



Narrow-line Seyfert 1 Galaxies in the Dark Energy Spectroscopic Instrument Data Release 1

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Abstract

Narrow-line Seyfert 1 (NLSy1) galaxies are peculiar active galactic nuclei (AGN) known to exhibit a variety of intriguing observational features from low-frequency radio waves to high-energy γ -rays. As of now, NLSy1 catalogs are primarily based on optical spectroscopic observations from the Sloan Digital Sky Survey (SDSS). Here we report, for the first time, a new catalog of NLSy1 galaxies using the high-quality optical spectroscopic observations made public in the first data release of the Dark Energy Spectroscopic Instrument (DESI). We performed a detailed spectral decomposition of more than 71,000 optical spectra of AGN not included in the SDSS catalog and located at $z < 0.9$. From this sample, we identify 18,749 objects as NLSy1 galaxies for the first time. We also supplement the NLSy1 catalog with a sample of broad-line Seyfert 1 galaxies. The NLSy1 galaxies identified in the DESI data tend to have slightly higher bolometric luminosities and lower black hole masses (though with large dispersions), leading to the higher Eddington ratios than those of the SDSS-NLSy1 sample matched in redshifts and absolute B -band magnitudes. Moreover, the fraction of DESI-NLSy1 galaxies detected in the radio, X-ray, and γ -ray catalogs was found to be lower than that of SDSS-NLSy1 sources. We conclude that deeper multiwavelength investigations of these enigmatic AGN will help unravel the low-luminosity end of the NLSy1 population. The catalog has been made available at <https://www.ucm.es/blazars/seiyfert> and Zenodo (doi:10.5281/zenodo.20484681).

Unified Astronomy Thesaurus concepts: Seyfert galaxies (1447); Active galactic nuclei (16); Spectroscopy (1558)

Materials only available in the online version of record: machine-readable table

1. Introduction

In the active galactic nuclei (AGN) zoo, narrow-line Seyfert 1 (NLSy1) galaxies are one of the most peculiar members. They were classified based on the narrowness of the broad $H\beta$ emission line ($\text{FWHM} < 2000 \text{ km s}^{-1}$), the strength of the forbidden [O III] line with respect to $H\beta$ ([O III] $\lambda 5007/H\beta$ flux ratio < 3) and identified as low-luminosity AGN (B -band absolute magnitude $M_B > -22.25$; D. E. Osterbrock & R. W. Pogge 1985; R. W. Goodrich 1989; M.-P. Véron-Cetty & P. Véron 2010). The observations of rapid X-ray variability, steep X-ray spectra, strong outflows, and strong Fe II complexes from some of these objects indicated NLSy1 galaxies to be powered by low-mass black holes ($M_{\text{BH}} \sim 10^6\text{--}8 M_\odot$) with a high accretion rate (e.g., T. Boller et al. 1996; K. M. Leighly 1999a, 1999b; D. Grupe & S. Mathur 2004; D. Grupe et al. 2010). Strong outflows allow us to study the feedback process in AGN (e.g., P. F. Hopkins & M. Elvis 2010; A. C. Fabian 2012; P. F. Hopkins et al. 2016). They are usually detected as flux-excess blueshifted with respect to the core component of [O III] $\lambda 5007$ emission line, leading to the observation of an asymmetric line profile (see S. Komossa et al. 2008). Strong outflows, with widths varying from a few hundred to a few thousand km s^{-1} are

often detected in AGN with high Eddington rates such as NLSy1 galaxies, where rapid accretion near the Eddington limit can trigger radiation-pressure-driven outflows (T. A. Boroson 2002; D. Grupe 2004; D. Xu et al. 2012; S. Komossa et al. 2018; S. Rakshit & J.-H. Woo 2018).

With the availability of high-quality observations delivered by the current generation of telescopes, it became evident that NLSy1 galaxies are intriguing sources. In the radio band, contrary to $\sim 10\%$ – 15% of the general AGN population being radio-loud, only $\sim 3\%$ – 5% NLSy1s were radio-detected, of which $\sim 60\%$ – 80% were found to be radio-loud in different samples (e.g., V. Singh & H. Chand 2018; V. S. Paliya et al. 2024). Superluminal motion has been observed from several objects of this class, indicating relativistic beaming, and identification of large-scale ($> 100 \text{ kpc}$) radio jets has also been reported (e.g., L. Fuhrmann et al. 2016; S. Rakshit et al. 2018; S. Chen et al. 2024; B. Kozák et al. 2024; S. Umayal et al. 2025). Furthermore, NLSy1 objects show flux variations at infrared (IR) and optical bands, including nightly brightness changes (V. S. Paliya et al. 2013; S. K. Kshama et al. 2017; S. Rakshit & C. S. Stalin 2017; S. Rakshit et al. 2019; M. Sudan et al. 2025). Recently, using Zwicky Transient Facility observations, S. Frederick et al. (2021) reported NLSy1 galaxies to exhibit rapidly rising and long-lasting flaring episodes in the optical band. Moreover, the high-resolution host-galaxy imaging of some radio-loud NLSy1 galaxies has revealed traces of mergers and interactions, thus indicating a possible connection between galaxy mergers and



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triggering of jets (A. Olguín-Iglesias et al. 2016; M. Berton et al. 2019; V. S. Paliya et al. 2020). These sources are typically hosted in disk or spiral galaxies (e.g., D. M. Crenshaw et al. 2003).

The X-ray observations of NLSy1 galaxies led to the detection of interesting spectral features, such as strong, often variable, soft X-ray excess, distorted Fe-K α emission line, and reflection-dominated hard X-ray emission. These findings suggested a complex radiative environment in the immediate vicinity of the central supermassive black hole where the interaction between matter and energy takes place (e.g., A. C. Fabian et al. 2009, 2015; M. L. Parker et al. 2014, 2019; E. Kara et al. 2017; K. Bonson et al. 2018; S. A. Mundo et al. 2020). Variable γ -ray emission has also been detected from a few radio-loud NLSy1 galaxies by the Fermi Large Area Telescope (LAT; see A. A. Abdo et al. 2009; G. Calderone et al. 2011; V. S. Paliya et al. 2015, 2018). This observation provides unambiguous evidence for the presence of closely aligned relativistic jets in these objects, similar to the blazar class of AGN. Considering the fact that NLSy1 galaxies are thought to be low-luminosity AGN in the early phase of their evolution (S. Mathur 2000), the γ -ray-detected objects of this class have been proposed as nascent blazars (see, e.g., L. Foschini et al. 2015; V. S. Paliya et al. 2019, 2020).

As of now, the samples of NLSy1 galaxies were prepared using the various data releases of the Sloan Digital Sky Survey (SDSS). For example, using the SDSS early data release (DR) and DR3, R. J. Williams et al. (2002) and H. Zhou et al. (2006) reported the identification of 150 and 2011 NLSy1s, respectively. S. Rakshit et al. (2017) analyzed optical spectra released in SDSS-DR12 and reported a catalog of 11,101 NLSy1 galaxies. More recently, a catalog of 22,656 NLSy1 objects was published using SDSS-DR17 (V. S. Paliya et al. 2024).

The Dark Energy Spectroscopic Instrument (DESI) collaboration recently announced the first release of the optical spectroscopic data acquired during the first 13 months of the DESI main survey (hereafter DESI-DR1; DESI Collaboration et al. 2026). With over 18 million optical spectra released in DESI-DR1, this is the largest optical spectroscopic survey ever conducted, surpassing SDSS. The optical spectroscopy is being carried out using DESI mounted at the Mayall 4 m telescope at Kitt Peak National Observatory, Arizona, United States of America. The details of the DESI-DR1 can be found in DESI Collaboration et al. (2026). Considering the broader sky coverage and deeper sensitivity of DESI compared to SDSS, it is imperative to increase the sample size of NLSy1 galaxies using the DESI-DR1 dataset. Also considering the ongoing and upcoming wide-field multiwavelength surveys, e.g., LOw Frequency ARray (LOFAR) and eROSITA, such an enlarged sample of NLSy1 galaxies will enable us to carry out detailed investigations of some of the faintest members of this class of AGN. With this objective in mind, we carried out a systematic spectroscopic decomposition analysis of a large sample of DESI-DR1 AGN optical spectra, and report here, for the first time, the identification of 18,749 NLSy1 galaxies.

In Section 2, we briefly describe the steps adopted to make the parent sample. The data analysis methodology is elaborated in Section 3. We present the new NLSy1 catalog in Section 4 and discuss their multiwavelength properties in Section 5. The results are summarized in Section 6.

Throughout, a flat cosmology with $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and $\Omega_M = 0.3$ was used.

2. Sample Selection

We considered the AGN/QSO value-added catalog (VAC) of 17,995,599 objects⁷ (S. Juneau et al. 2026, in preparation). Using the emission line measurements from FastSpecFit,⁸ the catalog includes AGN identified using optical and ultraviolet diagnostic diagrams and mid-IR classifications based on Tractor Wide-field Infrared Survey Explorer (WISE) photometry (S. Veilleux & D. E. Osterbrock 1987; L. J. Kewley et al. 2001; D. Lang et al. 2016). To optimize the sample selection, we adopted the following criteria:

1. Only considered the sources that have a primary coadded spectrum, i.e., the keyword `zcat_primary` is set to be `True`.
2. Only selected objects that have no measured redshift warning, i.e., `zwarn` = 0.
3. We crossmatched DESI sources with SDSS-DR17 using a search radius of 3", and removed all the matches. This step ensured the selection of sources whose optical spectra were not analyzed earlier for identifying NLSy1 galaxies.
4. The AGN/QSO VAC provides spectral parameters of several emission lines, including H β broad component. We considered only those sources that have a positive H β flux (keyword `HBETA_BROAD_FLUX` > 0), the ratio of the H β flux to the corresponding uncertainty > 3, and the dispersion of the H β broad component > 300. The last condition provided an initial filtering of objects in which the broad H β component is either weak or undetected.
5. We manually inspected the optical spectra of 104 sources that have a positive `HBETA_BROAD_FLUX`, but the quoted redshift was $z > 1.29$. We corrected the redshifts of 45 such sources and included them in the sample. The H β line was not covered in the optical spectra of the remaining sources.
6. Since NLSy1 classification also requires [O III] $\lambda 5007$ emission line flux values, we applied a redshift cutoff of $z \leq 0.9$ to ensure that [O III] $\lambda 5007$ lines falls into the wavelength range covered by DESI (3600–9800 Å). Additionally, we applied a lower redshift limit of $z \geq 0.01$ to avoid contamination from Galactic objects.

Following the abovementioned steps, we were left with 71,918 objects. The optical spectra of these sources were then analyzed following the methodology described in the next section.

3. Optical Spectroscopic Data Analysis

We followed the commonly adopted approach to decompose the optical spectrum, which involves fitting and subtracting the continuum radiation and modeling of the emission lines (e.g., S. Rakshit et al. 2017; D. Ilić et al. 2023). For spectral analysis, we considered the rest-frame wavelength range of 3800

⁷ <https://data.desi.lbl.gov/doc/releases/dr1/vac/agnqso/>

⁸ <https://fastspecfit.readthedocs.io/en/latest/iron.html>

–5500 Å, which contains the emission lines of interest, i.e., H β and [O III] $\lambda\lambda$ 4959,5007, and is large enough to reliably measure the continuum.

In the first step, the spectrum was brought to the rest frame and corrected for Galactic reddening following D. J. Schlegel et al. (1998). Next, we modeled the continuum emission with a combination of a power-law and a composite host-galaxy template. Since NLSy1 galaxies usually exhibit strong Fe II emission, we also used the optical Fe II template of T. A. Boroson & R. F. Green (1992).

To model the host-galaxy emission, we adopted the prior-informed AGN host spectral decomposition technique described in W. Ren et al. (2024) and implemented in the publicly available multicomponent spectral fitting code PyQSOFit⁹ (H. Guo et al. 2018). In particular, we adopted galaxy and quasar templates from principal component analysis (PCA) developed by C. W. Yip et al. (2004a, 2004b). The considered assumption is that the observed spectrum is a combination of two sets of eigenspectra from pure galaxy and quasar samples. Therefore, integrating the PCA spectra of both components enables us to separate them (e.g., D. E. Vanden Berk et al. 2006). However, PCA spectra from galaxy and quasar template libraries can be degenerate. More importantly, for the decomposition of low signal-to-noise ratio spectra, high-order PCA templates might overfit noise, thus leading to their disproportionate weighting in the spectral fitting. In this regard, the use of the PCA eigen coefficient distribution as prior information reduces the degeneracy of PCA templates between quasar and galaxy templates, thus significantly avoiding the overfitting issue (see W. Ren et al. 2024, for details).

Several previous studies have found that NLSy1 galaxies typically exhibit broad Balmer lines with extended wings, which are better represented with a Lorentzian profile (see E. C. Moran et al. 1996; M.-P. Véron-Cetty et al. 2001; J. W. Sulentic et al. 2002; M. R. Goad et al. 2012). Therefore, the broad H β component was modeled with a Lorentzian profile, and the narrow component was reproduced with a Gaussian shape. Furthermore, strong outflows have been detected in several NLSy1 galaxies; thus we model the [O III] doublet with double Gaussian functions, one each for the core and wing. We also applied the constraints that the FWHM of the wing should be larger than that of the core component and that the peak of the core should be larger than the wing component peak. The widths of the narrow H β and [O III] λ 4959 were tied to that of [O III] λ 5007 emission line. The flux ratio of [O III] doublet was fixed to the theoretical value of 3 (e.g., Y. Shen et al. 2011). The constraint that the width of the broad component must be larger than that of the narrow lines was also applied.

To determine the best-fitted spectral parameters and associated uncertainties, we employed a Monte Carlo bootstrapping approach. We ran 200 simulations and, in each run, the original spectrum was resampled with random normally distributed noise from the spectral variance, and the same fitting model was then applied. The median and median absolute deviation values of the derived spectral parameter distributions were considered as the best-fit values and corresponding 1σ uncertainties, respectively.

4. Results

The spectral fitting was applied to 71,918 DESI AGN using the methodology described above. We visually inspected all the fitted spectra to identify sources whose parameters could not be well constrained. The modeling was repeated, when required, for example, without [O III] wing components to avoid overfitting the [O III] lines when the outflowing component was not detected. Additionally, we further corrected the redshifts of 170 objects. There were 387 sources with repeated spectra and different DESI target IDs. In such cases, we retained the spectrum with a higher signal-to-noise ratio. All in all, this exercise led to the exclusion of 16,493 optical spectra. Most of them turned out to be either Type 2 AGN or emission line galaxies with no obvious broad H β component. Other remaining objects have extremely poor quality data, precluding us from deriving meaningful parameters.

Next, we analyzed the spectral parameters of the remaining 55,425 sources to identify NLSy1 and broad-line Seyfert 1 (BLSy1) galaxies among them. We show an example of the spectral fitting in Figure 1 and provide the information on the spectral parameters of the sample in the Appendix (Table 1). The parameters are available in the form of NLSy1 and BLSy1 catalogs¹⁰ at Zenodo (doi:10.5281/zenodo.20484681). The reported uncertainties in the spectral parameters, e.g., FWHM, were estimated from the model fitting. Though the uncertainties in the radio flux density values (used for radio-loudness calculation; see Section 5) are unavailable, it is typically 3%–5% of the measurements (see, e.g., Y. A. Gordon et al. 2021). Furthermore, a parameter value of –999 refers to the null flag, i.e., the corresponding parameter could not be estimated.

We estimated the goodness of fit by computing the reduced- χ^2 ($\chi_r^2 = \chi^2/\text{dof}$) for the continuum and line fittings and show the corresponding histograms in Figure 2. We found that the spectral fitting pipeline employed in this work reproduces the data reasonably well, with over 95% and 99% of the fitted sources having $\chi_r^2 < 2$ for the line and continuum fittings, respectively. The visual inspection of some of the objects with large χ_r^2 suggested their optical spectra to be of high signal-to-noise ratio. In such objects, the fitting pipeline could not model the data very well. The presence of artifacts in the data, e.g., likely due to imperfect cosmic-ray removal during the data processing, can also affect the χ_r^2 . However, we visually examined all spectra and confirmed that the fitting results are reliable.

For the whole sample, we also calculated bolometric luminosity (L_{bol}), B -band absolute magnitude (M_B), single-epoch virial black hole mass (M_{BH}), and Eddington ratio (R_{Edd}).

We considered the g - and r -band fluxes, in nanomaggies, estimated by DESI legacy surveys, and converted them to AB-magnitudes using the following formula:

$$m = 22.5 - 2.5 \log_{10}(f), \quad (1)$$

where f is the flux in nanomaggies. For 1510 sources, we could not find g - and/or r -band fluxes in the DESI catalogs. We used the PanSTARRS or SDSS g - and r -band magnitudes for them. For one source (target ID: 2781202851299403), we could not find the required magnitude information in the literature, likely

⁹ <https://github.com/legolason/PyQSOFit>

¹⁰ <https://www.ucm.es/blazars/seiyfert>

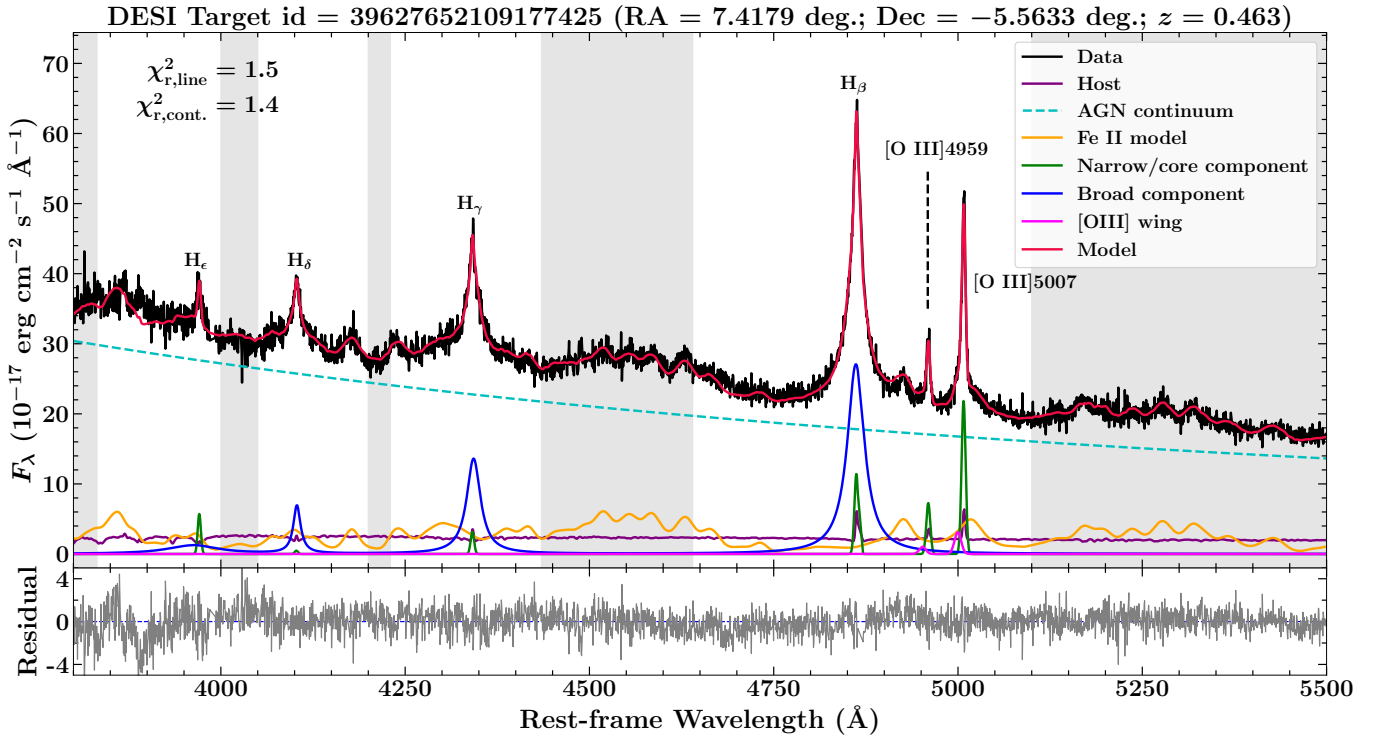


Figure 1. This plot shows an example of the spectral decomposition applied to the rest-frame DESI spectrum of an AGN. The model components are labeled, and several emission lines are marked. The vertical shaded regions refer to wavelength regions used for the continuum fitting.

due to it being in the proximity of a bright star, so it was not considered for the M_B calculation. The computed g - and r -band magnitudes were then used to derive the Bessel B -band magnitude using the following transformation equation (K. Jordi et al. 2006):

$$B = g + (0.313 \pm 0.003) * (g - r) + (0.219 \pm 0.002), \quad (2)$$

which was then used to estimate M_B using the AGN redshift and k -correction. Though most of the research works done on NLSy1 galaxies do not differentiate them from narrow-line quasars, the knowledge of M_B can be useful for a user to select genuine Seyfert galaxies ($M_B > -22.25$; M.-P. Véron-Cetty & P. Véron 2010). In the rest of the paper, we do not differentiate between galaxies and quasars and uniformly mention them as NLSy1 or BLSy1 galaxies.

The mass of the central supermassive black hole was calculated assuming the broad-line region (BLR) clouds to be virialized, the width of broad lines represents the virial velocity, and the continuum luminosity is a proxy for the BLR radius (e.g., R. J. McLure & J. S. Dunlop 2004; M. Vestergaard & B. M. Peterson 2006). The governing equation can be expressed as follows:

$$M_{\text{BH}} = \frac{\kappa R_{\text{BLR}} V_{\text{BLR}}^2}{G}, \quad (3)$$

where G is the gravitational constant and the terms R_{BLR} and V_{BLR} refer to the BLR radius and velocity of the BLR clouds, respectively. The geometry and kinematics of the lime-emitting BLR clouds are taken into account with the parameter κ , which was taken as $\kappa = 3/4$ for a spherical BLR cloud distribution (see S. Rakshit et al. 2017). The radius of the BLR,

i.e., R_{BLR} , was derived using the scaling relation between R_{BLR} and 5100 Å continuum luminosity ($\lambda L_{\lambda, 5100}$). Following P. Du & J.-M. Wang (2019), the relative strength of Fe II emission was taken into account since it can have strong implications on the continuum measurement in highly accreting AGN such as NLSy1 sources. We used the following equation to estimate R_{BLR} :

$$\log \left(\frac{R_{\text{BLR}}}{\text{lt-day}} \right) = K_1 + K_2 \log \left(\frac{\lambda L_{\lambda, 5100}}{10^{44} \text{ erg s}^{-1}} \right) + K_3 R_{4570}, \quad (4)$$

where R_{4570} is the relative Fe II strength defined as the ratio of the Fe II flux in the wavelength range 4434–4684 Å to the broad $H\beta$ component flux. We adopted the coefficients K_1 , K_2 , and K_3 as 1.65, 0.45, and -0.35 (P. Du & J.-M. Wang 2019). We note that the estimated uncertainty in M_{BH} does not consider any systematics inherent to the used scaling relations, which can be as large as 0.4 dex (e.g., Y. Shen 2013), and simply corresponds to measurement errors.

The M_{BH} measurement in NLSy1 galaxies is an active topic of debate. Since the single-epoch virial technique relies on the FWHM of the broad $H\beta$ emission line, NLSy1 objects, with lower FWHM values, tend to have smaller masses of the central black holes. The narrowness of the emission lines hints at a relatively slower motion of BLR gas, which indicates the presence of a low-mass black hole. However, the smaller line widths can also be due to projection effects caused by a “flat” BLR geometry and considering NLSy1 galaxies to be viewed preferentially pole-on (e.g., S. Collin & T. Kawaguchi 2004; R. Decarli et al. 2008; M. D’Onofrio et al. 2024). Moreover, J. E. Mejía-Restrepo et al. (2018) showed that the virial factor used to derive M_{BH} is not a constant but depends on line width and/or orientation. Interestingly, a few pieces of observational

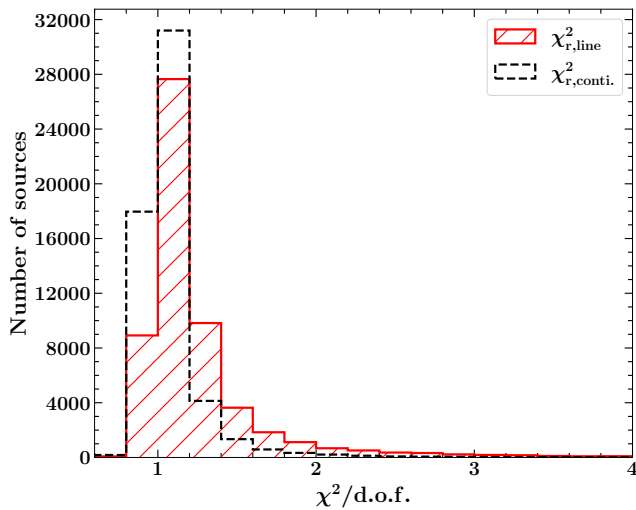


Figure 2. The histograms of the reduced- χ^2 estimated from the line ($\chi^2_{r,line}$, red-hatched) and continuum fitting ($\chi^2_{r,conti}$, black dashed).

evidence do not support the idea of large M_{BH} in NLSy1 galaxies. For example, if these objects are primarily oriented with a pole-on view, they should exhibit a larger radio-loud fraction and faster variability compared to BLSy1 galaxies, due to Doppler boosting effects. However, existing observations do not confirm these predictions (e.g., S. Rakshit & C. S. Stalin 2017; M. Sudan et al. 2025). In the sample of NLSy1s with radio sizes >100 kpc, the lack of any correlation of M_{BH} with radio core dominance, which is often used as a statistical indicator of orientation, also suggests that low M_{BH} may not be due to orientation (S. Umayal et al. 2025). The M_{BH} measurements done using X-ray excess variance also suggest low-mass black holes powering NLSy1s (e.g., Y. Lu & Q. Yu 2001; G. Ponti et al. 2012). Given the contrasting results found in several works, a dedicated study is needed to ascertain the origin of low M_{BH} values found in NLSy1 galaxies. In this work, on the other hand, we adopted the method that has been used in previous NLSy1 catalogs for consistency and a meaningful comparison.

From $\lambda L_{\lambda 5100}$, we derived L_{bol} using the bolometric correction factor of 9.26 following G. T. Richards et al. (2006). We note that the bolometric correction depends on the Eddington ratio as well as observed luminosity (H. Netzer 2019; G. J. Ferland et al. 2020). Therefore, a constant bolometric correction factor should be used with caution. We also calculated the Eddington ratio (R_{Edd}) from L_{bol} and M_{BH} .

4.1. The NLSy1 and BLSy1 Catalogs

Similar to our previous work, we adopted the following two criteria to identify NLSy1 galaxies in the sample of 55,425 objects:

1. Considering uncertainties, the FWHM of the broad $H\beta$ component is smaller than 2000 km s^{-1} , i.e., $\text{FWHM} - \Delta\text{FWHM} \leq 2000 \text{ km s}^{-1}$.
2. The ratio of the $[O III] \lambda 5007$ and total $H\beta$ line fluxes is <3 , while taking into account the uncertainties in the measured $H\beta$ and $[O III] \lambda 5007$ flux values.

The first condition of the FWHM threshold of 2000 km s^{-1} seems arbitrary, since no sharp differences in the physical properties of AGN have been found around this

value. Several works have proposed that a threshold of 4000 km s^{-1} is probably more physically motivated as this separates the population A and B sources on the fundamental plane (J. W. Sulentic et al. 2000, 2002; P. Marziani et al. 2018). Therefore, NLSy1 objects can be considered as a subsample of Population A sources. However, since the 2000 km s^{-1} FWHM threshold has been consistently used to identify and study these sources, we have also chosen the same threshold for a meaningful comparison with earlier works. Furthermore, the use of the FWHM uncertainty ensures that the borderline sources are properly considered.

For the second condition, we considered the fluxes of those narrow $H\beta$ and $[O III] \lambda 5007$ lines that had nonzero flux uncertainties and signal-to-noise ratio >1 . Otherwise, we assumed their flux values to be zero since the line detection in such cases is marginal.

The application of the abovementioned two criteria resulted in the identification of 18,749 NLSy1 sources present in DESI-DR1. Among them, 12,968 objects, i.e., $\sim 69\%$ of the whole sample, are genuine Seyfert galaxies with $M_B > -22.25$ (M.-P. Véron-Cetty & P. Véron 2010). We found 36 objects that qualified the first criterion but had $[O III] \lambda 5007$ to $H\beta$ lines flux ratio >3 .

We note that several works have reported Seyfert classification schemes based on the $[O III] \lambda 5007$ and total $H\beta$ line flux ratios. For example, H. Winkler (1992) adopted the flux ratio upper limit of 0.2, 0.5, and 3 for a Seyfert galaxy of Type 1, 1.2, and 1.5, respectively. Moreover, M. Whittle (1992) proposed a slightly relaxed upper limit of 0.3, 1, and 4, for Seyfert galaxies of Type 1, 1.2, and 1.5, respectively. On the other hand, as per the original classification by D. E. Osterbrock & R. W. Pogge (1985), an NLSy1 has an $[O III] \lambda 5007$ and $H\beta$ line flux ratio <3 , which is the lower limit for Type 2 Seyfert galaxies (J. M. Shuder & D. E. Osterbrock 1981). D. E. Osterbrock & R. W. Pogge (1985) briefly noted that sources with the line flux ratio of $\sim 2-3$ are more similar to Type 1.5 Seyfert galaxies. Given that all NLSy1 catalogs consistently use the $[O III] \lambda 5007$ and $H\beta$ line flux ratio threshold of 3, we also adopted the same criterion. However, this implies that a few Type 1.2 or 1.5 Seyfert galaxies could be present in our sample (M. Whittle 1992; H. Winkler 1992). For example, 676 sources, i.e., $\sim 3.6\%$ of the whole NLSy1 sample, have the $[O III] \lambda 5007$ and $H\beta$ line flux ratio smaller than 3 but larger than unity. However, none of them have this flux ratio larger than two.

The 36,640 BLSy1 sources were selected from the parent sample after excluding 18,749 NLSy1 galaxies and 36 narrow-line sources that failed to pass the second selection criterion as mentioned above. Among them, 16,582 sources are genuine broad-line Seyfert 1 AGN with $M_B > -22.25$. The remaining 20,058 objects can be considered broad emission line quasars ($M_B < -22.25$).

4.2. Comparison with SDSS-NLSy1 Galaxies

We have identified 18,749 AGN as NLSy1 galaxies for the first time using the DESI-DR1 data. Since all previous NLSy1 catalogs were made using SDSS datasets, it is intuitive to compare the measured properties of NLSy1s identified in both surveys. For SDSS, we used the NLSy1 catalog based on DR17 (V. S. Paliya et al. 2024). We show the redshift histograms for DESI-NLSy1 and SDSS-NLSy1 sources in panel (a) of Figure 3. The SDSS sample appears to have more

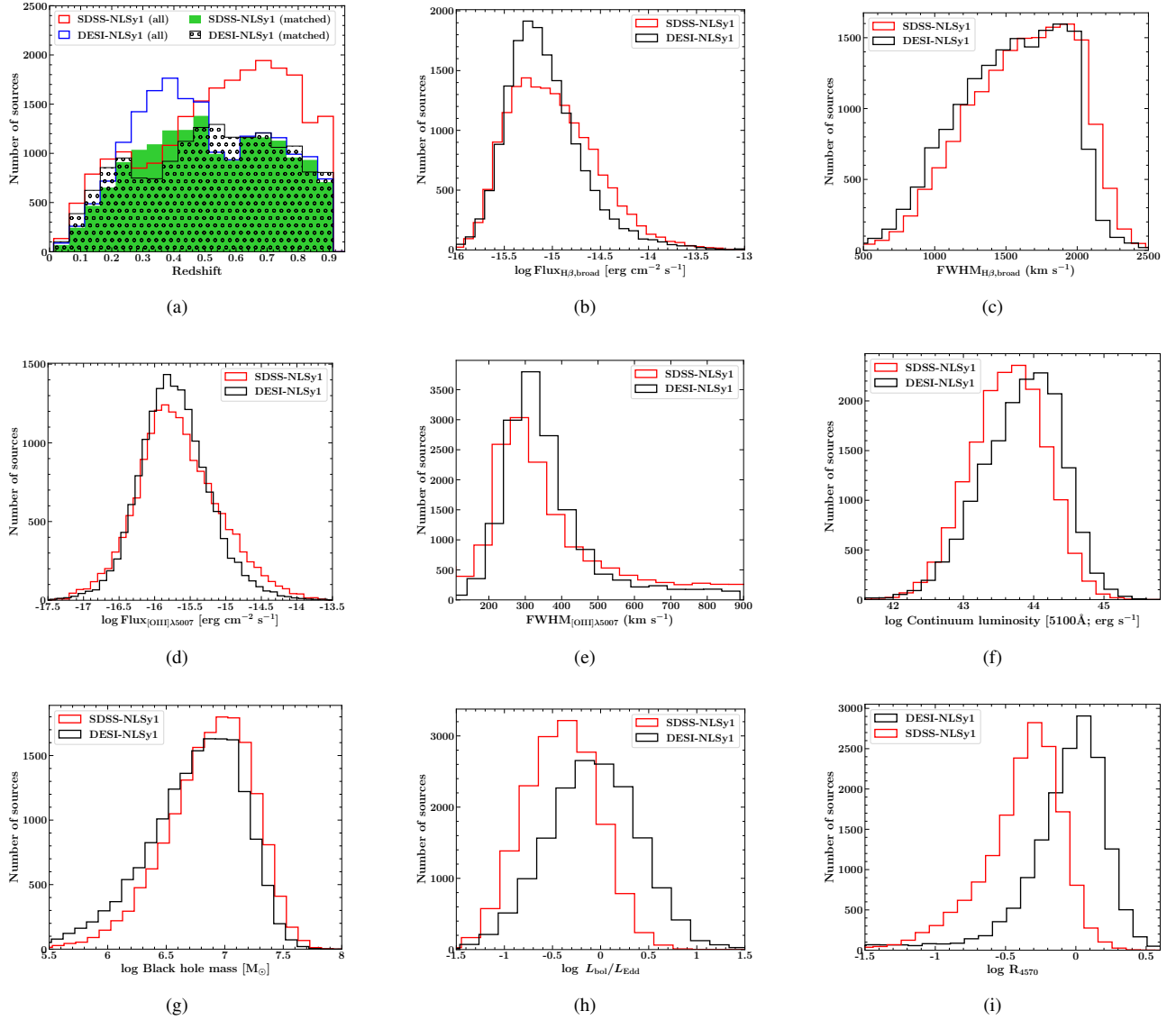


Figure 3. These plots show the comparison of several parameters measured/derived from the optical spectroscopic analysis of SDSS-NLSy1 (red) and DESI-NLSy1 (black) galaxies.

high-redshift NLSy1s (median $z = 0.58 \pm 0.17$) compared to those observed with DESI (median $z = 0.47 \pm 0.17$). For a meaningful comparison, we further made a matched selection by choosing SDSS-DESI-NLSy1 pairs with similar redshifts ($\Delta z < 0.05$) and absolute magnitudes ($\Delta M_B < 0.1$), finding 16,292 pairs. Their redshift distributions are highlighted in panel (a) of Figure 3. Below, we briefly describe the results of the comparison analysis.

Broad $H\beta$ flux. The comparison of the broad $H\beta$ component flux is shown in panel (b) of Figure 3. The overall distributions are similar for DESI-NLSy1 and SDSS-NLSy1 populations with median of the logarithmic flux values -15.1 ± 0.2 and -15.0 ± 0.3 (in $\text{erg cm}^{-2} \text{s}^{-1}$), respectively.

Broad $H\beta$ FWHM. We show the histograms of the FWHM values of the broad $H\beta$ component in panel (c) of Figure 3. Similar to the flux distribution, the FWHM also encompasses a similar range for both samples. The median FWHM for the DESI-NLSy1 and SDSS-NLSy1s are $1570 \pm 285 \text{ km s}^{-1}$ and $1650 \pm 280 \text{ km s}^{-1}$, respectively.

$[O III] \lambda 5007$ flux and FWHM. The distributions of $[O III] \lambda 5007$ flux and FWHM are plotted in panels (d) and

(e) of Figure 3, respectively. The median flux (log scale, in $\text{erg cm}^{-2} \text{s}^{-1}$) and FWHM (in km s^{-1}) values are -15.7 ± 0.3 and 334 ± 62 , and -15.7 ± 0.4 and 321 ± 86 for DESI-NLSy1 and SDSS-NLSy1 populations, respectively, indicating a similarity in parameters.

Continuum luminosity at 5100 Å. The comparison of $\lambda L_{\lambda, 5100}$ is shown in panel (f) of Figure 3. The distributions for DESI and SDSS-NLSy1s have the median values 43.88 ± 0.39 and 43.65 ± 0.36 (log scale, in erg s^{-1}), respectively, indicating the former to be slightly more luminous. Moreover, the L_{bol} distribution exhibits a similar trend for both populations, since it was derived from $\lambda L_{\lambda, 5100}$.

M_{BH} . The M_{BH} distributions for both source populations are plotted in panel (g) of Figure 3. DESI-NLSy1s tend to have lower black hole masses (median = 6.79 ± 0.27 , on log scale, in $M_{\odot}$) compared to the SDSS-NLSy1 objects (median = 6.91 ± 0.24 , on log scale, in $M_{\odot}$). However, the overall distributions are similar considering the spread.

Eddington ratio. We show the histograms of R_{Edd} ($= L_{\text{bol}}/L_{\text{Edd}}$) in panel (h) of Figure 3. For DESI-NLSy1 sources, the obtained results reveal a slightly higher R_{Edd}

(median = -0.07 ± 0.32 , on log scale), thus a higher accretion rate, compared to the SDSS-NLSy1 population (median = -0.40 ± 0.27 , on log scale), though the spread is large.

Fe II strength. We plot the histograms of the Fe II strength (R_{4570}) in panel (i) of Figure 3. Notably, the DESI-NLSy1 galaxies tend to have considerably larger R_{4570} compared to SDSS-NLSy1 sources. The median values for both populations are -0.02 ± 0.16 and -0.34 ± 0.17 , respectively. The observed behavior can be understood within the Eigenvector-1 framework introduced by T. A. Boroson & R. F. Green (1992), in which NLSy1 galaxies occupy the extreme end characterized by strong optical Fe II emission and high R_{Edd} . The parameter R_{4570} correlates primarily with R_{Edd} , which appeared to be larger for DESI-NLSy1s, and thus explains a higher R_{4570} . Photoionization simulations done with CLOUDY demonstrate that the optical Fe II strength increases with metallicity in dense BLR clouds. Supersolar metallicity enhances the iron abundance and alters the thermal and ionization structure of the gas, resulting in stronger Fe II emission relative to H β (e.g., S. Panda et al. 2019).

5. Multiwavelength Properties

We crossmatched the new DESI-NLSy1 catalog with several multifrequency databases and report our findings below.

5.1. Radio

Previous works have reported the detection of only $\sim 5\%$ NLSy1 to be radio emitters (S. Komossa et al. 2006; V. Singh & H. Chand 2018). In the SDSS-DR17 NLSy1 catalog, only $\sim 3\%$ objects were detected in the Faint Images of the Radio Sky at Twenty-Centimeters survey (FIRST; R. L. White et al. 1997). In this work, we have used the radio source catalog created by utilizing Very Large Array Sky Survey, an ongoing survey at 2–4 GHz covering the whole sky north of -40° decl. (M. Lacy et al. 2020; Y. A. Gordon et al. 2021). Since the sky coverage of VLASS is considerably larger than that of FIRST, this may enable us to identify more radio-emitting NLSy1 sources. We crossmatched the DESI-NLSy1 catalog with the VLASS source catalog made by using the first two epochs of observations and adopting a search radius of $5''$. We found 285 matches with nonzero integrated flux density values ranging from 0.7 to 503 mJy. Thus, the fraction of radio-detected DESI-NLSy1 is 1.5%. For an equal comparison, we also crossmatched the SDSS-DR17 NLSy1 catalog with the VLASS and found 683 sources, i.e., $\sim 3\%$ of the whole sample. The lower radio detection fraction of DESI-NLSy1 galaxies could be due to these being relatively low-luminosity galaxies, as radio AGN activity has been shown to have a strong dependence on galaxy mass (see J. Sabater et al. 2019), which in turn depends on the absolute magnitude (e.g., S. Savaglio et al. 2005).

We also estimated the radio-loudness parameter (R), which is defined as the ratio of the rest-frame 5 GHz flux density and $4400 \text{ \AA}$ (K. I. Kellermann et al. 1989). We extrapolated the 3 GHz flux density measured by VLASS to 5 GHz, assuming the spectral index $\alpha = -0.5$ ($F_\nu \propto \nu^\alpha$). A total of 230 NLSy1 objects, i.e., $\sim 81\%$ of all radio-detected ones, were found to be radio-loud ($R > 10$), which is larger than 63% found for the SDSS-NLSy1 sample (V. S. Paliya et al. 2024). It is relevant to note that while studying the radio properties of the sample of NLSy1s compiled by S. Rakshit et al. (2017), V. Singh & H. Chand (2018) found $\sim 81.7\%$ to be radio-loud, similar to

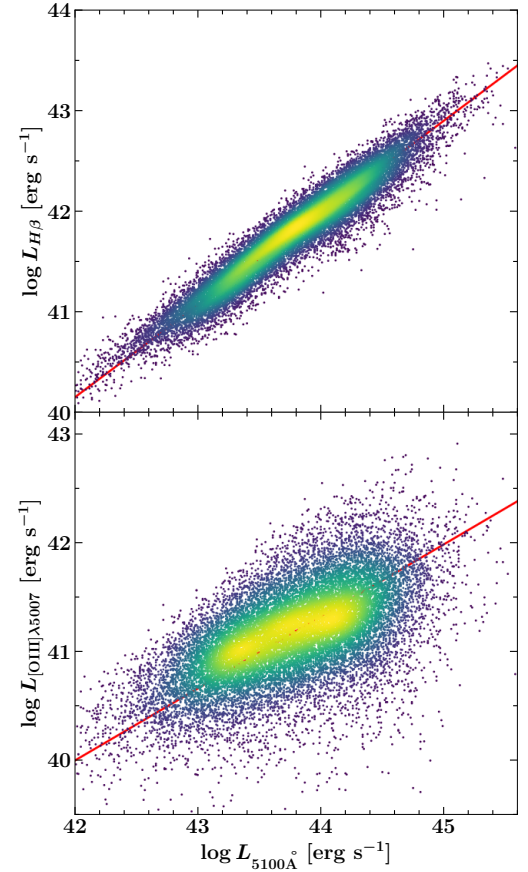


Figure 4. The variations of the luminosity of the H β and [O III] $\lambda 5007$ emission lines and 5100 $\text{\AA}$ continuum luminosity are shown in these plots. The color scheme is based on the number density of sources, with lighter colors representing a larger number of sources. The red line refers to the best-fitted correlation.

our sample of DESI-NLSy1s. The sample of SDSS-NLSy1s extends to higher redshifts, and it would be useful to make deeper observations to check whether radio-loud objects may have been missed in this sample.

5.2. IR

We crossmatched the DESI-DR1 NLSy1 catalog with the allWISE source catalog (E. L. Wright et al. 2019) with a search radius of $5''$. In the W1-filter, we found 17,801 detections at $\geq 3\sigma$ confidence level, i.e., $\sim 95\%$ of the whole sample, which is similar to $\sim 96\%$ found for the SDSS-NLSy1 catalog. On the other hand, 17,725 ($\sim 95\%$) and 12,909 ($\sim 69\%$) NLSy1s were identified in W2 and W3 bands, respectively. This implied a lower W3-band detection compared to $\sim 80\%$ found for the SDSS-NLSy1 sample (V. S. Paliya et al. 2024).

5.3. Optical

Several previous works reported a strong correlation between emission line luminosities and the continuum luminosity for AGN, including NLSy1 galaxies (J. E. Greene & L. C. Ho 2005; H. Zhou et al. 2006; S. Rakshit et al. 2017). We examined these correlations for the DESI-NLSy1 sample by applying a simple linear least-squares fit to the data. We

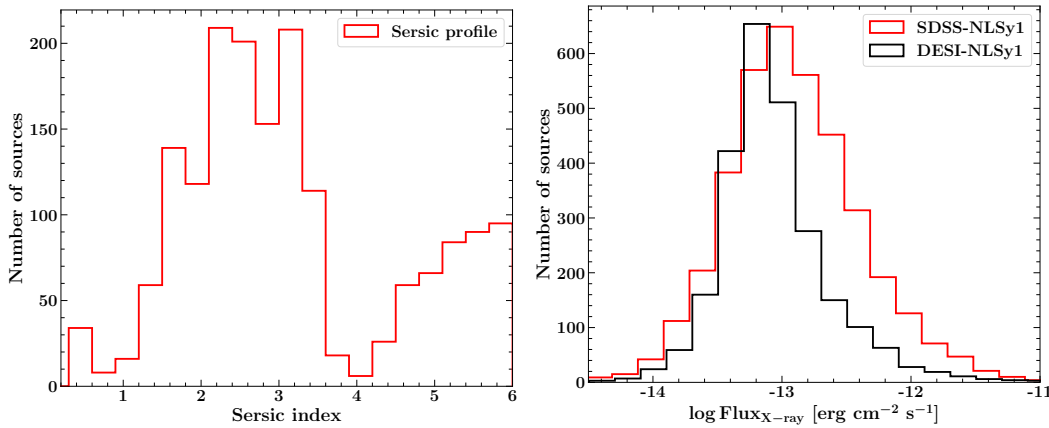


Figure 5. Left: the histogram of the Sérsic index taken from the DESI-DR1 redshift catalog. Right: the distributions of the observed X-ray fluxes for NLSy1 galaxies identified in the DESI (black) and SDSS (red) surveys.

obtained the following empirical relations (Figure 4):

$$\log(L_{\text{H}\beta}) = (1.769 \pm 0.085) + (0.914 \pm 0.002)\log L_{5100}. \quad (5)$$

$$\log(L_{[\text{OIII}]\lambda 5007}) = (12.161 \pm 0.218) + (0.663 \pm 0.005)\log L_{5100}. \quad (6)$$

These results are similar to those reported in the literature (e.g., V. S. Paliya et al. 2024).

The DESI-DR1 redshift catalog provides a measure of the galaxy morphology by fitting several models listed as follows¹¹: point source (type = “PSF”), round exponential galaxy model (“REX”), de Vaucouleurs model (“DEV”), exponential model (“EXP”), and a Sérsic model (“SER”). Among them, the commonly adopted Sérsic model can give clues about the galaxy light profile based on the parameter Sérsic index, also provided in the DESI-DR1 redshift catalog. Admittedly, the DESI legacy survey data modeling was done following an automated process; however, the estimated Sérsic index can give us clues about the host-galaxy morphology of the overall NLSy1 population. Among 18,749 DESI-DR1 NLSy1 galaxies, the Sérsic model is the best-fitted profile for 3228 sources. Excluding objects with Sérsic index value of 6, i.e., the upper limit, we had 1699 NLSy1 galaxies. We show the distribution of their Sérsic index in the left panel of Figure 5. As can be seen, most of the sources have Sérsic index smaller than 4, which implies their host galaxies to be late-type, disk-dominated (for Sérsic index $\lesssim 2$) or intermediate types (S0/Sb) with both disk and bulges. A large Sérsic index (>4), on the other hand, indicates an early-type, elliptical host. Since finding an NLSy1 nucleus in an elliptical host is uncommon, we examined the DESI legacy survey images of some of the sources with large Sérsic index. In several cases (e.g., target id: 39633342278142022), we found spiral arms and complex structures, thereby suggesting that a large Sérsic index may be due to poor fitting. All in all, these results support the notion that NLSy1 sources are generally hosted in late-type, nonelliptical galaxies (e.g., D. M. Crenshaw et al. 2003; A. Oguín-Iglesias et al. 2016).

5.4. X-Ray

To determine the X-ray-detected NLSy1 galaxies, using a search radius of $5''$, we scanned the Chandra source catalog

(CSC v2.1, 0.5–7 keV; I. N. Evans et al. 2024), the first X-ray catalogs and data release of the western Galactic hemisphere by the Spektrum Roentgen Gamma/eROSITA all-sky survey (eRASS-DR1, 0.2–2.3 keV; A. Merloni et al. 2024), XMM-Newton serendipitous source catalog (4XMM-DR14, 0.2–12 keV; N. A. Webb et al. 2020), and live Swift-X-ray Telescope Point Source Catalog (LSXPS, 0.3–10 keV; P. A. Evans et al. 2023), in sequential order. This exercise led to the identification of 264, 1388, 443, and 417 X-ray emitting NLSy1 galaxies, respectively. We show the X-ray flux measured by the mentioned surveys, albeit having overlapping yet different energy ranges, in the right panel of Figure 5. For comparison, we also plot the X-ray flux histogram for SDSS-DR17 NLSy1 galaxies using the flux values reported by the same catalogs mentioned above. The DESI-NLSy1 objects are slightly fainter (log-scale median flux = -13.12 ± 0.22 , in $\text{erg cm}^{-2} \text{s}^{-1}$) compared to the SDSS-NLSy1s (log-scale median flux = -12.94 ± 0.32 , in $\text{erg cm}^{-2} \text{s}^{-1}$), though the spreads of the distributions are large.

5.5. Gamma Rays

The presence of closely aligned relativistic jets in some of the radio-loudest NLSy1 galaxies was confirmed by their detection with Fermi-LAT (see V. S. Paliya 2019). The γ -ray detection also provides strong evidence that AGN powered by low black hole masses can also host powerful relativistic jets akin to blazars. To identify γ -ray emitting NLSy1 galaxies in the DESI sample, we utilized the recently released early 16 yr list of Fermi-LAT-detected sources (FL16Y; S. Abdollahi et al. 2022; J. Ballet et al. 2026). We crossmatched both catalogs using a $5''$ search radius and adopting the counterpart coordinates provided in FL16Y. We found two γ -ray emitting sources: FL16Y J0017.5–0512 and FL16Y J1754.8+3443. These objects are associated with radio sources PMN J0017–0512 ($z = 0.227$) and MG2 J175448+3442 ($z = 0.62$), respectively. Such a small number of γ -ray emitting DESI-NLSy1 galaxies is surprising. This is because the SDSS-NLSy1 sample, which has a slightly larger size of 22,656 NLSy1s compared to 18,756 DESI-NLSy1s, has 21 γ -ray-detected objects (V. S. Paliya et al. 2024). One possible reason to explain the differences could be the fact that DESI-NLSy1s are intrinsically less powerful AGN compared to SDSS-NLSy1 galaxies. This hypothesis can also explain their lower X-ray fluxes (Figure 5), fainter M_B , and lower black hole

¹¹ <https://www.legacysurvey.org/dr9/catalogs/>

masses (Figure 3). Deeper multiwavelength investigations of these objects are needed to probe their enigmatic behavior.

6. Summary

We have utilized the recently released optical spectroscopic data from the DESI-DR1 catalog to identify NLSy1 galaxies. We started with the AGN/QSO VAC released by the DESI collaboration, and applied a number of filters to remove contaminating objects. In the wavelength range of 3800–5500 Å, we subtracted the continuum by modeling the rest-frame optical spectrum with a combination of the nuclear power-law AGN emission, Fe II template, and prior-informed host-galaxy templates generated using PCA analysis. The continuum subtracted spectrum was reproduced with a combination of Lorentzian (for the broad H β component) and Gaussian (for the narrow components) functions, and spectral parameters were estimated by adopting a Monte Carlo bootstrapping technique. This exercise resulted in a new catalog of 18,749 NLSy1 galaxies identified for the first time. Several of their optical spectroscopic parameters or those derived from them are similar to those estimated for previously known NLSy1 objects. However, the detection fractions of DESI-NLSy1 galaxies in radio, X-ray, and γ -ray surveys were found to be lower than those of SDSS-NLSy1 objects. These intriguing findings indicate that NLSy1s identified in the DESI survey may belong to the low-luminosity members of this class of AGN. Deeper broadband observations of these enigmatic sources will play a pivotal role in exploring the physics of AGN at the faint end of the source population, thus setting a benchmark for their observations with the next generation of large telescopes.

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Appendix Details of the Catalog Fits File

We provide the full description of the catalog below in Table 1. The data are available in machine-readable format in two separate tables; one is the NLSy1 galaxy catalog, while the other is the broad-line Seyfert 1 galaxy catalog. These are bundled together in a .tar.gz package along with a ReadMe file. In both catalogs, the null flag is –999 for all columns.

Table 1
Format of the Narrow-line and Broad-line Seyfert 1 Galaxy Catalogs

Column	Format	Units	Description
NAME	STRING	...	J2000 designation
TARGET_ID	STRING	...	Spectroscopic Plate number, MJD, and fiber number
RA	DOUBLE	degree	R.A. (J2000)
DEC	DOUBLE	degree	Decl. (J2000)
Z	DOUBLE	...	Spectroscopic redshift
M_B	DOUBLE	...	Absolute <i>B</i> -band magnitude
BR_H_BETA_FWHM	DOUBLE	km s ⁻¹	FWHM of the broad H β emission line
BR_H_BETA_FWHM_ERR	DOUBLE	km s ⁻¹	Uncertainty in the FWHM of the broad H β emission line
BR_H_BETA_FLUX	DOUBLE	[erg cm ⁻² s ⁻¹]	Flux of the broad H β emission line on log scale
BR_H_BETA_FLUX_ERR	DOUBLE	[erg cm ⁻² s ⁻¹]	Uncertainty in the log-scale flux of the broad H β emission line
BR_H_BETA_LUM	DOUBLE	[erg s ⁻¹]	Luminosity of the broad H β emission line on log scale
BR_H_BETA_LUM_ERR	DOUBLE	[erg s ⁻¹]	Uncertainty in the log-scale luminosity of the broad H β emission line
NA_OIII_5007_FWHM	DOUBLE	km s ⁻¹	FWHM of the narrow [O III] λ 5007 emission line
NA_OIII_5007_FWHM_ERR	DOUBLE	km s ⁻¹	Uncertainty in the FWHM of the narrow [O III] λ 5007 emission line
NA_OIII_5007_FLUX	DOUBLE	[erg cm ⁻² s ⁻¹]	Flux of the narrow [O III] λ 5007 emission line on log scale
NA_OIII_5007_FLUX_ERR	DOUBLE	[erg cm ⁻² s ⁻¹]	Uncertainty in the log-scale flux of the narrow [O III] λ 5007 emission line
NA_OIII_5007_LUM	DOUBLE	[erg s ⁻¹]	Luminosity of the narrow [O III] λ 5007 emission line (erg s ⁻¹) on log scale
NA_OIII_5007_LUM_ERR	DOUBLE	[erg s ⁻¹]	Uncertainty in the log-scale luminosity of the narrow [O III] λ 5007 emission line
NA_H_BETA_FLUX	DOUBLE	[erg cm ⁻² s ⁻¹]	Flux of the narrow H β emission line on log scale
NA_H_BETA_FLUX_ERR	DOUBLE	[erg cm ⁻² s ⁻¹]	Uncertainty in the log-scale flux of the narrow H β emission line
NA_H_BETA_LUM	DOUBLE	[erg s ⁻¹]	Luminosity of the narrow H β emission line on log scale
NA_H_BETA_LUM_ERR	DOUBLE	[erg s ⁻¹]	Uncertainty in the log-scale luminosity of the narrow H β emission line
L5100	DOUBLE	[erg s ⁻¹]	Rest-frame AGN continuum luminosity at 5100 Å on log scale
L5100_ERR	DOUBLE	[erg s ⁻¹]	Uncertainty in the log-scale continuum luminosity at 5100 Å
L5100_HOST	DOUBLE	[erg s ⁻¹]	Rest-frame Host continuum luminosity at 5100 Å on log scale
R4570	DOUBLE	...	Fe II strength
SN_CONTI	DOUBLE	...	Continuum signal-to-noise ratio
M_BH	DOUBLE	[M _⊙]	black hole mass on log scale
M_BH_ERR	DOUBLE	[M _⊙]	Uncertainty in the log-scale black hole mass
L_BOL	DOUBLE	[erg s ⁻¹]	Bolometric luminosity on log scale
L_BOL_ERR	DOUBLE	[erg s ⁻¹]	Uncertainty in the log-scale bolometric luminosity
R_EDD	DOUBLE	...	Eddington ratio on log scale
R_EDD_ERR	DOUBLE	...	Uncertainty in the log-scale Eddington ratio
RL	DOUBLE	...	Radio-loudness parameter on log scale

(This table is available in its entirety in machine-readable form in the [online article](#).)

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References

- Abdo, A. A., Ackermann, M., Ajello, M., et al. 2009, *ApJL*, **707**, L142
 Abdollahi, S., Acero, F., Baldini, L., et al. 2022, *ApJS*, **260**, 53
 Ballet, J., Bruel, P., Burnett, T. H., & Lott, B. 2026, arXiv:2602.22148
 Berton, M., Congiu, E., Ciroi, S., et al. 2019, *AJ*, **157**, 48
 Boller, T., Brandt, W. N., & Fink, H. 1996, *A&A*, **305**, 53
 Bonson, K., Gallo, L. C., Wilkins, D. R., & Fabian, A. C. 2018, *MNRAS*, **477**, 3247
 Boroson, T. A. 2002, *ApJ*, **565**, 78
 Boroson, T. A., & Green, R. F. 1992, *ApJS*, **80**, 109
 Calderone, G., Foschini, L., Ghisellini, G., et al. 2011, *MNRAS*, **413**, 2365
 Chen, S., Kharb, P., Silpa, S., et al. 2024, *ApJ*, **963**, 32
 Collin, S., & Kawaguchi, T. 2004, *A&A*, **426**, 797
 Crenshaw, D. M., Kraemer, S. B., & Gabel, J. R. 2003, *AJ*, **126**, 1690
 Decarli, R., Dotti, M., Fontana, M., & Haardt, F. 2008, *MNRAS*, **386**, L15
 DESI Collaboration, Abdul-Karim, M., Adame, A. G., et al. 2026, *AJ*, **171**, 285
 D’Onofrio, M., Marziani, P., Chiosi, C., & Negrete, C. A. 2024, *Univ*, **10**, 254
 Du, P., & Wang, J.-M. 2019, *ApJ*, **886**, 42
 Evans, I. N., Evans, J. D., Martínez-Galarza, J. R., et al. 2024, *ApJS*, **274**, 22
 Evans, P. A., Page, K. L., Beardmore, A. P., et al. 2023, *MNRAS*, **518**, 174
 Fabian, A. C. 2012, *ARA&A*, **50**, 455
 Fabian, A. C., Lohfink, A., Kara, E., et al. 2015, *MNRAS*, **451**, 4375
 Fabian, A. C., Zoghbi, A., Ross, R. R., et al. 2009, *Natur*, **459**, 540
 Ferland, G. J., Done, C., Jin, C., Landt, H., & Ward, M. J. 2020, *MNRAS*, **494**, 5917
 Foschini, L., Berton, M., Caccianiga, A., et al. 2015, *A&A*, **575**, A13
 Frederick, S., Gezari, S., Graham, M. J., et al. 2021, *ApJ*, **920**, 56
 Fuhrmann, L., Karamanavis, V., Komossa, S., et al. 2016, *RAA*, **16**, 176
 Goad, M. R., Korista, K. T., & Ruff, A. J. 2012, *MNRAS*, **426**, 3086
 Goodrich, R. W. 1989, *ApJ*, **342**, 224
 Gordon, Y. A., Boyce, M. M., O’Dea, C. P., et al. 2021, *ApJS*, **255**, 30
 Greene, J. E., & Ho, L. C. 2005, *ApJ*, **630**, 122
 Grupe, D. 2004, *AJ*, **127**, 1799
 Grupe, D., Komossa, S., Leighly, K. M., & Page, K. L. 2010, *ApJS*, **187**, 64
 Grupe, D., & Mathur, S. 2004, *ApJL*, **606**, L41
 Guo, H., Shen, Y., & Wang, S. 2018, PyQSOFit: Python code to fit the spectrum of quasars, Astrophysics Source Code Library, ascl:1809.008
 Hopkins, P. F., & Elvis, M. 2010, *MNRAS*, **401**, 7
 Hopkins, P. F., Torrey, P., Faucher-Giguère, C.-A., Quataert, E., & Murray, N. 2016, *MNRAS*, **458**, 816
 Ilić, D., Rakić, N., & Popović, L. Č. 2023, *ApJS*, **267**, 19

- Jordi, K., Grebel, E. K., & Ammon, K. 2006, *A&A*, **460**, 339
- Kara, E., García, J. A., Lohfink, A., et al. 2017, *MNRAS*, **468**, 3489
- Kellermann, K. I., Sramek, R., Schmidt, M., Shaffer, D. B., & Green, R. 1989, *AJ*, **98**, 1195
- Kewley, L. J., Dopita, M. A., Sutherland, R. S., Heisler, C. A., & Trevena, J. 2001, *ApJ*, **556**, 121
- Komossa, S., Voges, W., Xu, D., et al. 2006, *AJ*, **132**, 531
- Komossa, S., Xu, D., Zhou, H., Storchi-Bergmann, T., & Binette, L. 2008, *ApJ*, **680**, 926
- Komossa, S., Xu, D. W., & Wagner, A. Y. 2018, *MNRAS*, **477**, 5115
- Kozák, B., Frey, S., & Gabányi, K. É. 2024, *Galax*, **12**, 8
- Kshama, S. K., Paliya, V. S., & Stalin, C. S. 2017, *MNRAS*, **466**, 2679
- Lacy, M., Baum, S. A., Chandler, C. J., et al. 2020, *PASP*, **132**, 035001
- Lang, D., Hogg, D. W., & Mykytyn, D. 2016, The Tractor: Probabilistic astronomical source detection and measurement, Astrophysics Source Code Library, ascl:1604.008
- Leighly, K. M. 1999a, *ApJS*, **125**, 297
- Leighly, K. M. 1999b, *ApJS*, **125**, 317
- Lu, Y., & Yu, Q. 2001, *MNRAS*, **324**, 653
- Marziani, P., Dultzin, D., Sulentic, J. W., et al. 2018, *FrASS*, **5**, 6
- Mathur, S. 2000, *MNRAS*, **314**, L17
- McLure, R. J., & Dunlop, J. S. 2004, *MNRAS*, **352**, 1390
- Mejía-Restrepo, J. E., Lira, P., Netzer, H., Trakhtenbrot, B., & Capellupo, D. M. 2018, *NatAs*, **2**, 63
- Merloni, A., Lamer, G., Liu, T., et al. 2024, *A&A*, **682**, A34
- Moran, E. C., Halpern, J. P., & Helfand, D. J. 1996, *ApJS*, **106**, 341
- Mundo, S. A., Kara, E., Cackett, E. M., et al. 2020, *MNRAS*, **496**, 2922
- Netzer, H. 2019, *MNRAS*, **488**, 5185
- Olguín-Iglesias, A., León-Tavares, J., Kotilainen, J. K., et al. 2016, *MNRAS*, **460**, 3202
- Osterbrock, D. E., & Pogge, R. W. 1985, *ApJ*, **297**, 166
- Paliya, V. S. 2019, *JApA*, **40**, 39
- Paliya, V. S., Ajello, M., Rakshit, S., et al. 2018, *ApJL*, **853**, L2
- Paliya, V. S., Parker, M. L., Jiang, J., et al. 2019, *ApJ*, **872**, 169
- Paliya, V. S., Pérez, E., García-Benito, R., et al. 2020, *ApJ*, **892**, 133
- Paliya, V. S., Stalin, C. S., Domínguez, A., & Saikia, D. J. 2024, *MNRAS*, **527**, 7055
- Paliya, V. S., Stalin, C. S., Kumar, B., et al. 2013, *MNRAS*, **428**, 2450
- Paliya, V. S., Stalin, C. S., & Ravikumar, C. D. 2015, *AJ*, **149**, 41
- Panda, S., Marziani, P., & Czerny, B. 2019, *ApJ*, **882**, 79
- Parker, M. L., Longinotti, A. L., Schartel, N., et al. 2019, *MNRAS*, **490**, 683
- Parker, M. L., Wilkins, D. R., Fabian, A. C., et al. 2014, *MNRAS*, **443**, 1723
- Ponti, G., Papadakis, I., Bianchi, S., et al. 2012, *A&A*, **542**, A83
- Rakshit, S., Johnson, A., Stalin, C. S., Gandhi, P., & Hoenig, S. 2019, *MNRAS*, **483**, 2362
- Rakshit, S., & Stalin, C. S. 2017, *ApJ*, **842**, 96
- Rakshit, S., Stalin, C. S., Chand, H., & Zhang, X.-G. 2017, *ApJS*, **229**, 39
- Rakshit, S., Stalin, C. S., Hota, A., & Konar, C. 2018, *ApJ*, **869**, 173
- Rakshit, S., & Woo, J.-H. 2018, *ApJ*, **865**, 5
- Ren, W., Guo, H., Shen, Y., et al. 2024, *ApJ*, **974**, 153
- Richards, G. T., Lacy, M., Storrie-Lombardi, L. J., et al. 2006, *ApJS*, **166**, 470
- Sabater, J., Best, P. N., Hardcastle, M. J., et al. 2019, *A&A*, **622**, A17
- Savaglio, S., Glazebrook, K., Le Borgne, D., et al. 2005, *ApJ*, **635**, 260
- Schlegel, D. J., Finkbeiner, D. P., & Davis, M. 1998, *ApJ*, **500**, 525
- Shen, Y. 2013, *BASI*, **41**, 61
- Shen, Y., Richards, G. T., Strauss, M. A., et al. 2011, *ApJS*, **194**, 45
- Shuder, J. M., & Osterbrock, D. E. 1981, *ApJ*, **250**, 55
- Singh, V., & Chand, H. 2018, *MNRAS*, **480**, 1796
- Sudan, M., Chand, H., Wiita, P. J., & Kumar, R. 2025, *MNRAS*, **543**, 121
- Sulentic, J. W., Marziani, P., & Dultzin-Hacyan, D. 2000, *ARA&A*, **38**, 521
- Sulentic, J. W., Marziani, P., Zamanov, R., et al. 2002, *ApJL*, **566**, L71
- Umayal, S., Paliya, V. S., Saikia, D. J., et al. 2025, *ApJ*, **995**, 125
- Vanden Berk, D. E., Shen, J., Yip, C.-W., et al. 2006, *AJ*, **131**, 84
- Veilleux, S., & Osterbrock, D. E. 1987, *ApJS*, **63**, 295
- Véron-Cetty, M.-P., & Véron, P. 2010, *A&A*, **518**, A10
- Véron-Cetty, M.-P., Véron, P., & Gonçalves, A. C. 2001, *A&A*, **372**, 730
- Vestergaard, M., & Peterson, B. M. 2006, *ApJ*, **641**, 689
- Webb, N. A., Coriat, M., Traulsen, I., et al. 2020, *A&A*, **641**, A136
- White, R. L., Becker, R. H., Helfand, D. J., & Gregg, M. D. 1997, *ApJ*, **475**, 479
- Whittle, M. 1992, *ApJS*, **79**, 49
- Williams, R. J., Pogge, R. W., & Mathur, S. 2002, *AJ*, **124**, 3042
- Winkler, H. 1992, *MNRAS*, **257**, 677
- Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., et al. 2019, AllWISE Source Catalog, NASA IPAC DataSet, IRSA1, doi:10.26131/IRSA1
- Xu, D., Komossa, S., Zhou, H., et al. 2012, *AJ*, **143**, 83
- Yip, C. W., Connolly, A. J., Szalay, A. S., et al. 2004a, *AJ*, **128**, 585
- Yip, C. W., Connolly, A. J., Vanden Berk, D. E., et al. 2004b, *AJ*, **128**, 2603
- Zhou, H., Wang, T., Yuan, W., et al. 2006, *ApJS*, **166**, 128