photometry obtained quasi-simultaneously with *Swift*/UVOT and GROND. We provided the first reliable redshift measurements for eight sources and new upper limits for an additional 66 targets. Of the eight sources with reliable redshift, seven are located at $z_{\text{phot}} > 1.3$. Six of those belong to the BL Lac population. For comparison, out of the total 395 BL Lac in the 2LAC sample only two sources have previously been known to lie at $z > 1.3$ (Fig. 7). Redshifts for these two, PKS 0332-403 and CRATES J1312-2156, have also been confirmed with our photometric observations.

Fig. 7. Redshift distribution for the nine BL Lac objects with reliable photometric redshifts (blue filled histogram) together with the distribution for the BL Lac in the 2LAC catalog (empty histogram; Ackermann et al. 2012). Sources with $z < 0.5$ have been omitted for clarity.

The six new BL Lac redshifts at $z > 1.3$ represent a dramatic (from two to eight) increase of the confirmed high- z *Fermi* sample and thus demonstrate the opportunity that the SED template fitting technique holds for obtaining photometric redshifts for BL Lac sources. For our sample, this was possible due to the densely-covered wide spectral range (160–2200 nm), necessary for a reliable constraint of the spectral slope, the excellent ultra-violet coverage to measure the Lyman-limit, and the quasi-simultaneity of the observations, important for minimizing the impact of source-intrinsic variability. The method applied in this work overcomes significant challenges inherent in other redshift techniques, namely the simplicity of the optical emission of BL Lacs manifested as the power-law-shaped synchrotron spectral component. This complicates spectroscopic redshift measurements, which are in most cases limited to the optical wavelength regime and thus insensitive to the Lyman-limit. Instead, spectroscopy relies on the detection of very faint emission features, mainly from the underlying host galaxy. It therefore requires very high signal-to-noise, often at the cost of long exposure times. On the other hand, the photometric redshift method for BL Lac does not require significant telescope time, in particular when data from efficient multi-channel instruments like GROND are available. Its weakness, however, is that the method relies on the detection of a particular spectral feature, which, albeit strong, is located in the rest-frame far-ultra-violet. For $z \lesssim 3$, this is only accessible with space-based ultra-violet telescopes, and even then usually limited to redshifts above $z \approx 1.2$, as shown above.

The sensitivity of this method to high-redshift sources also allows the placement of upper limits for those SEDs that do not show the imprint of the Lyman-limit. Only for three targets is this boundary above $z = 2$. In one case, CRATES J0250+1708 ($z < 3.1$), the optical counterpart is too faint ($r' \approx 20.7$ mag) and only upper limits in all six UVOT bands could be obtained. The counterpart of CRATES J0705-4847 is only detected in the GROND *J* (≈ 19.7 mag_{AB}) and *H* bands and its SED and redshift are thus poorly constrained. Finally, the SED of ATG20 J0124-0625 ($z < 2.46$) shows a significant break at $z \sim 1.9 \pm 0.5$. However, as the redshift probability distribution is broad, and the χ^2 of the power law fit comparable to that of a $z \approx 0.4$ solution for a galaxy template, the photometric redshift is considered to be unreliable. Except for those three, no other source in our sample has a best-fit photometric redshift at $z > 2$. Thus,

CRATES J0402-2615 can now be considered the most distant known BL Lac with a measured redshift of $z \approx 1.92$.

Figure 7 indicates that our high-redshift findings are the natural extension of the existing 2LAC redshift sample. However, due to the incompleteness of both samples, we refrain from drawing any quantitative conclusions at this stage. We note, however, that our result is in general agreement with the theoretical predictions from [Giommi et al. \(2012\)](#). A more detailed physical interpretation of the establishment of an increased fraction of high- z BL Lacs in the 2LAC sample will be reported separately.

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Table 1. Target list.

Name	FGL name ^a	α_{J2000}^b	δ_{J2000}^b	Offset ["] ^c	E_{B-V} [mag] ^d
CRATES J0001-0746	2FGLJ0000.9-0748	00:01:18.00	-07:46:26.9	0.2	0.03
CRATES J0009+0628	2FGLJ0009.0+0632	00:09:03.93	06:28:21.3	1.1	0.07
CRATES J0021-2550	2FGLJ0021.6-2551	00:21:32.56	-25:50:49.1	0.8	0.02
1RXS J002209.2-185333	2FGLJ0022.2-1853	00:22:09.26	-18:53:34.9	3.1	0.03
RX J0035.2+1515	2FGLJ0035.2+1515	00:35:14.71	15:15:04.2	3.4	0.07
FRBA J0037+1238 ^(*)	2FGLJ0037.8+1238	00:37:50.88	12:38:20.2	2.0	0.10
BZB J0045+2127	2FGLJ0045.3+2127	00:45:19.28	21:27:40.3	2.5	0.04
PKS 0047+023	2FGLJ0050.2+0234	00:49:43.23	02:37:04.1	2.4	0.02
PKS 0048-09	2FGLJ0050.6-0929	00:50:41.29	-09:29:04.7	2.0	0.03
RBS 119	2FGLJ0051.4-6241	00:51:16.64	-62:42:04.4	2.5	0.02
FRBA J0054-2455	2FGLJ0055.0-2454	00:54:46.76	-24:55:28.7	2.2	0.02
PKS 0055-328	2FGLJ0057.9-3236	00:58:02.23	-32:34:20.5	2.1	0.02
BZB J0114+1325	2FGLJ0114.7+1326	01:14:52.77	13:25:37.7	2.8	0.03
CLASS J0115+0356	2FGLJ0115.4+0358	01:15:40.51	03:56:43.3	1.8	0.03
BZB J0115+2519	2FGLJ0115.7+2518	01:15:46.14	25:19:53.4	2.1	0.10
AT20G J0124-0625	2FGLJ0124.5-0621	01:24:50.48	-06:25:00.4	1.8	0.04
CRATES J0154+0823	2FGLJ0153.9+0823	01:54:02.76	08:23:51.1	2.4	0.08
RBS 259	2FGLJ0157.2-5259	01:56:57.98	-53:02:00.0	3.6	0.03
CGRaBS J0158-3932	2FGLJ0158.3-3931	01:58:38.10	-39:32:03.6	0.3	0.02
CRATES J0159-2740	2FGLJ0159.6-2741	01:59:43.39	-27:40:38.4	1.2	0.02
BZB J0209-5229	2FGLJ0209.5-5229	02:09:21.59	-52:29:22.6	1.8	0.02
CGRaBS J0211+1051	2FGLJ0211.2+1050	02:11:13.18	10:51:34.8	1.3	0.14
CRATES J0216-6636	2FGLJ0216.9-6630	02:16:50.78	-66:36:42.7	0.4	0.04
RBS 334	2FGLJ0237.5-3603	02:37:34.03	-36:03:28.2	3.0	0.05
BZB J0238-3116	2FGLJ0238.6-3117	02:38:32.47	-31:16:58.0	2.4	0.03
CRATES J0250+1708	2FGLJ0250.6+1713	02:50:17.39	17:08:08.5	1.8	0.13
AT20G J0314-5104	2FGLJ0314.2-5106	03:14:25.69	-51:04:31.6	0.9	0.02
BZB J0323-0111	2FGLJ0323.6-0108	03:23:43.62	-01:11:46.1	1.8	0.08
CRATES J0325-5629	2FGLJ0325.1-5635	03:25:22.66	-56:29:05.0	2.1	0.03
CRATES J0325-5635 ^(*)	2FGLJ0325.1-5635	03:25:23.53	-56:35:44.6	2.8	0.03
PKS 0332-403	2FGLJ0334.2-4008	03:34:13.63	-40:08:25.3	3.1	0.02
CRATES J0334-3725	2FGLJ0334.3-3728	03:34:15.41	-37:25:43.1	0.6	0.01
PKS 0355-500	2FGLJ0357.0-4950	03:57:00.16	-49:55:48.6	2.2	0.01
CRATES J0402-2615	2FGLJ0402.0-2616	04:02:00.82	-26:15:39.0	1.6	0.03
PKS 0422+00	2FGLJ0424.7+0034	04:24:46.82	00:36:06.5	1.8	0.10
CRATES J0430-2507	2FGLJ0430.4-2507	04:30:16.02	-25:07:38.7	0.3	0.04
CRATES J0434-2015	2FGLJ0434.1-2014	04:34:07.90	-20:15:17.2	0.0	0.04
BZB J0448-1632	2FGLJ0448.5-1633	04:48:37.63	-16:32:43.4	0.7	0.06
CRATES J0505+0415	2FGLJ0505.4+0419	05:05:34.78	04:15:54.6	1.2	0.08
RBS 621	2FGLJ0506.7-5435	05:06:57.80	-54:35:03.9	4.9	0.03
CGRaBS J0509+0541	2FGLJ0509.4+0542	05:09:25.98	05:41:35.5	1.2	0.11
PKS 0516-621	2FGLJ0516.8-6207	05:16:44.93	-62:07:05.7	3.1	0.04
FRBA J0536-3343	2FGLJ0536.2-3348	05:36:29.07	-33:43:02.6	0.4	0.03
SUMSS J053748-571828	2FGLJ0537.7-5716	05:37:48.96	-57:18:30.4	2.6	0.06
1RXS J053810.0-390839	2FGLJ0538.5-3909	05:38:10.36	-39:08:42.7	1.5	0.03
BZB J0543-5532	2FGLJ0543.9-5532	05:43:57.22	-55:32:07.4	5.0	0.08
PKS 0600-749	2FGLJ0558.7-7501	05:58:46.02	-74:59:05.4	0.8	0.13
1ES 0602-482	2FGLJ0604.2-4817	06:04:08.64	-48:17:25.4	2.3	0.05
CRATES J0630-2406	2FGLJ0630.9-2406	06:30:59.52	-24:06:46.2	3.1	0.06
CRATES J0647-6058	2FGLJ0647.8-6102	06:47:40.86	-60:58:05.3	0.9	0.13
1ES 0647+250	2FGLJ0650.7+2505	06:50:46.49	25:02:59.7	2.6	0.10
PKS 0700-661	2FGLJ0700.3-6611	07:00:31.27	-66:10:45.4	1.3	0.12
CRATES J0705-4847	2FGLJ0706.7-4845	07:05:58.74	-48:47:24.4	2.6	0.11
CRATES J0718-4319	2FGLJ0718.7-4320	07:18:43.65	-43:19:50.0	3.8	0.10
CRATES J0811-7530	2FGLJ0811.1-7527	08:11:03.26	-75:30:27.9	0.8	0.14
AT20G J0814-1012	2FGLJ0814.0-1006	08:14:11.70	-10:12:10.4	3.3	0.16
BZB J0816-1311	2FGLJ0816.4-1311	08:16:27.21	-13:11:52.7	4.5	0.08
CGRaBS J0817-0933	2FGLJ0818.2-0935	08:17:49.75	-09:33:30.6	2.3	0.10
CRATES J0856+2057	2FGLJ0856.3+2058	08:56:39.74	20:57:43.3	1.1	0.03
CGRaBS J0856-1105	2FGLJ0856.6-1105	08:56:41.80	-11:05:14.4	0.4	0.05
SDSS J090226.91+205046.4	2FGLJ0902.4+2050	09:02:26.91	20:50:46.4	1.7	0.03
CRATES J0905+1358	2FGLJ0905.6+1357	09:05:34.99	13:58:06.4	3.1	0.04
CRATES-Va J0906-0905	2FGLJ0906.2-0906	09:06:18.07	-09:05:44.9	2.7	0.05
CRATES J0953-0840	2FGLJ0953.1-0839	09:53:02.72	-08:40:18.2	3.3	0.05
CGRaBS J1008+0621	2FGLJ1007.7+0621	10:08:00.82	06:21:21.2	1.9	0.02

Table 1. continued.

Name	FGL name ^a	α_{J2000}^b	δ_{J2000}^b	Offset ["] ^c	E_{B-V} [mag] ^d
BZB J1022-0113	2FGLJ1023.1-0115	10:22:43.75	-01:13:02.3	2.3	0.05
BZB J1023-4336	2FGLJ1023.8-4335	10:23:56.03	-43:36:01.7	2.2	0.12
PKS 1029-85	2FGLJ1026.3-8546	10:26:34.6	-85:43:14.4	0.5	0.15
PKS B1035-281	2FGLJ1037.5-2820	10:37:42.48	-28:23:04.0	1.2	0.06
CLASS J1049+2338 ^(*)	2FGLJ1048.6+2336	10:49:00.25	23:38:20.1	1.5	0.04
CLASS J1054+2210	2FGLJ1054.5+2212	10:54:30.62	22:10:55.1	0.3	0.02
BZB J1107+0222	2FGLJ1107.5+0223	11:07:35.92	02:22:24.7	1.9	0.04
OM 235	2FGLJ1124.2+2338	11:24:02.69	23:36:45.8	1.2	0.02
PKS B1130+008	2FGLJ1132.9+0033	11:32:45.63	00:34:27.8	2.0	0.03
PKS 1216-010	2FGLJ1218.5-0122	12:18:34.94	-01:19:54.3	1.3	0.03
BZB J1233-0144	2FGLJ1233.7-0145	12:33:41.33	-01:44:23.7	2.5	0.03
SDSS J125117.88+103907.2	2FGLJ1251.2+1045	12:51:17.89	10:39:07.4	2.7	0.02
1RXS J130421.2-435308	2FGLJ1304.3-4353	13:04:21.03	-43:53:10.1	3.1	0.13
1RXS J130737.8-425940	2FGLJ1307.5-4300	13:07:38.00	-42:59:38.9	4.4	0.11
4C +12.46	2FGLJ1309.3+1154	13:09:33.94	11:54:24.5	0.8	0.04
CRATES J1312-2156	2FGLJ1312.4-2157	13:12:31.55	-21:56:23.5	0.8	0.12
CRATES J1314+2348	2FGLJ1314.6+2348	13:14:43.81	23:48:26.8	2.9	0.01
BZB J1351+1114	2FGLJ1351.4+1115	13:51:20.85	11:14:53.0	0.9	0.03
PKS 1350+148	2FGLJ1353.3+1435	13:53:22.85	14:35:39.3	0.8	0.03
CRATES J1359-3746	2FGLJ1359.9-3746	13:59:49.75	-37:46:00.6	3.1	0.08
CGRaBS J1407-4302	2FGLJ1407.5-4257	–	–	–	0.09
SDSS J141826.33-023334.1	2FGLJ1418.4-0234	14:18:26.33	-02:33:34.0	2.7	0.06
PKS 1424+240	2FGLJ1427.0+2347	14:27:00.42	23:48:00.2	1.7	0.06
CRATES J1440+0610	2FGLJ1440.9+0611	14:40:52.93	06:10:16.3	1.1	0.04
PKS 1514+197	2FGLJ1516.9+1925	15:16:56.80	19:32:13.0	0.3	0.04
PG 1553+113	2FGLJ1555.7+1111	15:55:43.05	11:11:24.2	0.7	0.05
SUMSS J195945-472519	2FGLJ1959.9-4727	19:59:45.67	-47:25:19.0	2.7	0.06
PKS 2012-017	2FGLJ2015.1-0137	20:15:15.15	-01:37:32.5	0.8	0.12
CRATES J2039-1046	2FGLJ2039.1-1046	20:39:00.71	-10:46:41.6	1.2	0.06
CRATES J2103-6232	2FGLJ2103.6-6236	21:03:38.39	-62:32:25.7	1.3	0.04
PKS 2104-668	2FGLJ2108.9-6636	21:08:51.82	-66:37:22.6	1.1	0.03
PKS B2147+031	2FGLJ2149.6+0326	21:49:41.87	03:22:51.6	1.5	0.08
BZB J2221-5225	2FGLJ2221.6-5223	22:21:29.31	-52:25:27.7	2.5	0.02
PKS 2233-148	2FGLJ2236.5-1431	22:36:34.07	-14:33:22.0	1.0	0.04
BZB J2255+2410	2FGLJ2255.2+2408	22:55:15.47	24:10:11.3	2.5	0.07
BZB J2313+1444	2FGLJ2314.0+1446	23:13:57.33	14:44:23.3	3.5	0.06
PKS 2312-505	2FGLJ2315.7-5014	23:15:44.33	-50:18:39.4	1.3	0.01
1ES 2322-409	2FGLJ2324.7-4042	23:24:44.67	-40:40:49.0	5.4	0.02
CLASS J2352+1749	2FGLJ2352.0+1753	23:52:05.83	17:49:14.3	0.5	0.04

Notes. ^(a) *Fermi*/LAT ID. ^(b) GROND coordinates of the optical counterpart with typical uncertainties of 0".3 in both directions. ^(c) Offset of counterpart location from those given in Ackermann et al. (2012). ^(d) From Schlegel et al. (1998). ^(*) Extended morphology.

Table 2. *Swift*/UVOT photometry.

Name	UT date ^a	AB magnitude ^b						$\Delta m_{\text{GR} \rightarrow \text{UV}}^c$ [mag]
		<i>uvw2</i>	<i>uvm2</i>	<i>uvw1</i>	<i>u</i>	<i>b</i>	<i>v</i>	
CRATES J0001-0746	2010-10-14 10:40	18.99 ± 0.08	18.74 ± 0.10	18.58 ± 0.09	18.18 ± 0.09	17.88 ± 0.10	17.90 ± 0.19	0.01
CRATES J0009+0628	2010-12-07 08:55	20.16 ± 0.15	19.71 ± 0.19	19.69 ± 0.18	19.24 ± 0.19	18.51 ± 0.18	18.14 ± 0.24	-0.24
CRATES J0021-2550	2010-11-18 18:32	18.86 ± 0.08	18.90 ± 0.27	18.57 ± 0.09	18.15 ± 0.10	17.82 ± 0.11	17.93 ± 0.21	0.09
1RXS J002209.2-185333	2010-11-18 13:49	18.36 ± 0.07	17.95 ± 0.08	17.91 ± 0.08	17.48 ± 0.07	17.20 ± 0.08	16.97 ± 0.12	-0.08
RX J0035.2+1515	2011-01-14 01:08	18.36 ± 0.08	17.95 ± 0.08	17.91 ± 0.08	17.48 ± 0.07	17.20 ± 0.08	16.97 ± 0.12	-0.24
FRBA J0037+1238	2010-11-22 05:55	18.53 ± 0.10	18.60 ± 0.13	17.96 ± 0.10	17.59 ± 0.09	16.83 ± 0.08	16.22 ± 0.09	-0.53
BZB J0045+2127	2010-10-11 15:21	17.99 ± 0.08	17.86 ± 0.08	17.73 ± 0.08	17.37 ± 0.07	17.33 ± 0.07	17.01 ± 0.01	0.08
PKS 0047+023	2010-10-04 14:24	21.17 ± 0.15	20.57 ± 0.17	20.62 ± 0.19	19.56 ± 0.14	19.23 ± 0.19	19.14 ± 0.37	0.01
PKS 0048-09	2010-11-18 23:16	17.64 ± 0.05	17.48 ± 0.06	17.25 ± 0.05	16.74 ± 0.04	16.39 ± 0.04	16.22 ± 0.06	0.12
RBS 119	2010-09-23 21:48	17.97 ± 0.05	18.00 ± 0.09	17.91 ± 0.07	17.50 ± 0.06	17.42 ± 0.07	17.38 ± 0.14	0.20
FRBA J0054-2455	2010-11-13 10:18	17.54 ± 0.05	17.38 ± 0.06	17.35 ± 0.06	17.06 ± 0.05	16.85 ± 0.06	16.78 ± 0.09	-0.33
PKS 0055-328	2010-09-23 01:00	19.16 ± 0.09	18.75 ± 0.10	18.77 ± 0.10	18.26 ± 0.10	17.61 ± 0.09	17.60 ± 0.15	0.18
BZB J0114+1325	2010-11-22 04:23	17.78 ± 0.05	17.72 ± 0.07	17.61 ± 0.07	17.20 ± 0.06	16.98 ± 0.07	16.86 ± 0.10	-
CLASS J0115+0356	2010-11-22 02:46	18.82 ± 0.08	18.67 ± 0.09	18.66 ± 0.10	18.04 ± 0.09	18.01 ± 0.12	17.82 ± 0.19	0.22
BZB J0115+2519	2011-06-03 13:24	18.90 ± 0.11	18.71 ± 0.13	18.54 ± 0.06	18.08 ± 0.05	17.88 ± 0.17	18.52 ± 0.68	-0.00
AT20G J0124-0625	2010-11-22 01:11	>22.18	>21.58	>21.21	>20.10	>19.58	>18.56	-
CRATES J0154+0823	2011-01-06 05:09	17.68 ± 0.07	17.61 ± 0.09	17.36 ± 0.07	16.81 ± 0.06	16.63 ± 0.06	16.46 ± 0.08	0.07
RBS 259	2010-11-04 07:42	19.14 ± 0.06	19.06 ± 0.09	18.86 ± 0.08	18.53 ± 0.07	18.36 ± 0.09	18.46 ± 0.17	0.28
CGRaBS J0158-3932	2010-11-18 20:15	-	18.43 ± 0.09	18.18 ± 0.08	17.86 ± 0.07	17.62 ± 0.08	17.58 ± 0.13	-0.02
CRATES J0159-2740	2010-11-20 10:45	18.54 ± 0.06	18.28 ± 0.09	18.18 ± 0.08	17.82 ± 0.07	17.75 ± 0.09	17.43 ± 0.12	0.14
BZB J0209-5229	2010-11-04 02:55	17.82 ± 0.05	17.79 ± 0.07	17.60 ± 0.06	17.30 ± 0.06	17.00 ± 0.06	16.69 ± 0.08	-0.00
CGRaBS J0211+1051	2011-01-29 02:30	14.93 ± 0.07	14.88 ± 0.06	14.48 ± 0.06	13.96 ± 0.05	13.63 ± 0.04	13.40 ± 0.04	-
CRATES J0216-6636	2010-09-23 10:39	18.35 ± 0.08	18.18 ± 0.11	18.14 ± 0.09	17.96 ± 0.10	17.44 ± 0.10	17.57 ± 0.18	0.01
RBS 334	2010-10-24 18:17	18.34 ± 0.06	18.49 ± 0.35	18.12 ± 0.08	17.99 ± 0.08	17.65 ± 0.09	17.63 ± 0.15	0.24
BZB J0238-3116	2010-11-12 00:31	17.23 ± 0.05	17.19 ± 0.07	17.13 ± 0.06	16.86 ± 0.05	16.81 ± 0.05	16.46 ± 0.09	0.17
CRATES J0250+1708	2010-10-22 09:46	>20.31	>19.84	>19.50	>18.99	>18.16	>17.55	-
AT20G J0314-5104	2010-10-29 10:30	19.63 ± 0.09	19.39 ± 0.19	19.13 ± 0.10	18.57 ± 0.10	18.33 ± 0.11	18.00 ± 0.16	0.03
BZB J0323-0111	2010-10-09 23:21	18.45 ± 0.09	18.30 ± 0.09	17.97 ± 0.08	17.67 ± 0.08	17.27 ± 0.08	17.42 ± 0.14	-0.01
CRATES J0325-5629	2010-10-31 20:23	19.01 ± 0.08	18.89 ± 0.11	18.84 ± 0.10	18.78 ± 0.13	18.68 ± 0.17	>17.95	-
CRATES J0325-5635	2010-10-31 12:20	19.00 ± 0.08	18.77 ± 0.10	18.47 ± 0.09	17.55 ± 0.06	16.56 ± 0.05	15.89 ± 0.06	-
PKS 0332-403	2010-10-10 23:25	20.25 ± 0.11	19.59 ± 0.13	19.20 ± 0.10	18.54 ± 0.09	18.35 ± 0.11	17.87 ± 0.15	0.45
CRATES J0334-3725	2010-10-09 00:58	17.75 ± 0.04	17.53 ± 0.05	17.31 ± 0.05	16.95 ± 0.04	16.71 ± 0.04	16.56 ± 0.06	0.29
PKS 0355-500	2010-10-24 19:53	19.06 ± 0.08	18.96 ± 0.08	18.72 ± 0.09	18.29 ± 0.08	18.00 ± 0.09	17.56 ± 0.10	-0.01
CRATES J0402-2615	2010-10-21 19:42	21.92 ± 0.27	21.13 ± 0.26	20.09 ± 0.14	19.60 ± 0.14	19.06 ± 0.15	18.68 ± 0.22	0.03
PKS 0422+00	2010-07-10 17:00	16.90 ± 0.06	16.90 ± 0.06	16.70 ± 0.06	16.15 ± 0.05	15.94 ± 0.04	-	0.22
CRATES J0430-2507	2010-10-18 03:26	19.28 ± 0.09	19.17 ± 0.14	18.72 ± 0.10	18.32 ± 0.11	18.26 ± 0.14	17.66 ± 0.17	-
CRATES J0434-2015	2010-10-20 14:47	19.98 ± 0.12	19.91 ± 0.17	19.35 ± 0.13	18.95 ± 0.13	18.45 ± 0.13	18.17 ± 0.20	-0.37
BZB J0448-1632	2010-10-26 04:07	18.25 ± 0.07	18.21 ± 0.08	18.17 ± 0.09	17.77 ± 0.08	-	17.59 ± 0.16	-
CRATES J0505+0415	2010-12-08 10:53	18.64 ± 0.09	18.63 ± 0.11	18.45 ± 0.10	18.07 ± 0.10	17.80 ± 0.11	17.56 ± 0.16	0.09
RBS 621	2010-10-29 00:58	17.90 ± 0.06	17.74 ± 0.07	17.77 ± 0.07	17.60 ± 0.07	17.25 ± 0.07	17.14 ± 0.12	-0.14
CGRaBS J0509+0541	2010-12-08 09:16	16.12 ± 0.06	16.08 ± 0.06	15.69 ± 0.06	15.32 ± 0.05	14.95 ± 0.05	14.78 ± 0.04	0.14
PKS 0516-621	2010-11-06 14:46	19.58 ± 0.08	19.25 ± 0.09	18.96 ± 0.08	18.50 ± 0.08	18.09 ± 0.08	17.85 ± 0.12	0.07
FRBA J0536-3343	2010-11-05 00:18	17.64 ± 0.05	17.52 ± 0.07	17.36 ± 0.06	17.11 ± 0.05	16.97 ± 0.06	16.93 ± 0.10	0.10
SUMSS J053748-571828	2010-11-23 19:30	19.51 ± 0.11	18.45 ± 0.11	18.45 ± 0.10	17.85 ± 0.08	17.77 ± 0.10	17.34 ± 0.14	0.14
1RXS J053810.0-390839	2010-11-22 16:21	>20.17	-	19.85 ± 0.17	19.24 ± 0.15	19.22 ± 0.22	-	0.30
BZB J0543-5532	2010-11-12 21:49	17.74 ± 0.06	17.69 ± 0.08	17.56 ± 0.07	17.34 ± 0.05	17.18 ± 0.06	17.09 ± 0.11	0.08
PKS 0600-749	2010-11-16 20:42	19.21 ± 0.15	18.89 ± 0.17	18.64 ± 0.15	18.05 ± 0.12	17.55 ± 0.12	17.26 ± 0.18	0.07
1ES 0602-482	2010-10-29 05:42	18.44 ± 0.05	18.35 ± 0.07	18.23 ± 0.07	17.96 ± 0.06	17.91 ± 0.08	17.79 ± 0.12	0.02
CRATES J0630-2406	2010-12-11 04:48	18.16 ± 0.06	17.32 ± 0.06	16.94 ± 0.05	16.48 ± 0.04	16.22 ± 0.04	16.04 ± 0.06	0.13
CRATES J0647-6058	2010-11-23 18:03	>20.28	>19.71	20.17 ± 0.25	20.06 ± 0.31	19.55 ± 0.34	>17.68	-
1ES 0647+250	2010-11-11 11:44	16.80 ± 0.06	16.82 ± 0.06	16.55 ± 0.05	16.17 ± 0.05	15.97 ± 0.04	15.79 ± 0.05	0.08
PKS 0700-661	2010-12-08 14:05	17.20 ± 0.08	17.10 ± 0.09	16.83 ± 0.07	16.38 ± 0.06	15.99 ± 0.06	15.89 ± 0.07	0.01
CRATES J0705-4847	2010-12-08 22:22	-	-	-	-	-	-	-
CRATES J0718-4319	2010-12-07 14:16	18.16 ± 0.08	18.04 ± 0.10	17.78 ± 0.10	17.51 ± 0.08	17.27 ± 0.09	17.07 ± 0.12	0.21
CRATES J0811-7530	2010-10-31 19:32	18.82 ± 0.14	18.64 ± 0.19	18.11 ± 0.14	17.74 ± 0.14	17.50 ± 0.17	17.48 ± 0.28	-0.18
AT20G J0814-1012	2011-01-11 01:42	18.14 ± 0.12	18.04 ± 0.14	17.86 ± 0.14	17.20 ± 0.11	16.91 ± 0.11	17.03 ± 0.18	0.09
BZB J0816-1311	2011-01-12 21:00	17.66 ± 0.07	17.53 ± 0.09	17.49 ± 0.08	17.15 ± 0.07	17.09 ± 0.08	17.00 ± 0.12	-
CGRaBS J0817-0933	2011-01-08 15:26	19.47 ± 0.13	19.42 ± 0.17	19.08 ± 0.15	18.38 ± 0.12	17.96 ± 0.13	17.61 ± 0.17	0.07
CRATES J0856+2057	2010-09-25 14:08	19.59 ± 0.11	19.59 ± 0.17	19.18 ± 0.14	18.90 ± 0.18	18.67 ± 0.29	18.51 ± 0.56	-
CGRaBS J0856-1105	2010-09-27 16:10	19.33 ± 0.17	18.88 ± 0.21	18.57 ± 0.19	18.30 ± 0.20	17.90 ± 0.24	17.29 ± 0.29	0.10
SDSS J090226.91+205046.4	2011-01-13 08:00	17.58 ± 0.06	17.41 ± 0.08	17.31 ± 0.07	16.91 ± 0.06	16.74 ± 0.07	16.69 ± 0.12	0.20
CRATES J0905+1358	2011-01-10 22:21	17.78 ± 0.05	17.68 ± 0.06	17.54 ± 0.06	17.12 ± 0.05	16.83 ± 0.06	16.82 ± 0.09	0.04
CRATES-Va J0906-0905	2010-12-06 17:32	19.35 ± 0.09	18.77 ± 0.11	18.59 ± 0.10	17.90 ± 0.09	17.85 ± 0.11	17.37 ± 0.14	0.56
CRATES J0953-0840	2011-01-13 09:37	17.57 ± 0.05	17.44 ± 0.06	17.29 ± 0.06	16.99 ± 0.05	16.73 ± 0.05	16.69 ± 0.08	0.08
CGRaBS J1008+0621	2010-12-07 22:46	18.57 ± 0.07	-	18.16 ± 0.08	17.61 ± 0.07	17.17 ± 0.08	-	0.07

Table 2. continued.

Name	UT date ^a	AB magnitude ^b						$\Delta m_{\text{GR} \rightarrow \text{UV}}^c$ [mag]
		<i>uvw2</i>	<i>uvm2</i>	<i>uvw1</i>	<i>u</i>	<i>b</i>	<i>v</i>	
BZB J1022-0113	2010-12-07 00:15	18.20 ± 0.07	18.21 ± 0.09	18.05 ± 0.09	17.71 ± 0.08	17.61 ± 0.11	17.63 ± 0.22	0.13
BZB J1023-4336	2011-01-17 16:40	17.32 ± 0.08	17.28 ± 0.09	16.97 ± 0.07	16.57 ± 0.06	16.36 ± 0.06	16.27 ± 0.08	0.21
PKS 1029-85	2011-01-13 20:49	17.87 ± 0.10	17.87 ± 0.11	17.60 ± 0.10	17.16 ± 0.08	16.91 ± 0.09	16.65 ± 0.10	–
PKS B1035-281	2010-12-07 19:30	19.45 ± 0.10	19.05 ± 0.13	19.02 ± 0.13	18.89 ± 0.15	18.77 ± 0.20	19.05 ± 0.59	–
CLASS J1049+2338	2011-01-19 07:18	20.83 ± 0.20	20.99 ± 0.35	20.41 ± 0.25	19.39 ± 0.19	19.33 ± 0.30	18.36 ± 0.27	–
CLASS J1054+2210	2011-01-19 04:06	18.36 ± 0.06	18.20 ± 0.08	18.06 ± 0.07	17.67 ± 0.06	17.39 ± 0.07	17.20 ± 0.12	0.04
BZB J1107+0222	2011-02-08 18:48	19.76 ± 0.14	19.06 ± 0.18	19.08 ± 0.15	18.41 ± 0.14	18.51 ± 0.20	18.26 ± 0.33	0.41
OM 235	2011-04-21 13:25	21.85 ± 0.25	20.69 ± 0.19	20.19 ± 0.15	19.50 ± 0.14	19.32 ± 0.19	19.26 ± 0.38	0.01
PKS B1130+008	2011-04-22 20:13	19.78 ± 0.09	19.64 ± 0.11	19.37 ± 0.10	18.98 ± 0.11	18.54 ± 0.12	18.08 ± 0.16	0.14
PKS 1216-010	2011-04-24 18:44	19.47 ± 0.09	19.25 ± 0.12	19.17 ± 0.12	18.43 ± 0.10	18.30 ± 0.13	18.01 ± 0.20	0.30
BZB J1233-0144	2010-11-23 16:44	20.17 ± 0.14	19.63 ± 0.14	19.22 ± 0.13	19.16 ± 0.20	18.87 ± 0.32	>17.23	–
SDSS J125117.88+103907.2	2011-04-24 17:18	18.89 ± 0.07	18.77 ± 0.10	18.46 ± 0.09	18.32 ± 0.09	18.14 ± 0.11	17.73 ± 0.15	0.15
1RXS J130421.2-435308	2011-03-02 20:28	16.79 ± 0.07	16.78 ± 0.07	16.47 ± 0.07	16.09 ± 0.05	15.84 ± 0.05	15.71 ± 0.05	–0.17
1RXS J130737.8-425940	2011-02-24 23:21	17.20 ± 0.06	17.15 ± 0.07	16.84 ± 0.06	16.39 ± 0.05	16.10 ± 0.05	15.92 ± 0.06	0.31
4C +12.46	2010-11-29 14:12	20.17 ± 0.09	19.77 ± 0.11	19.64 ± 0.11	18.95 ± 0.10	18.72 ± 0.12	18.28 ± 0.16	0.25
CRATES J1312-2156	2010-08-31 22:03	19.49 ± 0.17	18.80 ± 0.18	17.98 ± 0.11	17.56 ± 0.10	17.27 ± 0.12	17.18 ± 0.21	0.38
CRATES J1314+2348	2011-04-24 15:46	17.93 ± 0.05	17.70 ± 0.07	17.55 ± 0.06	17.15 ± 0.05	16.83 ± 0.06	16.57 ± 0.08	–0.01
BZB J1351+1114	2010-12-02 22:41	18.52 ± 0.05	18.36 ± 0.07	18.29 ± 0.07	17.97 ± 0.07	17.82 ± 0.09	17.87 ± 0.18	0.23
PKS 1350+148	2011-04-25 17:18	18.65 ± 0.07	18.54 ± 0.09	18.32 ± 0.09	17.83 ± 0.07	17.51 ± 0.08	17.38 ± 0.13	0.02
CRATES J1359-3746	2011-03-18 02:37	18.80 ± 0.10	18.71 ± 0.11	18.40 ± 0.10	17.83 ± 0.09	17.57 ± 0.11	17.19 ± 0.14	–0.18
CGRaBS J1407-4302	–	–	–	–	–	–	–	–
SDSS J141826.33-023334.1	2010-08-31 03:00	16.69 ± 0.05	16.59 ± 0.05	16.36 ± 0.05	16.00 ± 0.04	15.85 ± 0.05	15.63 ± 0.06	0.24
PKS 1424+240	2010-11-21 19:48	15.22 ± 0.05	15.13 ± 0.05	14.91 ± 0.04	14.52 ± 0.04	14.34 ± 0.03	–	–0.08
CRATES J1440+0610	2010-08-31 15:28	18.36 ± 0.05	18.36 ± 0.08	18.04 ± 0.07	17.77 ± 0.06	17.41 ± 0.07	17.34 ± 0.12	0.12
PKS 1514+197	2010-12-05 14:41	19.77 ± 0.11	19.71 ± 0.15	18.97 ± 0.14	18.59 ± 0.13	18.19 ± 0.14	–	–0.66
PG 1553+113	2010-02-05 20:58	15.53 ± 0.04	15.44 ± 0.04	15.29 ± 0.03	14.91 ± 0.03	14.72 ± 0.02	14.57 ± 0.02	0.18
SUMSS J195945-472519	2010-08-29 09:14	17.86 ± 0.06	17.67 ± 0.06	17.54 ± 0.06	17.13 ± 0.05	16.94 ± 0.05	16.92 ± 0.06	0.10
PKS 2012-017	2011-10-27 04:01	19.10 ± 0.11	18.87 ± 0.19	18.81 ± 0.15	18.08 ± 0.12	17.86 ± 0.14	17.61 ± 0.20	0.13
CRATES J2039-1046	2010-12-14 10:55	18.08 ± 0.06	18.00 ± 0.06	17.75 ± 0.05	17.24 ± 0.05	16.95 ± 0.06	16.69 ± 0.09	–0.96
CRATES J2103-6232	2010-09-22 09:48	17.57 ± 0.05	17.45 ± 0.06	17.25 ± 0.06	16.91 ± 0.05	16.65 ± 0.06	16.56 ± 0.08	0.19
PKS 2104-668	2010-08-30 12:41	19.36 ± 0.08	19.32 ± 0.11	19.25 ± 0.11	18.57 ± 0.10	18.27 ± 0.11	18.32 ± 0.20	0.09
PKS B2147+031	2010-10-14 07:27	19.03 ± 0.10	18.53 ± 0.11	18.57 ± 0.11	18.01 ± 0.10	17.72 ± 0.11	17.31 ± 0.14	0.00
BZB J2221-5225	2010-09-22 11:39	17.25 ± 0.04	17.14 ± 0.05	17.07 ± 0.05	16.81 ± 0.04	16.57 ± 0.04	–	0.04
PKS 2233-148	2010-09-09 21:57	20.91 ± 0.10	21.01 ± 0.17	20.16 ± 0.11	19.53 ± 0.11	19.13 ± 0.13	18.66 ± 0.17	–0.17
BZB J2255+2410	2010-09-24 23:28	18.42 ± 0.08	18.23 ± 0.09	18.04 ± 0.08	17.65 ± 0.08	17.55 ± 0.09	17.23 ± 0.12	0.30
PKS 2312-505	2010-10-07 06:47	20.33 ± 0.13	20.35 ± 0.19	19.86 ± 0.15	19.21 ± 0.14	18.79 ± 0.15	18.95 ± 0.33	–0.12
BZB J2313+1444	2011-09-16 10:47	19.43 ± 0.13	19.47 ± 0.22	19.15 ± 0.18	18.55 ± 0.15	18.21 ± 0.18	17.14 ± 0.15	0.24
IES 2322-409	2010-10-30 05:42	16.39 ± 0.04	16.27 ± 0.04	16.21 ± 0.04	15.88 ± 0.04	15.72 ± 0.04	15.54 ± 0.05	0.30
CLASS J2352+1749	2010-10-14 13:52	20.25 ± 0.14	20.24 ± 0.23	19.76 ± 0.18	19.37 ± 0.18	18.83 ± 0.20	18.80 ± 0.38	–0.02

Notes. ^(a) Approximate start time of *uvw2* exposure. ^(b) Corrected for Galactic foreground reddening. Upper limits are 3- σ . ^(c) Variability-correction factor to be applied to GROND photometry (see text).

Table 3. GROND photometry.

Name	UT date ^a	AB magnitude ^b						
		g'	r'	i'	z'	J	H	K_s
CRATES J0001-0746	2010-10-14 03:33	17.80 ± 0.05	17.43 ± 0.05	17.18 ± 0.05	16.86 ± 0.05	16.48 ± 0.05	16.16 ± 0.06	15.76 ± 0.08
CRATES J0009+0628	2010-12-12 00:41	18.91 ± 0.05	18.49 ± 0.05	18.15 ± 0.05	17.89 ± 0.06	17.34 ± 0.06	16.90 ± 0.06	16.46 ± 0.08
CRATES J0021-2550	2010-11-23 00:13	17.69 ± 0.05	17.43 ± 0.05	17.20 ± 0.05	16.98 ± 0.05	16.76 ± 0.05	16.51 ± 0.05	16.15 ± 0.07
1RXS J002209.2-185333	2010-11-23 00:21	17.30 ± 0.05	16.92 ± 0.05	16.71 ± 0.05	16.51 ± 0.05	16.22 ± 0.05	16.00 ± 0.06	15.57 ± 0.08
RX J0035.2+1515	2011-01-14 00:48	17.39 ± 0.05	17.10 ± 0.05	16.96 ± 0.05	16.77 ± 0.05	16.41 ± 0.06	16.17 ± 0.05	15.92 ± 0.08
FRBA J0037+1238	2010-11-24 00:29	17.32 ± 0.57	15.59 ± 0.69	15.13 ± 0.37	15.13 ± 0.34	15.98 ± 0.05	15.84 ± 0.05	15.46 ± 0.08
BZB J0045+2127	2010-10-16 03:41	17.22 ± 0.05	17.03 ± 0.05	16.87 ± 0.05	16.71 ± 0.05	16.24 ± 0.05	15.97 ± 0.05	15.76 ± 0.07
PKS 0047+023	2010-10-06 04:31	19.14 ± 0.05	18.68 ± 0.05	18.29 ± 0.06	17.94 ± 0.06	17.35 ± 0.05	17.02 ± 0.05	16.45 ± 0.07
PKS 0048-09	2010-11-22 03:39	16.21 ± 0.09	15.92 ± 0.13	15.74 ± 0.15	15.31 ± 0.05	14.91 ± 0.05	14.55 ± 0.05	14.25 ± 0.07
RBS 119	2010-09-24 05:47	17.19 ± 0.05	17.04 ± 0.05	16.90 ± 0.05	16.73 ± 0.05	16.50 ± 0.05	16.35 ± 0.06	16.11 ± 0.07
FRBA J0054-2455	2010-11-24 00:20	17.48 ± 0.11	17.29 ± 0.11	17.12 ± 0.11	16.81 ± 0.11	16.67 ± 0.05	16.50 ± 0.06	16.09 ± 0.08
PKS 0055-328	2010-09-24 05:20	17.36 ± 0.05	16.99 ± 0.05	16.72 ± 0.05	16.46 ± 0.05	16.09 ± 0.05	15.70 ± 0.05	15.40 ± 0.08
BZB J0114+1325	2010-11-24 00:32	17.01 ± 0.05	16.86 ± 0.06	16.67 ± 0.06	16.45 ± 0.05	16.25 ± 0.05	16.05 ± 0.06	15.74 ± 0.08
CLASS J0115+0356	2010-11-24 00:41	17.74 ± 0.05	17.51 ± 0.05	17.32 ± 0.05	17.10 ± 0.05	16.85 ± 0.06	16.53 ± 0.06	16.30 ± 0.08
BZB J0115+2519	2011-06-03 10:17	17.83 ± 0.06	17.52 ± 0.05	17.29 ± 0.05	17.09 ± 0.05	16.75 ± 0.06	16.55 ± 0.06	16.45 ± 0.09
AT20G J0124-0625	2010-11-22 03:55	19.53 ± 0.06	19.14 ± 0.06	18.93 ± 0.06	18.51 ± 0.06	18.11 ± 0.06	17.88 ± 0.08	17.35 ± 0.09
CRATES J0154+0823	2011-01-07 02:05	16.51 ± 0.06	16.27 ± 0.05	16.04 ± 0.05	15.86 ± 0.05	15.56 ± 0.05	15.27 ± 0.05	14.86 ± 0.07
RBS 259	2010-11-28 00:29	17.78 ± 0.05	17.73 ± 0.05	17.45 ± 0.05	17.24 ± 0.05	16.84 ± 0.06	16.62 ± 0.06	16.20 ± 0.08
CGRaBS J0158-3932	2010-11-22 04:11	17.60 ± 0.05	17.27 ± 0.05	17.12 ± 0.05	16.70 ± 0.05	16.39 ± 0.06	16.09 ± 0.05	15.80 ± 0.08
CRATES J0159-2740	2010-11-22 04:03	17.57 ± 0.05	17.36 ± 0.05	17.22 ± 0.05	16.86 ± 0.05	16.48 ± 0.06	16.29 ± 0.06	15.87 ± 0.07
BZB J0209-5229	2010-10-28 06:14	16.96 ± 0.05	16.68 ± 0.05	16.53 ± 0.05	16.33 ± 0.05	15.80 ± 0.05	15.74 ± 0.05	15.46 ± 0.07
CGRaBS J0211+1051	2011-01-30 00:49	13.59 ± 0.06	13.29 ± 0.05	13.09 ± 0.05	12.81 ± 0.05	12.61 ± 0.05	12.44 ± 0.05	11.99 ± 0.07
CRATES J0216-6636	2010-09-25 07:19	17.40 ± 0.05	17.21 ± 0.05	17.03 ± 0.05	16.84 ± 0.05	16.57 ± 0.05	16.32 ± 0.06	15.96 ± 0.08
RBS 334	2011-01-18 00:53	17.37 ± 0.05	17.17 ± 0.05	17.00 ± 0.05	16.86 ± 0.05	16.60 ± 0.05	16.34 ± 0.06	15.98 ± 0.08
BZB J0238-3116	2010-10-24 05:47	16.61 ± 0.05	16.47 ± 0.05	16.32 ± 0.05	16.10 ± 0.05	15.81 ± 0.06	15.59 ± 0.06	15.53 ± 0.08
CRATES J0250+1708	2010-11-01 03:02	21.38 ± 0.09	20.71 ± 0.07	19.98 ± 0.07	19.80 ± 0.07	18.99 ± 0.09	18.56 ± 0.09	17.95 ± 0.12
AT20G J0314-5104	2010-11-01 04:41	18.23 ± 0.05	17.83 ± 0.05	17.60 ± 0.05	17.34 ± 0.05	16.93 ± 0.06	16.54 ± 0.05	16.25 ± 0.08
BZB J0323-0111	2010-10-16 06:13	17.25 ± 0.05	17.06 ± 0.05	16.87 ± 0.05	16.66 ± 0.05	16.42 ± 0.05	16.24 ± 0.05	15.79 ± 0.08
CRATES J0325-5629	2010-11-05 00:45	18.68 ± 0.05	18.72 ± 0.05	18.91 ± 0.06	18.84 ± 0.06	18.44 ± 0.11	18.60 ± 0.12	19.18 ± 0.44
CRATES J0325-5635	2010-11-05 00:52	16.87 ± 0.05	16.35 ± 0.06	16.07 ± 0.06	15.72 ± 0.06	15.06 ± 0.05	14.87 ± 0.05	14.67 ± 0.07
PKS 0332-403	2010-10-11 08:42	17.84 ± 0.05	17.48 ± 0.05	17.13 ± 0.05	16.86 ± 0.05	16.36 ± 0.05	15.97 ± 0.06	15.55 ± 0.07
CRATES J0334-3725	2010-10-16 06:04	16.39 ± 0.05	16.21 ± 0.05	16.01 ± 0.05	15.79 ± 0.05	15.52 ± 0.05	15.23 ± 0.05	14.86 ± 0.07
PKS 0355-500	2010-10-24 05:56	17.69 ± 0.05	17.35 ± 0.05	17.07 ± 0.05	16.78 ± 0.05	16.43 ± 0.05	16.07 ± 0.05	15.76 ± 0.07
CRATES J0402-2615	2010-10-21 05:57	18.94 ± 0.05	18.41 ± 0.05	18.21 ± 0.05	18.03 ± 0.05	17.51 ± 0.06	17.16 ± 0.07	16.85 ± 0.08
PKS 0422+00	2010-07-10 10:16	15.66 ± 0.05	15.37 ± 0.05	15.14 ± 0.05	14.93 ± 0.05	14.50 ± 0.05	14.27 ± 0.05	13.85 ± 0.07
CRATES J0430-2507	2010-10-21 06:06	17.93 ± 0.05	17.56 ± 0.05	—	17.08 ± 0.05	16.67 ± 0.05	16.39 ± 0.05	15.96 ± 0.07
CRATES J0434-2015	2010-10-21 06:14	19.08 ± 0.05	18.48 ± 0.05	18.22 ± 0.05	17.89 ± 0.05	17.52 ± 0.05	16.97 ± 0.06	16.53 ± 0.08
BZB J0448-1632	2010-10-26 08:54	17.56 ± 0.05	17.41 ± 0.05	17.29 ± 0.05	17.11 ± 0.05	16.96 ± 0.05	16.74 ± 0.05	16.49 ± 0.08
CRATES J0505+0415	2010-12-10 07:44	17.65 ± 0.05	17.31 ± 0.05	17.13 ± 0.05	16.92 ± 0.05	16.62 ± 0.05	16.35 ± 0.05	16.01 ± 0.08
RBS 621	2010-11-06 08:44	17.50 ± 0.05	17.38 ± 0.05	17.26 ± 0.05	17.12 ± 0.05	16.85 ± 0.05	16.71 ± 0.06	16.45 ± 0.08
CGRaBS J0509+0541	2010-12-10 07:53	14.75 ± 0.05	14.45 ± 0.05	14.28 ± 0.05	14.02 ± 0.05	13.83 ± 0.05	13.51 ± 0.05	13.20 ± 0.07
PKS 0516-621	2010-11-06 06:48	17.98 ± 0.05	17.73 ± 0.05	17.47 ± 0.05	17.21 ± 0.05	16.77 ± 0.05	16.38 ± 0.05	15.94 ± 0.07
FRBA J0536-3343	2010-11-06 08:53	16.86 ± 0.05	16.79 ± 0.05	16.75 ± 0.05	16.54 ± 0.05	16.24 ± 0.05	16.03 ± 0.05	15.86 ± 0.07
SUMSS J053748-571828	2010-11-23 08:00	17.61 ± 0.05	17.48 ± 0.05	17.31 ± 0.05	17.09 ± 0.05	16.75 ± 0.05	16.51 ± 0.06	16.29 ± 0.08
1RXS J053810.0-390839	2010-11-09 05:04	18.85 ± 0.05	18.47 ± 0.05	18.16 ± 0.05	17.95 ± 0.05	17.46 ± 0.06	17.24 ± 0.06	16.81 ± 0.08
BZB J0543-5532	2010-11-13 08:06	17.07 ± 0.05	16.89 ± 0.05	16.73 ± 0.05	16.50 ± 0.05	16.25 ± 0.05	16.08 ± 0.05	15.81 ± 0.08
PKS 0600-749	2010-11-16 08:02	17.41 ± 0.06	17.02 ± 0.05	16.79 ± 0.05	16.50 ± 0.05	16.12 ± 0.05	15.79 ± 0.05	15.38 ± 0.07
1ES 0602-482	2010-10-28 23:53	17.86 ± 0.05	17.67 ± 0.05	17.58 ± 0.05	17.21 ± 0.05	16.92 ± 0.05	16.71 ± 0.05	16.46 ± 0.08
CRATES J0630-2406	2010-09-28 08:06	16.16 ± 0.05	15.90 ± 0.05	15.73 ± 0.05	15.55 ± 0.05	15.28 ± 0.05	14.97 ± 0.05	14.70 ± 0.07
CRATES J0647-6058	2010-11-23 08:09	19.70 ± 0.07	19.30 ± 0.06	19.15 ± 0.06	18.93 ± 0.06	18.19 ± 0.07	17.93 ± 0.07	17.46 ± 0.09
1ES 0647+250	2010-11-13 08:24	15.86 ± 0.05	15.69 ± 0.05	15.56 ± 0.05	15.45 ± 0.05	15.19 ± 0.05	15.07 ± 0.05	14.79 ± 0.07
PKS 0700-661	2010-12-08 08:41	15.93 ± 0.05	15.62 ± 0.05	15.40 ± 0.05	15.12 ± 0.05	14.87 ± 0.05	14.55 ± 0.05	14.16 ± 0.07
CRATES J0705-4847	2010-12-08 08:49	—	—	—	—	19.73 ± 0.15	19.29 ± 0.15	—
CRATES J0718-4319	2010-12-10 08:02	17.03 ± 0.05	16.83 ± 0.05	16.66 ± 0.05	16.47 ± 0.05	16.18 ± 0.05	15.87 ± 0.05	15.65 ± 0.07
CRATES J0811-7530	2010-11-13 07:47	17.82 ± 0.06	17.56 ± 0.05	17.31 ± 0.05	16.99 ± 0.05	16.63 ± 0.05	16.39 ± 0.05	16.03 ± 0.08
AT20G J0814-1012	2011-01-11 06:08	16.79 ± 0.06	16.57 ± 0.05	16.37 ± 0.05	16.20 ± 0.05	15.83 ± 0.05	15.57 ± 0.05	15.23 ± 0.07
BZB J0816-1311	2011-01-13 08:56	17.16 ± 0.05	17.03 ± 0.05	16.92 ± 0.05	16.85 ± 0.05	16.30 ± 0.05	16.06 ± 0.05	15.76 ± 0.08
CGRaBS J0817-0933	2011-01-09 07:01	17.82 ± 0.05	17.43 ± 0.05	17.17 ± 0.05	16.81 ± 0.05	16.46 ± 0.05	16.02 ± 0.05	15.61 ± 0.07
CRATES J0856+2057	2010-11-28 08:20	18.41 ± 0.05	18.07 ± 0.05	17.77 ± 0.05	17.55 ± 0.05	17.18 ± 0.06	16.89 ± 0.06	16.53 ± 0.07
CGRaBS J0856-1105	2010-10-04 08:52	17.73 ± 0.05	17.36 ± 0.05	17.11 ± 0.05	16.76 ± 0.06	16.50 ± 0.05	16.14 ± 0.05	15.77 ± 0.08
SDSS J090226.91+205046.4	2011-01-13 08:48	16.51 ± 0.05	16.30 ± 0.05	16.10 ± 0.05	15.80 ± 0.06	15.59 ± 0.05	15.34 ± 0.05	14.99 ± 0.08
CRATES J0905+1358	2011-01-10 06:26	16.75 ± 0.05	16.53 ± 0.05	16.34 ± 0.05	16.10 ± 0.05	15.91 ± 0.05	15.59 ± 0.05	15.39 ± 0.07
CRATES-Va J0906-0905	2010-12-10 08:32	17.24 ± 0.05	16.96 ± 0.05	16.75 ± 0.05	16.47 ± 0.05	16.14 ± 0.05	15.79 ± 0.05	15.40 ± 0.07

Table 3. continued.

Name	UT date ^a	AB magnitude ^b						
		g'	r'	i'	z'	J	H	K_s
CRATES J0953-0840	2011-01-14 08:44	16.63 ± 0.05	16.51 ± 0.05	16.28 ± 0.05	16.07 ± 0.05	15.95 ± 0.06	15.66 ± 0.05	15.41 ± 0.08
CGRaBS J1008+0621	2010-12-10 08:40	17.04 ± 0.05	16.69 ± 0.05	16.45 ± 0.05	16.18 ± 0.05	15.78 ± 0.05	15.41 ± 0.05	15.01 ± 0.07
BZB J1022-0113	2010-12-10 09:03	17.47 ± 0.05	17.42 ± 0.05	17.32 ± 0.07	17.23 ± 0.06	16.94 ± 0.05	16.68 ± 0.05	16.50 ± 0.08
BZB J1023-4336	2011-01-17 08:47	16.13 ± 0.05	16.03 ± 0.05	15.86 ± 0.05	15.77 ± 0.05	15.50 ± 0.05	15.36 ± 0.05	15.10 ± 0.07
PKS 1029-85	2011-01-15 08:49	17.08 ± 0.06	16.93 ± 0.05	16.73 ± 0.05	16.41 ± 0.05	15.75 ± 0.05	15.33 ± 0.05	15.12 ± 0.07
PKS B1035-281	2011-01-06 08:37	18.71 ± 0.05	18.60 ± 0.05	18.72 ± 0.05	18.82 ± 0.05	18.59 ± 0.06	18.34 ± 0.07	17.60 ± 0.11
CLASS J1049+2338	2011-01-19 08:23	19.74 ± 0.21	18.79 ± 0.07	18.58 ± 0.08	18.40 ± 0.08	17.52 ± 0.06	17.18 ± 0.06	16.95 ± 0.09
CLASS J1054+2210	2011-01-19 08:30	17.30 ± 0.05	17.01 ± 0.05	16.43 ± 0.21	16.46 ± 0.05	16.32 ± 0.05	16.03 ± 0.06	15.81 ± 0.07
BZB J1107+0222	2011-02-08 08:55	18.06 ± 0.05	17.86 ± 0.05	17.66 ± 0.05	17.51 ± 0.05	17.08 ± 0.06	16.81 ± 0.07	–
OM 235	2011-04-21 01:52	19.26 ± 0.10	19.03 ± 0.05	18.74 ± 0.06	18.53 ± 0.06	18.15 ± 0.07	17.60 ± 0.07	17.68 ± 0.13
PKS B1130+008	2011-04-23 04:26	18.34 ± 0.05	18.00 ± 0.05	17.73 ± 0.05	17.45 ± 0.05	16.92 ± 0.05	16.16 ± 0.30	16.18 ± 0.08
PKS 1216-010	2011-04-24 03:15	17.94 ± 0.05	17.59 ± 0.05	17.28 ± 0.05	17.00 ± 0.05	16.62 ± 0.05	16.16 ± 0.06	15.67 ± 0.08
BZB J1233-0144	2010-11-23 08:46	18.96 ± 0.15	18.22 ± 0.08	18.04 ± 0.09	17.84 ± 0.08	17.46 ± 0.07	17.21 ± 0.07	16.63 ± 0.09
SDSS J125117.88+103907.2	2011-04-24 03:23	17.94 ± 0.05	17.65 ± 0.06	17.49 ± 0.06	17.19 ± 0.05	16.80 ± 0.05	16.50 ± 0.05	16.12 ± 0.08
1RXS J130421.2-435308	2011-03-04 09:34	16.14 ± 0.06	16.95 ± 0.05	15.72 ± 0.05	15.53 ± 0.05	15.19 ± 0.05	15.01 ± 0.05	14.71 ± 0.07
1RXS J130737.8-425940	2011-02-28 09:31	15.77 ± 0.05	15.66 ± 0.05	15.50 ± 0.05	15.29 ± 0.05	14.96 ± 0.05	14.83 ± 0.05	14.56 ± 0.07
4C +12.46	2011-02-28 09:14	18.41 ± 0.05	18.05 ± 0.05	17.78 ± 0.06	17.47 ± 0.05	16.99 ± 0.06	16.58 ± 0.06	16.20 ± 0.08
CRATES J1312-2156	2010-08-30 23:52	16.84 ± 0.05	16.56 ± 0.05	16.21 ± 0.05	16.05 ± 0.05	15.75 ± 0.05	15.49 ± 0.05	15.23 ± 0.08
CRATES J1314+2348	2011-04-24 03:07	16.80 ± 0.07	16.45 ± 0.06	16.21 ± 0.05	15.80 ± 0.06	15.54 ± 0.05	15.21 ± 0.08	15.10 ± 0.08
BZB J1351+1114	2011-01-19 08:48	17.57 ± 0.05	17.46 ± 0.05	17.34 ± 0.05	17.16 ± 0.06	16.87 ± 0.06	16.57 ± 0.06	16.24 ± 0.08
PKS 1350+148	2011-04-25 04:16	17.44 ± 0.05	17.18 ± 0.05	16.96 ± 0.05	16.63 ± 0.07	16.46 ± 0.06	16.08 ± 0.05	15.81 ± 0.09
CRATES J1359-3746	2011-05-26 00:24	17.85 ± 0.05	17.41 ± 0.05	17.13 ± 0.05	16.87 ± 0.05	16.41 ± 0.05	16.06 ± 0.05	15.75 ± 0.08
CGRaBS J1407-4302	–	–	–	–	–	–	–	–
SDSS J141826.33-023334.1	2010-09-04 23:58	15.58 ± 0.05	15.42 ± 0.05	15.21 ± 0.05	15.08 ± 0.05	14.87 ± 0.05	14.68 ± 0.05	14.38 ± 0.08
PKS 1424+240	2010-01-23 08:47	14.46 ± 0.05	14.27 ± 0.05	14.09 ± 0.05	13.88 ± 0.05	13.61 ± 0.05	13.54 ± 0.05	–
CRATES J1440+0610	2010-08-31 00:09	17.24 ± 0.05	16.96 ± 0.05	16.72 ± 0.05	16.54 ± 0.05	16.20 ± 0.05	15.97 ± 0.06	15.72 ± 0.08
PKS 1514+197	2011-02-16 09:20	19.43 ± 0.06	18.97 ± 0.05	18.60 ± 0.06	18.31 ± 0.07	17.65 ± 0.06	17.28 ± 0.06	16.65 ± 0.08
PG 1553+113	2010-02-08 09:13	14.52 ± 0.05	14.38 ± 0.05	14.23 ± 0.05	14.08 ± 0.05	13.89 ± 0.05	13.69 ± 0.05	13.54 ± 0.07
SUMSS J195945-472519	2010-08-30 03:09	16.81 ± 0.05	16.61 ± 0.05	16.42 ± 0.05	16.28 ± 0.05	15.97 ± 0.05	15.75 ± 0.05	15.46 ± 0.07
PKS 2012-017	2011-10-27 00:28	17.65 ± 0.05	17.24 ± 0.05	16.90 ± 0.05	16.61 ± 0.05	16.09 ± 0.05	15.63 ± 0.05	15.22 ± 0.07
CRATES J2039-1046	2011-05-20 09:25	18.78 ± 0.06	18.50 ± 0.05	18.28 ± 0.06	18.07 ± 0.05	17.09 ± 0.05	16.76 ± 0.06	16.31 ± 0.08
CRATES J2103-6232	2010-09-23 03:41	16.42 ± 0.05	16.22 ± 0.05	16.01 ± 0.05	15.82 ± 0.05	15.55 ± 0.05	15.21 ± 0.05	14.89 ± 0.08
PKS 2104-668	2010-08-30 03:29	18.12 ± 0.05	17.79 ± 0.05	17.57 ± 0.05	17.29 ± 0.05	16.83 ± 0.05	16.52 ± 0.05	16.07 ± 0.07
PKS B2147+031	2010-10-15 00:40	17.66 ± 0.05	17.31 ± 0.05	17.08 ± 0.05	16.88 ± 0.05	16.43 ± 0.05	16.11 ± 0.05	15.76 ± 0.07
BZB J2221-5225	2010-09-23 03:52	16.51 ± 0.05	16.38 ± 0.05	16.28 ± 0.05	16.12 ± 0.05	15.80 ± 0.05	15.60 ± 0.05	15.43 ± 0.07
PKS 2233-148	2010-09-10 03:59	19.34 ± 0.05	18.61 ± 0.05	18.16 ± 0.05	17.84 ± 0.05	17.27 ± 0.05	16.80 ± 0.06	16.24 ± 0.09
BZB J2255+2410	2010-09-24 04:28	17.22 ± 0.05	17.01 ± 0.05	16.79 ± 0.05	16.61 ± 0.05	16.32 ± 0.05	16.03 ± 0.05	15.64 ± 0.07
PKS 2312-505	2010-10-16 03:31	18.95 ± 0.05	18.48 ± 0.05	18.09 ± 0.05	17.74 ± 0.05	17.14 ± 0.05	16.66 ± 0.05	16.23 ± 0.07
BZU J2313+1444	2011-09-18 03:34	17.85 ± 0.06	17.22 ± 0.06	16.90 ± 0.06	16.55 ± 0.06	15.93 ± 0.05	15.70 ± 0.05	15.06 ± 0.09
1ES 2322-409	2010-10-31 23:54	15.40 ± 0.05	15.27 ± 0.05	15.07 ± 0.05	14.86 ± 0.05	14.90 ± 0.06	14.76 ± 0.06	14.53 ± 0.10
CLASS J2352+1749	2010-10-14 03:25	18.80 ± 0.06	18.40 ± 0.05	18.17 ± 0.07	17.91 ± 0.08	17.55 ± 0.06	17.29 ± 0.06	16.90 ± 0.09

Notes. ^(a) Exposure start time. ^(b) Corrected for Galactic foreground reddening. Not corrected for variability. Upper limits are $3\text{-}\sigma$.

Table 4. SED fits and photometric redshift solutions.

Name	$z_{\text{phot,best}}^a$	$z_{\text{spec,img}}^b$	Power law				Galaxy			
			z_{phot}^c	χ^2	P_z^d	β^e	z_{phot}^c	χ^2	P_z^c	model
CRATES J0001-0746	<1.25	–	$1.01^{+0.24}_{-0.93}$	5.6	36.5	1.20	$0.41^{+0.04}_{-0.04}$	6.9	77.5	pl_I22491_30_TQSO1_70
CRATES J0009+0628	<1.35	–	$1.11^{+0.24}_{-1.01}$	4.6	36.1	1.45	$0.67^{+0.05}_{-0.04}$	14.8	83.1	I22491_50_TQSO1_50
CRATES J0021-2550	<1.44	–	$1.25^{+0.19}_{-0.39}$	10.2	60.4	0.90	$0.47^{+0.04}_{-0.04}$	14.7	93.3	pl_I22491_20_TQSO1_80
1RXS J002209.2-185333	<1.38	–	$1.26^{+0.12}_{-0.23}$	5.8	77.4	0.95	$0.48^{+0.22}_{-0.25}$	16.8	47.9	pl_I22491_20_TQSO1_80
RX J0035.2+1515	$1.28^{+0.14}_{-0.17}$	–	$1.28^{+0.14}_{-0.17}$	2.6	90.1	0.90	$0.79^{+0.14}_{-0.13}$	8.7	75.5	I22491_60_TQSO1_40
FRBA J0037+1238	–	–	$1.64^{+0.12}_{-0.16}$	44.0	96.6	1.20	$0.64^{+0.07}_{-0.46}$	28.5	66.5	I22491_60_TQSO1_40
BZB J0045+2127	<1.06	–	$0.29^{+0.77}_{-0.23}$	21.6	28.9	0.85	$1.00^{+0.07}_{-0.04}$	11.6	85.6	pl_I22491_30_TQSO1_70
PKS 0047+023	$1.44^{+0.16}_{-0.19}$	–	$1.44^{+0.16}_{-0.19}$	10.8	94.9	1.60	$0.41^{+0.06}_{-0.08}$	13.6	80.5	pl_QSO_DR2_029_t0
PKS 0048-09	<1.34	0.64	$1.07^{+0.27}_{-1.03}$	5.6	44.9	1.25	$0.44^{+0.09}_{-0.07}$	7.3	74.1	pl_I22491_30_TQSO1_70
RBS 119	<1.12	–	$0.28^{+0.84}_{-0.20}$	4.5	26.5	0.65	$0.68^{+0.39}_{-0.04}$	23.0	69.1	I22491_60_TQSO1_40
FRBA J0054-2455	<1.14	–	$0.57^{+0.57}_{-0.51}$	16.9	31.3	0.60	$0.48^{+0.21}_{-0.13}$	13.1	73.8	pl_TQSO1_template_norm
PKS 0055-328	$1.37^{+0.14}_{-0.17}$	–	$1.37^{+0.14}_{-0.17}$	17.7	95.2	1.25	$0.47^{+0.23}_{-0.47}$	11.2	38.4	I22491_50_TQSO1_50
BZB J0114+1325	<1.22	–	$0.97^{+0.25}_{-0.91}$	6.3	37.0	0.75	$0.51^{+0.76}_{-0.09}$	27.7	56.0	pl_I22491_20_TQSO1_80
CLASS J0115+0356	<1.25	–	$1.02^{+0.23}_{-0.94}$	5.3	33.5	0.85	$0.66^{+0.04}_{-0.21}$	12.9	78.2	I22491_60_TQSO1_40
BZB J0115+2519	<1.45	–	$1.28^{+0.17}_{-0.33}$	12.8	63.4	0.90	$0.83^{+0.16}_{-0.12}$	18.6	96.3	I22491_60_TQSO1_40
AT20G J0124-0625	<2.46	–	$1.93^{+0.53}_{-0.41}$	12.1	69.0	1.30	$0.44^{+0.30}_{-0.07}$	7.4	54.9	pl_I22491_20_TQSO1_80
CRATES J0154+0823	<1.37	–	$1.22^{+0.16}_{-0.53}$	7.6	53.2	0.95	$0.50^{+0.17}_{-0.06}$	11.8	79.6	pl_I22491_20_TQSO1_80
RBS 259	<1.16	–	$0.29^{+0.87}_{-0.19}$	23.6	26.1	1.00	$0.49^{+0.20}_{-0.06}$	14.8	71.2	pl_I22491_20_TQSO1_80
CGRaBS J0158-3932	<1.35	–	$0.46^{+0.89}_{-0.38}$	13.3	25.0	1.10	$0.40^{+0.03}_{-0.07}$	5.3	75.4	pl_I22491_30_TQSO1_70
CRATES J0159-2740	<1.05	–	$0.10^{+0.95}_{-0.02}$	25.8	16.0	0.95	$0.45^{+0.49}_{-0.07}$	14.5	36.5	pl_I22491_20_TQSO1_80
BZB J0209-5229	<1.18	–	$0.06^{+1.12}_{-0.00}$	14.0	11.2	0.95	$0.76^{+0.08}_{-0.06}$	6.7	99.5	I22491_60_TQSO1_40
CGRaBS J0211+1051	–	–	$0.73^{+0.03}_{-0.71}$	49.9	32.3	1.05	$0.46^{+0.04}_{-0.03}$	27.0	99.5	I22491_60_TQSO1_40
CRATES J0216-6636	<1.25	–	$1.03^{+0.22}_{-0.95}$	10.4	38.2	0.85	$0.54^{+0.15}_{-0.09}$	10.0	66.4	I22491_60_TQSO1_40
RBS 334	<1.14	–	$0.26^{+0.89}_{-0.18}$	6.3	26.4	0.80	$0.51^{+0.06}_{-0.08}$	16.5	74.6	pl_I22491_20_TQSO1_80
BZB J0238-3116	<1.02	–	$0.06^{+0.96}_{-0.00}$	16.2	13.6	0.65	$0.81^{+0.09}_{-0.13}$	12.2	99.4	I22491_60_TQSO1_40
CRATES J0250+1708	<3.10	–	$2.69^{+0.41}_{-2.45}$	15.6	30.6	2.00	$0.62^{+1.27}_{-0.14}$	8.0	44.4	pl_I22491_20_TQSO1_80
AT20G J0314-5104	<1.43	–	$1.26^{+0.17}_{-0.25}$	1.8	70.8	1.20	$0.06^{+0.65}_{-0.06}$	6.8	56.6	I22491_40_TQSO1_60
BZB J0323-0111	<1.54	–	$1.34^{+0.20}_{-0.15}$	14.5	95.0	0.85	$0.47^{+0.04}_{-0.04}$	16.7	90.6	I22491_60_TQSO1_40
CRATES J0325-5629	<1.42	0.86	$1.24^{+0.19}_{-0.29}$	21.5	65.6	2.05	$0.71^{+0.05}_{-0.04}$	60.3	99.9	pl_QSOH_template_norm
CRATES J0325-5635	–	0.06	$1.83^{+0.07}_{-0.10}$	78.6	100.0	1.40	$0.88^{+0.08}_{-0.06}$	39.7	97.8	pl_I22491_20_TQSO1_80
PKS 0332-403	$1.47^{+0.11}_{-0.12}$	1.36	$1.47^{+0.11}_{-0.12}$	6.0	99.8	1.35	$1.11^{+0.10}_{-0.33}$	13.0	62.3	I22491_60_TQSO1_40
CRATES J0334-3725	<1.34	–	$1.13^{+0.21}_{-0.29}$	8.0	64.5	0.90	$0.66^{+0.05}_{-0.22}$	7.9	71.0	I22491_60_TQSO1_40
PKS 0355-500	<1.44	0.64	$1.23^{+0.22}_{-0.32}$	14.0	67.3	1.25	$0.00^{+0.69}_{-0.00}$	9.7	43.3	I22491_40_TQSO1_60
CRATES J0402-2615	$1.92^{+0.12}_{-0.09}$	–	$1.92^{+0.12}_{-0.09}$	8.6	100.0	1.25	$1.28^{+0.22}_{-0.23}$	9.5	48.9	I22491_60_TQSO1_40
PKS 0422+00	<1.25	–	$0.81^{+0.44}_{-0.77}$	7.0	31.2	1.10	$0.46^{+0.05}_{-0.22}$	10.2	78.4	pl_I22491_30_TQSO1_70
CRATES J0430-2507	<1.46	0.52	$1.33^{+0.13}_{-0.36}$	6.6	65.8	1.15	$0.49^{+0.21}_{-0.29}$	9.1	67.6	pl_I22491_30_TQSO1_70
CRATES J0434-2015	<1.26	0.93	$0.92^{+0.34}_{-0.82}$	12.8	34.8	1.45	$0.05^{+0.21}_{-0.05}$	17.5	76.2	pl_I22491_20_TQSO1_80
BZB J0448-1632	<1.25	–	$0.96^{+0.29}_{-0.88}$	5.5	35.8	0.65	$1.11^{+0.14}_{-0.05}$	24.5	96.6	I22491_60_TQSO1_40
CRATES J0505+0415	<1.26	–	$0.99^{+0.27}_{-0.91}$	3.0	37.6	0.95	$0.45^{+0.23}_{-0.45}$	8.6	59.6	pl_I22491_20_TQSO1_80
RBS 621	<1.07	–	$0.29^{+0.78}_{-0.21}$	7.8	28.6	0.60	$0.68^{+0.03}_{-0.02}$	7.7	99.5	pl_TQSO1_template_norm
CGRaBS J0509+0541	<1.24	–	$1.23^{+0.01}_{-0.16}$	17.1	86.7	0.95	$1.10^{+0.04}_{-0.03}$	20.6	97.7	pl_I22491_20_TQSO1_80
PKS 0516-621	<1.44	1.30	$1.31^{+0.13}_{-0.25}$	10.4	82.7	1.20	$0.59^{+0.12}_{-0.12}$	11.9	77.3	pl_I22491_20_TQSO1_80
FRBA J0536-3343	<1.16	–	$0.91^{+0.25}_{-0.85}$	20.1	35.2	0.60	$0.74^{+0.32}_{-0.07}$	14.5	73.0	pl_TQSO1_template_norm
SUMSS J053748-571828	$1.55^{+0.09}_{-0.13}$	–	$1.55^{+0.09}_{-0.13}$	20.5	99.9	0.80	$1.58^{+0.08}_{-0.07}$	21.5	99.6	pl_I22491_30_TQSO1_70
1RXS J053810.0-390839	<1.71	–	$0.31^{+1.40}_{-0.19}$	5.6	17.9	1.20	$0.48^{+0.50}_{-0.25}$	5.8	37.6	I22491_40_TQSO1_60
BZB J0543-5532	<1.08	–	$0.29^{+0.79}_{-0.23}$	4.8	28.8	0.75	$0.68^{+0.04}_{-0.25}$	15.2	34.9	pl_I22491_20_TQSO1_80
PKS 0600-749	$1.54^{+0.14}_{-0.19}$	–	$1.54^{+0.14}_{-0.19}$	6.9	98.1	1.20	$0.46^{+0.24}_{-0.05}$	7.5	58.1	I22491_60_TQSO1_40
1ES 0602-482	<0.99	–	$0.29^{+0.70}_{-0.21}$	25.3	32.2	0.80	$0.86^{+0.11}_{-0.44}$	8.9	88.2	pl_I22491_30_TQSO1_70
CRATES J0630-2406	$1.60^{+0.10}_{-0.05}$	–	$1.60^{+0.10}_{-0.05}$	9.3	100.0	0.85	$1.19^{+0.50}_{-0.12}$	24.6	83.7	I22491_60_TQSO1_40
CRATES J0647-6058	<1.69	–	$0.24^{+1.45}_{-0.08}$	19.2	16.0	1.35	$1.30^{+0.16}_{-0.10}$	10.3	88.8	I22491_60_TQSO1_40
1ES 0647+250	<1.47	–	$1.33^{+0.14}_{-0.23}$	9.5	75.9	0.65	$0.72^{+0.04}_{-0.04}$	24.5	92.3	pl_QSOH_template_norm
PKS 0700-661	<1.46	–	$1.33^{+0.12}_{-0.29}$	10.5	73.1	1.05	$0.45^{+0.03}_{-0.03}$	6.7	98.6	I22491_60_TQSO1_40
CRATES J0705-4847	–	–	$1.96^{+2.04}_{-1.75}$	0.0	15.7	1.50	$1.18^{+2.82}_{-1.18}$	0.0	11.0	S0_80_QSO2_20
CRATES J0718-4319	<1.26	–	$1.03^{+0.23}_{-0.97}$	4.0	38.1	0.85	$0.67^{+0.02}_{-0.03}$	8.4	90.2	I22491_60_TQSO1_40

Table 4. continued.

Name	$z_{\text{phot,best}}^a$	$z_{\text{spec,img}}^b$	Power law				Galaxy			
			z_{phot}^c	χ^2	P_z^d	β^e	z_{phot}^c	χ^2	P_z^c	model
CRATES J0811-7530	<1.40	–	$1.17^{+0.23}_{-1.09}$	10.7	41.5	1.05	$0.75^{+0.17}_{-0.34}$	8.8	68.4	pl_I22491_30_TQSO1_70
AT20G J0814-1012	<1.54	–	$1.37^{+0.17}_{-0.31}$	10.0	75.2	0.95	$0.65^{+0.46}_{-0.13}$	17.3	61.1	pl_I22491_20_TQSO1_80
BZB J0816-1311	–	–	$0.28^{+0.69}_{-0.22}$	51.4	31.6	0.75	$0.65^{+0.03}_{-0.03}$	17.1	96.2	pl_I22491_20_TQSO1_80
CGRaBS J0817-0933	<1.64	–	$1.42^{+0.21}_{-0.23}$	10.0	88.0	1.35	$0.40^{+0.05}_{-0.14}$	7.3	69.3	pl_I22491_20_TQSO1_80
CRATES J0856+2057	<1.41	–	$1.09^{+0.32}_{-0.99}$	5.0	42.6	1.15	$0.44^{+0.07}_{-0.44}$	5.8	55.0	pl_I22491_20_TQSO1_80
CGRaBS J0856-1105	<1.54	–	$1.36^{+0.19}_{-0.22}$	6.2	82.7	1.15	$0.42^{+0.27}_{-0.16}$	7.5	69.7	pl_I22491_20_TQSO1_80
SDSS J090226.91+205046.4	<1.21	–	$0.66^{+0.55}_{-0.60}$	7.4	31.1	0.90	$0.45^{+0.03}_{-0.03}$	6.3	91.9	I22491_60_TQSO1_40
CRATES J0905+1358	<1.35	–	$1.17^{+0.18}_{-1.11}$	8.3	46.1	0.85	$0.67^{+0.03}_{-0.02}$	17.3	93.5	I22491_60_TQSO1_40
CRATES-Va J0906-0905	<1.51	–	$1.40^{+0.12}_{-0.15}$	10.5	98.9	1.05	$1.11^{+0.09}_{-0.05}$	13.7	92.2	pl_I22491_30_TQSO1_70
CRATES J0953-0840	<1.28	–	$1.07^{+0.22}_{-1.01}$	7.7	45.6	0.75	$1.23^{+0.06}_{-0.05}$	30.9	91.7	pl_I22491_20_TQSO1_80
CGRaBS J1008+0621	<1.44	–	$1.23^{+0.21}_{-0.21}$	6.0	81.6	1.25	$0.45^{+0.25}_{-0.45}$	6.5	57.4	pl_I22491_30_TQSO1_70
BZB J1022-0113	<1.14	–	$0.28^{+0.87}_{-0.20}$	13.6	26.4	0.60	$0.66^{+0.03}_{-0.03}$	14.1	83.7	pl_TQSO1_template_norm
BZB J1023-4336	<1.54	–	$1.43^{+0.11}_{-0.25}$	8.6	88.6	0.60	$0.70^{+0.03}_{-0.03}$	19.3	96.4	pl_QSOH_template_norm
PKS 1029-85	–	–	$0.29^{+0.71}_{-0.23}$	76.8	30.8	1.20	$1.14^{+0.11}_{-0.11}$	51.9	99.4	I22491_70_TQSO1_30
PKS B1035-281	–	1.07	$1.27^{+0.18}_{-0.16}$	55.8	89.8	0.25	$0.59^{+0.08}_{-0.08}$	25.0	100.0	pl_QSOH_template_norm
CLASS J1049+2338	–	0.32	$1.07^{+0.41}_{-0.93}$	30.5	32.7	1.55	$0.74^{+0.58}_{-0.45}$	31.2	45.3	I22491_50_TQSO1_50
CLASS J1054+2210	<1.36	–	$1.12^{+0.23}_{-0.68}$	13.8	55.0	0.95	$0.42^{+0.29}_{-0.42}$	22.0	31.8	I22491_50_TQSO1_50
BZB J1107+0222	<1.45	–	$1.27^{+0.18}_{-0.22}$	11.0	78.6	0.90	$1.13^{+0.43}_{-0.49}$	9.9	54.3	pl_I22491_30_TQSO1_70
OM 235	$1.72^{+0.13}_{-0.13}$	1.55	$1.72^{+0.13}_{-0.13}$	18.2	99.9	1.10	$1.54^{+0.10}_{-0.09}$	11.9	94.9	pl_I22491_30_TQSO1_70
PKS B1130+008	<1.26	0.68	$1.01^{+0.25}_{-0.91}$	7.7	33.3	1.30	$0.64^{+0.09}_{-0.25}$	11.6	45.2	pl_I22491_30_TQSO1_70
PKS 1216-010	<1.23	–	$0.87^{+0.36}_{-0.77}$	8.7	34.7	1.30	$0.25^{+0.01}_{-0.01}$	10.2	78.8	pl_QSO_DR2_029_t0
BZB J1233-0144	<1.46	–	$1.28^{+0.18}_{-0.25}$	13.7	73.2	1.15	$0.32^{+0.06}_{-0.11}$	12.7	46.5	pl_I22491_20_TQSO1_80
SDSS J125117.88+103907.2	<1.06	0.25	$0.09^{+0.96}_{-0.01}$	13.4	15.9	1.00	$0.45^{+0.28}_{-0.41}$	12.9	40.9	pl_I22491_20_TQSO1_80
1RXS J130421.2-435308	–	–	$0.29^{+0.63}_{-0.25}$	525.0	33.5	1.25	$0.80^{+0.03}_{-0.03}$	347.1	100.0	I22491_70_TQSO1_30
1RXS J130737.8-425940	<1.53	–	$1.43^{+0.10}_{-0.22}$	15.0	90.6	0.75	$0.68^{+0.03}_{-0.03}$	21.3	99.7	I22491_60_TQSO1_40
4C +12.46	<1.40	–	$1.19^{+0.21}_{-0.28}$	5.7	67.8	1.35	$0.69^{+0.07}_{-0.04}$	11.1	88.4	pl_I22491_30_TQSO1_70
CRATES J1312-2156	$1.77^{+0.09}_{-0.11}$	1.49	$1.77^{+0.09}_{-0.11}$	7.1	100.0	0.95	$1.60^{+0.14}_{-0.09}$	18.4	100.0	I22491_60_TQSO1_40
CRATES J1314+2348	<1.30	–	$1.13^{+0.17}_{-1.07}$	15.8	52.3	1.10	$0.70^{+0.19}_{-0.70}$	14.3	33.3	I22491_50_TQSO1_50
BZB J1351+1114	<1.12	–	$0.10^{+1.02}_{-0.02}$	16.2	15.3	0.75	$1.09^{+0.08}_{-0.45}$	15.4	59.9	pl_I22491_20_TQSO1_80
PKS 1350+148	<1.43	–	$1.27^{+0.16}_{-0.34}$	9.8	63.8	1.00	$0.39^{+0.07}_{-0.39}$	14.6	35.1	I22491_50_TQSO1_50
CRATES J1359-3746	<1.26	0.33	$0.97^{+0.29}_{-0.89}$	5.1	36.4	1.25	$0.24^{+0.67}_{-0.24}$	12.5	34.0	I22491_40_TQSO1_60
SDSS J141826.33-023334.1	<1.37	–	$1.19^{+0.18}_{-0.23}$	5.2	69.3	0.70	$1.24^{+0.04}_{-0.05}$	25.4	99.9	pl_I22491_20_TQSO1_80
PKS 1424+240	<1.11	–	$1.09^{+0.02}_{-1.07}$	10.4	38.4	0.70	$0.46^{+0.03}_{-0.03}$	19.4	99.9	I22491_60_TQSO1_40
CRATES J1440+0610	<1.31	–	$1.09^{+0.22}_{-1.03}$	5.9	42.7	0.95	$0.65^{+0.06}_{-0.01}$	11.1	77.5	pl_I22491_20_TQSO1_80
PKS 1514+197	–	–	$0.24^{+0.80}_{-0.14}$	40.1	30.2	1.55	$1.21^{+0.05}_{-0.06}$	31.6	98.4	I22491_90_TQSO1_10
PG 1553+113	<1.35	–	$1.17^{+0.18}_{-0.22}$	6.0	80.8	0.65	$1.21^{+0.07}_{-0.16}$	29.7	99.5	I22491_60_TQSO1_40
SUMSS J195945-472519	<1.31	–	$1.14^{+0.17}_{-0.73}$	4.1	53.1	0.80	$0.65^{+0.03}_{-0.02}$	11.5	97.4	I22491_60_TQSO1_40
PKS 2012-017	<1.22	–	$0.29^{+0.93}_{-0.20}$	3.6	24.2	1.45	$0.67^{+0.05}_{-0.04}$	17.3	89.6	I22491_50_TQSO1_50
CRATES J2039-1046	–	–	$0.24^{+0.67}_{-0.16}$	259.6	34.4	1.30	$1.25^{+0.07}_{-0.07}$	174.9	99.3	I22491_80_TQSO1_20
CRATES J2103-6232	<1.24	–	$1.02^{+0.22}_{-0.96}$	5.2	39.4	0.90	$0.50^{+0.18}_{-0.07}$	8.4	65.3	I22491_60_TQSO1_40
PKS 2104-668	<1.20	–	$0.26^{+0.94}_{-0.16}$	10.6	25.4	1.25	$0.42^{+0.03}_{-0.03}$	12.8	90.4	pl_I22491_30_TQSO1_70
PKS B2147+031	<1.42	–	$1.23^{+0.19}_{-0.22}$	3.8	80.1	1.15	$0.66^{+0.03}_{-0.03}$	9.3	65.1	pl_I22491_20_TQSO1_80
BZB J2221-5225	<1.17	–	$0.10^{+1.07}_{-0.04}$	7.5	15.6	0.70	$0.90^{+0.19}_{-0.24}$	17.9	59.2	I22491_60_TQSO1_40
PKS 2233-148	<1.55	–	$1.43^{+0.12}_{-0.37}$	17.5	66.5	1.80	$0.66^{+0.21}_{-0.59}$	23.1	18.4	pl_QSO_DR2_029_t0
BZB J2255+2410	<1.25	–	$0.88^{+0.38}_{-0.80}$	8.1	33.1	0.90	$0.49^{+0.19}_{-0.06}$	8.7	69.6	I22491_60_TQSO1_40
PKS 2312-505	<1.29	0.81	$0.89^{+0.40}_{-0.79}$	7.2	34.1	1.65	$0.83^{+0.07}_{-0.08}$	25.0	85.2	I22491_60_TQSO1_40
BZB 2313+1444	<1.28	0.16	$0.85^{+0.43}_{-0.77}$	22.0	32.6	1.60	$0.39^{+0.04}_{-0.15}$	20.1	86.5	I22491_50_TQSO1_50
1ES 2322-409	<1.37	0.17	$1.24^{+0.12}_{-0.30}$	17.3	69.1	0.50	$1.09^{+0.03}_{-0.03}$	53.6	90.7	pl_TQSO1_template_norm
CLASS J2352+1749	$1.45^{+0.21}_{-0.18}$	–	$1.45^{+0.21}_{-0.18}$	7.5	91.8	1.15	$0.55^{+0.16}_{-0.14}$	7.1	64.2	pl_I22491_20_TQSO1_80

Notes. ^(a) Best photometric redshift, see text. ^(b) Spectroscopic or imaging redshift (if known) from [Ackermann et al. \(2012\)](#). ^(c) Photometric redshift with 90% confidence uncertainties. ^(d) Redshift probability density at $z_{\text{phot}} \pm 0.1(1 + z_{\text{phot}})$. ^(e) Spectral slope for power law model of the form $F_\lambda \propto \lambda^{-\beta}$. ^(f) Starburst/QSO hybrid templates with varying contributions of the two components. Template names reflect the relative contribution of the starburst (I22491_NN) and AGN (TQSO1_NN) models to the hybrid. “pl” marks an additional power-law component at short wavelengths. See [Salvato et al. \(2011\)](#) for details on the templates.