

A DUSTY QUENCHING-CANDIDATE AGN HOST AT $z = 5.7$: MASSIVE QUIESCENT GALAXIES MAY QUENCH ALREADY DURING THE DUST-OBSCURED PHASE

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Abstract

We present a spectro-photometric analysis of RUBIES-EGS-9809, a broad-line AGN-host galaxy at $z = 5.7$ with a Balmer break and a dominant point-source component. The source is clearly dust reddened ($A_V \gtrsim 3$ mag), shows hot- and cold-dust emission, and is a Compton-thick X-ray emitter, with X-ray-to-bolometric ratio **consistent with luminous AGN**. The large A_V agrees with a clear Na I absorption ($EW = 17 \pm 2$ Å), possibly from a neutral-gas outflow ($3\text{-}\sigma$), while broad [O III] traces an ionized outflow, suggesting AGN feedback may be affecting the host. We estimate a stellar mass $\log(M_\star/M_\odot) = 10.7 \pm 0.3$, $L_{\text{bol}} \sim 4 \times 10^{46}$ erg s^{−1}, and a virial black-hole mass $\log(M_\bullet/M_\odot) \sim 8.1$ (subject to large systematics). The Balmer break is spatially resolved (0.1 arcsec, 0.6 kpc), **consistent with a stellar origin**, implying the galaxy is already old in stars while still heavily obscured. This shows that massive galaxies can host evolved stellar populations during their compact, dust-obscured phase, **consistent with formation in an earlier dusty starburst**. SED modelling suggests a declining SFR, but low-resolution spectroscopy alone cannot constrain the recent SFR, so we treat the source as a strong quenching candidate rather than a secure post-starburst system. Because quenching follows the decline in SFR, star-formation-driven outflows are disfavoured, leaving AGN feedback as a plausible driver. We speculate that such rapid feedback (~ 100 Myr timescale) may precipitate quenching while the post-quenching phase stays dust-enshrouded, concealing the UV-bright quenched phase that would otherwise be easily detected, if dust free. By the time dust clears, the UV-luminous stars may have already dwindled, leaving a classic dust-free quiescent galaxy. This ‘dusty path’ to quiescence may explain the lack of intermediate-age quenched progenitors (ages 50–100 Myr) linking dusty starbursts to massive quiescent systems at $z = 3\text{--}7$.

Subject headings: Active galactic nuclei — AGN host galaxies — Galaxy evolution — Galaxy winds — High-redshift galaxies — Supermassive black holes

1. INTRODUCTION

Massive quiescent galaxies (stellar mass $M_\star \gtrsim 10^{10.5\text{--}11} M_\odot$) at redshifts $z = 3\text{--}7$ present a significant challenge to current models of galaxy formation, because they are unexpectedly numerous, massive and old compared to theoretical predictions (Carnall et al. 2023a; Valentino et al. 2023; Long et al. 2024; Russell et al. 2025; Alberts et al. 2024; Baker et al. 2025a). Problems with our observations appear unlikely: their quiescent nature is confirmed by spectroscopy (Nanayakkara et al. 2024; Baker et al. 2025b; Nanayakkara et al. 2025), their large masses are independently confirmed by stellar dynamics (Carnall et al. 2023b), including from spatially resolved dynamical models (Pascalau et al. 2026), and their old ages are tightly constrained by prominent Balmer breaks (Carnall et al. 2023b; de Graaff et al. 2025a; Weibel et al.

2025) or even 4000-Å breaks (Glazebrook et al. 2024; Baker et al. 2025b). Yet, this remarkable population also presents another challenge: it is almost as if these galaxies emerged fully formed, with no massive galaxies with intermediate ages (~ 50 Myr) that could plausibly serve as their progenitors.

The star-forming progenitors should have star-formation rates (SFRs) in excess of $100 M_\odot \text{ yr}^{-1}$ (e.g., Carnall et al. 2023b; Glazebrook et al. 2024; de Graaff et al. 2025a; although the precise value of the SFR also depends on the parametrization and probability priors adopted for the star-formation history, SFH; e.g., Tacchella et al. 2022; Turner et al. 2025). With such high SFRs, these star-forming galaxies should be readily detectable in the very same surveys that identified the quiescent population (Carnall et al. 2024; Nanayakkara et al. 2024; Baker et al. 2025b). Even conservatively assuming that all quiescent galaxies formed in extremely rapid starbursts lasting $\lesssim 100$ Myr (which, in reality, applies

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only to a fraction of $z \sim 1\text{--}2$ quiescent galaxies; Park et al. 2024), the observed number density of quiescent galaxies is so high that assuming a visibility ratio of 0.1 still predicts that we should detect at least several such progenitors within these survey footprints. The complete absence of such systems therefore suggests that these progenitors are heavily obscured. Recent work shows that extreme dust obscuration can be in place already at $z > 7\text{--}8$, with reports of very dusty galaxies and even direct dust detections at sub-mm wavelengths (Sun et al. 2026a; Bakx et al. 2025; Zavala et al. 2026). These systems demonstrate that rapid metal and dust build-up is feasible within the first 600 Myr, strengthening the plausibility of an early, deeply obscured formation pathway for the progenitors of massive quiescent galaxies.

The hypothesis of a highly obscured starburst phase is particularly promising, because most massive, quiescent galaxies are typically metal rich (e.g., Carnall et al. 2024; Turner et al. 2025). The build-up of metals and dust and the resulting obscuration could explain how the star-forming progenitors have been missed by large-area NIRCам surveys. The effect of dust would be amplified by the compact nature of these galaxies, whose quiescent descendants have half-light radii as small as $R_e = 250$ pc (e.g., Carnall et al. 2023b, 2024; de Graaff et al. 2025a). These compact starbursts should then be observable via cold-dust emission at sub-mm wavelengths. But while sub-mm galaxies have been proposed as the missing population, they seem too extended and rare (sizes of $R_e \gtrsim 1$ kpc; e.g., Swinbank et al. 2010; Hodge et al. 2016; Gillman et al. 2023) to explain the high number density of compact, quiescent galaxies. Important caveats to the size mismatch argument are rapid size evolution (Meidt & van der Wel 2024; van der Wel & Meidt 2025), and central dust in high-mass galaxies (Maheson et al. 2025), which could artificially inflate the UV–optical sizes of star-forming galaxies relative to their quiescent and dust-poor descendants. Recent progress in the search for suitable progenitors has come from the identification of compact, NIRCам-dark galaxies in the sub-mm survey ASPIRE (Sun et al. 2026a). These galaxies are so dust-obscured that they remain undetected by NIRCам, yet their relatively low SFRs also make them elusive in shallow sub-mm surveys (Sun et al. 2026a).

However, even these compact, NIRCам-dark galaxies do not fully solve the ‘missing progenitor’ problem. We still lack the population of intermediate-age galaxies (50–100 Myr) with weak Balmer breaks and intrinsically strong rest-frame UV continuum, which should represent the transition phase between dusty starbursts and dust-free quiescent galaxies. This phase should be easily detectable by *JWST* because galaxies with similar ages but much lower stellar masses ($M_\star = 10^{8.5} M_\odot$) have already been identified and spectroscopically confirmed (Looser et al. 2024; Kuruvanthodi et al. 2024; Baker et al. 2025c) at $z = 7\text{--}8.5$. Given that this transition is purely an ageing process, its duration is fixed by stellar evolution, and it is not sufficiently short to explain the observational gap.

An intriguing possibility is that some compact, dusty galaxies may already host these intermediate-age populations – instead of being active starbursts. Pérez-González et al. (2025) discovered a Balmer break in the compact, dusty sub-mm galaxy *Hyde* (Schreiber et al. 2018). This

galaxy is found at the centre of a bright and extended, bi-lobed ionized-gas structure, reminiscent of an outflow. Likewise, D’Eugenio et al. (2025a) identified a similar quasar-like nebula at $z = 5.89$ around *Mahler*, a $10^{10} M_\odot$ galaxy also showing a Balmer break and luminous UV continuum. While these are viable progenitors, their number density is at least ten times lower than required. Although rare, dusty, post-starburst galaxies have also been observed (Setton et al. 2024), while Ji et al. (2024) found a ring-like structure of cold and hot dust around the quiescent galaxy GS-9209 at $z = 4.7$. These discoveries suggest a scenario where massive galaxies stop or slow down their star formation while still retaining high column densities of dust, which reduces the visibility time of the ‘intermediate-age’ phase. At some point after star formation has already started to decline, the dust clears, revealing an already evolved stellar population.

Since in our hypothesis these galaxies must lack any significant star formation, active galactic nuclei (AGNs) are the only viable mechanism for rapid gas and dust removal. Such AGN-driven ‘outbursts’ are supported by tentative evidence of AGNs in both *Mahler* (D’Eugenio et al. 2025a) and *Hyde* (Pérez-González et al. 2025; although in *Hyde in-situ* AGNs inside the gas clouds cannot be ruled out, Perna et al. 2025a). In GS-9209, there is even direct evidence of an AGN, detected via broad-line region (BLR) emission (Carnall et al. 2023b).

In this article, we identify a galaxy at $z = 5.7$ that presents all the main characteristics of this outburst phase, caught in action. We present a compact, dusty galaxy with an AGN, detected at all wavelengths from X-rays to radio. The galaxy displays a Balmer break, which is spatially extended, implying an evolved stellar population. At the same time, a metal-loaded, multi-phase outflow may be actively removing the dust from this system, precipitating its transition to the quiescent stage. After introducing the target and data in Section 2, we illustrate the methods of our analysis (Sections 3 and 4) and the main results (Section 5). In Section 7 we discuss our findings and their possible implications for the progenitors of massive quiescent galaxies, while Section 8 presents a concise summary of our findings and our conclusions.

Throughout this work, we use a flat Λ CDM cosmology with $H_0 = 67.4 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and $\Omega_m = 0.315$ (Planck Collaboration et al. 2020), giving a physical scale of $6.00 \text{ kpc arcsec}^{-1}$ at redshift $z = 5.70$ (all physical scales are given as proper quantities). Stellar masses are total stellar mass formed, assuming a Chabrier (2003) initial mass function, integrated between 0.1 and $120 M_\odot$. All magnitudes are in the AB system (Oke & Gunn 1983) and all EWs are in the rest frame, with negative EW corresponding to line emission.

2. DATA AND TARGET

Our target (hereafter, RUBIES-EGS-9809) was identified as an X-ray emitter in the ‘Extended Groth Strip’ cosmological field (EGS; Rhodes et al. 2000; Davis et al. 2007).

The X-ray detection leverages the deepest *Chandra* X-ray observations available in EGS (AEGIS-XD, 800 ks; Nandra et al. 2015). We find a spatial match (separation $d < 0.29 \text{ arcsec}$) with the source XID 551 in the

TABLE 1: Summary of broad-band photometry for RUBIES-EGS-9809.

Instrument	Filter	Wavelength	Flux [μJy]	Ref.
<i>JWST</i> /NIRCam	—	0.9–4.4 μm	—	^a
<i>Spitzer</i> /IRAC	Ch3	5.8 μm	3.40 ± 0.90	^b
<i>Spitzer</i> /IRAC	Ch4	8.0 μm	10.9 ± 1.1	^b
<i>Spitzer</i> /MIPS	MIPS24	24 μm	140 ± 14	^c
JCMT/SCUBA-2	850- μm	850 μm	480 ± 120	^d
VLA	Band L	20 cm	99 ± 13	^e

Notes. ^a Table 2, source ‘9809’; ^b Nandra et al. (2015); ^c FIDEL (Far Infrared Deep Extragalactic Legacy Survey); ^d Zavala et al. (2018), ^e Willner et al. (2012).

AEGIS-XD catalogue. This source has a 0.5–10 keV X-ray flux of $F = (1.14 \pm 0.25) \times 10^{-15} \text{ erg s}^{-1} \text{ cm}^{-2}$ (Nandra et al. 2015), corresponding to an observed-frame X-ray luminosity of $L_X = (4.2 \pm 0.9) \times 10^{44} \text{ erg s}^{-1}$ in the 0.5–10 keV band. Applying the k -correction to the rest-frame 2–10 keV band (Section 6) gives $L_{2-10 \text{ keV}} \simeq 2.3 \times 10^{44} \text{ erg s}^{-1}$ before absorption correction.

For the near-infrared (NIR) counterpart, we use *JWST*/NIRCam images from the publicly available survey CEERS (the Cosmic Evolution Early Release Science Survey; Finkelstein et al. 2023). The matching NIRCam source is located at R.A. = 215.01730, Dec. = 52.880158 and has apparent magnitude 23.3 mag in F444W, but only 27.3 mag in F200W (Fig. 1a). We derive our own NIRCam photometry by fitting the images (Section 3), and we extend these NIR data to the mid- and far-infrared (MIR, FIR) ranges using publicly available data. Specifically, we use *Spitzer*/IRAC data (as reported by Nandra et al. 2015), *Spitzer*/MIPS 24 μm data from the Far-Infrared Deep Extragalactic Legacy Survey (FIDEL), and a 4- σ detection at 850 μm by the Submillimetre Common-User Bolometer Array 2 (SCUBA-2; Holland et al. 2013; Dempsey et al. 2013) on the James Clerk Maxwell Telescope (JCMT), from the SCUBA-2 Cosmology Legacy Survey (source S2CLS EGS.0113; separation $d = 1.5$ arcsec, or 10 percent of the 14.6-arcsec beam size at 850 μm ; Zavala et al. 2018). Finally, we also identify a radio counterpart in the AEGIS20 20-cm survey (Iverson et al. 2007), using the AEGIS20 catalogue (Willner et al. 2012). RUBIES-EGS-9809 matches EGS20 J142004.19+525248.5, with a separation of 0.3 arcsec (consistent with the stated uncertainty of 0.23 arcsec) and flux density $S_{20 \text{ cm}} = 99 \pm 13 \mu\text{Jy}$. For the analysis, we use Sérsic NIRCam photometry (Section 3) and aperture-based *Spitzer*, JCMT, and VLA data; a summary of the non-NIRCam data is provided in Table 1.

In 2024, RUBIES-EGS-9809 was selected for follow-up spectroscopy by the Cycle 2 programme RUBIES (Red Unknowns: Bright Infrared Extragalactic Survey; PI A. de Graaff and G. Brammer), which targets red sources identified by NIRCam (de Graaff et al. 2025b). The observations use NIRSpect (Jakobsen et al. 2022) and the Micro-Shutter Assembly (MSA; Ferruit et al. 2022), employing two dispersers: 47 minutes integration with both the prism and the G395M grating. In 2025, RUBIES-EGS-9809 was further observed for 4.74 hours with the prism by the Cycle-3 programme CAPERS (the CANDELS-Area Prism Epoch of Reionization Survey; PI M. Dickinson; CAPERS-27615). We use data from the DAWN JWST archive (DJA; Heintz et al. 2025), us-

ing their v4 data reduction.

The position of the MSA shutters is reported in Fig. 1a, with black and green indicating RUBIES and CAPERS, respectively. The RUBIES observations are better centred on the source, while the CAPERS pointing is offset to the south. For this reason, and to fully benefit from joint fitting the prism and G395M observations, in the rest of this paper we always use the RUBIES data as reference, except for studying spatial variations in the spectrum.

3. IMAGING ANALYSIS

3.1. Morphology

To measure the morphology and photometry of the source and its immediate environment, we use the same approach as D’Eugenio et al. (2025a), based on multi-component Sérsic-profile fitting with PYSERVIC (Pasha & Miller 2023). We obtain 15-arcsec square cutouts in the eight NIRCam bands observed by CEERS, using the fully reduced mosaics from the Dawn *JWST* Archive (DJA; version v7.2; Heintz et al. 2025). The raw NIRCam images were processed using a combination of the data-reduction pipeline JWST and GRIZLI (Brammer 2023), as described in Valentino et al. (2023). To take into account the instrument point spread function (PSF), we use empirical PSFs also provided by the DJA (Genin et al. 2025), and obtained using PSFEX (Bertin 2013; following the methods of Leauthaud et al. 2007). These PSFs are calculated at the average position angle of CEERS, resulting in a 35° rotation relative to our cutouts, which we address by de-rotating the PSF accordingly. The summary of the data and results is shown in Fig. 2 and Table 2. The fiducial model is the model with maximum posterior probability, where we used a fat-tailed loss function parametrized by a Student’s t distribution. The marginalized posterior probability on the free model parameters was obtained using the stochastic variational inference method (Hoffman et al. 2013).

We find three sources within ~ 2 arcsec of RUBIES-EGS-9809. We mask the brightest one (not shown, just outside the North edge of Fig. 1a), and we fit the other two using a Sérsic profile. These two sources (tentatively denoted 9809B and 9809C in Table 2) are compact and blue (Fig. 1a), but we lack spectroscopic information, so their association with RUBIES-EGS-9809 remains uncertain. For RUBIES-EGS-9809, our fiducial model is a single Sérsic profile.

The fit results are reported in Fig. 2 and Table 2. While 9809B and 9809C are detected in all filters, the main source is not detected in F090W (rest-frame FUV), and only marginally detected in F115W (4- σ significance). It displays a spatially extended structure in all filters, more so at blue wavelengths, consistent with a heavily dust-obscured core. The half-light radius declines steadily from $R_e = 500$ –600 pc in F200W and F277W (rest-frame NUV and B bands, respectively), to only 140 pc in F444W (rest-frame R). The latter is probably over-estimated, given that the resulting Sérsic index is $n \sim 4$, suggesting that a point-source component may be necessary in this band. We also tested a multi-component model consisting of a central point source plus a Sérsic

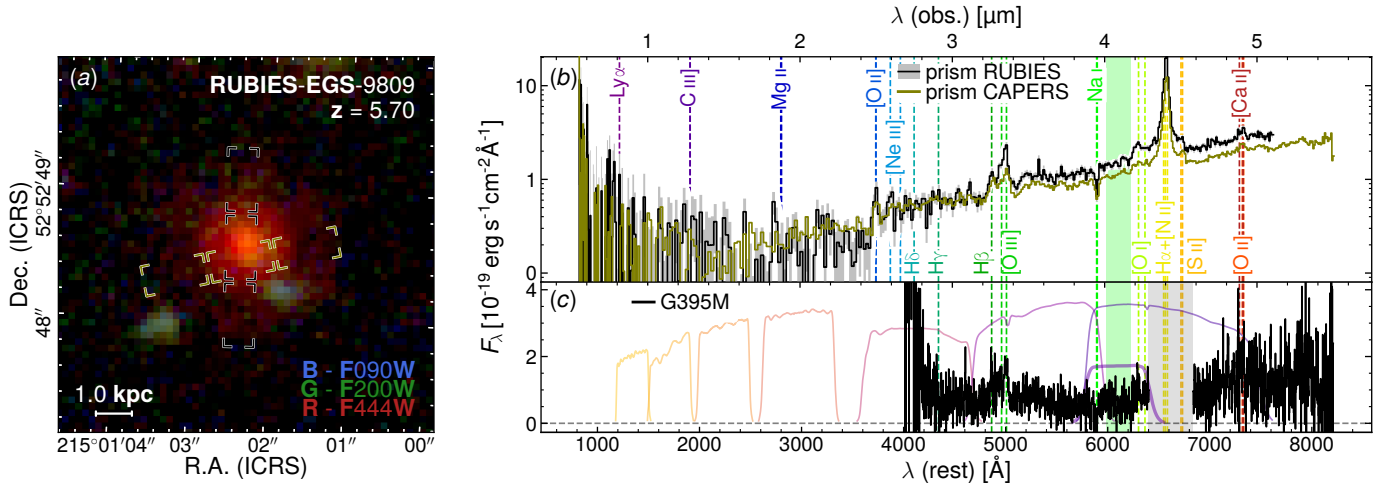


FIG. 1.— **a.** NIRCcam false-colour image of RUBIES-EGS-9809, highlighting the compact nature in F444W and the extended emission in the rest-frame UV. The NIRSspec/MSA micro-shutters are overlaid for both RUBIES (black) and CAPERS (green). **b.** Prism spectra, showing the Balmer break and broad $H\alpha$ emission, while the UV continuum appears very weak, due to strong dust attenuation. Weaker rest-optical emission lines are also visible. The optical continuum presents both a strong positive slope, indicative of dust reddening, and clear Na I $\lambda\lambda 5890, 5896$ absorption; the different spectral shape between the RUBIES and CAPERS spectra may be due to the different slit position (panel a). **c.** [O III] $\lambda\lambda 4959, 5007$ emission and Na I $\lambda\lambda 5890, 5896$ absorption are also visible in the medium-resolution spectrum from the G395M grating, but $H\alpha$ falls in the gap between the NIRSspec detectors (grey vertical band). Panel c also shows the transmission curves of the NIRCcam filters we use.

profile. In this alternative model, all the F444W flux is taken up by the point-source component, although the fit quality does not improve over the simpler single-Sérsic model, since both models achieve the same reduced χ^2 of 3.5.

The fact that a point-source model achieves the same fit quality as the Sérsic profile may indicate that at $4.4\ \mu\text{m}$ the AGN is dominating over the host galaxy. This is supported by the bright and broad $H\alpha$ emission line (Fig. 1b), and is also consistent with the SED model, where the AGN starts to dominate redward of $\lambda \simeq 3\ \mu\text{m}$ (Section 3.2). Besides these modelling difficulties, the change in spatial extent with wavelength is clearly visible in Fig. 3, where we compare the observed radial profiles of the five best-detected bands, from F200W to F444W. The source is clearly more extended at bluer wavelengths, despite the full-width at half-maximum (FWHM) of the instrument PSF increasing with wavelength. We also remark that both F277W and F356W contain emission lines that may be associated with extended gas emission, [O II] $\lambda\lambda 3726, 3729$ and [O III] $\lambda\lambda 4959, 5007$, both of which are routinely seen around bright AGNs (e.g., Crawford & Fabian 1989; Nesvadba et al. 2017; Helton et al. 2021; Johnson et al. 2022, 2024; Saxena et al. 2024; D’Eugenio et al. 2025b for [O II] $\lambda\lambda 3726, 3729$; Liu et al. 2013; Nesvadba et al. 2017; Husemann et al. 2022; Perna et al. 2023; Vayner et al. 2023; Solimano et al. 2024; Saxena et al. 2024; D’Eugenio et al. 2025a for [O III] $\lambda\lambda 4959, 5007$). However, line contamination cannot dominate the F277W morphology. Convolution of the fitted [O II] $\lambda\lambda 3726, 3729$ and [Ne III] $\lambda 3869$ fluxes from the Balmer-break spectral model (Table 5) with the F277W bandpass gives a line contribution of only $\simeq 3$ percent of the observed F277W flux. Even if all of this line emission were spatially extended, it could not drive the measured

F277W half-light radius.

A remaining possibility is that while the continuum is compact, there is diffuse line emission not captured by the RUBIES aperture spectrum, but still able to inflate the F277W half-light radius. In such a scenario, the EW of the [O II] $\lambda\lambda 3726, 3729$ and [Ne III] $\lambda 3869$ lines increases away from the centre of RUBIES-EGS-9809. However, the CAPERS spectrum, which is offset to the south of RUBIES-EGS-9809 (Fig. 1a), shows similar or even smaller EWs for both [O II] $\lambda\lambda 3726, 3729$ and [Ne III] $\lambda 3869$ (Fig. 1b). Thus, while extended ionized gas may contribute at some low level, the broad-band F277W extension is dominated by continuum emission redward of the Balmer break.

While emission lines cannot explain the even more extended profile in F200W, in this filter RUBIES-EGS-9809 appears double peaked (Fig. 2; top row, fourth column). Of course, the double peak (located within $\lesssim 0.1$ arcsec from the peak) cannot be reproduced by our single-Sérsic model. At redder wavelengths, the larger PSF and coarser LW sampling may prevent us from separating the two peaks, if they persist. Alternatively, the presence of double-peaked emission at short observed-frame wavelengths would be in agreement with the scenario of a heavily dust-obscured core, and is routinely seen in sub-mm galaxies (e.g., Swinbank et al. 2010; Hodge et al. 2016).

3.2. SED modelling

We use CIGALE (Yang et al. 2022) to model the galaxy SED, fitting the NIRCcam photometry (from the best-fit models of the previous section) and the *Spitzer* and

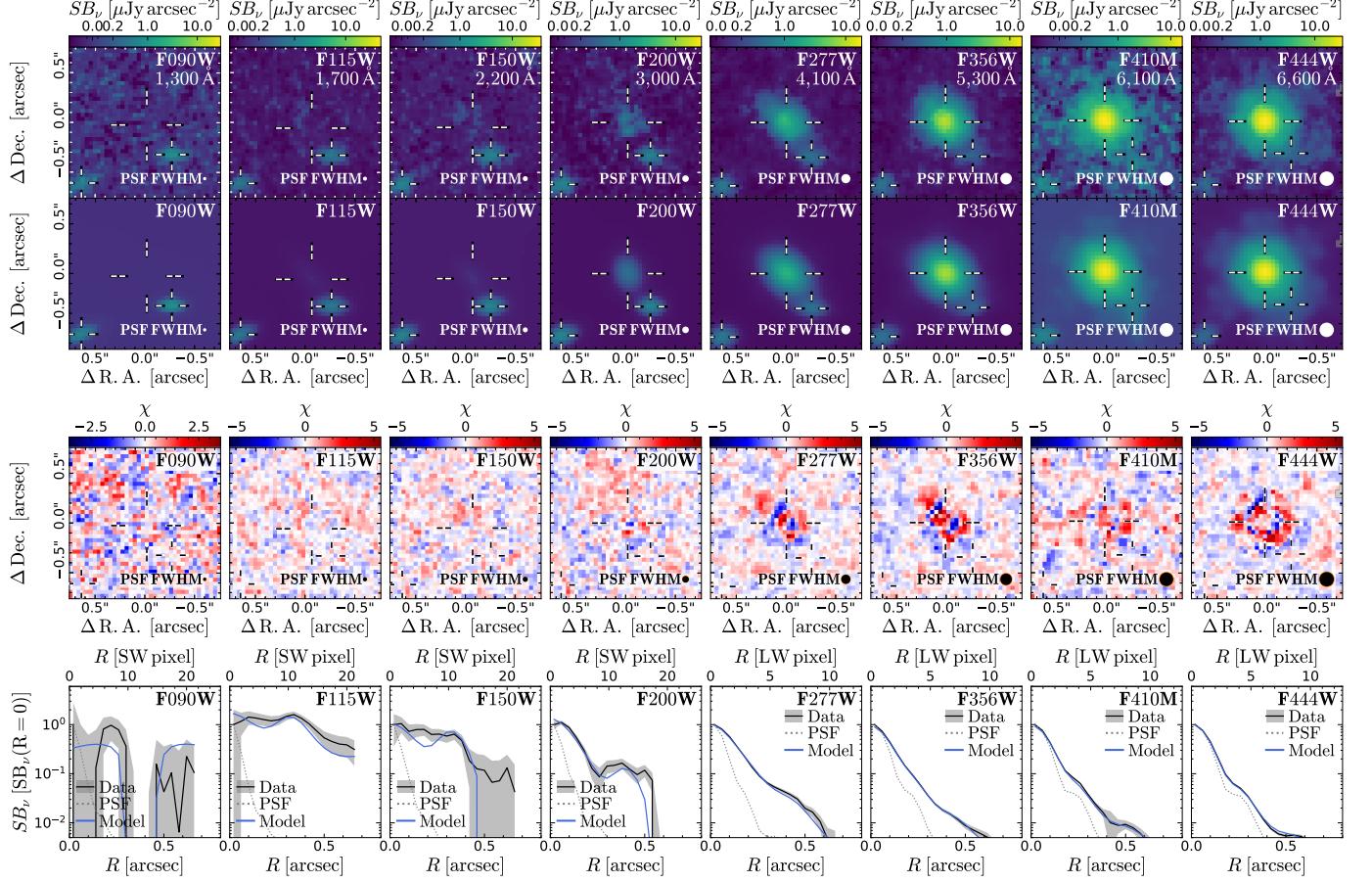


FIG. 2.—: NIRCам cutout images (top row), best-fit models (second row), χ residuals (third row; defined by (data–model)/noise), and radial surface brightness profiles (bottom row). We use an arcsinh scaling to enhance faint structures in the cutouts. The NIRCам filter name and rest-frame wavelength are indicated in each inset. The source morphology transitions from extended in the rest-frame UV to marginally resolved in the rest-frame optical.

JCMT fluxes from the literature. For the AGN, we employ the SKIRTOR implementation from [Stalevski et al. \(2016\)](#), while for the host galaxy we use the stellar-population templates from [Bruzual & Charlot \(2003\)](#). We assume a delayed–exponential star-formation history (SFH), using the standard SFH parametrization implemented in CIGALE. Dust attenuation assumes the [Gordon et al. \(2003\)](#) law for the AGN, and the [Calzetti et al. \(2000\)](#) law for the stellar populations, with extra dust attenuation towards birth clouds ([Charlot & Fall 2000](#)). The fit uses the standard CIGALE energy-balance framework, so the inferred SFRs are constrained by the UV–optical stellar light and by the IR emission, while allowing for a separate AGN contribution to the dust luminosity. The resulting fits are shown in Fig. 4, where we contrast the model excluding or including an AGN (panels a–b and panels c–d, respectively).

The SED analysis demonstrates the presence of AGN-powered, hot-dust emission, since models without an AGN cannot match the MIR observations. Similarly, no amount of star formation can explain the VLA flux. The model with an AGN is strongly preferred over the model without it, with reduced $\chi^2_\nu = 5.64$ and 13.38, respectively.

From the fiducial model, we derive an AGN bolomet-

ric luminosity of $\log(L_{\text{bol}}/(\text{erg s}^{-1})) = 46.18$. We do not report the formal CIGALE uncertainties for L_{bol} , M_* , A_V , or SFR because they are much smaller than, and therefore not representative of, the true error budget, which is likely dominated by systematics such as the adopted SFH parametrization, dust prescription, AGN treatment, and the tension between the fitted photometric points. We highlight that the fiducial model overpredicts the FIR flux (4σ) and underpredicts both the MIR and radio flux (4σ). Removing the JCMT/SCUBA-2 and VLA measurements and repeating the fit, we obtain $\log(L_{\text{bol}}/(\text{erg s}^{-1})) = 45.9$. We take the difference between this value and the fiducial L_{bol} as an estimate of our systematic uncertainties (the formal uncertainties are only 0.03 dex); within this range, both results are in reasonable agreement (within 1–2 σ) with what we derive from emission-line analysis (Section 5.3).

We infer total (formed) stellar masses $\log(M_*/M_\odot) = 10.72$ (fiducial model) and 11.24 (without AGN); the surviving stellar masses are $\log(M_*/M_\odot) = 10.55$ and 11.04, respectively. The true uncertainties are dominated by systematics, such as the adopted parametrization for the SFH (e.g., [Leja et al. 2019](#); [Carnall et al. 2019](#)). Recent work has shown that stellar masses from CIGALE can be biased in AGN-dominated systems ([Buchner et al. 2024](#)).

TABLE 2: Morphological parameters of RUBIES-EGS-9809 and the two nearby sources (all assumed at $z = 5.7$), derived from PYSERSIC modelling. Each group of three rows corresponds to a single NIRCcam filter, with the rows showing RUBIES-EGS-9809, 9809B, and 9809C, respectively. The columns report the marginalized posterior distributions on the model parameters, with the median and 16th–84th percentile range.

Filter	Source	Type	Flux [nJy]	R_e [arcsec]	R_e [kpc]	n	b/a	P.A. [rad]
F090W	9809	Sérsic	$0.74^{+0.12}_{-0.07}$	(< 0.33)	(< 1.9)	4^{+3}_{-2}	$0.4^{+0.3}_{-0.3}$	$1.4^{+1.1}_{-0.9}$
	9809B	Sérsic	34^{+4}_{-2}	$0.065^{+0.009}_{-0.009}$	$0.39^{+0.05}_{-0.05}$	$1.1^{+0.7}_{-0.4}$	$0.73^{+0.08}_{-0.10}$	$2.5^{+0.1}_{-0.1}$
	9809C	Sérsic	33^{+3}_{-3}	$0.091^{+0.012}_{-0.008}$	$0.55^{+0.07}_{-0.05}$	$0.74^{+0.22}_{-0.06}$	$0.73^{+0.07}_{-0.10}$	$2.84^{+0.08}_{-0.09}$
F115W	9809	Sérsic	12^{+2}_{-2}	$0.15^{+0.04}_{-0.03}$	$0.9^{+0.2}_{-0.2}$	$1.0^{+0.9}_{-0.2}$	$0.3^{+0.2}_{-0.2}$	$1.7^{+0.9}_{-0.9}$
	9809B	Sérsic	42^{+3}_{-2}	$0.074^{+0.005}_{-0.006}$	$0.44^{+0.03}_{-0.03}$	$0.71^{+0.09}_{-0.05}$	$0.57^{+0.05}_{-0.06}$	$2.45^{+0.07}_{-0.07}$
	9809C	Sérsic	41^{+3}_{-3}	$0.082^{+0.007}_{-0.006}$	$0.49^{+0.04}_{-0.04}$	$0.76^{+0.19}_{-0.07}$	$0.68^{+0.05}_{-0.06}$	$2.86^{+0.06}_{-0.07}$
F150W	9809	Sérsic	15^{+2}_{-1}	$0.12^{+0.03}_{-0.02}$	$0.7^{+0.2}_{-0.1}$	$0.9^{+1.2}_{-0.2}$	$0.4^{+0.2}_{-0.2}$	$1.2^{+0.5}_{-0.5}$
	9809B	Sérsic	51^{+3}_{-2}	$0.068^{+0.004}_{-0.005}$	$0.41^{+0.03}_{-0.03}$	$0.72^{+0.11}_{-0.05}$	$0.53^{+0.06}_{-0.07}$	$2.52^{+0.09}_{-0.09}$
	9809C	Sérsic	49^{+3}_{-3}	$0.071^{+0.006}_{-0.004}$	$0.42^{+0.04}_{-0.02}$	$0.80^{+0.23}_{-0.07}$	$0.67^{+0.06}_{-0.07}$	$2.86^{+0.06}_{-0.06}$
F200W	9809	Sérsic	56^{+4}_{-3}	$0.083^{+0.008}_{-0.007}$	$0.50^{+0.05}_{-0.04}$	$0.67^{+0.05}_{-0.01}$	$0.24^{+0.10}_{-0.10}$	$1.2^{+0.3}_{-0.3}$
	9809B	Sérsic	43^{+3}_{-2}	$0.055^{+0.004}_{-0.005}$	$0.33^{+0.03}_{-0.03}$	$0.78^{+0.26}_{-0.10}$	$0.54^{+0.08}_{-0.08}$	$2.4^{+0.1}_{-0.1}$
	9809C	Sérsic	55^{+3}_{-2}	$0.071^{+0.005}_{-0.004}$	$0.42^{+0.03}_{-0.02}$	$0.69^{+0.05}_{-0.02}$	$0.62^{+0.05}_{-0.05}$	$2.74^{+0.05}_{-0.06}$
F277W	9809	Sérsic	233^{+7}_{-5}	$0.102^{+0.003}_{-0.002}$	$0.61^{+0.02}_{-0.01}$	$1.19^{+0.05}_{-0.04}$	$0.41^{+0.01}_{-0.01}$	$1.72^{+0.02}_{-0.02}$
	9809B	Sérsic	63^{+4}_{-3}	$0.2778^{+0.0007}_{-0.0008}$	$1.667^{+0.004}_{-0.005}$	$7.3^{+0.1}_{-0.2}$	$0.032^{+0.001}_{-0.001}$	$1.16^{+0.04}_{-0.05}$
	9809C	Sérsic	88^{+4}_{-3}	$0.29913^{+0.00006}_{-0.00008}$	$1.7946^{+0.0004}_{-0.0005}$	$7.68^{+0.10}_{-0.16}$	$0.00142^{+0.00012}_{-0.00010}$	$1.3^{+1.3}_{-0.8}$
F356W	9809	Sérsic	541^{+7}_{-5}	$0.064^{+0.001}_{-0.001}$	$0.384^{+0.008}_{-0.008}$	$2.21^{+0.09}_{-0.08}$	$0.29^{+0.02}_{-0.01}$	$1.77^{+0.03}_{-0.02}$
	9809B	Sérsic	36^{+2}_{-1}	$0.2816^{+0.0006}_{-0.0007}$	$1.689^{+0.003}_{-0.004}$	$6.3^{+0.3}_{-0.5}$	$0.033^{+0.001}_{-0.001}$	$0.8^{+0.2}_{-0.2}$
	9809C	Sérsic	79^{+3}_{-3}	$0.29927^{+0.00004}_{-0.00006}$	$1.7955^{+0.0002}_{-0.0004}$	$7.6^{+0.1}_{-0.2}$	$0.0019^{+0.0002}_{-0.0001}$	$1.4^{+1.0}_{-0.8}$
F410M	9809	Sérsic	960^{+10}_{-10}	$0.036^{+0.001}_{-0.001}$	$0.214^{+0.009}_{-0.009}$	$3.3^{+0.3}_{-0.3}$	$0.28^{+0.03}_{-0.03}$	$1.69^{+0.06}_{-0.07}$
	9809B	Sérsic	38^{+6}_{-4}	$0.24^{+0.02}_{-0.03}$	$1.4^{+0.1}_{-0.15}$	$0.70^{+0.14}_{-0.04}$	$0.86^{+0.03}_{-0.09}$	$1.03^{+0.07}_{-0.07}$
	9809C	Sérsic	29^{+4}_{-4}	$0.06^{+0.03}_{-0.01}$	$0.35^{+0.08}_{-0.08}$	3^{+3}_{-2}	$0.7^{+0.1}_{-0.3}$	$2.6^{+0.3}_{-0.3}$
F444W	9809	Sérsic	1801^{+9}_{-7}	$0.0227^{+0.0006}_{-0.0007}$	$0.136^{+0.004}_{-0.004}$	$4.0^{+0.1}_{-0.1}$	$0.26^{+0.03}_{-0.02}$	$1.87^{+0.04}_{-0.04}$
	9809B	Sérsic	$33.0^{+1.2}_{-0.8}$	$0.2789^{+0.0005}_{-0.0008}$	$1.673^{+0.003}_{-0.005}$	5^{+1}_{-1}	$0.064^{+0.005}_{-0.003}$	$1.9^{+0.5}_{-1.2}$
	9809C	Sérsic	53^{+3}_{-3}	$0.2987^{+0.0001}_{-0.0001}$	$1.7922^{+0.0007}_{-0.0009}$	$7.3^{+0.4}_{-0.8}$	$0.36^{+0.05}_{-0.07}$	$2.1^{+0.7}_{-1.5}$

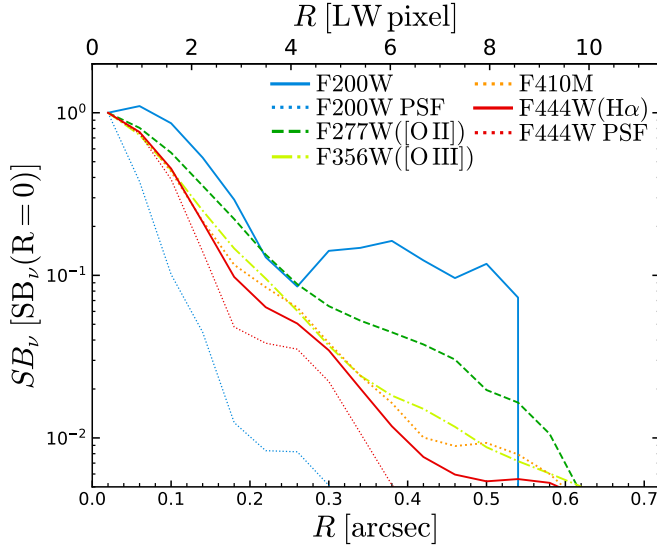


FIG. 3.—: Observed radial profiles of RUBIES-EGS-9809, showing the larger extent at bluer wavelengths (2–2.8 μm) than at redder wavelengths (4.1–4.4 μm). The F444W PSF is the broadest PSF considered here. We also indicate bands containing strong emission lines.

In our case, the systematic bias should be < 0.3 dex (Buchner et al. 2024, their fig. 21). In addition, the detection of a spatially resolved Balmer break implies that the host galaxy dominates at least at those wavelengths, providing a robust handle on the underlying stellar populations.

The dust attenuation is consistent between the two models, with $A_V \simeq 1.8$ mag for the continuum and $A_V \simeq 4.1$ mag for young stars and emission lines. As for the SFR, the fiducial AGN model gives $\log(\text{SFR}/(\text{M}_\odot \text{ yr}^{-1})) = 1.3$ and 1.5 on timescales of 10 and 100 Myr, respectively. These are still high rates, but they suggest a decreasing trend, which explains the Balmer break. For reference, the model without AGN has even lower SFRs, with $\log(\text{SFR}/(\text{M}_\odot \text{ yr}^{-1})) = 0.9$ and 1.1 on the same timescales.

Before proceeding with the analysis, it is worth recalling that the masses and SFRs for this kind of source may be particularly challenging to estimate, which we discuss further in the article (Section 7.2).

4. SPECTRAL FITTING

We model the RUBIES prism and grating spectra piecewise, focusing on four spectral features of interest: the Balmer break, the $\text{H}\beta$ – $[\text{O III}]\lambda\lambda 4959, 5007$ emission-line group, the $\text{Na I}\lambda\lambda 5890, 5896$ doublet, and the region around $\text{H}\alpha$. The region around the Balmer break is fitted separately, due to its low signal-to-noise ratio (SNR) compared to the spectral features at redder wavelengths. When comparing models, we use the Bayesian information criterion (BIC; Schwarz 1978), with a threshold $\Delta\text{BIC} \geq 10$.

The model employs Gaussian lines to model $\text{H}\beta$, $[\text{O III}]\lambda\lambda 4959, 5007$, $[\text{O I}]\lambda\lambda 6300, 6364$, $\text{H}\alpha$, $[\text{N II}]\lambda\lambda 6548, 6583$, $[\text{S II}]\lambda\lambda 6716, 6731$, and the transauroral quadruplet $[\text{O II}]\lambda\lambda 7319–7331$. All narrow lines share the same redshift z and intrinsic velocity dispersion σ_n . For $\text{H}\alpha$ and $\text{H}\beta$, we also include a broad component,

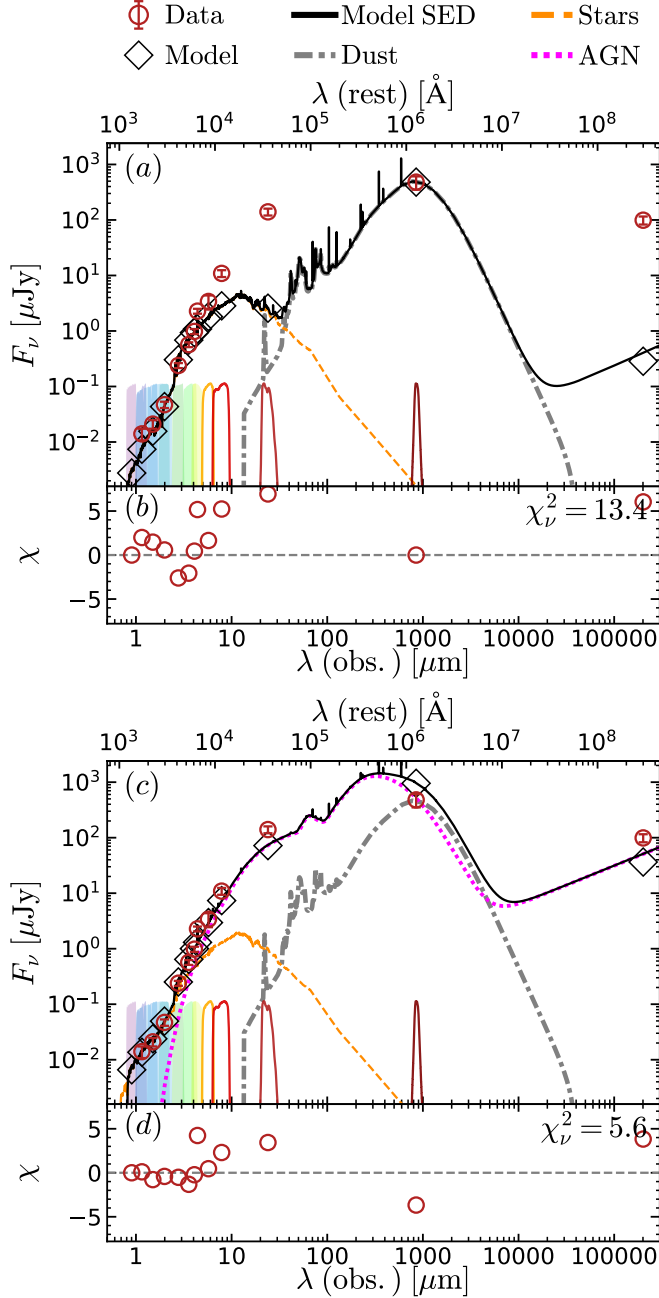


FIG. 4.—: Results of the CIGALE modelling, without (panel a) or including (panel c) an AGN, now also including the VLA L-band point. The AGN model remains strongly preferred, while both fits imply a declining recent SFH.

modelled as two Gaussians with a single redshift, but different flux and full-width at half maximum (FWHM; D’Eugenio et al. 2026a). For [O III] $\lambda\lambda 4959, 5007$, we also use a broad component with free velocity, representing a gas outflow (the double Gaussian and the [O III] $\lambda\lambda 4959, 5007$ outflow are justified later). The broad [O III] $\lambda\lambda 4959, 5007$ component uses a flat prior on the velocity dispersion σ_{out} between 0 and 2000 km s $^{-1}$, and is further subject to a complementary-error-function (erfc) prior on $\sigma_{\text{n}}/\sigma_{\text{out}}$ with mean 1 and scatter 0.1, which

avoids swapping the outflow and galaxy components. The flux ratios of the three doublets with variable line ratio are constrained to their physically allowed values. Even though we lack the spectral resolution to resolve these three doublets, our physically motivated priors avoid biasing the model for marginally resolved doublets (e.g., the [S II] $\lambda\lambda 6716, 6731$ doublet requires $R \sim 450$, which is reachable by the prism for point sources; de Graaff et al. 2024). The other four doublets in the model have fixed line ratios, which we take from PYNEB (Luridiana et al. 2015). Here we only report the values adopted for the less common transauroral quadruplet [O II] $\lambda\lambda 7319-7331$. The flux of the [O II] $\lambda 7320$ line is a free parameter, while the flux ratio between [O II] $\lambda 7330$ and [O II] $\lambda 7320$ is free but constrained within the physically allowed range 0.435–0.565. The remaining two lines, [O II] $\lambda 7319$ and [O II] $\lambda 7331$, arise from the same levels of [O II] $\lambda 7330$ and [O II] $\lambda 7320$, respectively. Therefore, we fix the flux ratios [O II] $\lambda 7330$ /[O II] $\lambda 7319 = 1.656$ and [O II] $\lambda 7320$ /[O II] $\lambda 7331 = 1.908$ calculated again using PYNEB.

Na I $\lambda\lambda 5890, 5896$ absorption is modelled using a Gaussian optical depth with free velocity and velocity dispersion (see e.g., Davies et al. 2024). The model employs four free parameters: a variable covering factor C_f , the velocity and velocity dispersion of the absorber, v_{abs} and σ_{abs} , and the optical depth at line centre, $\tau(\text{Na I } \lambda 5896)$. The optical depth of the Na I $\lambda 5890$ line is fixed to $2 \cdot \tau(\text{Na I } \lambda 5896)$, set by the oscillator strengths (e.g., Rupke et al. 2005; Davies et al. 2024).

The continuum is modelled piecewise as a polynomial within each of three wavelength intervals centred on [O II] $\lambda 4959$, Na I $\lambda 5896$, and H α . The first two intervals use a 1st-order polynomial, while the third and widest interval uses a 2nd-order polynomial. In addition to the background, we add a step function $\mathcal{H}$ under H α , to account for possible metal absorption (Appendix A).

To reduce the degeneracies in the model, we add external constraints by providing informative priors, drawn from the sub-mm galaxy ALESS073.1 (Parlanti et al. 2024). We require that the intrinsic narrow-line dispersion must be $\sigma_{\text{n}} < 500$ km s $^{-1}$ (which generously extends the parameter space relative to the measurement of Parlanti et al. 2024, i.e., $\sigma_{\text{n}} = 220 \pm 25$ km s $^{-1}$), and the narrow-line flux ratio [N II] $\lambda 6583$ /[S II] $\lambda\lambda 6716, 6731$ must be less than 5. This second prior exploits the sulphur doublet to mitigate the effects of the otherwise full degeneracy between the narrow H α and [N II] $\lambda\lambda 6548, 6583$ lines. Of course, a few cases of higher [N II] $\lambda 6583$ /[S II] $\lambda\lambda 6716, 6731$ are known (e.g., D’Eugenio et al. 2024), but to fully test if these conditions apply we would require medium- or high-resolution spectroscopy. The outflow velocity dispersion σ_{out} is penalized against solutions with $\sigma_{\text{out}} \leq \sigma_{\text{n}}$; this avoids swapping the narrow and outflow components of [O III] $\lambda\lambda 4959, 5007$. All three priors are implemented using an erfc function, which penalizes unwanted solutions more gently than a sharp boundary.

A critical weakness of our model is the inability to estimate an accurate dust attenuation A_V , due to the lack of H α coverage in the grating. Measuring A_V is crucial, because the observed spectrum shows clear evidence of dust reddening. We attempt to estimate A_V from the

Balmer decrement observed in the *total* $H\alpha$ and $H\beta$ lines, as follows. We assume the [Gordon et al. \(2003, hereafter: G03\)](#) SMC bar dust extinction law; even though the true attenuation law may be different at $z = 5.7$ than in the local Universe (e.g., [Sanders et al. 2025](#)), the G03 still provides a useful benchmark for comparison with other high-redshift works (e.g., [Juodžbalis et al. 2024](#); [D'Eugenio et al. 2026b](#)). We assume an intrinsic $H\alpha/H\beta$ flux ratio of 2.86 for the narrow lines, and adopt 10 as our fiducial value for the broad lines. The first value is the widely used ratio appropriate for Case-B recombination and the typical ISM conditions of local galaxies (e.g., [Osterbrock & Ferland 2006](#)). The second is motivated by fit quality; we tried models with intrinsic broad-line decrements of 10, 5, and 3.1 and found that 10 is moderately preferred over 5, and strongly preferred over 3.1 ($\Delta\text{BIC} = 3$ and 24, respectively). We use an erfc prior on A_V too, penalizing solutions with $A_V > 1.8/0.44$ mag. This constraint exploits the SED continuum from CIGALE, and assumes a constant scaling between continuum and nebular attenuation. To assess the model response to our assumptions and priors, we also run otherwise identical setups without the CIGALE-based dust prior, using a separate attenuation for the narrow and broad lines, and adding an $H\alpha$ -only outflow component; none of these alternative models outperform our default run. In detail, our $H\alpha$ decomposition is driven purely by the grating spectrum of $H\beta$ and by the model assumptions. As we discuss further, our approach is driven primarily by the assumptions, but a better model would require medium- or high-resolution coverage of $H\alpha$.

The region around $[\text{O II}]\lambda\lambda 3726, 3729$ and $[\text{Ne III}]\lambda 3869$, which includes the Balmer break, is modelled separately, with a custom continuum model $\mathcal{C}(\lambda)$ given by

$$\mathcal{C}(\lambda) \equiv \begin{cases} a_0 & \lambda \leq \lambda_{\text{break}} \\ A_{\text{break}} \cdot a_0 + a_1 \cdot (\lambda - \lambda_0) & \lambda > \lambda_{\text{break}}, \end{cases} \quad (1)$$

where $\lambda_0 \equiv 3728 \text{ \AA}$ and $\lambda_{\text{break}} = 3750 \text{ \AA}$, while a_0 , a_1 , and A_{break} are free parameters. We constrain $0 \leq A_{\text{break}} \leq 5$, where $A_{\text{break}} = 1$ would correspond to no discontinuity, while $A_{\text{break}} < 1$ or > 1 would correspond respectively to a Balmer jump or a Balmer break. The emission lines and the break wavelength λ_{break} share the same redshift, which is formally a free parameter, but is strongly constrained by using the posterior probability from the $H\beta$ - $[\text{O II}]\lambda\lambda 7319\text{--}7331$ model as prior probability. We also experimented with leaving λ_{break} free and found this does not change our conclusions.

The parameters are estimated by comparing this model to both the prism and grating data simultaneously, with the model being realized on each dataset using the appropriate line spread function. We use a 2nd-order multiplicative polynomial to account for flux mismatch between the two dispersers. The resulting physical quantities refer to the prism spectrum. The model is optimized in a Bayesian framework, using Markov-chain Monte-Carlo integration, with the setup presented in [D'Eugenio et al. \(2026b\)](#). The fit quality is shown in Fig. 5, where we overlay the data (black) and maximum joint-posterior model (red).

The results of the spectral fitting are listed in Table 3 and described in detail in Section 5.

5. SPECTROSCOPIC RESULTS

5.1. Dust attenuation

The dust attenuation inferred from the Balmer decrement is highly uncertain: $H\alpha$ falls in the G395M detector gap, the $H\alpha$ - $[\text{N II}]\lambda\lambda 6548, 6583$ blend is unresolved at prism resolution, and the $H\beta$ and $H\gamma$ SNRs are too low to obtain meaningful constraints. For this reason, we compare the family of alternative line models in Table 4. Within the common two-BLR-component, SMC-bar framework, the best-fitting solutions are those with intrinsic broad-line decrements of 10 and 5. These return comparatively moderate attenuations, closer to the continuum-based estimate than the lower-decrement alternatives ($A_V \simeq 3.6$ and 4.7 mag, respectively), and differ very little in fit quality ($\Delta\text{BIC} = 3$). A lower intrinsic decrement of 3.1 (e.g., [Dong et al. 2008](#)) requires much larger attenuation, $A_V \simeq 5.5$ mag, and is substantially worse than the fiducial model ($\Delta\text{BIC} \simeq 24$).

The control run without the CIGALE-based dust prior improves the $H\alpha/H\beta = 3.1$ model by $\Delta\text{BIC} \simeq 13$ relative to the same model with the prior; this means that the preference for large decrements is driven in part by the CIGALE constraint. However, even without the prior, the alternative model is still worse than the fiducial model. In practice, our data do not measure the intrinsic BLR decrement, but they generally favour models with high observed flux ratio between the $H\alpha$ - $[\text{N II}]\lambda\lambda 6548, 6583$ complex and $H\beta$; a strongly obscured outflow or high BLR dust could both explain our observations. However, the more flexible model with separate $A_{V,\text{ISM}}$ and $A_{V,\text{BLR}}$ is not supported by the data, because it increases the number of parameters without substantially improving the fit. Likewise, adding an $H\alpha$ outflow or broad Fe II does not improve the fit. On the other hand, removing the step function $\mathcal{H}$, adopting the Calzetti law, or forcing a single broad Gaussian are all strongly disfavoured (Table 4).

An alternative possibility is very strong $[\text{N II}]\lambda\lambda 6548, 6583$ emission, such as seen in some PSB galaxies (e.g., [D'Eugenio et al. 2024](#)). Since we cannot accurately deblend $[\text{N II}]$ from $H\alpha$ given our data, any $[\text{N II}]\lambda\lambda 6548, 6583$ emission beyond our probability prior (which caps $[\text{N II}]\lambda\lambda 6548, 6583/[\text{S II}]\lambda\lambda 6716, 6731 \leq 5$, Section 4) would be interpreted incorrectly as $H\alpha$, thus artificially increasing A_V .

For reference, from CIGALE we infer an effective dust attenuation of $A_V = 1.8$ mag, although the uncertainties of 0.004 mag are clearly under-estimated. While this value is lower than the line-based estimates of Table 4, this is estimated primarily from the continuum, which dominates the emission in rest-frame V -band, while the corresponding nebular attenuation would be stronger and close to the findings of the fiducial model.

5.2. Narrow-line fluxes and SFR

Our narrow-line information relies primarily on the $H\beta$ - $[\text{O III}]\lambda\lambda 4959, 5007$ complex, which is poorly detected and blended with broad emission, possibly from the BLR and from ionized outflows (Fig. 5g). The rest of the information derives from sufficiently isolated lines and doublets, such as $[\text{O II}]\lambda\lambda 3726, 3729$, $[\text{Ne III}]\lambda 3869$, $[\text{O I}]\lambda 6300$

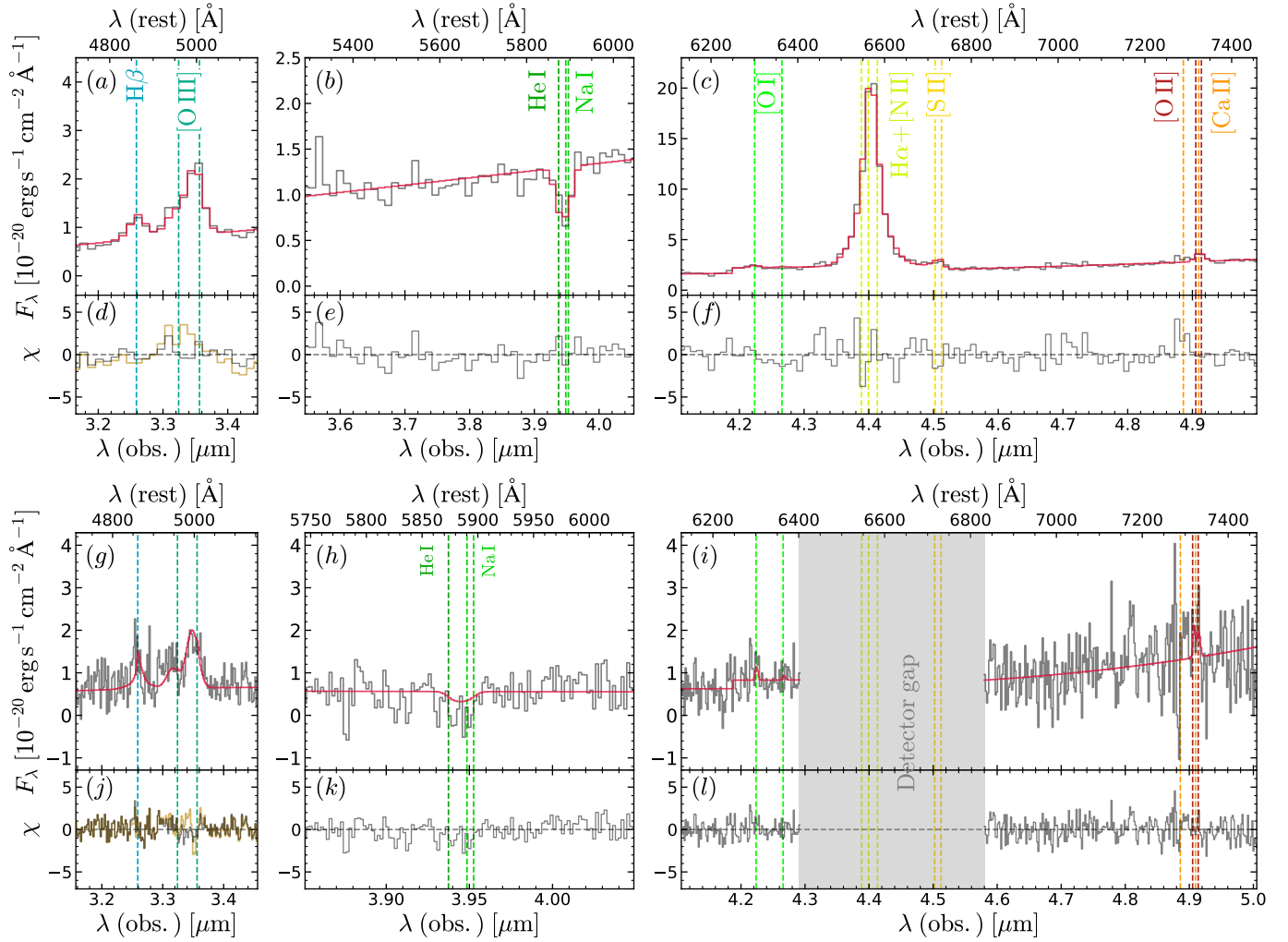


FIG. 5.— We model simultaneously data from the prism (panels a–f) and G395M grating (panels g–l). Panels a–c and g–i show the data (black) and maximum joint-posterior models (red), while panels d–f and j–l show the χ residuals. The $H\alpha$ line has a complex profile, which is not fully described even by our three-Gaussian model. The sand-coloured χ residuals in panels d and j are from a model without an $[O\text{ III}]\lambda\lambda 4959,5007$ outflow component.

and $[S\text{ II}]\lambda\lambda 6716,6731$ seen in the prism; these lines set an upper limit to the velocity dispersion, and – through our informative priors – also set an upper limit to the $[N\text{ II}]\lambda 6583/H\alpha$ ratio.

Given these limitations, we regard the emission-line SFR as very tentative. In the fiducial model, the dust-corrected narrow-line SFR is $\log(SFR/(M_\odot \text{ yr}^{-1})) \simeq 1.3$, while across the range of models tested we reach values of 1.7–2.3 (Table 4). Therefore, the emission-line analysis is consistent with the recently declining SFH inferred by CIGALE, but it does not independently establish quiescence, nor can it rule out substantial obscured star formation. Our main evidence for a declining SFH therefore comes from the SED modelling (Section 3.2). Deep, medium-resolution spectroscopy with simultaneous coverage of $H\alpha$ and $H\beta$ is required to break this degeneracy.

5.3. Broad-line profile and black-hole mass

The two broad Gaussians have $FWHM_{b,1} = 1200^{+200}_{-100} \text{ km s}^{-1}$ and $FWHM_{b,2} = 3800^{+400}_{-300} \text{ km s}^{-1}$, with the flux ratio $F_{b,1}/F_b = 0.43^{+0.07}_{-0.05}$. The sum of the

two Gaussians has $FWHM_b = 1500^{+200}_{-100} \text{ km s}^{-1}$. Using a single Gaussian is disfavoured by the data; repeating the model inference with a single broad Gaussian, we find a $\Delta\text{BIC} > 100$. The measured FWHM value is well beyond the range expected for emission from the interstellar medium (ISM), but is comparable to what is seen in some fast outflows in $[O\text{ III}]\lambda 5007$ (e.g., Harrison et al. 2014; Carniani et al. 2015; Husemann et al. 2019; Perna et al. 2025b; Zamora et al. 2025; Bertola et al. 2025). However, these outflows are typically seen in massive systems, while more typical outflows have broadening of 500 km s^{-1} (Cooper et al. 2025b) or less (Carniani et al. 2024). Nevertheless, the outflow seen in $[O\text{ III}]\lambda\lambda 4959,5007$ (Section 5.5 below) must have a counterpart in $H\alpha$ too, and this outflow emission can bias the measurement of the broad-line FWHM. However, our data cannot constrain the detailed properties of the outflow, such as its metallicity, dust attenuation, ionization parameter, and shape of the ionizing field – all of which should impact the expected $[O\text{ III}]\lambda 5007/H\alpha$ ratio. For this reason, we cannot estimate the outflow contribution to the $H\alpha$ line. Indeed, dust-obscured out-

TABLE 3: Posterior probabilities for key parameters of the emission-lines model, based on simultaneous fits of the prism and G395M RUBIES spectroscopy. The five groups of rows are, from top to bottom, narrow-line parameters, outflow parameters, broad-line parameters, sodium-absorption parameters, and derived quantities.

Parameter	Unit	Posterior
z_n	[—]	$5.704^{+0.001}_{-0.001}$
σ_n	[km s ⁻¹]	110^{+110}_{-70}
A_V	[mag]	$3.6^{+0.2}_{-0.2}$
$F_n(\text{H}\beta)$	[10 ⁻¹⁸ erg s ⁻¹ cm ⁻²]	$0.18^{+0.09}_{-0.08}$
$F_n([\text{O III}]\lambda 5007)$	[10 ⁻¹⁸ erg s ⁻¹ cm ⁻²]	$0.12^{+0.14}_{-0.08}$
$F_n(\text{H}\alpha)$	[10 ⁻¹⁸ erg s ⁻¹ cm ⁻²]	$1.9^{+1.0}_{-0.9}$
$F_n([\text{S II}]\lambda 6716)/F_n([\text{S II}]\lambda 6731)$	[—]	$0.9^{+0.3}_{-0.3}$
$F_n([\text{O II}]\lambda 7330)/F_n([\text{O II}]\lambda 7320)$	[—]	$0.50^{+0.03}_{-0.02}$
$F_{\text{out}}([\text{O III}]\lambda 5007)$	[10 ⁻¹⁸ erg s ⁻¹ cm ⁻²]	$4.4^{+0.3}_{-0.3}$
v_{out}	[km s ⁻¹]	-800^{+100}_{-100}
σ_{out}	[km s ⁻¹]	870^{+80}_{-70}
v_{BLR}	[km s ⁻¹]	190^{+50}_{-70}
$FWHM_{\text{BLR},1}$	[km s ⁻¹]	1200^{+200}_{-100}
$FWHM_{\text{BLR},2}$	[km s ⁻¹]	3800^{+300}_{-400}
$F_{\text{BLR}}(\text{H}\beta)$	[10 ⁻¹⁸ erg s ⁻¹ cm ⁻²]	$1.6^{+0.2}_{-0.1}$
$F_{\text{BLR}}(\text{H}\alpha)$	[10 ⁻¹⁸ erg s ⁻¹ cm ⁻²]	66^{+1}_{-2}
$F_{\text{BLR},1}/F_{\text{BLR}}$	[—]	$0.43^{+0.07}_{-0.05}$
v_{abs}	[km s ⁻¹]	-400^{+200}_{-100}
σ_{abs}	[km s ⁻¹]	300^{+100}_{-100}
$C_{f,\text{Na I}}$	[—]	$0.5^{+0.2}_{-0.1}$
$\tau_{\text{Na I}}$	[—]	$0.8^{+1.0}_{-0.4}$
$F_{\text{BLR}}(\text{H}\alpha)$	[10 ⁻¹⁸ erg s ⁻¹ cm ⁻²]	900^{+100}_{-100}
$FWHM_{\text{BLR}}$	[km s ⁻¹]	1500^{+200}_{-100}
$\log SFR(\text{H}\alpha)$	[M _⊙ yr ⁻¹]	$1.3^{+0.2}_{-0.3}$
$\log L_b(\text{H}\alpha)$	[10 ⁴² erg s ⁻¹]	$2.54^{+0.05}_{-0.07}$
$\log(M_{\bullet})$	[M _⊙]	$8.16^{+0.07}_{-0.09}$
λ_{Edd}	[—]	$2.4^{+0.6}_{-0.5}$

TABLE 4: Sensitivity of the emission-line A_V and SFR to the model assumptions. Unless otherwise specified, the models use the SMC-bar attenuation law and a double-Gaussian BLR, with a prior on $A_V < 1.8/0.44$ mag derived from CIGALE. We do not report the model uncertainties, since they are smaller than the model-to-model variations.

Model	BIC	A_V [mag]	$\log SFR(\text{H}\alpha)$ [M _⊙ yr ⁻¹]
$F_{\text{BLR}}(\text{H}\alpha)/F_{\text{BLR}}(\text{H}\beta) = 10$	-589.7	3.6	1.3
$F_{\text{BLR}}(\text{H}\alpha)/F_{\text{BLR}}(\text{H}\beta) = 5$	-587.4	4.7	1.7
$F_{\text{BLR}}(\text{H}\alpha)/F_{\text{BLR}}(\text{H}\beta) = 3.1$	-565.6	5.5	2.3
No CIGALE-based prior	-578.5	5.9	2.2
Separate ISM/BLR A_V	-566.8	2.6/5.8 [†]	1.0
No $\mathcal{H}$ function	-516.1	5.4	2.7
Fe II templates [‡]	-548.4	5.3	2.1
Single-Gaussian BLR	-389.8	4.8	3.4
Calzetti dust law	-471.4	5.7	2.0

[†] For this model we report $A_{V,\text{ISM}}$ and $A_{V,\text{BLR}}$. [‡] See Appendix B.

flows have already been detected in the sub-mm galaxies (Parlanti et al. 2024), which also display high-EW broad-line emission (we measure a broad-component EW of $\text{EW}(\text{H}\alpha) = -410^{+20}_{-10}$ Å).

Adding an outflow component with velocity and intrinsic velocity dispersion tied to the $[\text{O III}]\lambda\lambda 4959, 5007$

outflow yields a very high $\text{H}\alpha/[\text{O III}]\lambda 5007$ flux ratio of 22 ± 5 . This is implausibly high for a blue-shifted outflow, as typical dust-obscured AGN have outflows with observed ratios of order unity (e.g., Liu et al. 2025). In our case, we interpret such a large ratio as due to the SNR and resolution limitations of the data. The $\text{H}\alpha$ outflow appropriates a fraction of the narrowest broad Gaussian, resulting in lower $F_{b,1}/F_b$ and in broader $FWHM_{b,1}$ and $FWHM_{b,2}$, which together yield $FWHM_b = 2800 \pm 300$ km s⁻¹, nearly twice as broad as the fiducial value of $FWHM_b = 1500$ km s⁻¹. A comparison of the BIC value yields $\Delta\text{BIC} = 38$ in favour of the fiducial model without an $\text{H}\alpha$ component in the outflow, so we conclude that there is not enough evidence for a dust-obscured outflow. In our fiducial interpretation, we therefore attribute the broad $\text{H}\alpha$ to emission from the BLR, while noting that unresolved outflow contamination cannot be fully excluded with the current prism data.

Under this fiducial BLR interpretation, we use the measured FWHM and the dust-corrected broad $\text{H}\alpha$ flux in the virial calibration of Reines & Volonteri (2015), and find a black-hole mass $\log(M_{\bullet}/M_{\odot}) = 8.1 \pm 0.7$. This value should be regarded as an illustrative virial estimate rather than a secure black-hole mass, because the $\text{H}\alpha$ - $[\text{N II}]\lambda\lambda 6548, 6583$ blend is unresolved and the separation between BLR and outflow emission is model dependent. The uncertainties are dominated by model assumptions (0.4 dex) and by the scatter in the calibration (0.55 dex; Reines & Volonteri 2015), for a total of 0.7 dex, after summing in quadrature. To estimate the systematics of 0.4 dex, we reasoned that increasing the very uncertain dust attenuation from $A_V \sim 3$ mag to 6 mag would increase $M_{\bullet}$ by 0.4 dex. A similar change is obtained when including the outflow component of $\text{H}\alpha$ in the model, which increases $M_{\bullet}$ by a factor of 2.6 (the twice broader FWHM we have seen in the previous paragraph is compensated by lower line flux). For this reason, our subsequent interpretation does not rely on the precise value of $M_{\bullet}$, but only on the robust multi-wavelength evidence for a luminous AGN.

To estimate the bolometric luminosity we use the calibration of Stern & Laor (2012), based on the broad $\text{H}\alpha$ line. We use the dust-corrected luminosity $\log(L_b(\text{H}\alpha)/(10^{42} \text{ erg s}^{-1})) = 2.54^{+0.05}_{-0.07}$ and obtain $\log(L_{\text{bol}}/(\text{erg s}^{-1})) = 46.65^{+0.05}_{-0.07}$, where the uncertainty is formal only and does not include the $\simeq 0.5$ -dex systematics of the calibration. This is an order of magnitude brighter than most luminous LRDs (e.g., Juodžbalis et al. 2024; Loiacono et al. 2025), with the only exception of A2744-45924 (Greene et al. 2024; Labbe et al. 2024), which has $\log(L_{\text{bol}}/(\text{erg s}^{-1})) = 46.3 \pm 0.2$ (Matthee et al. 2025). Our broad- $\text{H}\alpha$ estimate is 0.5 dex higher than the fiducial CIGALE estimate of $\log(L_{\text{bol}}/(\text{erg s}^{-1})) = 46.18$ (Section 3.2); the two are consistent within the systematic uncertainties of both methods (1–2 σ ; Section 3.2).

5.4. Balmer break

The spectral region near the Balmer limit is displayed in Fig. 6. A Balmer break is visible in the data, and is qualitatively consistent with the best-fit model from CIGALE (downscaled to match the continuum level, and overlaid in purple in Fig. 6a). Statistically, the CIGALE model represents an adequate match to the data, with

a reduced $\chi^2_\nu = 1.7\text{--}2.2$ (where the range is due to subtracting no or all free parameters from the number of degrees of freedom, since we do not optimize CIGALE on the spectrum, but on the photometry; see Section 3.2).

The presence of a Balmer break is independently confirmed by a statistical analysis of the spectrum. First, replacing the fiducial continuum model of Eq. 1 with a 2nd-order polynomial and with no break yields a worse fit, with $\Delta\text{BIC} = 11$ in favour of the fiducial model. If we extend the fiducial model by letting the break wavelength λ_{break} vary freely between 3600 and 4000 Å, the resulting posterior distributions give $A_{\text{break}} = 1.8 \pm 0.2$ and $\lambda_{\text{break}} = 3740^{+50}_{-70}$ Å, which is fully consistent with the effective wavelength of the Balmer break. From the MCMC chains, we calculate an emission-line corrected D_{n4000} index of $1.18^{+0.03}_{-0.02}$ (Balogh et al. 1999) and a Balmer break index of $3.5^{+0.4}_{-0.3}$ (where we have used the standard wavelength windows of Curtis-Lake et al. 2023). Note that the Balmer-break index is more sensitive to dust attenuation than D_{n4000} .

Statistically, the Balmer break can be established by calculating the probability $P(A_{\text{break}} \geq 1)$ in the fiducial model. After ensuring that our sampler contains more than 10^7 points, we can calculate the probability that $A_{\text{break}} \geq 1$ directly from the posterior. This yields $P(A_{\text{break}} \leq 1) < 2 \times 10^{-6}$, which would correspond to a one-tailed significance of better than 4.5 σ .

If we repeat the analysis using the CAPERS spectrum, we infer $P(A_{\text{break}} \leq 1) < 10^{-7}$, i.e. better than 5 σ significance, limited by the number of chains for calculating the posterior probability. Interestingly, CAPERS finds a weaker break amplitude than RUBIES, $A_{\text{break}} = 1.49 \pm 0.05$. This difference is likely due to spatial variations in the SED, since the (nominal) position of the CAPERS micro-shutter is off-centre. Confirming this hypothesis would require spatially resolved spectroscopy.

In any case, since a discontinuity consistent with the Balmer break is supported independently by RUBIES and CAPERS, and by the photometry (Fig. 4) and SED modelling (Section 3.2), we conclude that RUBIES-EGS-9809 does possess a Balmer break.

Our D_{n4000} measurement can be used to infer directly a simple stellar population (SSP) age. By comparing to the Bruzual & Charlot (2003) models (assuming a single burst with solar or 0.2-solar metallicity; e.g., Kauffmann et al. 2003) we would infer a burst age of 250 Myr for $D_{\text{n4000}} = 1.18$, while $D_{\text{n4000}} = 1.00$ (corresponding to a 4- σ deviation with respect to our measurement) would still imply an age older than 50 Myr. So the strength of the spectral break would correspond to intermediate SSP ages between star-formers and post-starburst galaxies.

5.5. Ionized outflow

The need for an [O III] $\lambda\lambda 4959, 5007$ outflow component is visible in the fit residuals; when the outflow component is removed, the best-fit model leaves structured positive residuals blueward of [O III] $\lambda 5007$, in both the prism and independently in the G395M spectra (sand lines in Fig. 5d and j). The fiducial model captures this excess with a broad, blueshifted [O III] $\lambda\lambda 4959, 5007$ component, consistent with the complex [O III] $\lambda\lambda 4959, 5007$

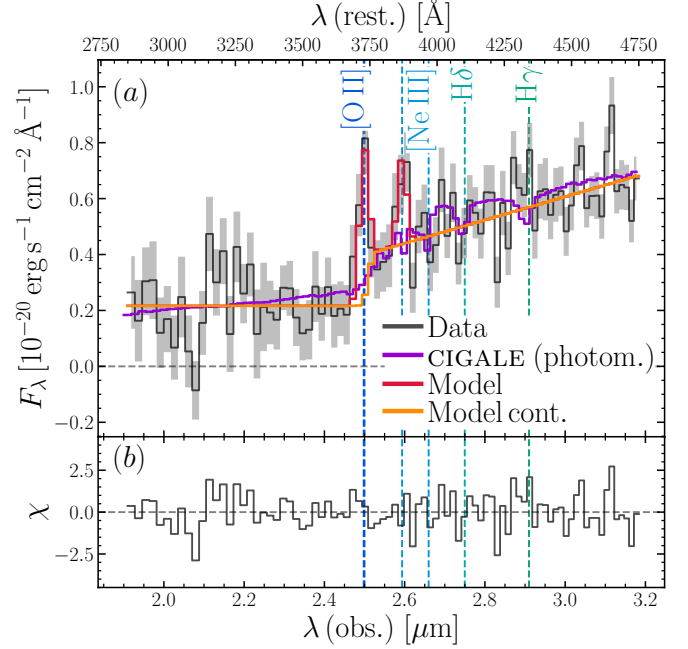


FIG. 6.— a. Spectral region near the Balmer limit, illustrating the data and maximum joint-posterior model. The model continuum is shown in orange; it coincides with the maximum joint-posterior model everywhere, except near the emission lines. The presence of a spectral break is clear both in the data and in the model (4- σ significance), but we lack the spectral resolution and SNR to characterize the exact shape of the break. The purple line is the best-fit CIGALE model from Fig. 4c, which reproduces the break reasonably well, even though CIGALE is not fit to the spectroscopy. b. χ residuals, highlighting the good fit.

TABLE 5: Free parameters of the model describing the spectral region around the Balmer limit (see Fig. 6). [‡] The break is detected regardless of whether λ_{break} is fixed or free.

Parameter	Prior	Unit	Posterior
z_n	$\mathcal{G}(5.702, 0.001)$	—	—
σ_n	$\mathcal{G}(90, 100)$	km s ⁻¹	—
$F([\text{O III}]\lambda\lambda 3726, 3729)$	$\mathcal{U}(0, 10)$	10 ⁻¹⁸ erg s ⁻¹ cm ⁻²	$1.5^{+0.5}_{-0.6}$
$F([\text{Ne III}]\lambda 3869)$	$\mathcal{U}(0, 10)$	10 ⁻¹⁸ erg s ⁻¹ cm ⁻²	$0.8^{+0.3}_{-0.3}$
$\lambda_{\text{break}}^\ddagger$	$\mathcal{U}(3600, 4000)$	Å	3740^{+50}_{-70}
A_{break}	$\mathcal{U}(0, 5)$	—	$1.8^{+0.2}_{-0.2}$

profile seen in the G395M spectrum (Fig. 1c), although the grating spectrum has low SNR in this region. Crucially, the improvement in the residuals is statistically favoured even after penalizing the three additional outflow parameters, since we find $\Delta\text{BIC} = 22$ in favour of the model with outflows.

Although the parameters are very uncertain, we can attempt to estimate a mass outflow rate, following the standard methodology of Carniani et al. (2015), which has been applied to both AGN (e.g., Kakkad et al. 2022) and star-forming galaxies (e.g., Carniani et al. 2024). We

adapt the formula reported in D’Eugenio et al. (2024)

$$M_{\text{out}} = 8 \times 10^7 \cdot \left(\frac{1}{10^{\log(\text{O/H}) - \log(\text{O/H})_{\odot}}} \right) \cdot \left(\frac{L_{[\text{O III}]\lambda 5007}}{10^{44} \text{ erg s}^{-1}} \right) \left(\frac{n_e}{500 \text{ cm}^{-3}} \right)^{-1} M_{\odot} \quad (2)$$

$$\dot{M}_{\text{out}}^{[\text{O III}]} = 3 (|v_{\text{out}}| + 2\sigma_{\text{out}}) \frac{M_{\text{out}}}{R_{\text{out}}},$$

where O/H is the outflow metallicity, expressed by the abundance ratio of oxygen to hydrogen atoms, $L_{[\text{O III}]\lambda 5007}$ is the outflow luminosity (without dust attenuation correction, lacking any constraints), n_e is the electron density, v_{out} and σ_{out} refer to the model parameters of the $[\text{O III}]\lambda\lambda 4959, 5007$ outflow, and R_{out} is the extent of the outflow. Compared to D’Eugenio et al. (2024), we replaced their spatially and spectrally resolved v_{out} with $|v_{\text{out}}| + 2\sigma_{\text{out}}$ (e.g., Rupke et al. 2005). For lack of constraints on the physical properties of the ionized gas in the outflow, we adopt solar metallicity, as massive, dusty galaxies tend to be metal rich. We set $n_e = 2200 \text{ cm}^{-3}$, equal to the geometric mean of the range of electron densities observed in outflows ($n_e = 500\text{--}10,000 \text{ cm}^{-3}$; Baron 2019; Davies et al. 2020). Finally, we use $R_{\text{out}} = 1 \text{ kpc}$, set by the size of the UV-bright clump. We calculate the full posterior distribution of $\dot{M}_{\text{out}}^{[\text{O III}]}$ from the MCMC sampler, obtaining $\log(\dot{M}_{\text{out}}^{[\text{O III}]} / (M_{\odot} \text{ yr}^{-1})) = 0.36 \pm 0.04$, but we stress that the systematic uncertainties are much larger. Varying n_e between 500 and 10,000 cm^{-3} , $\dot{M}_{\text{out}}^{[\text{O III}]}$ spans 1.3 dex, or a factor 4.5 additional uncertainty.

5.6. Neutral gas absorption and possible outflow

The presence of $\text{Na I}\lambda\lambda 5890, 5896$ absorption is extremely clear in the prism spectrum (Fig. 1b) and, tentatively, in the G395M spectrum (Fig. 1c). Our joint analysis yields an $\text{EW}(\text{Na I}\lambda\lambda 5890, 5896) = 17 \pm 2 \text{ \AA}$ – much higher than any stellar-population model, even the most metal-rich local galaxies with the highest Na/Fe abundance ratio ($\text{EW}(\text{Na I}\lambda\lambda 5890, 5896) \lesssim 6 \text{ \AA}$ for $[\text{Na}/\text{Fe}] = 0.5\text{--}0.7$ dex, La Barbera et al. 2017). High EW absorption is also confirmed by the CAPERS spectrum, where we measure $15 \pm 1 \text{ \AA}$ (Appendix A). Our data cannot establish if the absorption is observed in the rest frame (as seen in many hydrogen absorbers in LRDs; D’Eugenio et al. 2026b; Ma et al. 2026; D’Eugenio et al. 2026a), or if it is blue-shifted. This is because we find a velocity $v_{\text{abs}} = -400_{-100}^{+200} \text{ km s}^{-1}$, which is only 2- σ away from rest (defined as $v = 0 \text{ km s}^{-1}$). The absorber velocity dispersion is $\sigma_{\text{abs}} = 300_{-100}^{+100} \text{ km s}^{-1}$, which again comes with too large uncertainties to assess if the line is intrinsically broad or not.

Under the outflow hypothesis – strengthened by the detection of the $[\text{O III}]$ outflow – we can estimate the mass outflow rate using the methods outlined in Rupke et al. (2005). From their formulae, and using the same assumptions about the gas metallicity and ionization state as Davies et al. (2024), we can calculate the mass outflow rate for each sample in the set of Markov chains, and we obtain $\log(\dot{M}_{\text{out}}^{\text{Na I}} / (M_{\odot} \text{ yr}^{-1})) = 2.3_{-0.3}^{+0.2}$. This value is remarkably large, among the highest values reported e.g.

in massive galaxies at $z = 1\text{--}2$ (Davies et al. 2024; Sun et al. 2026b). The reported precision and the statistical significance of the outflow may seem surprising, given the large uncertainties on v_{abs} and σ_{abs} . However, having defined the outflow velocity as $v_{\text{out}} \equiv |v_{\text{abs}}| + 2 \cdot \sigma_{\text{abs}}$, we obtain a much larger v_{out} value than $|v_{\text{abs}}|$ alone, one that is clearly inconsistent with 0 (unlike v_{abs} itself). This means that, under the outflow hypothesis, the data suggest a high mass outflow rate, yet the current SNR is insufficient to establish if outflows are the correct scenario.

6. A REGULAR X-RAY EMITTER

We derive the X-ray luminosity directly from the published catalogue of Nandra et al. (2015). To estimate the luminosity in the 2–10 keV range, we assumed a photon index $\Gamma = 1.9$, which is the median value for normal AGNs at this redshift (Shemmer et al. 2006; Just et al. 2007; Nanni et al. 2017; Vito et al. 2019). We obtain a range of $L_{2\text{--}10 \text{ keV}} = (2.3\text{--}3.8) \times 10^{44} \text{ erg s}^{-1}$, where the limits of the interval correspond to the extreme cases of no absorption ($N_H = 0 \text{ cm}^{-2}$) or Compton-thick absorption ($N_H = 10^{24} \text{ cm}^{-2}$).

In Fig. 7 we show $k_{\text{bol,X}}$, the ratio between L_{bol} and $L_{2\text{--}10 \text{ keV}}$, as a function of L_{bol} . By comparing RUBIES-EGS-9809 to quasars and other *JWST* AGN, we infer that RUBIES-EGS-9809 is not X-ray weak, unlike most *JWST*-discovered AGN at $z > 2$ (Yue et al. 2024; Maiolino et al. 2025), which include some of the most luminous LRDs known (Juodžbalis et al. 2024; Wang et al. 2025; Loiacono et al. 2025), and even blue, luminous AGNs (Übler et al. 2023). While RUBIES-EGS-9809 is 10 times brighter than typical high-redshift AGNs – making detection in X-rays easier – several LRDs and high-redshift AGNs have *more stringent* constraints on $k_{\text{bol,X}}$ than RUBIES-EGS-9809, due to being at lower redshifts (e.g., Juodžbalis et al. 2024; Loiacono et al. 2025), or in deeper *Chandra* fields (e.g., Übler et al. 2023), or both.

7. DISCUSSION

7.1. The Physical Nature of RUBIES-EGS-9809: A Massive, Quenching Galaxy with Powerful Outflows

RUBIES-EGS-9809 is massive, $M_{\star} \sim 10^{10.5\text{--}11} M_{\odot}$, as implied by its luminosity and by the pronounced, spatially resolved Balmer break and inferred from the SED fit (Section 3.2). For reference, these values are larger than the ‘knee’ of the galaxy mass function at $z = 5\text{--}6$, ($10^{10\text{--}10.3} M_{\odot}$; Weaver et al. 2023; Weibel et al. 2024). In terms of mass formed, RUBIES-EGS-9809 is already on par with massive quiescent galaxies at redshifts $z \sim 5$ (e.g., GS-9209, Carnall et al. 2023b; RUBIES-QG-1, de Graaff et al. 2025a).

The source is compact yet resolved in all robust NIR-Cam detections (Section 3.1). The size decreases with increasing wavelength (Fig. 2 and Table 2), a fact that is consistent with either an increasing contribution from a point source at red wavelengths or centrally concentrated dust. Using the size in F356W (rest-frame $\sim 0.5 \mu\text{m}$) as reference, we find $R_e \simeq 380 \text{ pc}$, fully consistent with the

mass-outflow rate ($\log(\dot{M}_{\text{out}}^{\text{NaI}}/(\text{M}_{\odot} \text{ yr}^{-1})) = 2.3^{+0.2}_{-0.3}$). This is another case of multiphase outflows at high redshift in which the mass outflow rate is higher in the neutral phase than in the ionized one (Davies et al. 2024; D’Eugenio et al. 2024; Belli et al. 2024; Parlanti et al. 2025). While both outflow rates have large systematics, their coincidence with a luminous AGN strongly favours AGN-driven clearing of the ISM.

The duration of this phase cannot be derived solely from our data, but we can provide a rough estimate by comparing the expected gas content to the mass outflow rate. For a galaxy with $M_{\star} = 10^{10.5-11} \text{ M}_{\odot}$ on the star-forming sequence, we expect a molecular-to-stellar mass ratio of ~ 75 percent (Tacconi et al. 2020). This must be an upper limit, since the downturn in SFR suggests that quenching has been already underway. Dividing the inferred molecular gas mass by the mass rate of the neutral-gas outflow, we obtain a depletion time $\tau_{\text{dep}} \lesssim 150\text{--}450 \text{ Myr}$. This is clearly too long to explain the lack of progenitors for massive, quiescent galaxies at $z \gtrsim 3$. Moreover, we have not even considered the fact that over such a long time period, main-sequence galaxies are expected to further accrete substantial amounts of gas from the cosmic web (Tacconi et al. 2020). A shorter depletion time is possible if the galaxy has a low molecular gas fraction, and if the system is no longer undergoing cold-gas accretion, for instance due to preventative feedback being already at work (e.g., Scholtz et al. 2026). Alternatively, the mass outflow rate could be under-estimated, for instance if our assumptions about the metallicity and ionization state of the neutral gas are incorrect, or if we are missing entirely an even colder phase of the outflow (which is seen in high-redshift galaxies; e.g., Herrera-Camus et al. 2019; Jones et al. 2019).

Deeper spectroscopy can help determine more precisely the recent SFH of this galaxy, thus providing independent constraints on the quenching timescale (e.g., Carnall et al. 2023b; Park et al. 2024; Baker et al. 2025b).

To provide an order-of-magnitude reference estimate for the space density of sources like RUBIES-EGS-9809, we rely on its X-ray detection. At $z = 5.7$, RUBIES-EGS-9809 is the only dust-obscured X-ray source (Nandra et al. 2015) in the CEERS survey footprint of 90 arcmin^2 (Finkelstein et al. 2025). To calculate the survey volume, we consider redshift limits of $z \geq 3\text{--}4$ (since this is the redshift range where the abundance of massive quiescent galaxies is in tension with theory; Carnall et al. 2023b; Valentino et al. 2023; Baker et al. 2025b) and $z \leq 7.3$ (since above this redshift $\text{H}\alpha$ is not observable by NIRSpec). With these limits, and the assumed cosmology, we find a comoving number density $n = (0.9\text{--}1.3) \times 10^{-6} \text{ cMpc}^{-3}$. Clearly, this estimate cannot be interpreted as the total number density of dusty, quenching galaxies, nor as a lower limit on the cosmic mean. First, it is based on a single source, hence it is subject to large Poisson uncertainty. Second, by relying on a single field, we are subject to cosmic variance (e.g., Valentino et al. 2023). Finally, this is conditional on an X-ray selection, and is therefore incomplete for X-ray faint AGN, including intrinsically X-ray-weak AGNs, heavily absorbed sources, and systems in which the AGN has already faded. In particular, we are certainly missing objects that are more naturally selected through deep

MIR observations.

With these limitations in mind, the CEERS X-ray-selected value is ten times lower than the number density of massive, quiescent galaxies, which is around $n = 10^{-5} \text{ cMpc}^{-3}$. The two numbers could be reconciled if the visibility of the dusty-progenitor phase was significantly shorter than that of massive galaxies. This shorter visibility could arise if – for example – the breakout phase is short compared to both the dust-obscured starburst and the quiescent phase, or, alternatively, from the limitations outlined above. This is particularly relevant because the other compelling candidate, the dusty post-starburst galaxy *Hyde*, is undetected in the X-rays (but the relevant X-ray data are much shallower than for RUBIES-EGS-9809; cf. Nandra et al. 2015 vs Civano et al. 2016). The purpose of this work is therefore not to provide a definitive measurement of the number density of dusty, quenching AGN hosts. Rather, RUBIES-EGS-9809 demonstrates that such systems exist, and that they can combine an evolved stellar population, heavy dust obscuration, luminous AGN activity, and possible outflows at $z > 5$. Establishing whether this pathway is common enough to contribute substantially to the progenitor population of massive quiescent galaxies will require a dedicated census across multiple fields, with joint X-ray, MIR, FIR, radio, and *JWST* selection functions.

7.2. A massive galaxy, not a Little Red Dot AGN

JWST has discovered a new population of broad-line AGNs, whose unique characteristics are extremely rare in the local Universe (Ma et al. 2026, Lin et al. 2025, Euclid Collaboration et al. 2026, Lin et al. 2025). These include systems in which even the optical continuum is AGN-dominated (Ji et al. 2025; Lin et al. 2025; D’Eugenio et al. 2025c). These works cast doubt on our ability to accurately measure $M_{\star}$ in LRDs (Wang et al. 2025; Juodžbalis et al. 2024; Ma et al. 2025). In fact, strong Balmer breaks in LRDs (Furtak et al. 2024; Labbe et al. 2024; Wang et al. 2024) are demonstrably associated with low- $M_{\star}$ galaxies, as inferred from both their clustering (Pizzati et al. 2025; Matthee et al. 2025; Lin et al. 2026) and from the physical upper limit set by their low dynamical masses (Wang et al. 2025; Juodžbalis et al. 2024; Ji et al. 2025; D’Eugenio et al. 2026b; Akins et al. 2026). Recently, a possible LRD embedded in an extended galaxy has also been discovered (Rinaldi et al. 2026).

Since our source RUBIES-EGS-9809 presents several characteristics in common with LRDs, it is worth assessing whether it may be an LRD itself, or at least an intermediate system, similar to *Saguaro* (Rinaldi et al. 2026). The answer to this question is consequential for our confidence in the inferred $M_{\star}$ and SFH. The overestimated $M_{\star}$ in LRDs stems from the incorrect interpretation of the Balmer break, which in these AGNs arises from dense-gas absorption near the black hole, and not in the atmosphere of evolved stellar populations (Ji et al. 2025; Naidu et al. 2026; de Graaff et al. 2025c).

Two diagnostics argue against the LRD interpretation. First, the emission redward of the Balmer break is spatially extended: we measure $R_e \sim 0.5 \text{ kpc}$ in F277W (which samples the continuum just longward of the break) and a similarly extended size in F200W (Section 3.1). Although F277W includes $[\text{O II}]\lambda\lambda 3726, 3729$

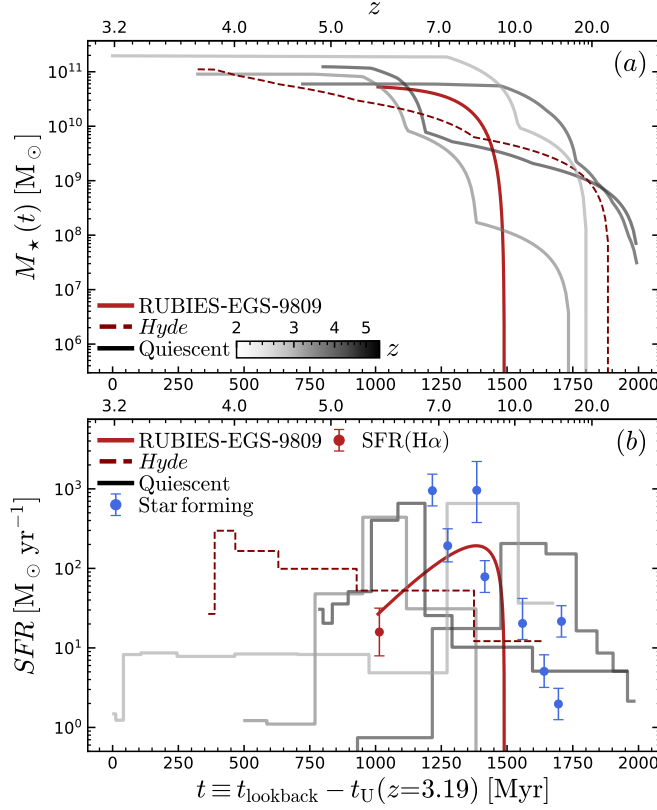


FIG. 8.—: The SFH of RUBIES-EGS-9809 is similar to that of massive, quiescent galaxies at $z \gtrsim 3$. Panel a shows the cumulative SFH, highlighting the similarity in final M_* . Greyscale curves are massive, quiescent galaxies from the literature (in order of increasing redshift: Glazebrook et al. 2024, with the SFH from Turner et al. 2025; Glazebrook et al. 2017, with the SFH from Pérez-González et al. 2025; Carnall et al. 2023b, with the SFH from Ji et al. 2024; and de Graaff et al. 2025a). The red dashed curve is the compact and dusty quenching galaxy *Hyde* (Schreiber et al. 2018, with the SFH from Pérez-González et al. 2025). Panel b shows the SFR vs lookback time; we also show the 10-Myr SFR from H α , and a set of SFR measurements from the literature, compiled by Turner et al. (2025). All look-back times are matched to the lowest-redshift object, at $z = 3.19$.

and [Ne III] λ 3869, these lines contribute only $\simeq 3$ percent of the F277W broad-band flux when the fitted line fluxes are convolved with the filter curve (Section 3.1). Thus the extended F277W morphology cannot be explained primarily by extended ionized gas. Combined with the strong colour contrast across the break (F277W/F200W $\simeq 4.5$), this implies that the Balmer-break continuum is not dominated by a compact, unresolved component. The measured size is an order of magnitude larger than in LRDs, where the Balmer break is always extremely compact, and almost never spatially resolved (e.g., Furtak et al. 2024 place upper limits of $R_e < 30$ pc, while de Graaff et al. 2025c measure $R_e = 40$ pc).

Second, RUBIES-EGS-9809 is clearly detected in X-rays, MIR and FIR wavelengths. In contrast, spectroscopically confirmed LRDs are generally deficient in all

three wavelength ranges (Ananna et al. 2024; Yue et al. 2024; Maiolino et al. 2025; Kokubo & Harikane 2025; Akins et al. 2025; Casey et al. 2024, 2025; Williams et al. 2024; Setton et al. 2025), even though there are exceptions, with clear detections at MIR wavelengths (e.g., Juodžbalis et al. 2024; Barro et al. 2026) or even in the FIR (e.g., Barro et al. 2026). RUBIES-EGS-9809 is not X-ray weak (Fig. 7), unlike most *JWST*-discovered AGN at $z > 2$ (Yue et al. 2024; Maiolino et al. 2025).

Interestingly, RUBIES-EGS-9809 also displays outflows, both in the ionized phase (Section 5.5) and, possibly, in the neutral phase too (Section 5.6). This is in stark contrast to most LRDs, whose ionized outflows – when detected at all – are weak and more reminiscent of the modest galaxy-scale winds seen in low-mass star-forming galaxies at high redshift (cf. Juodžbalis et al. 2024; D’Eugenio et al. 2026a for LRDs and Xu et al. 2025; Carniani et al. 2024 for galaxies). Instead, even considering all the associated systematic uncertainties, the velocity and mass outflow rate of the outflows in RUBIES-EGS-9809 match what is seen in more massive AGN hosts at lower redshift (e.g., Bertola et al. 2025). In the context of all peculiar properties of RUBIES-EGS-9809 relative to LRDs, the presence of outflows detected in metal lines is unlikely to be a mere coincidence. Logically, metal-loaded outflows may be one way to clear paths through the dense absorbing gas, enabling ionizing radiation to escape, while also enhancing AGN feedback by increasing the coupling between radiation and dust or metals (e.g., Fabian et al. 2008).

Overall, these considerations give confidence to our measurements of an evolved stellar population and hence a genuinely large value of M_* . However, we also acknowledge that higher-resolution, high-quality spectroscopy capable of spectrally resolving the narrow-line emission is necessary to fully rule out the LRD interpretation.

While in the next sections we discuss the fiducial interpretation that RUBIES-EGS-9809 is a massive galaxy, there remains a possibility that we are also witnessing a transitional AGN between the LRD phase and a ‘normal’ AGN, as recently suggested for similar sources by Fu et al. (2026). Assuming that RUBIES-EGS-9809 was an LRD, detection in X-rays would imply that the intrinsic SED of LRDs is indeed hard – e.g. via the presence of a hot corona (Haardt & Maraschi 1991). This would require a high flux of ionizing radiation, thus explaining the detection of high ionization lines in some LRDs (Tripodi et al. 2024; Tang et al. 2025). The general lack of X-ray detection would then be in agreement with the high covering factor proposed by Maiolino et al. (e.g., 2025), without requiring an intrinsically soft X-ray spectrum, as posited by some models of super-Eddington accretion (Pacucci & Narayan 2024; Madau & Haardt 2024; Lambides et al. 2026).

The mix of ionized and neutral metals would be possible if the ISM was initially starved of ionizing photons (such would be possible for LRDs; Ji et al. 2025; Setton et al. 2025), but the system is observed right during the blow-out phase when feedback is starting to clear some of the obscuring material.

7.3. A ‘dusty path’ to quiescence

In Fig. 9 we show how RUBIES-EGS-9809 would evolve if it stopped forming stars at the epoch of ob-

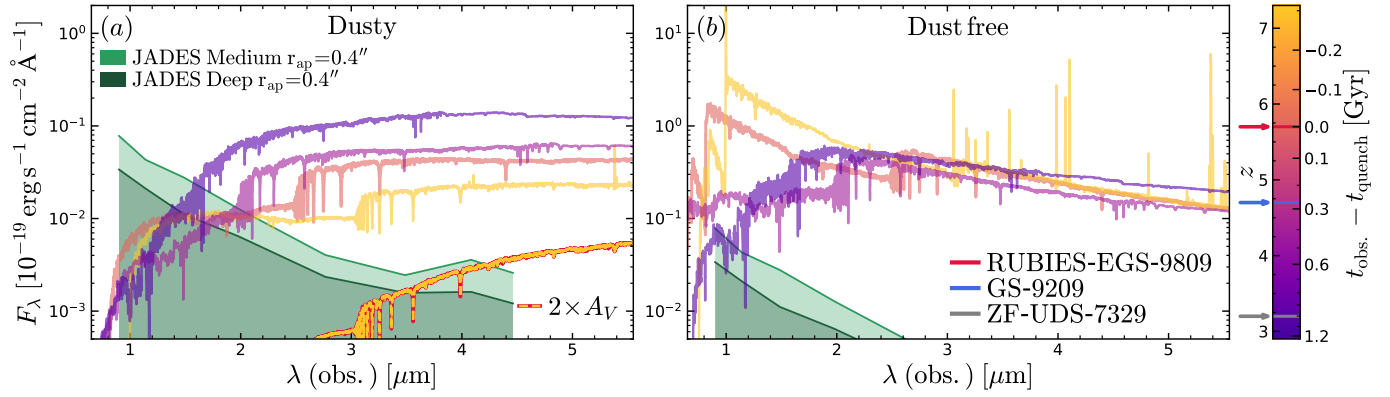


FIG. 9.— a. Toy model showing the spectral evolution of a dusty post-starburst galaxy, between $z = 7$ and $z = 3$. The reference model reproduces the best-fit CIGALE model at $z = 5.7$. b. Same as panel a, but without dust attenuation. The colorbar is the same for both panels. The lines across the colorbar mark the redshifts of RUBIES-EGS-9809 (red), a massive post-starburst and dust-free galaxy (GS-9209; Carnall et al. 2023b), and a very old 4000-Å break galaxy (ZF-UDS-7329; Glazebrook et al. 2024). Our proposed model would see the galaxy quenching first ($z \gtrsim 5.7$), then removing the dust ($z \sim 4.5$), thus skipping the UV-bright and quenched phase, which is readily detectable, but has not been observed. The green shaded regions show the 5- σ sensitivities of JADES medium and deep. The dust-obscured, star-forming progenitor of RUBIES-EGS-9809 should be readily detectable in JADES (yellow spectrum in panel a); the lack of reported detections may require even higher continuum attenuation than the CIGALE value of $A_V = 1.8$ mag (yellow-red curves).

servation (marked as $t_{\text{obs.}} - t_{\text{quench}} = 0$ in the colorbar). We take as reference the best-fit CIGALE model, with $A_V = 1.8$ mag, and evolve it backwards and forwards in time. Panels a and b show dust-attenuated and dust-free spectra, respectively. The four coloured spectra in each panel are four snapshots in time; the snapshot at $t_{\text{obs.}} - t_{\text{quench}} = 0.3$ Gyr is chosen to be close in time to the post-starburst galaxy GS-9209 (Carnall et al. 2023b), while the $t_{\text{obs.}} - t_{\text{quench}} = 1$ Gyr is near the very old galaxy ZF-UDS-7329 (Glazebrook et al. 2024). The highest-redshift snapshot (yellow) is the star-forming progenitor (with $2 \times$ lower M_*). In principle, the evolutionary tracks can jump from panel b to panel a by forming dust, and vice versa, dust removal would move the evolution from panel a back to b.

Since not all these phases have been observed, we can draw informed hypotheses on plausible evolutionary paths. As a reference, we show the 5- σ sensitivity of JADES for both the medium tier (~ 150 arcmin²) and deep tier (~ 32 arcmin²; Eisenstein et al. 2026), calculated inside a circular aperture with 0.4-arcsec radius (Sun et al. 2026a). Since all four models lie clearly above the JADES detection limits in both panels, we should in principle be able to detect all these evolutionary stages. Instead, the star-forming progenitors are missing, in both the dust-obscured and (even more so) in the dust-free scenarios. A possible explanation is that the dusty progenitors are even more obscured than inferred from CIGALE (red-and-yellow spectrum in panel a). This interpretation is consistent with the recent discovery of extremely dusty galaxies at $z \gtrsim 8$ (Bakx et al. 2025; Zavala et al. 2026), which likely sample the most obscured tail of the progenitor population and may be undercounted in NIRC2-selected spectroscopic follow-up (Sun et al. 2026a).

The bolometric luminosity of this galaxy (incl. the dominant AGN) is of order $10^{13} L_\odot$, meaning this galaxy

is on par with hot, dust-obscured galaxies discovered by *WISE* and *Spitzer* (e.g., Eisenhardt et al. 2012; Wu et al. 2012).

We summarize these considerations in the cartoon of Fig. 10. Here we show the two evolutionary sequences side by side (dusty and dust-free), and colour-code in grey evolutionary phases that are disfavoured by observations. Green-background phases instead have been directly observed, thus representing a plausible path. The star-forming progenitors should be heavily obscured starbursts, with SFR of $\sim 100 M_\odot \text{ yr}^{-1}$, sufficiently low to be missed by shallow ALMA surveys (Sun et al. 2026a). As quenching starts it reduces but – crucially – does not fully eliminate dust. This dust-obscured quenching phase is seen in RUBIES-EGS-9809 here, and in other systems such as *Hyde* (Schreiber et al. 2018; Pérez-González et al. 2025). AGN feedback is crucial in this phase: since the SFR is dwindling, it seems unlikely to us that it may drive dust-clearing outflows at this evolutionary stage, when it was unable to do so earlier, at the peak of the starburst. Instead, AGN are known to drive fast outflows in both quenching (D’Eugenio et al. 2024; Belli et al. 2024) and quiescent galaxies (Sun et al. 2026b), and are seen *acting* directly in both RUBIES-EGS-9809 and *Hyde*. The case of *Mahler*, a $10^{10} M_\odot$ galaxy at $z = 5.9$ may represent the ‘blowout’ phase when the AGN just removed a substantial fraction of the ISM. However, at this stage, the galaxy already has a well developed Balmer break, while dust can explain the lack of UV-bright Balmer-break galaxies in the mass range $M_* > 10^{10} M_\odot$. Indeed, young and post-starburst galaxies all display evidence for fast outflows or even dust removal (e.g., GS-9209, Ji et al. 2024; GS-10578, D’Eugenio et al. 2024; RUBIES-UDS-Qz7, Valentino et al. 2025).

We can thus propose a ‘dusty-path’ towards quiescence, where dust removal, being delayed relative to quenching, conceals the UV-bright, quenched phase that

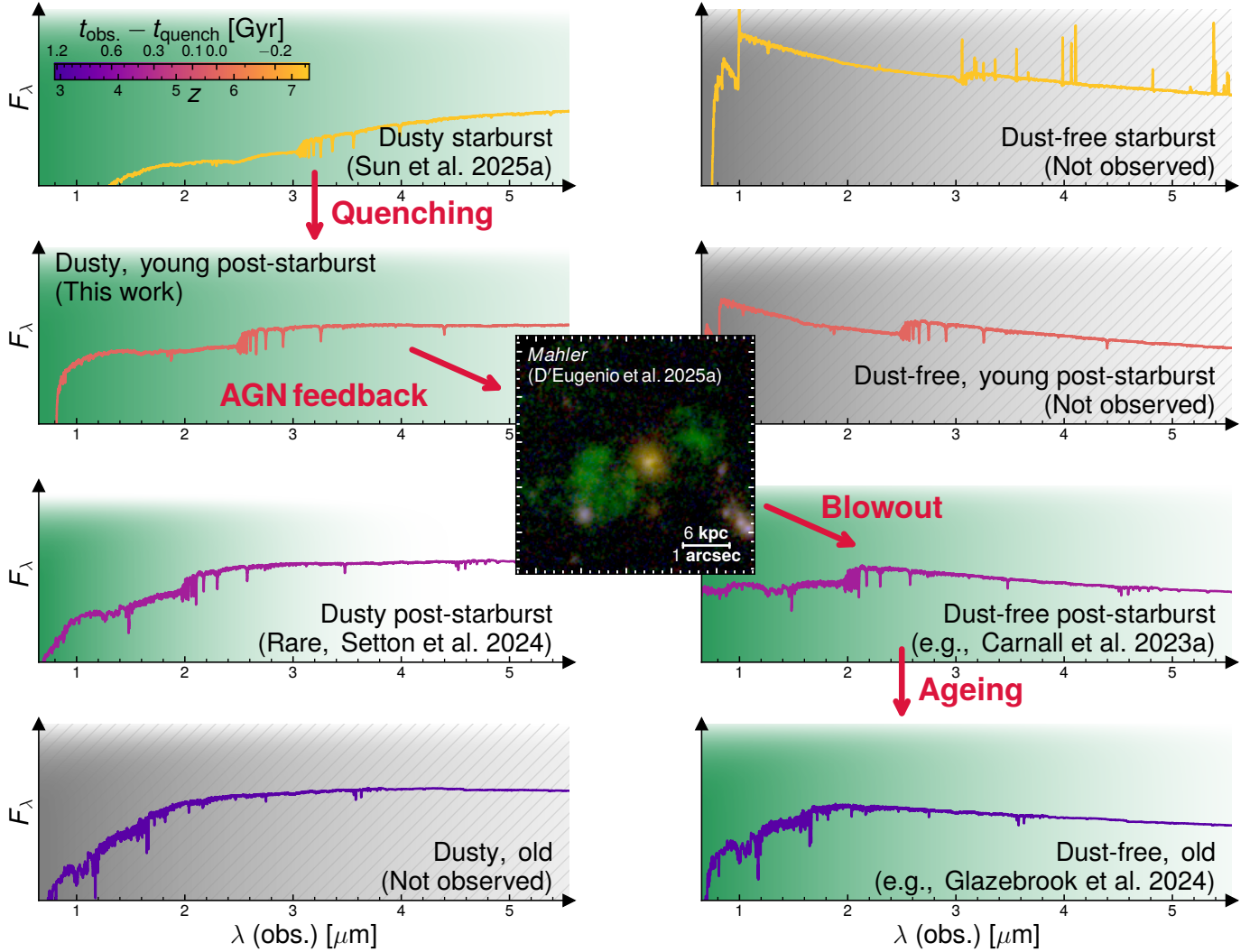


FIG. 10.—: Cartoon of the dusty path to quiescence of massive, early galaxies, where we illustrate in shaded green plausible paths, and in grey evolutionary phases that are disfavoured by observations. The star-forming phase must be dust obscured, since no suitable progenitors have been identified, despite their intrinsic brightness (Fig. 9b). Similarly, young post-starburst systems with ages $\lesssim 50$ Myr must be dust obscured, since they have not been observed, even though equal-age galaxies can be detected down to 2-dex lower M_* (e.g., Looser et al. 2024; Kuruvanthodi et al. 2024; Baker et al. 2025c). Quenching thus happens still in the dust-obscured phase (albeit the dust attenuation may be lower than during the starburst phase). When, eventually, dust is removed (for instance, by violent AGN feedback, D'Eugenio et al. 2025b; Pérez-González et al. 2025), the system is revealed to be already in a post-starburst phase, which is commonly observed (e.g., Carnall et al. 2023b; de Graaff et al. 2025a; in some rarer cases, dust can linger on during the post-starburst phase Setton et al. 2024). Passive evolution then leads to dust-poor (or dust-free) old systems (Glazebrook et al. 2024; McConachie et al. 2026).

is instead commonly observed in galaxies with 2-dex lower M_* (Looser et al. 2024; Kuruvanthodi et al. 2024; Baker et al. 2025c). The prevalence of this evolutionary path for the general population of massive quiescent galaxies at $z \gtrsim 3$ is unclear. The lack of massive, UV-bright and quenched galaxies suggests it should be widespread, but a complete census of dusty, post-starburst systems is yet to be done, because existing spectroscopic projects (Barrufet et al. 2025; Cooper et al. 2025a) selected targets from medium-depth photometry, which may be too shallow (Sun et al. 2026a), even though a few photometric candidates are known (Xiao et al. 2024).

More generally, the population of heavily obscured,

compact galaxies at $z > 2$ may be currently under-characterized: on one hand, the bulk of these galaxies may escape both medium-depth NIRCам and MIRI surveys, and shallow ALMA surveys (Sun et al. 2026a). On the other hand, their extremely red SEDs make it generally difficult to infer the redshift from photometry alone, let alone infer the full diversity of star-formation histories and AGN properties (Cooper et al. 2025a). Deep NIRSpect observations to follow up faint, dust-obscured candidates are a compelling path forward.

8. SUMMARY AND CONCLUSIONS

In this work, we present a full spectro-photometric analysis of the dust-reddened source RUBIES-EGS-9809,

originally identified as an X-ray emitter (Section 2), and spectroscopically confirmed with *JWST*/NIRSpec by RUBIES.

- Morphologically, the source is compact yet clearly resolved in all NIRCам bands, including both continuum- and line-dominated bands (Section 3.1). We find rest-frame optical half-light radii of order $R_e \sim 0.4\text{--}0.6$ kpc, consistent with massive, quiescent galaxies at comparable redshifts.
- Modelling the SED with CIGALE, we find clear evidence of a Balmer break in the photometry (Figs. 2 and 3), in agreement with the NIRSpec data, where we detect the break with 4- σ significance (Fig. 6).
- The AGN is also clearly seen at MIR wavelengths and in the radio. Cold dust emission is tentatively detected by JCMT/SCUBA-2 at 850 μm . CIGALE requires a dust-obscured AGN, and interprets the Balmer break as evidence for an evolved stellar population, with $M_\star = 10^{10.5-11} M_\odot$ (Section 3.2).
- The prism spectrum displays bright and broad emission, which we identify as broad $H\alpha$ from an AGN broad-line region. We model the line as the sum of two Gaussians, and we infer a combined $FWHM = 1500_{-100}^{+200} \text{ km s}^{-1}$, while the broadest component has $FWHM = 3800_{-300}^{+400} \text{ km s}^{-1}$. Due to the lack of medium-resolution coverage, we cannot readily deblend $H\alpha$ from $[\text{N II}]\lambda\lambda 6548, 6583$.
- The grating covers the $H\beta\text{--}[\text{O III}]\lambda\lambda 4959, 5007$ spectral range, where we detect broad $[\text{O III}]$, which we interpret as an ionized outflow. The resulting mass outflow rate is $\log(\dot{M}_{\text{out}}^{[\text{O III}]} / (M_\odot \text{ yr}^{-1})) = 0.36 \pm 0.04$, with much larger systematic uncertainties (Section 5.5).
- We detect deep $\text{Na I}\lambda\lambda 5890, 5896$ absorption, tentatively blueshifted (2σ), with high $\text{EW}(\text{Na I}\lambda\lambda 5890, 5896) = 17 \pm 2 \text{ \AA}$ – a value so large as to require an ISM origin. If interpreted as an outflow, this yields a neutral-phase mass outflow rate $\log(\dot{M}_{\text{out}}^{\text{Na I}} / (M_\odot \text{ yr}^{-1})) = 2.3_{-0.3}^{+0.2}$.
- The absorption-corrected X-ray luminosity is in line with scaling relations typical of broad-line AGN (Fig. 7), unlike X-ray weak LRDs.

We interpret this source as a massive, evolved galaxy and a strong quenching candidate. The causes underlying the decreasing SFR trend cannot be untangled with our data, and span all plausible ranges, from AGN or star-formation driven feedback, to gas consumption. The emission-line model grid favours high intrinsic BLR Balmer decrements, but leaves the recent SFR too uncertain to establish quiescence on its own. The current outflows observed in the source are consistent with an AGN-driven outburst, given their coincidence with a high-luminosity AGN, but confirmation would require further observations. We argue that RUBIES-EGS-9809 may be caught in a transition phase, similar to other such

systems observed near or during the removal of substantial amounts of ISM (Parlanti et al. 2024; D’Eugenio et al. 2025a; Pérez-González et al. 2025), some of which are confirmed to host evolved stellar populations (D’Eugenio et al. 2025a; Pérez-González et al. 2025) and all of which are reported to host luminous, dust-obscured AGN. This population represents one step closer to connecting massive, quiescent galaxies at $z = 3\text{--}4$ to their dust-obscured, star-forming progenitors (Sun et al. 2026a). If this quenched and dust-obscured phase was common, it could explain the lack of dust-free, intermediate-age post-starburst galaxies between the NIRCам-dark star-forming progenitors and their dust-free, quiescent descendants. An accurate characterization of their SED and SFH is crucial for understanding if and how AGN feedback is able to quench star formation in massive, early galaxies.

DATA AVAILABILITY

This work uses publicly available data: NIRCам imaging is from CEERS, using the reduction from the DAWN JWST Archive (DJA). NIRSpec spectroscopy is from the RUBIES and CAPERS programmes, using the DJA v4 reduction. The non-*JWST* data are taken from AEGIS-XD (*Chandra*), *Spitzer* PIDs 8, 41023 and 61042 (*Spitzer*/IRAC), FIDEL (*Spitzer*/MIPS), JCMT/SCUBA-2, and AEGIS20 (VLA).

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APPENDIX

POSSIBLE METAL ABSORPTION

Our continuum model uses an additive step function to capture the observed continuum depression highlighted by the green vertical band in Fig. 1b and c. In this appendix we summarize the measurement, clarify why we favour an absorption-based interpretation, and conclude by providing an empirical comparison to other sources.

The prism spectrum shows a sharp drop in flux at rest-frame wavelengths shortward of $\lambda \approx 6250$ Å (green vertical band in Fig. 1b). The same feature is also tentatively seen in the G395M spectrum (Fig. 1c), a fact that disfavors blended, unresolved emission lines (such as [O I] $\lambda\lambda 6300, 6364$ and [S III] $\lambda 6312$), and rules out an artefact, such as due to the data-reduction pipeline or to spoilers and failed-open or disobedient shutters (Ferruit et al. 2022), spectral overlaps (e.g., de Graaff et al. 2025b; D'Eugenio et al. 2026c), and short circuits (e.g., D'Eugenio et al. 2025d).

Denoting the 2nd-order polynomial representing the background as $\mathcal{P}_2$ (Section 4), the additive step function $\mathcal{H}$ is given by

$$\mathcal{H}(\lambda) \equiv \begin{cases} \beta_h(\lambda - \lambda_{h,0}) & \lambda_{h,0} \leq \lambda < \lambda_{h,1} \\ + (A_h - 1) \cdot \mathcal{P}_2(\lambda) & \\ 0 & \text{otherwise.} \end{cases} \quad (\text{A1})$$

This way, A_h represents the amplitude of the discontinuity at $\lambda = \lambda_{h,0}$, with $A_h = 1$ corresponding to no discontinuity. All of A_h , β_h , $\lambda_{h,0}$ and $\lambda_{h,1}$ are free parameters. Depending on their values, there can be a second discontinuity at $\lambda = \lambda_{h,1}$, with amplitude equal to $\beta_h(\lambda_{h,1} - \lambda_{h,0}) + (A_h - 1)\mathcal{P}_2(\lambda_{h,1})$. The above definition focuses on the region near $\lambda_{h,0}$, where we decouple the presence or absence of the discontinuity from the local value of the background.

To quantify its statistical significance, we fit this spectral region with the model of Section 4. The probability that no drop in flux is present is $P(A_h \leq 1) < 0.001$ (3- σ significance), and the model without this step function performs considerably worse, with $\Delta\text{BIC} = 74$ (Table 4). In the prism spectrum, the corresponding depression removes of order 15 percent of the local continuum flux across the interval $\lambda \simeq 6160\text{--}6250$ Å.

Albeit weaker, the feature seems also present in the CAPERS spectrum (Fig. 1b), which suggests a spatial association with the RUBIES shutter position – perhaps a preference for the central regions of the source. When fitting the CAPERS spectrum with the same setup as Section 4, we confirm the preference for the fit that includes the $\mathcal{H}$ model, with $\Delta\text{BIC} = 111$, due to the higher SNR of the CAPERS data (Fig. 11).

If confirmed by deeper and higher-resolution observations, this feature may be due to low-ionization metal absorption in the continuum, e.g. due to Ca I and Fe I.

As an alternative to the fiducial model of Eq. A1, we also attempted to explain this feature with permitted Fe II emission, but this model is disfavoured by the data (Appendix B), which reinforces the hypothesis that the feature represents true absorption, rather than (local) absence of spectrally unresolved emission lines. Of course, this conclusion remains tentative, but it is supported by the very strong Na I $\lambda\lambda 5890, 5896$ absorption (Section 5.6), which independently points to a metal-rich, low-ionization ISM along the line of sight.

The absorption feature near $\lambda = 6250$ Å is also seen in other galaxies. In Fig. 12, we compare RUBIES-EGS-9809 to two other galaxies: SDSS-J151806.1+424445.1 at $z = 0.04$ and JADES-GN-28074 at $z = 2.26$ (Juodžbalis et al. 2024). Both comparison sources display the same spectral drop, albeit with considerably smaller amplitude. In addition, both show clearly detected Na I absorption, while JADES-GN-28074 is a well-known LRD AGN (Juodžbalis et al. 2024). Motivated by this similarity, we define a simple phenomenological measure of the continuum depression, the Index for Metal-absorbing BLR-AGN (hereafter, IMB), following the spirit of the Lick indices (Worthey 1994). The IMB is

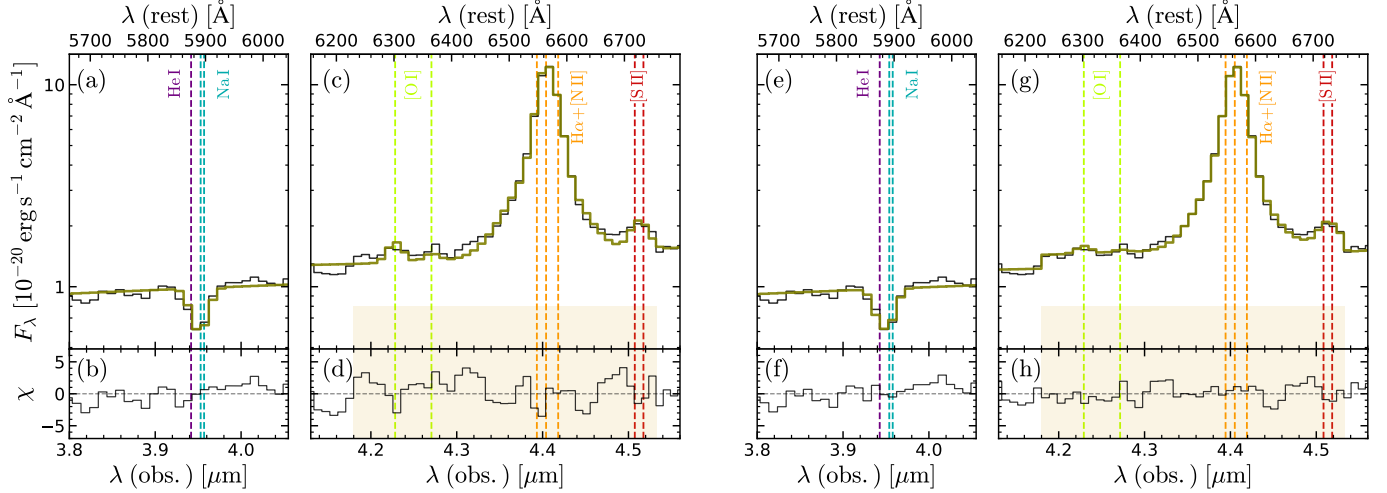


FIG. 11.—: The flux drop near $\lambda = 6250 \text{ \AA}$ is weaker but still present in the higher-SNR CAPERS spectrum. Panels a–d show the best-fit model without the $\mathcal{H}$ term, while panels e–h show the model that includes $\mathcal{H}$. The lines and colours are the same as Fig. 5; the shaded region shows the support of the $\mathcal{H}$ function, highlighting the strong residuals in panels d vs h.

intended only as an empirical comparison tool between spectra, rather than an actual metal-line index. We define a blue continuum as the median of the source continuum within the wavelength range 5600–5800 $\text{\AA}$, and a red continuum as the median within the wavelength range 6317–6440 $\text{\AA}$, masking the spectral region around $\sim 6360 \text{ \AA}$ (specifically: 6357–6375 $\text{\AA}$) to avoid the [O I] line contamination in the continuum estimate. We assume the interval midpoints as reference wavelengths for fitting a linear relation approximating the continuum around the absorption feature at $\lambda \sim 6250 \text{ \AA}$. We exploit such relation to retrieve the unabsorbed continuum estimate at reference wavelength 6118 $\text{\AA}$, which we compare with the measured absorbed flux evaluated as the median value within the absorption interval 6160–6250 $\text{\AA}$. From the prism spectrum of RUBIES-EGS-9809, we retrieve an absorption strength of 1.18 ± 0.42 , meaning that ~ 15 percent of the $\lambda \sim 6250 \text{ \AA}$ flux is absorbed. Following the same procedure, we also analyse SDSS-J151806.1+424445.1 and JADES-GN-28074, and find absorption strengths of 1.040 ± 0.027 and 1.12 ± 0.18 , respectively.

We then search for possible correlations with the nearby Na I absorption line strength. With this method, we measure rest-frame Na I equivalent widths of $13 \pm 3 \text{ \AA}$, $5.28 \pm 0.05 \text{ \AA}$ and $2.9 \pm 0.4 \text{ \AA}$ for RUBIES-EGS-9809, JADES-GN-28074, and SDSS-J151806.1+424445.1, respectively. Thus, within this small comparison set, RUBIES-EGS-9809 shows both the strongest continuum depression and the strongest Na I absorption. This is only suggestive, given the small, heterogeneous sample, but it is consistent with the idea that both features trace unusually strong columns of cool, metal-rich gas. A secure physical interpretation will require deeper medium-resolution spectroscopy covering this wavelength range in a larger sample of dusty AGN and Na I absorbers.

FE II EMISSION TESTS

To test if the continuum drop at 6160–6250 $\text{\AA}$ can be reproduced by broad Fe II emission instead of absorption, we re-run the fiducial spectral model by adding Fe II templates (Véron-Cetty et al. 2004). The Fe II contribution is described by three free parameters: the template amplitude $A_{\text{Fe II}}$, the attenuation applied to the Fe II component, $A_{V, \text{Fe II}}$ (assuming the G03 law, as before), and the iron-line width, $FWHM_{\text{Fe II}}$.

This model is disfavoured by the data ($\Delta \text{BIC} = 41$; Table 4) for two separate reasons. First, the wavelength distribution of the strongest Fe II lines does not match the features observed near 6200 $\text{\AA}$ at all. Moreover, the model cannot simultaneously reproduce a relatively sharp drop (Fig. 1b) and the lack of resolved nearby emission features: adequately fitting the drop would require low $FWHM_{\text{Fe II}}$, but the smooth observed spectrum needs $FWHM_{\text{Fe II}} \gtrsim 1000 \text{ km s}^{-1}$.

The fit therefore converges to a broad component, $FWHM_{\text{Fe II}} = 3400^{+900}_{-800} \text{ km s}^{-1}$, which successfully smooths out any resolved peaks, but at the same time still cannot reproduce the observed flux drop at $\lambda \sim 6250 \text{ \AA}$ (Fig. 1b). The fitted template amplitude is marginally non-zero, $A_{\text{Fe II}} = 28^{+11}_{-10}$, indicating that this model can indeed explain a small amount of residual structure, but the poor fit quality means that Fe II alone cannot fully explain the feature. Finally, the fit requires substantial attenuation of the Fe II component, $A_{V, \text{Fe II}} = 4.3^{+0.4}_{-0.4} \text{ mag}$, which further suppresses any associated bluer Fe II emission. We therefore disfavour the Fe II interpretation and favour an absorption-based model (Appendix A).

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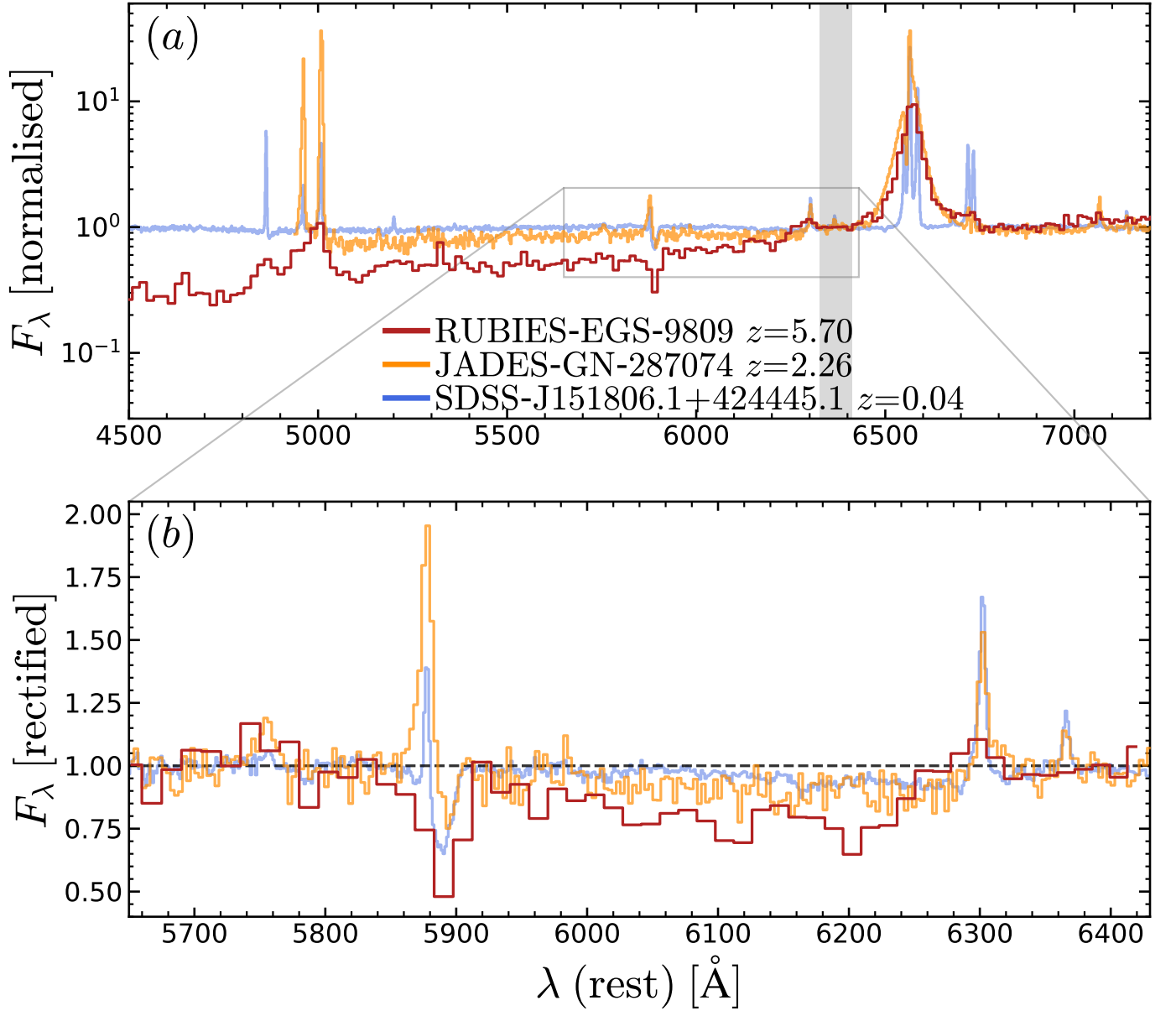


FIG. 12.— The flux drop at $\lambda \sim 6250$ Å we report in RUBIES-EGS-9809 is also seen in other sources associated with LRDs and/or outflows. Panel a shows two comparison objects, JADES-GN-28074 (a luminous LRD; Juodžbalis et al. 2024), and SDSS-J151806.1+424445.1, a dusty starburst with a neutral-gas outflow traced by Na I $\lambda\lambda 5890, 5896$. The spectra have been normalized using the median flux in the vertical grey interval. Panel b displays a detail of the absorption, enhanced by dividing by a continuum model. Note that RUBIES-EGS-9809 has both the strongest absorption feature and the highest-EW Na I $\lambda\lambda 5890, 5896$ absorption.

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