A Catalogue of *XMM-Newton* BL Lacs

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An XMM-Newton Catalogue of BL Lac X-ray properties (Álvarez Crespo et al. in prep.) is presented based on the cross-correlation with the 1374 BL Lac objects listed in the 13th edition of the Véron-Cetty & Véron Catalogue (V&V 2010). This catalogue was crossmatched with the XMM_Newton archive up to April 2018 finding 442 observations that correspond to 137 different BL Lacs. Data from the three European Photon Imaging Cameras (EPIC) and Optical Monitor (OM) were homogeneously analysed using the latest XMM-Newton SAS software. Images, lightcurves and spectral models are produced for those sources detected in any of the three EPIC cameras. OM fluxes are computed where available.

The results of the analysis are presented as a catalogue of X-ray spectral properties of the sample in the 0.2-10 keV energy band and in the V/UV band. Multiwavelength information at radio and high and very high gamma-ray energies complete the catalogue.

INTRODUCTION

According to the unified scheme of active galactic nuclei (AGNs), a Blazar is a radio-loud AGN that displays highly variable, beamed, non-thermal emission covering a broad range from radio to γ-ray energies. The observed properties point to a relativistic jet oriented at a small angles with respect to the line of sight. There are two blazar classes according to their optical spectral properties: BL Lacs show weak or no emission lines (EW < 5 A) and flat spectrum radio quasars (FSRQ) that show broad emission lines. Here we focus on the former class.

The spectral energy distribution (SED) of BL Lacs show two distinctive broad bumps. The interpretation of the first component is due to synchrotron radiation of relativistic electrons moving along the jet, and the second peak is the result of inverse Compton (IC) scattering of the synchrotron photons by the very same relativistic electrons (Synchrotron Self Compton, SSC). BL Lacs presenting the fist peak at frequencies $\nu^{S}_{peak} > 10^{15}$ Hz are referred to as High-synchrotron peaked (HSP), those at $10^{14} < \nu^{S}_{peak} < 10^{15}$ Hz are Intermediate-synchrotron peaked (ISP) and those presenting their synchrotron peak frequency at $\nu^{S}_{peak} < 10^{14}$ Hz are Low-synchrotron peaked (LSP).

The shape of the X-ray spectrum can give a fundamental hint for revealing the emission components since X-ray emission is probably originated in the inner parts of the relativistic jet. Here we present a catalogue of 442 observations of 137 different BL Lacs, summarise their spectral properties and their light curves.

DATA SAMPLE

- Initial sample: cross-correlation of the 1374 BL Lacs in the Véron-Cetty & Véron Catalogue (2010, V&V2010) with all public observations available in the *XMM-Newton* archive up to April 2018.
- Instruments: EPIC + OM
- Catalogue: 442 XMM-Newton observations corresponding to a 137 BL Lacs (Fig. 1).
- BL Lac SED: classification: ASDC SED builder tool source by source to calculate ν^{S}_{peak} :
  - 48% HSP
  - 14% ISP
  - 14% LSP

Instruments:

- EPIC: 3CCD cameras for X-ray imaging and spectroscopy.
- OM: optical/UV imaging.

CROSS-CORRELATION XMM-NEWTON AND VC&V10 BL LAC

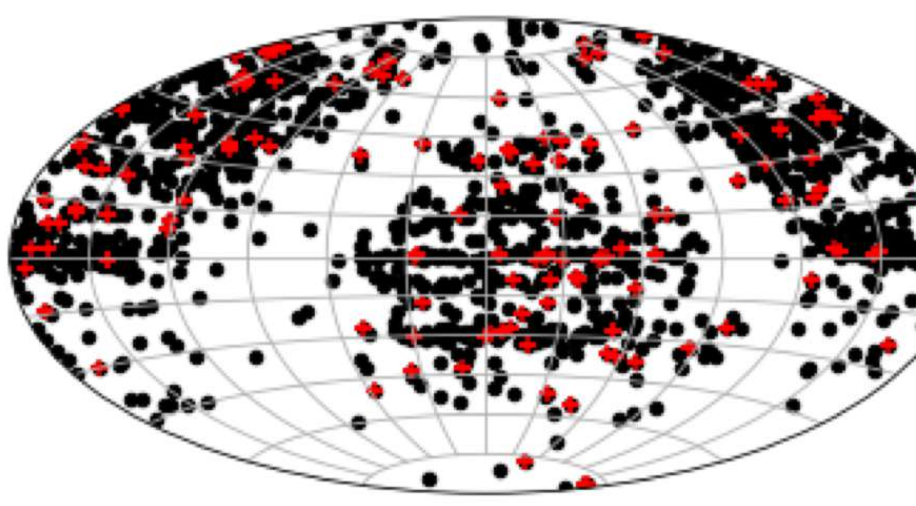

FIG. 1 In black points V&V2010 BL Lacs. In red crosses the *XMM-Newton* catalogue of BL Lacs.

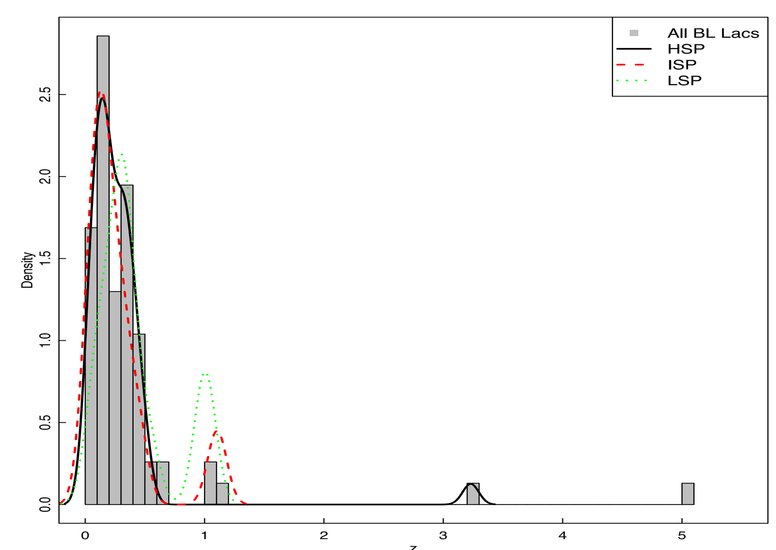

FIG. 2 Histogram of the redshifts in the *XMM-Newton* catalogue of BL Lacs.

DATA EXTRACTION AND ANALYSIS

Sample uniformly analysed with the Science Analysis System (SAS) software (v. 15.0) and the most updated calibration files:

1. Identification of the public XMM-Newton fields where BL Lacs from the VC&V10 Catalogue are present.
2. Source detection algorithms in all selected fields, both for EPIC and OM, and cross-correlate the detected sources with the BL Lacs from the VC&V10 Catalogue.
3. Extract EPIC and OM images, EPIC lightcurves and spectra and OM fluxes and magnitudes.
4. Extract variability parameters from EPIC lightcurves.
5. Fit all the extracted EPIC spectra with the two baseline models:
   - Power law: $N(E) = e^{-\sigma N_H} \cdot K \cdot E^{-\Gamma}$
   - Log-parabola: $N(E) = e^{-\sigma N_H} \cdot K \cdot (E/E_1)^{(-\Gamma-\beta \cdot log(E/E_1))}$

   Each one with the absorption column N_H set of variations:
   - N_H fixed to $N_{H,Gal}$
   - N_H free > $N_{H,Gal}$
   - $N_{H,Gal}$ + $N_{H,z}$

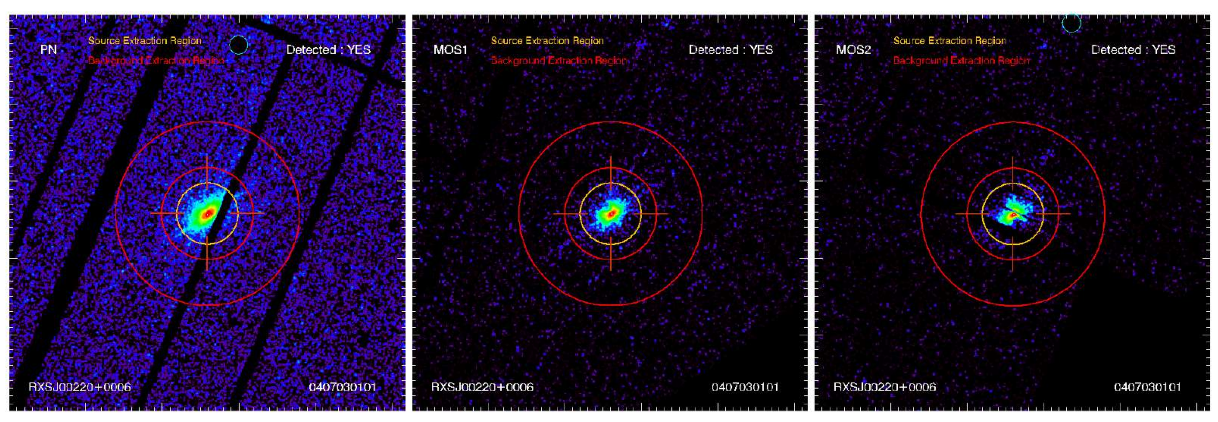

FIG. 3. Example of EPIC IMAGING mode source and background extraction regions for product extraction.

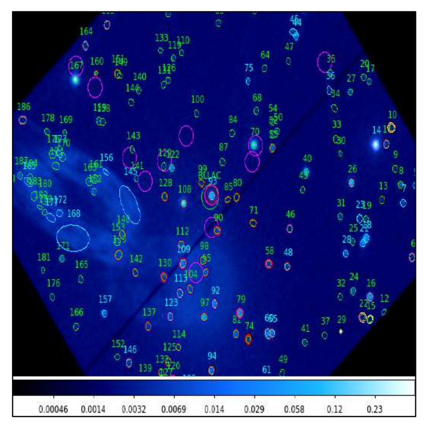

FIG. 4 OM detections

CATALOGUE INFORMATION

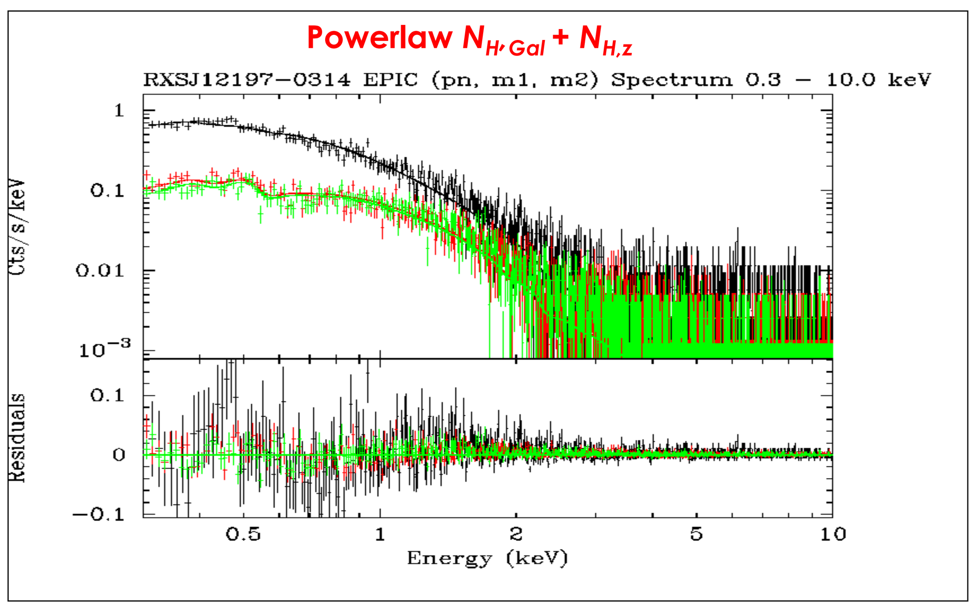

FIG. 5 RXSJ12197-0314 combined spectral fitting. EPIC-pn (black), EPIC-MOS1 (green) and EPIC-MOS2 (red) spectra.

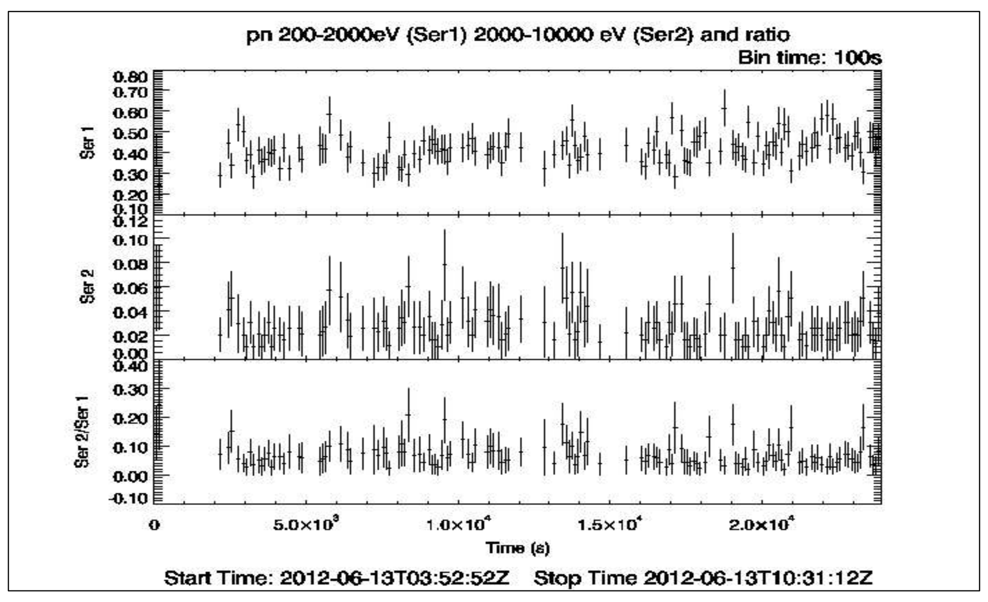

FIG. 6 RXSJ12197-0314 light curve in the 0.2-2 keV (top), and 2-10 keV (middle) energy ranges. Hardness ratio lightcurve (bottom).

- Description of the XMM-Newton BL Lac catalogue (table extract)

Column	Units	Description
Object	-	Source name as given in V&V2010
RA	deg	Right ascension (J2000)
DEC	deg	Declination (J200)
Redshift	-	Source redshift
GalNH	10^2 atoms cm^{-2}	Galactic HI Column Density from the Leiden/Argentine/Bonn (LAB) survey (Kalberla et al. 2005)
Obsid	-	*XMM-Newton* Observation ID
ObsDate	YYYY-MM-DD	Observation date
Duration	ksec	XMM-Newton Exposure duration
Model	-	PowerLawNHFixed: Power Law with N_H fixed to $N_{H,Gal}$ PowerLawNHFree: Power Law with N_H let free to vary PowerLawTABS+ZTABS: Power Law with $N_H = N_{H,Gal} + N_{H,Z}$ LogParabolicNHFixed: Log-parabola with N_H fixed to $N_{H,Gal}$ LogParabolicNHFree: Log-parabola with N_H let free to vary LogParabolicTABS+ZTABS: Log-parabola with $N_H = N_{H,Gal} + N_{H,Z}$
NH	10^2 atoms cm^{-2}	N_H let free to vary during the fitting procedure for PowerLawNHFree and LogParabolicNHFree
NH_me	10^2 atoms cm^{-2}	Lower limit error in NH
NH_pe	10^2 atoms cm^{-2}	Upper limit error in NH
Alpha	dimensionless	Photon index
Alpha_me	dimensionless	Lower limit error in Alpha
Alpha_pe	dimensionless	Upper limit error in Alpha
Beta	dimensionless	Curvature of Log Parabolic models
Beta_me	dimensionless	Lower limit error in Beta
Beta_pe	dimensionless	Upper limit error in Beta
F5keV	microJy	Flux at 5 keV (only for the Power Law models)
F5keV_me	10^{-11} ergs cm^{-2} s^{-1}	Lower limit error in F5keV
F5keV_pe	10^{-11} ergs cm^{-2} s^{-1}	Upper limit error in F5keV
Flux_ET	10^{-11} ergs cm^{-2} s^{-1}	Flux between 0.2 - 10.0 keV
Flux_ET_me	10^{-11} ergs cm^{-2} s^{-1}	Lower limit error in Flux_ET
Flux_ET_pe	10^{-11} ergs cm^{-2} s^{-1}	Upper limit error in Flux_ET
Flux_E1	10^{-11} ergs cm^{-2} s^{-1}	Flux between 0.2 - 2.0 keV
Flux_E1_me	10^{-11} ergs cm^{-2} s^{-1}	Lower limit error in Flux_E1
Flux_E1_pe	10^{-11} ergs cm^{-2} s^{-1}	Upper limit error in Flux_E1
Flux_E2	10^{-11} ergs cm^{-2} s^{-1}	Flux between 2.0 - 10.0 keV
Flux_E2_me	10^{-11} ergs cm^{-2} s^{-1}	Lower limit error in Flux_E2
Flux_E2_pe	10^{-11} ergs cm^{-2} s^{-1}	Upper limit error in Flux_E2
LuminET	10^{44} erg s^{-1}	Luminosity between 0.2 - 10.0 keV
LuminET_me	10^{44} erg s^{-1}	Lower limit error in LuminET
LuminET_pe	10^{44} erg s^{-1}	Upper limit error in LuminET
LuminE1	10^{44} erg s^{-1}	Luminosity between 0.2 - 2.0 keV
LuminE1_me	10^{44} erg s^{-1}	Lower limit error in LuminE1
LuminE1_pe	10^{44} erg s^{-1}	Upper limit error in LuminE1
LuminE2	10^{44} erg s^{-1}	Luminosity between 2.0 - 10.0 keV
LuminE2_me	10^{44} erg s^{-1}	Lower limit error in LuminE2
LuminE2_pe	10^{44} erg s^{-1}	Upper limit error in LuminE2
RedChi2	-	χ^2_r

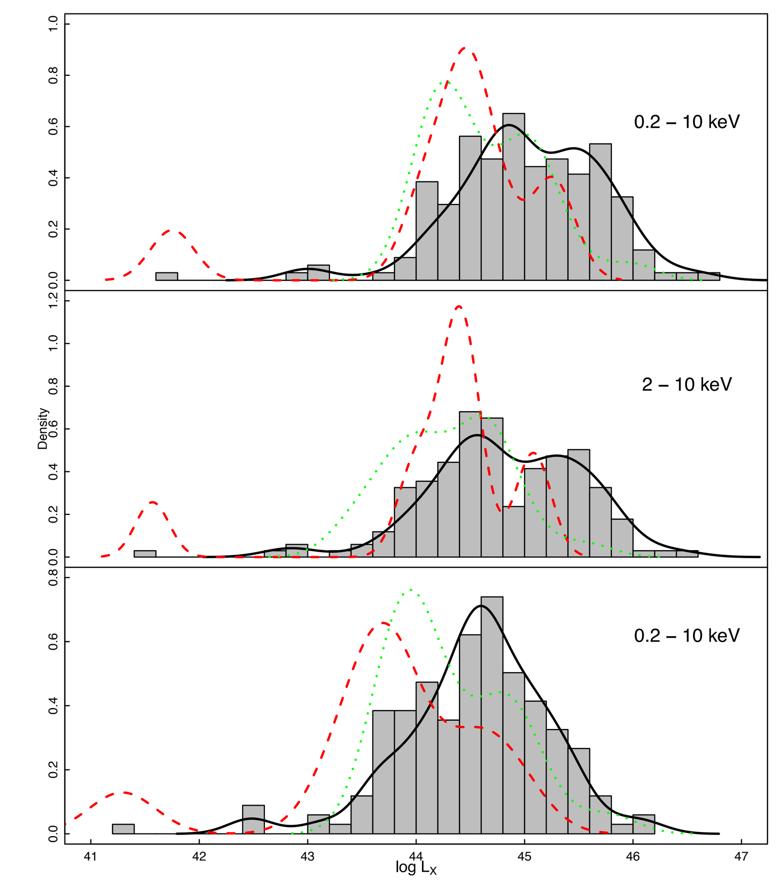

FIG. 7 X-ray luminosity distribution of all BL Lacs in the catalog (grey bars), HSPs (black line), ISPs (red line) and LSPs (green lines).

References:

- Ghisellini, G., 1999; Astropart. Phys., 11, 11
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SUMMARY AND ON-GOING WORK

- An XMM-Newton catalogue of BL Lacs X-ray properties is produced by searching the XSA archive for X-ray counterparts of the 1374 BL Lacs listed in VC&V10 Catalogue.
- The catalogue contains 442 observations for 137 BL Lacs with X-ray images, light curves and spectral information, and optical fluxes and magnitudes. This catalogue will be available on Vizier.
- Variability timescales and the dependence of this variability with flux, energy or other properties could allow to disentangle the possible physical mechanisms behind.
- A statistical study is presented to clarify which spectral model and statistics should be used to fit spectra in an homogenous way when dealing with a sample of different statistical quality.
- The information in the catalogue, together with information at other wavelengths, will allow us to identify BL Lac candidates at TeV energies.

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