Optical spectroscopic classification of a selection of Southern Hemisphere 3FHL blazar candidates

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ABSTRACT

The *Fermi*-LAT has detected more than 5000 γ-ray sources which show emission above 50 MeV of which 58 per cent belong to the blazar class. However, the Fourth Fermi-LAT catalogue (4FGL) lists 1312 of these as blazar candidates of uncertain type (BCU). Increasing the number of classified Fermi-LAT sources is important for improving our understanding of extra-galactic γ-ray sources and can be used to search for new classes of very high energy sources. We report on the optical spectroscopy of twelve unclassified BCUs with hard photon indices included in the Third Catalogue of Hard Fermi-LAT Sources (3FHL) during 2016 and 2017 using the SAAO 1.9-m telescope. We were able to classify all the sources observed as BL Lac objects, and were able to calculate the redshift for six sources and a potential redshift for one source.

1. INTRODUCTION

The Large Area Telescope (LAT) onboard the Fermi γ-ray telescope, has been in operation since 2008 and has detected 5000 γ-ray sources above 50 MeV [1]. Fermi's sensitivity, large Field-of-View (FoV) and near-continuous sky coverage has resulted in several γ-ray catalogues. These include the Fermi-LAT Third Source Catalog (3FGL), the Third Catalog of Hard Fermi-LAT Sources (3FHL) and the Fermi-LAT Fourth Source Catalogue (4FGL) [2,3,4].

The LAT catalogues have dramatically increased the number of γ-ray loud blazars that can be studied in the multi-wavelength regime, but have also revealed a large population of unclassified sources that most likely associated with blazars. For instance, the 4FGL lists 3137 blazars, 1312 of which are classified as blazar candidates of uncertain type (BCU). The BCUs listed in the 4FGL, and other LAT catalogues, are all sources that show blazar like characteristics, have a high degree of localization but lack a spectroscopic classification because of either low quality spectra, or because no observations have been undertaken.

While the majority of BCUs are most likely blazars, they may hide a population of novel non-blazar γ-ray emitting sources. The sources also represent a potential list of candidates for TeV gamma-ray observations. However, since VHE γ-rays are absorbed by the extragalactic background light (EBL), only sources closer than z∼1 can be studied in the VHE regime [5]. This makes spectroscopic classification of BCUs important for determining if new blazars can be classified in the VHE regime using ground based γ-ray observatories, such as H.E.S.S.or the upcoming CTA [6,7].

Following on previously reported spectroscopic classifications [8] we report on optical spectroscopic observations of twelve 3FHL BCUs observed during 2016/2017 with the South African Astronomical Obsertvatory (SAAO) 1.9-m SpUpNIC grating spectrograph.

2. EXPERIMENTAL

Observations were undertaken during July/August 2016, February 2017 and August/September 2017 using the SAAO1.9-m SpUpNIC (Spectrograph Upgrade: Newly Improved Cassegrain) grating spectrograph located at the South African Astronomical Observatory (SAAO) [9]. Observations were taken with "grating 7" at a grating angle of ~16 degrees, giving a wavelenth range of ~3500 – 9000 Å and a spectral resolution of ≈5 Å. Wavelenth calibration was performed with a CuAr arc lamp and Domeflats were taken during the day with the same instrument setup used for the observations.

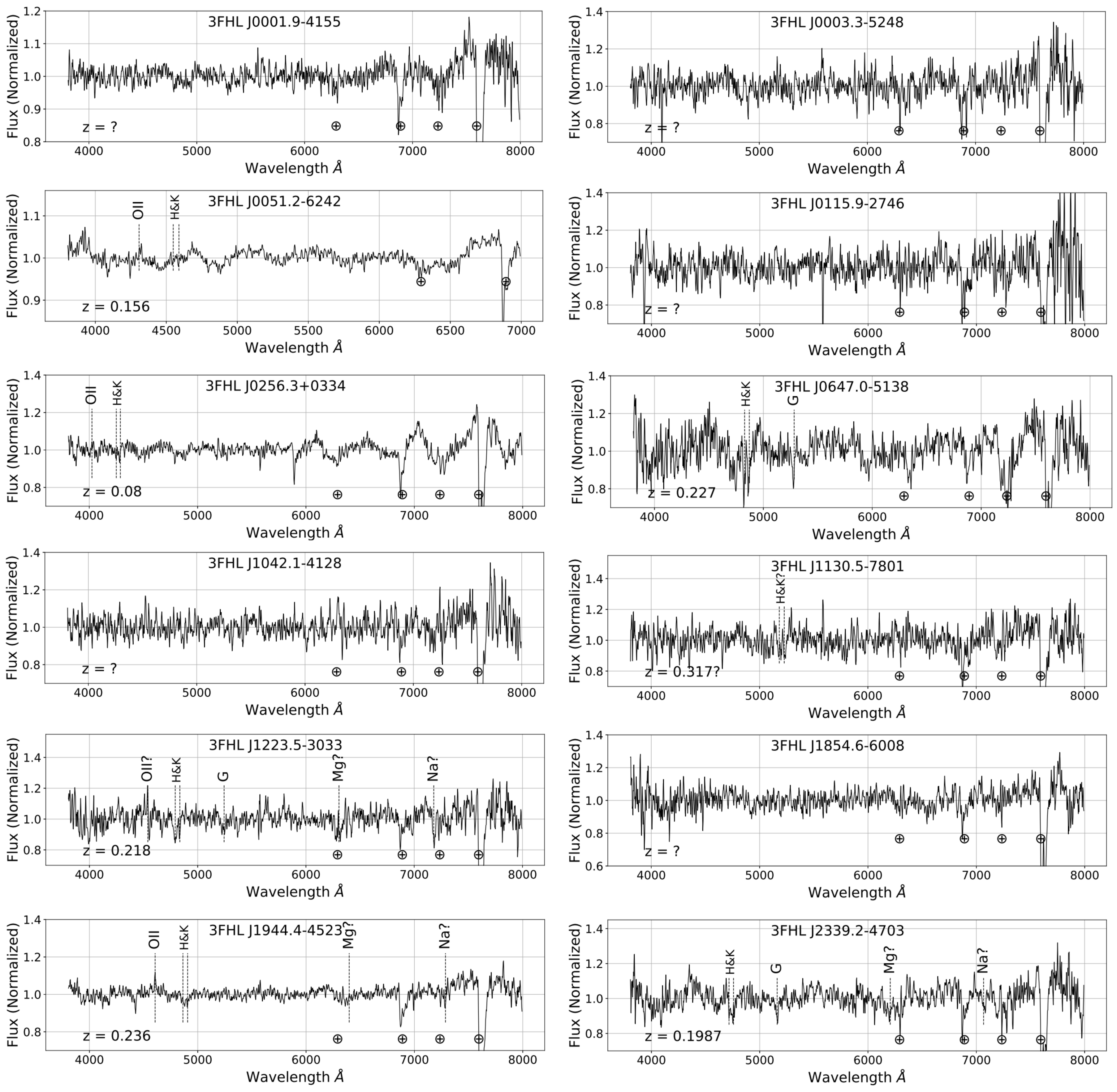
Data reduction was performed following the standard procedures using the noao/iraf packages. This included bias correction, flat correction and wavelength calibration. Cosmic ray removal was performed after the wavelength calibration using the lacosmic python module based on the L.A. Cosmic algorithm [10].

All spectra were analysed using the rvsao package to determined the redshift [11]. The rvsao package cross-correlates the target's one-dimensional normalised spectrum against various zero redshift template spectra to calculate the redshift to the source. This method also allows a confidence and error to be calculated for the redshift. A confidence of R>3 is suggested before a redshift is accepted. The cross-correlation method is useful in calculating redshifts for low S/N spectra. However, all our spectra have S/N≤50 and weak or absent features and rvsao was only able to calculate confidences of R≤3, and we, therefore, also visually inspected the spectra to confirm that the rvsao redshift measurements were realistic.

4FGL Name	Association	RA	Dec	Flux (1 -100 GeV)	Γ_γ
	(hh:mm:ss)	(dd:mm:ss)	10^{-10}	cm^{-2}	s^{-1}
J0001.6-4156	1RXS J000135.5-415519	00:01:32.7	-41:55:25.3	2.80 ± 0.39	1.83 ± 0.10
J0003.1-5248	RBS 0006	00:03:19.6	-52:47:27.6	3.01 ± 0.40	1.85 ± 0.09
J0051.2-6242	1RXS J005117.7-624154	00:51:16.6	-62:42:04.4	1.44 ± 0.72	1.71 ± 0.03
J0116.0-2745	1RXS J011555.6-274428	01:15:55.5	-27:44:31.7	1.31 ± 0.36	1.78 ± 0.17
J0256.3+0334	PKS B0253+033	02:56:28.1	+03:33:31.1	4.04 ± 0.51	2.16 ± 0.10
J0647.0-5138	1ES 0646-515	06:47:10.0	-51:35:47.7	1.82 ± 0.38	1.83 ± 0.14
J1042.1-4128	1RXS J104204.1-412936	10:42:03.0	-41:29:29.9	2.63 ± 0.43	1.87 ± 0.10
J1130.5-7801	SUMSS J113032-780105	11:30:31.9	-78:01:05.4	3.55 ± 0.50	1.64 ± 0.07
J1223.6-3032	NVSS J122337-303246	12:23:37.0	-30:32:50.1	2.24 ± 0.47	1.82 ± 0.14
J1854.6-6007	PMN J1854-6009	18:54:51.7	-60:09:23.6	1.33 ± 0.34	1.88 ± 0.17
J1944.4-4523	1RXS J194422.6-452326	19:44:22.3	-45:23:27.9	2.10 ± 0.39	1.70 ± 0.11
J2339.2-7403	1RXS J233919.8-740439	23:39:20.9	-74:04:36.1	4.33 ± 0.43	1.91 ± 0.07

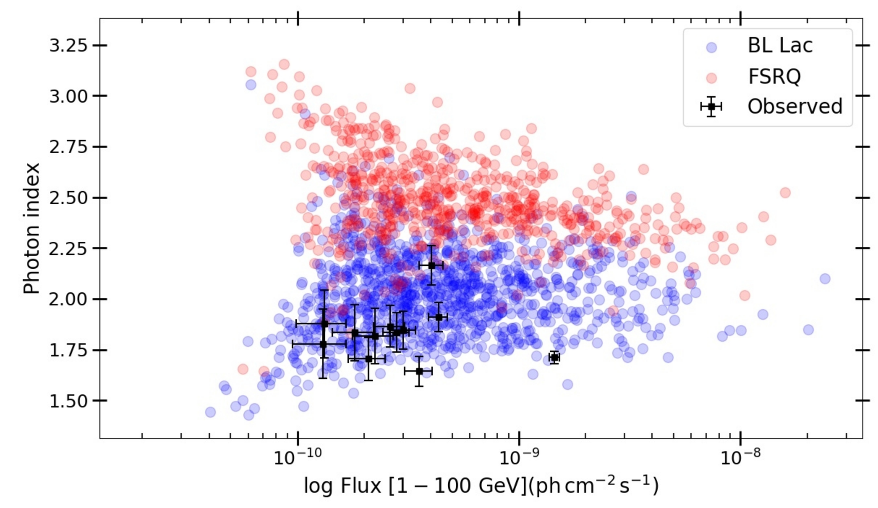
3. RESULTS AND DISCUSION

The spectroscopic results are presented for the individual sources below. For all the sources,the flux normalised spectrum is shown. For all the spectra, telluric lines and lines are indicated by a ⊕. All the spectra have been smoothed for display purposes using a smoothing box of 3 data points to more clearly show any features present in the spectra.



4. CONCLUSION

We pesented spectroscopic observations of twelve Fermi-LAT 4FGL BCUs taken with the SAAO 1.9-m SpUpNIC grating spectrograph. We were able to classify all the observed BCUs as BL Lac type sources, calculated redshifts for six of them and a potential redshift for one. The classification of these sources as BL Lacs are consistant with their γ-ray properties. These observations are part of an ongoing larger campaign to classify *Fermi*-LAT BCUs for potential detection with IACTs like H.E.S.S and the upcoming CTA.



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