

The little blue and red dot Rosetta stones

Non-Gaussian broad lines, hot dust, and X-ray weakness

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ABSTRACT

The population of active galactic nuclei (AGNs) newly discovered by the James Webb Space Telescope (JWST) exhibits peculiar properties that distinguish it from both local type I AGNs and high-redshift quasars. Most of these sources are compact, appearing as ‘little dots’; among them, the sub-class (10–30% of the total) characterised by significantly red optical colours is known as ‘little red dots’ (LRDs). In this work, we introduce the analogous term ‘little blue dots’ (LBDs) to characterise the remaining (bluer) sources (70–90%). We present a comparative analysis of two bright prototypical representatives, which we refer to as the Rosetta stones of the two classes: GN-28074 at $z=2.26$ as the red Rosetta stone and GS-3073 at $z=5.55$ as the blue Rosetta stone. Both Rosetta stones exhibit non-Gaussian broad Balmer lines, better described by exponential or double-Gaussian profiles rather than single Gaussians, similarly to normal low-redshift type I AGNs, indicating that non-Gaussian wings are not unique to LRDs. They are both extremely X-ray weak, showing strong auroral [O III] $\lambda 4363$ emission, weak hot dust mid-IR emission, and no time variability. However, they do differ in terms of excitation diagnostics: the He II $\lambda 4686$ line is undetected in the red Rosetta, but strongly detected in the blue Rosetta in both narrow and broad components, with the latter being much broader than hydrogen Balmer lines. This supports BLR stratification and disfavors the cocoon electron-scattering scenario in LBDs. An additional difference is the presence of prominent Balmer absorption in the red Rosetta, which is indicative of extremely dense gas along the line of sight and also happens to be absent in the blue Rosetta. Taken together, these results suggest that LRDs and LBDs share the same central engine as standard type I AGNs, while differing in terms of the amount and geometry of dense gas surrounding the accretion disk and/or in their accretion properties.

Key words. galaxies: active – quasars: absorption lines – quasars: emission lines – quasars: general – quasars: supermassive black holes

1. Introduction

The James Webb Space Telescope (JWST; [Gardner et al. 2023](#)) is revolutionising our understanding of the formation and

evolution of black holes in the early Universe. Indeed, thanks to its unprecedented sensitivity and wavelength coverage, JWST has opened a new discovery space by finding active galactic nuclei (AGNs) with bolometric luminosities of $\log L_{\text{bol}} [\text{erg s}^{-1}] \sim 42\text{--}46$ (e.g. [Harikane et al. 2023](#); [Adamo et al. 2025](#); [Scholtz et al. 2025](#)). This is much lower than those

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typically probed by both low- and high-redshift quasars identified in ground-based surveys. However, the new population of JWST-discovered AGNs is not simply a scaled down version of luminous quasars, nor a simple high-redshift extension of the AGN population found by previous surveys at later cosmic epochs. Even the most securely identified broad-line AGNs are characterised by properties that are quite different from the populations investigated by previous studies, including: X-ray weakness (Yue et al. 2024; Ananna et al. 2024; Maiolino et al. 2025; Tortosa et al. 2026), radio weakness (Mazzolari et al. 2025, 2026), nebular emission lines whose excitation properties deviate from those observed in local AGNs (Harikane et al. 2023; Übler et al. 2023; Maiolino et al. 2024; Juodžbalis et al. 2026a; Zucchi et al. 2026), lack of the optical iron bump (Trefoloni et al. 2025), an overall mid-IR deficiency (Setton et al. 2025b; Pérez-González et al. 2026), and absent or seldom observed variability (Kokubo & Harikane 2025; Ji et al. 2025; Naidu et al. 2025; Zhang et al. 2025; Burke et al. 2026). These properties have motivated a wide range of theoretical interpretations involving high gas obscuration (Inayoshi & Maiolino 2025; Juodžbalis et al. 2024; Ji et al. 2025), invoking scenarios characterised by high accretion rates (Pacucci & Narayan 2024; Madau & Haardt 2024; King 2025), and/or dense-gas cocoons fully enshrouding a rapidly accreting black hole, along with ‘quasi-stars’ (Begelman & Dexter 2026) and ‘black-hole stars’ (Naidu et al. 2025; de Graaff et al. 2025b).

Within the population of JWST-discovered AGNs, the class of so-called LRDs has attracted most of the attention. These sources are unresolved at rest-frame optical wavelengths, where a dominant point-like component often outshines the host galaxy. They exhibit red optical colours and a characteristic v-shaped continuum (Matthee et al. 2024; Kocevski et al. 2025), pivoting at the Balmer limit (Setton et al. 2025a) or close to it (de Graaff et al. 2025a). A large fraction of these photometrically selected LRD candidates display broad permitted emission lines (roughly 85%, Hviding et al. 2025; see also, Greene et al. 2024; Kocevski et al. 2025), typical of type I, broad-line AGNs. They often show Balmer absorption features (Juodžbalis et al. 2024; Matthee et al. 2024; D’Eugenio et al. 2026b, 2025b, 2026a; Lin et al. 2026b), as well as smooth Balmer breaks (Setton et al. 2025a; Ji et al. 2025; Naidu et al. 2025; de Graaff et al. 2025a,b), which have been interpreted as due to absorption by dense circumnuclear gas along the line of sight (Inayoshi & Maiolino 2025; Ji et al. 2025; Naidu et al. 2025). Based on MIRI observations, LRDs offer some evidence of some hot dust, although the emission is generally weak (Pérez-González et al. 2024; Williams et al. 2024; Casey et al. 2025; Setton et al. 2025b; Delvecchio et al. 2025; Ronayne et al. 2026).

While they do comprise a compelling population, LRDs constitute less than 30% of the AGNs identified by JWST at a redshift of $z \sim 5$ and at bolometric luminosities below the quasar regime (Hainline et al. 2025; Kocevski et al. 2025; Taylor et al. 2025). In contrast, the vast majority (>70%) of these spectroscopically confirmed, broad-line AGNs exhibit blue optical and UV colours (i.e. both $\beta_{\text{opt}} < 0$ and $\beta_{\text{UV}} < 0^1$) similar to those of standard type I AGNs and star-forming galaxies. These sources are predominantly compact (e.g. Hainline et al. 2025; Juodžbalis et al. 2026a, who find that 60% of JWST-discovered broad-line AGNs are unresolved in NIRCam), although we note that (just as in the case of LRDs) the presence of a more or less

dominant unresolved component does not preclude the existence of an extended component (i.e. a host galaxy).

Despite being the primary population of JWST-discovered AGNs, these blue counterparts have received less attention than LRDs. For instance, there are currently no studies that specifically investigate their UV–optical broad line spectral profiles and continuum emission, while these properties have been subject of intense scrutiny in LRDs (e.g. Rusakov et al. 2026; Naidu et al. 2025; D’Eugenio et al. 2026b, 2025b, 2026a; Chang et al. 2026; Labbe et al. 2024; Brazzini et al. 2025; Barro et al. 2026a). This is most likely due to the implicit assumption that the behaviour of these blue AGNs resembles that of so-called normal AGNs; however, they show remarkable peculiarities too, as discussed above, most notably their X-ray weakness. Therefore, their study is fundamental and complementary to the analysis of both standard luminous type I quasars and LRDs.

In this work, we present a comparative study of GN-28074 at $z = 2.26$, which we deem to be the Rosetta stone of LRDs (Juodžbalis et al. 2024), and GS-3073, a blue, intermediate-luminosity AGNs at $z = 5.55$ (Vanzella et al. 2010; Grazian et al. 2020; Übler et al. 2023). We adopted the latter as the Rosetta stone of the new population of blue AGNs discovered by JWST, which we call LBDs due to their blue colours and compact morphology (see next section for a more operational definition). GN-28074 and GS-3073 serve as ideal archetypical cases (i.e. Rosetta stones) of the LRD and LBD populations, respectively, enabling a detailed comparative analysis thanks to the high spectral signal-to-noise ratio (S/N) in their JWST spectra, along with the excellent ancillary data warranted by their location in the GOODS deep extragalactic fields. Throughout this work, we assume a flat Λ CDM cosmology with $\Omega_m = 0.315$ and $H_0 = 67.4$ km/s/Mpc (Planck Collaboration VI 2020).

2. LRDs and LBDs: Definitions

Here, we begin by defining the two classes of LRDs and LBDs, whereby GN-28074 and GS-3073 are considered representative examples, respectively. LRDs have been subject to extensive studies and several definitions have been proposed. Many of them rely on the diagram shown in Fig. 1, which compares the slopes of the rest-frame optical and UV continua (respectively β_{opt} and β_{UV} , usually measured from photometry; Kocevski et al. 2025; Hainline et al. 2025). The contours show the distribution of all non-AGN galaxies in the JADES sample, mostly star-forming galaxies, clustering around blue optical and UV slopes; in addition, it includes a tail towards red UV and optical slopes, attributed to dust-reddened galaxies. The diamonds mark all broad-line AGNs in the JADES sample (Juodžbalis et al. 2026a; Geris et al. 2026a). The red-shaded area shows the region with blue UV slopes and red optical slopes adopted by Kocevski et al. (2025) to identify LRDs. Leveraging this information, we adopted the definition of LRDs based on the following criteria (e.g. Kocevski et al. 2025):

- Red rest-frame optical slope: $\beta_{\text{opt}} > 0$ (Fig. 1);
- Blue rest-frame UV slope: $-2.8 < \beta_{\text{UV}} < -0.37$, where the lower limit was adopted by Kocevski et al. 2025 to exclude brown dwarfs and the upper limit is an attempt to avoid systems that are simply dust-reddened;
- Compact (unresolved or barely resolved) morphology in the rest-frame optical. A widely used criterion employs the F444W aperture–flux ratio as a size proxy, requiring $f_{\text{F444W}}(0.2'')/f_{\text{F444W}}(0.5'') > 0.5$ (Akins et al. 2025). This means that more than 50% of the F444W

¹ Where we define the slopes as $F_\lambda \propto \lambda^\beta$, and in this work the measurements are made directly from the spectrum.

broadband emission measured within a $0.5''$ diameter aperture must be enclosed within a $0.2''$ diameter aperture. The exact compactness criterion varies slightly across the literature, with studies adopting more or less stringent thresholds. For example, Hainline et al. (2025) require $f_{F444W}(0.2'')/f_{F444W}(0.5'') > 1/1.7$, while Greene et al. (2024) estimated the aperture-flux ratio using a $0.4''$ aperture, instead of $0.5''$. Other works define compactness by requiring sources to be unresolved in F444W; namely, indistinguishable from the point-spread function of the filter (PSF; e.g. Whalen et al. 2025; Hviding et al. 2025; Rinaldi et al. 2026). Although this latter definition is arguably the most rigorous, it becomes difficult to apply to stacked images that combine observations with different PSF orientations. Here, we adopt the compactness definition by Akins et al. (2025).

- Broad permitted emission lines (FWHM $\gtrsim 1000$ km/s) without a counterpart in the forbidden lines (such as [O III]), to exclude outflows, avoid contamination from compact post-starburst galaxies, and ensure the selection of AGNs only.

On the contrary, LBDs have not been clearly defined in the past. They broadly make up the vast majority of AGNs selected by JWST at high- z and which are not LRDs; that is, with both blue UV and optical slopes (see also, e.g. Hainline et al. 2025; Asada et al. 2026), with the exception of a few dust reddened AGNs. However, being found by JWST is not a clear operational definition. As said, in terms of spectral optical/UV features they share properties similar to normal AGNs (blue throughout the optical to UV spectral range). They are very compact, with their host galaxies barely detected; however, this is the case also for several luminous quasars. Yet, a remarkable difference with respect to normal AGNs is their extreme X-ray weakness (Übler et al. 2023; Maiolino et al. 2025). We therefore adopted the following definition for LBDs:

- Blue rest-frame optical slope: $\beta_{\text{opt}} < 0$ (Fig. 1);
- Blue rest-frame UV slope: $\beta_{\text{UV}} < -0.37$, which is the same upper limit as for the LRDs meant to minimise the selection of dust-reddened AGNs (see Fig. 1);
- Compact (unresolved, or barely resolved) morphology, with the same compactness definition as for LRDs;
- Broad permitted emission lines (FWHM $\gtrsim 1000$ km/s) without a counterpart in the forbidden lines (e.g. [O III]) to exclude outflows, thereby identifying type I AGNs;
- X-ray weakness, with $k_{\text{bol},X} := L_{\text{bol}}/L_{2-10\text{keV}}$ a factor of 10 higher than the $k_{\text{bol}} - L_{\text{bol}}$ relation identified for normal type I AGNs (Duras et al. 2020; Maiolino et al. 2025).

In Fig. 1, the red- and blue-shaded areas mark the regions of the $\beta_{\text{opt}} - \beta_{\text{UV}}$ diagram where LRDs and LBDs are selected, respectively (together with the other requirements listed above). LRDs can be readily selected through their colours, although some purity and completeness issues remain (Hviding et al. 2025). In particular, emission-line contamination can affect photometrically derived spectral slopes: at $z \sim 5-7$, the NIRCам F444W filter may be significantly contaminated by H α emission; meanwhile at $z \gtrsim 7$, it might be contaminated by [O III] $\lambda\lambda 4959, 5007 + \text{H}\beta$, resulting in redder optical slopes (Hainline et al. 2025; Rinaldi et al. 2026). In contrast, the photometric identification of LBDs is considerably more challenging, despite them being more numerous, because they occupy a region of the diagram that largely overlaps with the locus of star-forming galaxies. As a result, no robust photometric criterion currently exists to isolate LBDs from non-AGN populations. In practice, LBDs are therefore identified mostly serendipitously through

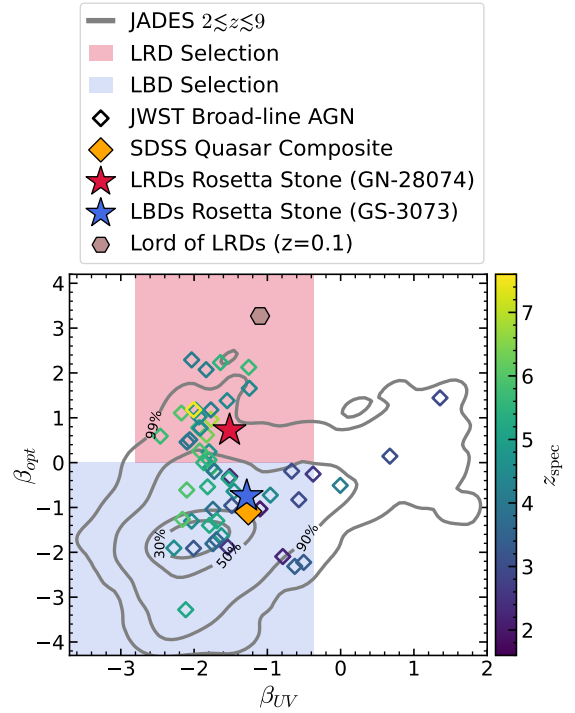


Fig. 1. Rest-frame optical versus UV continuum spectral slopes for a variety of sources. While LRDs occupy a distinctive region in this plane (red-shaded region), LBDs overlap with both AGN and non-AGN galaxies at $z = 2-9$ in the JADES survey (grey contours; Hainline et al. 2025), making their photometric selection at UV-optical wavelengths more challenging. The broad-line AGN sample (colour-coded by redshift) is from Hainline et al. (2025), who combined several literature samples (Kocevski et al. 2024; Matthee et al. 2024; Harikane et al. 2023; Kokorev et al. 2024; Sun et al. 2025; Zhang et al. 2026; Juodžbalis et al. 2026a), with continuum slopes derived from photometry. The local ‘Lord of LRDs’ is from Ji et al. (2026b). For this source, as well as for LRDs and LBDs Rosetta stones and the SDSS composite, the continuum slopes are derived directly from spectroscopy.

large spectroscopic surveys via the detection of broad permitted emission lines. Interestingly, most regular type I AGNs also fall in the same region of the plane as LBDs, as exemplified by the location of the SDSS quasars composite (orange-filled diamond; Vanden Berk et al. 2001).

Lastly, we note that the broad-line AGNs identified in JADES (hollow diamonds) do not show a bimodal distribution, but instead span continuously from the LBDs to the LRDs region. This suggests that LRDs and LBDs may not represent two separate AGN populations, but rather a continuous distribution, with the division between the two being somewhat arbitrary. This will be discussed more extensively in a separate paper (Geris et al. in prep.; see also Billand et al. 2026).

3. Overview of the red and blue Rosetta stones

Before providing our own analysis, we first clarify and justify the classification of GN-28074 and GS-3073 as representative of LRDs and LBDs, respectively. We summarise their properties based on previous studies.

3.1. Spectroscopic data

Spectroscopic observations of GN-28074 were carried out with the NIRSpec Micro-Shutter Assembly (MSA; Jakobsen et al. 2022; Ferruit et al. 2022), as part of the JWST Advanced

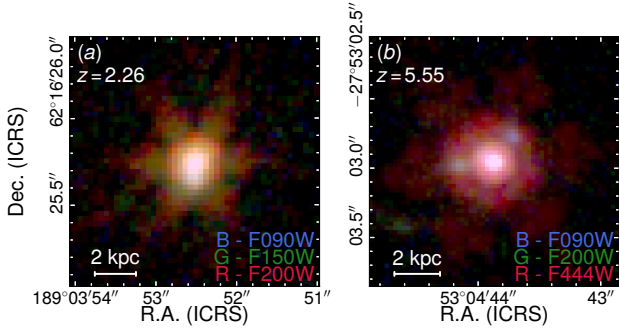


Fig. 2. Rosetta stone of LRDs, GN-28074 (Juodžbalis et al. 2024, panel a), and GS-3073 (panel b), a luminous blue AGN (Vanzella et al. 2010; Übler et al. 2023), taken here as the Rosetta stone of LRDs. The false-colour RGB cutouts are from the JADES Collaboration (Eisenstein et al. 2026; Rieke et al. 2023; D’Eugenio et al. 2025a).

Extragalactic Survey (JADES) programme (Rieke et al. 2020; Bunker et al. 2020; Eisenstein et al. 2026; D’Eugenio et al. 2025a; Curtis-Lake et al. 2026; Scholtz et al. 2026a, programme ID 1181), with data reduction described in detail in Juodžbalis et al. (2024) and in the previous data-release papers (D’Eugenio et al. 2025a). A detailed analysis of the spectral line profiles from the medium-resolution ($R = 700\text{--}1500$; Jakobsen et al. 2022) grating spectra has been presented in Brazzini et al. (2025). Here, we focus on the prism spectrum ($R = 30\text{--}300$).

GS-3073 was observed with the NIRSpec Integral Field Unit (Böker et al. 2022) as part of the programme Galaxy Assembly with NIRSpec Integral Field Spectroscopy (GA-NIFS, programme ID 1216; Böker et al. 2022), and further details on data reduction and extraction are provided by Perna et al. (2023) and Übler et al. (2023). Throughout this work, we use both the prism and the high-resolution G395H grating ($R = 1900\text{--}3600$) spectra, extracted from a $0.3''$ box centred on GS-3073, and already presented by Übler et al. (2023). The nominal uncertainties on the aperture spectrum were upscaled by a factor of 2.5. As explained in Übler et al. (2023), this ensures a good match between the standard deviation of the data (measured in featureless regions of the spectrum) and the noise vector. The most likely culprit for the mismatch in the nominal uncertainties is correlated noise in the spatial directions, which reduces the S/N of the aperture spectrum.

3.2. GN-28074: The Rosetta stone of LRDs

GN-28074 is a compact source in GOODS-North at redshift $z = 2.26$ (Fig. 2a), identified as a broad-line AGNs in Juodžbalis et al. (2024). In addition to broad hydrogen lines, its LRD nature is confirmed by its v-shaped continuum, as seen in its prism spectrum, shown with a red curve in Fig. 3 (from Juodžbalis et al. 2024). Notably, the same figure highlights the remarkable difference between the spectrum of GN-28074 and those of both GS-3073 (see Section 3.3), shown in blue, and the standard SDSS quasar composite, shown in yellow (from Vanden Berk et al. 2001). We note that we use the NIR extension from Glikman et al. 2006), which is adopted throughout this work as representative of standard type I AGNs. More quantitatively, Fig. 1 shows the location of GN-28074 in the $\beta_{\text{UV}}\text{--}\beta_{\text{opt}}$ diagram. GN-28074 falls within the region adopted by many authors for selecting LRDs, with $\beta_{\text{UV,GN-28074}} = -1.48 \pm 0.06$ and $\beta_{\text{opt,GN-28074}} = 0.73 \pm 0.05^2$.

² We have used ad-hoc fitting windows: 2160–3100 Å for the UV (masking Mg II), and 5360–6270 Å for the optical (masking He I 5876);

Morphologically, Juodžbalis et al. (2024) found that GN-28074 is compact in the rest-frame optical (effective radius of ~ 300 pc; van der Wel et al. 2014), satisfying the compactness criterion ($f_{\text{F444W}}(0.2'')/f_{\text{F444W}}(0.5'') = 0.61$; Sect. 2), yet it is clearly spatially resolved in both the UV and [O III] emission, a property observed in many LRDs, including spectroscopically confirmed ones at both low and high redshift (e.g. Rinaldi et al. 2025; Lin et al. 2026a; Torralba et al. 2026b; Ji et al. 2026b; D’Eugenio et al. 2026a). It shows forbidden [Fe II] emission and Na I absorption (Lin et al. 2026a; Ji et al. 2026b; Torralba et al. 2026a; D’Eugenio et al. 2025b), but no permitted Fe II or coronal lines such as [Fe VII]. GN-28074 exhibits rest-frame mid-infrared (IR) emission, detected by Spitzer/MIPS at 24 μm , likely tracing hot dust ($T_{\text{dust}} \sim 1500$ K; Juodžbalis et al. 2024), commonly associated with a dusty torus in typical AGNs. However, the presence of hot dust in LRDs remains debated. Several studies report both mid-IR and far-IR non-detections with different instruments including Spitzer, Herschel, ALMA, and JWST, suggesting a lack of this component in these sources (Williams et al. 2024; Pérez-González et al. 2024; Akins et al. 2025; Casey et al. 2025; de Graaff et al. 2025b; Inayoshi & Ho 2025; Barro et al. 2026b). Conversely, other works, particularly at low redshift (i.e. offering more sensitivity to longer wavelengths), find mid-IR emission to be common in LRDs (Lin et al. 2026a; Delvecchio et al. 2025; Ji et al. 2026b).

In contrast to the mid-IR, GN-28074 remains undetected in both radio (Mazzolari et al. 2026) and X-rays (Maiolino et al. 2025), with the 2-Ms Chandra data providing the most stringent upper limit to date on $k_{\text{bol,X}}$, about three orders of magnitude above the relation for normal AGNs (Fig. 4). We note that it would remain an outlier in the $k_{\text{bol,X}}\text{--}L_{\text{bol}}$ diagram even if L_{bol} , estimated to be $\log L_{\text{bol}}[\text{erg s}^{-1}] = 45.4$ (Juodžbalis et al. 2024; Scholtz et al. 2026b, using the extinction-corrected broad H α and the calibration of Stern & Laor 2012), were overestimated by a factor of 10 or more (as suggested for LRDs by Greene et al. 2026).

GN-28074 displays strong $n = 2$ hydrogen absorption of non-stellar origin (Juodžbalis et al. 2024), a strong and smooth Balmer break (Ji et al. 2026b), and broad Balmer lines with non-Gaussian wings (Juodžbalis et al. 2024; Brazzini et al. 2025), a feature common to several LRDs (Rusakov et al. 2026; Scholtz et al. 2026b), which has been interpreted as evidence of Doppler broadening by electron scattering (Torralba et al. 2026a; Chang et al. 2026). However, in the case of GN-28074, a detailed comparative analysis of the spectral shapes across three hydrogen lines (H β , H α , and Pa β) reveals different line widths (Brazzini et al. 2025), which is inconsistent with a simple scattering screen, where the optical depth is effectively wavelength independent. Recent works based on radiative transfer simulations (Chang et al. 2026; Sneppen et al. 2026) succeed in reproducing such line differences in terms of more complex models including also Balmer scattering, and/or bound-free absorption, and/or a combination of inflow and outflow.

Because GN-28074 shows all the typical properties of LRDs and benefits from high-SNR, high-resolution spectroscopy, we followed Juodžbalis et al. (2024) in adopting it as the Rosetta stone of LRDs, namely, a bright representative of the overall LRD population. Given the similar properties of LRDs across the wide redshift range where they are observed (e.g. Lin et al. 2026a; Ji et al. 2026b), we assume that the conclusions drawn for

this avoids strong emission lines and regions that are severely blended, due to the low spectral resolution of the NIRSpec prism.

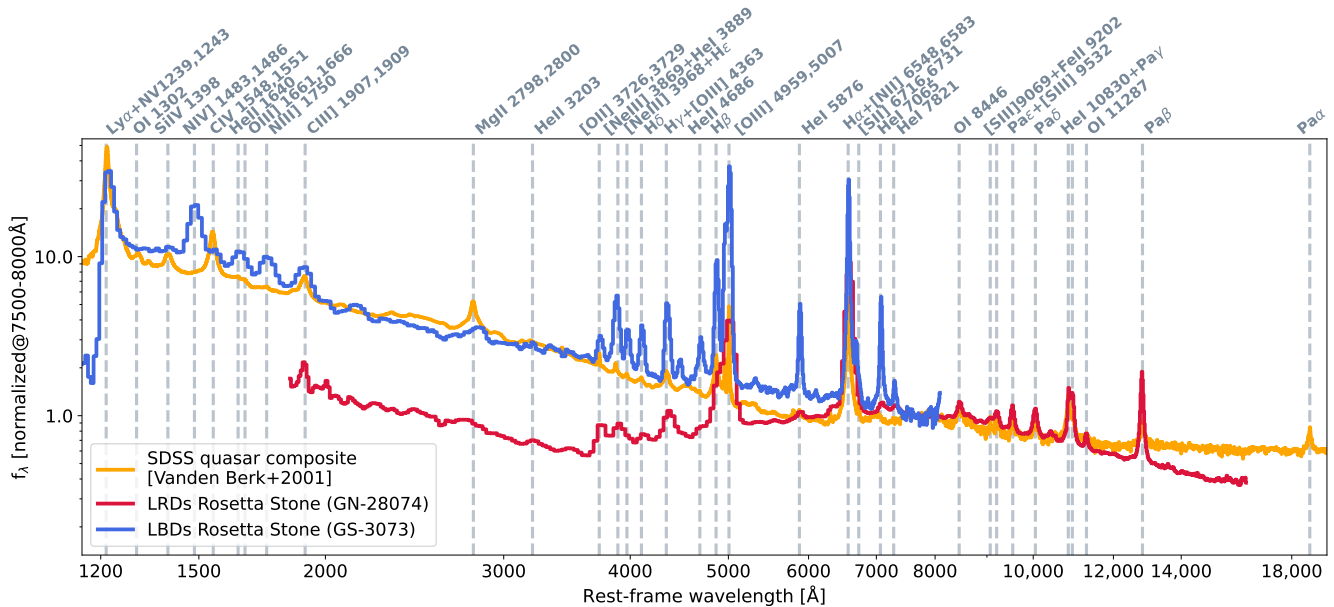


Fig. 3. Spectral comparison between the Rosetta stone of LRDs (GN-28074, from Juodžbalis et al. 2024, red) and that of LBDs (LBDs; GS-3073, from Übler et al. 2023, blue). LBDs share the blue UV–optical slopes of SDSS quasars (yellow; Vanden Berk et al. 2001, with the NIR extension from Glikman et al. 2006), but also show a number of differences (such as different emission-line ratios and EWs), meaning they are not scaled-down versions of quasars. The three spectra are normalised around $\lambda_{\text{rest}} \sim 8000 \text{ \AA}$ (the longest wavelength in common to the three spectra).

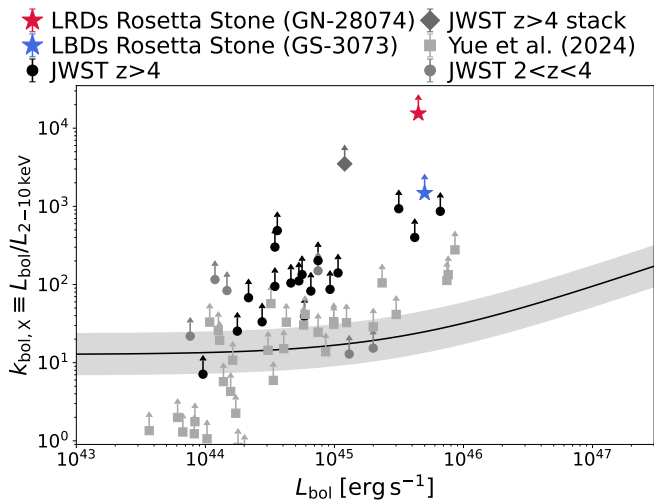


Fig. 4. Ratio $k_{\text{bol,X}}$ between the AGN bolometric luminosity and X-ray (2–10 KeV) luminosity, as a function of bolometric luminosity. Both blue and red Rosetta stones stand out as extremely X-ray weak sources, lying over an order of magnitude above the local $L_{\text{bol}}-k_{\text{bol,X}}$ relation (black line, with the grey shaded region representing 1σ scatter; Duras et al. 2020). While remaining undetected, other individual JWST AGNs do not have such constraining lower limits (grey circles, Maiolino et al. 2025; grey squares Yue et al. 2024). However, when stacked, their combined lower limits become extremely X-ray weak (grey diamond; Maiolino et al. 2025). Note: even when using a lower bolometric correction by an order of magnitude, the red Rosetta would still remain X-ray weak. X-ray weakness is a common feature of LBDs and LRDs.

this source at Cosmic Noon offer valuable insights for comparing and interpreting both high-redshift and local regimes.

3.3. GS-3073: The Rosetta stone of LBDs

GS-3073 was first identified by [Vanzella et al. \(2010\)](#) with ground-based observations. An AGN interpretation was later

explored in detail by Grazian et al. (2020) and Barchiesi et al. (2023), based on the detection of Ly α , Ly β , N IV], N V, and O VI UV emission lines. In particular, the presence of high-ionisation nitrogen and oxygen lines (with ionisation potentials of 97.9 eV and 138.1 eV for N V and O VI, respectively) favoured the presence of an AGN, although the non-detection in X-rays left open the possibility of a stellar interpretation. The type I AGN nature of this object was unambiguously confirmed by rest-frame optical spectroscopy with NIRSpec-IFU (Übler et al. 2023) from the GA-NIFS programme, showing prominent broad H α , H β and He II lines, and also other high ionisation lines such as [Fe VII], although very weak (Ji et al. 2024). GS-3073 also exhibits ionised outflows, traced by the presence of a weak broad component detected in [O III]. This component, while broader than the narrow emission, is not sufficiently broad to be confused with BLR emission – consistent with our definition of LBDs in Section 2 – and is present in all other emission lines (Sect. 6; see also Übler et al. 2023; Venturi et al. 2025). Additionally, based on the extremely strong N IV] and N III] seen in the prism spectrum, Ji et al. (2024) determined a very high N/O abundance ratio in the high-ionisation, inner regions (see also Ji et al. 2026a). Indeed, high N/O may be a general feature of low-luminosity, high-redshift AGNs, since spectral stacking of JWST-detected broad-line AGNs reveals unusually bright N III], which is not seen in (much deeper) stacks of non-AGN galaxies (Isobe et al. 2025). In contrast, among luminous AGNs and quasars, the fraction of ‘nitrogen loud’ sources is very small (~ 1 percent; Baldwin et al. 2003; Bentz & Osmer 2004; Jiang et al. 2008). Enhanced N/O could also explain the detection of N IV] in the luminous LRD UNCOVER-45924 (Labbe et al. 2024; Torralba et al. 2026b; Ji et al. 2026a), and the high N V/He II $\lambda 1640$ ratio observed in two broad-line AGNs at $z > 7$ – incidentally a LBD and a LRD (Tang et al. 2025).

GS-3073 is also included in the ALMA Large Programme to INvestigate [C II] at Early times (ALPINE) survey³ (Le Fèvre et al. 2020; Béthermin et al. 2020; Faisst et al. 2020), where

³ Source ID: CANDELS_GOODSS_14.

it is detected in [C II] 158 μm but not in the underlying continuum, with an inferred molecular-to-stellar mass ratio of 0.1 being among the lowest detected at this redshift (Barchiesi et al. 2023). This far-IR detection represents a significant difference with respect to LRDs, which remain undetected at these wavelengths, even in stacks (Akins et al. 2025; Casey et al. 2025). To date, only a single [C II] 158 μm detection has been reported for a LRDs (Golubchik et al. 2026), but the presence of a nearby companion complicates a definitive association of the emission with the LRD itself. Moreover, GS-3073 remains undetected at radio wavelengths in VLA 1.4 GHz observations (Miller et al. 2008).

Morphologically, it appears compact in the rest-frame optical continuum (Fig. 2b) and offers evidence of faint UV-blue neighbours which would be akin to LRDs (Juodžbalis et al. 2024; Killi et al. 2024; Baggen et al. 2024; Chen et al. 2025; Rinaldi et al. 2025; D'Eugenio et al. 2026a). It exhibits an aperture-flux ratio of $f_{\text{F444W}}(0.2'')/f_{\text{F444W}}(0.5'') = 0.61$ when subtracting the satellites, therefore satisfying the compactness criterion (Sect. 2).

Fig. 3 shows the prism spectrum of GS-3073 (in blue), highlighting its blue spectral slope from the rest-frame UV to the rest-frame optical, similar to the SDSS quasar composite spectrum (in yellow), although the latter is slightly redder. Despite the comparable continuum slopes, the two spectra clearly exhibit striking differences, not only in terms of emission line intensities and widths, but also in terms of relative line ratios. This will be discussed in detail in a forthcoming paper. The similarity in the optical and UV slopes of the blue Rosetta GS-3073 ($\beta_{\text{UV,GS-3073}} = -1.30 \pm 0.01$ and $\beta_{\text{opt,GS-3073}} = -0.76 \pm 0.02$) clearly makes GS-3073 fall in the LBDs classification region of Fig. 1, close to the bulk of type I AGNs and star-forming galaxies – which largely overlap. It is interesting that in terms of β_{UV} , GS-3073 is as blue as the SDSS type I composite ($\beta_{\text{UV,SDSS}} = -1.240 \pm 0.006$ and $\beta_{\text{opt,SDSS}} = -1.08 \pm 0.01$).

Lastly, GS-3073 is extremely X-ray weak (Fig. 4), remaining undetected in the 7-Ms Chandra campaign in GOODS-South (Luo et al. 2017). Due to its high luminosity ($\log L_{\text{bol}}[\text{erg s}^{-1}] \simeq 45.7$; Maiolino et al. 2025), the constraints on $k_{\text{bol,X}}$ are also very strong, resulting into one of the AGNs with the highest lower limit on $k_{\text{bol,X}}$ in the whole sample explored by Maiolino et al. (2025).

4. Time variability

Several studies have demonstrated a lack of variability in LRDs on relatively short timescales (months to years; Kokubo & Harikane 2025; Ji et al. 2025; Naidu et al. 2025; Zhang et al. 2025; Burke et al. 2026). Here, we explore the year-long variability of the red Rosetta stone, GN-28074, by comparing JWST NIRCам F090W, F115W, and F356W photometry measured from the JADES 1181 data and the Complete NIRCам Grism Redshift Survey data (CONGRESS, Egami et al. 2023, programme ID 3577). The JADES observations (epoch1) were obtained on UT 3 February 2023, while the CONGRESS observations (epoch2) were obtained on UT 13–18 February 2024. For each filter and epoch, we measure the source flux, f , within a $0.2''$ aperture and estimate the corresponding uncertainty, σ , using 500 randomly placed $0.2''$ apertures around the source. We then compute the SNR of variability, S/N_{var} , with the following equation,

$$S/N_{\text{var}} = \frac{|f_{\text{epoch1}} - f_{\text{epoch2}}|}{\sqrt{\sigma_{\text{epoch1}}^2 + \sigma_{\text{epoch2}}^2}}. \quad (1)$$

In all three photometric filters, the comparison between epoch1 and epoch2 yields $S/N_{\text{var}} < 3$. We therefore find no significant year-scale variability in the red Rosetta, consistent with previous results for other LRDs.

While no multi-epoch JWST/NIRCам observations are currently available for the blue Rosetta stone, GS-3073, we investigate its long-term variability by comparing NIRCам F150W photometry measured from the Observing All Phases of Stochastic Star Formation (OASIS, Looser et al. 2024, program ID 5997) program, obtained on UT 15–19 October 2024, to photometry measured from the Hubble Legacy Fields (HLF) HST/WFC3 F160W image (Whitaker et al. 2019) in the early 2010s. While the primary HLF v2.0 products are composite images containing many epochs of HST imaging, the HLF v2.0 GOODS-S images are available at the epoch-by-epoch level⁴. The blue Rosetta is only covered by the F160W filter in the epoch08 image, so we measure photometry using this image. As in the red Rosetta, photometry is measured within a $0.2''$ aperture, and uncertainties are estimated from randomly placed $0.2''$ apertures in nearby source-free regions. The resulting $S/N_{\text{var}} < 3$, indicates no evidence of variability.

Both the red and blue Rosetta stones show no significant time variability, which is instead a typical feature of normal type I AGNs. In LRDs, this lack of variability has been interpreted as evidence that the optical emission is dominated by thermal radiation from a pseudo-atmosphere embedding the black hole, with a characteristic temperature of ~ 5000 K Liu et al. (2025). In contrast, the UV emission is likely dominated either by the host galaxy or by scattered light (Kokubo & Harikane 2025). However, besides the observational challenges faced by this interpretation, such a scenario cannot easily explain the blue Rosetta stone, which also lacks variability despite not exhibiting a red optical continuum attributable to such an atmosphere. One possible alternative is that, contrary to previous models, the putative atmosphere is substantially hotter ($T \sim 40\,000$ K), as recently proposed by Pacucci et al. (2026) for LRDs, combined with modest dust reddening. Yet, without invoking new exotic scenarios, an alternative and simpler explanation may already exist within standard AGN models. Early studies predicted that dense BLR clouds, particularly in their outer regions, could become thermalised and emit a substantial thermal continuum themselves, thereby naturally damping continuum variability if this component dominates the observed emission (Baldwin et al. 2004). Indeed, continuum emission from BLR clouds has already been invoked in normal AGNs to explain their reduced variability, especially in the red part of the spectrum (Chelouche et al. 2019; Korista & Goad 2001; Netzer 2022; Korista & Goad 2019). It is therefore plausible that the same mechanism operates in both LRDs and LBDs, potentially enhanced by larger BLR covering factors and/or higher cloud densities.

Regardless of the possible interpretations, caution is warranted when claiming an absence of variability in these systems. At high redshift, cosmological time dilation makes variability intrinsically more difficult to detect. Indeed, variability is observed when leveraging the time delays of multiply-imaged LRD behind lensing clusters (Ji et al. 2025; Furtak et al. 2025; Zhang et al. 2025). Additionally, variability has been detected in the equivalent width of the broad Balmer lines (Ji et al. 2025, 2026b; Furtak et al. 2025; Naidu et al. 2025), suggesting that multi-epoch spectroscopy may be the most effective way to probe variability in these sources. Unfortunately, such datasets are still available for only a very limited number of objects.

⁴ <https://archive.stsci.edu/prepds/hlf/>

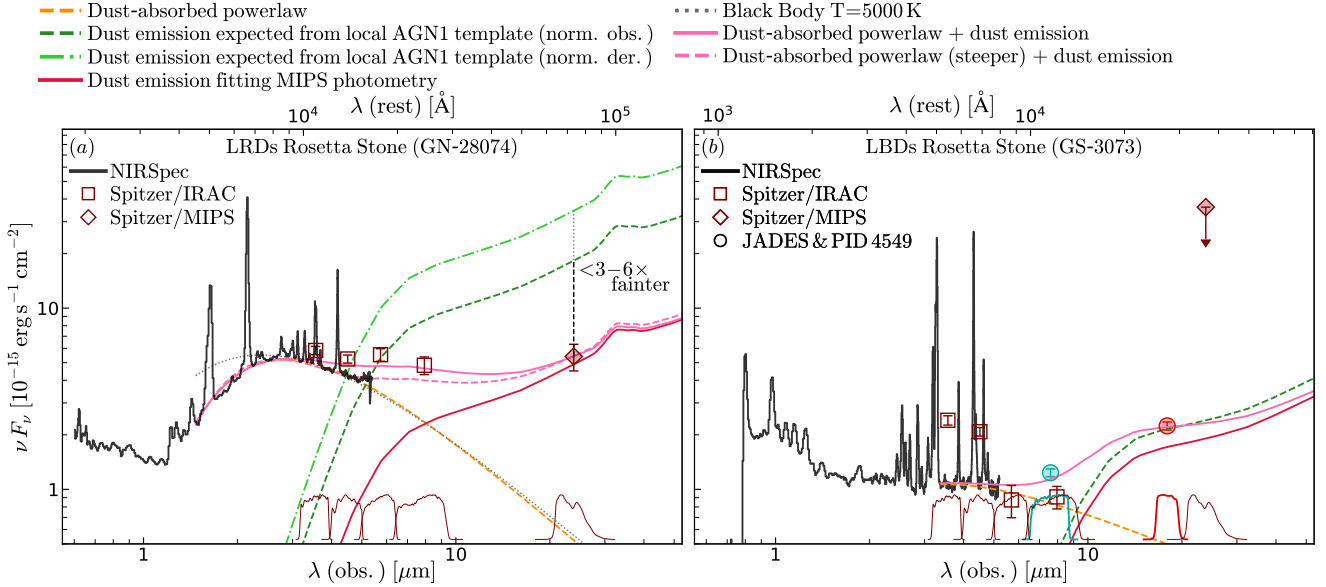


Fig. 5. Comparison of rest-frame optical-to-mid-IR emission for the red (left) and blue (right) Rosetta stones. Black curves show the NIRSpec spectra; the photometric data (and matching filter transmission curves, in solid brown) are Spitzer IRAC (empty brown squares) and MIPS24 (filled brown diamond), JADES MIRI F770W (filled light-blue circle), and GO-4549 MIRI F1800W (filled red circle). Empty data points are not used in the final SED fitting (see Sect. 5). The dashed orange curves represent dust-absorbed power-law extrapolations of the optical emission-line subtracted continua. For the red Rosetta, the gray dotted curve shows an extrapolation of a $T = 5000$ K blackbody fit to the optical spectrum. Dark green dashed curves show the expected torus hot dust emission assuming local type I AGN templates (from García-Bernete et al. 2019) normalised to the observed flux at rest-frame $1.15 \mu\text{m}$, while red solid curves show the same template scaled to match the mid-IR photometry (Spitzer/MIPS for the red Rosetta, JWST/MIRI F770W for the blue Rosetta). For the red Rosetta, the light green dot-dashed curve additionally shows the reddening-corrected torus template. Its mid-IR photometry lies above both power-law and blackbody extrapolations and is consistent with the presence of a hot dust torus component, although fainter by a factor of ~ 3 – 6 compared to local expectations, regardless of whether dust reddening is taken into account. In contrast, the required scaling for the blue Rosetta is much less significant. Finally, the pink solid curves represent the sum of dust-absorbed power-law and torus emission.

5. Mid-infrared emission

To investigate the presence of dust in both red and blue Rosetta stones, we complement their NIRSpec spectra with archival photometry from Spitzer/MIPS and Spitzer/IRAC, collected from the Rainbow Database (Figure 5). For the blue Rosetta (right panel), we also include JWST/MIRI data from JADES (JWST Advanced Deep Extragalactic Survey; Eisenstein et al. 2026) and PID 4549 (PI: G. Rieke; priv. comm.). We compare the mid-IR photometry of each source with the dust-absorbed power-law extrapolation of their optical emission-line subtracted continua (orange dashed curve), adopting the high-redshift extinction curve from Sun et al. (2026), which provides a better fit than a standard SMC curve. In both sources – especially the red Rosetta – the photometry lies above this extrapolation, requiring an additional component, likely hot dust emission, similar to what is observed in normal AGNs and quasars (although the dust temperature in GS-3073 remains unconstrained). We model dust emission adopting the local type I AGN SED template from García-Bernete et al. (2019) (dark-green dashed curve), which we normalise to the observed flux at rest-frame $1.15 \mu\text{m}$ and $0.75 \mu\text{m}$ for the red and blue Rosettas, respectively (the reddest wavelengths in their spectra not affected by emission lines⁵). However, to exactly match the observed mid-IR photometry, in both sources these templates have to be scaled down (red solid curve), especially in the red Rosetta that requires a rescaling

by a factor of ~ 3 . The final combined emission model, including the dust-absorbed optical power-law extrapolation and the rescaled dust emission (pink solid curve), successfully reproduces the observed photometry in both sources. This suggests that both LRDs and LBDs can host hot dust, consistent with Lin et al. (2026a) and Ji et al. (2026b), who both report similar findings in local LRDs, and (Delvecchio et al. 2025; Pérez-González et al. 2026). However, there are other works (e.g. Setton et al. 2025b) who instead suggest that hot dust in LRDs must be absent under the assumption of energy balance. As discussed in more detail in Section 8, this apparent discrepancy likely arises because the assumption of complete energy balance is not valid in these systems. Recent works by Geris et al. (2026b) and Sok et al. (2026) probe the presence of extended Ly- α emission in LRDs in both narrow and broad components, and therefore suggest that the obscuring material has a non-unity covering fraction, allowing a fraction of the intrinsic radiation to escape without being absorbed and reprocessed into the IR. Consequently, the observed IR emission is not expected to account for the full intrinsic luminosity. In addition, intrinsic variations in the dust content and emissivity of LRDs (as highlighted in stacked analysis from Pérez-González et al. 2026), together with the limited sensitivity of MIRI at high redshift, which may hinder the detection of weak hot-dust emission (Rinaldi et al. 2026), can further contribute to the observed diversity in the mid-IR properties of these sources. In fact, at $z > 4$ most MIRI bands probe only the Wien side of the dust blackbody SED: in this regime, the predicted flux is highly sensitive to assumptions about dust temperature and emissivity, making constraints on the dust properties intrinsically uncertain. Consequently, a robust characterisation of the hot dust requires deeper

⁵ We ignore the Spitzer/IRAC photometry in the rescaling, because it is either affected by strong emission lines (e.g. Ch3 in red Rosetta is affected by Pa α), or because it sits below more recent data (e.g. Ch4 in blue Rosetta is below the MIRI/F770W measurement).

observations at longer wavelengths ($\lambda_{\text{obs}} > 4\mu\text{m}$), which probe closer to the SED peak. The presence of dust at temperatures close to sublimation ($T_{\text{dust}} \sim 1000\text{ K}$) implies direct exposure to a strong UV radiation field, as typically associated with AGNs. This, in turn, provides important constraints on the geometry of the central region, suggesting that at least part of the UV ionising radiation must escape and reach the circumnuclear dust, in tension with simple cocoon or black-hole-star scenarios, where zero UV radiation is expected to escape.

5.1. Red Rosetta stone

The dust-absorbed power-law best-fit model of the red Rosetta stone optical continuum yields an intrinsic slope $\beta = -2.49 \pm 0.15$ (where β is defined as $F_{\lambda} \propto \lambda^{\beta}$), which is very close to the slope expected for classical accretion discs ($\beta = -2.33$, Lynden-Bell 1969; Shakura & Sunyaev 1973), and $A_V = 2.1 \pm 0.2$. In turn, this attenuation value is very close to that independently inferred from the total broad Balmer-line flux ratios under Case-B recombination assumptions: $A_V = 2.4\text{--}2.7^6$. However, as anticipated, the power-law extrapolation to the mid-IR fails in reproducing the observed photometry, and an additional component of hot dust emission is required. When normalised to the observed continuum emission at $1.15\mu\text{m}$, the dusty torus emission predicted from local type I AGN templates overpredicts the Spitzer/MIPS flux by a factor of ~ 3 . Accounting for reddening effects in both the data and the template (light-green long-dashed curve) increases this discrepancy up to a factor of ~ 6 , although this procedure is uncertain due to the stacked nature of the template optical continuum, which combines different spectra with different slopes and reddening. In summary, in the red Rosetta the expected hot dust emission from the local type I AGN template exceeds the observed one by a factor of $\sim 3\text{--}6$. These estimates should be regarded as upper limits, as they assume that the optical continuum is entirely AGN-dominated – if there is any contribution from a host galaxy (as inferred by Juodžbalis et al. 2024, 2026a), then the expected mid-IR flux from the AGN template should be lowered accordingly, thus reducing the tension. Alternative normalisations, such as those employing broad $H\alpha$, are also uncertain due to its unusually large equivalent width (Maiolino et al. 2025), which may reflect enhanced BLR covering factors or additional excitation mechanisms and radiative transfer effects (e.g. Chang et al. 2026; D’Eugenio et al. 2025b; Torralba et al. 2026a; Nikopoulos et al. 2026). Despite the uncertainties, our analysis clearly shows that the red Rosetta stone hosts hot dust, although its emission is fainter than local type I AGNs. Yet, this deficit can be naturally explained if the UV radiation heating the dust is partially absorbed by the same neutral gas responsible for the Balmer absorption lines. If radiation shortwards of the Lyman limit is suppressed, the available dust-heating energy is reduced by up to $\sim 80\%$, sufficient to lower the mid-IR emission by a comparable factor. A lower dust-to-gas ratio, expected in these lower-metallicity high-redshift systems, may further contribute to the reduced hot dust emission Pacucci et al. (2026).

While the combination of an optical power-law fit with a rescaled torus template has the capacity to reproduce the MIPS

and IRAC-Ch4 photometry, it fails to simultaneously match the NIRSspec optical continuum, suggesting that local AGN templates might not fully capture the hot dust properties of this source. It is alternatively possible to fit the NIRSspec spectrum with an absorbed steeper power-law (dashed pink curve), but in this case the IRAC-Ch4 point is under-fitted. A modest additional hot dust component (with $T \sim 1000\text{--}2000\text{ K}$) could alleviate these discrepancies, although the residual mismatches (10–20%) may also arise from inter-calibration uncertainties between Spitzer and JWST or from variability.

Finally, we test a $T_{\text{dust}} = 5000\text{ K}$ blackbody model (dotted gray line), as suggested by Liu et al. (2025) for their model of super-Eddington accretion envelopes. While this scenario can reproduce the red optical continuum, it struggles to explain both the blue spectral slope and the presence of emission lines, and does not improve the fit to the mid-IR data. Moreover, such an envelope would likely prevent UV photons from reaching and heating the dust. A more detailed assessment of this scenario is deferred to future work.

5.2. Blue Rosetta stone

The UV-to-optical continuum of the blue Rosetta stone cannot be described by a single power law, as it is steeper in the blue/UV and flatter in the red. The dust-absorbed power-law fit to the red yields $\beta = -1.85$ and $A_V = 0.6$. In normal quasars (e.g. SDSS), such a change in slope is usually attributed to different components dominating the emission: the accretion disc (with varying extinction levels) in the blue, and the host galaxy in the red. In the blue Rosetta, however, the lack of clear spatial evidence of a host galaxy suggests that the optical emission still originates from the AGN itself, in the form of scattered or transmitted continuum. Alternative contributions may include nebular emission, as suggested by Ji et al. (2024), and/or a nuclear star cluster.

The normalised torus template (red solid curve) closely matches the observed MIRI-F1800W photometry (pink circle). A full SED fit (pink solid curve), combining the reddened power-law with rescaled dust emission, can successfully reproduce both the MIRI photometry (including F770W, light-blue circle) and the NIRSspec spectrum, resulting in a slightly downscaled AGN template. This indicates that, unlike the red Rosetta, hot dust emission in the blue Rosetta is broadly consistent with expectations from local AGN templates within their intrinsic scatter (~ 0.5 dex). Alternative fits using an unreddened power law or stellar templates slightly reduce the required hot dust emission but worsen the overall fit.

Finally, we excluded the Spitzer/IRAC data from the SED fitting because the IRAC/Ch4 point lies more than ~ 0.1 dex below the MIRI-770W measurement, suggesting a calibration mismatch between Spitzer and JWST, as the source shows no time variability (Section 4). A similar issue might affect the red Rosetta Spitzer photometry and could explain the 10%–20% discrepancies seen there.

6. Emission line properties in the blue Rosetta stone

In this section, we analyse the emission-line profiles in GS-3073 only (i.e. the blue Rosetta) and we refer to Brazzini et al. (2025) for the analysis of GN-28074 – the red Rosetta – using the same methods as here. We focus on permitted lines observed in the high-resolution G395H spectrum, i.e. hydrogen and helium lines: Balmer ($H\alpha$, $H\beta$), singly ionised

⁶ The higher value of $A_V = 5.7$ reported by Brazzini et al. (2025) was obtained specifically for the broad scattered component within a scattering decomposition of the Balmer lines. As discussed in that work, however, the scattering model was not adopted as the preferred description of the Balmer-line profiles, so the corresponding attenuation should not be directly compared with the extinction inferred from the total broad-line emission.

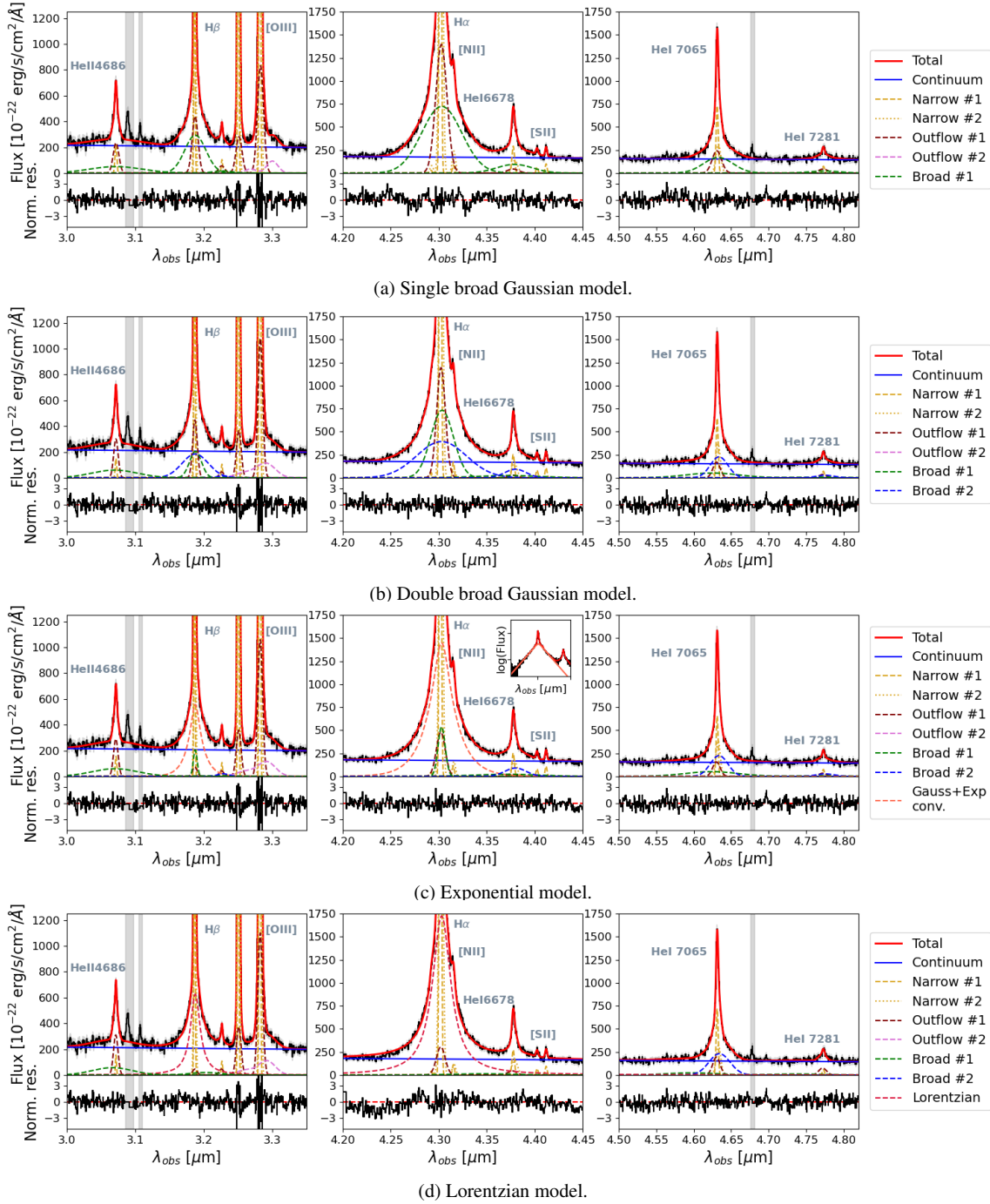


Fig. 6. Spectrum of GS-3073, showing the relevant hydrogen, helium and metal emission lines analysed in this work. The total best fit is reported in solid red for each of the four different broad emission models considered in this work (from top to bottom): single Gaussian, double Gaussian, exponential, Lorentzian. Individual line components are reported in dashed colours, and the underlying continuum in solid blue. For each model, the lower panels display the residuals between the best-fit model and the observed spectrum, normalised by the spectral uncertainties. The masked regions (in gray) correspond (from left to right) to the blend of He I $\lambda 4711$ and [Ar IV] $\lambda 4713$, [Ar IV] $\lambda 4740$ and [Ar III] $\lambda 7136$ lines.

He (He I $\lambda 4922, \lambda 6678, \lambda 7065, \lambda 7281$) and doubly ionised He (He II $\lambda 4686$). Metal lines (e.g. [N II] $\lambda \lambda 6548, 6583$, [S II] $\lambda \lambda 6716, 6731$) are considered only insofar as they are necessary to accurately model nearby lines of interest. We refer to Übler et al. (2023) and Ji et al. (2024) for a comprehensive list of emission line detections, including those not analysed in this work. Throughout the analysis we use the Bayesian information criterion (BIC; Schwarz 1978; Liddle 2007) with a threshold of $\Delta\text{BIC} = 10$ to assess the statistical preference of different models.

Regarding the He I emission, we masked He I $\lambda 4711$ due to its weakness and strong blend with [Ar IV] $\lambda 4713$. We also excluded He I $\lambda 5876$ from our analysis because of the presence of a continuum feature that is difficult to model. This feature skews the broad-Gaussian component, pushing for an extremely broad ($\sim 15\,000$ km/s) and blue-shifted (by almost 2000 km/s) solution which is not seen in any other broad line. Since this feature is seen only in the G395H data but not in the prism, it may arise from incorrect background subtraction in this spectral region, for instance due to a bright spoiler source or to a

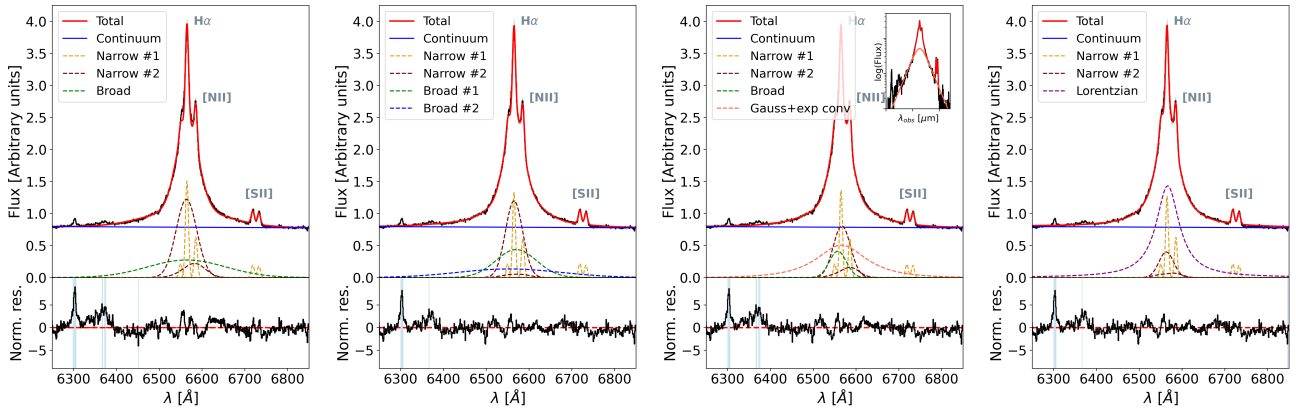


Fig. 7. Fit of the H α complex in the composite spectrum from Vanden Berk et al. (2001) using the three different models for broad emission analysed in this work (see Sect. 6), from left to right: single Gaussian, double Gaussian, exponential, Lorentzian. In the lower panels, data points differing from the model more than 4σ are highlighted in blue. Some of these points are associated to emission lines not considered in our model, for instance the doublet [O I] $\lambda\lambda 6300, 6363$ is clearly detected in the residuals of all the considered models, and some weak emission from [O I] or [Fe X] at ~ 6370 Å, as also reported in Vanden Berk et al. (2001).

Table 1. Statistics of the four broad-line models for GS-3073.

Model	χ^2_{red}	χ^2	BIC	χ^2_{wings}
Single Gauss.	1.17	1578	1999	265
Double Gauss.	1.04	1395	1874	177
Exponential	1.04	1392	1856	183
Lorentzian	1.26	1694	2136	273

Notes. The χ^2_{wings} is evaluated in the 500–4000 km/s wings of H α , while the other statistical parameters encompass also H β and helium lines, in both core and wings components.

‘disobedient’ shutter in the NIRSpect/MSA (Jakobsen et al. 2022; Ferruit et al. 2022).

For each emission line, we model the local continuum as a linear function and the line emission as a superposition of Gaussian functions: one outflow component, as seen in [O III] (see discussion below); two narrow components; and two broad components, adopted after verifying that a single broad component does not provide an adequate fit ($\Delta\text{BIC} = \text{BIC}_{\text{single_broad}} - \text{BIC}_{\text{double_broad}} = 125$, Table 1; Figs. 6a, b), at least for the brighter lines (but see Section 6.2 for a more detailed discussion on the broad profile of He II $\lambda 4686$ line). The need for a double narrow component in all lines – but the weak He II $\lambda 4686$ and [S II] doublet – is dictated by the poor fit obtained using a single one ($\Delta\text{BIC} = \text{BIC}_{\text{single_narrow}} - \text{BIC}_{\text{double_narrow}} = 127$).

We adopted a non-informative prior on the centroids of the various narrow components, therefore allowing for shifts by up to ± 500 km/s. We constrained the line full-width at half maximum (FWHM), respectively, between 50 and 700 km/s for the narrow components, and between 500 and 15 000 km/s for the broad and outflow components. Given the similarity of H α and H β profiles, and likewise among the He I profiles, we tied both the narrow and broad line widths within each group separately. Unlike GN-28074, GS-3073 offers no evidence of Balmer absorption, so it was not included in our model. The fitting results are shown in Fig. 6b and line widths are reported in Table 2.

Narrow components in all lines exhibit widths of a few hundreds of km/s and small relative velocity shifts of $\lesssim 50$ km/s. Two

Table 2. Line widths of hydrogen, helium and [O III] lines in GS-3073.

	Line parameter	Value (km/s)
Balmer series	$\text{FWHM}_{\text{H}\alpha, \text{narrow}, 1}$	147^{+3}_{-3}
	$\text{FWHM}_{\text{H}\alpha, \text{narrow}, 2}$	261^{+4}_{-4}
	$\text{FWHM}_{\text{H}\alpha, \text{broad}, 1}$	1935^{+65}_{-60}
	$\text{FWHM}_{\text{H}\alpha, \text{broad}, 2}$	4255^{+118}_{-112}
	$\text{FWHM}_{\text{H}\alpha, \text{broad}, \text{tot}}$	2453^{+77}_{-77}
[O III]	$\text{FWHM}_{[\text{O III}] \lambda 5007, \text{outflow}, 1}$	747^{+19}_{-16}
	$\text{FWHM}_{[\text{O III}] \lambda 5007, \text{outflow}, 2}$	2936^{+154}_{-154}
He I	$\text{FWHM}_{\text{He I} \lambda 7065, \text{narrow}, 1}$	190^{+13}_{-13}
	$\text{FWHM}_{\text{He I} \lambda 7065, \text{narrow}, 2}$	428^{+37}_{-35}
	$\text{FWHM}_{\text{He I} \lambda 7065, \text{broad}, 1}$	5439^{+479}_{-450}
	$\text{FWHM}_{\text{He I} \lambda 7065, \text{broad}, 2}$	1782^{+97}_{-89}
	$\text{FWHM}_{\text{He I} \lambda 7065, \text{broad}, \text{tot}}$	2038^{+128}_{-114}
He II	$\text{FWHM}_{\text{He II} \lambda 4686, \text{narrow}}$	216^{+51}_{-48}
	$\text{FWHM}_{\text{He II} \lambda 4686, \text{broad}}$	7678^{+548}_{-552}
Exponential fit	$\text{FWHM}_{\text{H}\alpha, \text{broad}}$	610^{+50}_{-52}
	W	1036^{+16}_{-15}
	f_{scatt}	$0.91^{+0.02}_{-0.02}$

Notes. The line widths are derived from the purely Gaussian emission-line model described in Sect. 6 and are reported for both the single and total components. For comparison, the results obtained with the exponential parametrisation (Sect. 6.1) are also listed.

broader components are detected in [O III], with FWHM ~ 750 and ~ 3000 km/s, respectively. The former is mildly blue-shifted with respect to narrow emission (< 100 km/s from the bluest narrow component), while the latter is significantly redshifted (by ~ 770 km/s). We interpret these components as likely signatures of outflows. Both of them were initially included in the

fit of the other emission lines; however, the broader and more blue-shifted component contributed a negligible flux and was therefore excluded from the modelling of the remaining lines for simplicity. Its absence in other emission lines leaves open the possibility that this feature, rather than tracing an outflow, may correspond to faint, broad Fe II emission (Trefoloni et al. 2025). In contrast, the narrower outflow component is clearly detected in the hydrogen and helium lines – but not in metal lines. We verified that the inclusion of such outflow component is required to obtain a satisfactory fit of hydrogen and helium lines, as removing it leads to a significant degradation of the fit quality, as established by studying both $\Delta\text{BIC} = \text{BIC}_{\text{double_broad, no_outflow}} - \text{BIC}_{\text{double_broad+outflow}} = 269$ and the reduced chi-squared statistics ($\chi^2_{\text{red}} = 1.28$ versus $\chi^2_{\text{red}} = 1.05$ for our fiducial double Gaussian model including the outflow component). We note that, given its relatively narrow width and small velocity shift, this component that we dubbed as ‘outflow’ does not conflict with the earlier definition of LBDs, which requires the absence of broad outflows with FWHM exceeding 1000 km/s. Indeed, it may alternatively be interpreted as an additional narrow component, possibly associated with satellites, that, combined with the other two, traces the complex gas kinematics within the galaxy. However, since the focus of our work is not on narrow or outflow emission, we do not discuss any further the physical interpretation of these narrow components. We just point out that two narrow components (at least) are necessary to achieve a satisfactory fit of hydrogen and helium lines, as the removal of one of them would significantly worsen the fit ($\Delta\text{BIC} > 100$), and cause one of the broad components to collapse into a narrow one. Such an intricate kinematic structure is plausible, given the presence of two likely companions identified in the photometry, as discussed above.

6.1. Broad components of the hydrogen Balmer lines

The two Gaussian components necessary to model broad hydrogen emission in the blue Rosetta are well constrained, with a FWHM of ~ 2000 km/s and ~ 4250 km/s, respectively, and comparable fluxes. The combined broad profile has an effective FWHM of ~ 2450 km/s, computed by applying the standard FWHM definition to the total profile resulting from the sum of the two components. Interestingly, the line dispersion measured from the second moment of the total profile is ~ 1400 km/s, corresponding to an equivalent Gaussian FWHM of ~ 3300 km/s: this discrepancy confirms the presence of significant flux in broad wings that are more extended than a Gaussian.

Indeed, there are several studies claiming that broad line profiles of LRDs are characterised by exponential wings ((Rusakov et al. 2026; Torralba et al. 2026a; Nikopoulos et al. 2026); Sneppen et al. 2026; Scholtz et al. 2026b): to investigate whether the same holds for LBDs, we alternatively fit the broad Balmer profiles of the blue Rosetta by adopting the same exponential model used for the red Rosetta in Brazzini et al. (2025). Following their prescriptions, broad emission is represented as the sum of a broad Gaussian component and the convolution of this broad Gaussian with a symmetric double exponential profile (Rusakov et al. 2026), representing the unscattered and scattered BLR emission, respectively. The parametrisation of helium and other metal lines is left unchanged, namely, pure Gaussians. Given the similarity of the H α and H β profiles, we impose the same exponential width, W , and scattered fraction, f_{scatt} (i.e. the fraction of BLR emission that undergoes at least one scatter within the dense gas envelope), in the two lines. This assumption yields good results (Fig. 6c; Table 2), with $W \sim 1000$ km/s, consistent with the typical values found in LRDs (Rusakov et al.

2026; Brazzini et al. 2025), $f_{\text{scatt}} = 0.9$, and $\text{FWHM}_{\text{broad}} \sim 600$ km/s. The exponential is highly preferred over the single Gaussian model. In fact, the exponential fit yields a $\chi^2_{\text{red}} = 1.04$, compared to $\chi^2_{\text{red}} = 1.17$ for the single Gaussian, and the difference in BIC is large ($\Delta\text{BIC} = \text{BIC}_{\text{single_broad}} - \text{BIC}_{\text{exp}} = 143$; Table 1). On the contrary, the comparison between exponential and double-Gaussian models is less straightforward. When considering the full set of emission lines, the two models produce similar χ^2_{red} and χ^2 , while the BIC criterion ($\Delta\text{BIC} = \text{BIC}_{\text{double_broad}} - \text{BIC}_{\text{exp}} = 18$) formally favours the exponential model – thus supporting the conclusion that exponential wings are not a prerogative of LRDs. However, when we restrict the analysis to the H α line only, and further limit to the broad wings of the line profile (500–4000 km/s), excluding the core emission within ± 500 km/s from the peak, we find that the two models perform equally well, with a difference in χ^2 of $\Delta\chi^2_{\text{wings}} = 6$, indicating that both models reproduce the broad Balmer wings with comparable accuracy. Of course, one cannot apply a statistical test for model selection to an arbitrary subset of the data (such as the broad-line wings) ignoring the rest of the fit. Still, this test serves to highlight *where* the model difference arises (i.e. in the line core and not in the fast wings). We obtain similar results also by including H β in the analysis, and by considering broad wings to extend either up to 4000 km/s or 5000 km/s, where limiting to 4000 km/s serves to avoid contamination from He I 4922 in the H β emission.

Another commonly adopted parametrisation for modelling broad-line emission involves Lorentzian profiles. We therefore perform a Lorentzian fit of H α and H β lines in the blue Rosetta, using the same kinematics for the two lines (Fig. 6d), and retrieve a FWHM of ~ 1800 km/s. However, this model does not provide a good fit, performing even worse than the single-Gaussian ($\Delta\text{BIC} = \text{BIC}_{\text{Lorentz}} - \text{BIC}_{\text{single_broad}} = 137$), either considering the total line profiles, or restricting again only to the broad wings.

We therefore conclude that the blue Rosetta stone exhibits broad Balmer emission that cannot be modelled with a single Gaussian or Lorentzian profiles. However, the available statistics does not provide a clear preference between the exponential and double Gaussian models, particularly when focusing on the high-velocity wings where the models differ most. In practice, these two models can hardly be differentiated using any statistical metrics alone, because their difference is largest where it matters the least (i.e. near the lines core). Here, the fit quality may be driven by the presence of hard-to-model effects, such as multiple kinematic components due to the companions (Fig. 2b), radiative-transfer effects (Chang et al. 2026), and the presence of narrow-line and outflow emission (Übler et al. 2023); all these effects may tip the scales in favour of the exponential model, even though the double Gaussian performs equally well in the line wings, i.e. the spectral regions where AGN emission is certainly dominant. This is a general warning when attempting to differentiate between exponential, multiple-Gaussian, but also Lorentzian and power-law profiles.

Lastly, we note that the adopted model for broad Balmer emission has no significant impact on the other helium or metal lines, and the widths of the narrow Balmer components remain consistent within 1σ .

6.2. Helium lines and BLR stratification

Similar to the Balmer lines, we model helium lines with one (He II) or two (He I) narrow, one outflow, and one (He II) or two (He I) broad components. For both He I and He II lines,

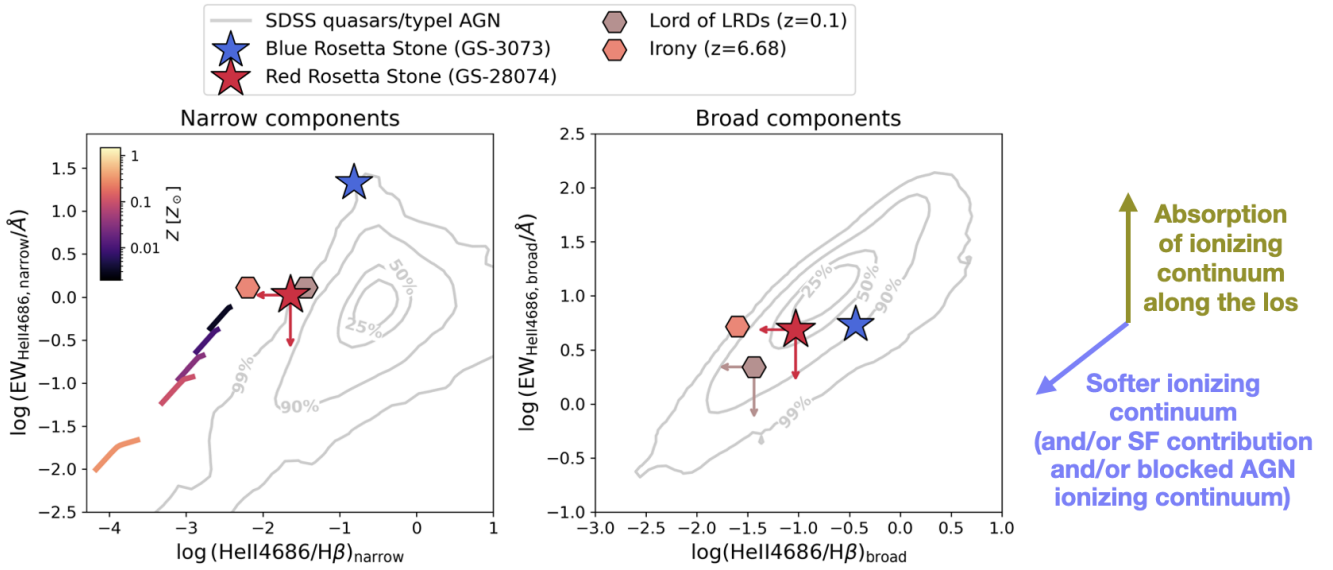


Fig. 8. $\log(EW_{\text{He II}}/\text{\AA})$ versus $\log(\text{He II } \lambda 4686/\text{H}\beta)$ for narrow He II emission (left panel), encompassing both narrow and outflow components, and broad He II emission (right panel). In both panels, the LBD GS-3073 is reported as a blue star, flanked with some significant LRDs from the literature: GN-28074 (upper limits), in red, the local Lord of LRDs at $z = 0.1$, and Irony at $z = 6.68$. The gray contours refer to local broad-line AGNs from the SDSS DR16 quasar catalogue (Wu & Shen 2022). In the left panel for the narrow components, we also show some predictions from photoionisation models of star-forming galaxies, considering single-burst, 1-Myr old stellar populations, with metallicities ranging from $0.001Z_{\odot}$ to solar values. Each segment represent a specific metallicity value, with ionisation parameter increasing from left to right from $\log U = -4$ to -1 . Assuming GS-3073 to be representative of the overall LBDs population, we observe that both LRDs and LBDs occupy a different position in the $\log(EW_{\text{He II, narrow}}/\text{\AA})$ versus $\log(\text{He II}/\text{H}\beta)_{\text{narrow}}$ plane with respect to standard AGNs. Instead, the difference between LRDs, LBDs and standard type I AGNs in their broad He II emission is less evident, with LRDs and LBDs characterised by similar $EW_{\text{He II, broad}}$ and $(\text{He II}/\text{H}\beta)_{\text{broad}}$ values, both still lying in the same region of local broad-line AGNs.

the kinematics of both narrow and broad component(s) are left free to explore similarities and differences with respect to lower-ionisation lines. The outflow component is tied to [O III].

The choice of a single Gaussian to model both the narrow and broad He II emission is motivated by the faintness of the line: this simpler parametrisation reduces parameter uncertainties and degeneracies, improving the overall fit quality (no difference in χ^2 , but $\Delta\text{BIC} = \text{BIC}_{\text{He II, double, broad}} - \text{BIC}_{\text{He II, single, broad}} = 19$). In contrast, He I broad lines show a clear preference for a profile more complex than a single Gaussian, with exponential or double Gaussian performing equally well ($\Delta\text{BIC} = \text{BIC}_{\text{double, gauss}} - \text{BIC}_{\text{exp}} = 7$).

Both He I and He II narrow components exhibit widths comparable to those of the narrow components of the Balmer lines. The broad He I emission also shows kinematics similar to the Balmer broad components. In contrast, the broad He II 4686 line displays a significantly larger width (FWHM ~ 7600 km/s), and is slightly blue-shifted by ~ 200 km/s. This difference in line widths is consistent with the BLR ionisation stratification seen in reverberation studies (Bentz et al. 2023; McDougall et al. 2026; Xi et al. 2025). Higher-ionisation lines, such as He II, are expected to originate closer to the central ionising source, where the radiation field is more intense and gas clouds in virial equilibrium reach higher velocities. This interpretation also supports the applicability of virial methods for estimating black hole masses in these systems. At the same time, the larger width of He II compared to both Balmer and He I lines places important constraints on alternative broadening mechanisms. In particular, scenarios in which the extended wings of broad emission lines are primarily produced by electron scattering in a dense cocoon surrounding the BLR would predict similar line widths across different species. The observed stratification instead suggests

that virial motions dominate the broadening of high-ionisation lines, while additional processes (e.g. scattering or radiative transfer effects) may still contribute to shaping the profiles of lower-ionisation transitions.

6.3. Diagnostic diagrams

In this section, we introduce the diagnostic diagrams used throughout the following analysis and discussed more in detail in Sections 7.2 and 7.3: $\log(EW_{\text{He II}})$ versus $\log(\text{He II } \lambda 4686/\text{H}\beta)$ (Fig. 8); $\text{He II}/\text{H}\beta$ versus $[\text{N II}]/\text{H}\alpha$ (Fig. 9); and $[\text{O III}] \lambda 4363/\text{H}\gamma$ versus $[\text{O III}] \lambda 5007/[\text{O II}] \lambda 3727$ (Fig. 10).

We first consider the $\log(EW_{\text{He II}})$ versus $\log(\text{He II } \lambda 4686/\text{H}\beta)$ diagram (Fig. 8), which relates the line-to-continuum strength (e.g. covering factor, optical depth, geometry) to the hardness of the ionising spectrum, considering separately the narrow and broad emission. From our emission-line fits, we measure He II rest-frame equivalent widths (EW) of 21 ± 4 Å for the narrow emission (including both the narrow and outflow Gaussian components), consistent with Übler et al. (2023), and 37 ± 7 Å for the broad emission. The relatively large uncertainties reflect the combined errors in the line and continuum estimates. To place the blue Rosetta stone in context, we compare with both local quasars from the SDSS DR16 quasar catalogue (grey contours; Wu & Shen 2022), and three LRDs from the literature: RUBIES-EGS-49140, dubbed ‘Irony’, currently the only high-redshift ($z = 6.68$) LRD known exhibiting He II $\lambda 4686$ detection (Wang et al. 2026; D’Eugenio et al. 2025b); the ‘Lord of LRDs’ J1025+1402, a recently discovered local LRD at $z = 0.1$ (Ji et al. 2026b; Lin et al. 2026a) showing He II emission only in its narrow component; and the red Rosetta stone, which shows neither narrow or broad He II emission. For sources with

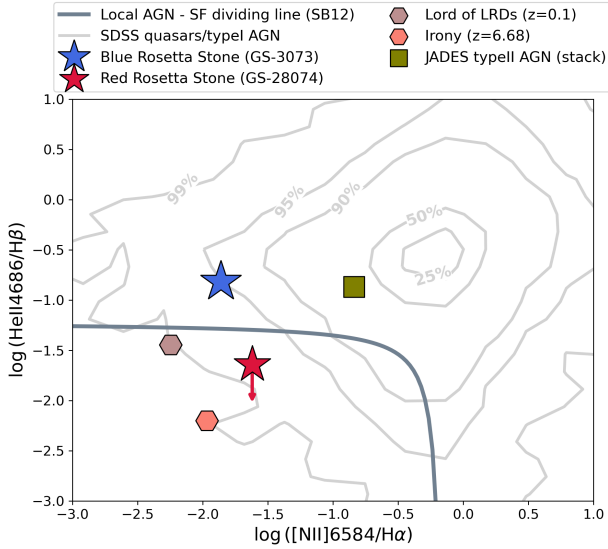


Fig. 9. $\log(\text{He II}/\text{H}\beta)$ versus $\log([\text{N II}]/\text{H}\alpha)$ for the narrow line components of GS-3073 (blue star), flanked with some typical LRDs: GN-28074 (red star), Lord of LRDs, and Irony. The gray contours are local broad-line AGNs from the SDSS DR16 quasar catalogue (Wu & Shen 2022). The green square represents the stack of type II AGNs from JADES (Scholtz et al. 2025). GS-3073 lies in the AGN region, with $\log(\text{He II}/\text{H}\beta) = -0.82 \pm 0.09$ and $\log([\text{N II}]/\text{H}\alpha) = -1.86 \pm 0.09$, slightly shifted towards lower $\log([\text{N II}]/\text{H}\alpha)$ values with respect to the bulk of SDSS AGNs – probably a metallicity effect. Instead, LRDs at all redshifts lie in the star-formation region, covering significantly lower values of both $\log(\text{He II}/\text{H}\beta)$ and $\log([\text{N II}]/\text{H}\alpha)$, probably due to a combined effect of low metallicity and absorption of ionising photons from the dense gas envelope.

no significant line detection, we derive 3σ upper limits assuming Gaussian line profiles with widths of 150 km/s and 6000 km/s for the narrow and broad components, respectively. For the narrow-line component, we further compare our measurements with predictions from CLOUDY (v23.01; Ferland et al. 1998; Gunasekera et al. 2023) photoionisation models of star-forming galaxies. We use BPASS v2.3 simple stellar population models (Byrne et al. 2022), assuming a single starburst episode 1 Myr ago and a Chabrier (2003) initial mass function. The clouds assume a single density of $\log n_{\text{H}} = 10^3 \text{ cm}^{-3}$ and solar-scaled abundances. Different metallicity regimes are explored, ranging from $0.001 Z_{\odot}$ to solar values. Each line represents a model with fixed metallicity, but with varying ionisation parameter (increasing left to right from $\log U = -4$ to -1). The predicted $\text{EW}_{\text{He II}}$ includes both nebular emission and the transmitted stellar component, as these cannot be reliably separated at the spectral resolution of the prism. (also, for the lowest metallicities relevant here, stellar He II $\lambda 4686$ may be significantly narrower than in more metal-rich young stars; e.g. Berg et al. 2026).

We investigated the position of the blue Rosetta stone on the $\log(\text{He II } \lambda 4686/\text{H}\beta)$ versus $\log([\text{N II } \lambda 6583]/\text{H}\alpha)$ diagram (Fig. 9) for the narrow component only, a diagnostic commonly used to distinguish between different ionising sources. Again, we made a comparison with SDSS quasars and LRDs from the literature and include the JADES type II AGN stack (green square; Scholtz et al. 2025). The division between AGNs and star-forming galaxies (gray solid line) is taken from Shirazi & Brinchmann (2012), further validated by Tozzi et al. (2023).

Lastly, we employed the new $[\text{O III}] \lambda 4363/\text{H}\gamma$ versus $[\text{O III}] \lambda 5007/[\text{O II}] \lambda 3727$ diagnostic diagram (Fig. 10), first proposed by Mazzolari et al. (2024). Mazzolari et al. (2024) noticed that

the region of the diagram with high $[\text{O III}] \lambda 4363/\text{H}\gamma$ and low $[\text{O III}] \lambda 5007/[\text{O II}] \lambda 3727$ is populated only by AGNs, both in the local Universe and at high redshift, while the rest of the diagram at lower $[\text{O III}] \lambda 4363/\text{H}\gamma$ ratios can be populated by both AGNs and star-forming galaxies. They interpreted this difference as due primarily to the AGN X-ray heating being more effective in heating the ISM at a given ionisation parameter (traced by $[\text{O III}]/[\text{O II}]$), hence boosting the auroral line emission. This hypothesis is also supported by photoionisation models, both in Mazzolari et al. (2024) and in the larger grid of CLOUDY models presented in Jones et al. (2026), drawn from the parent HOME-RUN grid by Marconi et al. (2024) and displayed in Fig. 10, with star-forming (SF) models on the left, and AGN-only models on the right. These models span a broad range of ionisation parameters and densities, and are colour-coded by gas density. Flux ratios for the red Rosetta come from Juodžbalis et al. (2024), while for the blue Rosetta from Mazzolari et al. (2026) and Ji et al. (2024).

7. Discussion

In this section, we compare the emission-line properties of blue and red Rosetta stones. We also highlight their commonalities and differences.

7.1. Hydrogen lines

The analysis of hydrogen lines in both red and blue Rosetta stones provides key insights into the physical conditions and geometry of the emitting gas. Both sources exhibit broad Balmer lines with FWHM of a few thousand km/s, whose high luminosities imply powering by an accreting SMBH (e.g. Maiolino et al. 2024), classifying them as sub-classes of broad-line AGNs. However, their broad profiles are markedly non-Gaussian, particularly in $\text{H}\alpha$, and cannot be adequately described by simple single-Gaussian models. The spectral shape of the $\text{H}\alpha$ line has been extensively studied in LRDs, where $\text{H}\beta$ is much harder to detect due to steep Balmer decrements, with $\text{H}\alpha/\text{H}\beta > 3$, typically of the order of 10 (e.g. Juodžbalis et al. 2024; D’Eugenio et al. 2026b, 2025b; Torralba et al. 2026a; Labbe et al. 2024), and up to 20 in some cases (D’Eugenio et al. 2026a; Ji et al. 2026b). In many (but not all; e.g. D’Eugenio et al. 2025b; Scholtz et al. 2026b) LRDs, broad $\text{H}\alpha$ can be reproduced with exponential wings (Rusakov et al. 2026), consistent with scattering by free electrons in a dense gaseous envelope surrounding the accretion disc. However, in few cases where multiple lines can be measured, their widths differ significantly (Brazzini et al. 2025; Torralba et al. 2026a), ruling out such simple electron-scattering scenario and suggesting either contributions from faint $[\text{Fe II}]$ emission (Torralba et al. 2026a), different virial broadening mechanisms, turbulence, or more complex radiative transfer (including multi-level absorption and emission; Chang et al. 2026). Recently, Scholtz et al. (2026b) and Madau et al. (2026) have demonstrated that exponential wings may also be explained in terms of virialised, radially stratified BLR, with each radius emitting as a Gaussian. Another probe disfavouring the electron-scattering scenario derives from integral-field spectroscopy of one lensed LRD at $z = 7.04$ (Abell2744-QSO1; Furtak et al. 2023, 2024) from the BlackTHUNDER programme, revealing that the intermediate-velocity component of $\text{H}\alpha$ (a few hundred km/s) is spatially resolved (a few hundred pc), while the broad wings remain spatially unresolved (< 30 pc; Juodžbalis et al. 2026b); such a large spatial mismatch disfavors electron

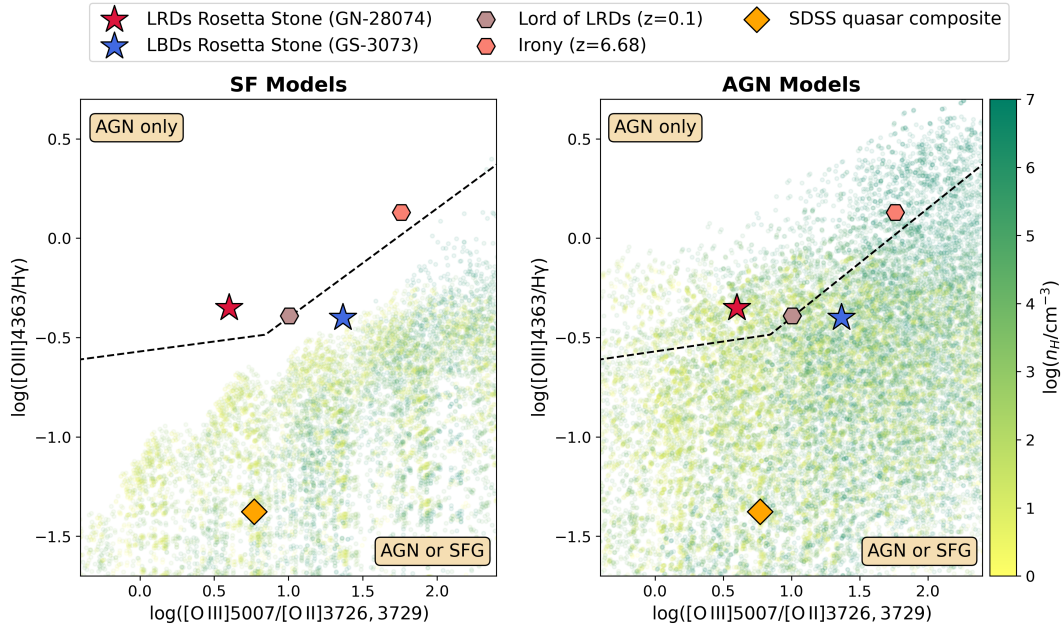


Fig. 10. Auroral-[O III] diagnostic diagram from [Mazzolari et al. \(2024\)](#) for GS-3073 (blue star), flanked with LRDs: GN-28074 (red star), Lord of LRDs, and Irony. Errors on the blue Rosetta’s flux ratios are of few %, too small to be reported in the figure. The SDSS composite quasar spectrum from [Vanden Berk et al. \(2001\)](#) is reported for comparison. Values from the large grid of CLOUDY models (drawn from the parent HOMERUN grid; [Marconi et al. 2024](#)) are coloured by hydrogen density, with star-forming models in the left column and AGN models in the right column.

scattering, which predicts that the entire broad line arises from the same compact region. The broad component can still be fit with an exponential profile ([D’Eugenio et al. 2026b](#)), but the resulting black hole mass would be almost two orders of magnitude lower than what measured directly from the spatially resolved velocity field. Similar studies (of both LRDs and LBDs) are necessary to build a representative picture.

In this work, we show that the LBD GS-3073 also exhibits non-Gaussian wings in its broad hydrogen lines. It is not clear yet if the overall AGN population exhibits this non-gaussianity to some degree, which would remain undetected in most cases because of data limitation (in particular, low SNR), and/or because a Gaussian profile is commonly assumed for simplicity. Indeed, alternative functional forms—including multiple Gaussians, exponential profiles, Lorentzians, or broken power laws—have long been explored in the literature (e.g. [Nagao et al. 2006](#); [Cano-Díaz et al. 2012](#); [Kollatschny & Zetzl 2013](#); [Scholtz et al. 2021](#); [Santos et al. 2025](#)). To further investigate this possibility, we fit the $H\alpha$ emission-line complex in the quasar composite spectrum from [Vanden Berk et al. \(2001\)](#), see Appendix A, using the four different models for broad emission discussed above for the blue Rosetta: single broad Gaussian, double broad Gaussian, exponential scattering kernel, and Lorentzian. Our results are displayed in Fig. 7. Consistent with the results for both the red ([Brazzini et al. 2025](#)) and blue Rosettas, a single Gaussian is ruled out, while the other models provide good fits, with the double-Gaussian statistically preferred (a more thorough investigation in individual SDSS quasars will be presented in a separate paper; Trefoloni et al. in prep.). Combined together, these results (i.e. where not all LRDs exhibit exponential profiles, while some LBDs and standard type I AGNs do) suggest that extended non-Gaussian wings are not exclusive to the LRD population.

Despite the common non-gaussianity of their broad profiles, hydrogen lines in the two Rosettas show important differences. In the blue Rosetta stone, $H\alpha$ and $H\beta$ have consistent widths and can be modelled with a single set of parameters, although it is not

yet clear whether this is a general property of LBDs. In contrast, the red Rosetta shows different line widths ([Brazzini et al. 2025](#)), and the overall picture in LRDs remains unclear, with both consistent (e.g. [D’Eugenio et al. 2025b](#); [Nikopoulos et al. 2026](#)) and discrepant (e.g. [Torralba et al. 2026a](#)) line widths reported.

Another key difference concerns absorption. The blue Rosetta shows no Balmer (or other) absorption despite high-quality data ([Übler et al. 2023](#)), whereas the red Rosetta exhibits clear absorption in $H\alpha$, $H\beta$, and also $\text{He I } \lambda 10830$ lines ([Juodžbalis et al. 2024](#)). Balmer absorption is common in LRDs and often shows complex kinematics (e.g. [D’Eugenio et al. 2026a, 2025b](#); [Naidu et al. 2025](#)), with a much higher incidence than in normal AGNs (>10%; e.g. [Matthee et al. 2024](#); [Maiolino et al. 2024](#)), and likely also higher than in LBDs – especially considering that the current fraction is almost certainly underestimated, due to SNR and spectral-resolution constraints (e.g. [D’Eugenio et al. 2026a](#)). In this context, the lack of Balmer absorption in blue Rosetta is consistent with an unobscured view of the accretion disc, similar to standard quasars.

Emission-line ratios provide further insight. LRDs exhibit extremely large Balmer decrements in their broad lines ([Juodžbalis et al. 2024](#); [Brooks et al. 2025](#); [D’Eugenio et al. 2026b,a, 2025b](#); [Torralba et al. 2026a](#)), as well as high Paschen-to-Balmer ratios ([de Graaff et al. 2025a](#)), while their narrow lines indicate little dust attenuation ([D’Eugenio et al. 2026b, 2025b, 2026a](#); [Lin et al. 2026a](#); [Ji et al. 2026b](#); [Nikopoulos et al. 2026](#)). This combination has been interpreted either as localised dust near the BLR (e.g. [Nikopoulos et al. 2026](#)), or as evidence of collisional excitation dominating the broad-line emission (e.g. [Ji et al. 2026b](#); [Torralba et al. 2026a,b](#)). Case-B recombination combined with standard dust-attenuation has been ruled out in at least one case ([D’Eugenio et al. 2025b](#); [Nikopoulos et al. 2026](#)) through the study of broad $H\alpha$, $H\beta$, and $H\gamma$ line ratios, although the limited number of high-S/N observations prevents firm conclusions for the full LRD population. In contrast, the blue Rosetta and typical quasars show broad Balmer decrements

closer to Case-B values (see Übler et al. 2023 for GS-3073, while Dong et al. 2008 find a $H\alpha/H\beta$ ratio of 3.06 and 10% scatter for SDSS Seyfert 1 and quasars). However, this apparent agreement may be misleading, as similar ratios can occur even in optically thick regimes (Ruff et al. 2012), a scenario supported by several lines of evidence, including the low $Pa\alpha/Pa\beta$ flux ratio (Glikman et al. 2006; Ruff et al. 2012). A key distinction is that LRDs span a wide range of $H\alpha/Pa\beta$ ratios (~ 3 –12; de Graaff et al. 2025a), while the BLR models of Ruff et al. (2012) remain confined to $H\alpha/Pa\beta \gtrsim 10$.

7.2. High-ionisation lines: He II λ 4686

The blue Rosetta stone shows a clear detection of both narrow and broad He II λ 4686 emission (Fig. 6), whereas the red Rosetta stone exhibits no evidence of He II, as already noted by Juodžbalis et al. (2026a). This behaviour is consistent with the general weakness of high-ionisation lines observed in JWST-selected AGNs and LRDs (e.g. Zucchi et al. 2026; Lambrides et al. 2026, 2025).

To physically interpret these results, we analyse the position of the blue Rosetta stone on the $\log(EW_{\text{He II}})$ versus $\log(\text{He II } \lambda 4686/H\beta)$ and $\log(\text{He II } \lambda 4686/H\beta)$ versus $\log([N \text{ II}] \lambda 6583/H\alpha)$ diagrams, flanked with local SDSS quasars and LRDs from the literature at both high and low redshift. We shall first discuss the $\log(EW_{\text{He II}})$ versus $\log(\text{He II } \lambda 4686/H\beta)$ diagnostic (Fig. 8). For the broad component (right panel), the blue Rosetta stone lies within the distribution of local quasars, although toward its lower-density end (i.e. the 90th-percentile density contour). This suggests an ionising spectrum broadly consistent with standard AGNs, although possibly under slightly different physical conditions (e.g. density or ionisation parameter). Similarly, the available measurements and upper limits for LRDs do not show strong deviations from the quasar locus, although current constraints remain relatively weak – for example, tighter upper limits pushing towards the bottom-left corner of the diagram would favour soft ionising continua. In contrast, the narrow He II emission shows a more peculiar behaviour (left panel). Both the blue Rosetta stone and the LRDs are offset from the local quasar distribution towards the upper-left region of the diagram (although in the case of red Rosetta we only have upper limits), corresponding to higher $EW_{\text{He II}}$ and/or lower $\text{He II}/H\beta$ ratios. For blue Rosetta, its location exceeds the maximum envelope of stellar populations by one dex in $\log(EW_{\text{He II}})$ and almost 2 dex in $\log(\text{He II } \lambda 4686/H\beta)$, implying a hard ionising continuum. For LRDs, the lower $\text{He II}/H\beta$ ratio could reflect either an intrinsically softer ionising continuum, or contribution by star formation in the host. Alternatively, it could also result from a gaseous medium blocking the AGN ionising radiation, or simply by BLR clouds with large covering factor. Higher $EW_{\text{He II}}$ could instead arise from intrinsically stronger line emission, or from a suppression of the AGN ionising continuum along our line of sight, resulting in a continuum that is dominated by host-galaxy emission or reflected AGN light.

Additional insights are provided by locating the same sources in the $\log(\text{He II } \lambda 4686/H\beta)$ versus $\log([N \text{ II}] \lambda 6583/H\alpha)$ diagram for narrow components (Fig. 9). The blue Rosetta lies within the AGN region, although offset towards lower $[N \text{ II}]/H\alpha$ values with respect to the bulk of local quasars, possibly reflecting lower metallicity in the narrow-line region. In contrast, the red Rosetta and other LRDs occupy the star-formation region of the diagram.

Taken together, these results indicate that the broad-line region properties of the blue Rosetta stone and LRDs are broadly

consistent with those of typical quasars, whereas the narrow-line emission shows significant differences. Indeed, in terms of broad He II, both blue Rosetta and the LRDs (even their upper limits) are well within the distribution of SDSS standard quasars, although such emission is more prominent in the blue Rosetta than in the red Rosetta and the other LRDs. This offset indicates that the BLR is seeing harder and softer ionising continuum in the two cases, respectively. This can be an effect of different incident SEDs (with the blue Rosetta exhibiting an intrinsically ‘hotter’ SED), but also of different BLR properties: for instance, higher density of the BLR clouds in LRDs could result into lower ionisation parameter, hence suppression of He II emission – this effect will be explored in a separate paper.

Explaining the narrow-line properties is more challenging. Scenarios involving anisotropic emission or obscuration blocking the nuclear radiation could move points towards the locus of star-formation galaxies in the $\text{He II}/H\beta$ versus $[N \text{ II}]/H\alpha$ diagram, as expected in super-Eddington accretion models with a geometrically thick inner disc (e.g. Madau & Haardt 2024; Madau 2026; King 2025; Zucchi et al. 2026). While this may account for the blue Rosetta stone, it does not naturally explain the behaviour of all LRDs, particularly those with broad-line properties consistent with normal quasars (e.g. Irony, whose $EW_{\text{He II, broad}}$ is fairly consistent with normal quasars). Therefore, no single scenario currently provides a fully satisfactory explanation for the diversity of He II properties observed in JWST-selected AGNs.

7.3. Auroral lines

Both blue and red Rosetta stones show prominent [O III] λ 4363 auroral line emission (Übler et al. 2023; Ji et al. 2024; Juodžbalis et al. 2024), allowing their placement on the [O III] λ 4363/ $H\gamma$ vs [O III] λ 5007/[O II] λ 3727 diagram by Mazzolari et al. (2024) (Fig. 10). Clearly, SF models fail to reproduce the very high value of [O III] λ 4363/ $H\gamma$ observed in the red Rosetta (for which $\log([O \text{ III}] \lambda 4363/H\gamma)_{\text{GN-28074}} = -0.350 \pm 0.014$, and $\log([O \text{ III}] \lambda 5007/[O \text{ II}] \lambda 3727)_{\text{GN-28074}} = 0.60 \pm 0.08$), despite models reaching extremely high densities (up to $n_H = 10^7 \text{ cm}^{-3}$, far exceeding the [O III] λ 5007 critical density of $7 \times 10^5 \text{ cm}^{-3}$), while AGNs can reproduce fairly high values of this ratio. Paradoxically, while the red Rosetta is solidly in the AGN-only region of the diagram, the blue Rosetta, which displays prominent He II, is located in the SF-AGN mixed region of the diagram, with $\log([O \text{ III}] \lambda 4363/H\gamma)_{\text{GS-3073}} = -0.49 \pm 0.02$, and $\log([O \text{ III}] \lambda 5007/[O \text{ II}] \lambda 3727)_{\text{GS-3073}} = 1.362 \pm 0.013$. Note that invoking densities even higher than those explored in the models presented by Jones et al. (2026) would not help, as they are approaching the critical density of [O III] λ 4363 ($5 \times 10^7 \text{ cm}^{-3}$), where this line starts to saturate relatively to $H\gamma$. Moreover, significantly higher densities would place the emitting gas in the BLR realm, in which case the [O III] λ 4363 line should be considerably broader. Therefore, a more likely scenario is that the medium emitting [O III] λ 4363 is irradiated by X-rays, which are effective in heating it and making it fairly hot. The presence of an AGN might appear to contradict the absence of He II in red Rosetta. However, it is also true that AGNs accreting well below Eddington are characterised by prominent X-ray emission and modest blue bump. This would be in tension with the scenario that LRDs are super-Eddington sources (Madau & Haardt 2024; Lambrides et al. 2026; Pacucci & Narayan 2024; Inayoshi et al. 2025). Within this context and in the same direction, we note that the only LRD for which the BH mass has been measured directly (dynamically), A2744-QSO1, is actually found to be accreting well below Eddington – $L_{\text{AGN}} \sim 10^{-2} L_{\text{Edd}}$ (Juodžbalis et al.

Table 3. Comparison of the observational diagnostics for the two Rosetta stones GN-28074 and GS-3073, and the SDSS quasar stack.

Reference source	GN-28074	GS-3073	SDSS composite
Category	LRDs	LBDs	‘Standard’ type I
Broad line emission	✓	✓	✓
Non-Gaussian wings in Balmer lines	✓	✓	✓
Compactness	✓	✓	✓
v-shaped SED	✓	✗	✗
Excitation diagnostics:			
1. High-ionisation lines (He II 4686)	✗	✓	✓
2. BPT diagram	✗	✗	✓
3. Auroral diagnostic	✓	✓	✓
Balmer absorption	✓	✗	✗
Large (broad c.) Balmer decrement	✓	✗	✗
X-ray weakness	✓	✓	✗
Mid-IR deficiency	✓	✗	✗
Presence of hot dust	✓	✓	✓
Radio weakness	✓	✓	✗
Variability	✗	✗	✓
Overmassive BH ^a	✓	✓	✗

Notes. Green ticks and red crosses indicate the presence and absence of a given feature, respectively. ^aBH masses using standard virial relations.

2026b). Of course, given that these properties are being assessed only for a small subset of very well studied objects, it is possible that LRDs are a heterogeneous population with different properties.

8. LBDs and LRDs Rosetta stones: Bringing the pieces together

In this section, we summarise the observational properties of the blue and red Rosetta stones, and place them in the general context of standard type I AGNs by further comparing with the SDSS composite spectrum (Table 3).

Both sources are broad-line AGNs, with broad permitted lines (hydrogen and helium) having widths of thousands of km/s. The line profiles are markedly non-Gaussian, with extended wings that are well described by double Gaussians or exponential kernels. Similar features are observed also in the SDSS composite and other type I AGNs (Laor 2006, Trefoloni et al., in prep.), suggesting that extended exponential wings should not be regarded as a prerogative of LRDs. In this context, we remark that even within a ‘standard’ virial BLR framework, no theoretical requirement exists for Gaussian line profiles (e.g. Kollatschny & Zetzl 2013). However, the physical origin of the wings remains uncertain, with possible contributions from electron or resonant scattering (see respectively Rusakov et al. 2026 and Naidu et al. 2025), or virial motions (Juodžbalis et al. 2026a,b).

Despite similar non-Gaussian line shapes, the two Rosettas differ markedly in their broad Balmer-line ratios and absorption features. The red Rosetta shows a large Balmer decrement, typical of LRDs (e.g. Brooks et al. 2025; Juodžbalis et al. 2024; de Graaff et al. 2025a), while blue Rosetta is consistent with Case-B ratios (Übler et al. 2023), similar to the SDSS

composite (Vanden Berk et al. 2001). Still, several lines of evidence caution against interpreting the Balmer decrement of LBDs as evidence of optically thin regimes (e.g. Ruff et al. 2012). The red Rosetta shows prominent Balmer absorption and a strong Balmer break, indicating the presence of very dense gas along the line of sight (Juodžbalis et al. 2024). In contrast, blue Rosetta lacks Balmer absorption and shows only weak C IV and possible redshifted Mg II absorption (which, however, could also be interpreted as blended [Fe IV] $\lambda\lambda 2839, 2836$ emission given the presence of many other iron lines in the optical; Ji et al. 2024).

The UV/optical continuum further distinguishes the two sources. The red Rosetta displays the v-shaped SED and red optical colours typical of LRDs (Matthee et al. 2024; Pérez-González et al. 2024; Williams et al. 2024; Hviding et al. 2025), enabling their efficient photometric selection (Kocevski et al. 2025; Hviding et al. 2025). In contrast, blue Rosetta has a blue power-law continuum similar to the SDSS composite, with UV and optical slopes consistent with the broader population of high-redshift star-forming galaxies, complicating LBDs photometric selection.

Additional notable differences concern Fe II emission. Classical type I AGNs and quasars generally display strong Fe II pseudo-continuum emission (e.g. Baldwin et al. 2004; Kovačević et al. 2010), as also seen in the Vanden Berk et al. (2001) stack (see e.g. Boroson & Green 1992, for Fe II deficient quasars). In contrast, the blue Rosetta and most JWST-discovered AGNs lack this feature, completely missing the strong 4464–4684 Å bump (Trefoloni et al. 2025), even in extremely deep observations. LRDs, instead, regularly show iron emission, although in narrower forbidden transitions (Lin et al. 2026a; Ji et al. 2026b; Lambrides et al. 2025; D’Eugenio et al. 2025b; Kokorev et al. 2026), possibly arising from a cool envelope

(Lin et al. 2026a; Torralba et al. 2026a), although other solutions cannot be ruled out (see e.g. Ji et al. 2026b).

Emission-line diagnostics provide a complex picture. In the BPT diagram (reported in Juodžbalis et al. 2024 and Übler et al. 2023 for the red and blue Rosettas, respectively), neither source occupies the same region as local AGNs, due to the low $[\text{N II}]/\text{H}\alpha$ ratio, overlapping instead with low-metallicity starbursts at $z = 5\text{--}7$ (e.g. Cameron et al. 2023). In contrast, the $\text{He II } \lambda 4686$ diagnostic behaves remarkably different for the two Rosettas, as the He II line is undetected down to stringent upper limits in the red Rosetta, but clearly detected in the blue Rosetta, in both narrow and broad components. This suggests that a hard ionising continuum reaches not only the BLR but also the NLR in the blue Rosetta, while in the red Rosetta it may be suppressed by an additional obscuring component, such as a dense gas envelope, which efficiently suppresses the highest-energy photons along most lines of sight, while still allowing the broad Balmer lines to escape; such a component could even be the cold, outer layer of the BLR gas, if the covering factor was sufficiently high. Lastly, the auroral $[\text{O III}]$ diagnostic Mazzolari et al. (2024) places the red Rosetta in the ‘AGN-only’ region of the diagram, while the blue Rosetta is also consistent with star-formation photoionisation (Fig. 10). This suggests that LRDs may still host hard ionising photons (Jones et al. 2026), potentially in a low-accretion-rate regime with strong X-ray production but weak UV emission. Although direct constraints on the accretion rate are lacking for red Rosetta, similar objects show low Eddington ratios (e.g. the LRD QSO1 from Juodžbalis et al. 2026b), though this scenario requires further quantitative testing.

Both Rosettas are undetected in X-rays down to stringent upper limits, independently of the assumed bolometric correction (see, e.g. the extreme scenario proposed by Greene et al. 2026). For red Rosetta, X-ray weakness can plausibly be explained by strong absorption associated with the same dense medium responsible for Balmer absorption and suppression of the ionising continuum (e.g. Maiolino et al. 2025; Rusakov et al. 2026). In this scenario, LRDs would be intrinsically X-ray luminous, and the X-ray emission could heat the gas that primarily produces auroral line emission, although the lines of sight reaching such gas should not be Compton thick. In contrast, the absence of X-ray emission in the blue Rosetta is more puzzling. The lack of Balmer absorption disfavors the same explanation adopted for LRDs, as there is no evidence of dense gas along the line of sight. While the presence of absorbing material cannot be entirely ruled out, as observed in some local type I AGNs (e.g. Risaliti et al. 2009, 2011; Maiolino et al. 2010; Kumar et al. 2024), such gas is unlikely to be Compton thick. In this case, the co-existence of strong high-ionisation lines (Vanzella et al. 2010; Übler et al. 2023; Ji et al. 2024) with very weak X-ray emission suggests that “X-ray weakness” cannot always be interpreted as simple obscuration, and may instead reflect intrinsic suppression of the corona, as observed in local narrow-line Seyfert I galaxies, or strongly anisotropic radiation (Lambrides et al. 2026; Pacucci & Narayan 2024; Madau & Haardt 2024; Madau 2026; Maiolino et al. 2025; Mazzolari et al. 2025; King 2025). If LRDs and LBDs share the same central engine, then intrinsic X-ray weakness may also apply to LRDs, although this may imply re-visiting the interpretation of the auroral line strength as due to X-ray heating in these systems. An additional possible scenario, which could apply to both LBDs and LRDs, is the one proposed by Pacucci et al. (2026), in which X-rays are absorbed by a dense gas envelope that also emits at a temperature of 40 000 K; hence producing the blue spectrum in LBDs and the redder spectrum in LRDs via some dust reddening.

Both sources show mid-IR emission consistent with thermal dust near the sublimation temperature. In blue Rosetta, the strength of such mid-IR emission is comparable to that observed in normal type I AGNs; in red Rosetta it is weaker by a factor of a few, but still clearly detected. The presence of hot dust suggests that some UV radiation must reach the circumnuclear regions even in LRDs; therefore, the obscuring medium cannot fully cover the central source, placing strong constraints on scenarios in which all UV emission is absorbed by dense gas (e.g. the black-hole star model).

While mid-IR emission indicates the presence of hot dust, its relative weakness in LRDs introduces an apparent tension with simple energy balance expectations. If a significant fraction of the UV emission is absorbed, the reprocessed energy must emerge elsewhere in the SED. Gas is likely to provide a major contribution to the absorption, as in this case the reprocessed energy can emerge not only as IR dust emission, but also as nebular line and continuum emission in the optical, consistent with the large equivalent widths observed in LRDs. This helps alleviate the apparent inconsistency arising from the mid-IR deficiency. Additional effects may further reduce the observed reprocessed output, making the assumption of energy balance no longer valid. Anisotropic emission and/or partial covering can allow a significant fraction of the radiation to escape along directions not aligned with our line of sight. In fact, although the lack of an extended $\text{Ly}\alpha$ halo has been interpreted as evidence against substantial escape of ionising radiation (e.g. Torralba et al. 2026b), such analyses are currently limited to single objects. More recent studies instead suggest that LRDs may contain lower-density channels through which $\text{Ly}\alpha$ photons can preferentially escape (Ji et al. 2026c; Tang et al. 2026). Consistent with this picture, Geris et al. (2026b) and Sok et al. (2026) find that LRDs (and LBDs as well) exhibit narrow emission-line ratios indicative of AGN excitation, together with $\text{Ly}\alpha$ emission that is significantly stronger than expected for star-forming galaxies. They also report a broad $\text{Ly}\alpha$ component consistent with emission from a broad-line region. Taken together, these results indicate that the absorbing material is not fully covering the central source and, therefore, a significant fraction of the intrinsic radiation can escape without being intercepted and reprocessed by the surrounding medium. In this scenario, the energy balance argument is no longer applicable. In addition, the likely low dust-to-gas ratios at high redshift reduce the efficiency of dust reprocessing and shift the emission toward longer wavelengths and lower temperatures.

Another puzzling similarity between the two Rosettas is the apparent lack of variability (at least with the photometric data available so far). While in LRDs this has been linked to a warm ($T \sim 5000$ K) pseudo-atmosphere, this interpretation does not seem applicable to the blue Rosetta. If the origin of the lack of variability in both red and blue Rosettas is the same, then it must be a different mechanism, such as continuum emission from the BLR clouds, as already inferred for normal AGNs.

Finally, both sources appear overmassive relative to local BH–stellar mass relations, as in the majority of high-redshift JWST-discovered AGNs for which BH masses are estimated using local virial relations (e.g. Harikane et al. 2023; Maiolino et al. 2024; Juodžbalis et al. 2026a,b; Pacucci et al. 2023; Jones et al. 2025; Geris et al. 2026a). While the validity of such relations is uncertain for LRDs (e.g. Rusakov et al. 2026), direct measurements in at least one case support their validity (Juodžbalis et al. 2026b). The red Rosetta appears overmassive relative to the $M_{\text{BH}} - \sigma_*$ relation (Juodžbalis et al. 2026a), although this specific case could be a misplacement due to

significant BH mass overestimation (Sneppen et al. 2026). The blue Rosetta is also overmassive (Übler et al. 2023), and in this case the large width of He II emission excludes line broadening from electron or resonant scattering, even after accounting for bound-free absorption, hence suggesting that the estimation based on the virial relations is probably approximately correct.

Taken together, these observations suggest that LRDs and LBDs may share the same central engine (i.e. an accretion disc with a broad-line region and hot dust), but they may differ in the amount and geometry of dense gas, capable of (i) reddening the UV-optical continuum, generating a v-shaped SED and (ii) imprinting Balmer absorption, and (iii) absorbing the ionising continuum, such that high-ionisation narrow lines are intrinsically weak, and standard ionisation diagrams break down. In this scenario, LBDs may even represent lower-obscuration phases of the same AGN phenomenon, while still retaining some of the unique properties (such as X-ray and radio weakness) that set them apart from standard type-I AGNs. Alternatively (or even additionally) LBDs and LDRs may also be characterised by different regimes of accretion (e.g. sub- and super-Eddington) or in terms of properties of the central engine (e.g. presence or absence of a hot corona); in this scenario, the X-ray weakness of LRDs could be due to Compton thick absorption, while it could be due to intrinsic X-ray weakness in the case of LBDs. While our work establishes a detailed comparison using two among the most luminous objects as reference, similar studies of larger samples are needed to build a representative picture of the population.

9. Conclusions

We present a comparative study of the two sources, GS-3073 and GN-28074, taken as the archetypical little blue dot and little red dot, respectively, following the definitions given in Section 2. By highlighting their commonalities and differences, and placing them in relation to luminous quasars from SDSS, we have drawn the following conclusions:

- LRDs are spectroscopically characterised by a v-shaped SED, with optical colours that are typically redder than those of high- and low-redshift broad-line AGNs. GN-28074, the red Rosetta stone, exhibits precisely these characteristics. In contrast, GS-3073, the blue Rosetta stone, shows optical and UV slopes consistent with the bulk of $z \gtrsim 2$ broad-line AGNs in JADES, and also consistent with the bulk of star-forming galaxies. This makes the identification of LBDs challenging; specifically, a simple photometric selection based on optical and UV colours would be ineffective, leaving the serendipitous identification in spectroscopic surveys as the only viable strategy;
- Both red and blue Rosettas are characterised by broad emission in hydrogen and helium lines, with line widths of $\sim$ few thousands km/s, confirming their AGN nature. If extended to the full LRD and LBD populations, this result suggests that these sources may represent different sub-classes of a common AGN phenomenon, differing from one another, and from standard type I AGNs, in the amount and geometry of dense gas; however, they could differ in terms of accretion regimes (e.g. sub- vs super-Eddington accretion);
- Hydrogen lines with exponential profiles are not exclusive to LRDs, given that not only the red Rosetta, but also the blue Rosetta and the SDSS composite (representative of LRDs, LBDs, and standard type I AGNs, respectively) all exhibit exponential wings in their Balmer lines. While current

models of LRDs can account for these wings through electron scattering by free electrons within a dense, partially ionised medium embedding the central source, the physical mechanism and responsible scattering agent remain unclear for LBDs and, more generally, for broad-line AGNs; potentially, simple scattering by the partially ionised gas in the BLR clouds can explain this phenomenon (Laor 2006). This indicates that the functional form of hydrogen lines alone is insufficient as a diagnostic of the emission line process itself.

- In the blue Rosetta, the correlation of line widths with their ionisation potentials is consistent with the BLR stratification seen in normal AGNs, where higher ionisation lines originate in the inner regions of the BLR, where gas clouds move faster;
- The detection in the blue Rosetta stone of the high-ionisation line He II $\lambda 4686$, in both narrow and broad components, implies the presence of a high ionising flux, further supported by the detection of coronal lines. This radiation is able to reach not only the BLR, but also the NLR. In this scenario, LBDs are expected to exhibit a high intrinsic production of energetic photons, possibly exceeding that of typical type I AGNs, and no significant absorption. In contrast, the absence of He II 4686 in most LRDs (and, in particular, in red Rosetta, at least in its narrow component) is possibly due to the presence of the dense gaseous envelope, that efficiently filters high-energy photons, or an intrinsically softer ionising source;
- Both blue and red Rosettas are characterised by extreme X-ray weakness. While in the latter this can be ascribed to absorption by the dense gas absorption, as suggested by the presence of deep Balmer absorption, in the former there is no evidence of dense absorbers along the line of sight. Therefore, X-ray weakness could be explained in terms of intrinsic X-ray deficiency, such as the lack of a properly developed hot corona;
- Dust is present in the nuclear regions of both LRDs and LBDs. Furthermore, this dust is hot ($T \sim 1000$ K), as commonly observed in AGNs. Such temperatures imply that the dust is directly exposed to the UV ionising radiation field, and located close to the sublimation radius. This, in turn, requires that a significant fraction of the AGN-produced UV radiation escapes the central region, in contrast with the simple black-hole star scenario adopted for LRDs. In the red Rosetta the amount of mid-IR radiation is a factor of 3–6 lower than expected from standard type I AGN templates; however, this could be due to ionising part of the UV radiation being filtered by the neutral absorber and/or could also be associated with the lower metallicity (and, hence, lower dust-to-gas ratio) in these systems;
- Both the red and blue Rosettas lack clear variability. Reprocessing of the continuum by surrounding gas or by BLR clouds with large covering factor, can potentially explain this phenomenon.

The main results discussed above are summarised in Table 3. Our comparative analysis of GS-3073 and GN-28074 probes that, despite sharing a common AGN paradigm, these newly JWST-discovered sources exhibit significant differences both with respect to each other and to luminous type I AGNs commonly observed with ground-based facilities. The peculiar properties of LRDs have been the subject of intense investigation in recent months; one of the interpretations proposed recently is the so-called ‘black-hole star’ scenario, according to which the central supermassive black hole is embedded within a dense gaseous envelope, that absorbs most of the emitted

ionising radiation. We have discussed that this scenario presents various observations issues. However, leaving aside those issues, clearly this framework, does not work for LBDs, as these sources show intermediate characteristics between AGNs and LRDs which complicates their identification and classification, especially considering that their analysis so far has been almost entirely overlooked. The goal of this work is not to provide a definitive interpretation of the nature of LBDs, but rather to highlight their existence as a distinct and peculiar sub-class within the AGN population, characterised by physical properties that differ significantly from those of both classical AGNs and LRDs, and that warrant subsequent investigations in greater detail.

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Table A.1: Statistics of the four models fitted to the broad $H\alpha$ emission in the SDSS quasar composite from [Vanden Berk et al. \(2001\)](#).

Model	χ^2_{red}	χ^2	BIC	χ^2_{wings}
Single Gauss.	2.16	1908	1996	346
Double Gauss.	1.56	1377	1485	190
Exponential	1.96	1734	1836	236
Lorentzian	2.03	1802	1891	166

Notes: The χ^2_{wings} is evaluated in the 500 – 5000 km/s wings of $H\alpha$.

Appendix A: Modelling broad Balmer emission in the SDSS composite quasar spectrum

In this section, we fit the $H\alpha$ complex in the quasar composite template from [Vanden Berk et al. \(2001\)](#), neglecting the spectral region around $H\beta$ and $[\text{O III}]$ due to the strong contamination from Fe II. The $H\alpha$ line is fitted with a narrow component, an outflow component, and different recipes for broad emission, as described in Section 6: single broad Gaussian, double broad Gaussian, broad Gaussian combined with an exponential kernel, and Lorentzian. We consider two components also in the nitrogen lines, with kinematics bound to those of narrow and outflow $H\alpha$. We try to adhere as much as possible to the same line constraints provided in Section 6, apart from the outflow component whose kinematics is left free, as we do not fit the $[\text{O III}]$ lines.

The narrow and outflow components exhibit FWHM of ~ 350 km/s and ~ 2200 km/s, respectively, independently of the model adopted for broad emission. The single broad Gaussian model predicts an extremely large $\text{FWHM}_{\text{broad}} \sim 9800$ km/s, and performs significantly worse than the other three models (Table A.1). The double Gaussian model (broad components with $\text{FWHM}_{\text{broad},1} \sim 5100$ km/s, $\text{FWHM}_{\text{broad},2} \sim 13,000$ km/s, and comparable fluxes) is the statistically preferred one when considering the whole spectral range, while if we restrict only to the 500 – 5000 km/s high-velocity wings, we find that the Lorentzian model performs better. If we limit our analysis only to a visual inspection of residuals (Fig. 7, lower panels), we see that the exponential model also fits the data quite well, with the difference in χ^2 and BIC values likely due to the incomplete parametrisation of the $H\alpha$ complex (e.g. no constraints on the outflow component, or need to add at least the $[\text{O I}]$ or He I $\lambda 6678$ lines). A detailed analysis of this kind, which would provide more robust results, is beyond the scope of this work. Nevertheless, our results allow us to conclude that we cannot ascribe exponential profiles in Balmer lines as a prerogative property of LRDs, given that such non-Gaussian broad wings are clearly detected also in the composite spectrum of low-redshift, luminous type I AGNs. In particular, the exponential parameters for the SDSS composite spectrum are not degenerate, and their best values are: $\text{FWHM}_{\text{broad}} = 2125^{+150}_{-110}$ km/s, $W = 2760 \pm 40$ km/s, and $f_{\text{scatt}} = 0.81^{+0.17}_{-0.07}$, implying a broad profile broader than both GN-28074 and GS-3073. We further strengthen these results by carrying out the same $H\alpha$ fit in other high-resolution local quasar spectra from [Dalla Bontà et al. \(2025\)](#), and always find the same result: the double broad Gaussian and exponential models perform significantly better than the single broad Gaussian.