SDSS J211852.96–073227.5: a new γ-ray flaring narrow-line Seyfert 1 galaxy

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ABSTRACT
We report on the identification of a new γ-ray-emitting narrow-line Seyfert 1 (NLS1) galaxy, SDSS J211852.96–073227.5 (hereinafter J2118−0732). The galaxy, at a redshift of 0.26, is associated with a radio source of flat/inverted spectrum at high radio frequencies. The analysis of its optical spectrum obtained in the Sloan Digital Sky Survey (SDSS) revealed a small linewidth of the broad component of the Hβ line (full width at half-maximum = 1585 km s−1), making it a radio-loud NLS1 galaxy – an intriguing class of active galactic nuclei with exceptional multiwavelength properties. A new γ-ray source centred at J2118−0732 was sporadically detected during 2009–2013 in form of flares by the Fermi-LAT. Our XMM-Newton observations revealed a flat X-ray spectrum described by a simple power law, and a flux variation by a factor of ∼2.5 in five months. The source also shows intraday variability in the infrared band. Its broad-band spectral energy distribution can be modelled by emission from a simple one-zone lepton jet model, and the flux drop from infrared to X-rays in five months can be explained by changes of the jet parameters, though the exact values may be subject to relatively large uncertainties. With the NLS1-blazar composite nucleus, the clear detection of the host galaxy, and the synchronous variation in the multiwavelength fluxes, J2118−0732 provides a new perspective on the formation and evolution of relativistic jets under the regime of relatively small black hole masses and high accretion rates.

Key words: galaxies: active – galaxies: individual (SDSS J211852.96–073227.5) – galaxies: jets – galaxies: nuclei.

1 INTRODUCTION
A new class of γ-ray loud active galactic nuclei (AGNs) has been emerging since the first detection of γ-ray emission from the radio-loud (RL) narrow-line Seyfert 1 galaxies (NLS1s) by the Large Area Telescope (LAT) onboard the Fermi γ-ray Space Telescope (hereinafter, Fermi) satellite (Abdo et al. 2009a). Distinctly different from the well-known paradigm that powerful relativistic jets are generally associated with elliptical galaxies in typical RL AGNs like blazars and radio galaxies, γ-ray emitting NLS1s have drawn great attention from the AGN community in the past decade.

NLS1s are conventionally defined as type 1 AGNs with the full width at half-maximum (FWHM) of the broad Hβ line less than 2000 km s−1, weak [O III] emission ([O III]/Hβ < 3), and usually strong Fe II emission lines (Osterbrock & Pogge 1985). Several correlations have been found among optical emission lines and X-ray properties referred to as the eigenvector 1 (EV1) correlations (Boroson & Green 1992; Boroson 2002). Given their relatively small widths of the broad lines, NLS1s tend to have lower black hole (BH) masses and higher Eddington ra-

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Evidence that indicates the presence of relativistic jets in some RL NLS1s has been accumulated in recent years (Komossa et al. 2006), especially at the highest radio loudness regime, due to their blazar-like characteristics (Zhou et al. 2007; Yuan et al. 2008). RL NLS1 usually shows a compact radio morphology with a one-sided core-jet structure detected at parsec scale (Gu et al. 2015). In some objects, the radio emission extends up to kpc scales (e.g. Antón et al. 2008; Doi et al. 2012; Richards & Lister 2015). A significant fraction of RL NLS1s presents a flat/inverted radio spectrum, usually with a very high brightness temperature (Yuan et al. 2008; Gu et al. 2015). Some RL NLS1s are found to have intraday infrared variability (e.g. Jiang et al. 2012; Yao et al. 2015b). Besides, superluminal motions have also been found in some RL NLS1s (e.g. SBS 0846+513: D’Ammando et al. 2013; 1H 0323+342: Fuhrmann et al. 2016). Since the launch of the Fermi satellite in 2008, γ-ray detections from some genuine RL NLS1s have confirmed the existence of relativistic jets in this new class of γ-ray loud AGNs (Abdo et al. 2009a,b; Foschini et al. 2011a; D’Ammando et al. 2012, 2015b; Yao et al. 2015b; Paliya et al. 2018). With their extreme distributions in AGN parameter space and different host environments, RL NLS1s allow us to readdress some of the key questions regarding the formation and evolution of relativistic jets under extreme physical conditions as well as the coupling of jets and accretion flows. However, further investigation is hindered by the scarcity of this particular class of objects.

In this paper, we report on the discovery of a new γ-ray source detected by the Fermi-LAT associated with a RL NLS1, SDSS J211852.96–073227.5 (hereinafter J2118–0732). This γ-ray-emitting NLS1 was found in our ongoing study on a sample of RL NLS1s (Zhou et al. 2007; Yuan et al. 2008; Komossa et al. 2015; Yao et al. 2015b). While we were analysing this NLS1, it was independently reported as a new γ-ray source by Paliya et al. (2018) and in The Preliminary Fermi-LAT 8-yr Point Source List (FLSPY)\(^1\), and classified as an NLS1 by Rakshit et al. (2017). It was also included in the All-Sky Targeted Eight GHz Survey (CRATES; Healey et al. 2007) catalogue as a flat-spectrum radio source due to its flat spectrum below 4.8 GHz. The object was detected in the ROSAT All Sky Survey (RASS), with the total counts < 20 (Anderson et al. 2007). The X-ray spectral and timing properties are essential for linking the postulated high energy γ-ray emission with other wavelength data of this AGN, and for understanding its radiation mechanism. To this end, we proposed to observe J2118–0732 with the XMM-Newton at two epochs separated by about five months to study its X-ray spectral and timing properties. We report the results of these observations in this paper.

The paper is organized as follows. In Section 2, we report the optical spectroscopic analysis and results. The Fermi-LAT data selection and analysis are included in Section 3. We report the XMM-Newton observations and results in Section 4. The radio properties, infrared variability, and optical/ultraviolet (UV) characteristics are discussed in Section 5.1, Section 5.2, and Section 5.3, respectively. The broad-band spectral energy distribution (SED) modelling is given in Section 6, followed by discussions in Section 7 and a summary in Section 8. Throughout this paper, we assume a cosmology with \(H_0 = 67.8\) km s\(^{-1}\) Mpc\(^{-1}\), \(\Omega_M = 0.692\), and \(\Omega_k = 0.308\) (Planck Collaboration et al. 2016).

2 OPTICAL SPECTROSCOPY AND THE NLS1 CLASSIFICATION

The optical spectrum was obtained by the Sloan Digital Sky Survey (SDSS) on 2001 August 25, with an exposure time of 911 s. After being corrected for Galactic extinction with \(E(B - V) = 0.18\) mag (Schlafly & Finkbeiner 2011) and an \(R_V = 3.1\) extinction law, the spectrum is transformed into the rest frame with a redshift of \(z = 0.26\) (see Fig. 1).

In the spectrum, the host galaxy contribution is negligible. Thus, a similar strategy as in Dong et al. (2008) and Yao et al. (2015b) was adopted to fit the spectrum. We fitted simultaneously the continuum, the Fe II multiplets, and other emission lines in the range of 4200–6900 Å. A broken power law (PL) with a break wavelength of 5600 Å and the optical Fe II emission multiplets modelled with the templates from Dong et al. (2008) were used to fit the so-called pseudo-continuum. The emission lines identified from the composite SDSS quasar spectrum (see table 2 in Vanden Berk et al.

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\(^1\) https://fermi.gsfc.nasa.gov/ssc/data/access/lat/f18y/
were modelled as follows. The broad Hα and Hβ were assumed to have the same redshift and profile fitted by either a single Lorentzian or concentric double Gaussians. Other broad emission lines were modelled with one Gaussian. One single Gaussian with a constraint of FWHM < 1000 km s\(^{-1}\) was used for modelling each narrow emission line. Both flux ratios of the [NII] doublets and the [OIII] doublets were fixed to their theoretical values of 3. The broad Hβ line was equally well fitted with either a Lorentzian profile or a concentric double-Gaussian profile. In the former case, the width of the broad component is FWHM(Hβ broad) = 1585 ± 182 km s\(^{-1}\), while in the latter case it is FWHM(Hβ broad) = 1882 ± 375 km s\(^{-1}\) after subtracting the effect of instrumental broadening. Shen et al. (2011) also obtained a similar FWHM(Hβ broad) = 1597 ± 441 km s\(^{-1}\) using a single Gaussian or multiple Gaussians model. In the following, we adopted the fitting results using the Lorentzian profile since the Lorentzian model is better suited for the broad-line profiles of NLS1s (e.g. Véron-Cetty et al. 2001; Zhou et al. 2006). The line width of [OIII]\(\lambda4007\) is 36 ± 15 km s\(^{-1}\) and there is no obvious evidence of blue wings in [OIII] lines. The flux ratio of [OIII]\(\lambda4007\) to H\(\beta_{\text{broad}}\) is \(\sim 1.7\) and \(R_{4070} = \text{FeII}\(\lambda4570)/\text{H}\beta_{\text{broad}} \approx 0.06\) (FeII is calculated by integrating from 4434 to 4684 Å). The small broad-line width and the relatively weak [OIII] of J2118–0732 fulfill the conventional definition of an NLS1. However, the FeII emission is rather weak compared to most NLS1s and the optical continuum is red with \(\delta_{\text{opt}} = -1.5\) (\(S_\nu \propto \nu^\delta\)) for J2118–0732. Nevertheless, there is no quantitative definition for the FeII strength, and some NLS1s do emit weak FeII emission (Zhou et al. 2006; Xu et al. 2012; Cracco et al. 2016; Rakshit et al. 2017).

Under the assumption of a virialized broad-line region (BLR), we can estimate the BH mass of J2118–0732 using FWHM(H\(\beta_{\text{broad}}\)) = 1585 km s\(^{-1}\) and the H\(\beta\)-based estimator from Wang et al. (2009), with a 1σ uncertainty of 0.5 dex. Considering the contamination from the jet contribution to the continuum, a surrogate for the 5100 Å luminosity (\(L_{5100}\)) estimated from the broad H\(\beta\) line luminosity using equation (5) from Zhou et al. (2006) was applied. We found \(M_{\text{BH}} \approx 3.4 \times 10^5 M_\odot\) (\(M_{\text{BH}} \approx 3.7 \times 10^5 M_\odot\) if the line parameters fitted from the double-Gaussian profile were used), which is consistent with the estimations from Greene & Ho (2007) and Li et al. (2008) based on other commonly used single-epoch formalisms.

The bolometric luminosity can be calculated assuming \(L_{\text{bol}} \approx 9 L_{5100}\) (estimated from H\(\beta\)), as suggested by Kaspi et al. (2000), which results in \(L_{\text{bol}} \approx 6.2 \times 10^{44}\) erg s\(^{-1}\). The Eddington ratio of this object is \(\lambda \approx 0.15\), relatively low compared to other NLS1s but higher than typical broad-line Seyfert 1 galaxies (Xu et al. 2012; Cracco et al. 2016; Rakshit et al. 2017). The bolometric luminosity and the Eddington ratio of J2118–0732 estimated by Shen et al. (2011) are \(L_{\text{bol}} \approx 1.1 \times 10^{44}\) erg s\(^{-1}\) and \(\lambda \approx 0.39\), slightly larger than our estimations. This discrepancy has mainly resulted from the overestimation of the bolometric luminosity using the directly measured luminosity at 5100 Å, where the jet contribution cannot be ignored, especially for those RL AGNs. The fitting results and the basic parameters estimated for J2118–0732 are summarized in Table 1.

### Table 1. The spectroscopic fitting results and basic parameters of J2118–0732.

| Model  | FWHM(H\(\beta\))/km s\(^{-1}\) | L | 2G |
|--------|-------------------------------|---|----|
|        | 1585 ± 182                    | 1882 ± 375 |      |
|        | 364 ± 15                      | 327 ± 14   |      |
| [OIII]/H\(\beta\) | 1.7                          | 2.0    |    |
| \(R_{4070}\)        | 0.06                         | 0.06   |    |
| \(M_{\text{BH}}/10^7 M_\odot\) | 3.4                        | 3.7    |    |

\(^a\) Models used for fitting the broad H\(\beta\) emission lines are: one Lorentzian profile (L) or a double-Gaussian profile (2G).

2 Several emission lines were masked out, for either they were too weak to constrain in the fit or had little effect on the results. Hy\(\lambda4340\), [OIII]\(\lambda4363, 4466, 4861\), [OII]\(\lambda4459, 5007\), He I\(\lambda4861\), [NiII]\(\lambda6548, 6583\), He I\(\lambda6636\), and [SII]\(\lambda6716, 6731\) were included in our spectroscopic analysis.

### 3 γ-RAY DATA ANALYSIS

#### 3.1 Observations and data reduction

The Fermi-LAT is a pair-conversion γ-ray telescope operating from 20 MeV to > 300 GeV. It has a large peak effective area (~8000 cm\(^2\) for 1 GeV photons), allowing a large field of view (~2.4 sr) with an angular resolution (68 per cent containment radius) better than 1° for energies above 1 GeV and an energy resolution of typically ~10 per cent. Further details about the Fermi-LAT are given in atwood et al. (2009).

We analysed the Pass 8 data collected by the LAT from 2008 August 4th (Modified Julian Day, MJD 54 682) to 2017 July 14 (MJD 57 948). During this period, the LAT instrument operated in survey mode, scanning the entire sky every 3 h. The data analysis was performed with the standard ScienceTools version v10r0p5 software package. We used the standard binned maximum likelihood method implemented in the Science tool gtlike to analyse each time bin longer than or equal to 1 yr. For shorter time bins, we used the unbinned method where the number of events was expected to be small. The LAT data were extracted from a region of interest (ROI) defined as a circle of 30° radius centred at the location of J2118–0732 for the binned method and a circle of 20° radius for the unbinned method. Only events belonging to the ‘Source’ class from 100 MeV to 300 GeV were used with P8R2_SOURCE_V6 Instrument Response Functions. In addition, a cut on the zenith angle (< 90°) was applied to minimize the contamination from Earth limb γ-rays. Isotropic (iso_P8R2_SOURCE_V6_v06.txt) and Galactic diffuse emission (gll_ecl_m06.fits) components were used to model the background. The normalization of each component was set to be free during the spectral fitting.

The significance of the γ-ray signal from the source was evaluated by means of a maximum-likelihood test statistic (TS) that results in TS = 2 (log(L1 - log(L0)) where L is the likelihood of the data given the model with (L1) or without (L0) a point source at the location of J2118–0732 (e.g. Mattox et al. 1996). Because our data cover a 9-yr period, the source model included all the point sources from
The spectra of these sources were parameterized by a PL, a log-parabola, or a super exponential cut-off, as in the 3FGL catalogue, and by a PL for 18 new sources in FL8Y. Sources within $10^5$ of J2118–0732 and with their significances greater than 5 calculated from 3FGL and FL8Y were included with the normalization factors and the photon indices left as free parameters. For other sources in the source model, we fixed the normalizations and the photon indices to the values in the catalogues. The uncertainties correspond to 68 per cent confidence for the Fermi-LAT results.

3.2 Results

First, we tested whether a $\gamma$-ray source at the optical position of J2118–0732 was detected by the Fermi-LAT over the whole duration from 2008 August 4 to 2017 July 14 with a binned maximum likelihood analysis using a PL model. A source was clearly detected with a TS value of 27 ($\sim 5 \sigma$) for J2118–0732, an average $\gamma$-ray integrated photon flux from 0.1 to 300 GeV of $F_{0.1-300\text{GeV}} = (6.6 \pm 1.8) \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$, and a photon index $\Gamma_{\gamma} = 2.65 \pm 0.16$. This flux corresponds to an isotropic $\gamma$-ray luminosity of $L_{\gamma} = (0.7 \pm 0.3) \times 10^{45}$ erg s$^{-1}$ in the 0.1–300 GeV rest-frame energy band. The isotropic $\gamma$-ray luminosity is given as $L_{\gamma} = 4\pi d_L^2 S_{\gamma}$, where $d_L$ is the luminosity distance and $S_{\gamma}$ is the flux density.

Next, the integrated flux of each year during the whole 9-yr Fermi-LAT observation was calculated to investigate the long-term $\gamma$-ray variability of J2118–0732. For each 1-yr bin, the spectral parameters of J2118–0732 and all sources within $10^5$ were frozen to the values obtained from the likelihood analysis over the entire period. J2118–0732 was relatively active during 2009 August 5–2013 July 20 with higher flux measurements and significant TS values, but remained undetected in other years. The 95 per cent upper limits were provided if TS < 9 during 2008 August 4–2009 August 5 and 2013 July 20–2017 July 14 with 1-yr bins in the long-term $\gamma$-ray light curve of J2118–0732 in Fig. 2. A further likelihood analysis of the data taken during the relatively active 4 yr resulted in a TS of 50 ($\sim 7 \sigma$). We obtained a photon flux index of $\Gamma_{\gamma} = 2.79 \pm 0.16$ and a flux of $F_{0.1-300\text{GeV}} = (15.4 \pm 3.1) \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$, corresponding to an isotropic $\gamma$-ray luminosity of $L_{\gamma} = (1.5 \pm 0.4) \times 10^{46}$ erg s$^{-1}$ during the 4-yr period. We performed a $\gamma$-ray point source localization using the gtfindsrc tool over the photons in the energy band from 1 to 300 GeV extracted during this period. The fit resulted in R.A. = $21^\circ 18^\prime 45.4^\prime$, Dec. = $-7^\circ 25'02.1''$ with a 95 per cent error circle radius of $R_{95\%} = 0.161''$. Here, we excluded the low-energy photons because of their poor angular resolutions. The $\gamma$-ray source is located 0.128° away from the optical position of J2118–0732, which is within the 95 per cent error circle of the $\gamma$-ray position.

We also calculated the $\gamma$-ray light curve of J2118–0732 during 2009–2013 using 60-d time bins and 20-d time bins and added it into Fig. 2. For each time bin, the spectral parameters of J2118–0732 and all sources within $10^5$ were frozen to the values obtained from the 4-yr likelihood analysis. The 95 per cent upper limit was also calculated if TS < 5. The systematic uncertainty in the flux is dominated by the systematic uncertainty in the effective area (Ackermann et al. 2012), which amounts to 10 per cent at 100 MeV, decreasing to 5 per cent at 560 MeV and increasing to 10 per cent above 10 GeV.

J2118–0732 was detected sporadically by the Fermi-LAT, with an increase in flux and a high TS value of 24 ($\sim 5 \sigma$) during 2010 December 2–2011 February 1. The flux was doubled within 20 d and quickly dropped to a lower state below the Fermi-LAT detection limit. During this flaring period, we obtained a photon index of $\Gamma_{\gamma} = 2.62 \pm 0.01$ and a flux of $F_{0.1-300\text{GeV}} = (43.7 \pm 1.6) \times 10^{-8}$ ph cm$^{-2}$ s$^{-1}$, corresponding to an isotropic $\gamma$-ray luminosity of $L_{\gamma} = (4.6 \pm 0.2) \times 10^{45}$ erg s$^{-1}$, a factor of ~7 higher than the average value during the whole period. A point source localization using full energy band photons was also performed during this 60-d high state. The fit resulted in R.A. = $21^\circ 18^\prime 37.1^\prime$, Dec. = $-7^\circ 28'42.7''$ which is 0.091° away from the optical position of J2118–0732 with a 95 per cent error circle radius of $R_{95\%} = 0.264''$.

The $\gamma$-ray detection of this source has also been independently reported by Paliya et al. (2018) and FL8Y. A brief comparison between their results and ours regarding the $\gamma$-ray properties is summarized in Table 2. The $\gamma$-ray detected source suffers from a large spatial uncertainty given the limited resolution of the Fermi-LAT. So the association of the $\gamma$-ray source with J2118–0732 will be discussed further in Section 7.2.
Table 2. Results of the Fermi-LAT data analysis.

| Optimized position (J2000) hh mm ss.s dd mm ss.s | Separation from optical position (°) | $R_{90\%}$ (°) | $F_{9.1-300 GeV} \times 10^{-9}$ ph cm$^{-2}$ s$^{-1}$ | $\Gamma$ | $L_\gamma$ (10$^{45}$ erg s$^{-1}$) |
|---------------------------------------------------------|-----------------------------------|-----------------|---------------------------------------------|-----|------------------|
| (1) 21 18 45.4 -07 25 02.1                             | 0.128                             | 6.6 ± 1.8       | 2.65 ± 0.16                                 | 0.7 ± 0.3 | 27               |
| (2) 21 18 37.1 -07 28 42.7                             | 0.091                             | 0.161           | 15.4 ± 3.1                                  | 1.5 ± 0.4 | 50               |
| (3) 21 18 58.9 -07 30 04.5                             | 0.047                             | 0.264           | 43.7 ± 1.6                                  | 4.6 ± 0.2 | 24               |
| (4) 21 19 14.1 -07 28 31.1                             | 0.109                             | 0.14            | 9.2 ± 2.0                                   | 0.9 ± 0.3 | 40               |
| (5) 21 18 58.9 -07 30 04.5                             | 0.047                             | 0.20×0.16       | 13.2 ± 2.5                                  | 1.3 ± 0.3 | 47               |

(1) our results analysed from the whole period during 2008 August 4–2017 July 14.
(2) our results analysed from the active 4 yr during 2009 August 5–2013 July 20.
(3) our results analysed from the flare during 2010 December 2–2011 February 1.
(4) Paliiy et al. (2018) results analysed from the period during 2008 August 5–2017 January 5.
(5) Fl8Y results analysed from the period during 2008 August 4–2016 August 2.

Table 3. XMM EPIC observations for J2118–0732.

| Data Set       | X-2016-05-10 | X-2016-10-27 |
|----------------|--------------|--------------|
| Observation ID | 0784090201   | 0784090301   |
| Start Time     | 2016 May 10  | 2016 October 27 |
| (UTC)          | 12:36:12     | 10:55:03     |
| Duration (ks)  | 31.9         | 32.8         |
| Detectors      | PN MOS1/2    | PN MOS1/2    |
| Good Exposure  | 18.6         | 29.3         |
| Net Count Rate | 0.193        | 0.117        |
| (count s$^{-1}$) | 0.069       | 0.043       |

4 X-RAY OBSERVATIONS AND DATA ANALYSIS

4.1 XMM observations and data reduction

We conducted two observations on J2118–0732 with the XMM-Newton (Jansen et al. 2001) in 2016: for 31.9 ks on 2016 May 10 and for 32.8 ks on 2016 October 27 (Observation IDs 0784090201 and 0784090301, PI: Su Yao), hereinafter X-2016-05-10 and X-2016-10-27. All observations were performed with the European Photon Imaging Camera (EPIC) using PN (Struder et al. 2001) and MOS (Turner et al. 2001) CCD arrays as well as the Optical Monitor (OM; Mason et al. 2001). OM data analysis will be discussed in Section 5.3. All EPIC observations operated in prime large window mode with the thin filter. The XMM-Newton EPIC observations are summarized in Table 3. Observation data files were processed to create calibrated event lists and full frame images following standard procedures with the XMM-Newton Science Analysis System (sas Version 16). Source regions were extracted from a circular aperture around J2118–0732 with an optimized radius of 35″. The background regions were chosen from either a source-free circle for PN or a source-centre annulus for MOS with similar readout distances to ensure similar background noise levels. A weak X-ray source near J2118–0732 positioned at R.A. = 21°18′53.76″, Dec. = −7°32′2.4″ was detected by the sas algorithm edetect_chain and was excluded during the region selections. Pile-up was negligible in all observations and flaring particle background was filtered. The resulting net (source minus background) PN count rates and good exposures are 0.193 cts s$^{-1}$ and 18.6 ks (0.117 cts s$^{-1}$ and 29.3 ks for the combined MOS spectrum) and 0.069 cts s$^{-1}$ and 16.2 ks (0.043 cts s$^{-1}$ and 29.4 ks for the combined MOS spectrum) for the first and the second observations, respectively. The uncertainties correspond to 90 per cent confidence for EPIC results.

4.2 X-ray spectra and variability

The MOS1 and MOS2 spectra were co-added to produce a single combined spectrum. And all the spectra were binned to contain at least 25 counts per bin needed for $\chi^2$ analysis.
Table 4. Spectral fits to XMM EPIC observations for J2118–0732

| Data Set | X-2016-05-10 | X-2016-10-27 |
|----------|--------------|--------------|
| Detectors| PN+MOS       | PN+MOS       |

| Source | N_{H} (10^{21} cm^{-2}) | Γ_{X} | Flux (10^{-12} erg cm^{-2} s^{-1}) | L_{X} (10^{33} erg s^{-1}) | χ2/d.o.f. |
|--------|-------------------------|-------|-----------------------------------|---------------------------|------------|
| TBA3S2TBA3S2P0W, fixed N_{H} = N_{H}^{Gal} = 1.15 × 10^{21} cm^{-2} at z = 0, free N_{H} at z = 0.26, fitted over 0.3–10 keV | 1.78^{+0.03}_{-0.02} | 1.70 ± 0.19 | 62.2/73 | 31.5/34 |
| TBA3S2P0W, fixed N_{H} = N_{H}^{Gal} = 1.15 × 10^{21} cm^{-2} at z = 0, fitted over 0.3–10 keV and extrapolated to 0.3–10 keV | 1.63^{+0.12}_{-0.11} | 1.70 ± 0.19 | 62.2/73 | 31.5/34 |

a) zpower-law photon index; b) unabsorbed flux integrated from 0.3 to 10 keV in units of 10^{-13} erg cm^{-2} s^{-1}; c) isotropic X-ray luminosity in the 0.3–10 keV rest-frame energy band in units of 10^{33} erg s^{-1}.

5 OTHER DATA

5.1 Radio properties

J2118–0732 was detected as a single unresolved source within 5″ of the SDSS position in several surveys from the NASA/IPAC Extragalactic Database website (NED) and the VizieR website listed in Table 5. The Faint Images of the Radio Sky at 20 cm Survey (FIRST; White et al. 1997) observation indicates a compact radio structure at FIRST resolution (5″). The NRAO VLA Sky Survey (NVSS; Condon et al. 1998) 1.4 GHz flux density is 96.1 ± 2.9 mJy, corresponding to a radio power of P_{1.4GHz} = (1.98 ± 0.06) × 10^{25} W Hz^{-1}, and the polarized flux density is 3.16±0.49 mJy, thus a fractional polarization of ~ 3.3 per cent. The source shows a steep spectrum between 74 MHz and 1.4 GHz with α_{rad} = −0.7 (Vollmer et al. 2010), however, a flat/inverted spectrum above 1.4 GHz (see Fig. 4). We refitted the radio spectrum using a broken PL with a break frequency at 1.4 GHz and obtained α_{rad} = −0.66 in the lower frequency band and α_{rad} = 0.15 in the higher frequency band without considering the variability of the radio flux as the data were not all simultaneous. However, the synchronous observations across 72–231 MHz from the GaLactic and Extragalactic All-sky Murchison Widefield Array (GLEAM) survey (Hurley-Walker et al. 2017) indicate the sincerity of a steep radio spectrum at lower frequency.

To estimate the radio loudness parameter defined as R_{5GHz} = f_{5GHz}/f_{4GHz}(4400 Å), we used the 4.85 GHz flux from the Parkes-MIT-NRAO surveys (PMN surveys; Griffith et al. 1995) and the 4400 Å flux from the SDSS g band point-spread function (PSF)-model magnitude with Galactic extinction considered. The k-correction with the radio spectral index α_{rad} = 0.15 and the optical index α_{opt} = −1.5 was adopted. It results in R_{5GHz} = 920, which is consistent with R = f_{5GHz}/f_{4GHz}(2500 Å) = 1227 derived from Shen et al. (2011). However, it cannot be ruled out, though unlikely, that a strong starburst may contribute to the radio power.

4 http://ned.ipac.caltech.edu
5 http://vizier.u-strasbg.fr/index.gml
emission. Such an estimation of radio luminosity from a star-burst contribution can be obtained using the observed far-infrared (FIR)-radio luminosity correlation from Yun et al. (2001) and the extrapolated FIR luminosity [using the Wide-field Infrared Survey Explorer (WISE, Wright et al. 2010) data and a power-law assumption in the infrared band]. This gives $P_{1.4\,\text{GHz}} \sim 8.9 \times 10^{25} \, \text{W} \, \text{Hz}^{-1}$, which is about two orders of magnitude smaller than the observed radio luminosity, excluding a strong starburst contribution to the radio emission. Besides, there is also a possibility that intrinsic reddening may affect the optical continuum slope. Nevertheless, just using the radio power itself, $P_{1.4\,\text{GHz}} \sim 2 \times 10^{25} \, \text{W} \, \text{Hz}^{-1}$, makes SDSS J2118–0732 formally radio-loud.

### 5.2 WISE infrared data and intraday variability

SDSS J2118–0732 was observed with the WISE in four bands w1, w2, w3, w4 centred at 3.4, 4.6, 12 and 22 μm. Its long-term light curves of w1 and w2 bands were constructed from the PSF profile-fit photometric magnitudes via the near-Earth objects WISE (NEOWISE) Reactivation Single-exposure data base (Mainzer et al. 2014) and the AllWISE Multi-epoch Photometry data base (see Fig. 5), while w3 and w4 light curves are not available due to the lack of the data in the NEOWISE data base. Those data with poor signal-to-noise ratios ($S/N < 10$ or marked as ‘null’) or the excluded $\chi^2$ of the profile-fit photometries larger than 2 were excluded.

Significant intraday variability was detected in epoch 4, 5 in the w1 band and epoch 5, 6 in the w2 band, with $p$-values < 0.1 per cent using the $\chi^2$-test against the null hypothesis of no variation. This variability time-scale sets an upper limit on the size of the emitting region to $\lesssim 8 \times 10^{-4}$ pc, which is much smaller than the scale of a putative torus but consistent with that of the jet-emitting region. The last two epochs of w1 and w2 light curves coincided with our two XMM-Newton observations (see Section 4) which provided the quasi-simultaneous infrared fluxes together with the X-ray and optical/UV fluxes. The average fluxes during these two epochs were calculated to construct the broadband SEDs in Section 6 and are reported in Table 6. A 1σ error of 0.2 magnitude was assumed due to the significant intraday variability of the infrared fluxes.

### 5.3 Optical/UV photometry and the morphology of the host galaxy

The source was also observed with the OM detector onboard the XMM-Newton configured in ‘imaging’ mode with an exposure of 5ks for each filter both on X-2016-05-10 and X-2016-10-27. We extracted the background-subtracted photometric data using the omichain processing pipeline with the default parameter settings, as recommended by the SAS.

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**Table 5.** The GHz radio data of J2118–0732 retrieved from NED and VizieR.

| Frequency (GHz) | Flux (mJy) | Polarized flux (mJy) | Resolution (arc sec) | Observation date | Surveys and References |
|----------------|-----------|---------------------|----------------------|-----------------|------------------------|
| 0.074          | 750 ± 130 |                     | 80                   | 2003-09-20      | (1)                    |
| 0.15           | 383.5 ± 39|                     | 25                   | 2016-03-15      | (2)                    |
| 0.17–0.231     | 307.3 ± 9.1$^a$ | ~ 100              | 2013-08-13           | (3)             |
| 0.365          | 277 ± 30  |                     | 6                    |                 | (4)                    |
| 1.4            | 98.7 ± 20 |                     | 5                    | 1997-05-26      | (5)                    |
| 1.4            | 96.1 ± 2.9| 3.16                | 45                   | 1993-09-20      | (6)                    |
| 4.85           | 102 ± 12  |                     | 168                  | 1990-11-06      | (7)                    |
| 8.4            | 97.5      |                     |                      |                 | (8)                    |
| 19.9           | 113 ± 6   | 6                   | 34                   | 2007 Oct 26–30  | (9)                    |

Surveys and References: (1) The VLA Low-Frequency Sky Survey (VLSS, Cohen et al. 2007), (2) The Giant Metrewave Radio Telescope (GMRT) 150 MHz All-sky Radio Survey (Intema et al. 2017), (3) GaLactic and Extragalactic All-sky Murchison Widefield Array (GLEAM) survey (Hurley-Walker et al. 2017), (4) The Texas Survey of radio sources at 365MHz (Douglas et al. 1996), (5) The Faint Images of the Radio Sky at 20 cm Survey (FIRST, White et al. 1997), (6) The NRAO VLA Sky Survey (NVSS, Condon et al. 1998), (7) The Parkes-MIT-NRAO Surveys (PMN surveys, Griffith et al. 1995), (8) The Combined Radio All-Sky Targeted Eight GHz Survey (CRATES, Healey et al. 2007), (9) The Australia Telescope 20 GHz Survey (AT20G survey, Murphy et al. 2010)

$^a$ integrated flux between 170 and 231 MHz.

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**Figure 5.** w1 (upper panel) and w2 (lower panel) light curves of SDSS J2118–0732 obtained from the WISE data base. The numbers in the upper panel refer to the epoch number of each intraday epoch. The data showing significant intraday variability are differentiated with diamond marks. Epoch (6) in blue and (7) in red correspond to X-2016-05-10 and X-2016-10-27, respectively.
threads. The source was not detected in the UVM2 and UVW2 bands in both observations, and in the V band in the second observation utilizing the omdetect searching algorithm with a minimum significance of 3.

We also collected non-simultaneous data from the SDSS Photometric Catalog Data Release 9 (Ahn et al. 2012) and the Medium Imaging Survey (MIS) observed by the Galaxy Evolution Explorer (GALEX; Martin et al. 2005). The SDSS performed photometric measurements three times on J2118−0732 from 2000 to 2008 which showed variations of ~0.5 mag on time-scale of years. The source was also detected in the GALEX Far-UV (FUV) and Near-UV (NUV) bands with magnitudes FUV=21.58 and NUV=21.38 centred at an effective wavelength of 1516 Å and 2267 Å in the AB magnitude system.

The collection of the optical/UV magnitudes from the OM, the SDSS, and the GALEX observations is also reported in Table 6. All the optical/UV magnitudes were corrected for Galactic extinction using extinction law described in Section 2 before further analysis. Particularly for the GALEX magnitudes, we used $A_{\text{FUV}}/E(B-V) = 8.376$ and $A_{\text{NUV}}/E(B-V) = 8.741$, following Wyder et al. (2005).

Of particular interest, the optical image of J2118−0732 obtained from the SDSS (see Fig. 6) shows an extended galaxy structure and likely shows a disturbed morphology, possibly suggesting a recent merger.

6 BROAD-BAND SPECTRAL ENERGY DISTRIBUTION

For γ-ray loud NLS1s like J2118−0732, which exhibit the hybrid properties of both NLS1s and blazars, it would be revealing to study their broad-band SEDs. Here, we made use of the XMM-Newton data and the WISE data to construct the quasi-simultaneous SEDs in a relatively high state (on 2016 May 10) and low state (on 2016 October 27). The radio spectrum was taken from the NED and VizieR websites as presented in Section 5.1. We also made use of the GALEX data in the UV band to constrain the disc component in the high state because of the similar UV flux levels of the GALEX data and the OM data. The broad-band SEDs are shown in Fig. 7. The source was not detected in γ-rays at the epochs around the XMM-Newton observations within a time span of 60 d (see the study on the γ-ray light curve in Section 3.2). The flux limits derived above are denoted as arrows. As a first-order approximation, the average γ-ray spectrum obtained from all the data over the total 9-yr time span was used instead, which is consistent with the upper limits. We assume that the γ-ray emission in the SED of J2118−0732 at the epochs concerned can be approximated by the averaged spectrum. This allows us to perform spectral modelling of the SED, which is expected to be still revealing, though the best-fitting model and parameters may suffer.

Table 6. Infrared/optical/UV photometric results before corrected for Galactic extinction.

| Date       | FUV (1516 Å) | NUV (2267 Å) |
|------------|-------------|--------------|
| 2003-08-06 | 21.58 ± 0.12| 21.38 ± 0.10 |

Figure 6. SDSS r band image of J2118−0732. The ‘x’ mark shows the optical position of the source and the colour bar is in units of nanomaggy.

http://galex.stsci.edu/GalexView/
To fit the broad-band SED, we first used a simple one-zone leptonic jet model, which consists of synchrotron, synchrotron-self-Compton (SSC), and external-Compton (EC) processes (e.g. Abdo et al. 2009b; D’Ammando et al. 2012; Paliya et al. 2013; Sun et al. 2015). The \( \chi^2 \) minimization technique is applied to perform the fitting. The radio emission may come from radio lobes at larger scales and/or superposition of multiple jet components and thus does not fit to the synchrotron component which is self-absorbed below 10\(^{11}\) Hz. Two scenarios were considered for the EC scattering process: a seed photon field dominated from the torus and from the BLR, respectively. The energy density of the former was assumed to be 3 \times 10^{-3} \text{ erg cm}^{-3} (see more details in Cleary et al. 2007; Ghisellini & Tavecchio 2008) and the latter was estimated from the broad H\( \beta \) line luminosity derived in Section 2 (see more details in Sun et al. 2015; Zhang et al. 2015). The energy distribution of the injected relativistic electrons was assumed to be a broken PL in the range of \( [\gamma_{\text{min}}, \gamma_{\text{max}}] \) with a break energy \( \gamma_b \). The value of \( \gamma_{\text{min}} \) was taken as \( \gamma_{\text{min}} = 1 \) in the EC/torus model which was constrained from the soft X-ray slope of the SSC bump and \( \gamma_{\text{max}} = 78 \) in the EC/BLR model which is the mean value of the \( \gamma_{\text{min}} \) distribution for a GeV-NLS1 sample (Sun et al. 2015). The \( \gamma_{\text{max}} \) is usually poorly constrained and does not significantly affect our results, so it was fixed at a large value. The two indices \( p_1, p_2 \) of the broken PL were derived from the spectral indices of the observed SEDs.

Given the prominent broad emission lines in the optical spectrum of J2118–0732, a thermal emission contributed by an accretion disc is very likely present in J2118–0732. This is particularly true when J2118–0732 was in the high state, where the UV fluxes calculated from the OM data and the GALEX data started to rise towards the frequency range near the peak of the big blue bump. We used a multitemperature blackbody model of a standard thin disc to account for this component in the high state. But for the low state, we did not add a disc model due to the lack of available data points covering the frequency range where the disc is from uncertainties to some extent due to possible spectral variations.

To fit the broad-band SED, we first used a simple one-zone leptonic jet model, which consists of synchrotron, synchrotron self-Compton (SSC), and external-Compton (EC) emissions for the high/low state. And the solid blue lines indicate the disc models for the high state.

### Table 7. Parameters of the best-fitting SED models in the EC/torus and EC/BLR cases.

| Parameter | 2016-05-10 (high state) | 2016-10-27 (low state) | 2016-05-10 (high state) | 2016-10-27 (low state) |
|-----------|-------------------------|------------------------|-------------------------|------------------------|
| \( \gamma_{\text{min}} \) | 1 | 78 | 1 | 78 |
| \( \gamma_{\text{max}} \) | 575 \pm 146 | 269 \pm 81 | 617 \pm 185 | 372 \pm 111 |
| \( \gamma_{\text{bol}} \) | 20000 | 6000 | 15000 | 10000 |
| \( p_1^d \) | 2.02 | 1.54 | 1.92 | 1.2 |
| \( p_2^d \) | 3.8 | 3.8 | 3.92 | 3.9 |
| \( N_0 \) | 120 \pm 61 | 28 \pm 8 | 19 \pm 11 | 2.6 \pm 0.7 |
| \( \delta \) | 8.9 \pm 1.5 | 5.9 \pm 0.7 | 10.3 \pm 1.5 | 5.8 \pm 0.7 |
| \( B_R \) | 1.0 \pm 0.3 | 3.7 \pm 0.1 | 0.9 \pm 0.3 | 2.6 \pm 0.5 |
| \( \chi^2_{\text{red}} \) | 0.5 | 0.7 | 0.3 | 0.5 |
| \( L_{\text{bol}} \) | 2.46 | 2.88 |
| \( L_{\text{bol}}^\text{EC} \) | 0.06 | 0.07 |

### Notes:

\( a \) minimum Lorentz factor of the injected electrons.

\( b \) break Lorentz factor of the injected electrons.

\( c \) maximum Lorentz factor of the injected electrons.

\( d \) low-energy electron spectral index.

\( e \) high-energy electron spectral index.

\( f \) electron density parameter in units of \( 10^3 \text{ cm}^{-3} \).

\( g \) Doppler boosting factor which equals to bulk Lorentz factor assumed in Zhang et al. (2015).

\( h \) magnetic field in units of Gauss.

\( i \) reduced \( \chi^2 \) of the SED fittings with one-zone leptonic jet model.

\( j \) bolometric luminosity \( L_{\text{bol}} = L_{\text{disc}} \) in units of \( 10^{44} \text{ erg s}^{-1} \).

\( k \) Eddington ratio calculated from \( L = L_{\text{bol}}/L_{\text{Edd}} \).
the strongest. A black hole mass of $3.4 \times 10^7 M_\odot$ was employed. We also note that the optical fluxes should be treated as upper limits (marked as arrows in Fig. 7) caused by the contamination from the host galaxy, as revealed by the SDSS optical image (see Fig. 6) which shows an extended galaxy structure, while the UV fluxes\textsuperscript{7} are not. Since the hard X-ray spectrum is more flat than the average of radio-quiet NLS1s, we assume that it is dominated by jet emission (in addition to fainter emission from the corona). For simplicity, in the SED modelling, we therefore do not include coronal emission.

Both the EC/torus and the EC/BLR models can adequately fit the broad-band SEDs and the disc component can be roughly constrained in the high state using the additional GALEX data. The parameters of the fitting are given in Table 7, together with their 1σ errors. As can be seen in Fig. 7, the infrared to ultraviolet is dominated by the synchrotron radiation and the γ-ray band is dominated by the EC radiation, respectively. The EC peak of the EC/torus model is broader than that of the EC/BLR model and extends to the X-ray band while only the SSC peak dominates the X-ray band in the EC/BLR model. The best-fitting parameters show that the EC/BLR model contains a higher magnetic field and the Doppler boosting factor is smaller compared with that of the EC/torus model. Noticing that the main difference of the broad-band SEDs of these two models lies in the luminosity from 10 keV up to 100 MeV, hard X-ray and/or soft γ-ray data would help to distinguish between the EC/torus and the EC/BLR models. However, only the upper limit of the source in the hard X-ray and/or soft γ-ray band can be constrained from surveys like the latest 105-month Swift-BAT all-sky hard X-ray survey in the 14–195 keV (Oh et al. 2018) which is not sensitive enough to discriminate between the two models for the SED yet. Further data are needed to distinguish between the two models and give better understandings of the EC process in astrophysical jets.

The multiwavelength SEDs of J2118–0732 changed from a high state on 2016 May 10 to a low state on 2016 October 27 with a synchronous drop of the broad-band fluxes from infrared to X-rays in five months. The electron density parameter varied by about an order of magnitude between the two states for both models. The Eddington ratio was estimated to be $\approx 0.07$ in the high state. For the low state, a reliable estimate of the Eddington ratio cannot be made, but it is probably lower than that of the high state, as indicated by its upper UV fluxes.

The best-fitting parameter values, including the magnetic fields, the Doppler boosting factors, and the electron densities are within the typical range of some other GeV NLS1s (e.g. Abdo et al. 2009b; Foschini et al. 2011b; D’Ammando et al. 2012; Paliya et al. 2013; Sun et al. 2015; Yao et al. 2015a) and similar to those of blazars (e.g. Tavecchio et al. 2010; Zhang et al. 2015). However, the exact values of these parameters may be subject to relatively large uncertainties, given the degeneracies among some of the parameters (e.g. Tavecchio et al. 1998; Zhang et al. 2012) as well as the non-simultaneity of the multiwavelength data.

7 DISCUSSIONS

7.1 Blazar-like properties of J2118–0732

Blazar-like characteristics have been found in some RL NLS1s (Yuan et al. 2008), suggesting the presence of relativistic jets which was later confirmed by the detection of γ-ray emission from some of these objects with the Fermi. The similar multiwavelength properties of J2118–0732 make it a new member of this interesting and rare class of objects. The flat radio spectrum above 1.4 GHz of J2118–0732 is probably the result of a superposition of several jet components (Konigl 1981) while the steep spectrum below 1.4 GHz is likely coming from radio lobes. The short time-scale of infrared emission is consistent with the size of the jet-emission region. Besides, the hard X-ray spectrum of J2118–0732 is similar to those of some blazar-like NLS1s, hinting perhaps at a jet origin. Furthermore, D’Abrusco et al. (2014) found that the WISE mid-infrared colours of J2118–0732 are similar to those of the confirmed γ-ray emitting blazars that occupy the so-called WISE blazar locus (D’Abrusco et al. 2013) in the WISE colour space, which makes J2118–0732 a ’WISE blazar-like radio-loud source’.

The blazar-like characteristics of J2118–0732 are also reminiscent of another γ-ray-emitting NLS1s – PKS 2004–447. PKS 2004–447 has a very high radio loudness ($1710 < R < 6320$) and a low BH mass ($M_{BH} = 10^{6.7} M_\odot$) at a redshift of 0.24. The jet emission is also suggested to dominate at multiple wavelengths in PKS 2004–447 which is supported by the multiwavelength analysis and the SED modelling (Abdo et al. 2009b; Paliya et al. 2013; Orienti et al. 2015). Moreover, both J2118–0732 and PKS 2004–447 show weak FeII emission and lack an obvious soft X-ray excess\textsuperscript{8}, while a soft X-ray excess has been detected in most other γ-loud NLS1s that have good-quality X-ray spectra (e.g. de Rosa et al. 2008; D’Ammando et al. 2014; Foschini et al. 2015; Kynoch et al. 2018; Larsson et al. 2018).

7.2 Association of the γ-ray source with J2118–0732

Even though the blazar-like characteristics make the RL NLS1 J2118–0732 a highly possible counterpart for the γ-ray source detected by the Fermi-LAT and both Paliya et al. (2018) and FLSY reported a high association probability of the source, we still make a sanity check of the association between the two within the relatively large error circle of the γ-ray source detection.

There are 11 radio sources detected in the FIRST survey within the gamma-error circle above the 1.5 mJy flux threshold and J2118–0732 is the brightest one with its radio flux higher than the combined flux of the rest 10 sources. Its monochromatic radio luminosity ($2.7 \times 10^{41} \text{ergs}^{-1}$) at

\textsuperscript{7} The observational $U$ band of the OM will be blueshifted to the UV band at the rest frame considering the redshift of J2118–0732.

\textsuperscript{8} We note a tentative soft excess has been reported in only one of the three XMM-Newton observations of PKS 2004–447 (Gallo et al. 2006; Kreikenbohm et al. 2016).
1.4 GHz and the 9-yr averaged monochromatic γ-ray luminosity at 1 GeV (0.9 × 10^{35} \text{erg s}^{-1}) of the γ-ray source follow the correlation between the two luminosities as claimed by Fan et al. (2016). The source detection algorithm on the EPIC images found 45 X-ray sources within the gamma-error circle and J2118−0732 is the brightest X-ray source with its X-ray flux in accordance with other γ-ray emitting Fermi blazars from a sample in Fan et al. (2016). Although a small part of the γ-ray error circle is not covered by the EPIC field of view, the only detection of J2118−0732 within this error circle by the RASS can set an upper limit on the fluxes of other X-ray sources. Furthermore, J2118−0732 is the only X-ray bright source in the EPIC image which has a radio counterpart among 11 radio sources detected in the FIRST catalogue, making it most likely associated with the γ-ray source. No known blazar is discovered by checking every X-ray source and radio source found above. However, an unambiguous and independent confirmation should come from future monitoring observations which search for the correlated variability of γ-ray emission with emission from other wavelengths.

### 7.3 γ-ray Variability

So far, only a limited number of γ-loud NLS1s have been detected by Fermi-LAT including J2118−0732. However, the γ-ray properties are different from source to source. Three objects, PMN J0948+0022, SBS 0846+513, and 1H 0323+342, have shown short-term strong γ-ray flares emerging and dying out within one month (D’Ammando et al. 2012, 2015a). Other γ-ray sources have not shown strong flares so far.

J2118−0732 was in a relatively high-flux state during 2009−2013 and dimmed below the detection limit of Fermi-LAT after 2013. During the active 4 yr, at least one flare was detected. The long-term activity with relatively high fluxes lasting for years of J2118−0732 may be a common feature since similar behaviours have been observed among some other γ-ray loud NLS1s: a nine-month flare was observed in a long time variability analysis of FBQS J1644+2619 (D’Ammando et al. 2015b), and a relatively high-flux state was also observed in SDSS J1442+4629+4714+29.4 in late 2012 lasting for several months (Liao et al. 2015). This may indicate that a number of RL NLS1s may radiate in γ-rays but remain undetected by the Fermi-LAT because they spend more of the time in a low-flux state. Therefore, because of this characteristic of long-term variability, more RL NLS1s, especially those with the highest radio loudness, are expected to be observed in the γ-ray band in the future.

### 8 SUMMARY

γ-ray-emitting NLS1s have been providing new insights into the formation and evolution of relativistic jets and the jet-disc coupling mechanism under the extreme conditions of low BH masses and high accretion rates. Here, we present our discovery of a new γ-ray-emitting NLS1–SDSS J211852.96−073227.5 by analysing the SDSS spectrum, the Fermi-LAT, and the XMM-Newton observational data. The multiwavelength observations presented here allow a comprehensive study of the properties of its broadband radiation. The main results are summarised below:

1. The optical spectrum of J2118−0732 from the SDSS confirms its NLS1 nature: a broad Hβ emission line with a width (FWHM) of 1585 km s\(^{-1}\) and a flux ratio [O III]/Hβ ≈ 1.7 even though the Fe II emission is rather weak. The estimated BH mass is ~3.4 × 10^7 M\(_{\odot}\) and the Eddington ratio is ~0.15.

2. The Fermi-LAT observations centred at J2118−0732 detected a new γ-ray source with a 9-yr averaged isotropic luminosity of 0.7 × 10^{35} \text{erg s}^{-1} in the 0.1–300 GeV rest-frame energy band. The new γ-ray source experienced a relatively high state for about 4 yr and remained in a quiescent state in other Fermi-LAT observations. At least one flare was emerging during the long-term activity.

3. Our two XMM-Newton observations covering a significant part of the γ-ray source error circle reveal that J2118−0732 is the brightest X-ray source in the field, and the one with large X-ray variability. The X-ray spectrum of J2118−0732 is flat, with no significant evidence of a soft excess.

4. Other blazar-like properties of J2118−0732 include a large radio loudness with a flat/inverted radio spectrum and remarkably rapid infrared variability of less than a day, detected by WISE. This short time-scale implies a compact emission region much more compact than the torus.

5. The broad-band SED can be modelled by emission from a simple one-zone leptonic jet, and the flux variation from infrared to X-rays in five months can be explained by changes of the jet parameters. Besides, there may exist a relatively strong disc component, at least in the high state. We note the caveat that, however, the exact values of the fitted parameters in our model may be subject to relatively large uncertainties, given the degeneracies among some of the model parameters as well as the non-simultaneity of the multiwavelength data.

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