The Astronomical Journal, 149:163 (7pp), 2015 May doi:10.1088/0004-6256/149/5/163

OPTICAL SPECTROSCOPIC OBSERVATIONS OF γ-RAY BLAZAR CANDIDATES. III. THE 2013/2014 CAMPAIGN IN THE SOUTHERN HEMISPHERE*

M. Landoni[1,2,3], F. Massaro[4,5], A. Paggi[6], R. D'Abrusco[6], D. Milisavljevic[6], N. Masetti[7], H. A. Smith[6], G. Tosti[8],
L. Chomiuk[9], J. Strader[9], and C. C. Cheung[10]
[1] INAF—Osservatorio Astronomico di Brera, Via Emilio Bianchi 46, I-23807 Merate, Italy; marco.landoni@brera.inaf.it
[2] INFN—Istituto Nazionale di Fisica Nucleare, Italy
[3] Harvard—Smithsonian Center of Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[4] Yale Center for Astronomy and Astrophysics, Physics Department, Yale University, P.O. Box 208120, New Haven, CT 06520–8120, USA
[5] Dipartimento di Fisica, Università degli Studi di Torino, via Pietro Giuria 1, I-10125 Torino, Italy
[6] Harvard—Smithsonian Center of Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[7] INAF—Istituto di Astrofisica Spaziale e Fisica Cosmica di Bologna, via Gobetti 101, I-40129, Bologna, Italy
[8] Dipartimento di Fisica, Università degli Studi di Perugia, I-06123 Perugia, Italy
[9] Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, US
[10] Space Science Division, Naval Research Laboratory, Washington, DC 20375, USA

Received 2014 October 15; accepted 2015 February 5; published 2015 April 23

ABSTRACT

We report the results of our exploratory program carried out with the southern Astrophysical Research telescope aimed at associating counterparts and establishing the nature of the *Fermi* Unidentified γ-ray Sources (UGSs). We selected the optical counterparts of six UGSs from the *Fermi* catalog on the basis of our recently discovered tight connection between infrared and γ-ray emission found for the γ-ray blazars detected by the *Wide-Field Infrared Survey Explorer* in its all-sky survey. We perform for the first time a spectroscopic study of the low-energy counterparts of the *Fermi* UGSs, in the optical band, confirming the blazar-like nature of the whole sample. We also present new spectroscopic observations of six active galaxies of uncertain type associated with *Fermi* sources which appear to be BL Lac objects. Finally, we report the spectra collected for six known γ-ray blazars belonging to the Roma BZCAT that were obtained to establish their nature or better estimate their redshifts. Two interesting cases of high redshift and extremely luminous BL Lac objects ($z \geqslant 1.18$ and $z \geqslant 1.02$, based on the detection of Mg II intervening systems) are also discussed.

Key words: BL Lacertae objects: general – galaxies: active – radiation mechanisms: non-thermal

Supporting material: extended figure

1. INTRODUCTION

According to the Second *Fermi*-LAT Source Catalog (2FGL; Nolan et al. 2012) and subsequent analyses performed on the Unidentified γ-ray Sources (UGSs; e.g., Massaro et al. 2012a; Acero et al. 2013) a significant fraction of the γ-ray sky (about 30%) is yet unknown (Massaro et al. 2013a). For this reason, we developed two association procedures (e.g., Massaro et al. 2012a; D'Abrusco et al. 2013) able to associate counterparts of *Fermi* UGSs. These methods are based on a correlation between infrared, detected in the *Wide-Field Infrared Survey Explorer* (*WISE*; Wright et al. 2010), and γ-ray emission (e.g., Massaro et al. 2011a; D'Abrusco et al. 2012) of blazars which are the largest known population of γ-ray sources.

Blazars are active galactic nuclei (AGNs) dominated by non-thermal radiation over the entire electromagnetic spectrum, presenting very peculiar observational properties with respect to other AGN classes. In particular they show very rapid variability at all frequencies, high polarization, superluminal motion, and very high luminosities (e.g., Urry & Padovani 1995). Their emission is interpreted as arising from ultra-relativistic particles accelerated in a relativistic jet closely aligned to our line of sight (Blandford & Rees 1978). According to the literature, there are two classes of blazars objects. Briefly, the blazar subclass of BL Lacs is characterized by an optical spectrum where observed features have a rest-frame equivalent width EW $\leqslant$ 5 Å (e.g., Stickel et al. 1991; Stocke et al. 1991; Laurent-Muehleisen et al. 1999) while the Flat Spectrum Radio Quasars (FSRQs) show a typical quasar-like optical spectra characterized by strong and broad emission lines and higher radio polarization.

Here we report the results of our recent spectroscopic campaign in the Southern hemisphere using the southern Astrophysical Research (SOAR, see Clemens et al. 2014) telescope. In this campaign we obtained spectra for optical counterparts of *Fermi* UGSs selected adopting the procedure previously described in D'Abrusco et al. (2013 and references therein). Preliminary results for our exploratory program in the Northern hemisphere obtained with the Telescopio Nazionale Galileo, the Multiple Mirror Telescope (MMT), and the Observatorio Astronómico Nacional in San Pedro Mártir (México) Observatory have been already presented in Paggi et al. (2014). Although additional multifrequency campaigns to investigate the origin of the UGSs are already ongoing, e.g., at radio frequencies (e.g., Kovalev 2009; Massaro et al. 2013b; Petrov et al. 2013; Nori et al. 2014) or in the X-rays such as the *Swift* X-ray survey of the UGSs[11] (e.g., Mirabal 2009; Paggi et al. 2013; Stroh & Falcone 2013; Takeuchi et al. 2013), the

---

* Based on observations obtained at the southern Astrophysical Research (SOAR) telescope, which is a joint project of the Ministério da Ciência, Tecnologia, e Inovação (MCTI) da República Federativa do Brasil, the U.S. National Optical Astronomy Observatory (NOAO), the University of North Carolina at Chapel Hill (UNC), and Michigan State University (MSU).

[11] http://www.swift.psu.edu/unassociated/

Table 1
Selected Sample and Observation Log

Name	*WISE* name	R.A. (J2000)	Decl. (J2000)	Obs. Date (yy-mm-dd)	Exp. (min)	Notes	Class
UGS sample							
2FGL J0116.6-6153	J011619.62-615343.4	01:16:19.62	−61:53:43.5	13 Sep 16	30	S,w,U,M	BLL
2FGL J0133.4-4408	J013306.37-441421.4	01:33:06.37	−44:14:21.4	13 Sep 16	40	S,w,U	BLL
2FGL J0143.6-5844	J014347.41-584551.4	01:43:47.42	−58:45:51.4	14 Jan 10	20	S,w,M,U,u,x	BLL
2FGL J0316.1-6434	J031614.34-643731.4	03:16:14.34	−64:37:31.5	14 Jan 10	20	S,w,M,U,u,x	BLL
2FGL J0416.0-4355	J041605.82-435514.6	04:16:05.83	−43:55:14.7	13 Sep 16	40	S,w,M,U	QSO
2FGL J0555.9-4348	J055618.74-435146.0	05:56:18.74	−43:51:46.0	13 Sep 16	40	S,w,M,U	BLL
2FGL J2257.9-3646	J225815.00-364434.3	22:58:14.65	−36:44:38.0	13 Nov 28	20	S,N,rf,w,u,x	BLL
AGU Sample							
2FGL J0157.2-5259*	J015658.00-530200.0	01:56:57.75	−53:01:57.5	13 Aug 03	20	S,w,M,6,U,g,X,u,x	BLL
2FGL J0335.3-4501	J033513.88-445943.8	03:35:13.90	−44:59:40.0	13 Sep 16	10	S,w,U,X,g,6,u,x,U,X	BLL
2FGL J0424.3-5332	J042504.27-533158.2	04:25:04.26	−53:31:58.3	13 Sep 15	20	Pm,S,A,c,w,M,U,X	BLL
2FGL J0537.7-5716*	J053748.96-571830.1	05:37:48.96	−57:18:30.2	13 Sep 15	30	S,w,M,U,X	BLL
2FGL J0604.2-4817*	J060408.61-481725.1	06:04:08.62	−48:17:23.6	13 Sep 16	20	S,w,M,U,X,6	BLL
2FGL J1103.9-5356	J110352.22-535700.7	11:03:52.32	−53:57:00.79	14 Jan 11	120	Pm,Pk,A,M,w	BLL
γ-rays Blazars							
BZB J0158-3932	J015838.10-393203.8	01:58:38.09	−39:32:03.8	13 Sep 15	20	⋯	BLL
BZB J0237-3603	J023734.04-360328.4	02:37:34.04	−36:03:28.4	13 Sep 16	10	⋯	BLL
BZB J0238-3116	J023832.48-311658.0	02:38:32.48	−31:16:57.9	13 Sep 16	10	⋯	BLL
BZB J0334-4008	J033413.65-400825.4	03:34:13.65	−40:08:25.5	13 Sep 16	10	⋯	BLL
BZB J0428-3756	J042840.41-375619.3	04:28:40.42	−37:56:19.6	13 Sep 15	30	⋯	BLL
BZB J1443-3908	J144357.20-390840.0	14:43:57.21	−39:08:39.9	13 Sep 15	5	⋯	BLL

Note. The asterisk (*) close to the source name marks sources that are also associated in the 1FGL catalog (Abdo et al. 2010). —Catalog/survey symbols in notes: PMN (Wright et al. 1994,—Pm), SUMSS (Mauch et al. 2003,—S), AT20G (Murphy et al. 2010,—A), CRATES (Healey et al. 2007,—c), *WISE* (Wright et al. 2010; Cutri et al. 2012,—w), 2MASS (Skrutskie et al. 2006,—M), USNO-B1 (Monet et al. 2003, - U), *GALEX* (- g), RBSC and RFSC (Voges et al. 1999, 2000, - X), Deep *Swift* X-ray Telescope Point Source Catalog (1SXPS; Evans et al. 2014, - x) and *Swift* X-ray survey for all the *Fermi* UGSs[9] (Paggi et al. 2013; Stroh & Falcone 2013; Takeuchi et al. 2013), Six-degree-field Galaxy Survey (6dFGS; Jones et al. 2004, 2009,—6).

optical spectroscopic campaigns (such as the one presented in this series of papers) are a crucial step, in particular for blazars, to disentangle and confirm the true nature of the low-energy counterparts selected with different methods (e.g., Landoni et al. 2012, 2013, 2014; Masetti et al. 2013; Shaw et al. 2013a, 2013b; Massaro et al. 2014; Paggi et al. 2014). In this paper we also present spectroscopy for six active galaxies of uncertain type (AGUs) in the *Fermi* catalog and for six other known blazars in order to confirm their nature.

The paper is organized as follows. In Section 2 we discuss the data reduction procedures adopted to analyze the SOAR observations acquired. Then in Section 3 we describe the results of our analysis providing details on each source. Finally, the summary and conclusions are given in Section 4. We use cgs units unless stated otherwise and the following cosmological parameters $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_m = 0.27$, $\Omega_\Lambda = 0.73$.

2. OBSERVATIONS AND DATA REDUCTION

We obtained spectra in Visiting mode at the SOAR 4 m class telescope using the High Throughput Goodman spectrograph (Clemens et al. 2004). We adopted a slit of $1\farcs0$ or $1\farcs3$ (depending on the availability at the telescope) width combined with a low resolution grating (400 grooves $\mathrm{mm^{-1}}$) yielding a dispersion of about 2 Å $\mathrm{pixel^{-1}}$ ($\Delta\lambda \sim 5$ Å) in both cases. The majority of the spectra (14/19) were obtained in a dedicated run from 2013 September 15 to 16 while individual spectra were obtained for the remaining targets in 2013 August and November and 2014 January (see Table 1). The average seeing during both runs was about $1\farcs0$ and skies were almost clear. Data reduction was done using IRAF[12] by the adoption of standard procedures. In particular, for each object we performed bias subtraction, flat fielding, and cosmic ray rejection. Since for each target we secured two individual frames, we averaged them according to their signal-to-noise ratios (S/Ns). We rejected any spurious features (e.g., cosmic rays or CCD defect) by comparing the two individual exposures. The wavelength calibration was achieved using the spectra of helium–neon–argon or iron–argon lamps which enures a full coverage of the entire range. In order to take into account flexures of the instruments and drift due to poor long-term stability during the night, we took an arc frame before each target in order to guarantee a good wavelength calibration for the scientific spectra. The accuracy achieved is about 0.2 Å rms. We observed a photometric standard star each night even though this program does not require an accurate flux calibration in order to ensure a flux calibration of spectra. We applied a correction law for Galactic reddening (Cardelli et al. 1989) assuming E_{B-V} values computed by Schlegel et al. 1998. Finally, in order to better investigate the

---

[12] IRAF (Image Reduction and Analysis Facility) is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

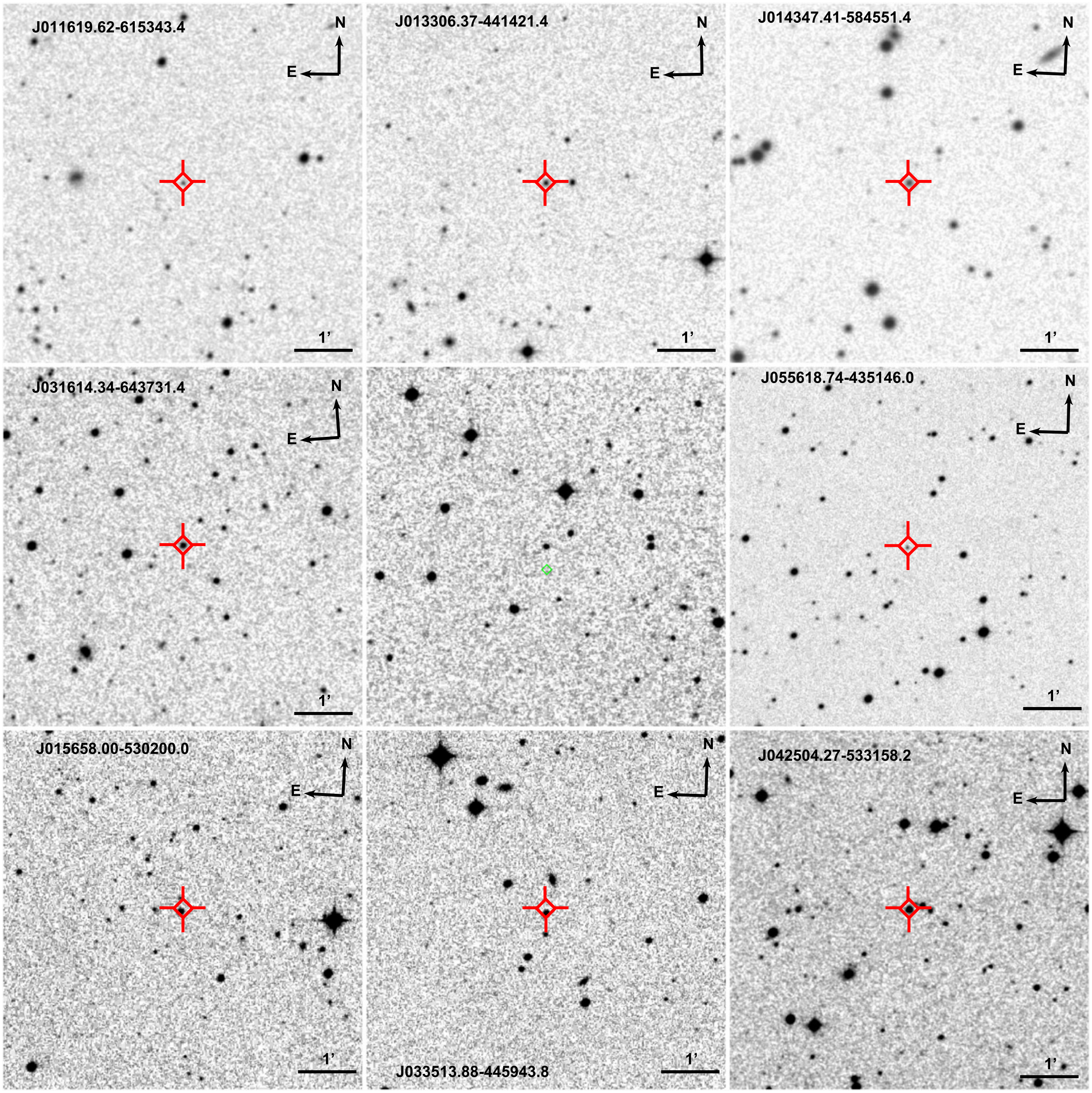

Figure 1. Optical images of the fields of the *WISE* sources selected in this paper for optical spectroscopic follow-up (see Table 1). The object name, image scale, and orientation are indicated in each panel. The proposed optical counterparts are indicated with red marks (*WISE* coordinates) and the fields are extracted from the DSS-II-red survey.

detectability of faint spectral features, we normalized each spectrum by dividing by the continuum best fit computed on the observed data. We report in Figures 1 the finding charts of each object while the full spectra are reported from Figures 2(a) to 2(s).

3. RESULTS

According to the optical spectra obtained during our campaign, we found that all the sources selected as counterparts of the seven UGSs are indeed blazars (see Section 3.1). The six AGUs, classified according to the Second *Fermi*-LAT AGN catalog (2LAC; Ackermann et al. 2011b) are also BL Lacs that show a typical power-law spectrum with weak intrinsic (or absent) emission features with a rest-frame equivalent width EW $\geqslant 5$ Å (see Section 3.2). The remaining six sources were labeled as BL Lac candidates in the Roma BZCAT (Massaro 2009) because no optical spectra were found can now be classified as BL Lac from careful inspection of each spectrum secured in this campaign (see Section 3.3). Although some of the sources considered in our campaign have been also observed at different observatories and groups, as reported in the following sections, we decided to reobserve these targets for two main reasons. First, at the time when our observations were scheduled and performed these spectra were not yet published and, second, due to the well-known BL Lac

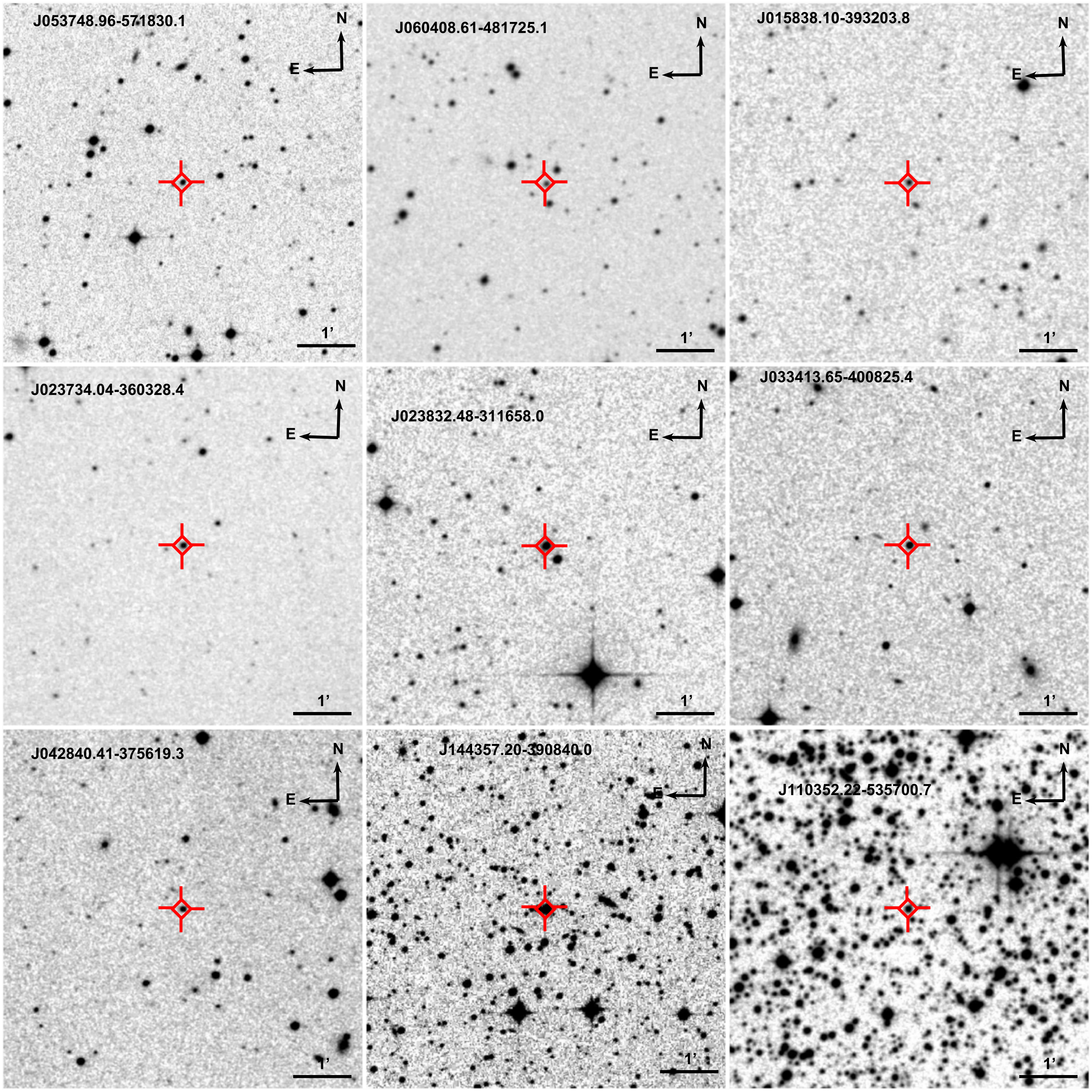

Figure 1. (Continued.)

variability in the optical band there is always the chance to observe the source in a low state and detect some features allowing the determination of their redshifts. Moreover, for a number of objects the available spectra in the literature exhibit rather low S/Ns making it almost impossible to secure an affordable classification of sources and, if possible, the determination of their distance. Source details are given in the next section.

3.1. *Unidentified Gamma-ray Sources*

The *WISE*-selected counterparts to these UGSs show IR *WISE* colors similar to those of γ-ray blazars considered in the analysis performed by Massaro et al. (2013a). In particular, they were predicted to be BL Lacs rather than FSRQs (see D’Abrusco et al. 2013) since their IR colors are consistent with those of the *Fermi* BL Lacs. Such probabilites are computed by adopting the same procedures described in the previous *Fermi* catalog releases (Abdo et al. 2010; Nolan et al. 2012; 1FGL and the 2FGL). They are all detected in the radio band, having counterparts in the Sydney University Molonglo Sky Survey (SUMSS; Mauch et al. 2003, S in Table 1) in agreement with the expectations of the radio–γ-ray connection (e.g., Ghirlanda et al. 2010; Mahony et al. 2010; Massaro et al. 2013b). Five out of seven sources are detected in the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006, denoted M in Table 1) while the whole sample of UGSs have an optical counterpart in the USNO-B1 Catalog (Monet et al. 2003, U in Table 1). We

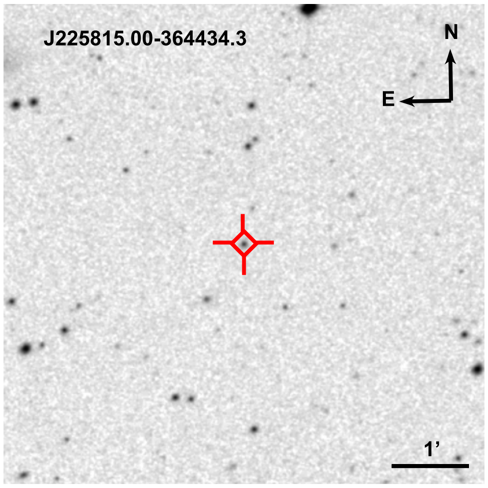

Figure 1. (Continued.)

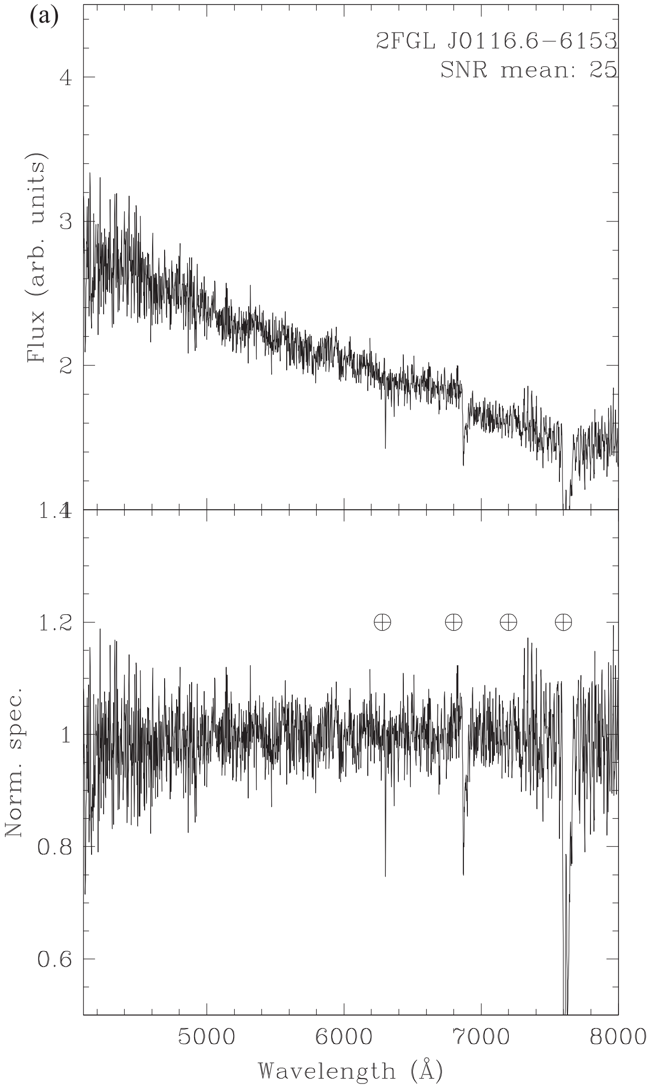

Figure 2. 2FGL J0116.6-6153 optical spectrum obtained at SOAR with High Throughput Goodman Spectrograph. Upper panel: flux-calibrated (relative units) spectrum of the source. Lower panel: normalized spectrum (see text for details). (An extended version of this figure is available.)

report the main multifrequency properties of each source in Table 1, together with their 2FGL name, the *WISE* name, and the counterpart coordinates. We also searched for optical counterparts in the Six-degree-field Galaxy Survey (6dFGS; Jones et al. 2004, 2009, denoted as 6 in Table 1) while, at high energies, we analyzed the *ROSAT* all-sky survey in both the *ROSAT* Bright Source Catalog (RBSC; Voges et al. 1999,—X) and the *ROSAT* Faint Source Catalog (RFSC; Voges et al. 2000, X in Table 1) as well the Deep *Swift* X-ray Telescope Point Source Catalog (1SXPS; Evans et al. 2014, x in Table 1). We also took into account the *Swift* X-ray survey for all the *Fermi* UGSs[9] (Paggi et al. 2013; Stroh & Falcone 2013; Takeuchi et al. 2013).[13] We adopt the same symbols for the X-ray catalog of *XMM-Newton*, *Chandra*, and *Swift* because they provide observations for *only pointed* sources while most of the X-ray counterparts of our potential counterparts can be serendipitous.

In agreement with the expectations of the method developed by D'Abrusco et al. (2013), for six out of seven sources our spectroscopic observations confirmed their BL Lac nature (see Figures 2(a)–(g)). We note that their completely featureless spectra do not allow us to determine their redshifts. The remaining one, namely 2FGL J0416.0-4355, appears to have a quasar-like spectrum in the optical band (see Figure 2(e)), similar to FSRQ sources with a redshift estimate of 0.398 from Hβ (λ 6800, EW 110 Å) and [O III] doublet ($\lambda\lambda$6913–6976, EW 25–50 Å). However, in this case the lack of additional information necessary to compute the radio spectral index did not permit us to classify the source as an FSRQ. Finally, we highlight that the chance probabilities of having a spurious association for the *WISE* sources selected according to their blazar-like IR colors and confirmed as blazars thanks to these new observations will be assessed in the upcoming *Fermi*-LAT catalog release once these new blazars are added to comparison catalogs of potential counterparts (Abdo et al. 2015).

3.2. Gamma-ray AGUs

In the sample of AGUs, chosen on the same basis as the IR color analysis performed for UGSs, three out of six sources belong to the First *Fermi*-LAT Source Catalog (1FGL; Abdo et al. 2010), as marked in Table 1, while all the AGUs are detected in X-rays and show counterparts in both the RBSC and RFSC, as well as radio counterparts in the SUMSS. In particular, 2FGL J0424.3-5332 is also detected in the Parkes-MIT-NRAO Surveys (PMN; Wright et al. 1994, shown as Pm in Table 1) as well as in the Australia Telescope 20 GHz Survey (AT20G; Murphy et al. 2010, denoted A) and, since it has a flat radio spectrum, also belongs to the Combined Radio All-Sky Targeted Eight-GHz Survey (CRATES; Healey et al. 2007, denoted c). 2FGL J0157.2-5259 is also detected by *GALEX* (NASA Extragalactic Database (NED)[14]).

As shown by Massaro et al. (2012b), four of the AGUs have *WISE* colors typical of *Fermi* blazars at a 95% level of confidence, while the other two, namely 2FGL J0335.3-4501 and 2FGL J0604.2-4817[15], are only marginally consistent with the *WISE* Gamma-ray Strip. However, they are all detected by *WISE* and five out of six also have counterparts in 2MASS.

---

[13] http://www.swift.psu.edu/unassociated/

[14] http://ned.ipac.caltech.edu/

[15] Also observed during our program even if its optical spectrum was already published in Masetti et al. (2013) since our data were taken while that paper was submitted.

Moreover, the X-ray, γ-ray, and radio properties of the *WISE* counterparts of 2FGL J0157.2-5259 (Takeuchi et al. 2013) and 2FGL J1103.9-5356 (Keith et al. 2011) are also consistent with a blazar nature for these sources.

Our spectroscopic observations confirm that all six sources are BL Lac objects (see Figures 2(h)–(m)). For three of them, 2FGL J0335.3-4501, 2FGL J0424.3-5332 and 2FGL J0537.7-5716, we have been able to set a lower limit on their redshifts based on the detection of Mg II absorption lines that could be due to the blazar host galaxy or, more probably, to intervening systems. The lower limit on the redshift is $z \geqslant 0.88$ for 2FGL J0335.3-4501 and $z \geqslant 0.461$ for 2FGL J0424.3-5332, respectively. More interesting is the case of 2FGL J0537.7-5716 where multiple Mg II absorption system are detected. The first one is found to be at redshift $z = 0.521$ while the second one is at $z = 1.18$ making this source one of the most distant and infrared luminous ($L \geqslant 3 \times 10^{45}$ erg s^{-1}) BL Lac ever observed. Finally, we note that the sources 2FGL J0424.3-5332 and 2FGL J1103.9-5356 also appear in Shaw et al. (2013a), but for the first one, we are able to set a spectroscopic lower limit to the redshift from an intervening system of Mg II ($z = 0.461$, in agreement with the proposed lower limit) that was not detected by Shaw et al. (2013a). For the second source, our spectrum exhibits a higher supernova remnant (SNR) with respect to the one reported by Shaw et al. (2013a).

3.3. γ-ray Blazars

We report in Table 1 for our six γ-ray blazars their Roma-BZCAT and *WISE* name. No multifrequency notes are present in this table since they are already discussed in the Roma-BZCAT. All these six blazars belong to the sample named *locus* used in D'Abrusco et al. (2013) to identify blazar-like sources within the positional uncertainty region of the *Fermi* UGSs. Thus all the *WISE* counterparts have the IR consistent with the remaining *Fermi* blazars.

The first four blazars listed in Table 1 are BL Lac candidates, thus no optical spectrum was available in literature preventing us to provide a firm classification. The remaining two, BZB J0428-3756 and BZB J1443-3908, were indeed confirmed blazars with an uncertain redshift estimate. Our spectroscopic observations verified that all the BL Lac candidates have featureless optical spectra as shown in Figures 2(n)–(s) with the exception of BZB J0238-3116 for which the Ca II ($\lambda\lambda$4850–4891, EW ~ 1.00–0.70 Å) and Mg I (λ 6420, EW ~2.50 Å) absorption lines from its host galaxy starlight allow us to estimate a redshift $z = 0.232$. We finally note that in the spectrum of BZB J0428-3756 multiple Mg II intervening systems ($z = 0.558$ and $z = 1.02$) are clearly detected allowing us to put a stringent spectroscopic lower limit to this high redshift BL Lac object. These absorption features are also confirmed from spectroscopic study of Heidt et al. (2004). However, we could not detect the broad emission feature at 5906 Å ascribed to Mg II as reported in Heidt et al. (2004) suggesting that our observation may have been carried out while the source was in a high state.

We note that three of the four sources (BZB J0158-3932, BZB J0334.2-4008 and BZB J1443.9-3908) also appear in Shaw et al. (2013a). Nevertheless, while for BZB J0158-3932 and BZB J1443.9-3908 the spectra are similar in terms of SNR and spectral coverage, for BZB J0334.2-4008 we could not confirm the detection of broad emission lines of Mg II and C III reported in Shaw et al. (2013a) supporting the fact that we probably observed the source during a high state of the relativistic jet which outshined the underlying emission lines from the BLR.

4. SUMMARY AND CONCLUSIONS

We report the results of our exploratory spectroscopic campaign carried out in the Southern hemisphere with the SOAR telescope from 2013 August to 2014 January. We observed a selected sample of 19 targets. Seven sources were *WISE* counterparts of *Fermi* UGSs listed in the 2FGL and identified thanks to the IR-based procedure developed by D'Abrusco et al. (2013) and Massaro et al. (2013a). In addition we collect spectra for six AGUs associated in the 2FGL catalog and six γ-ray BL Lac candidates for which no optical spectra where found in literature leaving the classification uncertain.

Our main goal was to confirm the nature of the counterparts for the UGSs selected on the basis of their IR colors and correctly classify the remaining targets. We found that six out of seven *WISE* sources chosen to be potential counterparts of the UGSs are clearly BL Lac objects while 2FGL J0416.0-4355 appears to be identified with a QSO at $z = 0.398$. The lack of radio information did not allow us to classify this source as a FSRQ. These results are fully in agreement with the predictions of our developed association methods (see Massaro et al. 2013a for more details). We also discovered that all the AGUs observed are indeed BL Lac objects and for two of them we were able to report a first redshift estimate employing Mg II intervening absorption system along the line of sight (or due to their host galaxies). Finally, all the BL Lac candidates that belong to the *WISE* sample of *Fermi* blazars used in the sample adopted to calibrate the association methods (e.g., D'Abrusco et al. 2013, 2012) are firmly established as bona fide BL Lacs through our spectroscopic observations. For BZBJ0238-3116 we measured a redshift $z = 0.232$ through Ca II break and Mg I absorption lines from host galaxy starlight, while for BZBJ0428-3756 we put a lower limit on the redshift of$z \geqslant 1.02$ from an intervening Mg II absorption system detected along the line of sight.

This investigation is supported by the NASA grants NNX12AO97G and NNX13AP20G. H.A.S. acknowledges partial support from NASA/JPL grant RSAs 1369566, 1369556, and 1369565. The work by G. Tosti is supported by the ASI/INAF contract I/005/12/0 while work by C.C.C. at NRL is supported in part by NASA DPR S-15633-Y. We are grateful to Dr. S. Points for his help to schedule, prepare, and perform the SOAR observations. Part of this work is based on archival data, software, or online services provided by the ASI Science Data Center. This research has made use of data obtained from the high-energy Astrophysics Science Archive Research Center (HEASARC) provided by NASA's Goddard Space Flight Center; the SIMBAD database operated at CDS, Strasbourg, France; and the NASA/IPAC Extragalactic Database (NED) operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. The Molonglo Observatory site manager, Duncan Campbell-Wilson, and the staff, Jeff Webb, Michael White, and John Barry, are responsible for the smooth operation of Molonglo Observatory Synthesis Telescope (MOST) and the day-to-day observing programme of SUMSS. The SUMSS survey is dedicated to Michael Large whose expertise and vision made the project possible. MOST is operated by the School of Physics with the support of the Australian Research Council and the Science Foundation for Physics within the University of Sydney. This publication makes use of data products from the *Wide-field Infrared Survey Explorer*, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, funded by the National Aeronautics and Space Administration. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. This research has made use of the USNOFS Image and Catalogue Archive operated by the United States Naval Observatory, Flagstaff Station (http://www.nofs.navy.mil/data/fchpix/). TOPCAT[16] (Taylor 2005) for the preparation and manipulation of the tabular data and the images.

REFERENCES

Abdo, A. A., Ackermann, M., Ajello, M., et al. 2010, ApJS, 188, 405
Abdo, A. A., et al. 2015, ApJ, submitted
Acero, F., Donato, D., Ojha, R., et al. 2013, ApJ, 779, 133
Ackermann, M., Ajello, M., Allafort, A., et al. 2011a, ApJ, 743, 171
Ackermann, M., Ajello, M., Allafort, A., Antolini, E., Atwood, W. B., et al. 2011b, ApJ, 741, 30
Blandford, R. D., & Rees, M. J. 1978, PhyS, 17, 265
Cardelli, J. A., Clayton, G. C., & Mathis, J. S. 1989, ApJ, 345, 245
Clemens, J. C., Crain, J. A., & Anderson, R. 2004, Proc. SPIE, 5492, 331
Cutri, R. M., Wright, E. L., Conrow, T., Bauer, J., Benford, D., et al. 2012, wise rept 1C
D'Abrusco, R., Massaro, F., Ajello, M., et al. 2012, ApJ, 748, 68
D'Abrusco, R., Massaro, F., Paggi, A., et al. 2013, ApJS, 206, 12
Evans, P. A., Osborne, J. P., Beardmore, A. P., et al. 2014, ApJS, 210, 8
Ghirlanda, G., Ghisellini, G., Tavecchio, F., Foschini, L., et al. 2010, MNRAS, 407, 791
Healey, S. E., Romani, R. W., Taylor, G. B., et al. 2007, ApJS, 171, 61
Heidt, J., Tröller, M., Nilsson, K., et al. 2004, A&A, 418, 813
Jones, D. H., Saunders, W., Colless, M., Read, M. A., Parker, Q. A., et al. 2004, MNRAS, 355, 747
Jones, D. H., Read, M. A., Saunders, W., Colless, M., Jarrett, T., et al. 2009, MNRAS, 399, 683
Keith, M. J., Johnston, S., Ray, P. S., et al. 2011, MNRAS, 414, 129
Kovalev, Y. Y. 2009, ApJL, 707L, 56
Landoni, M., Falomo, R., Treves, A., et al. 2012, A&A, 543, A116
Landoni, M., Falomo, R., Treves, A., et al. 2013, AJ, 145, 114
Landoni, M., Falomo, R., Treves, A., & Sbarufatti, B. 2014, arXiv:1407.3085
Laurent-Muehleisen, S. A., Kollgaard, R. I., Feigelson, E. D., Brinkmann, W., & Siebert, J. 1999, ApJ, 525, 127
Mahony, E. K., Sadler, E. M., Murphy, T., Ekers, R. D., & Edwards, P. G. 2010, ApJ, 718, 587
Masetti, N., Sbarufatti, B., & Parisi, P. 2013, A&A, 559A, 58
Massaro, E., Giommi, P., Leto, C., et al. 2009, A&A, 495, 691
Massaro, F., D'Abrusco, R., Ajello, M., Grindlay, J. E., & Smith, H. A. 2011a, ApJL, 740, L48
Massaro, E., Giommi, P., Leto, C., et al. 2011b, in Multifrequency Catalogue of Blazars (3rd edn.; Rome, Italy: ARACNE Editrice)
Massaro, F., D'Abrusco, R., Tosti, G., et al. 2012a, ApJ, 752, 61
Massaro, F., D'Abrusco, R., Tosti, G., et al. 2012b, ApJ, 750, 138
Massaro, F., D'Abrusco, R., Paggi, A., Tosti, G., & Gasparrini, D. 2012c, ApJL, 750, L35
Massaro, F., D'Abrusco, R., Paggi, A., et al. 2013a, ApJS, 206, 13
Massaro, F., D'Abrusco, R., Giroletti, M., et al. 2013b, ApJS, 207, 4
Massaro, F., Masetti, N., D'Abrusco, R., Paggi, A., & Funk, S. 2014, AJ, 148, 66
Mauch, T., Murphy, T., Buttery, H. J., et al. 2003, MNRAS, 342, 1117
Mirabal, N. 2009, ApJ, 701, 129
Monet, D. G., Levine, S. E., Canzian, B., Ables, H. D., Bird, A., et al. 2003, AJ, 125, 984
Murphy, T., Sadler, E. M., Ekers, R. D., Massardi, M., Hancock, P. J., et al. 2010, MNRAS, 402, 2403
Nolan, P. L., Abdo, A. A., Ackermann, M., et al. 2012, ApJS, 199, 31
Nori, M., Giroletti, M., Massaro, F., et al. 2014, ApJS, 212, 3
Paggi, A., Massaro, F., D'Abrusco, R., et al. 2013, ApJS, 209, 9
Paggi, A., Milisavljevic, D., Masetti, N., et al. 2014, AJ, 147, 112
Petrov, L., Mahony, E. K., Edwards, P. G., et al. 2013, MNRAS, 432, 1294
Shaw, M. S., Romani, R. W., Cotter, G., et al. 2013a, ApJ, 764, 135
Shaw, M. S., Filippenko, A. V., Romani, R. W., et al. 2013b, AJ, 146, 127
Schlegel, D. J., Finkbeiner, D. P., & Davis, M. 1998, ApJ, 500, 525
Skrutskie, M. F., Cutri, R. M., Stiening, R., Weinberg, M. D., Schneider, S., et al. 2006, AJ, 131, 1163
Stickel, M., Padovani, P., Urry, C. M., Fried, J. W., & Kuehr, H. 1991, ApJ, 374, 431
Stocke, J. T., Morris, S. L., Gioia, I. M., Maccacaro, T., Schild, R., et al. 1991, ApJS, 76, 813
Stroh, M. C., & Falcone, A. D. 2013, ApJS, 207, 28
Takeuchi, Y., Kataoka, J., Maeda, K., et al. 2013, ApJS, 208, 25
Taylor, M. B. 2005, ASP Conf. Ser, 347, Astronomical Data Analysis Software and Systems XIV, ed. P. Shopbell et al. (San Francisco, CA: ASP), 29
Urry, C. M., & Padovani, P. 1995, PASP, 107, 803
Voges, W., Aschenbach, B., Boller, Th., Bräuninger, H., Briel, U., et al. 1999, A&A, 349, 389
Voges, W., Aschenbach, B., Boller, T., Brauninger, H., Briel, U., et al. 2000, IAUC, 7432R, 1
Wright, A. E., Griffith, M. R., Burke, B. F., & Ekers, R. D. 1994, ApJS, 91, 111
Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., Ressler, M. E., Cutri, R., et al. 2010, AJ, 140, 1868

---

[16] http://www.star.bris.ac.uk/~mbt/topcat/