Redshift measurement of the BL-Lac gamma-ray blazar PKS 1424+240

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Abstract:

PKS 1424+240 is a BL-Lac blazar with unknown redshift detected at high-energy gamma rays by Fermi-LAT with a hard spectrum. It was first detected at very-high-energy (VHE) by VERITAS and latter confirmed by MAGIC. Attempts to find limits on its redshift include three estimations by modeling gamma-ray observations, and one obtained by analyzing Ly_β and Ly_γ absorption lines observed in the far-UV spectra (from HST/COS) caused by absorbing gas along the line of sight. They allowed to constrain the redshift range to $0.6 < z < 1.19$, which places PKS 1424+240 in the very interesting condition to be one of the few candidates to be the most distant blazars detected at VHE gamma rays.
Redshift determination of BL-Lac objects are difficult to achieve. We have found that redshift of blazars can be determined by its association to a galaxy group or cluster. To explore this possibility for PKS 1424+240, we have carried out spectroscopic measurements of galaxies in its field of view with the Gemini North telescope. In this work we present the optical spectrum of PKS 1424+240 and show preliminary results of the blazar environment characterization. Spectroscopic redshift using the optical spectrum of PKS 1424+240 could not be determined in this work.

1. Introduction:

Due to the photon-photon interaction, gamma-rays traveling to Earth suffer attenuation with the Extragalactic Background Light (EBL), which limits the number of sources observed in the gamma-ray domain. For VHE gamma-ray astronomy the TevCat catalog (http://tevcat.uchicago.edu/) shows 65 discovered extragalactic sources, from which 59 are blazars (53 of them are BL-Lacs). 56 extragalactic sources in the catalog have a measured redshift (distribution in **Figure 1**). The newly announced sources PKS 1441+25 and S3 0218+35 are the more distant ones at z>0.9.

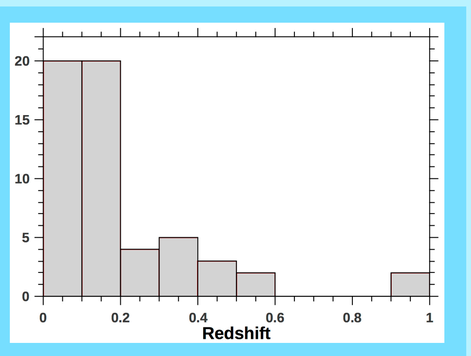

Fig. 1: Redshift distribution of extragalactic gamma-ray sources detected at VHE. 90 % of them are blazars (81 % of type BL-Lac).

Extragalactic gamma-ray sources are mainly BL-Lac blazars, whose spectroscopic redshift is difficult to measure due to the lack of emission and absorption lines in their spectra. By modeling the drop in the spectral energy distribution (SED) at gamma rays an estimation of the photon-photon interaction effects may be obtained, which in turn can be used to estimate the redshift.
In view of the difficulties, we have proposed an interesting alternative method to estimate the redshift in an indirect way. Given that BL-Lacs are typically hosted by elliptical galaxies, which in turn are associated to groups or clusters, we have proposed to realize spectroscopic observations to find the host group of galaxies associated with the blazar. The method was successfully proved with Gemini GMOS observations of the BL-Lac gamma-ray blazar PK 0447-439 and its environment [1].
Here we present the optical spectrum of PKS 1424+240 from data acquired with Gemini using the GMOS-N spectrometer, as well as preliminary results of the blazar environment.

PKS 1424+240 is a BL-Lac blazar with unknown redshift detected at HE by Fermi-LAT with a hard spectrum [2]. It was first detected at VHE by VERITAS [3], and latter confirmed by MAGIC [4]. Modeling the drop in the SED an upper limit of $z < 0.66$ was found considering different EBL models [3]. Their result is in agreement with the upper limit of $z < 1.19$, for which only the lowest EBL estimation was used. A two-component synchrotron self-Compton model was found to describe the SED of the source well if it is located at $z \sim 0.6$ [4]. Leaving the gamma-ray domain, a photometric upper limit of $z < 1.11$ was reported [5]. Also, a totally independent and more firm lower limit of $z > 0.6$ was reported using recent UV observations taken with the HST/COS [6]. They have analyzed the Ly_β and Ly_γ absorption lines observed in the far-UV spectra caused by absorbing gas along the line of sight. All these results place PKS 1424+240 in the very interesting condition to be one of the few most distant blazars detected at VHE, with redshift in the range $0.6 < z < 1.19$.

2. Observations and data reduction:

Spectra for PKS 1424+240 and 30 other objects around it were obtained with the Gemini Multi-Object Spectrograph (GMOS), program GN-2015A-Q12. A multislit mask was created for this purpose using a pre-image provided by Gemini. We placed one field centered on PKS 1424+240, covering a region of 5×5 arcmin^2, and selected other extragalactic objects in the field to characterize the environment. The spectroscopic data was acquired in queue mode on April 26, 2015. Technical data of the observations are as follows:

- Grating B600(G5323) (ruling density of 600 lines/mm).
- Five exposures of 900 s each through a 1.0 arcsec slit at 5400 Å, 5500 Å, and 5600 Å.
- Airmass of 1.25 with a seeing ranging from 0.64 to 0.80 arcsec.
- Flatfields + spectra of the standard star *Feige 66* + *CuAr* lamp were also acquired.
- Scale of 0.146 arcsec per pixel and a theoretical dispersion of ~ 0.9 Å per pixel.

All science and calibration files were retrieved from the Gemini Science Archive hosted by the Canadian Astronomy Data Center. The data reduction was carried out with the Gemini IRAF package.

Summary:

We observed the BL-Lac blazar PKS 1424+240 with the Gemini North telescope on April 26, 2015, to perform spectroscopic measurements with a signal to noise ratio of S/N = 300 at 5500 Å. We were not able to identify any spectral feature to obtain a spectroscopic redshift of this blazar; only Galactic and telluric spectral lines were identified (Na I and O2). A jet-to-galaxy luminosity ratio was estimated to be > 100, which is consistent with the featureless kind of spectrum of PKS 1424+240. We have also obtained optical spectroscopic data on 30 other objects to characterize the blazar environment. We are currently analyzing those spectra searching for the presence of a group or cluster of galaxies to which associate PKS 1424+240. Three out of the 30 objects have redshift measurements at the SDSS spectroscopic catalogue to which we can compare our estimations.

[1] H. Muriel, C. Donzelli, A.C. Rovero, and A. Pichel. A&A 574 (2015) A101.
[2] A.A. Abdo, et al., ApJ 707 (2009) 1310.
[3] V. Acciari, et al., ApJ 708 (2010) L100.
[4] J. Aleksić, et al., A&A 567 (2014) A135.
[5] A. Rau, et al., A&A 538 (2012) A26.
[6] A. Furniss, et al., ApJ 769 (2013) L31.

3. New optical spectrum:

Figure 2 shows the observed spectrum of PKS 1424+240 after data reduction and calibration. The spectrum covers the range 3940-6792 Å, in which we have determined a signal to noise ratio for the continuum of S/N=300 at 5500 Å. There are not distinguishable features in the blazar spectrum other than local absorption lines. We clearly identify the Galactic Na I absorption lines at 5891 Å and 5898 Å, and molecular Oxygen telluric absorption (see the insets of Figure 2).

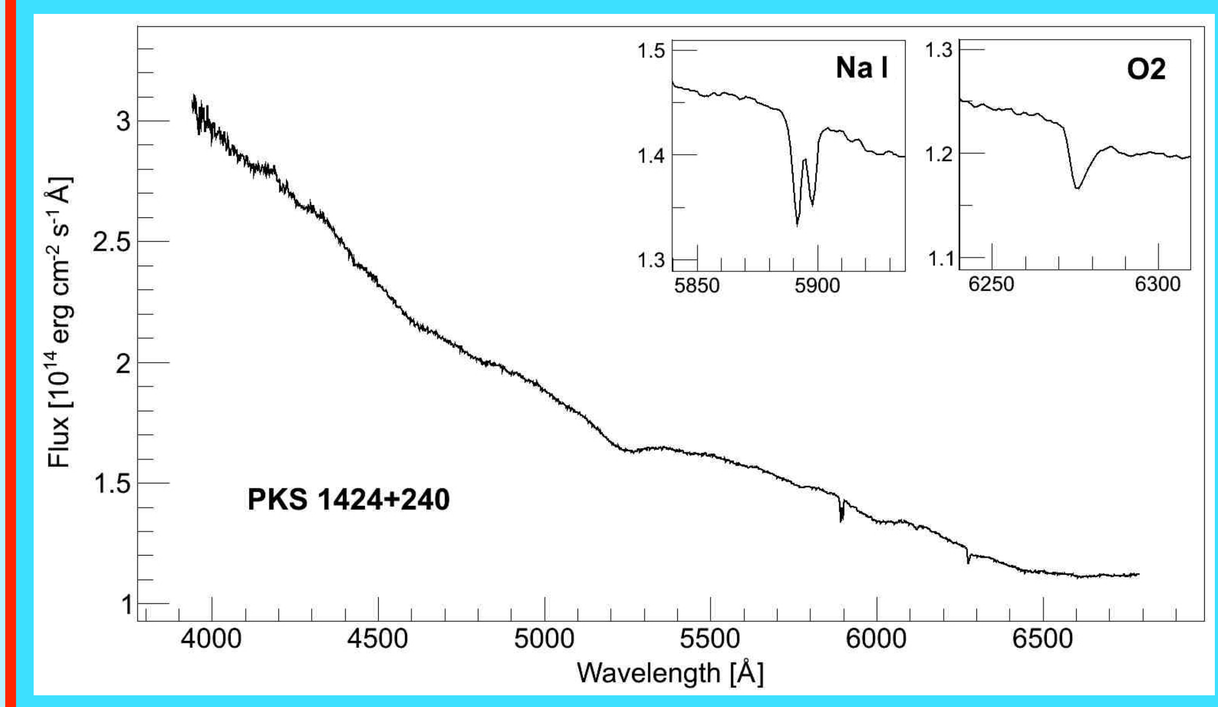

Fig. 2: Observed optical spectrum of PKS 1424+240

4. Spectral lines:

Within the range of wavelength covered by the new optical spectrum of PKS 1424+240 we have not identified any spectral line from any chemical element other that those interpreted as either Galactic or terrestrial. Alternatively, we checked visually possible evidences of the presence of ten absorption and six known emission lines with rest frame wavelengths in the range 2800 Å to 6800 Å. This was done in the redshift range $z = 0.0 - 1.5$. No significant or marginal evidence of coincidences between these commonly observed lines and the spectrum of PKS 1424+240 was found.

Consequently, no spectroscopic estimation for the redshift of this blazar could be determined in this work.

5. Blazar environment:

To characterize the environment of PKS 1424+240 we have acquired spectra of 30 objects around the blazar. Table 1 shows the coordinates of the objects targeted for spectroscopy and their estimated magnitude from the r′ filter. We are currently analyzing all those spectra to find possible groups or clusters of galaxies to with associate the blazar.

Table 1: Objects in the field of view with spectroscopic data. Column 1: slit number; columns 2 and 3: RA and Dec; column 4: total r′ integrated magnitude. (#) Has spectroscopic measurement at SDSS. (*) PKS 1424+240. (–) saturated.

Slit	RA (J2000.0)	DEC (J2000.0)	$m_{r'}$	Slit	RA (J2000.0)	DEC (J2000.0)	$m_{r'}$
1	14:26:52.5	23:47:47.7	22.2	17	14:27:01.7	23:49:43.0	21.3
2	14:26:53.8	23:47:18.5	22.6	18	14:27:03.4	23:49:10.0	21.6
3	14:26:54.8	23:48:48.2	20.3	19	14:27:03.6	23:47:35.5	20.4
4	14:26:56.4	23:50:29.5	21.5	20	14:27:05.2	23:49:17.9	21.6
5	14:26:56.4	23:48:33.3	21.8	21	14:27:06.2	23:49:19.9	21.4
6	14:26:57.6	23:48:09.7	19.1	22	14:27:06.5	23:47:14.2	21.0
7	14:26:58.0	23:47:53.8	21.4	23	14:27:09.2	23:50:10.4	20.2
(#) 8	14:26:59.0	23:47:42.0	20.5	24	14:27:10.4	23:49:40.1	19.8
(*) 9	14:27:00.4	23:48:00.4	—	25	14:27:10.9	23:49:37.5	19.8
10	14:26:59.6	23:46:39.1	21.0	26	14:27:11.4	23:47:54.1	21.7
11	14:27:01.7	23:48:33.1	18.8	27	14:27:11.6	23:47:34.5	21.9
12	14:26:59.4	23:50:20.0	20.6	28	14:27:12.6	23:46:16.1	22.0
(#) 13	14:27:01.8	23:46:31.1	17.5	29	14:27:14.3	23:48:13.1	18.4
14	14:27:04.1	23:47:49.8	20.1	(#) 30	14:27:14.5	23:50:07.6	17.2
15	14:26:54.6	23:50:32.6	21.5	31	14:27:12.8	23:48:50.9	22.3
16	14:27:00.4	23:49:38.4	21.6				

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