

Between Degeneracy and Evolution: UV-to-optical Insights into the BH* Model in Little Red Dots

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ABSTRACT

Little Red Dots (LRDs) are a heterogeneous class of objects, with several proposed scenarios for their physical nature and evolution. While these theories have been tested on individual LRDs using limited spectral features, a systematic Bayesian analysis of the LRD population incorporating the different models across a broad wavelength range is still lacking. In this study, we conduct a consistent ultraviolet (UV)-to-optical continuum fitting analysis of 66 LRDs at $2 < z < 6$ using *JWST*/NIRSpec PRISM spectroscopy. Employing a modified version of *Bagpipes*—including blackbody (BB) emission affected by Balmer absorption, stellar and nebular emission attenuated by dust, and an active galactic nucleus (AGN) component—we assess the performance of the black hole star (BH*) model in describing the LRD population. We adopt broad priors and therefore do not impose any specific physical scenario. Our results show that only $\sim 6\%$ of LRDs with statistically robust solutions (52 objects in total) are best-fit by a BH* in the optical and a host galaxy in the UV. $\sim 8\%$ of LRDs show BB-dominated optical continua but lack a stellar component or exhibit AGN UV leakage. Most LRDs are dominated by stellar and/or AGN emission in the optical, with minor BB contribution. When we adopt a prior that disfavors a strong AGN continuum to enforce BH*-like solutions, the percentage of BH* systems increases to $\sim 40\%$, highlighting the strong degeneracy between a BH* solution and alternative scenarios. Even when BH*-like solutions are enforced, many LRDs still **require a stellar-dominated optical continuum**. This may reveal limitations of the BH* model or point to an evolutionary sequence in which the BB contribution decreases as the host grows, leading to lower BB temperatures and higher stellar masses at lower z . In this scenario, more pronounced “V” shapes would correspond to later stages in LRD evolution.

Key words. Galaxies: active – high-redshift – structure – evolution

1. Introduction

Little Red Dots (LRDs; Labbé et al. 2023, Barro et al. 2024, Greene et al. 2024, Matthee et al. 2024) have challenged our understanding of galaxy evolution with their characteristic “V”-shaped spectral energy distributions (SEDs), compact sizes, absence of X-ray and infrared-to-millimeter emission, and number counts’ rapid decline at $z \lesssim 2$ (e.g., Ananna et al. 2024, Casey et al. 2024, Kokorev et al. 2024, Maiolino et al. 2024, Pérez-González et al. 2024, Hviding et al. 2025, Kocevski et al. 2025a, Labbe et al. 2025, Perger et al. 2025, Setton et al. 2025b, Ma et al. 2026, Zhuang et al. 2026). Since LRDs cannot be straightforwardly explained using traditional combinations of stellar and active galactic nucleus (AGN) emission, new theories have emerged that explore alternative, more exotic physical scenarios.

The black hole star (BH*) model is currently one of the most popular theories (e.g., de Graaff et al. 2025c, Inayoshi & Maiolino 2025, Ji et al. 2025, Naidu et al. 2025, Rusakov et al. 2026). This model pictures LRDs as accreting BHs whose emission is reddened by a dense envelope or cocoon of neutral gas ($n_H \sim 10^9\text{--}11\text{ cm}^{-3}$, $N_H \sim 10^{24\text{--}26}\text{ cm}^{-2}$), with a near-unity covering factor (Torralba et al. 2026b). Such

a gas envelope behaves as a photosphere near the Hayashi limit, with temperatures $\sim 5,000\text{--}7,000\text{ K}$ (e.g., Inayoshi & Maiolino 2025, Kido et al. 2025, Inayoshi et al. 2026).

From the observational perspective, this model is a good representation of the optical continuum of LRDs (see Barro et al. 2025, de Graaff et al. 2025b,c, Ji et al. 2025, Lin et al. 2025, Taylor et al. 2025, Mérida et al. 2026b, Pérez-González et al. 2026, Sun et al. 2026, Umeda et al. 2026, among many others). However, the nature and broadening of the Balmer lines in LRDs is still a matter of debate (e.g., electron scattering through nuclear dense plasma, Rusakov et al. 2026; broad line region BLR stratification, Scholtz et al. 2026; hard, ionizing-rich intrinsic SEDs and an anisotropic radiation field, Madau & Maiolino 2026; young massive stars surrounding the envelope, Asada et al. 2026). Consequently, it is still unclear whether the BH* model provides the means to explain the nebular emission of LRDs.

The rest-frame ultraviolet (UV) part of the “V” shape is also yet to be explored in more detail in the context of the BH* model. This emission is proposed to be powered by a low-mass, metal and dust-free host, with stellar masses $M_\star \sim 10^{7\text{--}8} M_\odot$ (e.g., Matthee et al. 2025, Pizzati et al. 2025, Lin et al. 2026 via clustering analysis; see also Korber et al. 2026, Sun et al. 2026, although see Barro et al. 2025 reporting $M_\star > 10^9 M_\odot$ and

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$A_V \sim 0.5$ mag for some LRDs). However, a full and consistent UV-to-optical spectral fitting of a sample of LRDs is still required to achieve a more complete understanding of LRDs’ hosts and their contribution to the “V” shape.

de Graaff et al. (2025b) (dG25 hereafter), Barro et al. (2025) (B25 hereafter), and Pérez-González et al. (2026) (PG26 hereafter) are pioneer examples providing statistical analyses of LRDs based on large spectroscopic samples. dG25 modeled the LRD optical continuum using a modified blackbody (BB) prescription (see also Umeda et al. 2026), but did not model the UV emission of their sample.

B25 and PG26 fitted the LRD UV-to-optical flux following a semi-empirical approach, assuming a stellar origin for the UV continuum and a *Cliff*-like nature for the optical. *The Cliff* (de Graaff et al. 2025c) is an LRD at $z_{\text{spec}} = 3.55$ that exhibits an extreme break at the Balmer limit (Balmer strength ~ 6.9), which, given its compact size, cannot be attributed to a combination of stellar and AGN emission. In short, B25 fitted the optical continuum of *The Cliff* with a low-order polynomial and applied it, together with a dust-attenuation component, to reproduce the optical continuum of the LRDs in their sample. PG26 also used an empirical LRD-core template based on the LRD exhibiting the most pronounced “V”-shaped continuum in their sample.

In Mérida et al. (2026b) (M26 hereafter), we improved upon previous attempts at UV-to-optical spectral fitting. We used a modified version of the *Bagpipes* spectral-fitting code (Carnall et al. 2018) to obtain a consistent, data-driven description of the spectrum of *The Cliff*, as observed with the Near Infrared Spectrograph (NIRSpec; Jakobsen et al. 2022), onboard the *James Webb Space Telescope* (JWST; Gardner et al. 2023), in PRISM mode ($R \sim 100$). This modified version of *Bagpipes* allows a BB spectrum component to be fitted, with a peak temperature ranging from 1,000 to 7,000 K. In our methodology, this BB component is subject to gas absorption near the Balmer limit. An essential aspect of our approach is that neither a BB-dominated optical continuum nor a stellar origin for the UV emission is imposed a priori. Instead, we let the code select the contribution of each model component, including also AGN emission. This treatment of the envelope is thus more flexible than a semi-empirical approach.

A central outcome of this method is the suppressed AGN continuum in *The Cliff*, which—as noted earlier—is not enforced by the priors but was naturally recovered by the fit. The BH* model provides a statistically robust solution for this LRD, yielding a BB temperature $\sim 4,500$ K and an optical continuum dominated by the BB spectrum. The UV is powered by the host galaxy, spatially unresolved in JWST imaging but recovered through the fit. However, some level of dust attenuation, acting on the stellar and nebular components, is required to fit the UV continuum emission of this LRD ($A_V \sim 0.5 - 1$ mag depending on the selected dust attenuation law), ruling out a dust-free scenario for *The Cliff*.

Another key finding of the M26 analysis of *The Cliff* is that the solutions are degenerate in the UV. For this LRD, a purely stellar UV continuum and a mixed stellar + AGN origin are statistically indistinguishable options. This is essential since AGN UV leakage is not expected within the BH* framework, as the envelope is assumed to reprocess all of the AGN continuum. However, the leakage scenario cannot be fully ruled out given the detection in some LRDs of hard-ionization UV lines (Tang et al. 2025, Treiber et al. 2025) and Fe II emission, typically associated with classical AGNs (e.g., Labbe et al. 2024, Tripodi et al. 2025a, PG26, Torralba et al. 2026a). These features open the possibility that the BH* envelope may not be perfectly spheri-

cal or may exhibit a patchy structure (e.g., Hviding et al. 2026). Such geometries would allow for partially transparent lines of sight through which these emission lines, and perhaps a small fraction of the AGN continuum, could escape.

However, it remains to be seen whether these results for *The Cliff*, pointing to moderate dust levels in the host and possible AGN UV leakage, are representative of the full LRD population. The availability of spectroscopic data from NIRSpec using PRISM for hundreds of LRDs (with medium or high resolution additionally available for half of them) enables, for the first time, a statistical characterization of the LRD population, as well as consistent UV-to-optical spectral fitting analyses.

In this work, we follow the method presented in M26 and use PRISM spectra to probe the rest-frame UV and optical continuum of LRDs at $2 < z < 6$. We examine the relative contributions of the AGN, stellar, and BB components to the total LRD emission, assessing whether any tensions arise for the BH* scenario or, alternatively, whether this model provides a physically consistent description for a wide range of LRDs. In Sect. 2, we describe the LRD selection process and compare our sample with the datasets from dG25 and B25. Section 3 summarizes the method implemented in this work, based on M26. Section 4 presents the diverse demographics that emerge when no specific physical scenario is imposed during the fitting, and describes the resulting properties of our LRD sample. Section 5 evaluates the viability of the best-fitting solutions and the trends reported in Sect. 4, and also examines the fits and inferred properties obtained when a BH* solution is enforced through the priors. Finally, Sect. 6 presents the summary and main conclusions of this work. Throughout this work, we assumed $\Omega_{M,0} = 0.3$, $\Omega_{\Lambda,0} = 0.7$, and $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$. All M_* and star formation rate (SFR) estimates assumed a Chabrier (2003) initial mass function.

2. Sample selection

This work is based on JWST NIRSpec/PRISM data, which provides $0.6 - 5.3 \mu\text{m}$ spectral coverage, using the micro-shutter assembly. Data were obtained from version 4 of the DAWN JWST Archive (DJA; Brammer & Valentino 2025). We selected grade=3 sources, corresponding to high-quality data and accurate redshifts, and imposed no signal-to-noise cut. This led to a parent sample of 37,290 NIRSpec spectra at $0.1 < z < 11$.

Once only PRISM data were selected, the sample was screened to include only LRD candidates following dG25. In short, we computed the rest-frame UV and optical slopes (β_{UV} and β_{opt}) and applied the following cuts to ensure the characteristic “V”-shaped spectra of LRDs (see also Hviding et al. 2025):

$$\beta_{\text{opt}} > 0; \beta_{\text{UV}} < -0.2; \beta_{\text{opt}} - \beta_{\text{UV}} > 0.5$$

As mentioned in dG25, the pivot point of the “V” shape, used to measure the slopes and located around the Balmer limit (see Setton et al. 2025a), varies from galaxy to galaxy. For each source, we identified this pivot wavelength by searching for an inflection point around the Balmer limit.

After masking the emission lines, the continuum was smoothed using a median filter (`medfilt` from `scipy`, Virtanen et al. 2020) with an 11×11 pixel kernel, reducing the noise while preserving the underlying continuum shape. We then computed the local slopes in log–log space. The pivot point, selected within the $3,000 - 5,000 \text{ \AA}$ wavelength range, was defined as the wavelength where the slope changes from negative to positive and remains positive for at least five consecutive points. This

transition is taken as the “V” shape’s pivot point and is used to separate the rest-frame UV and optical regimes. If no such transition was found, which can happen when the noise level exceeds what can be mitigated by the smoothing, the pivot point was instead selected as the wavelength where the slope reaches its most negative value, corresponding to the point of strongest curvature.

Once the pivot point was identified, the UV and optical slopes were measured through weighted linear fits in log–log space, i.e., $\log(f_\lambda)$ vs $\log(\lambda/\lambda_{\text{pivot}})$, using the flux uncertainties as weights in the fit. A minimum of 20 data points was required in each part of the “V” shape. The UV window was defined between $1,300 \text{ \AA}$ and the pivot point, while the optical window was defined between the pivot point and $7,500 \text{ \AA}$. The resulting slopes were then used to evaluate the LRD selection criteria.

Additionally, we only considered objects with broad $H\alpha$ emission (or $H\beta$ when $H\alpha$ is not included in the NIRSpect spectra). These screenings left us with 224 LRD candidates. We then removed duplicates, as some galaxies were observed in more than one survey and are linked to more than one identifier. This yielded 207 unique LRD candidates.

Next, we applied a compactness cut based on the sources’ emission in the $F444W$ NIRCcam band (see Kokorev et al. 2024, Kocevski et al. 2025b). We defined compactness as the ratio of the flux measured in 0.5 and $0.3''$ apertures and imposed compactness < 1.7 (Mérida et al. 2025). For this purpose, we used JWST/NIRCcam image mosaics from the DJA (version 7; pixel scale of $0.04''$) and performed background subtraction using photutils (Bradley et al. 2016).

These mosaics were obtained as part of the Canadian NIRISS Unbiased Cluster Survey (CANUCS; GTO-1208, PI: Willott; Willott et al. 2022); the Public Release IMaging for Extragalactic Research (PRIMER; GO-1837; PI: Dunlop); the Ultra-deep NIRSpect and NIRCcam Observations before the Epoch of Reionization (UNCOVER; GO-2561; PIs: Labbe & Bezanson; Bezanson et al. 2024); the North ecliptic pole EXtragalactic Unified Survey (NEXUS; GO-5105; PI: Shen; Shen et al. 2024); the Parallel wide-Area Nircam Observations to Reveal And Measure the Invisible Cosmos (PANORAMIC; GO-2514; PI: Williams; Williams et al. 2025); the JWST Advanced Deep Extragalactic Survey (JADES; GTO-1180, 1181, 1210, 1286, GO-1895, 1963; Eisenstein et al. 2026); and the Cosmic Evolution Early Release Science (CEERS; ERS-1345; PI: Finkelstein; Finkelstein et al. 2025). We note that $F444W$ NIRCcam coverage was not available for 85/207 of these candidates. The final screened sample consisted of 66 LRDs, located at $2 < z < 6$. Six LRDs at $z > 6$ were dismissed, as we require enough optical continuum coverage to properly constrain the BB emission (see also dG25).

Figure 1 shows the spectroscopic redshifts of our sample and its location in the β_{UV} vs β_{opt} plane, together with a dataset of compact Type I AGN extracted from the parent sample. These Type I AGNs are non-LRD objects at $2 < z < 6$ that show broad Balmer emission but lack a “V”-shaped spectrum (1,381 objects in total).

20 of the LRDs in our dataset were observed as part of JADES; 11 are from NEXUS; 9 are from the Red Unknowns: Bright Infrared Extragalactic Survey (RUBIES; PIs: de Graaff & Brammer; de Graaff et al. 2025a); 8 are from UNCOVER; 7 are from CANUCS; 5 are from the CANDELS-Area Prism Epoch of Reionization Survey (CAPERS; GO-6368; PI: Dickinson); 3 are from NIRSpect GTO-Wide (Maseda et al. 2024); 2 are from Barrufet et al. 2025; and 1 is from Mirage or Miracle? (MoM; GO-5224, PIs: Oesch & Naidu). For galaxies in cluster

fields (i.e., objects from CANUCS and UNCOVER), the physical properties that we report in this work were corrected for lensing magnification using the best-fit lensing magnification factors reported in the CANUCS DR1 (Sarrouh et al. 2026) and the UNCOVER DR3 SUPER (Suess et al. 2024) catalogs.

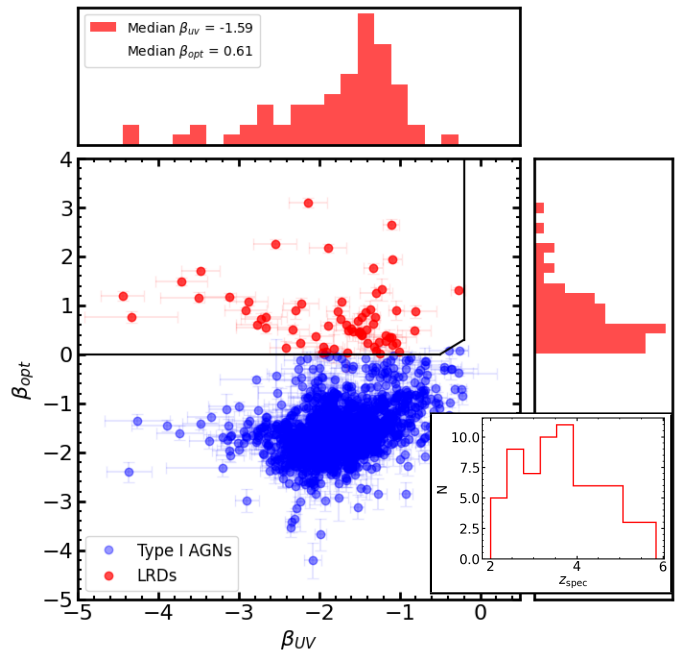


Fig. 1: β_{UV} vs β_{opt} of our sample (red), consisting of 66 LRDs. Compact non-LRD Type I AGN extracted from the parent sample are shown in blue. The demarcation line between the LRD and non-LRD loci is highlighted in black. The redshift distribution of the LRDs is included as an inset.

2.1. Cross-matching with other spectroscopic LRD samples

We matched the 66 LRDs selected earlier in Sect. 2 with the LRD sample from dG25 and B25, which provide a list of identifiers for their respective objects. 31 out of the 99 LRDs at $2 < z < 6$ from dG25 are present in our dataset. From the 68 remaining objects, we could not find $F444W$ NIRCcam coverage for 22 of them. This screening does not account for the associated duplicates, which are not removed from the total 99 objects. Additionally, 8 of dG25 LRDs are not present in our parent sample. These are objects from MoM that are not publicly available in DJA.

Besides the duplicates or the lack of data, some of the dG25 LRDs did not pass our screenings because (a) we did not measure a clear broad component in their Balmer lines based on PRISM (e.g., DJA srcid = 4111589, 2015) or (b) we measured a $\beta_{\text{opt}} < 0$. This last possibility takes place when β_{opt} is close to 0 (e.g., srcid = 149501, 61496). In those cases, the definition of the inflection point can lead to slight variations in classification.

Additionally, the definition of compactness in dG25 differs from ours, since they used 0.1 and $0.2''$ apertures. They also performed a two-component point source and Sérsic profile fitting when possible. Consequently, objects close to the compactness limit according to our criterion may not be selected following their approach. However, the aim of this work is also to understand how the physical properties of LRDs evolve with compactness. Therefore, it is important to include objects with potential

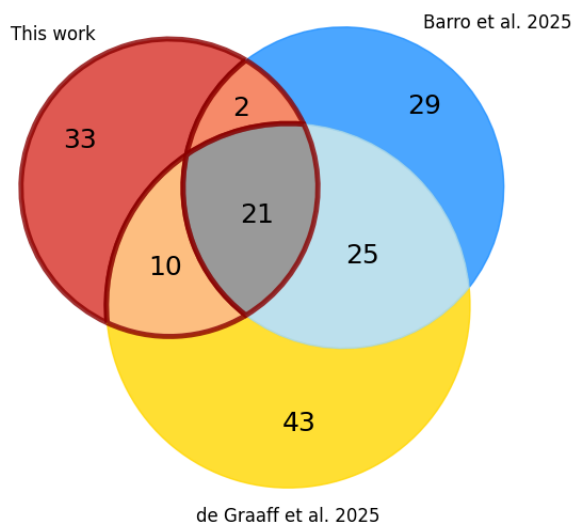


Fig. 2: Venn diagram illustrating the intersections between our LRD sample (red) and the LRD samples from **dG25** (gold), and **B25** (blue). The figure quantifies both the shared objects and the subsets unique to each catalog.

extended emission that meet the average compactness criteria, since they may be included in more conservative LRD selections.

The **B25** sample contains 77 LRDs at $2 < z < 6$, of which 46 are in common with **dG25**, and 23 are in common with our sample. 10 LRDs from our sample are only present in **dG25**, whereas 2 are only present in **B25**. This sums up a total of 33 LRDs in common with the set of **dG25** and **B25** galaxies ($\text{dG25} \cup \text{B25}$). A comparison of the properties retrieved in those studies and the values reported in this work is included in Appendix A.

40/77 LRDs from **B25** did not pass our slope and broad-line component screenings. These correspond to cases where $\beta_{\text{opt}} \sim 0$ (e.g., `srcid` = 2783, 3284) and a lack of a broad component as measured from PRISM data (e.g., `srcid` = 30148719). From the remaining 37/77 LRDs, we found NIRC*am* coverage for 23. Note that **B25** imposed $f(0.5'')/f(0.2'') < 1.5$, with f being the flux in the *F444W* NIRC*am* band, which is a less conservative compactness limit than ours.

Fig. 2 shows a Venn diagram illustrating the overlap between our LRD sample and the samples from **dG25** and **B25**. These comparisons highlight how heterogeneous LRD selections can be, even when similar criteria are applied. Nevertheless, our final sample provides a reliable and representative census of objects broadly considered LRDs.

3. Methodology

In order to derive the physical properties of our LRD sample, we followed the spectral fitting method presented in **M26**, which is based on a modified version of *Bagpipes*. To include the ingredients of the BH* model, our custom version of *Bagpipes* incorporates some built-in functions and additional custom components.

The model components work as follows. For the stellar model, we selected non-parametric star formation histories (SFHs) through the *continuity* mode (Leja et al. 2019). For the dust component, we assumed a Small Magellanic Cloud (SMC; Gordon et al. 2003) dust attenuation law (see **M26** for

a comparison between SMC and a Calzetti et al. 2000 law in the context of *The Cliff*).

We used a prior configuration that potentially allows massive, metal-rich, and dusty solutions for the host galaxy. In **M26**, we referred to this setup as the BH*+dusty host configuration, where it was tested in the context of *The Cliff*. There, we showed that a dust-free host solution cannot properly fit the UV continuum emission of this object. Therefore, in the present work, we let the code explore a broad range of A_V values.

The AGN is modeled as a broken power law, with α_λ and β_λ controlling the UV and optical slopes, `f5100A` setting the flux at 5,100Å, and `hanorm` controlling the intensity of the Balmer lines. The width of the lines was fixed through the $H\alpha$ line width as measured by us from the spectra.

The `f5100A` parameter can act to suppress or enhance the AGN continuum emission. This parameter was left free in the code, following **M26**. We refer to this approach as “AGN-agnostic”. In Sect. 5.2 we force the BH*-model by manually suppressing the AGN continuum through this `f5100A` parameter (referred to as “AGN-suppressed” in Sect. 5.2).

We explored a wide range of UV slopes (α_λ), which naturally allows AGN UV leakage even when the code selects a relatively low `f5100A` normalization in the AGN-agnostic setup. By contrast, in the AGN-suppressed configuration, such leakage cannot occur because the imposed normalization is forced to be extremely low.

We then included additional model components using the option `extra_components`. These additional components correspond to a BB spectrum and a gas absorption feature that acts on the BB at the Balmer limit. We modeled the emission from the BB analytically using Planck’s law, introducing two parameters: temperature and a normalization factor. We included a gas absorption component to account for the sharp drop in the continuum caused by strong breaks at the Balmer limit. This absorption is controlled by a column density N , a cross-section σ_B , the inflection point wavelength λ_{break} , and a width parameter that adjusts how sharp or smooth the absorption is. This absorption feature was modeled similarly to the Lyman break, assuming a $\sigma_B \propto (\lambda/\lambda_{\text{break}})^3$. A detailed description of the formulation adopted for this component is provided in **M26**.

In **M26**, we derived two fits per galaxy: one based on the full spectrum and one based only on the continuum. We did this to isolate the effect of the emission lines, whose origin is still under debate (see Sect. 1). The analysis presented in this work is based on fits to the continuum only. As a result, even though Balmer lines are included in the AGN model, they have no impact on the resulting best-fitting solution. We leave the analysis of emission lines for future work, once a better understanding of their origin and the mechanisms involved is achieved. As a result, we work with 18 free parameters. A summary of the prior configuration is provided in Table 1, and further details on this method can be consulted in **M26**.

4. Results

4.1. Demographics

The dataset presented in this work is far from being complete. It is based on available public PRISM and *F444W* NIRC*am* data and thus is biased toward bright or peculiar LRDs that were selected for follow-up with NIRS*pec*. Moreover, slightly different definitions of the inflection point or the compactness criterion can yield different sample selections (see Sect. 2.1).

Table 1: *Bagpipes* priors used in this work

SFH	Nebular	Dust	AGN	BB	Absorption
$\text{bin_edges} = [0, 10, 30, 100, 300, 700]$ $\text{massformed} = [4, 10]$ $\text{metallicity} = [0.001, 2.5]$	$\log U = [-4, 0]$	$A_V = [0, 5]$	$\text{alphalam} = [-2.8, 2]$ $\text{betalam} = [0.8, 1.6]$ $\text{hanorm} = [0, 5 \times 10^{-16}]$ $\text{f5100A} = [0, 3 \times 10^{-16}]$	$T = [1000, 7000]$ $\log A = [-25, -16]$	$\log \text{sigma_B0} = [-18, -15]$ $\log N = [19, 24]$ $\lambda_{\text{break}} = [3000, 4000]$ $\text{break_width} = [10, 100]$

Notes. The SFH is set to the continuity mode, and the bins are expressed in Myr. dSFR_i , which represents the change in \log SFR between two consecutive SFH bins, is set to $[-10, 10]$, following a Student-t distribution. The massformed parameter is logarithmic and in M_\odot units; the metallicity is logarithmic and in Z_\odot units; A_V is in magnitudes; hanorm has units of erg/s/cm^2 and f5100A is in $\text{erg/s/cm}^2/\text{\AA}$; λ_{break} and break_width are in units of \AA . The normalization factor of the BB, A , is expressed in $\text{erg/s/cm}^2/\text{\AA}$ and the temperature is in K. In the absorption component, the $\text{sigma_B0} \times N$ product is dimensionless. In total, we worked with 18 free parameters.

At the same time, this dataset is intrinsically highly heterogeneous. While some LRDs, such as *The Cliff*, exhibit extreme Balmer breaks, others display less pronounced “V”-shaped SEDs (e.g., Fig. 3, see also PG26). Some show strong collisional lines, such as [OIII], while others only exhibit hydrogen lines, with a negligible contribution from other optical lines. It is possible that no single model is capable of reproducing the full variety of LRDs. However, the BH* model is hypothesized to provide a universal framework for understanding all LRDs, and that is the focus of our investigation in this work.

As a result of our fitting, following the method described in Sect. 3 (“AGN-agnostic”), we were able to recover statistically robust fits for 52/66 LRDs. The remaining 14 objects show large reduced χ^2 values ($\chi_{\text{red}}^2 > 3$). Within these 52 LRDs, we were able to identify different subtypes based on how well the BH* scenario was represented by the best-fitting solution. Note that we are not imposing the BH* model, since we assumed broad priors for all the parameters.

In general, most of the fits did not exactly match the expectations from the BH* model, with an important AGN contribution in some cases, a lack of host emission, or a lack of BB flux in the fit. To better understand these differences and delve deeper into the physical drivers of the LRD continuum emission, we classified these 52 objects into 5 classes, summarized in Table 2.

 Table 2: LRD classification based on the AGN, stellar, and BB contribution to the *Bagpipes* best-fitting model.

	# Objects	AGN		Stars		BB	
		$\chi_{\text{red}}^2 < 3$	UV	Opt	UV	Opt	UV
BH*	3	< 10%	< 10%	> 90%	< 20%		> 70%
BH*-AGN leaks	2	< 50%	< 10%	> 40%	< 20%		> 70%
BH*-hostless	2	> 70%	< 30%	< 10%	< 10%		> 70%
Type I AGN	9						< 10%
Hybrid	36						

Notes. We divide the contribution of each component into rest-frame UV and optical. The BB does not contribute to the UV by construction due to the gas absorption component. The second and third classes, BH*-AGN leaks and -hostless, correspond to quasi-BH* configurations in which the optical continuum is mainly powered by the BB, but the UV is partially or totally driven by the AGN continuum. The fourth class corresponds to galaxies with a negligible contribution from the BB. Objects that do not match any of these criteria were classified as Hybrid (fifth class), in between a BH*-like LRD and a compact Type I AGN.

Within the BH* framework, the optical continuum is expected to be powered by the BB component, while the UV emission is attributed to the stars. These assumptions define our

first class, BH*. To explore the possibility of AGN UV leakage, which is not allowed within the strict BH* scenario, we reduced the contribution of the stars to the UV criterion and instead permitted some AGN flux. These criteria define the quasi-BH* class BH*-AGN leaks.

We then extended this idea to investigate LRDs with a negligible host contribution while still exhibiting a BH*-like optical continuum powered by the envelope. To this end, we selected LRDs that show a strongly suppressed stellar component in the fit, meaning that the UV emission is primarily driven by the AGN. These criteria characterize the quasi-BH* class BH*-hostless.

We also selected objects in which the BB component is negligible in the fit. These systems correspond to compact Type I AGN LRDs, consistent with being Little Blue Dots (e.g., Asada et al. 2026, Brazzini et al. 2026, Madau & Maiolino 2026, Scholtz et al. 2026).

LRDs showing some BB contribution in the optical (i.e., > 10%) but not meeting the criteria of the previous classes were grouped into the Hybrid category. These objects occupy an intermediate regime between a BH*-like LRD and a compact Type I AGN.

In total—considering only fits with $\chi_{\text{red}}^2 < 3$ —we identified 3 pure BH* systems, 2 BH* with AGN UV leakage, 2 BH*-hostless LRDs, 9 Type I AGNs, and 36 Hybrid objects. Consequently, only a small fraction of the sample naturally matches the BH* picture, while most of the sources fall between a BH* and a Type I AGN description. Figure 3 presents one example of each of these categories. The properties of these five representative LRDs, all of which are also members of the dG25UB25 sample, are listed in Table 3 (“AGN-agnostic” column). The fits for the rest of the objects, divided in categories, can be consulted in Appendix B.

The galaxy showcasing the BH* class is located in the JADES fields. The parameters defining this LRD resemble those found for *The Cliff* in M26, classified as BH* in this work. Our results point to a low-mass, star-forming, metal-poor host subject to a moderate level of dust attenuation (~ 0.5 mag), and a temperature of the envelope $\sim 4,700$ K. This LRD was also studied in B25 and dG25. B25 reported values of $\log M_*/M_\odot = 8.57 \pm 0.89$ and $A_V = 0.39 \pm 0.17$ mag, which are compatible with our results within uncertainties. dG25 found a modified-BB temperature of 4097^{+186}_{-4021} K, ~ 600 K colder than our results, although both temperatures are consistent with the theoretical expectations from the BH* model.

The LRD showcasing the BH*-AGN leaks class is from NEXUS. In this case, the host is more massive ($\sim 10^{9.4} M_\odot$) than *The Cliff*. The level of dust attenuation matches the BH* example, with a slightly warmer envelope temperature of $\sim 5,000$ K. This LRD was included in dG25, but no temperature is reported

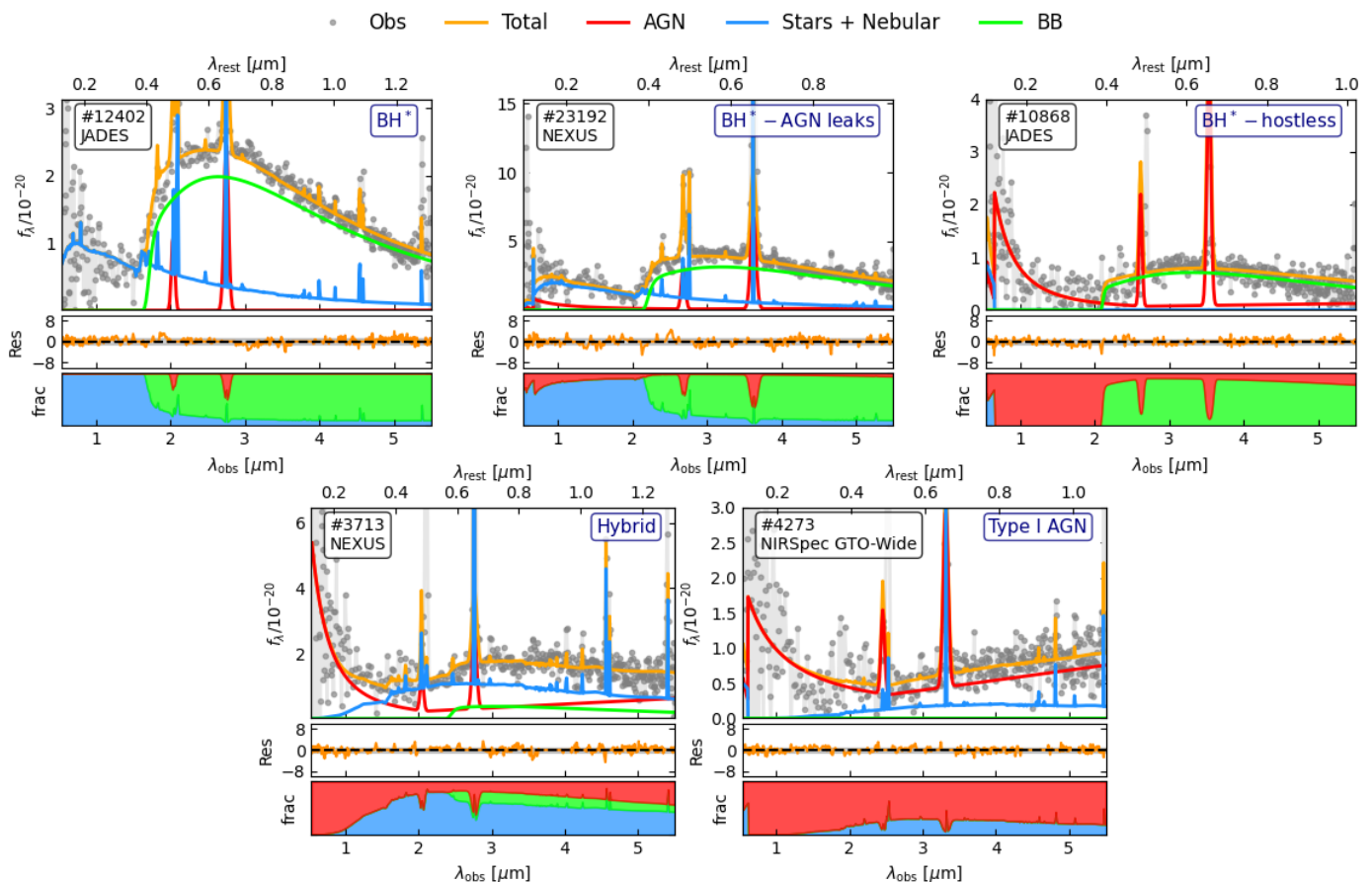


Fig. 3: Best-fitting models from *Bagpipes* (“AGN-agnostic” approach) based on the continuum emission of a subset of 5 LRDs, that are illustrative of the BH*, BH*-AGN leaks, BH*-hostless, Hybrid, and Type I AGN categories (see Table 2 and Sect. 4.1). Fluxes in all panels are expressed in units of $\text{erg/s/cm}^2/\text{\AA}$. In each panel, the top row shows the observed spectrum (gray), the total best-fitting model (orange), the AGN component (red), the stellar + nebular component, attenuated by dust (blue), and the composite of the BB and Balmer absorption (green). The associated DJA identifiers and surveys are included at the top. The residuals of the fit are plotted in the second row. The shaded gray region depicts the standard deviation. The fractional contribution of each component to the total best-fitting model is displayed in the last row, following the same color code as above. In the “AGN-agnostic” setup, we get many different combinations of AGN + stars + BB emission, most of them not meeting the BH* model requirements.

by these authors, as their analysis of the envelope was only performed on LRDs at $z < 4$.

The LRD exemplifying the BH*-hostless class is located in the JADES fields. The host parameters show how *Bagpipes* is opting for a negligible stellar contribution while pushing for an AGN + BB solution. The code does this by increasing the dust to eliminate the host contribution to the UV continuum and then reducing the M_* and SFR_{100} (i.e., the SFR measured on a 100 Myr timescale). The lack of stellar constraints is also reflected in the broad 16th-50th-84th percentile range. In terms of the BB temperature, we retrieve a $\sim 4,800$ K value, in line with the estimates for the previous categories. This LRD was studied in *dG25*, who reported a modified-BB temperature of $2,758_{2,533}^{2,990}$ K, much lower than our value and far from the typical range of temperatures expected from the BH* theory (see Sect. 1).

As an example of a *Hybrid* object, which constitutes the most numerous class in our sample, we show an LRD from NEXUS. The M_* is larger in this source than in the other examples, as well as the A_V , which in this case is not an artifact produced by the code to remove the stellar component. Rather, it is a mechanism that suppresses the host’s contribution to the UV, which is in turn mainly powered by the AGN. The BB plays a minor role

in the optical continuum, with the stellar and AGN components being the primary drivers instead. The BB peak is further away from the “V” shape inflection point, resulting in a lower temperature of $\sim 4,000$ K. This value is consistent with the temperature reported in *dG25*, of $4,205_{3,985}^{4,597}$ K.

Lastly, we show an example of a Type I AGN LRD, in which a BB component is not required by the fit. This LRD is from the NIRSpect GTO-Wide and corresponds to a massive, star-forming, and dusty galaxy. In this case, the temperature of the BB is not being constrained, as highlighted by the broad 16th-50th-84th percentile range and the low normalization factor. This object was also studied in *B25*, who reported values of $\log M_*/M_\odot = 8.39 \pm 0.74$ and $A_V = 0.01 \pm 0.13$ mag, depicting a dust-free and ~ 1 dex less massive host. The temperature reported in *dG25* is $5,070_{4,373}^{5,785}$ K.

4.2. Physical properties

The properties derived following the methodology of *M26* for the 66 galaxies in our sample are displayed in Fig. 4. Hereafter, we will focus on the LRDs with statistically reliable fits based

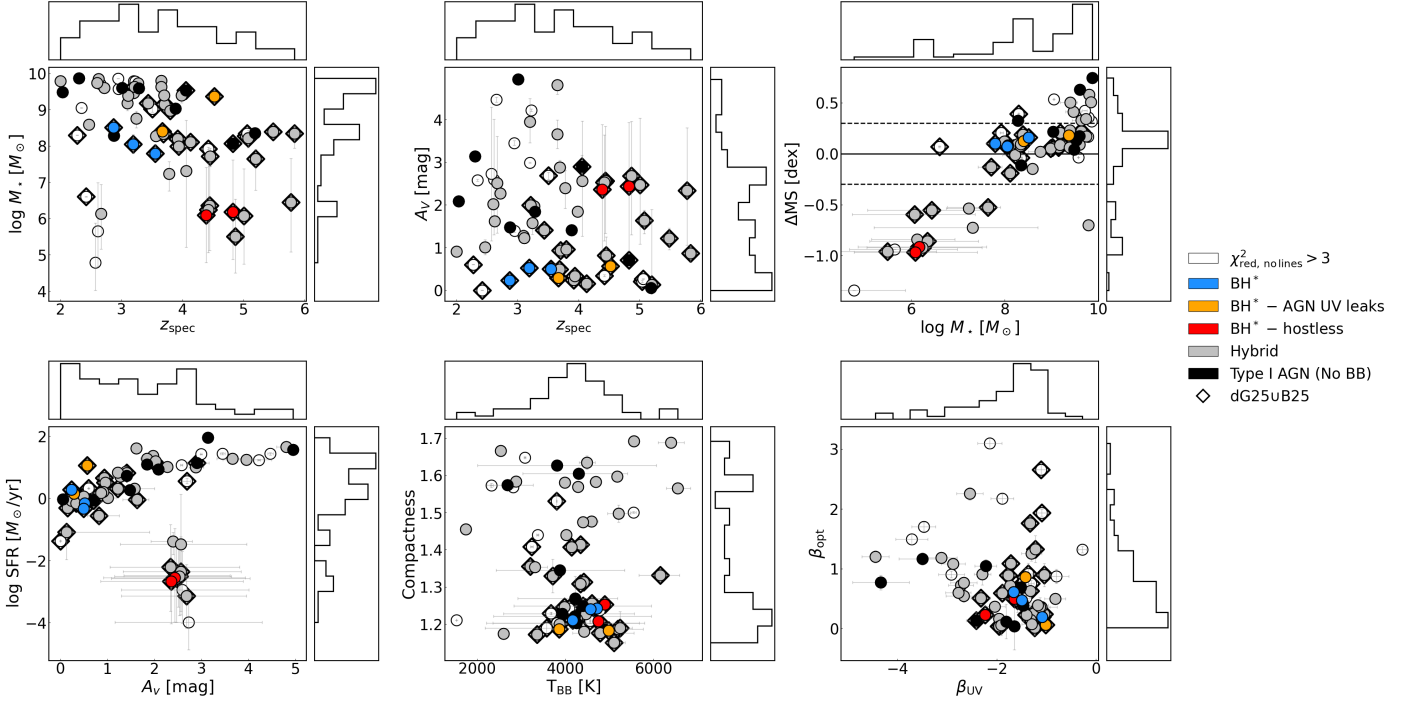


Fig. 4: Properties of our sample obtained following M26 using broad priors (“AGN-agnostic” approach). From left to right and top to bottom: stellar mass M_\star vs z_{spec} , dust attenuation A_V vs z_{spec} , distance to the Main Sequence ΔMS vs M_\star , star formation rate vs A_V , compactness vs BB temperature, and optical vs UV observed slopes. In every plot, we represent $\chi^2_{\text{red}} > 3$ fits with empty markers, whereas filled markers correspond to $\chi^2_{\text{red}} < 3$ fits (52 LRDs). Blue denotes galaxies in the BH* class, orange highlights LRDs in the BH*-AGN leaks class, red denotes the BH*-hostless class, Hybrid objects are represented in silver, and Type I AGN systems are plotted in black. Galaxies in common with dG25uB25 are highlighted with diamond markers. We include histograms in every panel, derived from the total sample made up of 66 LRDs. ΔMS values are offsets from the star-forming Main Sequence relation of Mérida et al. (2026c) fits. The dashed lines denote the typical MS scatter, $\Delta \text{MS} \sim 0.3$ dex.

on the χ^2_{red} values (i.e., 52 galaxies out of the total sample of 66 LRDs). A summary of their median properties, distinguishing between classes, can be consulted in Appendix C.

The evolution of the M_\star with z shows that more massive objects appeared at more recent times, with $M_\star > 10^9 M_\odot$ retrieved at $z \lesssim 4$. The median M_\star of the sample is $\sim 10^{8.4} M_\odot$, with the majority of more massive galaxies corresponding to Hybrid and Type I AGN-like systems. There is also a subpopulation of galaxies displaying $M_\star \sim 10^6 M_\odot$, which are systems in which the stellar component is not being constrained by the code.

Bearing in mind that only the Hybrid and Type I AGN classes are sufficiently populated, we see that the objects of the BH* class, represented in blue, lie at $z < 4$ whereas the LRDs in the other quasi-BH* categories (-AGN leaks and -hostless, in orange and red) are located at $z \gtrsim 4$. The median M_\star of these LRDs, not considering the -hostless class, is $\sim 10^8 M_\odot$. Type I AGN-like systems and LRDs in the Hybrid category are spread across all M_\star and z , with Type I AGN-like galaxies showing median M_\star values of $\sim 10^{9.3} M_\odot$ and Hybrid LRDs $M_\star \sim 10^{8.4} M_\odot$.

In terms of dust attenuation, $A_V > 1$ mag values correspond to objects in the Hybrid and Type I AGN categories (in the BH*-hostless class, dust is used as an artifact to remove the stellar contribution to the fit). Objects in the BH* and BH*-AGN leaks classes display a median $A_V \sim 0.5$ mag, in line with the results presented in M26 for *The Cliff*.

We also studied the star-forming nature of these galaxies, comparing it with the secular evolution of galaxies on the star-forming Main Sequence (MS). This calculation is based on the MS fits from Mérida et al. (2026c) for low-mass galaxies. Let

us note that these fits were derived using a mass-complete sample that reaches down to $10^8 M_\odot$ at $2 < z < 2.5$ ($10^{8.6} M_\odot$ at $5 < z < 7$) and thus estimates for lower-mass galaxies are based on extrapolations of these fits. On average, our sample is consistent with secular evolution (median $\Delta \text{MS} \sim 0.1$ dex, with ΔMS being the distance to the MS). LRDs in the BH*-hostless category fall below the MS ($\Delta \text{MS} \sim -1$ dex, although neither SFR nor M_\star are being well constrained by the code), and some Hybrid and Type I AGN objects lie below and above the typical MS scatter (i.e., $\Delta \text{MS} \sim 0.3$ dex). Galaxies with the highest SFR values also correspond to objects with the largest A_V values, pointing to obscured SFR in those systems.

In terms of the envelope temperature, our sample is concentrated around $\sim 4,500$ K, with BH*-hostless LRDs showing slightly warmer temperatures ($\sim 4,800$ K). When analyzing compactness, only sources in the Type I AGN and Hybrid classes are found close to the compactness limit (i.e., $f(0.5'')/f(0.3'') = 1.7$, with f being the flux at $F444W$). Conversely, most of the sources exhibit $f(0.5'')/f(0.3'') < 1.3$ values.

Our classification does not yield clear delimitations or trajectories in the β_{opt} vs β_{UV} diagram. Only some Type I AGNs and Hybrid objects are located farther from the bulk of the points, which are concentrated at $\beta_{\text{opt}} < 1$.

These results demonstrate that the physical properties of LRDs can vary significantly, with only a few LRD hosts matching the characteristics of a low-mass, metal-poor, low-dust galaxy. Furthermore, only a few LRDs satisfy the overall requirements of the BH* model. In Sect. 5.1 we explore the phys-

ical implications of our solutions, while in Sect. 5.2 we modify our method to force a BH* scenario across the entire the sample.

5. Discussion

5.1. Viability of the current solution

As mentioned in Sect. 3, our method involves using broad priors and providing all the necessary ingredients to produce the BH* scenario, should it be supported by the data, while still allowing `Bagpipes` to converge on a different, non-BH* best-fitting solution. This means that we are not imposing any particular physical scenario, and the solutions are data-driven only.

In a small number of cases, `Bagpipes` indeed naturally yields a BH* configuration ($\sim 5,000$ K BB emission and a low-mass, low- A_V host galaxy). However, most of the LRDs in our sample do not fully meet the requirements of the BH* model, yet we still obtain statistically robust fits. Nevertheless, mathematical robustness does not imply physical robustness; it is important to compare our results with additional observables. For example, past attempts to fit the UV-to-optical emission of LRDs based on composite models consisting of stars and AGN emission, with no gas envelope, yielded good fits in some LRDs (e.g., Mérida et al. 2025, Tripodi et al. 2025b). However, the high A_V values obtained in some of these studies (and high M_* in some cases) often exceeded those expected based on the observed dust masses in LRDs (see Casey et al. 2024, Setton et al. 2025b). In our particular case, some of the solutions presented in Sect. 4 also require high A_V values, which would likewise be difficult to reconcile with these dust masses observations.

Furthermore, our model yields different AGN contributions to the UV, ranging from 0 to 100% of the total UV flux. However, if the host galaxy were resolved in the UV (see Chen et al. 2025a, Rinaldi et al. 2025, Cloonan et al. 2026), this emission could be attributed to the host galaxy. The presence of an extended emission in the UV would therefore call into question a potential AGN origin of the UV emission. In this subsection, we examine the validity of our solutions in light of these physical considerations.

5.1.1. Dust attenuation

From the BH* perspective, LRD hosts are dust-free/low- A_V systems. In M26, we inferred dust attenuation values for *The Cliff* from its UV-to-optical SED, obtaining $A_V \sim 0.5-1$ mag depending on the adopted attenuation law (see also PG26). Based on the infrared (IR)-to-submillimeter emission of LRDs, Chen et al. (2025b) estimated A_V upper limits for these objects using data from the JWST Mid-Infrared Instrument, *Herschel*, and the Atacama Large Millimeter/submillimeter Array. They obtained values of $A_V \leq 1-1.5$ mag (depending on the dust attenuation law selected) for the brightest LRDs to date, A2744-45924 (Labbe et al. 2024) and RUBIES-BLAGN-1 (Wang et al. 2025), as well as for stacked SEDs from a large sample of LRDs. Consequently, some level of dust attenuation is permitted from both the UV-to-optical and IR-to-submillimeter perspectives, but this quantity is subject to stringent constraints.

Looking at Fig. 4, we see that the objects from the BH* and BH*-AGN leaks categories, as well as some Type I AGN and Hybrid LRDs, agree well with the upper limits derived by Chen et al. (2025b). In the BH*-hostless case, the A_V is a mathematical artifact of the code, but there are many Hybrid and Type I AGNs LRDs that exhibit $A_V > 1.5$ mag, pointing to potentially nonphysical solutions.

However, note that Chen et al. (2025b) computed their A_V upper limits by considering different dust distribution parameters: n_0 and γ . Here, n_0 is the density at the inner edge of the radial density profile, and γ is the power-law index. In other words, they used a range of values to control the normalization and concentration of the dust density profile. Their $A_V \leq 1-1.5$ mag upper limit is based on the assumption of concentrated density profiles ($\gamma \geq 1$), as the high-density regime allows for significantly lower dust masses. However, less restrictive A_V upper limits are obtained for flat density profiles ($\gamma \sim 0$) with $n_0 \sim 10-30 \text{ cm}^{-3}$.

While these alternative values for the A_V upper limits are still incompatible with the dust-obscured AGN scenario (Wang et al. 2024) (i.e., a scenario without a gas envelope, which would require $A_V \sim 3$ mag), they are consistent with $A_V \sim 1.4$ mag using the SMC law, $A_V \sim 1.9$ mag using a Milky Way dust law, and $A_V \sim 2.4$ mag using an Orion Nebula dust law in the case of RUBIES-BLAGN-1. Therefore, depending on the dust law and dust configuration, A_V values such as those reported in Fig. 4 could be physically realistic in some cases.

Nevertheless, Chen et al. (2025b) caution that such profiles may represent unphysical configurations. They point out that, if the density profile connects the BLR and dust sublimation scales, flat profiles are unlikely. Therefore, alternative scenarios invoking lower A_V values should be explored for the highly attenuated LRDs in our sample.

5.1.2. UV morphology

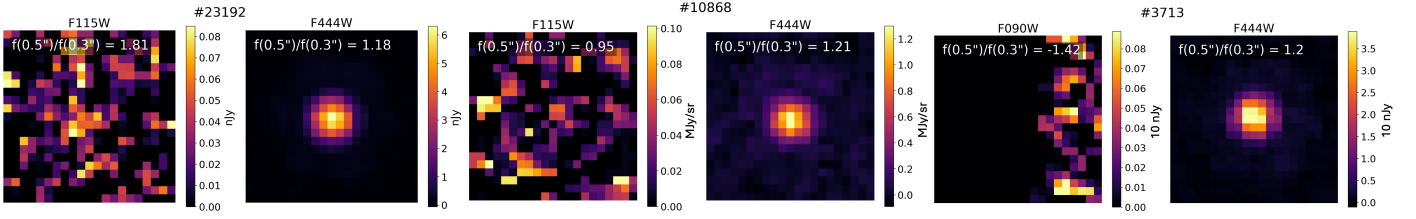
We investigated the UV morphology of the potential LRDs' galaxy hosts to explore the probable origin of the UV emission. If the host galaxy were resolved, the UV emission would predominantly originate from the stellar component, ruling out an AGN origin (or at least the AGN as the primary mechanism). However, an unresolved host would not provide conclusive evidence, as in that case the galaxy may simply be too faint to be detected.

For this exercise, for each LRD in the sample, we selected the NIRCcam band closest to the rest-frame UV range and compared the normalized radial profile of the LRD within a radius of $0.5''$ with that of the point spread function (PSF). The PSFs were taken from the library of simulated NIRCcam PSFs provided by the Space Telescope Institute and produced using the Space Telescope PSF package (Perrin et al. 2014). These are not PSFs extracted empirically for each image. However, they should suffice here as our aim is not to carry out a detailed study of UV morphologies, but rather to detect potential emission that is incompatible with a PSF-like profile.

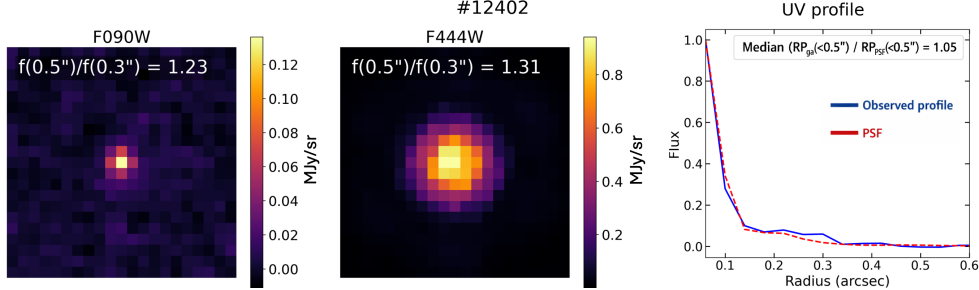
Figure 5 shows cutouts in the rest-frame UV of the objects described in Sect. 4.1 and displayed in Fig. 3. Overall, we did not find UV coverage for some LRDs, such as object #3713, classified as Hybrid. In other cases, such as in objects #23192 and #10868 belonging to the BH*-AGN leaks and -hostless classes, respectively, the image is too noisy. In neither of these cases can we rule out any UV origin.

We could study the UV radial profiles of objects #12402 and #4273, belonging to the BH* and Type I AGN classes, respectively. The profile of object #12402 is consistent with the PSF and the unresolved nature of the UV emission, with $f(0.5'')/f(0.3'') = 1.23$ and f being the flux in the rest-frame UV. Therefore, stellar and stellar+AGN origins remain degenerate solutions for this LRD.

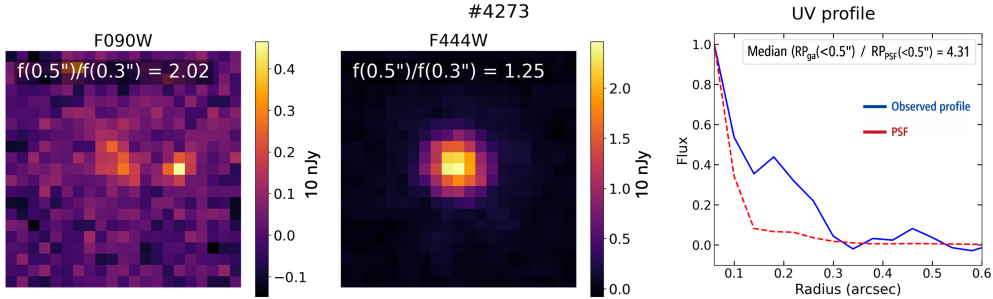
LRD #4273 exhibits signs of complex and extended UV morphology ($f(0.5'')/f(0.3'') = 2.02$ in *F090W*), indicating the presence of two potential clumps or galaxies. The rightmost



(a) Rest-frame UV and $F444W$ cutouts of LRDs #23192, #10868, and #3713, which belong to the BH*-AGN leaks, BH*-hostless, and Hybrid categories, respectively.



(b) Rest-frame UV and $F444W$ cutouts followed by the radial profile in the rest-frame UV of source #12402, which belongs to the BH* category.



(c) Rest-frame UV and $F444W$ cutouts followed by the radial profile in the rest-frame UV of source #4273, which belongs to the Type I AGN category.

Fig. 5: 0.8×0.8 arcsec² cutouts in the rest-frame UV ($F090W$ or $F115W$) and $F444W$ of the LRDs displayed in Fig. 3. In the legend, we show the ratio of the flux measured in that band using 0.5 and 0.3'' apertures. Panels (b) and (c) also include the UV radial profile (blue) compared to the PSF (red), as well as the median ratio of these two curves, as measured for radii $< 0.5''$. While the UV morphology is sometimes difficult to measure due to noise, we can identify structure in some objects. In a minority of cases, we see hints of a potential resolved galaxy host (e.g., #4273).

component corresponds to either a companion/interacting galaxy (see Chen et al. 2025a, Golubchik et al. 2025, Mérida et al. 2025, Baggen et al. 2026) or a projected foreground source. It is quite challenging to derive a robust photo- z for this potential companion, as the small projected separation ($\sim 0.2''$, corresponding to ~ 1.5 kpc at $z = 4.05$) likely leads to contamination of the longer-wavelength photometry. Nevertheless, at $z = 4.05$ galaxies are V -band dropouts and, in this case, both clumps remain undetected in the $F435W$ band of the *Hubble Space Telescope*. Consequently, the observed UV emission may arise from the combined contribution of the two clumps or galaxies associated with the LRD system.

Under this interpretation, a dominant stellar contribution to the UV emission appears more plausible. However, the best-fitting solution for this object, shown in Fig. 3, attributes most of the UV flux to the AGN continuum, suggesting that this solution may not provide a physically realistic description of this LRD and that alternative approaches should be considered.

Note, however, that most of the objects in our sample remain undetected or unresolved in the rest-frame UV. We found two additional LRDs with potential host signatures, #23438 and #53757, also included in dG25UB25 and classified as Hybrid in Sect. 4.1. To delve deeper into alternative solutions likely involv-

ing lower A_V values and reducing the role played by the AGN continuum in the fit, we will explore a modification of our current fitting method in Sect. 5.2.

5.2. Forcing a BH* scenario

The original method presented in M26 is based on the assumption of broad priors for all the components. This enables Bagpipes to identify the best-fitting model based on the data, and allows potential AGN continuum contribution to the model flux. In Sect. 4, we show that following this permissive approach the BH* is only recovered in a subset of objects. In most cases the solutions do not align with the BH* framework requirements, yielding instead high levels of dust attenuation and AGN UV leakage in some LRDs. This high level of dust may conflict with the A_V upper limits inferred from the typical IR-to-submillimeter emission of LRDs (Chen et al. 2025b), as well as the potential resolved UV emission detected in some of them (see Sect. 5.1).

In order to prevent potential AGN leakage and limit A_V , in this subsection we repeat the analysis performed in Sect. 4 with one key difference: we manually suppress the AGN continuum. We do this by lowering the $f5100A$ parameter, imposing a range

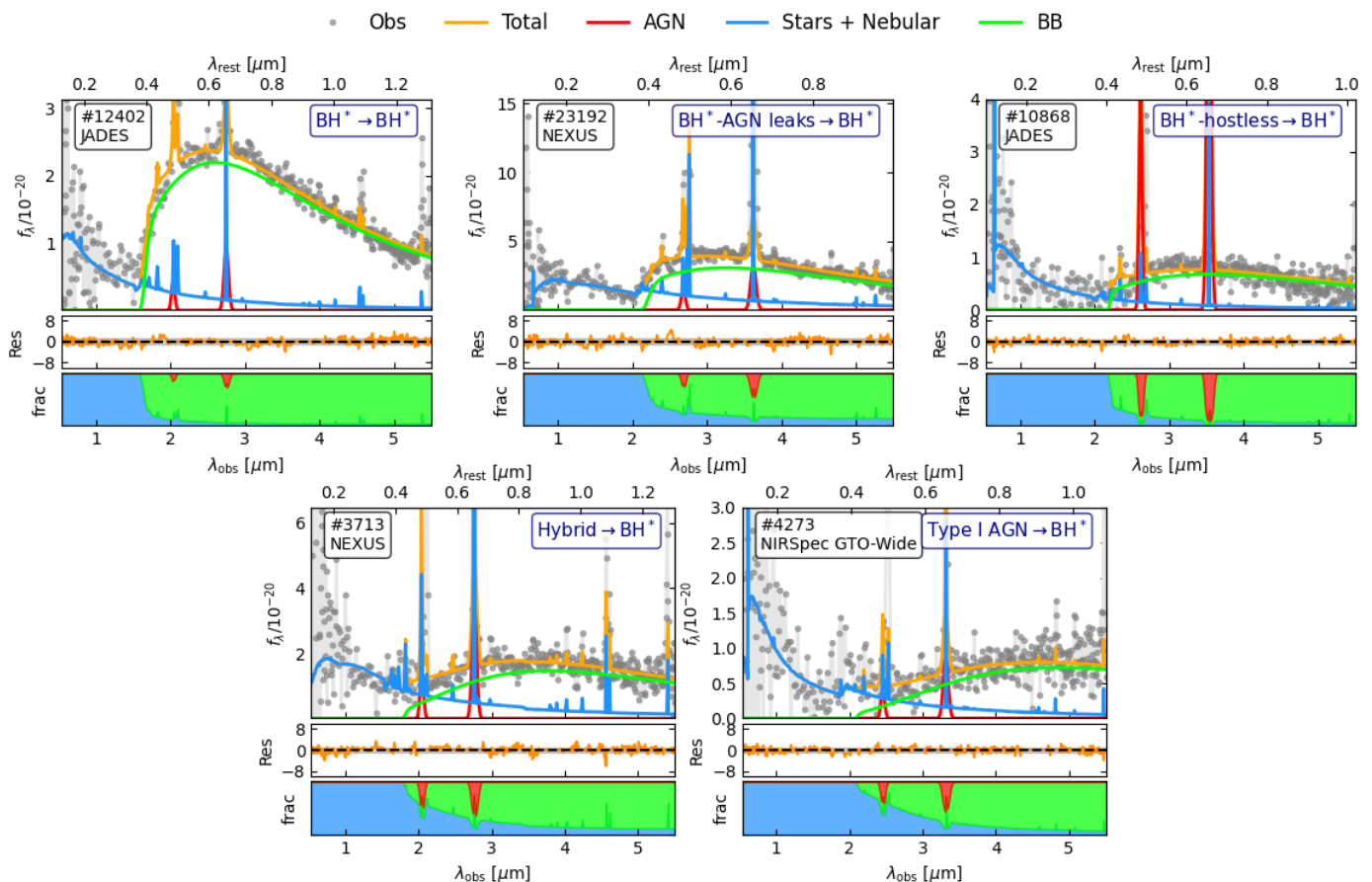


Fig. 6: Best-fitting models from Bagpipes based on the continuum of the LRD subset displayed in Fig. 3 obtained after suppressing the AGN continuum in the fit. See Fig. 3 for a full description of the markers and color codes shown here. In the legend, we specify the classes (see Table 2) based on the AGN-agnostic method. The new class that results from suppressing the AGN in the fit is indicated with an arrow. In this case, all the objects belong to the BH* class when suppressing the AGN in the code.

of $[0, 5 \times 10^{-24}]$ erg/s/cm²/Å instead. The rest of the priors were left unchanged (see Table 1).

As a result of this new approach (which we refer to as “AGN-suppressed”), we obtained 51 fits with $\chi_{\text{red}}^2 < 3$. We include a comparison of the properties reported in this subsection with those from dG25UB25 in Appendix A. Following the criteria listed in Table 2, 21 LRDs are now classified as BH*, 29 belong to the Hybrid class, and 1 corresponds to the Type I AGN class. The other two classes, BH*-AGN leaks and -hostless, remain empty by construction of the model. In this case, the object in the Type I AGN class corresponds to a galaxy whose continuum is purely stellar, whereas Hybrid objects display an optical continuum that is not dominated by the BB component, but have significant contributions from the galaxy host.

Figure 6 shows the LRDs displayed previously in Fig. 3, together with the new best-fitting models. Table 3 shows a full list of their properties (“AGN-suppressed” column). Best-fitting models for the rest of the objects based on this approach, distinguishing between classes, can be consulted in Appendix D.

The χ_{red}^2 values obtained for these and the rest of the LRDs in the sample do not differ significantly from those reported in Sect. 4.1, making the “AGN-agnostic” and “AGN-suppressed” solutions statistically degenerate. Additional observational constraints are therefore required to resolve this conflict.

The solution for LRD #12402, which was also previously classified as BH*, remains consistent with the results presented

in Sect. 4.1. LRD #23192, classified as BH*-AGN leaks under the “AGN-agnostic” configuration, now belongs to the BH* class, with a galaxy host that is ~ 0.8 dex less massive than before, and that exhibits the same amount of dust attenuation and a similar BB temperature.

Object #10868, classified as BH*-hostless in Sect. 4.1, is fitted with a dust-free $\sim 10^{7.6} M_{\odot}$ galaxy host. The temperature in this case is lower by ~ 200 K. LRD #3713, which showcased the Hybrid category, now corresponds to a galaxy that’s ~ 1.6 dex less massive than before, with a dust attenuation $A_V \sim 0.58$ mag, now in line with a *Cliff*-like level of dust. However, the temperature is ~ 600 K colder than the value reported in Sect. 4.1. Finally, object #4273, which exemplified the Type I AGN category in Sect. 4.1 and shows hints of a complex UV morphology (see Sect. 5.1.2), is now a ~ 1 dex less massive galaxy subject to low dust attenuation ($A_V \sim 0.3$ mag).

In these last three examples (#10868 BH*-hostless, #3713 Hybrid, and #4273 Type I AGN), suppressing the AGN continuum results in lower dust attenuation levels, in line with the numbers discussed in Sect. 5.1.1. While the BB temperatures in LRDs #12402 and #23192 (BH* and BH*-AGN leaks) remain unchanged when the AGN is suppressed, the temperatures for the objects previously classified as BH*-hostless and Hybrid are lower than those reported in Sect. 4.1.

For objects #3713 and #4273 (Hybrid and Type I AGN), the stellar component now contributes significantly to the optical

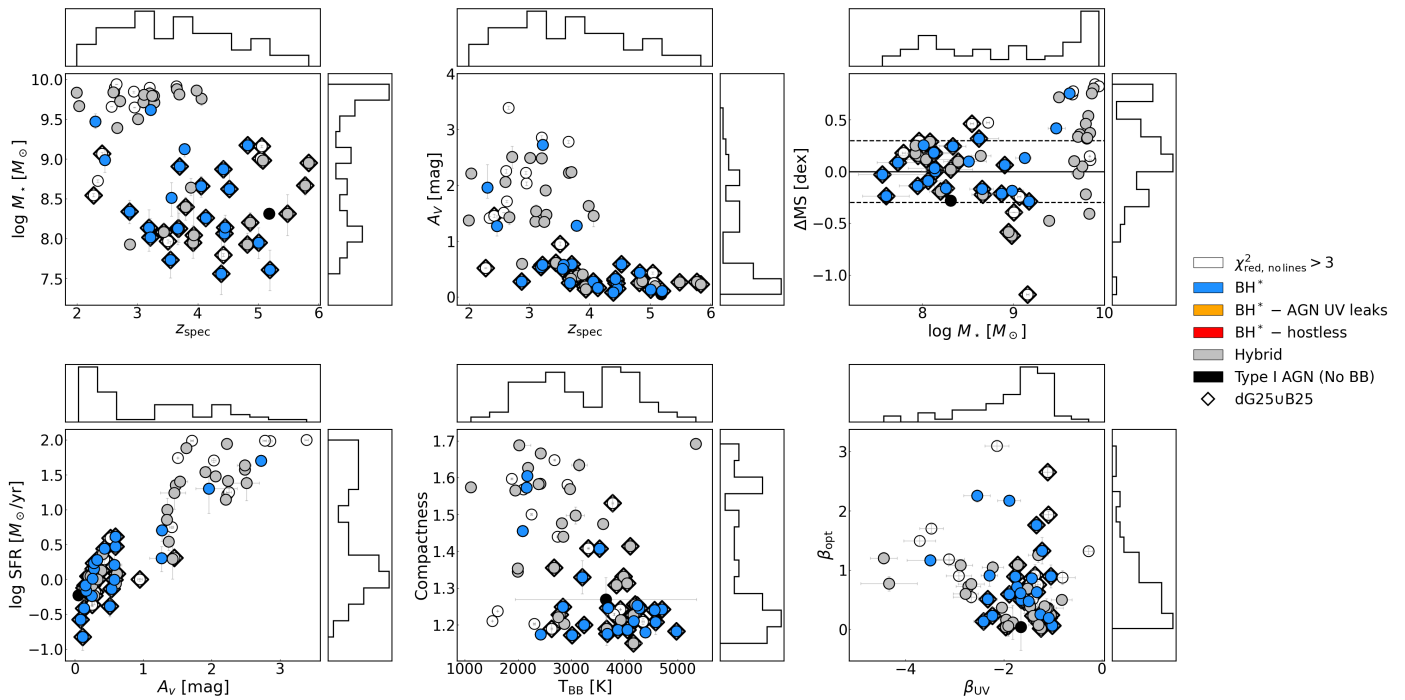


Fig. 7: Properties of our sample after suppressing the AGN continuum. From left to right and top to bottom: stellar mass M_* vs z_{spec} , dust attenuation A_V vs z_{spec} , distance to the Main Sequence ΔMS vs M_* , star formation rate vs A_V , compactness vs BB temperature, and optical vs UV observed slopes. See Fig. 4 for a full description of the markers and color codes shown here.

continuum close to the Balmer limit. Consequently, under the “AGN-suppressed” approach the BB peak shifts to longer wavelengths (i.e., colder temperatures) in these LRDs.

5.2.1. Physical properties. AGN-agnostic vs AGN-suppressed

By suppressing the AGN component during the fitting process, the BH* scenario is effectively enforced. As a consequence, lower M_* and A_V values, together with colder temperatures, tend to be favored. In this subsection, we examine the properties of the full sample to assess whether these trends become statistically significant when increasing the sample size.

Figure 7 presents the inferred properties of the full LRD sample obtained with this “AGN-suppressed” approach, analogous to Fig. 4, which is based on the “AGN-agnostic” method. A summary of the median properties of the sample using the AGN-suppressed method is also included in Appendix C.

Examining the diagrams reveals two distinct subpopulations. On the one hand, there are LRDs with $M_* < 10^9 M_\odot$ that are subject to moderate to low dust attenuations ($A_V \sim 1$ mag) and lie within the MS scatter. These are compact sources with BB temperatures around $\sim 4,500$ K, showing some scatter towards colder temperatures. This first subpopulation aligns with the expectations of the BH* model.

On the other hand, there is a subpopulation of massive ($\sim 10^9\text{--}10^{10} M_\odot$) and dusty systems ($A_V > 1.5$ mag), some of them starbursts. These are also less compact objects. This subpopulation mainly comprises LRDs in the Hybrid category according to the “AGN-suppressed” approach, where the BB component is subdominant to the stars in the optical. Within this massive and dusty subpopulation, there are also two LRDs now classified as BH* systems, #1333 and #20152, neither of them studied in dG25uB25. These LRDs were previously classified as Hy-

brid and Type I AGN in Sect. 4.1. They have complex continua, showing evidence for Paschen Jumps, which makes it difficult to constrain the full optical continuum with a single temperature.

Paschen jumps in LRDs were also explored in Sneppen et al. (2026), who report evidence for this feature in a subset of LRDs, consistent with free-bound recombination to hydrogen $n = 3$. In LRDs with the strongest jumps, they found that simple BB emission can reproduce the Brackett continuum or the very bluest Paschen continuum emission. However, it cannot smoothly fit both wavelength regimes, pointing to the need for more sophisticated models.

Figure 8 compares the M_* , A_V , and BB temperatures obtained using the AGN-agnostic and AGN-suppressed methods. Most objects that required high M_* values in the AGN-agnostic scenario are still massive after suppressing the AGN continuum. LRDs compatible with being BH*-hostless (including some Hybrid objects) are assigned larger M_* when the BH* scenario is forced. In many cases, estimates of A_V agree between methods. LRDs that exhibited high A_V values in the AGN-agnostic scenario are now assigned lower values. However, there are still some instances in which $A_V > 1.5$.

In summary, suppressing the AGN does not automatically lead to the BH* scenario. Although the AGN contribution to the UV continuum is excluded by design, a significant contribution from an additional component (i.e., stellar emission) is often still required in many LRDs to reproduce the optical continuum. In some cases, large A_V values are still inferred that are difficult to reconcile with the observed dust masses in LRDs (see Sect. 5.1.2). While some of these LRDs may simply not be compact enough under alternative LRD classifications, the persistence of a substantial Hybrid population, even in the AGN-suppressed scenario, may indicate intrinsic diversity or an evolutionary sequence within the LRD population. In the following

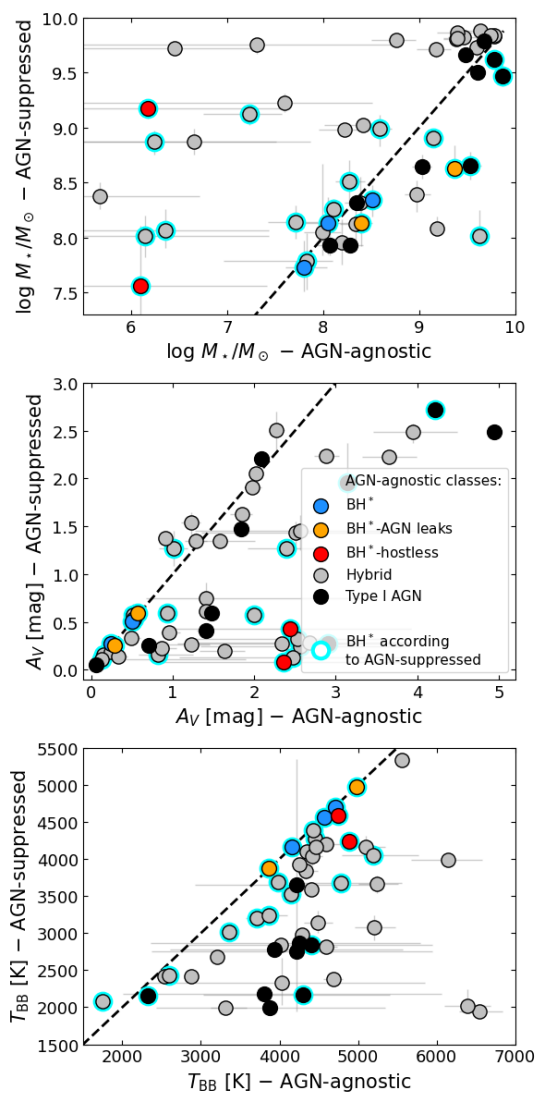


Fig. 8: A comparison of the M_* (top), A_V (middle), and BB temperature (bottom) is shown for the AGN-agnostic and AGN-suppressed methods. Only results in which $\chi_{\text{red}}^2 < 3$ according to both methods (51 LRDs in total) are included. Markers are color-coded following the classification based on the AGN-agnostic results. Objects that are classified as BH* systems according to the AGN-suppressed method are encircled in cyan.

subsection, we investigate the role of the stellar contribution to the optical continuum in more detail.

5.2.2. A potential evolutionary sequence

Interestingly, suppressing the AGN consistently produces similar or lower BB temperatures, particularly for objects classified as Type I AGNs and Hybrid in the AGN-agnostic scenario (see Fig. 8). Colder BB temperatures are usually accompanied by a larger stellar contribution to the optical continuum, as noted in Fig. 6. It remains to be explored whether this interplay between the stellar and BB contributions is a sign of evolution in LRDs or just a feature of a subpopulation of these objects.

According to the observational work by Billand et al. (2026), the decline in the number density of LRDs over cosmic time is driven by the acquisition of a stellar component that settles

in the outskirts. As M_* increases, the characteristic “V” shape fades, and the physical size of the galaxies grows. Similarly, Hainline et al. (2025) propose a trend between luminosity and optical slope, whereby lower-luminosity AGNs display bluer slopes as a consequence of the star-forming host galaxy becoming more dominant in these weak AGNs.

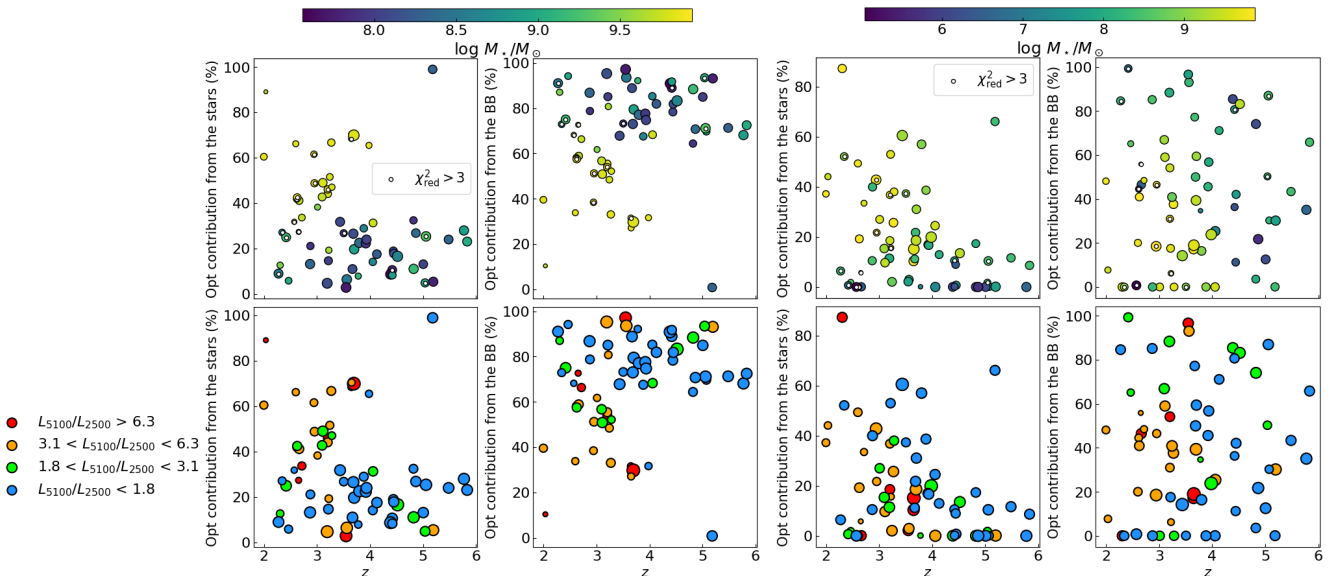
From a theoretical perspective, Kido et al. (2025) propose a different scenario, pointing out that a decrease in the rate of infalling mass onto the BH envelope, combined with BH mass growth, could lead to the dissolution of the gas envelope. Likewise, the theoretical work by Inayoshi et al. (2026) argues that supernova explosions from massive stars in nuclear starbursts can inject sufficient energy and momentum to expel gas from the nucleus, quenching the gas supply to the envelope and ultimately driving a transition to a normal AGN phase (see also Mérida et al. 2026a for an observational point of view).

A common feature of these scenarios is the impact of the stellar component, which can either increase the size of the system and make it more extended or indirectly induce the envelope dissolution. In Fig. 9 we investigated whether the stellar contribution evolves with z or if a strong stellar contribution is simply a feature observed in a subpopulation of LRDs regardless of z . We computed this contribution as the median ratio of the model component to the total best-fitting solution in the rest-frame optical.

According to the AGN-suppressed method (top row in panel a) the stellar contribution increases towards lower z , where the most massive galaxy hosts are also located. This increase in the stellar component is negatively correlated with the BB temperature, as shown by the increasingly smaller size of the markers towards lower z , indicating low BB temperatures. The opposite trend to that observed for the stellar component emerges when examining the BB component, whose contribution decreases towards lower z . In other words, the observed decrease in BB temperature toward lower z , together with the increasing stellar contribution and M_* values, may suggest an evolutionary sequence. In this sequence, early LRDs correspond to compact, heavily embedded systems dominated by hot reprocessed emission, while lower- z systems represent more evolved stages where stellar emission progressively emerges as the envelope expands, cools, or disperses.

These trends are more difficult to identify when the AGN-agnostic method is assumed (top row in panel b). While the stellar contribution evolves similarly to panel (a), the BB component does not exhibit a clear trend. The AGN component is also playing a role in this case, as it is not being suppressed, which makes interpretation more challenging. In addition, a considerable fraction of the most massive systems correspond to less reliable fits in both approaches. Despite these limitations, the possibility of an underlying evolutionary sequence remains intriguing and warrants further investigation in future work.

A useful point of comparison is provided by PG26, who also examined the contribution of stars to the optical continuum and the potential role of the host galaxy in LRD evolution. In that study, four LRD subtypes were defined based on the optical-to-UV luminosity ratio of a sample of 249 LRDs at $2.3 < z < 9.3$. As a result of their semi-empirical UV-to-optical spectral fitting (see Sect. 1), they found that the stellar contribution to the optical continuum increases as the optical-to-UV ratio decreases. In other words, the contribution of the host galaxy to the optical continuum increases as the “V” shape becomes less pronounced, with systems such as *The Cliff* showing a negligible stellar contribution to the optical.



(a) Evolution of the BB and stellar contribution to the optical as obtained following the AGN-suppressed method. (b) Evolution of the BB and stellar contribution to the optical as obtained following the AGN-agnostic method.

Fig. 9: Evolution with z of the stellar and BB contribution to the optical flux as derived following the AGN-suppressed (panel a) and AGN-agnostic (panel b) methods, respectively. In both panels, the first row shows the evolution of the components color-coded by M_* . Those objects whose fits have $\chi_{\text{red}}^2 > 3$ are highlighted with a white circle. The second row distinguishes between the 4 LRD subtypes as defined in PG26 based on the optical-to-UV luminosity ratio. The size of the markers in all the panels is defined by the temperature of the BB, with smaller markers corresponding to colder temperatures. The outlier located at $z \sim 5.2$ in panel (a) is the LRD classified as a Type I AGN, which does not exhibit BB emission.

PG26 argue that LRDs such as *The Cliff* would correspond to an early evolutionary phase, after which evolution would progress to bluer LRDs with an increasing stellar contribution. Nevertheless, they point out that discussions on evolutionary pathways based on M_* values are challenging due to the unknown contribution of stars to the rest-frame optical and near-IR. Unlike our observed trend of M_* , their M_* values remain fairly constant across LRD subtypes, with $M_* \sim 10^{8.3} M_\odot$. The dust attenuation acting on the stellar component also remains fairly constant, with $A_V \sim 0.8$ mag. However, our method goes beyond a semi-empirical approach, enabling us to investigate the stellar contribution to the full spectrum. Therefore, the results reported in this work reinforce the idea that LRDs may evolve into more traditional AGN systems as a result of the growth of their host galaxies over cosmic time.

Figure 9 (bottom rows in each panel) also shows the redshift evolution of the stellar and BB components, separating our LRD sample into different subtypes according to the PG26 classification. Focusing on the results from the AGN-suppressed method, we find a trend opposite to that reported in PG26: LRDs with more extreme optical-to-UV ratios tend to exhibit a larger stellar contribution and are preferentially found at lower z . *The Cliff* constitutes a notable exception, with $L_{5100}/L_{2500} > 6.3$ yet a negligible stellar component.

Our results suggest that LRDs with more pronounced “V” shapes may correspond to later evolutionary stages, while systems with stronger UV emission may represent earlier phases in the sequence. Nevertheless, this interpretation should be treated with caution. More massive LRDs are generally associated with poorer fits, and our analysis does not incorporate the information encoded in the emission lines. Moreover, the inferred solutions remain highly degenerate: in most cases, an AGN origin for the UV emission cannot be ruled out.

These findings may therefore indicate the presence of distinct subpopulations within the broader LRD class, superimposed on any putative evolutionary sequence, or may reflect intrinsic limitations of the BH* framework itself. These considerations highlight the need to explore additional models in a UV-to-optical SED fitting framework, such as the Super-Eddington Unification Model (Madau & Maiolino 2026), direct-collapse black holes (e.g. Baggen et al. 2026; Pacucci et al. 2026), or young globular clusters in formation (Chisholm et al. 2026).

6. Conclusions

In this work, we performed a consistent UV-to-optical continuum fitting of 66 LRDs located at $2 < z < 6$ using *JWST*/NIRSpec PRISM spectroscopy from the DAWN *JWST* Archive. Following the method showcased in Mérida et al. (2026b), we employed a modified version of *Bagpipes* that includes BB emission, subject to gas absorption, to test the performance of the BH* model in describing a sample of LRDs.

When the contribution of the AGN is left free in the code (i.e., using broad priors), only $\sim 6\%$ of the LRDs with statistically robust fits match the BH* model’s expectations. Furthermore, none of these LRDs corresponds to a dust-free scenario, requiring ~ 0.5 mag of dust attenuation. $\sim 8\%$ of the LRDs match quasi-BH* configuration. These are systems with BB-dominated optical continua and UV emission driven by AGN + stars (AGN leakage) or totally powered by the AGN (hostless systems). The remaining 86% of LRDs correspond to systems in which the BB does not dominate in the optical, which is, in turn, mainly driven by stars and/or AGN emission.

Forcing a BH*-like solution by manually suppressing the AGN continuum elevates the number of BH* systems to $\sim 40\%$.

However, these solutions are statistically indistinguishable from those obtained with an AGN-agnostic setup, which are more prone to deviating from the BH* scenario. Breaking this degeneracy requires additional observables, such as incorporating IR-to-submillimeter constraints or exploring the UV morphology to search for host signatures. Nevertheless, in most LRDs, these degeneracies are still present.

On the other hand, forcing BH*-like solutions still yields a large fraction of fits in which the optical continuum is dominated by stars rather than by BB emission. While this may indicate limitations of the BH* model, it could also point towards an evolutionary sequence in which the BB contribution gradually decreases as the host galaxy grows, leading to lower BB temperatures and increasing stellar masses toward lower z . This evolution is accompanied by an increase in the optical-to-UV ratio, with the most pronounced “V”-shaped SEDs potentially representing later evolutionary stages. In this picture, LRDs may eventually evolve into more typical star-forming galaxies hosting AGNs at $z < 2$.

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Table 3: Properties derived with Bagpipes following the M26 method using broad priors or suppressing the AGN continuum for the galaxies included in Fig. 3.

	#12402 (JADES)		#23192 (NEXUS)		#10868 (JADES)		#3713 (NEXUS)		#4273 (NIRSpec GTO-Wide)	
	AGN-agnostic	AGN-suppressed	AGN-agnostic	AGN-suppressed	AGN-agnostic	AGN-suppressed	AGN-agnostic	AGN-suppressed	AGN-agnostic	AGN-suppressed
z_{spec}										
$\log M/M_{\odot}$	$8.05^{+0.31}_{-0.78}$	$8.13^{+0.36}_{-0.84}$	$9.37^{+0.44}_{-0.29}$	$8.62^{+0.84}_{-0.54}$	$6.10^{+0.41}_{-0.78}$	$7.56^{+0.10}_{-0.30}$	$9.63^{+0.70}_{-0.57}$	$8.02^{+0.25}_{-0.92}$	$9.53^{+0.65}_{-0.38}$	$8.66^{+0.78}_{-0.52}$
$\log \text{SFR}_{100} [M_{\odot}/\text{yr}]$	$-0.16^{+0.01}_{-0.32}$	$-0.14^{+0.05}_{-0.50}$	$1.06^{+0.12}_{-1.00}$	$0.61^{+0.71}_{-0.56}$	$-2.67^{+1.22}_{-4.03}$	$-0.58^{+0.34}_{-0.73}$	$1.17^{+1.26}_{-1.07}$	$-0.01^{+0.14}_{-0.07}$	$1.14^{+1.26}_{-0.99}$	$0.15^{+0.28}_{-0.02}$
$A_V [\text{mag}]$	$0.52^{+0.59}_{-0.47}$	$0.53^{+0.58}_{-0.48}$	$0.57^{+0.59}_{-0.54}$	$0.59^{+0.62}_{-0.56}$	$2.36^{+0.88}_{-0.86}$	$0.08^{+0.15}_{-0.03}$	$1.99^{+0.09}_{-1.89}$	$0.58^{+0.63}_{-0.53}$	$2.90^{+3.16}_{-2.69}$	$0.28^{+0.35}_{-0.21}$
$\log Z/Z_{\odot}$	$0.017^{+0.041}_{-0.004}$	$0.018^{+0.047}_{-0.005}$	$0.030^{+0.045}_{-0.023}$	$0.170^{+0.187}_{-0.150}$	$0.057^{+0.453}_{-0.006}$	$0.003^{+0.006}_{-0.002}$	$0.011^{+0.022}_{-0.005}$	$0.003^{+0.008}_{-0.002}$	$0.104^{+0.173}_{-0.041}$	$0.137^{+0.231}_{-0.069}$
$\log U$	$-2.29^{+1.38}_{-3.38}$	$-2.15^{+1.21}_{-3.12}$	$-0.29^{+0.12}_{-0.58}$	$-0.45^{+0.27}_{-0.65}$	$-1.80^{+0.73}_{-2.84}$	$-3.05^{+2.12}_{-4.71}$	$-1.45^{+0.50}_{-2.81}$	$-0.78^{+0.26}_{-1.53}$	$-3.36^{+2.84}_{-3.61}$	$-2.58^{+2.15}_{-3.24}$
α_{λ}	$-0.59^{+0.02}_{-1.93}$	$1.09^{+0.58}_{-0.48}$	$-1.98^{+1.65}_{-2.31}$	$1.06^{+1.60}_{-0.44}$	$-2.69^{+2.58}_{-2.76}$	$0.88^{+0.48}_{-0.36}$	$-2.50^{+2.38}_{-2.62}$	$1.01^{+1.54}_{-0.43}$	$-1.41^{+1.20}_{-1.65}$	$1.03^{+1.63}_{-0.46}$
β_{λ}	$1.11^{+1.36}_{-0.92}$	$1.16^{+1.43}_{-0.94}$	$1.15^{+1.34}_{-0.98}$	$1.16^{+1.43}_{-0.94}$	$0.92^{+1.05}_{-0.84}$	$1.23^{+1.44}_{-0.96}$	$0.90^{+0.98}_{-0.84}$	$1.12^{+1.34}_{-0.93}$	$1.07^{+1.26}_{-0.94}$	$1.18^{+1.45}_{-0.93}$
hanorm [erg/s/cm ²]	$1.63^{+2.00}_{-1.17} \times 10^{-17}$	$1.55^{+1.95}_{-1.12} \times 10^{-17}$	$5.25^{+5.89}_{-4.57} \times 10^{-17}$	$4.46^{+5.25}_{-3.63} \times 10^{-17}$	$4.57^{+6.03}_{-3.02} \times 10^{-17}$	$4.27^{+5.89}_{-2.95} \times 10^{-17}$	$1.09^{+1.74}_{-0.51} \times 10^{-17}$	$1.95^{+2.88}_{-1.02} \times 10^{-17}$	$4.79^{+8.32}_{-2.04} \times 10^{-18}$	$5.01^{+9.55}_{-1.38} \times 10^{-18}$
f5100 [erg/s/cm ² /Å]	$3.09^{+7.08}_{-0.81} \times 10^{-23}$	$2.40^{+3.89}_{-0.91} \times 10^{-24}$	$7.41^{+13.49}_{-2.88} \times 10^{-23}$	$2.34^{+3.98}_{-0.91} \times 10^{-24}$	$2.75^{+3.16}_{-2.51} \times 10^{-21}$	$2.45^{+4.17}_{-0.91} \times 10^{-24}$	$9.55^{+10.47}_{-8.51} \times 10^{-21}$	$2.00^{+3.55}_{-0.87} \times 10^{-24}$	$1.41^{+1.66}_{-1.12} \times 10^{-20}$	$2.19^{+3.84}_{-0.72} \times 10^{-24}$
T _{BB} [K]	4712^{+4733}_{-4687}	4701^{+4721}_{-4676}	4982^{+5005}_{-4956}	4972^{+5000}_{-4950}	4747^{+4821}_{-4690}	4581^{+4656}_{-4511}	3869^{+4098}_{-3688}	3241^{+3274}_{-3205}	4401^{+5948}_{-2831}	2840^{+5919}_{-2757}
A _{BB} [erg/s/cm ²]	$9.33^{+9.33}_{-9.12} \times 10^{-20}$	$9.12^{+9.33}_{-8.91} \times 10^{-20}$	$1.74^{+1.78}_{-1.74} \times 10^{-19}$	$1.82^{+1.86}_{-1.82} \times 10^{-19}$	$3.80^{+3.89}_{-3.80} \times 10^{-20}$	$3.89^{+3.98}_{-3.80} \times 10^{-20}$	$2.34^{+2.57}_{-2.14} \times 10^{-20}$	$6.17^{+6.31}_{-6.03} \times 10^{-20}$	$1.95^{+2.188}_{-1.41} \times 10^{-23}$	$3.80^{+3.98}_{-3.72} \times 10^{-20}$
log N	$19.86^{+20.63}_{-19.29}$	$19.87^{+20.70}_{-19.32}$	$20.29^{+20.88}_{-19.65}$	$19.82^{+20.67}_{-19.23}$	$20.04^{+21.08}_{-19.32}$	$20.30^{+21.78}_{-19.41}$	$23.80^{+23.92}_{-23.61}$	$21.57^{+23.01}_{-20.14}$	$21.36^{+22.75}_{-20.10}$	$20.91^{+22.58}_{-19.61}$
log σ_{B_0}	$-17.16^{+16.39}_{-17.71}$	$-17.10^{+16.32}_{-17.64}$	$-16.96^{+16.26}_{-17.48}$	$-17.32^{+16.69}_{-17.79}$	$-17.12^{+16.22}_{-17.66}$	$-17.01^{+16.04}_{-17.66}$	$-15.20^{+15.07}_{-15.44}$	$-16.66^{+15.74}_{-17.49}$	$-16.50^{+15.76}_{-17.33}$	$-16.66^{+15.74}_{-17.49}$
$\lambda_{\text{break}} [\text{Å}]$	3252^{+3455}_{-3091}	3235^{+3418}_{-3083}	3160^{+3266}_{-3080}	3277^{+3518}_{-3116}	3037^{+3090}_{-3012}	3229^{+3475}_{-3057}	3948^{+3982}_{-3897}	3554^{+3803}_{-3284}	3499^{+3758}_{-3264}	3324^{+3629}_{-3100}
Width [Å]	98^{+99}_{-95}	98^{+99}_{-95}	95^{+99}_{-99}	98^{+99}_{-99}	152^{+125}_{-112}	68^{+73}_{-28}	98^{+99}_{-95}	53^{+73}_{-28}	58^{+67}_{-32}	38^{+67}_{-21}
χ^2_{red}	1.28	1.28	1.62	1.55	0.98	0.86	1.16	1.27	0.86	0.84
$\chi^2_{\text{red,UV}}$	1.44	1.52	1.96	1.94	1.36	1.25	1.43	1.61	1.24	1.09

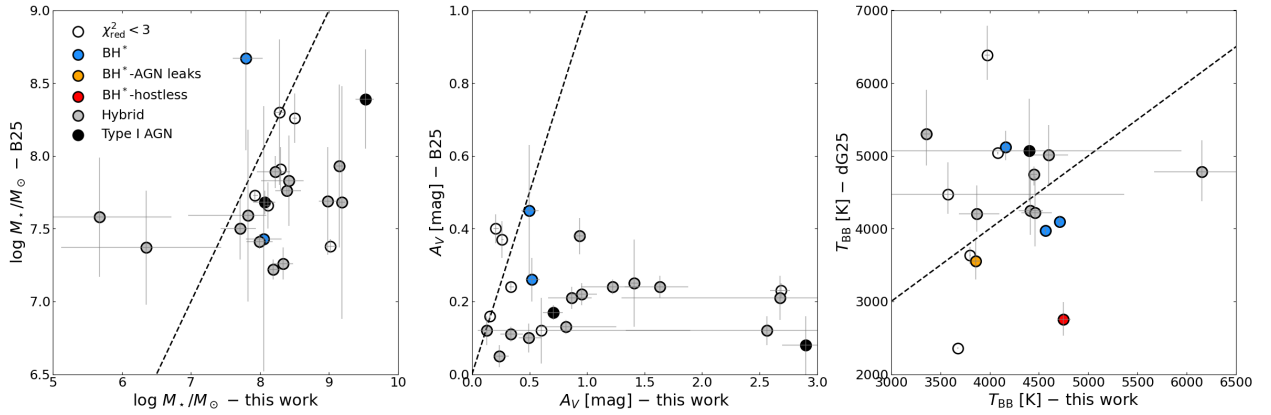
Notes. The values correspond to the median and 16th and 84th percentiles, and are based on fits to the continuum. SFR_{100} corresponds to the SFR measured over the past 100 Myr. We include the reduced χ^2 values associated with the best-fitting models. χ^2_{UV} refers specifically to the UV continuum. For each object, we include two columns. The first includes the results derived using the original M26 method, based on selecting broad priors (AGN-agnostic; see Sects. 3 and 4), whereas the second shows the values obtained once the AGN continuum is manually suppressed (AGN-suppressed; see Sect. 5.2).

Appendix A: Comparison with dG25 and B25

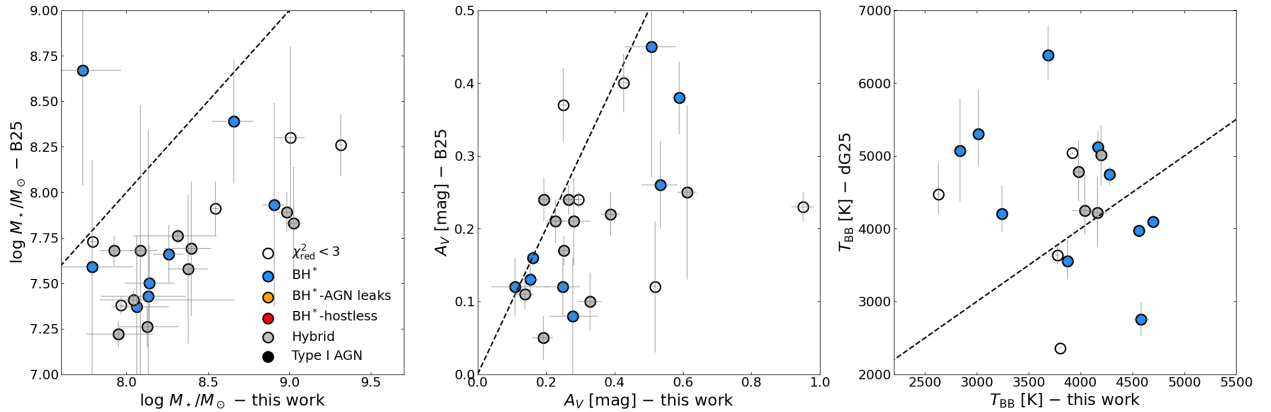
33 of the LRDs studied in dG25UB25 are also included in our sample. 23 LRDs have associated M_\star and A_V values from B25 whereas 18 LRDs have measured temperatures from dG25. Fig. A.1 shows a comparison of the values retrieved in those works and ours, based on the original method presented in M26 (panel a, AGN-agnostic; see Sect. 3), and on the approach introduced in Sect. 5.2, where we force a BH* solution (panel b, AGN-suppressed; see Sect. 5.2).

Looking at the comparison based on the AGN-agnostic method (panel a), we see that our M_\star estimates are overall higher than those reported by B25. However, uncertainties in some of the M_\star values from B25 are quite large, yielding results consistent with the 1:1 line. In terms of A_V , most of our LRDs display higher values than those reported in B25. Comparing the temperatures, in this case extracted from dG25, we see that some values agree with the 1:1 line, but there is significant scatter. We estimated a much warmer temperature for the LRD's envelope in the BH*-hostless class, as mentioned in Sect. 4.1, and ~ 700 K warmer temperatures for 2 of the LRDs in the BH* class.

When imposing a BH*-solution, suppressing the AGN continuum (panel b), the M_\star and A_V values decrease. However, overall, they are still larger than those reported in B25, especially the M_\star values. The scatter in temperatures also increases, with values from dG25 being overall warmer than those we report. It is worth mentioning that none of these studies is directly comparable to ours, as B25 used a semi-empirical approach and dG25 only fitted the optical continuum, in this case using a modified BB. However, these are the only works currently available against which we can compare our results.



(a) Comparison of the properties derived in B25 and dG25 with the values obtained following M26, with a free AGN component (see Sect. 3).



(b) Comparison of the properties derived in B25 and dG25 with the values obtained following M26 but manually suppressing the AGN continuum (see Sect. 5.2).

Fig. A.1: From left to right we show stellar masses, dust attenuations, and BB temperatures. The markers are color-coded following the classification defined in Table 2, depending on the method used (i.e., AGN-agnostic or -suppressed). The AGN-suppressed plots do not contain BH*-AGN leaks and hostless objects by design.

Appendix B: Best-fitting solutions for 52 LRDs - AGN-agnostic method

In this Appendix, we include the solutions for the remaining objects not included in Fig. 3 that satisfy $\chi_{\text{red}}^2 < 3$. In this case, we followed the method presented in M26 and allowed broad priors, not imposing a BH* solution (“AGN-agnostic” method). Figure B.1 shows the fits for the objects in the BH*, BH*-AGN leaks, and BH*-hostless classes, whereas Figs. B.2 and B.3 show the fits for the Type I AGNs and Hybrid LRDs, respectively.

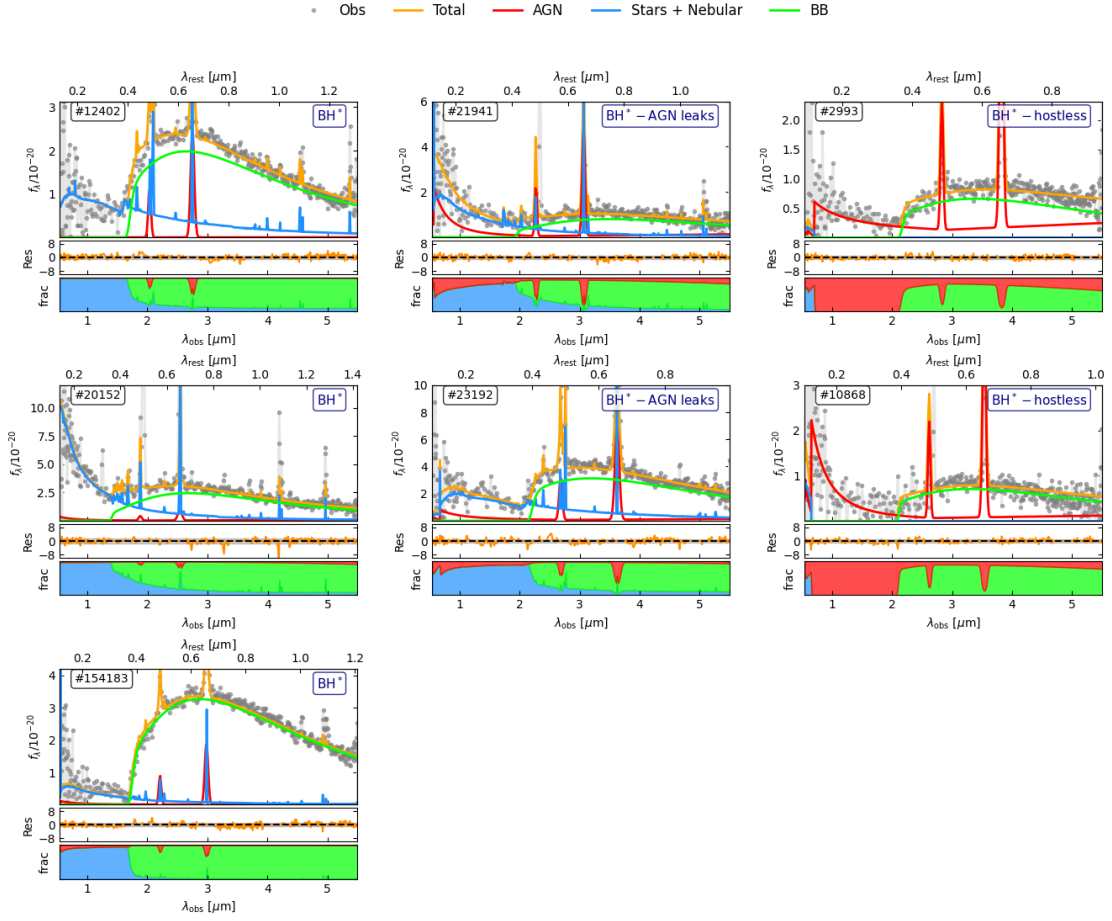


Fig. B.1: Best-fitting models from Bagpipes based on the continuum of the LRDs corresponding to the BH*, BH*-AGN leaks, and BH*-hostless categories (see Table 2 and Sect. 4.1). See Fig. 3 for a description of the markers and color-codes shown here.

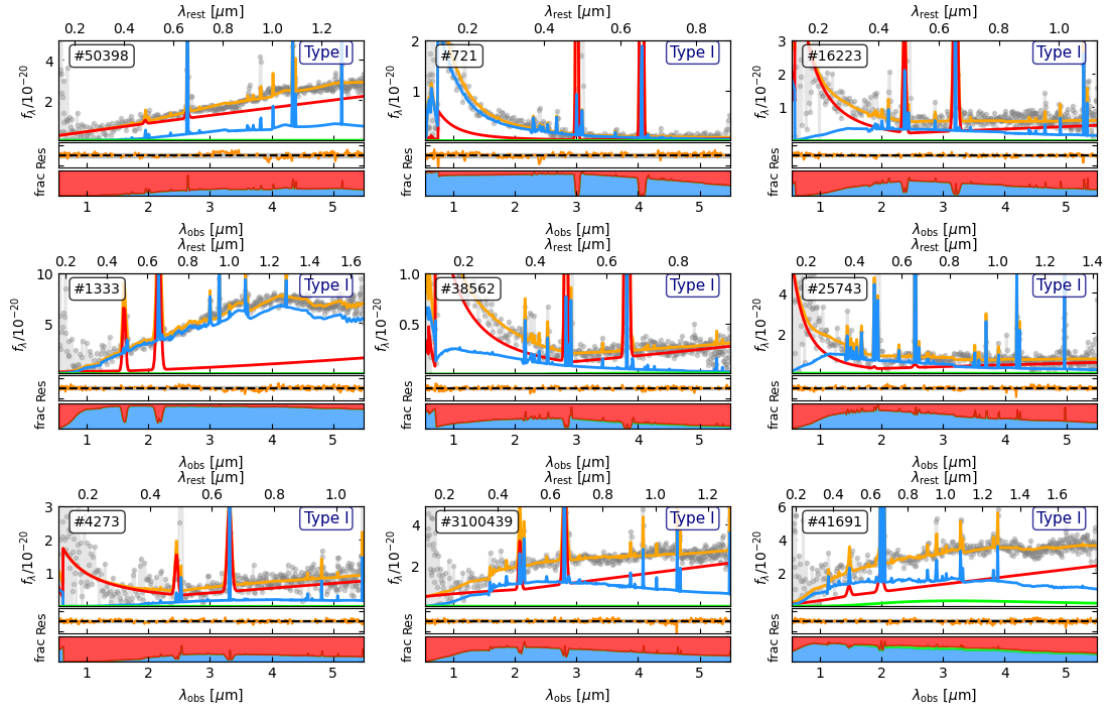


Fig. B.2: Best-fitting models from Bagpipes based on the continuum of the LRDs corresponding to the Type I AGN category (see Table 2 and Sect. 4.1). See Fig. 3 for a description of the markers and color-codes shown here.

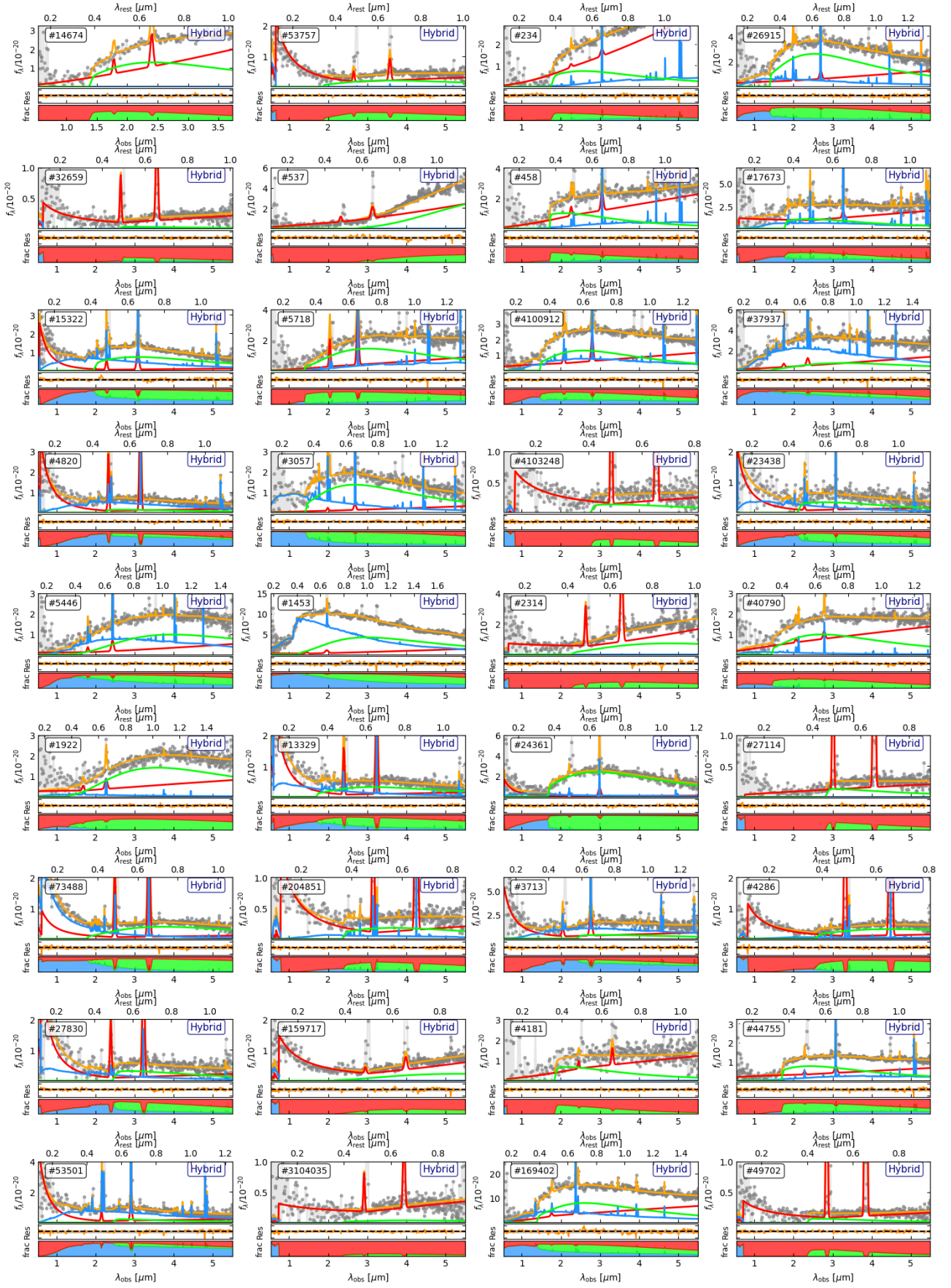


Fig. B.3: Best-fitting models from *Bagpipes* based on the continuum of the LRDs corresponding to the Hybrid category (see Table 2 and Sect. 4.1). See Fig. 3 for a description of the markers and color-codes shown here.

Appendix C: Median properties

Table C.1 shows the median properties of the sample—based on those fits with $\chi_{\text{red}}^2 < 3$ —as a result of the AGN-agnostic and AGN-suppressed methods, described in Sect. 3 and Sect. 5.2, respectively.

Appendix D: Best-fitting solutions for 51 LRDs - AGN-suppressed method

In this Appendix, we include the solutions for the remaining objects not included in Fig. 6 that satisfy $\chi_{\text{red}}^2 < 3$. In this case, we imposed a BH* solution, suppressing the AGN continuum (“AGN-suppressed”). Figure D.1 shows the fits for the objects in the BH* class, whereas Fig. D.2 shows the fits for the Type I AGNs and Hybrid LRDs.

Table C.1: Median properties derived with Bagpipes following M26 using broad priors or suppressing the AGN continuum for the LRDs analyzed in this work ($\chi^2_{\text{red}} < 3$ fits).

	BH*		BH* - AGN leaks		BH* - hostless		Hybrid		Type I AGN	
	AGN-agnostic	AGN-suppressed	AGN-agnostic	AGN-suppressed	AGN-agnostic	AGN-suppressed	AGN-agnostic	AGN-suppressed	AGN-agnostic	AGN-suppressed
z_{spec}	3.1927	3.7790	4.0958	–	4.6066	–	3.6985	3.6534	3.2810	5.1841
$\log M/M_{\odot}$	8.05	8.34	8.89	–	–	–	8.50	9.67	9.48	8.31
$\log \text{SFR}_{100} [M_{\odot}/\text{yr}]$	-0.16	0.15	0.61	–	–	–	0.23	0.62	0.93	-0.22
A_V [mag]	0.50	0.43	0.43	–	–	–	1.63	1.35	1.84	0.05
$\log Z/Z_{\odot}$	0.017	0.011	0.031	–	–	–	0.037	0.096	0.092	0.065
$\log U$	-2.21	-1.71	-0.62	–	–	–	1.99	-1.33	-2.58	-2.36
α_1	-0.59	–	-2.30	–	-2.01	–	-0.21	–	-1.41	–
β_1	1.13	–	1.17	–	0.89	–	0.98	–	1.07	–
hanorm [erg/s/cm ²]	9.33×10^{-18}	–	3.47×10^{-17}	–	3.24×10^{-17}	–	9.12×10^{-18}	–	1.38×10^{-17}	–
f5100 [erg/s/cm ² /Å]	6.17×10^{-23}	–	4.79×10^{-22}	–	4.57×10^{-21}	–	7.59×10^{-21}	–	1.17×10^{-20}	–
T _{BB} [K]	4565	3687	4421	–	4818	–	4407	2864	–	–
A _{BB} [erg/s/cm ²]	9.77×10^{-20}	6.03×10^{-20}	8.51×10^{-20}	–	3.89×10^{-20}	–	3.63×10^{-20}	2.82×10^{-20}	–	–
$\log N$	19.86	20.85	20.48	–	19.98	–	20.99	21.43	–	–
$\log \sigma_{R_0}$	-17.76	-16.75	-16.71	–	-17.20	–	-16.68	-16.54	–	–
λ_{break} [Å]	3252	3295	3321	–	3110	–	3332	3527	–	–
Width [Å]	98	53	83	–	53	–	42	55	–	–
χ^2_{red}	1.28	1.25	1.34	–	0.94	–	1.17	1.19	1.42	2.43

Notes. For each category, we include two columns. The first includes the median parameters derived using the original M26 method, based on selecting broad priors (AGN-agnostic; see Sects. 3 and 4), whereas the second shows the values obtained once the AGN continuum is suppressed (AGN-suppressed; see Sect. 5.2). Empty fields correspond to parameters from components that were suppressed (i.e., the AGN) or that are not robustly constrained (e.g., M_* in the hostless class). Note that some classes are populated with $\lesssim 3$ objects.

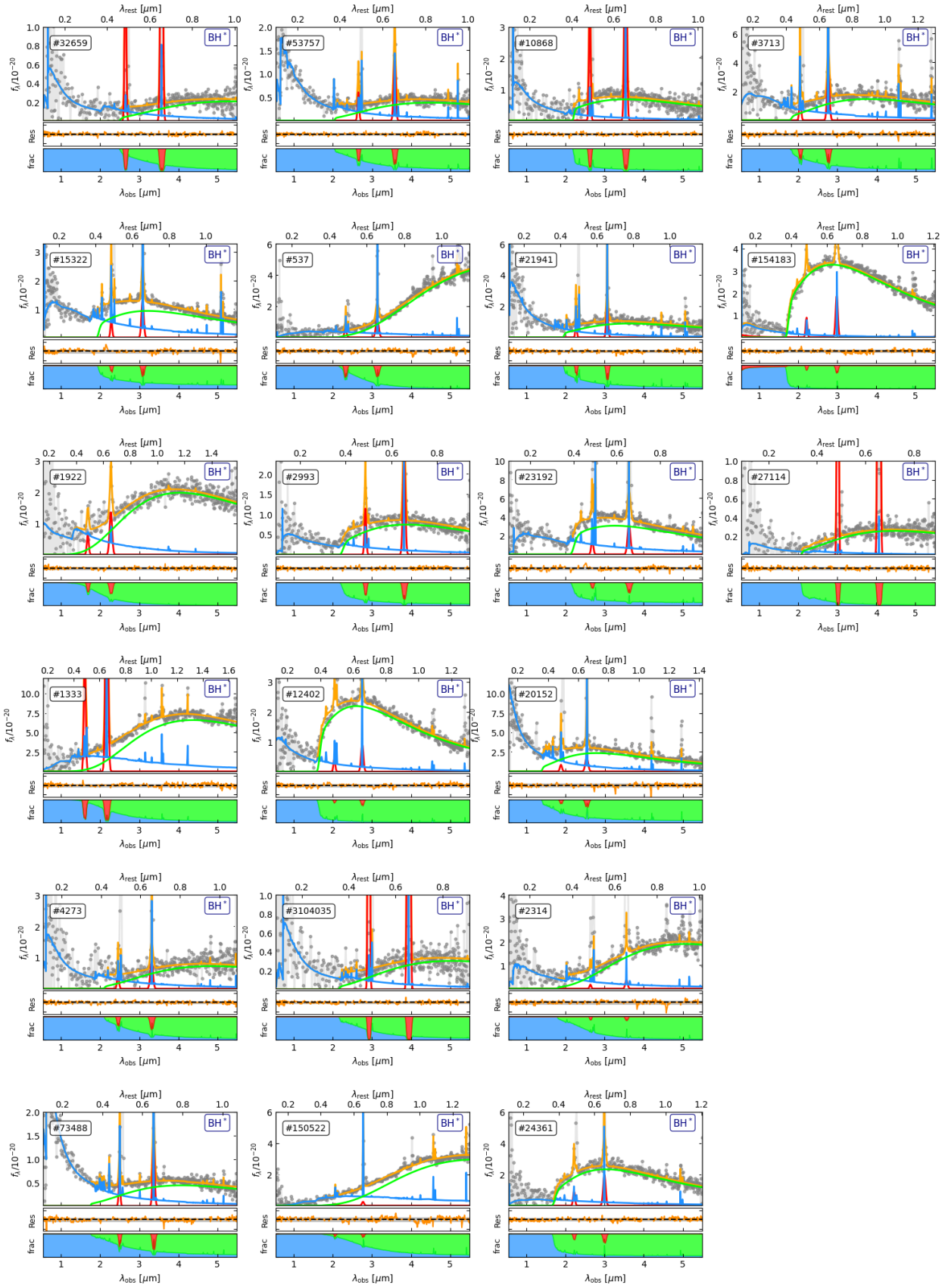


Fig. D.1: Best-fitting models from Bagpipes based on the continuum of the LRDs corresponding to the BH* category (see Table 2 and Sect. 5.2) using the AGN-suppressed method. See Fig. 3 for a description of the markers and color-codes shown here.

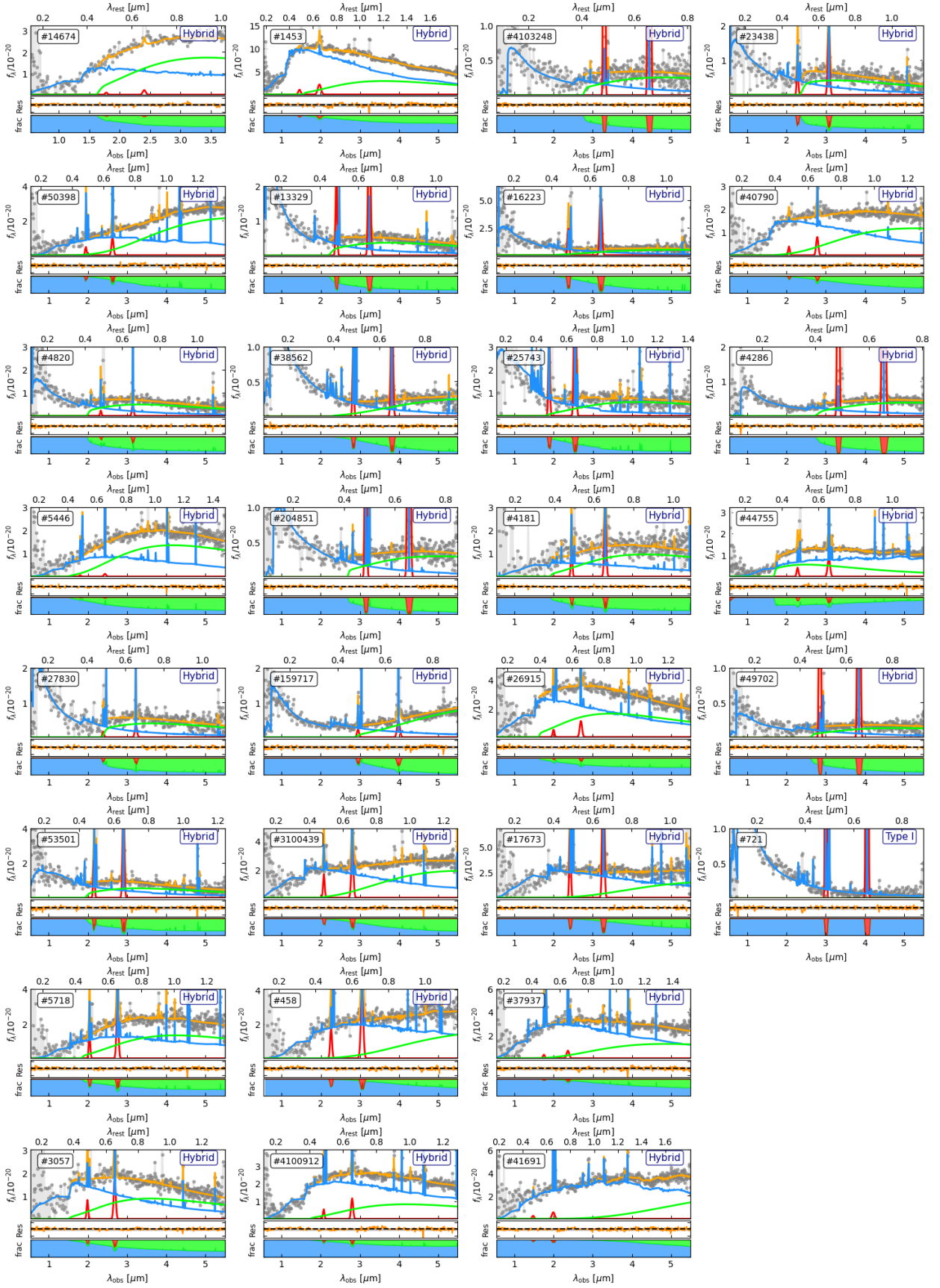


Fig. D.2: Best-fitting models from Bagpipes based on the continuum of the LRDs corresponding to the Hybrid and Type I AGN categories (see Table 2 and Sect. 5.2) using the AGN-suppressed method. See Fig. 3 for a description of the markers and color-codes shown here.