

A Population of Little Red Dot-like Quasars in SDSS*

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ABSTRACT

Compact and red sources in the high redshift ($z \sim 5$) Universe, known as “Little Red Dots” (LRDs), are among JWST’s most intriguing discoveries. These sources have broad Balmer emission lines, weak X-ray emission, and unique spectral energy distributions (SEDs) poorly fit by either stellar or AGN templates. Local analogs of LRDs allow for detailed studies of the underlying physical processes with archival multi-wavelength datasets unavailable in the high- z Universe. We show that the SDSS *ugriz* filters at $z \approx 0.4, 0.8$ overlap well with the JWST filters used to select LRDs at $z \sim 5$. We use SDSS quasars to define a sample of ~ 1300 Local Red Dots (LoRDs) which share the same photometric colors of LRDs. A subset of the LoRD sample selected to have V-shaped continua ($N = 244$) show prominent higher-order Balmer absorption features and [Ne V] $\lambda 3426$ emission, both of which would likely be missed in JWST/PRISM observations given the low spectral resolution. A composite SED of the LoRDs differs from a typical quasar SED in the rest-frame UV/optical, but the two agree with each other in the NIR. The LoRD SED matches well with a stack of LRDs and can be modeled either as a reddened AGN combined with a host galaxy, or as a reddened AGN combined with a host galaxy and a cool blackbody. Interestingly, the LoRDs are X-ray detected at a rate comparable to typical quasars. However, the probability that LoRDs and typical quasars would go undetected, if subject to the LRD X-ray upper limits, is $> 50\%$.

Keywords: Active galactic nuclei (16), Supermassive black holes (1663), X-ray active galactic nuclei (2035)

1. INTRODUCTION

The James Webb Space Telescope (JWST) has uncovered a puzzling population of sources at high redshift which are compact and red. These systems, frequently referred to as “Little Red Dots” (LRDs, Matthee et al. 2024), have garnered immense attention due to their large number density in the early Universe (e.g., Kokorev et al. 2024; Kocevski et al. 2025; Ma et al. 2026),

weak (or no) X-ray emission (e.g., Ananna et al. 2024; Yue et al. 2024; Lambrides et al. 2026), and spectral energy distributions (SEDs) which push theoretical models to their limits (e.g., Greene et al. 2024; Kokorev et al. 2024; Durodola et al. 2025).

LRDs are characterized by a number of observables: broad Balmer emission lines, a “V-shaped” UV-to-optical continuum, and a compact morphology (e.g., Hviding et al. 2025). Our understanding of the optical spectral features primarily comes from JWST/PRISM observations (e.g., Setton et al. 2025b; Hviding et al. 2025), but medium and high resolution grating observations are becoming more common in recent JWST cycles (e.g., Kokorev et al. 2026; de Graaff et al. 2025). The broad ($\gtrsim 1000 \text{ km s}^{-1}$) Balmer emission and red col-

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ors are often interpreted as originating from an active galactic nuclei (AGN; e.g., [Matthee et al. 2024](#); [Akins et al. 2025](#); [Inayoshi 2025](#)); however, these observables can also be interpreted as stellar in origin (e.g., [Baggen et al. 2024](#); [Guia et al. 2024](#); [Kokubo & Harikane 2025](#); [Pérez-González et al. 2024](#)). A significant population of LRDs exhibit narrow absorption features within their broad Balmer lines (e.g., [Inayoshi & Maiolino 2025](#); [Matthee et al. 2026](#); [Davis et al. 2026](#)) which is highly unusual for typical QSOs. The rest-frame continua of LRDs tend to be blue at wavelengths shorter than the Balmer limit (3645Å) and red at the longer optical wavelengths, thus this change in slope forms a V-shape centered around the Balmer limit (e.g., [Setton et al. 2025b](#)). Numerous physical processes have been proposed to explain the Balmer breaks, such as super-Eddington accretion (e.g., [Lambrides et al. 2026](#); [Liu et al. 2025](#)), scattered UV light and a reddened QSO (e.g., [Akins et al. 2025](#); [Barro et al. 2024](#); [Greene et al. 2024](#); [Labbé et al. 2025](#)), a gas-enriched black hole (e.g., [Inayoshi & Maiolino 2025](#); [Naidu et al. 2025](#)), among other scenarios (e.g., [Akins et al. 2023](#); [Labbé et al. 2023](#); [Williams et al. 2024](#); [Wang et al. 2024, 2025](#)).

The emission from LRDs has been constrained to varying levels of accuracy across the majority of the electromagnetic spectrum, and their SEDs are poorly fit with typical AGN and stellar templates. The mid-infrared (MIR) slope of LRDs is relatively flat (e.g., [Williams et al. 2024](#); [Wang et al. 2025](#)), which is inconsistent with observations of local AGN where the MIR rises due to emission from the dusty torus (e.g., [Hickox et al. 2017](#)). The majority of individual LRDs have remained undetected in both far-infrared (FIR) and radio wavelengths ([Casey et al. 2024](#); [Williams et al. 2024](#); [Setton et al. 2025a](#); [Labbé et al. 2025](#)) which is also inconsistent with observations of local AGN. However, stacked observations suggest a non-negligible contribution from hot dust emission ([Delvecchio et al. 2025](#); [Pérez-González et al. 2026](#)). SED modeling has suggested the rest-frame UV emission originates from the host galaxy and the rest-frame optical is due to a reddened AGN (e.g., [Kokorev et al. 2024](#); [Kocevski et al. 2025](#); [Labbé et al. 2025](#)), but conclusive evidence for the origin of these emission components has remained elusive.

Given that many LRD interpretations require an AGN component, we expect these sources to be luminous ($L_X > 10^{42}$ erg s $^{-1}$) in X-rays similar to nearby AGN (e.g., [Hickox & Alexander 2018](#)). X-rays are created in AGN through the inverse Compton scattering of photons produced by the accretion disk, but LRDs are observationally weak in X-rays (e.g., [Ananna et al. 2024](#);

[Furtak et al. 2024](#); [Yue et al. 2024](#)). Results from stacking analyses suggest LRDs are $\sim 10 - 100$ times weaker in X-rays than what is expected from local $L_X - L_{H\alpha}$ relations (e.g., [Ananna et al. 2024](#); [Yue et al. 2024](#)). Various explanations for the X-ray weakness include super-Eddington accretion (e.g., [Lambrides et al. 2026](#); [Pacucci & Narayan 2024](#)), obscuration processes not observed in the local Universe (e.g., [Maiolino et al. 2025](#); [Naidu et al. 2025](#); [Lin et al. 2026](#)), and scenarios without an AGN (e.g., [Akins et al. 2025](#); [Baggen et al. 2024](#); [Williams et al. 2024](#)).

The number density of LRDs is $\sim 10 - 100$ times more numerous than UV-selected quasars (QSOs) of similar magnitudes between $4 \lesssim z \lesssim 8$ (e.g., [Kokorev et al. 2024](#); [Kocevski et al. 2025](#)). At $z \lesssim 4$ the number density of LRDs has been shown to decline rapidly (e.g., [Kocevski et al. 2025](#); [Ma et al. 2026](#)) which may be related to the “inside-out” growth of galaxies (e.g., [van Dokkum et al. 2014](#); [Kocevski et al. 2025](#)). Due to this decreasing number density, as well as a lack of rest-frame UV spectroscopic observations, much of our understanding of these sources comes from high redshift observations which are observationally expensive. [Lin et al. \(2026\)](#) discovered a handful of nearby LRDs ($z = 0.1 - 0.2$) in the Sloan Digital Sky Survey (SDSS) by projecting LRD spectra into *Galaxy Evolution Explorer* (GALEX; [Martin et al. 2005](#)) and SDSS photometry to determine what their local colors would look like. One of these sources was also independently discovered by [Ji et al. \(2026b\)](#) by searching for V-shaped spectra in a catalog of broad-line dwarf galaxies. Likewise, [Lin et al. \(2026\)](#) identified 27 LRDs at $z = 0.2 - 0.9$ by selecting broad line sources in the Dark Energy Spectroscopic Instrument (DESI; [DESI Collaboration et al. 2026](#)) DR1 catalog which share similar emission line properties to the LRDs at high- z . These local analogs provide higher quality observations which can be used to test theoretical models, but the small number statistics make it difficult to say anything on a population scale.

In this paper we take advantage of both the redshift range ($z \sim 0.4, 0.8$) where the rest-frame wavelengths probed by SDSS and certain JWST filters (at $z \sim 5$) overlap with each other, as well as the wealth of archival data at these redshifts. Compared to previous local LRD studies, our sample is much larger, due to our rest-frame matched selection, which allows us to treat the analogs in a statistical sense. Section 2 describes the parent sample and how we select analogs of LRDs. We investigate the multiwavelength properties of the local red dots (LoRDs) in Section 3. In Section 4 we discuss the impact of morphology, spectral resolution, and X-ray upper limits on our understanding of the similarity between

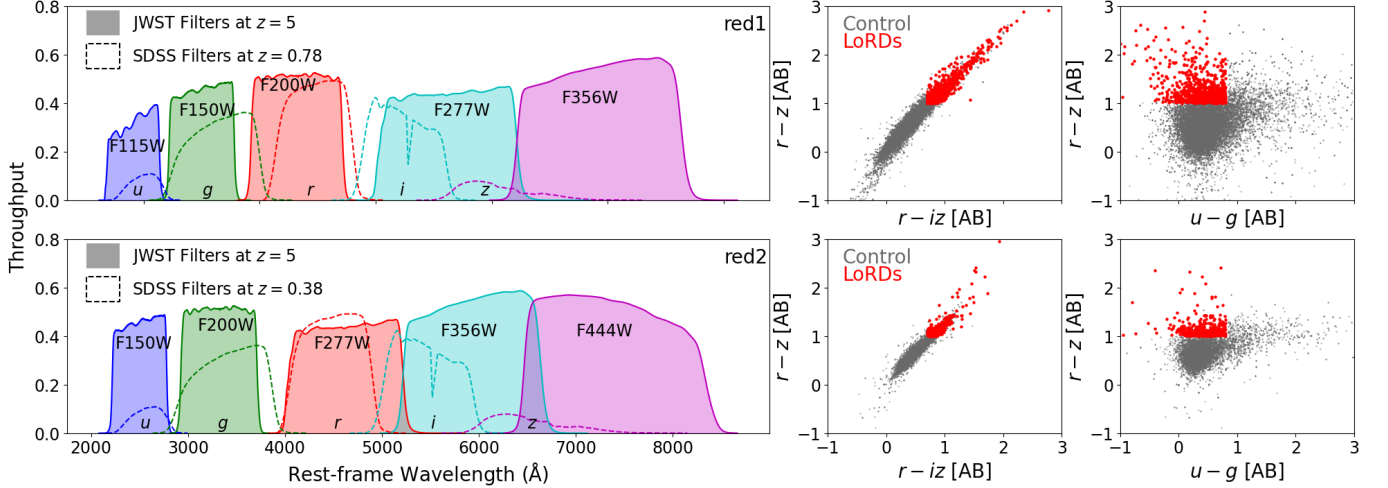


Figure 1. *Left:* The throughput curves for the JWST filters at $z = 5.0$ (shaded curves) compared to the SDSS filters (dotted lines) at $z = 0.78$ (red1, top panel) and $z = 0.38$ (red2, bottom panel). The significant overlap between the filter sets allows us to select LoRDs using the SDSS filters. *Center:* $r - iz$ versus $r - z$ in AB magnitudes for the control sample (gray) and the LoRDs (red); the red1 sample is the top panel and red2 is the bottom panel. *Right:* $u - g$ versus $r - z$ in AB magnitudes.

LoRDs and LRDs. We summarize our findings and conclude with potential use cases of the LoRDs in Section 5. When necessary we utilize the following cosmology: $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_M = 0.3$, and $\Omega_\Lambda = 0.7$.

2. DATA AND SAMPLE SELECTION

We draw from the SDSS DR16 quasar (DR16Q) catalog of Wu & Shen (2022) which contains optical spectroscopy for $\sim 750,000$ broad line quasars which were observed during the SDSS-I/II/III/IV campaigns (York et al. 2000; Eisenstein et al. 2011; Blanton et al. 2017). The SDSS-I/II legacy spectrographs were used through DR7; these observations use $3''$ diameter fibers and cover a wavelength range of $\sim 3800 - 9200 \text{ Å}$. SDSS-III/IV use the upgraded Baryon Oscillation Spectroscopic Survey (BOSS) spectrographs (Smei et al. 2013) which employ $2.5''$ diameter fibers and have a wavelength coverage of $\sim 3650 - 10400 \text{ Å}$. Both spectrographs have a spectral resolution of $R \sim 2000$. If a source was observed in multiple campaigns then the SDSS-IV observation is adopted as the primary spectrum in the DR16Q catalog.

The DR16Q spectra are fit with a global continuum+emission line model using the PyQSOFIT code described in Guo et al. (2018), Shen et al. (2016, 2019), and Wu & Shen (2022). Along with emission line measurements, the DR16Q catalog contains single-epoch virial black hole (BH) masses, bolometric luminosities (assuming a typical AGN), and updated systemic redshifts. As described in Wu & Shen (2022), bolometric luminosities are estimated from continuum luminosities at rest-frame wavelengths of 1350, 3000, or 5100 Å, depending on the redshift of the source (3000 Å is the default). BH masses are estimated from $H\beta$ ($z < 0.7$), Mg II ($0.7 \leq z \lesssim 2.0$),

and C IV ($z \gtrsim 2.0$) where the redshifts change slightly based on the spectrograph used. This quasar sample covers a broad range of redshifts ($0.1 \lesssim z \lesssim 6.0$) and luminosities ($44 \lesssim \log(L_{\text{bol}}/\text{erg s}^{-1}) \lesssim 48$).

2.1. Photometric Selection

Greene et al. (2024) introduced two photometric criteria to select red JWST sources, the majority of which are LRDs: red1 = $(F115W - F150W < 0.8) \wedge (F200W - F277W > 0.7) \wedge (F200W - F356W > 1.0)$, and red2 = $(F150W - F200W < 0.8) \wedge (F277W - F356W > 0.7) \wedge (F277W - F444W > 1.0)$. They also require a compactness criterion which ensures the majority of the flux is dominated by a point source. Given that a large number of LRDs reside at $z \approx 5$, the rest-frame red1 and red2 selection criteria probe the near-UV and optical wavelength ranges for which there exists a large amount of archival data in the local Universe.

To select local analogs of LRDs (i.e., LoRDs) in SDSS we identify redshift bins where the JWST and SDSS filters have significant rest-frame overlap. We do this by minimizing a mismatch function, $M(z)$ (Equation 1, where i represents the filters used in red1/red2) which evaluates the overlap between the filters used in the red1/red2 selection and the SDSS *ugriz* filter set.

$$M(z) = \sum_i \left[\left(\frac{\lambda_{\text{blue}}^{\text{JWST},i}}{1+5} - \frac{\lambda_{\text{blue}}^{\text{SDSS},i}}{1+z} \right)^2 + \left(\frac{\lambda_{\text{red}}^{\text{JWST},i}}{1+5} - \frac{\lambda_{\text{red}}^{\text{SDSS},i}}{1+z} \right)^2 \right] \quad (1)$$

We find the red1 and red2 filters at $z = 5.0$ are offset the least when the SDSS filters are redshifted to $z = 0.78$

and $z = 0.38$, respectively (see Figure 1). In the rest-frame, the SDSS i and z bands both overlap with the F277W (red1 selection) and the F356W (red2 selection) filters. To remedy this we define an “ iz ” band which is the logarithmic average of the fluxes in those two bands. Therefore, at $z = 0.78$, we can map the JWST filters to the SDSS filters as follows: F115W maps to u , F150W to g , F200W to r , F277W to iz , and F356W to z . Similarly, at $z = 0.38$, the filter F150W maps to u , F200W to g , F277W to r , F356W to iz , and F444W to z . Given this mapping, we can apply the red1/red2 selection criteria using the SDSS filters as shown in Equations 2 and 3 (colors in AB magnitudes):

$$\begin{aligned} \text{local red1} = & (u - g < 0.8) \wedge (r - iz > 0.7) \wedge \\ & (r - z > 1.0) \wedge (0.68 < z_{\text{spec.}} < 0.88) \end{aligned} \quad (2)$$

$$\begin{aligned} \text{local red2} = & (u - g < 0.8) \wedge (r - iz > 0.7) \wedge \\ & (r - z > 1.0) \wedge (0.28 < z_{\text{spec.}} < 0.48). \end{aligned} \quad (3)$$

We select quasars from DR16Q which pass the local red1/red2 selection criteria and have redshifts within $z \pm 0.1$ of the optimized redshift values. We also require a bolometric luminosity greater than $10^{43.5}$ erg/s to ensure high quality spectra. The red1 and red2 selections yield 935 and 390 LoRDs which corresponds to $\approx 1.8\%$ and $\approx 6.9\%$ of the entire DR16Q sample in their respective redshift ranges. We also define a QSO “control” sample to match the LoRD sample in redshift and bolometric luminosity. Figure 1 (center and right panels) shows our selection of LoRDs and the control sample in color-color space. To select the control sample, we define a rectangle around each LoRD with widths 0.05 (in Δz) and 0.3 dex (in bolometric luminosity) and select the nearest twenty five QSOs within the rectangle for each LoRD, allowing for multiple counts of the same source to ensure a similar luminosity distribution between the LoRDs and the control sample (see Figure 2). There are $\sim 23,000$ and $\sim 9,700$ control QSOs in the red1 and red2 samples in total, but only $\sim 14,000$ and $\sim 5,500$ unique sources in each redshift bin.

SDSS required an unresolved optical morphology in order for a source to be targeted as a quasar (Ross et al. 2012; Myers et al. 2015), but the Wu & Shen (2022) QSO catalog is not necessarily built from SDSS targeting, and therefore some sources are resolved in the optical. We do not impose any explicit compactness criteria in our selection given that the angular resolution of SDSS and JWST differ by more than an order of magnitude (e.g., $r_{\text{SDSS, phys}} \approx 6.4$ kpc, $r_{\text{JWST, phys}} \approx 0.4$ kpc at $z = 0.4$). Furthermore, whether or not the physical processes which produce LRD-like emission can exist

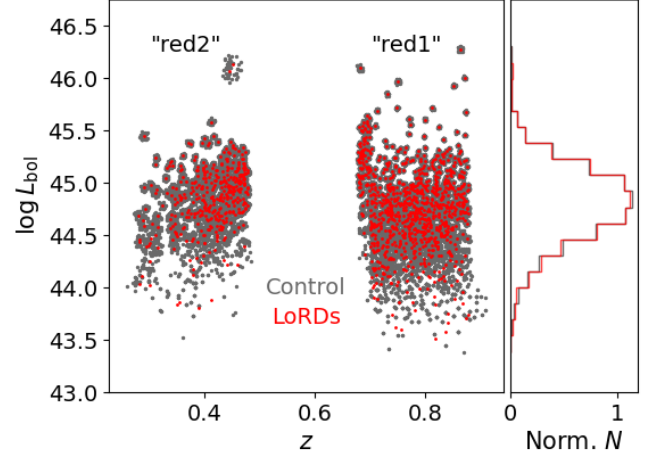


Figure 2. Distribution of LoRDs and control QSOs in redshift-bolometric luminosity space. LoRDs are selected based on Equations 2 and 3, and control QSOs are selected to match LoRDs in redshift-bolometric luminosity space allowing for double counting.

within a normal sized (e.g., Milky Way like) host galaxy at low- z is an open question. Of the 1325 LoRDs, 59% are classified as stars (i.e., point source like) by the SDSS imaging pipeline (Lupton et al. 2001), compared to 92% of the control sample. In Section 4.1 we discuss the impact of compactness on our sample and how this alters our interpretation of a subset of sources.

3. MULTIWAVELENGTH ANALYSIS

3.1. Optical Spectroscopy

Many LRDs are selected from photometry alone, but numerous studies have shown that sources which do not share the same physical properties of LRDs may contaminate this selection (e.g., Hviding et al. 2025; Labbé et al. 2025) such as brown dwarfs (Langeroodi & Hjorth 2023). Therefore, selecting LRDs with high confidence usually requires spectroscopic determinations of redshift, broad emission lines, and a V-shaped continuum. Interestingly, Hviding et al. (2025) showed that in the high- z Universe nearly all point source objects with V-shaped spectral continua also have broad Balmer lines. Each object in the DR16Q catalog is a broad-line source, so we need not trim our LoRD/control samples on this criterion.

We adopt an approach similar to Setton et al. (2025b) and Hviding et al. (2025) to determine whether the LoRDs have V-shaped spectral continua. We first mask prominent emission lines (i.e., Mg II $\lambda\lambda 2797, 2803$, [O II] $\lambda 3727$, H β , [O III] $\lambda\lambda 4959, 5007$, H α , [N II] $\lambda 6584$), and require a median signal-to-noise ratio greater than three per pixel on the spectra between 3000 and 5000 Å to eliminate noisy spectra. We fit the SDSS spectra with

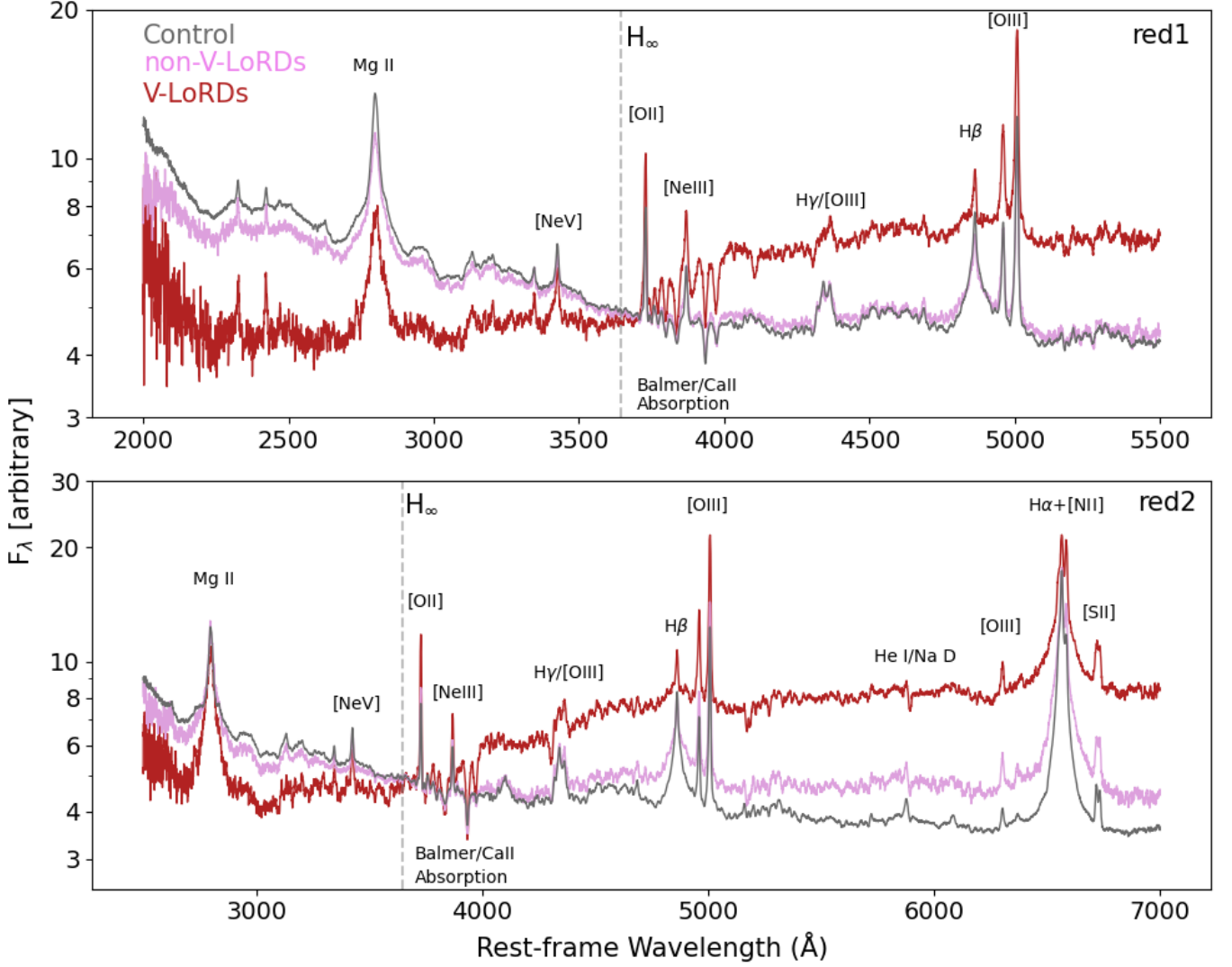


Figure 3. Median stacked spectra for the red1/red2 LoRDs as well as the control sample. The spectra are normalized to the integrated flux between $3645 \pm 100 \text{ \AA}$ and scaled by a factor of 1000. The red spectra are selected to have V-shaped continua (top $N = 111$, bottom $N = 133$) and the pink spectra do not (top $N = 238$, bottom $N = 148$). Prominent emission/absorption features and the Balmer limit (H_∞) are labeled. The stacked spectra for the control sample is shown in gray.

a broken power law function of the form $f_\lambda = a\lambda_{\text{rest}}^\beta$, and allow the break to occur anywhere between $\lambda_{\text{rest}} = 3645 \pm 100 \text{ \AA}$. We fit the broken power law to the spectra using `emcee` (Foreman-Mackey et al. 2013) and consider a photometrically selected LoRD to be “V-shaped” if the following criteria are true: $\beta_{\text{opt}} > 0.5$ at the 1σ level and $\beta_{\text{opt}} > 2\beta_{\text{UV}}$. These criteria differ from the selection of LRDs at high- z (e.g., Hviding et al. 2025 requires $\beta_{\text{UV}} < -0.2$, $\beta_{\text{opt}} > 0$, and $\beta_{\text{opt}} - \beta_{\text{UV}} > 0.5$) given that growing evidence suggests the rest-UV component of LRDs has a substantial stellar contribution (e.g., Cloonan et al. 2026; Pérez-González et al. 2026) and the stellar populations of LRDs and LoRDs may differ. In the red1 and red2 samples we classify 111 and 133 LoRDs as V-shaped, respectively (henceforth referred to

as V-LoRDs). In red1 (red2) there are 238 (148) sources without a V-shaped continuum (i.e., non-V-LoRDs) and 586 (109) sources which are too noisy to fit.

Our V-shape criteria could, in principle, select sources with a pure rising red continuum and a weak break around the Balmer limit which would serve as a poor LRD analog. However, we choose to retain sources with modestly positive UV slopes relative to their optical slopes in our V-LoRD sample as many of these sources have the most positive optical slopes. For V-LoRDs with a UV slope greater than zero, the mean UV slope is $\langle\beta_{\text{UV}}\rangle = 0.19 \pm 0.15$ compared to $\langle\beta_{\text{opt}}\rangle = 1.3 \pm 0.51$ in the optical, where the quoted uncertainty is the standard deviation. The majority of our analysis focuses

on the entire LoRD sample, so this should not bias our results, but we discuss caveats in Section 4.

Figure 3 shows the median stacked spectra for the V-LoRDs and non-V-LoRDs in red and pink, respectively; control QSOs are shown in gray. To perform the stack we shift each spectrum into its rest-frame (using the systemic redshifts from DR16Q) and smooth it using SciPy’s `medfilt` function with a kernel size of seven. We interpolate the smoothed rest-frame spectra along a wavelength grid spanning $\lambda = 2000 - 5500\text{\AA}$ for the red1 sample and $\lambda = 2500 - 7000\text{\AA}$ for the red2 sample; in both cases we use wavelength bins of $0.5\text{\AA}$. We require each flux measurement and the associated error to be greater than 0 and normalize each spectrum to the integrated flux between $3645 \pm 100\text{\AA}$.

There exist clear differences between the V-LoRDs and the non-V-LoRDs/control sample in both redshift bins. The control and non-V-LoRDs have declining UV slopes, whereas the V-LoRDs are relatively flat. The stacked spectra of the control sample and the non-V-LoRDs show a similar blue rest-optical continuum, which is in stark contrast to the V-LoRDs’ red rest-optical. None of the stacked spectra show a steep jump at the Balmer limit which is seen in some of the high- z LRDs (c.f., “The Cliff,” de Graaff et al. 2025b). Some individual spectra ($\sim$ a few percent) do exhibit this steep Balmer break regardless of their V-shaped classification, but it is not ubiquitous in the LoRD spectra. There are significant Balmer (H ϵ -H12) and Ca II (H and K) absorption features in both V- and non-V-LoRDs relative to the control sample ($3750\text{\AA} \lesssim \lambda \lesssim 3970\text{\AA}$); these features are more prevalent in the red1 sample. The LoRDs and the control sample both show prominent emission at [Ne V] $\lambda 3426$. Ne $^{4+}$ requires 97 eV; thus, [Ne V] emission is most often attributed to luminous AGN (e.g., Gilli et al. 2010; Cleri et al. 2023a,b; Negus et al. 2023). We interpret these spectra in the context of LRDs in Section 4.1 and 4.2.

A unique feature in high- z LRD spectra is narrow absorption within the broad Balmer emission lines. The exact percentage of LRDs with this absorption feature is uncertain as its prominence increases with increased spectral resolution/sensitivity, and the number of LRDs observed with medium/high-resolution spectroscopy is currently meager. Current estimates suggest $\sim 40-60\%$ of LRDs (e.g., Davis et al. 2026; Matthee et al. 2026) have this feature, and it is more commonly seen in the H α emission line compared to H β . We manually inspect the LoRD H α and H β emission lines and find that a substantial number of sources show signatures of narrow absorption within their broad lines. However, trying to prove this Balmer absorption in the SDSS spectra

would be challenging as low signal-to-noise and sky lines complicate the identification of this feature. Therefore, we choose not to quantify the Balmer absorption in this work as new observations would likely be necessary. We show a select number of LoRD spectra in the Appendix which display signatures of this absorption feature; fitting the feature is beyond the scope of this work.

3.2. UV/Optical/NIR SEDs

Standard SED modeling (e.g., CIGALE/PROSPECTOR) of LRDs has consistently struggled to fully reproduce the observations (e.g., Williams et al. 2024; Ronayne et al. 2026). To understand the differences between the control QSOs and LoRDs, we construct composite SEDs with archival SDSS and the *Wide-field Infrared Survey Explorer* (WISE; Wright et al. 2010) photometry using the same approach as Hickox et al. (2017). For each source in the control and LoRD samples we require $S/N > 3$ in each band. We exclude the less sensitive W4 band from the composite SEDs to retain more sources in our sample. In total we have $N \sim 400$ LoRDs and $N \sim 10000$ control QSOs which contribute to the composite SED, around $\sim 30\%$ of each sample size. If we included W4 we would only retain $\sim 10\%$ of either sample.

To build the SEDs we shift each flux measurement into its rest-frame and interpolate between the fluxes (in νF_ν) using piecewise power laws in log-log space. We normalize each individual SED by the integrated flux between 0.4 and 4 microns which roughly traces the stellar component in typical AGN. We remove individual flux measurements more than 6σ from the mean and average the flux at each wavelength bin. The composite SEDs are shown in Figure 4. For comparison purposes we include a stack of LRDs from Akins et al. (2025) over the same wavelength range as the composite SEDs; the filters contributing to the LRD stack that is shown are JWST/F115W, F150W, F200W, F277W, F356W, F410W, F444W, F770W, F1800W, and Spitzer/MIPS $24\mu\text{m}$ (upper-limit).

As a qualitative exercise to better understand the sample differences, we perform simple multi-component fits by eye to the composite SEDs. The components we include are a type 1 AGN continuum template from Richards et al. (2006), galaxy templates from Assef et al. (2010) (elliptical, spiral, and irregular components), the empirical emission line galaxy (ELG) SED from Forrest et al. (2018), and a cool ($T = 4500\text{K}$) blackbody. A cool blackbody is frequently invoked when modeling LRD spectral continua and is interpreted as an optically thick gas envelope surrounding the supermassive black hole (SMBH; e.g., de Graaff et al. 2025). We allow the

Table 1. Sample of photometrically selected LoRDs. z and $\log L_{\text{bol}}$ are from the DR16Q catalog (Wu & Shen 2022), the V-shape criteria are described in Section 3.1, and we determine $\log L_{X, 2-10 \text{ keV}}$ in Section 3.3.

Name	z	$\log L_{\text{bol}}$ [erg s ⁻¹]	V-Shape	β_{UV}	β_{opt}	$\log L_{X, 2-10 \text{ keV}}$ [erg s ⁻¹]
SDSS J231224.75+290710.9	0.28	44.7 ± 0.01	False	-0.27 ± 0.14	0.01 ± 0.02	—
SDSS J132700.12+490344.4	0.28	44.4 ± 0.01	False	-0.12 ± 0.07	0.01 ± 0.02	—
SDSS J092621.14+310847.8	0.28	44.5 ± 0.0	True	0.01 ± 0.04	0.54 ± 0.01	42.8 ± 0.1
SDSS J104947.35+452323.2	0.28	44.0 ± 0.02	—	-0.15 ± 0.07	0.75 ± 0.04	—
SDSS J010906.64+001825.2	0.28	44.1 ± 0.01	—	-0.02 ± 0.05	0.76 ± 0.02	—

(This table is available in its entirety in a machine-readable form in the online journal.)

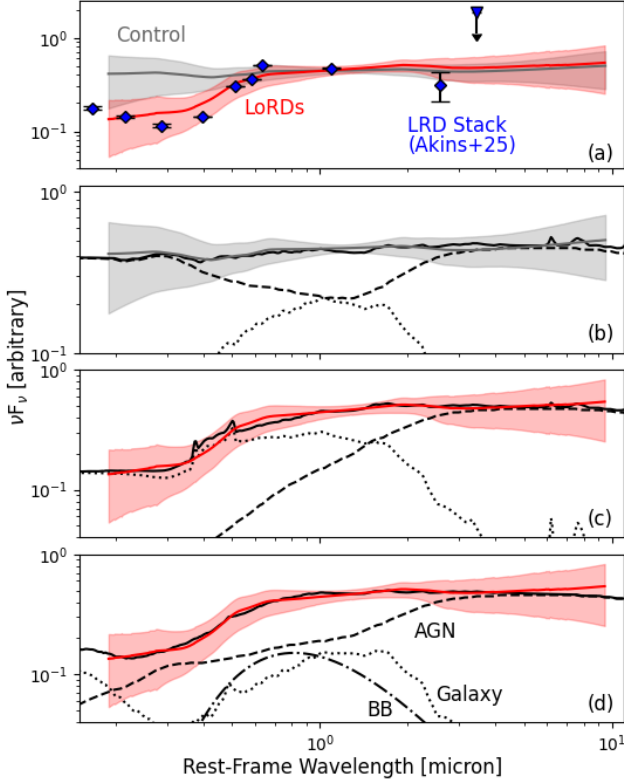


Figure 4. Composite SEDs for the control (gray) and LoRD (red) samples; in panel (a) we show a stack of LRDs from Akins et al. (2025) in blue. The solid gray/red lines represent the mean SED and the shaded region is one standard deviation from the mean. In panels (b), (c), and (d) we show fits to the composite SEDs in black. Solid black shows the cumulative fit, dashed lines represent the AGN component, dotted lines are the galaxy component, and the dot-dashed line is the blackbody feature. Panels (c) and (d) illustrate that the LoRD SED can be fit well with or without the blackbody component.

AGN and galaxy templates to be dust reddened according to the prescription of Calzetti et al. (2000). The control sample is well fit with a minimally reddened AGN which dominates the flux, as well as a mixture of elliptical/spiral components.

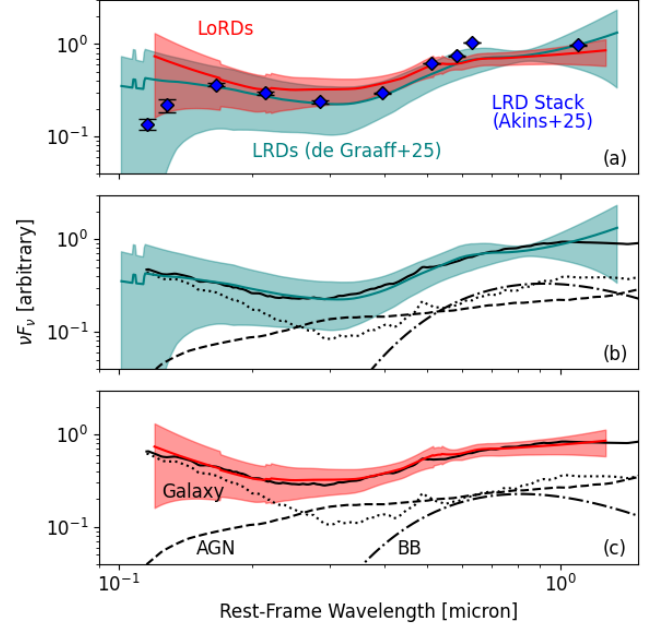


Figure 5. Composite SEDs for the LRDs (teal) and the LoRDs (red); the LRD stack from Akins et al. (2025) is shown as blue diamonds. Similar to Figure 4, panels (b) and (c) show exploratory fits to the SEDs in black, where the solid line is the cumulative fit, the dotted line is the galaxy component, dashed line is the AGN component, and the dot-dashed line is the blackbody feature.

This is similar to the result of Hickox et al. (2017) with slightly different contributions. We show two different fits to the LoRD SED in Figure 4 (panels c and d) to demonstrate that the SEDs can be fit well with or without a cool blackbody component. Both fits require a dominant reddened AGN ($1.0 \lesssim A_V \lesssim 2.0$ mag) which is needed to match the NIR, a slightly reddened elliptical component in the optical, and a small contribution from the ELG in order to match the UV. The differences between the fits are a function of AGN reddening as well as the mechanism which produces the

Table 2. The composite SEDs presented in Section 3.2 and Figures 4 and 5. The flux measurement is the mean and the quoted uncertainty is one standard deviation from the mean; the units on νF_ν are arbitrary due to the normalization.

λ (μm)	Control ^a νF_ν	LoRD ^b νF_ν	LRD ^c νF_ν	LoRD ^d νF_ν
0.1013	–	–	0.352 ± 0.379	–
0.1018	–	–	0.351 ± 0.376	–
0.1023	–	–	0.349 ± 0.373	–
0.1029	–	–	0.348 ± 0.370	–
0.1034	–	–	0.347 ± 0.367	–

(This table is available in its entirety in a machine-readable form in the online journal.)

^a The control SED as shown in Figure 4 (gray).

^b The LoRD SED as shown in Figure 4 (red).

^c The SED using the LRDs from de Graaff et al. (2025), as shown in Figure 5 (teal).

^d The LoRD SED as shown in Figure 5 (red).

increased flux at the Balmer limit: a cool blackbody or the irregular (i.e., starburst) galaxy template.

In order to more directly compare the SEDs of LoRDs and LRDs, we create a composite SED using the LRDs from de Graaff et al. (2025). The de Graaff et al. (2025) LRD sample ($N = 116$) was selected spectroscopically and thus likely suffers from less contamination than the sources in the Akins et al. (2025) stack. We include the following filters in the LRD stack: HST/F814W, JWST/F090W, F115W, F150W, F200W, F277W, F356W, and F444W. To create the LoRD SED and compare across a similar rest-frame wavelength range we use *GALEX*/NUV, SDSS/*u*, *g*, *r*, *i*, *z*, and the UKIRT Infrared Deep Sky Survey (UKIDSS, Lawrence et al. 2007) *Y*, *J*, and *H* bands. We require 3σ detections in each band and are left with 35 LRDs and 58 LoRDs. We construct the composite SEDs in the same fashion as previously described, except we normalize the individual SEDs between 0.2 and 1.3 microns; the SEDs are shown in Figure 5. Both SEDs are fit with slightly different combinations of galaxy, blackbody, and AGN components. In both cases the UV is fit with the ELG template, and the Balmer break is produced by a combination of the elliptical template, a $T = 4500\text{K}$ blackbody, and a reddened AGN. We emphasize that the fits in Figures 4 and 5 are merely exploratory and not meant to be interpreted as definitive. The composite SEDs are presented in Table 2.

3.3. X-Ray Properties

Given the X-ray weakness observed in the LRDs, we seek to determine whether the LoRDs are X-ray weak as well. We cross-match the LoRDs and the control sam-

XMM	Control	LoRDs
Band	$N = 2212$	$N = 149$
0.5 – 2 keV	$75.1 \pm 0.9\%$	$77.9 \pm 3.4\%$
0.5 – 10 keV	$45.6 \pm 1.1\%$	$50.3 \pm 4.1\%$
2 – 10 keV	$29.9 \pm 1.0\%$	$36.9 \pm 4.0\%$

Table 3. Detection percentages in the soft, full, and hard XMM-Newton bands for the control sample and the LoRDs. The number, N , listed below the sample name is the number of sources which have an XMM source within $4'$. The uncertainty on the detection percentage is the standard deviation assuming a binomial distribution.

ple to the XMM-Newton Serendipitous Source Catalog DR14 (4XMM-DR14; Webb et al. 2020) using a maximum matching radius of $4'$. We consider X-ray sources within $10''$ of the SDSS source to be a true match and require $S/N > 3$ to count the source as a detection. Above the $10''$ threshold, matches are dominated by random (chance) alignments rather than true associations; 2212 control QSOs and 149 LoRDs are covered by archival XMM observations. The detection fractions in the soft (0.5 – 2 keV), full (0.5 – 10 keV), and hard (2 – 10 keV) bands are reasonably consistent with each other across the control and LoRD samples (see Table 3). For sources which were covered with XMM but not detected, we estimate the flux upper limits using the High-energy Light curve GeneraTor (HILIGT; Saxton et al. 2022) assuming a spectral model with a power law slope of $\Gamma = 2.0$ (e.g., Nandra & Pounds 1994).

Given the LoRDs largely appear to have normal X-ray detection fractions compared to the control sample (i.e., $< 2\sigma$ difference in each band), we compare their X-ray luminosities to the stacking-based inferred LRD luminosities at $z \approx 5$. We want to directly compare the upper-limits from Yue et al. (2024) and Ananna et al. (2024) (which are quoted in the rest-frame 2 – 10 keV range) to LoRD X-ray luminosities. We use the X-ray SEDs of Revnivtsev et al. (2008) and Baloković et al. (2018) (see also Hickox & Alexander 2018) with varying column densities, $\log N_H = 21, 22, 23 \text{ cm}^{-2}$ (i.e., the same regime explored by Yue et al. 2024), and normalize the SEDs to the observed-frame 0.5 – 2 keV luminosities of the LoRDs. We estimate their rest-frame 2 – 10 keV luminosities by integrating the normalized X-ray SEDs over this energy range.

The mean luminosities of the $\log N_H = 21, 22, 23 \text{ cm}^{-2}$ models for the X-ray detected LoRDs are $\log L_{2-10 \text{ keV}} = 43.4, 43.7, 44.4 \text{ erg s}^{-1}$, respectively. Given that broad line QSOs typically have minimal amounts of obscuration (e.g., Koss et al. 2017), we focus our analysis on the $\log N_H = 21 \text{ cm}^{-2}$ regime. The rest-frame 2 – 10 keV luminosity upper-limit

of the AGN sample from [Ananna et al. \(2024\)](#) is $\log L_{2-10 \text{ keV}} < 43.28 \text{ erg s}^{-1}$; 42% of all X-ray detected LoRDs fall below this upper limit in the low obscuration regime. Likewise, the mean upper-limit from [Yue et al. \(2024\)](#) is $\log L_{2-10 \text{ keV}} < 43.4 \text{ erg s}^{-1}$ and 52% of LoRDs fall below this luminosity threshold.

We show the $L_X - L_{H\alpha}$ relation, where $L_{H\alpha}$ is calculated from the broad component, for red2 LoRDs and the [Yue et al. \(2024\)](#) LRDs in Figure 6 (a). The LoRDs largely sit at, or below, the [Jin et al. \(2012\)](#) relation for broad line AGN, and the LRD upper limits are distributed both above and below the line; however, LRDs with large $H\alpha$ luminosity ($\gtrsim 10^{43} \text{ erg s}^{-1}$) are preferentially situated below the relation. We calculate the difference between the inferred 2 – 10 keV luminosity and the expected luminosity from the [Jin et al. \(2012\)](#) relation. The average X-ray detected LoRD is situated -0.24 ± 0.48 dex below the relation and the LRD upper limits are -0.16 ± 0.70 dex below the relation, where the quoted uncertainty is the root-mean-square scatter. The control sample (not shown in Figure 6 a) is -0.20 ± 0.45 dex below the relation. The intrinsic scatter of the $L_X - L_{H\alpha}$ relation is ~ 0.3 dex which suggests the LRD upper limits, the control sample, and the LoRDs are overall consistent with the relation.

Differences in the optical luminosities may impact our interpretation as the LRD $H\alpha$ luminosity distribution differs from our sample of control QSOs and LoRDs. Therefore, we correct the 2 – 10 keV X-ray luminosity distributions ($L_{X,\text{cor.}}$) according to Equation 4,

$$L_{X,\text{cor.}} = L_X + \alpha(\log L_{H\alpha,\text{LRD}} - \log L_{H\alpha}) \quad (4)$$

where α is the slope of the $L_X - L_{H\alpha}$ relation ($\alpha = 0.83$, [Jin et al. 2012](#)). We randomly sample the X-ray and $H\alpha$ luminosities of our samples within their uncertainties and assign it to a [Yue et al. \(2024\)](#) LRD source (sampled within the $H\alpha$ uncertainty) and compute Equation 4. We perform 100,000 such iterations to estimate the scaled X-ray luminosity which is independent of $H\alpha$ (Figure 6 b). After correcting for the $H\alpha$ luminosity, 56% of LoRDs and 52% of the control QSOs are below the [Yue et al. \(2024\)](#) mean upper-limit.

This is, of course, only applicable to the red2 LoRD sample, but we wish to determine how the full sample of LoRD 2 – 10 keV luminosities (detections and upper limits) compare to the [Yue et al. \(2024\)](#) upper limits. We treat the LoRD luminosity distribution as a left-censored, log-normal distribution. We determine the log-likelihood of the LoRD distribution by summing the probability density function of the detections ($N_{\text{det}} = 116$) and the cumulative density function of the upper limits ($N_{\text{UL}} = 19$); we maximize this to es-

timate the distribution’s mean and standard deviation, i.e., $\log L_{X, \text{LoRDs}} \sim \mathcal{N}(\mu = 43.3, \sigma = 0.52)$. To propagate the uncertainty in the fit, we bootstrap resample (with replacement) the LoRD luminosities (detections and upper limits) 10,000 times, refit the distribution, and evaluate the cumulative distribution function at each LRD upper limit from [Yue et al. \(2024\)](#). The average probability that a randomly drawn LoRD is fainter than an LRD upper limit is $\bar{p} = 0.56$ with a 95% confidence interval (CI) of $[0.51, 0.61]$. If we split the LoRDs into V-LoRDs ($N_{\text{det}} = 29$, $N_{\text{UL}} = 4$) and non-V-LoRDs ($N_{\text{det}} = 32$, $N_{\text{UL}} = 4$) we find that the V-LoRDs are more likely to be less luminous than the LRDs ($\bar{p} = 0.59$, CI $[0.49, 0.69]$) relative to the non-V-LoRDs ($\bar{p} = 0.45$, CI $[0.34, 0.56]$). We perform the same analysis on the control sample ($N_{\text{det}} = 1661$, $N_{\text{UL}} = 744$) and find the probability that a given control QSO is less luminous than an LRD upper limit is $\bar{p} = 0.58$ (CI $[0.57, 0.59]$).

Lastly, if we perform a Monte Carlo resampling analysis, where each low- z luminosity is drawn from its uncertainty (upper limits are treated as a left-truncated normal distribution) and compared to an LRD upper limit, we find that 55% of LoRDs and 56% of the control QSOs are less luminous than the LRD upper limits. Given that the average low- z X-ray luminosity is less than the average LRD upper-limit, we conclude that it is not unreasonable to assume that a majority of the LoRDs (and control QSOs) would go undetected in archival Chandra observations at high- z . We discuss these findings, their implications, and the use of local X-ray scaling relations in Section 4.3.

4. DISCUSSION

4.1. Morphology

A key feature of high- z LRDs is that the majority of sources appear unresolved in JWST imaging (e.g., [Greene et al. 2024](#); [Kokorev et al. 2024](#); [Kocevski et al. 2025](#)); this inferred compact morphology also serves as an important argument for the AGN nature of LRDs. Recent work has shown that the rest-UV of LRDs is typically more extended than the rest-optical ([Cloonan et al. 2026](#)). However, there exists significant uncertainty in modeling LRD sizes through traditional parametric fitting codes, especially in the low S/N regime ([Whalen et al. 2026](#)). We should note that classes of post starburst galaxies are known to be ultra-compact ($\lesssim 100$ pc) as well (e.g., [Sell et al. 2014](#); [Whalen et al. 2022](#); [Davis et al. 2023](#)). The angular resolution of SDSS and JWST imaging greatly differ ($\sim 1.2''$ compared to $< 0.1''$), so selecting sources as “unresolved” in SDSS imaging is entirely different than an unresolved source in JWST.

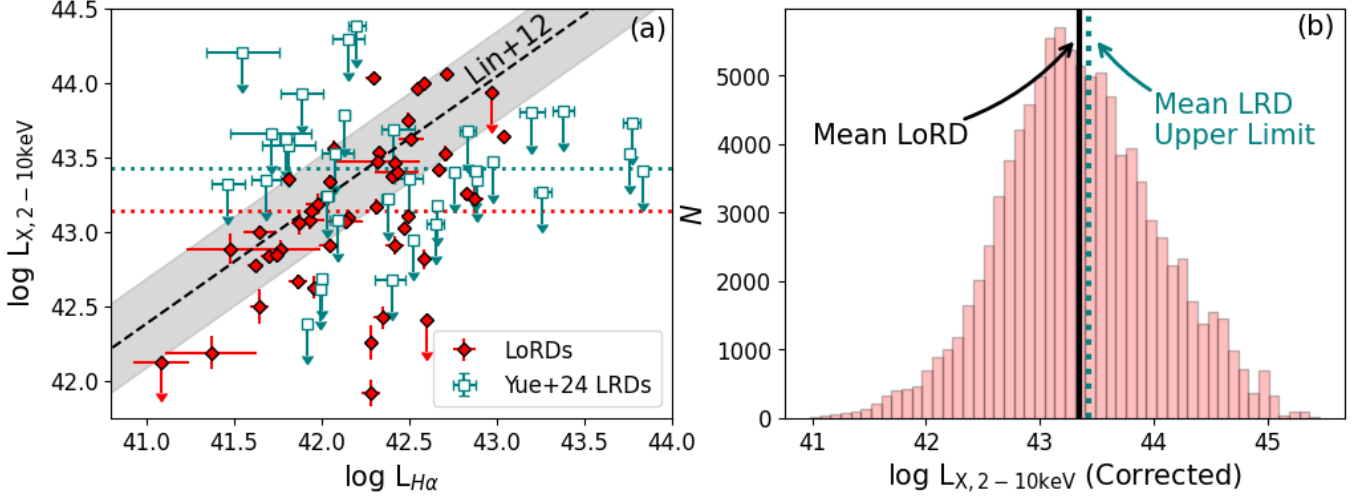


Figure 6. (a): Broad $H\alpha$ luminosity versus rest-frame 2 – 10 keV luminosity. Teal squares are LRD upper limits from Yue et al. (2024) and red points are our sample of LoRDs, where diamonds with downward facing arrows indicate upper limits. The black dashed line is the $L_X - L_{H\alpha}$ relation from Jin et al. (2012) and the shaded region is the intrinsic scatter (~ 0.3 dex). The dotted horizontal lines represent the mean of each sample. (b): LoRD X-ray luminosity distribution after correcting for $H\alpha$ luminosity (Equation 4). The mean LoRD luminosity is the black solid line and the mean LRD upper-limit is the dashed teal line. LRD X-ray luminosity upper-limits are, on average, larger than the LoRD X-ray luminosities which may suggest that the average LoRD would go undetected in archival Chandra imaging at high- z .

Rather than selecting unresolved sources in SDSS, we use observations from the Hyper Suprime-Cam (HSC; Aihara et al. 2018) survey which combines high angular resolution ($\sim 0.4''$) and a wide survey area overlapping with SDSS. A $0.4''$ resolution corresponds to ~ 2.1 kpc at $z = 0.4$ and ~ 3.0 kpc at $z = 0.8$ which is still much larger than the inferred rest-optical LRD sizes ($R_{50} \lesssim 100$ pc; Cloonan et al. 2026); however, this is the highest resolution currently achievable in large-scale ground-based imaging. We visually inspect $2'' \times 2''$ r -band cutouts of LoRDs observed with HSC. $\sim 25\%$ of LoRDs have suitable HSC imaging (61 V-LoRDs and 75 non-V-LoRDs) and $84 \pm 2.1\%$ of those are unresolved, where the uncertainty is the binomial error. $62 \pm 6.2\%$ of V-LoRDs have an unresolved morphology compared to $89 \pm 3.6\%$ of non-V-LoRDs. On average, resolved sources exhibit larger optical spectroscopic slopes (1.1 ± 0.7 , where 0.7 is the standard deviation) relative to the unresolved sources (0.32 ± 1.1), but the large uncertainties show significant overlap between the two samples.

Given that resolved sources have a steeper optical slopes, we deduce that some of this flux must be coming from the stellar populations of the host galaxy. This is in agreement with our SED modeling (see Section 3.2 and Figures 4 and 5) which requires a galaxy component to partly explain the optical flux. Interestingly, both the resolved/unresolved sources have the higher-order Balmer absorption features (i.e., H9-H12) and Ca II H & K in their stacked spectra (although Ca II H and

H ϵ are blended). In the resolved population these features may simply be explained by stellar atmospheric absorption; however, we propose an AGN interpretation for the Balmer absorption in the unresolved population. An absorber with a significant population of neutral hydrogen in the $n = 2$ state can produce these features (e.g., Hall 2007; Aoki 2010). This population may arise from either collisional excitation with densities $n \sim 10^9\text{--}11 \text{ cm}^{-3}$ (Inayoshi & Maiolino 2025), or Ly α trapping (Hall 2007). Balmer absorption is primarily associated with the H α and H β emission lines when considering LRD spectra, but the higher-order absorption features (i.e., H9-H12), if present, would likely be difficult to detect in LRD observations due to both small EWs and the low spectral resolution of PRISM observations (see Section 4.2 and Figure 7a).

4.2. Spectral Comparison

The stacked LoRD spectra (Figure 3) do not look exactly like the “typical” LRD observed with JWST/PRISM. Part of this discrepancy is due to the low resolution of PRISM observations ($R \sim 100$) which only captures lines with the largest equivalent widths; another reason is that the stark Balmer break in some LRDs is not ubiquitous in our sample of LoRDs (although certain individual spectra do show this behavior). Additionally, our V-shape criteria differs from those used in high- z studies; we primarily use the V-LoRDs for illustrative purposes, so our different criteria does not bias our interpretation of the sample

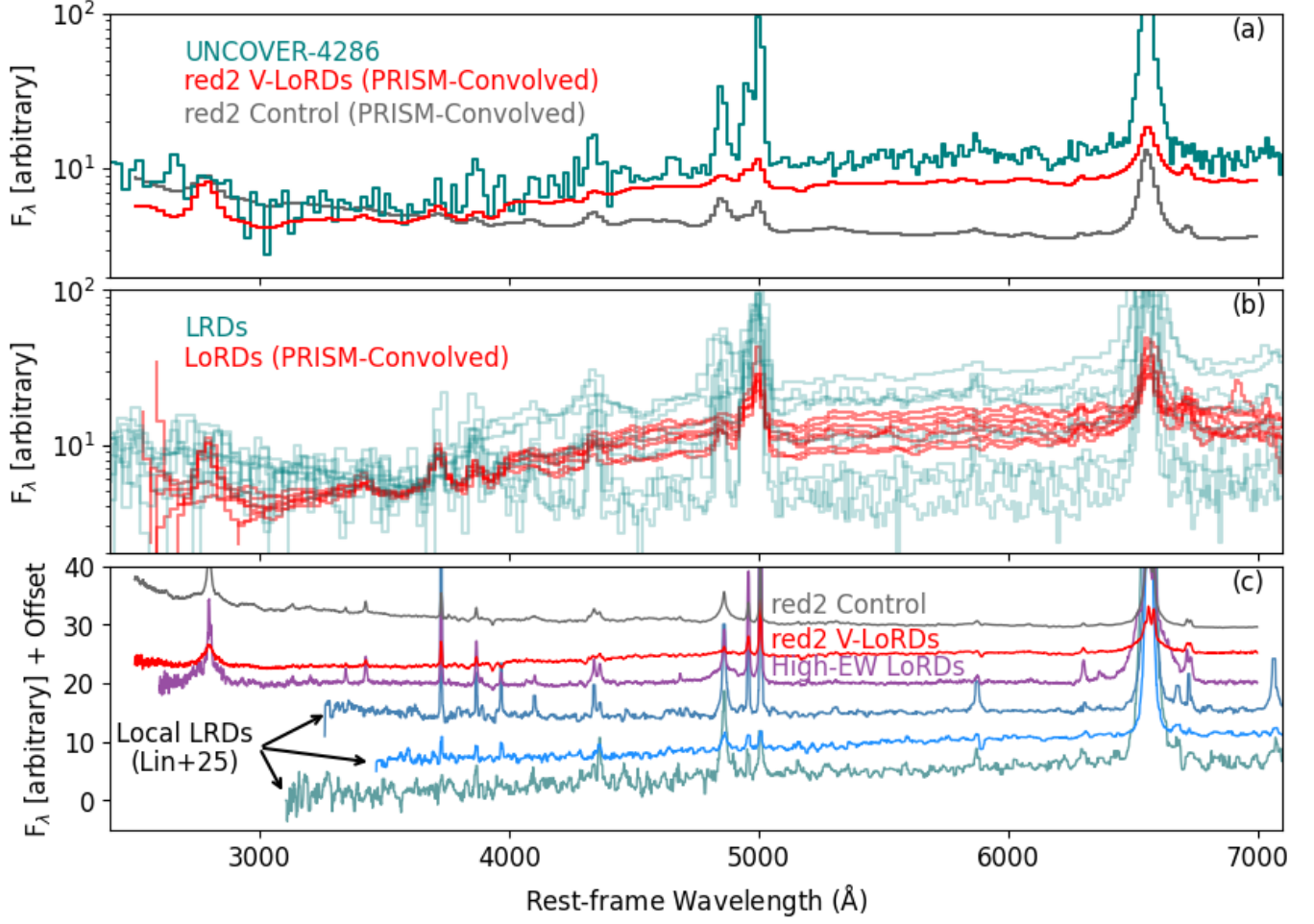


Figure 7. (a): JWST/PRISM spectrum for the LRD UNCOVER-4286 (teal) compared to a stacked SDSS spectrum of the red2 V-LoRDs (red) and the red2 control sample (gray). The stacked SDSS spectra are convolved with the PRISM resolution and matched to the same wavelength grid as UNCOVER-2486. Each spectrum is normalized to the integrated flux at $3645 \pm 100 \text{ \AA}$. (b): The same as panel (a), except we show more LRDs (teal) and compare them to a sample of individual LoRDs (red); the LoRDs match the LRD spectral shapes. (c): Spectral comparison between the local red dots of Lin et al. (2026) (various shades of blue) and LoRD/control samples presented in this work. We show the stacked red2 V-LoRD spectrum in red, a subset of high EW LoRDs in purple, and the red2 control sample in gray.

as a whole. To illustrate the loss of spectral information in PRISM observations we convolve the red2 V-LoRD stacked SDSS spectrum (Figure 3) with the wavelength-dependent PRISM dispersion and match the SDSS wavelength grid to an LRD. We compare the PRISM-convolved SDSS spectrum to UNCOVER-4286 (Bezanson et al. 2024) because it has a V-shaped continuum (Setton et al. 2025b) and its redshift ($z = 5.8$) means the spectral resolution is on the higher end. In Figure 7 (a) we show the stacked SDSS-convolved spectrum compared to UNCOVER-4286.

We show seven individual LoRD spectra relative to a sample of nine LRDs in Figure 7 (b) to highlight both the similarity between LRDs and LoRDs as well as to illustrate the diversity of LRD spectra. The sub-

set of LoRD spectra were chosen to match the spectral shapes of these LRDs, but many more such examples exist. The LRD spectra in Figure 7 (b) are all unresolved V-shape sources (Setton et al. 2025b). Specifically, we show JADES-68797/53501/13704/28074 (Eisenstein et al. 2026), RUBIES-uds-40579/31747/47509 (de Graaff et al. 2025a), and UNCOVER-4286/45924 (Bezanson et al. 2024).

Only the brightest emission lines are clearly visible in the PRISM-convolved SDSS spectra: Mg II $\lambda 2800$, [O II] $\lambda 3727$, H γ /[O III] $\lambda 4363$, H β , [O III] $\lambda 5007$, and H α . Mg II is not normally detected in individual LRD spectra, but this typical AGN line is weakly identified in stacks of LRD spectra (e.g., Pérez-González et al. 2026). The Balmer absorption features redward of [O II]

$\lambda 3727$ are completely washed out and make [O II] appear broader than it is. Therefore, if LRDs have such features, we would be unable to detect them in existing PRISM observations. This is consistent with the recent results which have found that absorption in the $H\alpha$ emission line is detected at a higher rate when observed with higher spectral resolutions (Matthee et al. 2026). While this is not surprising, it highlights the importance of deep GRISM observations across the entire UV/optical spectrum where we may see typical stellar/AGN features too faint for PRISM level resolutions.

Similarly, the [Ne V] $\lambda 3426$ line, which is clearly visible in Figure 3, barely registers above the continuum in the PRISM-convolved spectrum. Labbe et al. (2024) reports the detection of [Ne V] $\lambda 3426$ in the LRD A2744-45924 with deep PRISM observations; the presence of such high-ionization emission lines may be difficult to explain in the absence of a typical AGN SED. In the popular “BH-star” model (e.g., Begelman et al. 2008; Inayoshi & Maiolino 2025; Naidu et al. 2025), the high-ionization emission lines are absorbed by a dense gas envelope surrounding the BH. Such emission lines are produced by the inner region of the accretion disk; if detected, this suggests a covering factor less than unity. However, their presence means that even higher energy photons (i.e., X-rays) should also escape given that the photoionization cross section decreases with energy (e.g., Inayoshi & Ho 2025). We explore this possibility in Section 4.3.

The shape of the optical continuum in UNCOVER-4286 is the same as the red2 V-LoRD stack; both of which are clearly distinct from the control sample in the optical. The difference between the LoRD stack and UNCOVER-4286 in the UV is expected given that we do not enforce a negative UV slope when defining sources as V-shaped. The most pronounced difference between the LoRDs and the UNCOVER-4286 spectrum is the EWs of the prominent emission lines (namely $H\alpha$ and $H\beta$), which is also apparent when we compare individual LoRDs and LRDs. LRDs, and high- z AGN in general, are known to have large EWs – roughly three times larger than local AGN (Maiolino et al. 2025), but the nature of the large EWs in LRDs is uncertain. The differences between the LoRD and LRD EWs may be driven by variations in the covering factor, metallicity, ionization parameter, or host galaxy contamination. In star-forming galaxies the metallicity is known to decrease while the ionization parameter increases with increasing redshift (e.g., Yuan et al. 2013; Nakajima & Ouchi 2014; Cleri et al. 2026); this evolution is less understood in AGN partly due to selection effects (Juneau et al. 2014), as well as difficulties in disentangling AGN from

star-forming galaxies at high- z (e.g., Kewley et al. 2013; Cleri et al. 2025).

We compare our sample of LoRDs to the local red dots presented in Lin et al. (2026), one of which was independently discovered by Ji et al. (2026b). The three sources (SDSS J1047+0739, J1025+1402, and J1022+0841) were discovered in SDSS and reside at $z = 0.1-0.2$; we show their SDSS spectra in Figure 7 (c) in different shades of blue. Similar to the LRDs, the Lin et al. (2026) sources exhibit $H\alpha$ and $H\beta$ EWs much larger than the red2 V-LoRD stack; to illustrate similarities between certain sources in our sample and the Lin et al. (2026) sources we select a subset of LoRDs with large EWs. Specifically, we select LoRDs with $H\alpha$ EW $> 570\text{\AA}$, or $H\beta$ EW $> 110\text{\AA}$; the $H\alpha$ bound is set by photoionization models from Madau & Maiolino (2026) and the $H\beta$ bound is the mean EW of a stack of LRDs from Sun et al. (2026). There are 96 LoRDs which satisfy these criteria ($H\alpha$ is redshifted out of the SDSS spectrographs for the red1 sample), we show the stacked spectrum for this sample in purple. In the high EW LoRD subset, we see more similarities in the emission line properties with the Lin et al. (2026) sample compared to the full red2 V-LoRDs (e.g., $H\epsilon$, $H\delta$, $H\gamma$, He II $\lambda 4686$, He I $\lambda 5876$, Fe II $\lambda 6369$).

4.3. X-ray Detection Limits

LoRDs and the control sample are detected at similar rates in each X-ray band; these detection fractions are much larger than what we have come to expect for individual LRDs ($\sim 0\%$). However, as we showed in Section 3.3, the average LoRD X-ray luminosity (and control QSO luminosity) is at or below the average LRD X-ray upper limit of Yue et al. (2024). When we consider the shape of the LoRD optical continua, we find that V-shaped LoRDs are more likely ($\bar{p} = 0.59$) to be less luminous than the LRD upper limits compared to non-V-shaped LoRDs ($\bar{p} = 0.45$), but the total number of sources is small. Therefore, we cannot say for certain whether the LoRDs or typical QSOs would be detected in archival Chandra imaging at high- z .

This highlights that the LRD X-ray upper limits are not all that constraining; therefore, the assumption that all LRDs will be undetected in archival (or new) Chandra imaging may not be a particularly sound assumption. Indeed the majority of LRDs are X-ray weak when considering well-established local relations. The $L_X - L_{H\alpha}$ relation from Jin et al. (2012) was constructed using a sample of 51 unobscured AGN with high quality optical and X-ray spectra at $0.03 < z < 0.38$ ($\langle z \rangle = 0.14$). They specifically exclude AGN with strong reddening effects and signatures of a warm X-ray ab-

sorber. Certain evidence suggests LRDs may have a non-negligible dust contribution (e.g., Delvecchio et al. 2025) which may cause the $L_X - L_{H\alpha}$ relation to fail. Given the observed differences between LRDs and the local AGN used to construct the $L_X - L_{H\alpha}$ relation (e.g., SED shape, Balmer line EWs, etc.), it is not unreasonable to think that LRDs may reside off this relation. If this is the case, we cannot comment on their intrinsic X-ray weakness, only that LRDs (and LoRDs) do not abide by the same processes assumed in local type I AGN.

Hviding et al. (2026) reported an X-ray luminous ($L_{2-10 \text{ keV}} = 10^{44.18} \text{ erg s}^{-1}$) source that has all the typical hallmarks of an LRD, which they refer to as the “XRD” (see also “The Forges,” Fu et al. 2026). The XRD is lower redshift ($z = 3.1$) compared to the samples of Yue et al. (2024) and Ananna et al. (2024) ($z \approx 5.0$) and its X-ray luminosity is significantly larger than the LRD upper limits. Depending on the dust attenuation, the XRD is either consistent with or below the $L_X - L_{H\alpha}$ relation and exhibits a moderate column density ($N_H \approx 2.4 \times 10^{22} \text{ cm}^{-2}$). The authors suggest the XRD is an object transitioning between a gas enshrouded black hole and a typical AGN, where optically thin lines of sight towards the nucleus allow the X-rays to escape.

When we consider that the LRD X-ray upper limits are poorly constraining, and that high ionization emission lines are difficult to detect in current PRISM observations (Figure 7a), this raises uncertainty regarding the popular “BH-star” model. In this model, high energy accretion disk photons should be scattered/absorbed by the surrounding hydrogen envelope; detecting such photons implies a covering factor less than unity (i.e., there exist direct lines of sight between the accretion disk and gas beyond the broad line region), or a clumpy absorbing medium. Detections of such high-energy photons in LRDs have been observed (e.g., Labbe et al. 2024; Lambribes et al. 2025; Tang et al. 2025; Tripodi et al. 2025; Ji et al. 2026), but the vast majority of X-ray observations have resulted in non-detections. This highlights the importance of deep, well-constraining X-ray observations of nearby LRD analogs, as well as the necessity of next generation X-ray observatories.

4.4. Implications for LRD Understanding

Important questions regarding LRDs are whether they are physically distinct from typical AGN, and if they form a homogeneous population. A statistical study by Billand et al. (2026) suggests that only a few percent of LRD-selected sources are physically distinct from the broader galaxy population, and the bulk of LRDs make up a continuous distribution of galaxies. Our analysis of

the LoRD population suggests that a substantial portion of these sources resemble reddened AGN with a young stellar population (see Section 3.2); this suggests that certain LRDs may be reddened AGN given that they share similar colors and spectroscopic characteristics.

The most extreme LRD sources (i.e., those with the largest Balmer breaks) are likely not reddened AGN as a steep extinction curve would be necessary to reproduce the spectral shape of the break (e.g., Ma et al. 2025a; de Graaff et al. 2025b). However, these sources make up the minority of what is currently referred to as an LRD (e.g., de Graaff et al. 2025b; Naidu et al. 2025; Billand et al. 2026; Pérez-González et al. 2026). Likewise, local reddened AGN do not tend to have the narrow Balmer absorption feature in their Balmer lines as is seen in some LRDs. Statistical studies of the luminosity function and space density are necessary to infer the prevalence and evolution of LRDs (e.g., Matthee et al. 2024; Kocevski et al. 2025; Ma et al. 2025a,b; Greene et al. 2026), but distinguishing between reddened AGN and the more exotic sources (at both high and low- z) is imperative for these studies.

A recent study by Barger & Cowie (2026) found that the majority of LRD selected sources in the Abell 2744 field have close companions ($< 0.25''$). While this has important implications for the observed LRD properties, it also agrees with our current understanding of AGN evolution. WISE-selected AGN, that include many dust-obscured sources, are more likely to be found in interacting pairs (e.g., Satyapal et al. 2014; Weston et al. 2017; Goulding et al. 2018), and the AGN merger fraction increases significantly with AGN obscuration (e.g., Glikman et al. 2015; Gao et al. 2020; Barrows et al. 2023). Whether this holds for the LRDs that have features inconsistent with reddened AGN is yet to be seen.

Deeper observations with JWST’s Mid Infrared Instrument (MIRI; Rieke et al. 2015) in future cycles will help to distinguish between reddened AGN and novel sources (e.g., the “BH-star” picture) in the LRD population. Current evidence of IR emission (presumably from dust) comes from stacked observations (e.g., Delvecchio et al. 2025; Pérez-González et al. 2026), but, if reddened AGN are included with the novel sources, the dust emission will be underestimated. The same argument applies to X-ray emission which can lead to an overestimation of the sample’s X-ray weakness. The origin of the narrow Balmer absorption in LRDs’ Balmer lines is under debate and a complete sample would require deep medium/high-resolution spectroscopy (e.g., Matthee et al. 2026; Davis et al. 2026), but this feature is not seen in typical reddened AGN and can be used to differen-

tiate reddened AGN from the atypical sources (see the Appendix for LoRDs with potential Balmer absorption). Making such distinctions between sources is important for our understanding of the evolution of these enigmatic sources.

5. SUMMARY AND CONCLUSIONS

In this paper we have shown that the JWST filters used to select LRDs at $z \sim 5$ align well with the SDSS filters at both $z = 0.38$ and $z = 0.78$. We leverage this mapping to photometrically select Local Red Dots (LoRDs) from SDSS using selection criteria similar to the red1/red2 criteria from [Greene et al. \(2024\)](#); our selection is given in Equations 2 and 3. In total we find ~ 1300 QSOs which share similar photometric colors to the LRDs (Section 2.1). While not every LoRD we identify serves as a proper analog to LRDs, this is the first step towards studying LRD-like systems in the local Universe at the population level where archival data is plentiful.

We fit the spectra using a broken power law in Section 3.1 to select 244 LoRDs with V-shaped continua similar to those observed in LRDs. The V-LoRDs exhibit a relatively flat UV continuum and a red rest optical. The stacked spectra show traditional AGN signatures such as Mg II, [Ne V], broad H α and H β , as well as higher-order Balmer absorption. The V-LoRDs have modest Balmer breaks similar to “typical” LRDs (c.f., [Setton et al. 2025b](#)), but we do not identify any SDSS source with Balmer breaks as large as the most extreme LRDs (c.f., “The Cliff,” [de Graaff et al. 2025b](#)).

A morphological analysis on a subset of LoRDs with HSC coverage shows that the majority of sources ($> 80\%$) are compact regardless of their spectral shape (see Section 4.1). We find that LoRDs with a V-shaped continuum are more likely to have a resolved morphology compared to sources without the V-shape. This suggests that some of the V-shaped spectra ($\sim 40\%$) are the result of an underlying stellar population and thus are unlikely to serve as proper LRD analogs. The remaining $\sim 60\%$ of V-shaped LoRDs are proper LRD analog candidates, but space-based imaging is necessary to quantify their compactness.

Much of the spectral information in the stacked SDSS spectrum is lost when we convolve it with a PRISM-like resolution. This is important as information dense spectral features (e.g., high-ionization emission lines or stellar absorption features) may simply be undetectable in PRISM observations given the spectral resolution (see Section 4.2). This highlights the importance of deep GRISM observations at all rest-UV/optical wavelengths. Likewise, higher-quality spectra on the LoRDs would

help us to better understand the percentage of sources exhibiting narrow absorption in the broad Balmer emission lines (i.e., H α and H β , see the Appendix for LoRDs with potential absorption).

In Section 3.2, we create composite SEDs of the control sample, LoRDs, and LRDs. The LRD and LoRD SEDs are consistent with each other in the rest-frame NUV to the NIR; both can be well modeled by a combination of a young stellar population (UV), a $T = 4500$ K blackbody (optical) and a reddened AGN (optical/NIR). The LoRD SED is clearly distinct from the control QSO SED, particularly in the NUV/optical. The difference in the optical is due to an apparent Balmer break which can be modeled as either a cool blackbody or a starburst galaxy component. The reddening of the AGN component differentiates the LoRDs and control QSOs, where the LoRDs require more reddening. Given the similarities between the LoRDs and LRDs, it is plausible that an important fraction of LRDs can be understood as reddened AGN. Determining this fraction is essential for population level studies of these sources.

The LoRDs are detected at a similar rate compared to the control QSOs across each X-ray band. This detection fraction is much larger than what is expected from an LRD; however, we show that the LoRD (and control QSO) X-ray luminosities are consistent with the upper limits of LRD non-detections. We emphasize that the LRD X-ray upper limits are poorly constraining, regardless of whether or not the LoRDs are good analogs (see Sections 3.3 and 4.3).

Analogues of LRDs, or any high- z galaxy for that matter, provide a useful testbed for theories and models of these enigmatic sources in a statistical sense. Galaxies in the nearby Universe have extensive archival multi-wavelength coverage which are frequently of higher quality than the high- z data and allow us to probe wavelength regimes which are inaccessible at high- z . Follow-up observations (e.g., deep X-ray exposures, space-based imaging, high signal-to-noise UV/optical spectroscopy) will be the true test as to what fraction of LoRDs are low- z analogs of the LRDs. Such sources will enable us to garner a deeper understanding of this novel form of SMBH growth and galaxy evolution.

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Software: *astropy* (Astropy Collaboration et al. 2022), *matplotlib* (Hunter 2007), *numpy* (Harris et al. 2020), *pandas* (Reback et al. 2021), *scipy* (Virtanen et al. 2020), *Topcat* (Taylor 2005).

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APPENDIX

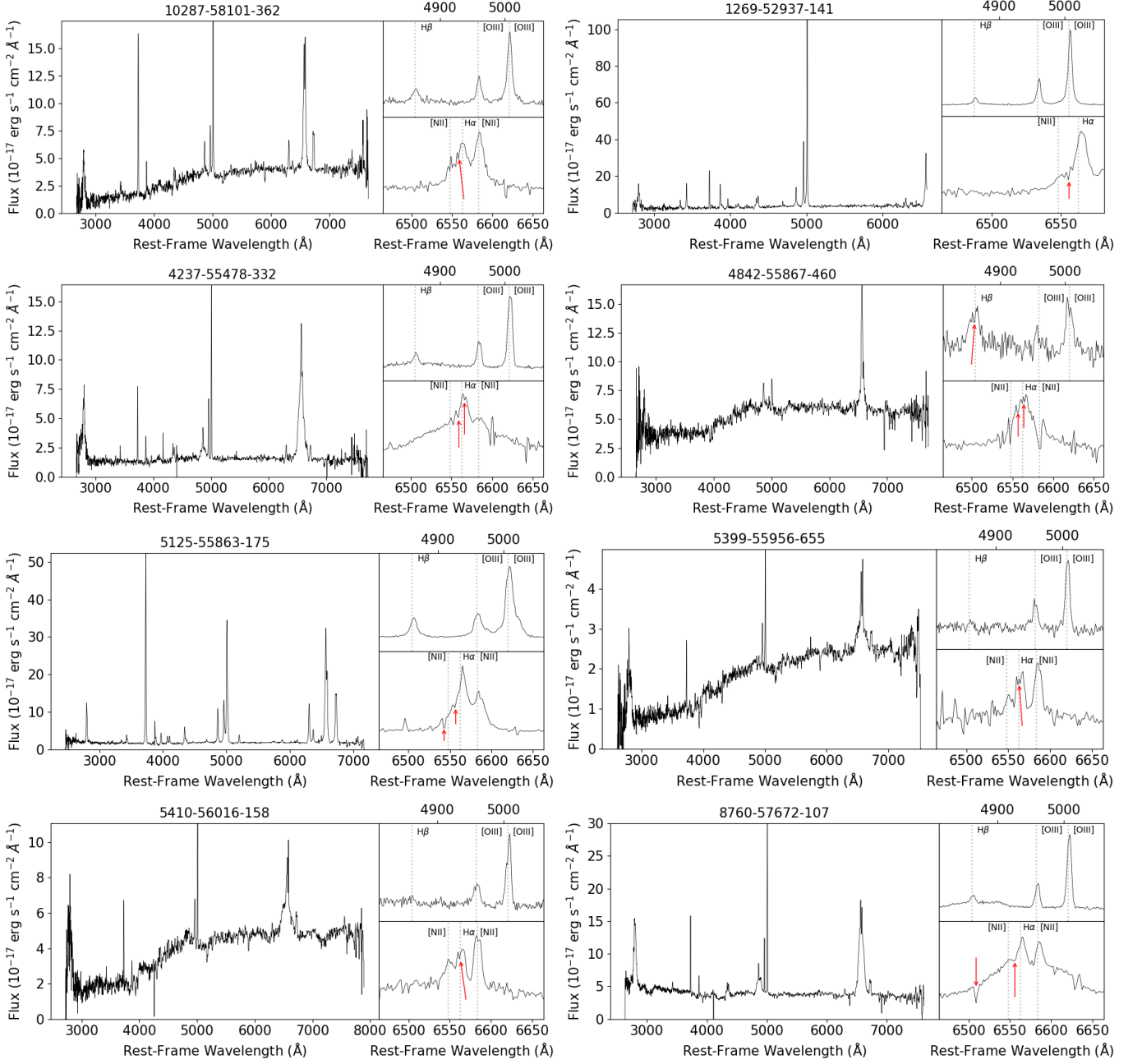


Figure 8. A subsample of the LoRDs which have signatures of absorption features in their Balmer lines (H α and H β). The left panel shows the full SDSS spectrum smoothed using SciPy’s `medfilt` function with a kernel size of seven. The right panels zoom in on the H α (bottom) and H β (top) regions of the spectrum, and we do not apply any smoothing. Prominent emission lines are labeled, and potential absorption features are denoted with a red arrow. The title of the figure corresponds to the plate, MJD, and fiber of the SDSS observation.

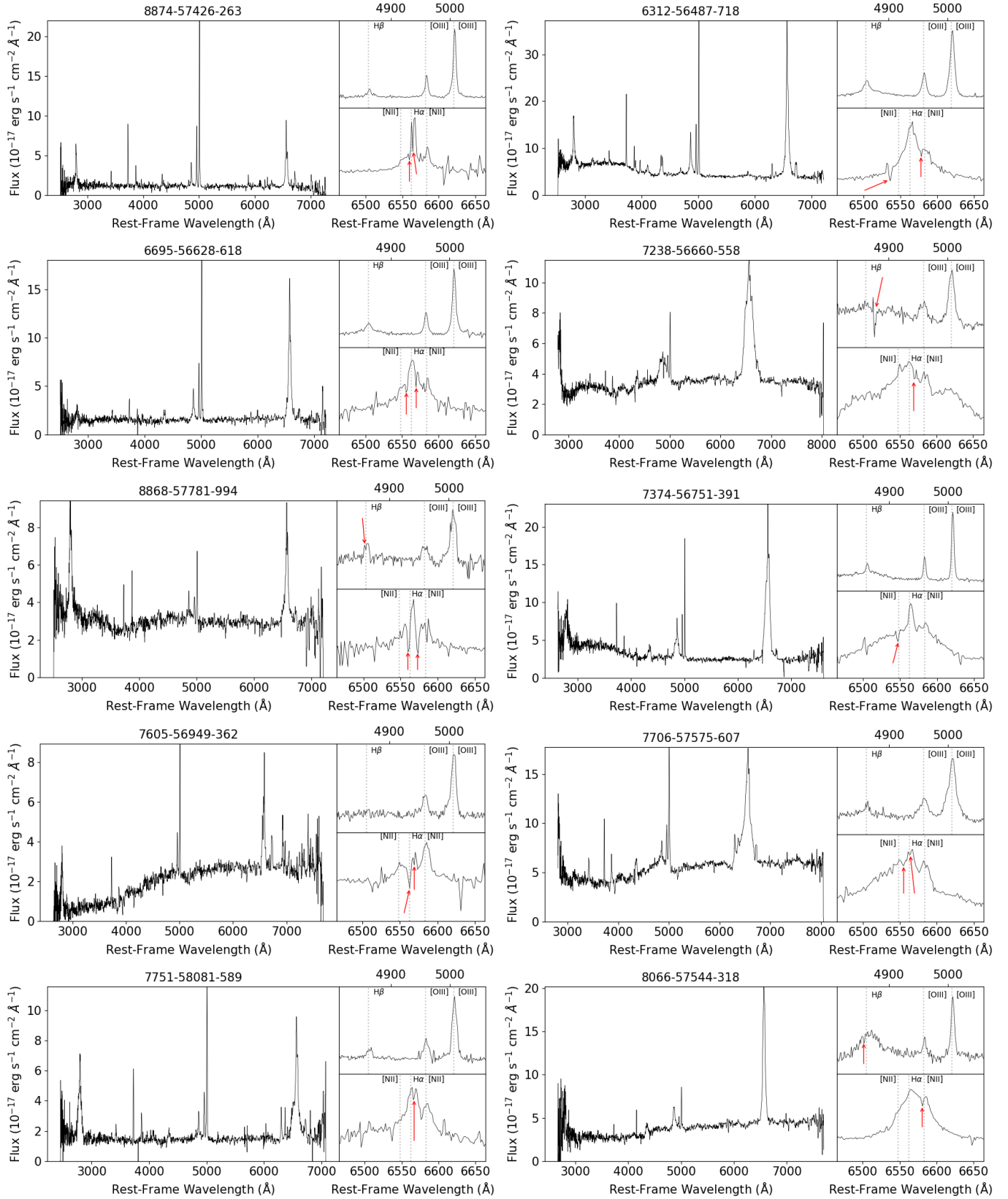


Figure 9. The same as Figure 8.