Absorbed jets in gamma-ray narrow-line Seyfert 1 Galaxies: the case of SDSS J164100.10+345452.7

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ABSTRACT

In the last 15 years narrow-line Seyfert 1 galaxies (NLS1) have been investigated mainly in the radio, optical, UV and X-ray energy bands. In 2008, the detection of PMN J0948+0022 by Fermi-LAT allowed us to extend their spectral energy distribution to the γ-ray energy band, paving the way to include γ-ray NLS1 galaxies into the class of extra-galactic jetted sources. Indeed, their properties place them at the low-power end of the flat-spectrum radio quasar luminosity function, displaying low black-hole masses, accretion rates close to the Eddington limit, and low jet powers. Despite being considered radio silent, γ-ray NLS1s may present short and intense radio flares. We carried out an intensive multi-wavelength monitoring of SDSS J164100.10+345452.7 by means of the Metsähovi radio (37GHz) and *Swift* (Optical, UV, X-ray) observatories over a 2-year baseline with a weekly pace. Our campaign allowed us to obtain *Swift* data almost simultaneous with a radio flare. Detailed pre-, post-, and flare X-ray spectroscopy allowed us to discover a remarkable difference in the source spectrum in the distinct epochs, which permitted to establish the origin of the 37 GHz radio flare as the emergence of a jet from an obscuring neutral absorber detected in the X-ray observations. This result is the first detection of an absorbed jet in a γ-ray narrow-line Seyfert 1 galaxy.

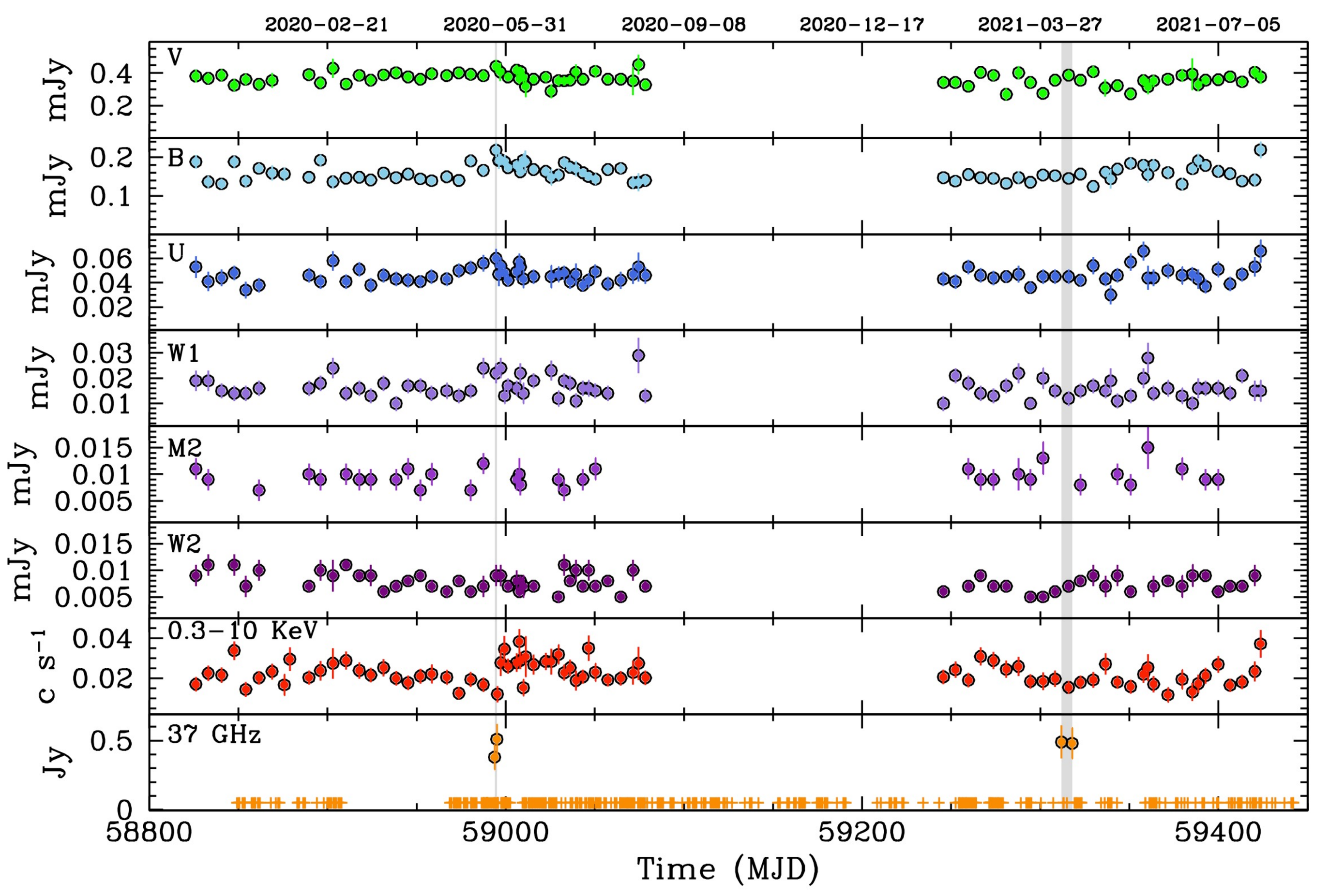

Fig. 1. Multi-wavelength light curves of SDSS J164100.10+345452.7. The optical, UV, and X-ray light curves were collected by *Swift* from 2019-12-09 to 2020-08-17 (first year campaign), from 2021-01-31 to 2021-07-28 (second year), and are shown with 1σ errorbars. The data at 37 GHz were collected at Metsähovi (<4σ non-detections represented by crosses). The grey bands mark the Metsähovi detections. The top axis reports representative dates.

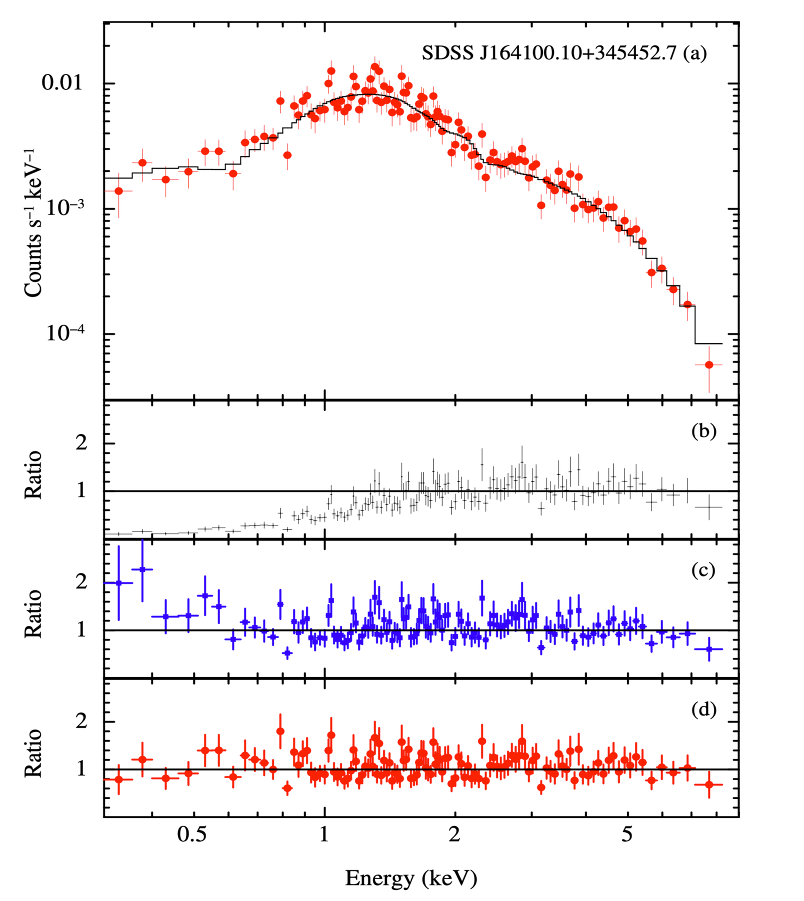

Fig. 2. *Swift*/XRT average spectrum of SDSS J164100.10+345452.7. The data are drawn from the whole 2 yr observing campaign (details on the spectral fits can be found in Table 1). Panel (a) best fit obtained by adopting the model tbabs * zpcfabs * zpowerlw; panel (b): data/model ratio from the fit with tbabs * zpowerlw in the 2–10 keV band; panel (c) data/model ratio from the fit with tbabs * ztbabs * zpowerlw (0.3-10 keV); panel (d) data/model ratio from the fit with tbabs * zpcfabs * zpowerlw (0.3–10 keV).

Tab. 1 Time-selected *Swift*/XRT spectroscopy.

Spectrum parameter	Total value	Flare value	Units
	tbabs * zpowerlw (2–10 keV)		
Γ_{2-10}	1.84 ± 0.15	0.94 ± 1.35	
F_{2-10}	6.24	14.1	$\times10^{-13}$ erg cm^{-2} s^{-1}
χ^2/d.o.f.	42.40/48	12.72/20 (70.48)	
nhp	0.701	0.808	
	tbabs * zpowerlw (0.3–10 keV)		
$\Gamma_{0.3-10}$	1.13 ± 0.04	$0.67^{+0.38}_{-0.39}$	
$F_{0.3-10}$	10.3	17.3	$\times10^{-13}$ erg cm^{-2} s^{-1}
χ^2/d.o.f.	359.00/118	32.98/37 (98.40)	
nhp	3.77×10^{-26}	0.658	
	tbabs * ztbabs * zpowerlw (0.3–10 keV)		
$N_{H,z}$	$3.2^{+0.6}_{-0.5}$	$2.6^{+5.3}_{-2.6p}$	$\times10^{21}$ cm^{-2}
$\Gamma_{0.3-10}$	$1.75^{+0.10}_{-0.09}$	$1.08^{+0.71}_{-0.64}$	
$F_{0.3-10}$	8.71	14.5	$\times10^{-13}$ erg cm^{-2} s^{-1}
χ^2/d.o.f.	142.83/117	33.96/36 (98.17)	
nhp	0.0525	0.566	
	tbabs * zpcfabs * zpowerlw (0.3–10 keV)		
$N_{H,z}$	6.2 ± 1.3	–	$\times10^{21}$ cm^{-2}
f	$0.91^{+0.02}_{-0.03}$	–	
$\Gamma_{0.3-10}$	1.93 ± 0.12	–	
$F_{0.3-10}$	8.54	–	$\times10^{-13}$ erg cm^{-2} s^{-1}
χ^2/d.o.f.	124.47/116	–	
nhp	0.279	–	
	tbabs * absori * zpowerlw (0.3–10 keV)		
$N_{H,z}$	$5.4^{+1.2}_{-1.1}$	–	$\times10^{21}$ cm^{-2}
$\Gamma_{0.3-10}$	$1.89^{+0.12}_{-0.11}$	–	
ξ	$2.4^{+2.5}_{-2.0}$	–	$\times10^{-2}$
$F_{0.3-10}$	8.52	–	$\times10^{-13}$ erg cm^{-2} s^{-1}
χ^2/d.o.f.	128.51/116	–	
nhp	0.201	–	
	tbabs * zxipcf * zpowerlw (0.3–10 keV)		
$N_{H,z}$	$6.2^{+1.3}_{-1.8}$	–	$\times10^{21}$ cm^{-2}
$\log\xi$	$-0.63^{+0.17}_{-1.07}$	–	
f	$0.99^{+0.01p}_{-0.04}$	–	
$\Gamma_{0.3-10}$	$2.00 \pm +0.17$	–	
$F_{0.3-10}$	8.46	–	$\times10^{-13}$ erg cm^{-2} s^{-1}
χ^2/d.o.f.	127.88/115	–	
nhp	0.194	–	

Tab. 2. Overall properties of SDSS J164100.10+345452

Parameter	Value	Units
M_{BH}	1.41	$\times10^7 M_\odot$
$L_{H\beta}$	2.51	$\times10^{41}$ erg s^{-1}
L_{Edd}	1.8	$\times10^{45}$ erg s^{-1}
L_{disc}	6.8	$\times10^{43}$ erg s^{-1}
L_{disc}/L_{Edd}	0.04	–
R_{BLR}	2.6	$\times10^{16}$ cm
L_{BLR}	5.3	$\times10^{42}$ erg s^{-1}
u_{BLR}	0.02	erg cm^{-3}
$\alpha_{1.6-5.2\,GHz}$	1.04	–
$\alpha_{5.2-9.0\,GHz}$	1.24	–
$\alpha_{9.0-37\,GHz}$	−4.92	–
$S_{15\,GHz}$	4.33	mJy
$L_{15\,GHz}$	1.95	$\times10^{40}$ erg s^{-1}
P^{rad}_{jet}	1.65	$\times10^{42}$ erg s^{-1}
P^{kin}_{jet}	1.83	$\times10^{42}$ erg s^{-1}
P^{tot}_{jet}	3.48	$\times10^{42}$ erg s^{-1}

DISCUSSION

SDSS J164100.10+345452.7 is a nearby γ-ray NLS1 (z = 0.16409), hosted in a spiral galaxy, initially classified as radio-quiet and then detected at 37 GHz with F = 0.46 and at E>100 MeV with F = (12.5 ± 2.18) x 10^{-9} ph cm^{-2} s^{-1} (Lähteenmäki et al. 2018). Given this hint for the presence of a jet, we performed a monitoring with *Swift* simultaneously with radio observations at Metsähovi.

The *Swift* data were collected through two yearly monitoring campaigns (Target ID 11395, PI: P. Romano) with a pace of one ~ 2–3 ks observation per week from 2019-12-09 to 2020-08-17 (97 ks) and from 2021-01-31 to 2021-07-28 (68 ks) with the *Swift*/X–ray Telescope (XRT) and the *Swift*/UV/Optical Telescope (UVOT), as shown in Fig. 1.

Fig. 2 shows the average XRT spectrum (~181 ks), that can be described well by an absorbed power-law model with a photon index Γ = 1.93±0.12 but requires a partially covering neutral absorber (Fig. 2 d: tbabs * zpcfabs * zpowerlw) with a covering fraction f = 0.91±0.02 (the details of the spectral fits are in Table 1). On the contrary, the flare spectrum (MJD 58994–58997, ~3.5 ks) does not require any such extra absorber and is much harder (Γ_{flare} ~ 0.7±0.4), thus implying the emergence of a further harder spectral component. **We interpret this as the jet emission emerging from a gap in the absorber.**

Overall, the spectral energy distribution (SED), although not well constrained at the high energies due to the lack of simultaneous *Fermi*/LAT data, does show a resemblance to the SEDs of jetted sources, with hints at the presence of two humps. The SED of J1641 is reminiscent of other γ-ray NLS1 galaxies with a synchrotron peak below 10^{13} Hz, a host galaxy component peaking at a few 10^{14} Hz, and the X-ray data which could be modelled with a synchrotron self-Compton component (Foschini et al. 2015). Assuming that the radio emission is due to a jet, then we can calculate its power, $\log(P_{tot}\ jet) \simeq 42.54$ erg s^{-1}, which is one of the lowest measured when compared with the Foschini et al. (2015) sample, and reminiscent of the γ-ray NLS1 J0706+3901. The overall properties of SDSS J164100.10+345452.7 are summarised in Table 2.

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References: Foschini et al. 2015, A&A 575 A13; Lähteenmäki et al., 2018, A&A, 614, L1; **Romano et al., 2023, A&A 673, A85**