

OCEANS of Absorption: High-resolution NIRSpec Spectroscopy Reveals Diverse Balmer-line Absorption in Little Red Dots

KELCEY DAVIS ^{1,2,*} MADISYN BROOKS ^{1,*} RAYMOND C. SIMONS ³ JONATHAN R. TRUMP ¹
GUILLERMO BARRO ⁴ PABLO ARRABAL HARO ^{5,6} BREN E. BACKHAUS ⁷ NIKKO J. CLERI ^{8,9,10}
ALEXANDER DE LA VEGA ¹¹ STEVEN L. FINKELSTEIN ^{12,13} MAURO GIAVALISCO ¹⁴ NORMAN A. GROGIN ¹⁵
MICHAELA HIRSCHMANN ¹⁶ TAYLOR A. HUTCHISON ^{6,†} DALE KOCEVSKI ¹⁷ ANTON M. KOEKEMOER ¹⁵
ERINI LAMBRIDES ^{6,18,19} MARIO LLERENA ²⁰ RAY A. LUCAS ¹⁵ MADELINE A. MARSHALL ²
ELIZABETH J. MCGRATH ¹⁷ CASEY PAPOVICH ^{21,22} AIDAN STARRS ³ ANTHONY J. TAYLOR ¹²
PHOEBE R. UPTON SANDERBECK ² XIN WANG ^{23,24,25} AND STIJN WUYTS ²⁶

¹Department of Physics, 196A Auditorium Road, Unit 3046, University of Connecticut, Storrs, CT 06269, USA

²Los Alamos National Laboratory, Los Alamos, NM 87545, USA

³Department of Engineering and Physics, Providence College, 1 Cunningham Sq, Providence, RI 02918 USA

⁴Department of Physics, University of the Pacific, Stockton, CA 90340 USA

⁵Center for Space Sciences and Technology, UMBC, 5523 Research Park Dr, Baltimore, MD 21228 USA

⁶Astrophysics Science Division, NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 20771, USA

⁷Department of Physics and Astronomy, University of Kansas, Lawrence, KS 66045, USA

⁸Department of Astronomy and Astrophysics, The Pennsylvania State University, University Park, PA 16802, USA

⁹Institute for Computational and Data Sciences, The Pennsylvania State University, University Park, PA 16802, USA

¹⁰Institute for Gravitation and the Cosmos, The Pennsylvania State University, University Park, PA 16802, USA

¹¹Department of Physics and Astronomy, University of California, 900 University Ave, Riverside, CA 92521, USA

¹²Department of Astronomy, The University of Texas at Austin, Austin, TX, USA

¹³Cosmic Frontier Center, The University of Texas at Austin, Austin, TX, USA

¹⁴University of Massachusetts Amherst, 710 North Pleasant Street, Amherst, MA 01003-9305, USA

¹⁵Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

¹⁶Institute of Physics, Laboratory of Galaxy Evolution, Ecole Polytechnique Fédérale de Lausanne (EPFL), Observatoire de Sauverny, 1290 Versoix, Switzerland

¹⁷Department of Physics and Astronomy, Colby College, Waterville, ME 04901, USA

¹⁸Department of Astronomy, University of Maryland, College Park, MD 20742, USA

¹⁹Center for Research and Exploration in Space Science and Technology, NASA/GSFC, Greenbelt, MD 20771 USA

²⁰INAF Osservatorio Astronomico di Roma, Via Frascati 33, 00078 Monte Porzio Catone, Rome, Italy

²¹Department of Physics and Astronomy, Texas A&M University, College Station, TX, 77843-4242 USA

²²George P. and Cynthia Woods Mitchell Institute for Fundamental Physics and Astronomy, Texas A&M University, College Station, TX, 77843-4242 USA

²³School of Astronomy and Space Science, University of Chinese Academy of Sciences (UCAS), Beijing 100049, China

²⁴National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100101, China

²⁵Institute for Frontiers in Astronomy and Astrophysics, Beijing Normal University, Beijing 102206, China

²⁶Department of Physics, University of Bath, Claverton Down, Bath BA2 7AY, UK

ABSTRACT

The “Little Red Dots” (LRDs) that appeared in early JWST deep field images have been the subject of significant study since their discovery. In this work, we present high-resolution follow-up spectroscopy from the OCEANS program of 10 LRDs with H α coverage at $3 < z < 7$ in the CEERS/EGS legacy deep field. We find Balmer-line absorption in 4 of these LRDs, a 40% detection rate, higher than the fractions reported in lower-resolution NIRSpec surveys. All of the absorbers are presented in high-resolution for the first time here and two have Balmer-line absorption detected for the first time. We demonstrate that this increased recovery of absorbers is partly tied to survey spectral resolution,

Corresponding author: Kelcey Davis

kelcey.davis@uconn.edu

with higher resolution recovering more absorbers. Of the 10 LRDs, 7 are best fit by $H\alpha$ profiles with exponential wings. This includes 2 of the LRDs with absorption. We find that absorbers tend to be blue-shifted with a median velocity offset of near-zero (-49 km s^{-1}) and an absorption equivalent width of $5.3 \text{ \AA}$. Trends are explored to compare LRD absorption velocity and equivalent width along the sequence of LRD properties. We find significant correlation between absorption velocity and LRD color and Balmer break strength. We confirm an LRD observed previously at medium-resolution has statistically significant absorption velocity offsets between $H\alpha$ and $H\beta$. The diversity of LRD absorption properties can be effectively explained by a model with a radial distribution of partial-covering absorbing gas that is often co-located near the broad-line emission regions, along with a radial gradient of close inflow and distant outflow velocities for the absorbing gas. We present other interesting LRDs, including an outflow-dominated LRD (OCEANS 20504) and an LRD with a weak Balmer break and relatively blue UV-to-optical colors but clear Balmer-line absorption (OCEANS 102364). This high occurrence of absorbing hydrogen in LRDs, evident by both the Balmer-line absorption features and Balmer break strengths, implies a near-ubiquitous presence of excited $n = 2$ hydrogen near the central engines, with a diversity of absorption-line kinematics that likely represents a radial gradient of inflowing and outflowing gas.

1. INTRODUCTION

The previous years of high-redshift ($z > 4$) JWST discovery have been defined by the emergence of a new class of luminous sources in the early universe. These “Little Red Dots” (LRDs, e.g: Kocevski et al. 2023; Matthee et al. 2024; Kokorev et al. 2024) were unidentified by previous space-based telescopes but detected in almost all JWST extragalactic deep fields. LRDs are defined by compactness, with angular sizes $\lesssim 200 \text{ pc}$, “v-shaped” spectral energy distributions (SEDs) with incongruous blue rest-UV and red rest-optical continuum slopes, and broad Balmer-lines (Hviding et al. 2025).

LRDs are abundant in the first 0.5–2 billion years of cosmic time ($\sim 4 < z < 9$) with UV and Bolometric number densities of $\Phi \sim 10^{-5}\text{--}10^{-4} \text{ cMpc}^{-3} \text{ mag}^{-1}$ (Kokorev et al. 2024). At $z < 4$, they become increasingly rare (see some exceptions in Euclid Collaboration et al. 2025; Ji et al. 2026; Ma et al. 2026; Rinaldi et al. 2025). This over-abundance of atypical sources in the first few billion years implies that LRDs represent a phenomenon that is unique to the conditions of the early Universe. An explanation for these unexpected sources is key to understanding how early galaxies and black holes formed.

Balmer breaks, a prominent feature in most LRDs, are typical in nearby galaxies. They are signatures of excited ($n=2$) hydrogen common in the atmospheres of A type stars. In galaxies with such stars in abundance, hydrogen atoms have the correct energy to absorb rest-UV photons blueward of $\lambda = 3646 \text{ \AA}$. This results in a forest of absorption features that blends together into a

“break” in the SED. Such breaks in LRDs occur at their characteristic SED “kink”.

Early work attempted to explain the Balmer breaks of LRDs with old stellar populations but found that the implied galaxy masses and ages were in conflict with the young age of the universe at high redshift (Labbé et al. 2023; Boylan-Kolchin 2023). LRDs also have Balmer breaks that are much smoother and often much stronger than observed for stellar populations (Naidu et al. 2025). Together, this implies Balmer breaks in LRDs are driven by a process independent of, or in addition to, stellar light. Such a process must invoke a large density of hydrogen in the $n=2$ state to create the observed Balmer breaks.

Follow-up observations of LRDs indicate they may host accreting supermassive black holes (SMBHs) that dominate the rest-optical light output, as evidenced by their broadened Balmer lines (Hviding et al. 2025; Greene et al. 2024; Matthee et al. 2024; Pang et al. 2026; Wang et al. 2025) and rest optical continuum slopes best fit by SMBH contribution (Kocevski et al. 2025). A popular model that explains the LRD observed properties invokes, not star formation, but a SMBH veiled in a cocoon of dense, excited hydrogen gas (Inayoshi & Maiolino 2025; Torralba et al. 2025). This is the only model thus far that can explain both the presence and strength of the Balmer breaks, including the extreme break-strength outliers, or “cliff” sources (de Graaff et al. 2025a; Naidu et al. 2025; Taylor et al. 2025a).

Recently, the physical mechanism that broadens the Balmer lines in these sources has been under question. In low- z quasars, most Balmer-line broadening is attributed to kinematics associated with rotating high density gas surrounding the SMBH known as the broad-

* NSF Graduate Research Fellow

† NASA Postdoctoral Fellow

line region (BLR). In many LRDs, the line-shape outside of the Gaussian core has an exponential profile, which requires stratification in the BLR (Madau et al. 2026; Tang et al. 2026; Ji et al. 2026) or exponential scattering from dense hydrogen (Rusakov et al. 2026). This emission-line structure is not unique to LRDs and has been observed in many quasars identified by the Sloan Digital Sky Survey (SDSS) interpreted as evidence for thermal electron scattering (Kollatschny & Zetzl 2013; Laor 2006). Honing in on the mechanisms by which Balmer emission is broadened is another critical step in developing a complete model for LRDs.

A subset of the LRDs also have narrow Balmer-line absorption features, frequently offset from the emission-line center (Kocevski et al. 2025; Matthee et al. 2024, 2026; Naidu et al. 2025; Taylor et al. 2025b,a; Lambrides et al. 2025). Such absorption features should be present in all LRDs that have Balmer breaks if the break is non-stellar in origin since the absorption arises from the same hydrogen that causes the break. The features are critical probes of the kinematic nature of LRDs which can be inferred from the velocity offset of the absorption.

Many Balmer-line absorber LRDs have been identified in medium-resolution spectroscopy survey data (de Graaff et al. 2025b; Hviding et al. 2025; Matthee et al. 2024; Taylor et al. 2025b; Kocevski et al. 2025). Other surveys recover absorption in medium and high-resolution spectroscopy of single sources (D'Eugenio et al. 2025a,b; Kokorev et al. 2025; Lambrides et al. 2025; Naidu et al. 2025; Taylor et al. 2025a; Torralba et al. 2025; Wang et al. 2025) while Matthee et al. (2026) and D'Eugenio et al. (2026) identified multiple Balmer-line absorbers for the first time in a high-resolution spectroscopy survey with the BlackTHUNDER Large Programme (Black holes in THe early Universe aNd their DensE surRoundings; program ID 5015; PIs: H. Übler, R. Maiolino). Although current samples remain small and heterogeneous, the reported Balmer-line absorbers appear to lie preferentially among the reddest LRDs (Barro et al. 2025; Matthee et al. 2026). Here, we expand the known Balmer-line absorbing LRD population through a new high-resolution spectroscopy survey to assess whether this apparent color dependence holds and to explore how absorption relates to other LRD properties.

In this work, we use high-resolution ($R \sim 2700$) NIRSpec spectroscopy from the Observing Cosmic Evolution Among Nascent Systems (OCEANS) survey to identify and quantify this Balmer absorption and the presence of exponential wings in the emission lines of LRDs. In Section 2, we describe the OCEANS program, the low-resolution spectroscopy programs that targeted the

OCEANS LRDs, which we utilize for continuum measurements, and the photometric coverage used to identify the LRDs. In Section 4, we explore selection effects for Balmer-line absorption and explore trends with net-to-narrow emission, UV-to-optical color, and Balmer break strength. We present a case of velocity offset Balmer-line absorption and an accompanying cartoon model. Throughout this work, we assume a flat Λ CDM cosmology consistent with measurements from Planck with $H_0 = 67.4 \text{ kms}^{-1}\text{Mpc}^{-1}$ and $\Omega_M = 0.315$ (Planck Collaboration et al. 2020). All logarithms are base ten. Redshift is denoted by z . Equivalent Widths (EWs) for absorption features are reported as a positive value from the rest-frame. All magnitudes (mag) are AB (Osterbrock 1989).

2. DATA

We utilize NIRSpec spectroscopy from the high-resolution (G235H + G395H) OCEANS survey to probe the nature of Balmer-absorbing and non-absorbing LRDs. The CEERS photometry was used both to design the OCEANS MSA layout and select the LRDs in this work. We describe the data and selection methodology here. We also utilize lower-resolution spectroscopy when available to measure the continuum and for comparison to the high-resolution spectral measurements.

2.1. OCEANS High-Resolution Spectroscopy Survey

OCEANS We use high spectral resolution JWST/NIRSpec multi-shutter assembly (MSA) spectroscopy from the Cycle 4 Observing Cosmic Evolution Among Nascent Systems (OCEANS) survey [GO-8410, PI: R.C. Simons].

OCEANS consists of 6 NIRSpec MSA pointings in the Extended Groth Strip (EGS), targeting regions with existing NIRCам IR imaging from the CEERS survey (Finkelstein et al. 2025) and optical-to-near-IR *HST* imaging from the CANDELS survey (Grogin et al. 2011; Koekemoer et al. 2011).

NIRCам photometric data from the CEERS survey was used in the selection and classification of the LRDs and in targeting for the OCEANS survey. The photometric data used here is described in Bagley et al. (2023). We use the CEERS photometric catalog version 0.51.2 and photometric redshifts presented in Finkelstein et al. (2024). At the time of this survey, CEERS has photometric coverage in the rest-IR from the NIRCам filters F115W, F150W, F200W, F277W, F356W, F410M, and F444W in the Cycle 1 footprint.

In parallel, OCEANS gathered F115W, F150W, F356W, and F410M NIRCам imaging in regions flanking the Extended Groth Strip (EGS). A photometric

catalog and reduced images for the NIRCam component of OCEANS will be the subject of future work (Davis et al., in prep).

The spectroscopic targets for the MSA in OCEANS were selected from NIRCam imaging from the CEERS (ERS-1345; Finkelstein et al. 2025) survey and NIRSpec prism/medium-grating spectroscopy from the CEERS, CAPERS (GO-6368; PI: M. Dickinson), THRILS (GO-5507; PIs: T. Hutchison and R. Larson; Hutchison et al. 2025), and RUBIES (GO-4233; PIs: A. de Graaff and G. Brammer; de Graaff et al. 2025b) surveys. The primary targets were selected to enable spatially-resolved kinematic and outflow measurements at high redshift ($2 \lesssim z \lesssim 7$; Simons et al. in prep). Of particular relevance to this work, the masks also include a high-priority sample of both confirmed and candidate LRDs and broad-line Active Galactic Nuclei (AGN), for which OCEANS provides the first high-resolution rest-optical spectroscopy. This enables the study of outflow kinematics from the LRD central engine presented here that are inaccessible in most systems at lower resolution.

The LRD and AGN targets were compiled and prioritized by members of the OCEANS team on the basis of either (1) prior spectroscopic confirmation of broad-line emission (Taylor et al. 2025b) or (2) photometric identification as an LRD candidate with no prior spectroscopic observations (Kocevski et al. 2025). The selection also prioritized LRDs with previously identified absorption lines in CEERS. The majority of the LRD/AGN targets were observed with a single MSA pointing. Four of the targets discussed here were observed in multiple OCEANS pointings, detailed in the Appendix. For these sources we co-add the 1D extractions to decrease the signal to noise and improve our line fits. We exclude the OCEANS pointing 2 observation from co-adds because of a single unexpected closed shutter.

All targeted sources were observed using 2-shutter-long slitlets (total spatial extent $0''.92$), and the observations executed a 2-position nod pattern that placed the target in each shutter sequentially. Given that the high-redshift primary targets ($z > 2$) are generally compact enough to fall within a single centered MSA shutter, the 2-shutter slitlets provide an ideal balance for estimating the local sky and maximizing the MSA multiplexing efficiency. Each OCEANS MSA pointing typically includes 70–90 science targets alongside 10 dedicated “background” slitlets.

Each OCEANS MSA pointing was observed with both the G235H/F170LP and G395H/F290LP grating-filter combinations, providing continuous spectral coverage from $1.7\text{--}5.1\ \mu\text{m}$ at $R \sim 2700$. Science exposures consist of 10 integrations of 8 groups each for a total exposure

time of 14,734 s (~ 4.1 h) per grating per pointing. Target acquisition was performed via the MSA target acquisition (MSATA) method using the F140X filter with 6–8 suitable reference stars distributed across the MSA field of view. No additional spatial dithers were employed, with the 2-position nod serving as the only positional stepping between exposures. Of relevance to this paper, the P2 pointing of OCEANS-35829 (targeted by 3 total pointings) experienced a single unexpected closed shutter. As a result, the 1D spectrum for this source is extracted from a single nod position. The six pointings were observed across a range of aperture position angles ($5^\circ \lesssim \text{APA} \lesssim 315^\circ$).

We reduce the NIRSpec MOS data using the *JWST* calibration pipeline (v1.20.2, CRDS context `jwst_1464.pmap`; Bushouse et al. 2025), adapting the NIRSpec MOS pipeline notebook (Law et al. 2025) with custom modifications for cosmic ray rejection and bad pixel self-calibration. In Stage 1 (`calwebb_detector1`), we adopt the enhanced snowball correction parameters used by the CEERS survey, with an expansion factor of 3 and a minimum flagged area of 15 pixels. In Stage 2 (`calwebb_spec2`), we enable bad pixel self-calibration (`badpix_selfcal`; $f_{\text{flag}} = 0.005$) and apply standard noded background subtraction. Final combined spectra were produced in Stage 3 (`calwebb_spec3`) by co-adding the two nod positions for each source. 1D spectra (`x1d`) were extracted using a 5-pixel wide box-car aperture centered on the source. For each source, we measure the empirical pixel-level noise as $1.486 \times \text{NMAD}$ of the continuum subtracted 1D spectrum and compare it to the median of the pipeline-reported uncertainties. We find that the pipeline systematically underestimates the noise by $\sim 35\text{--}65\%$ across the sample (mean 45%). For each source, we rescale the 1D uncertainty array by its empirical correction factor.

The OCEANS spectroscopy achieves an empirical 5σ line flux sensitivity of $\sim 2\text{--}4 \times 10^{-19}\ \text{erg s}^{-1}\ \text{cm}^{-2}$ across the G235H bandpass and $\sim 1\text{--}3 \times 10^{-19}\ \text{erg s}^{-1}\ \text{cm}^{-2}$ across G395H, assuming a line width of $\sigma = 50\ \text{km s}^{-1}$, with a sensitivity minimum near $\lambda_{\text{obs}} \sim 4.0\ \mu\text{m}$ in G395H. The empirical sensitivity is derived from a median error spectrum from each pointing, scaled by the empirical underestimation of the pipeline errors.

2.2. OCEANS LRD Photometric Sample Selection

We select our sample of LRDs by defining the sources in the photometry to retain consistency with the original selection of LRDs and ensure no targets from the OCEANS survey with LRD properties are missed. Our sample is selected with the color cuts described in Barro

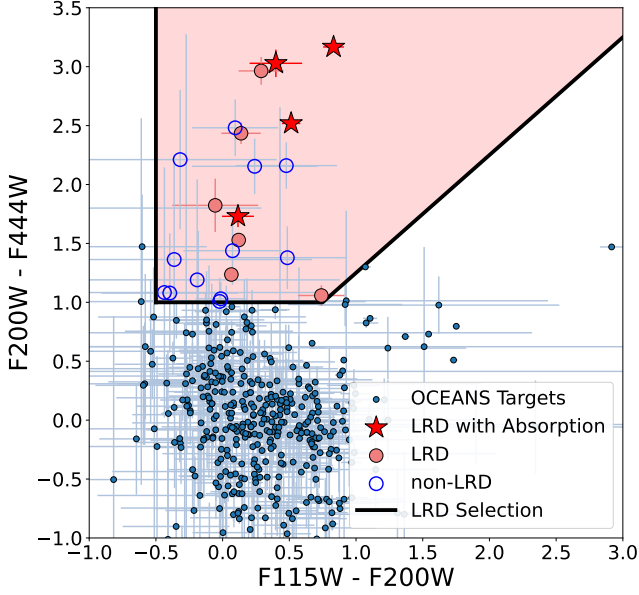


Figure 1. The OCEANS LRD sample in color-color space. All OCEANS targets are shown in solid light blue, OCEANS LRDs with broad $H\alpha$ emission are shown as coral circles, and OCEANS LRDs with broad Balmer emission and absorption features are indicated with red stars. Blue circles indicate OCEANS sources with LRD colors that did not pass the compactness selection in Figure 2 or the $F444W < 27$ (mag) constraint. The black line and red shaded region shows the color-color selection from Barro et al. (2026) for LRDs.

et al. (2026) and further required LRDs to have compact half-light radii (R_e).

We first apply the selection in Barro et al. (2026) that defined the LRD color-color selection as $F200W - F444W > 1$, $(F200W - F444W) > (F115W - F200W) + 0.25$, $F115W - F200W > -0.5$, and limit of $F444W < 27$ mag. We show our LRD sample selection with all other OCEANS targets in Figure 1. Sources that met LRD color criteria for compactness were checked against the $F444W R_e$, requiring that sources have angular sizes < 200 pc. This kept our definition of LRDs consistent with established rest-UV and rest-optical colors combined with optical compactness (Kocevski et al. 2025).

We use GALFIT measurements from McGrath et al. (2026) of R_e for our compactness cut in Figure 2. Our expectation is that LRDs are highly compact in rest-optical light and may be unresolved in the photometry. We indicate an unresolved R_e with the red shaded region in Figure 2, the half-width-half-max (HWHM) of the point spread function (PSF) for the $F444W$ photometric filter. We also indicate an angular size corresponding to 200 pc with a black dashed line. This corresponds roughly with the HWHM of an unresolved source in $F444W$, consistent with this compactness threshold

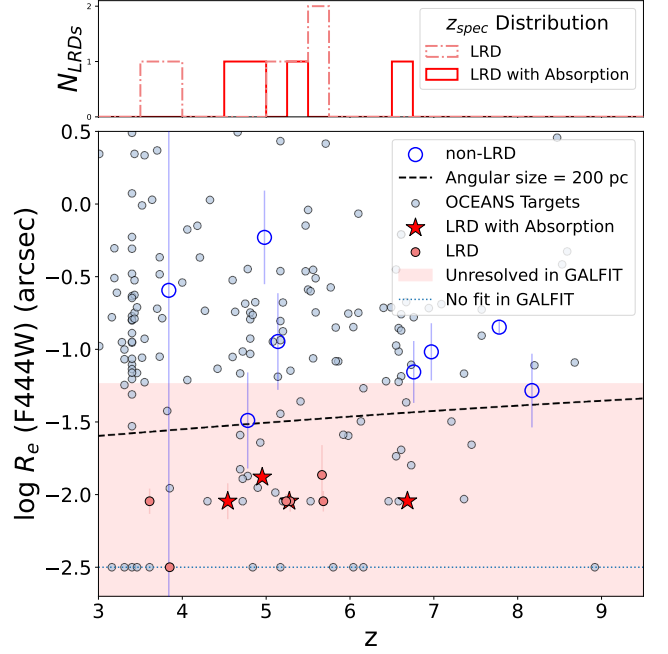


Figure 2. GALFIT measurements from McGrath et al. (2026) for CEERS and the LRD population. LRDs are plotted as coral circles while OCEANS LRDs with Balmer absorption are plotted as red stars. We use these half-light radii (R_e) to apply a compactness cut associated with an angular size of < 200 pc and ensure our color selected LRDs are compact. We mark sizes smaller than the HWHM of the $F444W$ PSF by the red shaded region and call sources that fall below this limit “unresolved.” This approximately correlates with our angular size cut, consistent with the LRD representing unresolved point sources. Other oceans targets that are not color selected are plotted as solid blue circles.

translating to unresolved point sources in $F444W$. We allow any flag in GALFIT to return a result so that we can recover sources that are unresolved in rest-optical light but we visually inspect all postage stamps to confirm compactness.

The color-color selection identifies 22 candidate LRDs. When the magnitude constraint ($F444W < 27$ mag) is applied, 9 LRDs are removed. The compactness cut removes an additional LRD, OCEANS 33961, that passes the color and mag cuts. All removed sources are marked with open blue circles in Figures 1 and Figure 2. All potential targets were investigated for broad Balmer lines present in all true LRDs (Hviding et al. 2025) and none were found. We exclude OCEANS 33082 which has evidence for broad $H\alpha$ but no reference forbidden lines or low-resolution spectroscopy. The source was selected from the photometry in Kocevski et al. (2025) and is likely a genuine LRD, but we cannot verify the broad-line AGN nature without reference narrow lines. We also remove OCEANS 110839 because of a slit failure.

All remaining LRDs in the sample are also photometrically selected as LRDs by Kokorev et al. (2024) and/or Kocevski et al. (2025) except for OCEANS 169045 and 1794. OCEANS 169045 was identified as an early low-luminosity AGN in Kocevski et al. (2023) and OCEANS 1794 has a similar line profile shape. These sources pass all previously mentioned cuts and therefore pass our defined LRD criteria and we include them in the sample.

Our color selection selects 22 LRDs, 9 of which are lost to the magnitude cut. An additional source is lost to the compactness cut and one source is removed for insufficient line coverage while another is removed because the observation failed. This leaves 10 LRDs 4 of which are best fit with absorption components. These numbers are given in Table 1.

Table 1. LRD sample selection by cut

Selection Step	N LRDs
Color-color selection	22
F444W < 27 mag)	−9
($R_e < 200$ pc)	−1
Insufficient line coverage	−1
Failed slit	−1
Final LRD sample	10
LRDs with Absorption	4

2.3. Archival Lower-Resolution Spectroscopy

Low-resolution ($R \sim 100$) prism spectroscopy from NIRSpec programs targeting CEERS are utilized in this work to measure the rest-optical and rest-UV continuum of the LRDs. We describe the overlapping surveys in brief here.

CAPERS The CANDELS-Area Prism Epoch of Reionization Survey (CAPERS) [program ID 6838, PI: Mark Dickinson] target selection and reduction are described in Kokorev et al. (2025); Taylor et al. (2025a). The CAPERS program included 7 pointings of NIRSpec spectroscopy in EGS/CEERS with 1–3 micro-shutter array (MSA) configurations and exposure times of 1.58–4.74 hours. This prism spectroscopy has a low resolution of $R \sim 100$.

RUBIES We include NIRSpec data from the Red Unknowns: Bright Infrared Extragalactic Survey (RUBIES) [program ID 4233, PIs: A. de Graaff & G. Brammer] (de Graaff et al. 2025b), utilizing reductions from Taylor et al. (2025b). The RUBIES program included 6 NIRSpec pointings in EGS/CEERS using both low-resolution prism spectroscopy ($R \sim 100$) and medium-resolution G395M spectroscopy ($R \sim 1000$) with 0.8 hour exposures in both modes. We use the medium-

resolution spectra for resolution comparisons and the low-resolution spectra for continuum measurements.

We measure continuum properties for the LRDs from available low-resolution spectroscopy, always choosing the observation with the longest exposure time. We measure Balmer breaks as $f_{\nu,4100}/f_{\nu,3600}$ and the UV-to-optical color as $f_{\nu,5500}/f_{\nu,3600}$. All fluxes for the colors are median flux densities taken from a rest-frame 300 Å window centered on the target wavelength.

3. LRD PROFILE FITTING

3.1. Balmer Line Profile Fitting

We begin our line-fitting procedure by calculating a redshift from the peak of the [OIII]λ5008 line to define the systemic redshift. For the Balmer emission lines, we fit with a narrow Gaussian whose width and line center we allow to vary, a narrow Gaussian whose parameters we tie to [OIII]λ5008, an exponential convolved with a Gaussian component (or optionally, a purely Gaussian component), and an absorption feature. The absorption features are fit by a Gaussian profile whose amplitude, width, and line center are allowed to vary. We set a minimum width of 40 km s^{-1} for the absorption feature. Our Hα fits include potential contribution from the [NII]λ6548,6583 doublet with a fixed flux ratio of 3 (Osterbrock 1989).

Our combined narrow and broad line profiles, $f(\lambda)_{\text{dual}}$, are described by Equation 1 where f_c is the local continuum, f_{nar} is the narrow-only line component, and f_{broad} is the broad Gaussian amplitude. σ_{nar} and σ_{broad} are the narrow and broad line widths.

$$f(\lambda)_{\text{dual}} = f_c + f_{\text{nar}} \exp\left(-\frac{1}{2} \frac{(\lambda - \lambda_{0,\text{narrow}})^2}{\sigma_{\text{nar}}^2}\right) + f_{\text{broad}} \exp\left(-\frac{1}{2} \frac{(\lambda - \lambda_{0,\text{broad}})^2}{\sigma_{\text{broad}}^2}\right) \quad (1)$$

In the case that an exponential line shape is preferred, the second term in 1 takes the form of an exponential convolved Gaussian described in Equation 2 where γ is a scale parameter defined within the double exponential function $f(\lambda) = (1/2\gamma) * e^{-x|(\lambda - \lambda_0)/\gamma|}$ which is then convolved with a broad Gaussian feature. Our definitions are consistent with those from other exponential wing fitting papers (Matthee et al. 2026; Rusakov et al. 2026; Kokorev et al. 2025).

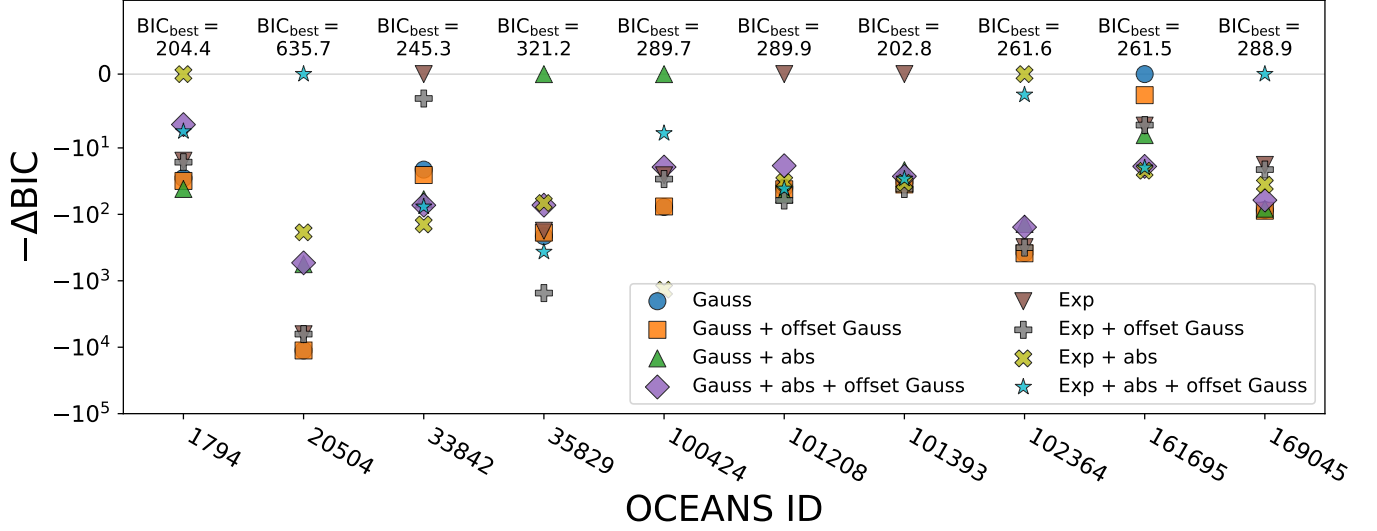


Figure 3. $H\alpha$ ΔBIC by source for the OCEANS LRD set. Each possible combination of fit parameters is listed in the legend and assigned a unique marker. The ΔBIC is plotted relative to the minimized ΔBIC which best fit each source with the best-fit ΔBIC plotted at 0. Gauss is short for Gaussian only (no exponential line wings), Exp indicates an exponential convolved with a Gaussian was the best fit. Offset Gauss indicates sources where the broad centroid is offset from 0 velocity. Abs indicates a fit favors the addition of an absorption component. The absorption fits favored for OCEANS 169045 and 1794 are ΔBIC artifacts, since the sources does not have any signs of absorption in their line profiles. The next best fit without absorption (exponential only) fit is assumed in this work. OCEANS 101393 has potential near-zero-velocity weak absorption (see the insets for all sources in Figure 4 and 5) but the ΔBIC does not favor an absorption feature and the visual dips in flux span a few pixels. We exclude it from the absorbers.

$$\begin{aligned}
 f(\lambda)_{broad} = & \sqrt{\frac{\pi}{2}} \frac{f_{broad}}{2} \frac{\sigma_{broad}}{\gamma_{wings}} \left[\exp \left(\frac{\sigma_{broad}^2}{2\gamma_{wings}^2} - \frac{(\lambda - \lambda_0)}{\gamma_{wings}} \right) \right. \\
 & \times \operatorname{erfc} \left(\frac{\sigma_{broad}^2 - (\lambda - \lambda_0)\gamma_{wings}}{\sqrt{2}\sigma_{broad}\gamma_{wings}} \right) \\
 & + \exp \left(\frac{\sigma_{broad}^2}{2\gamma_{wings}^2} + \frac{(\lambda - \lambda_0)}{\gamma_{wings}} \right) \\
 & \left. \times \operatorname{erfc} \left(\frac{\sigma_{broad}^2 + (\lambda - \lambda_0)\gamma_{wings}}{\sqrt{2}\sigma_{broad}\gamma_{wings}} \right) \right] \quad (2)
 \end{aligned}$$

We fit the $[OIII]\lambda 4960, 5008$ lines by allowing two narrow Gaussians of fixed flux ratio 2.98 (from Osterbrock (1989)) and two broad Gaussian components which we allow to vary in line center. Figures 4 and 5 show that, while three LRDs (two of which are absorbers) have evidence for weak broad $[OIII]$, the lines are much weaker and narrower than the broad $H\alpha$ components. None of the LRDs that have broad $[OIII]$ are comparable in strength to the broad $H\alpha$. Our results are consistent with previous studies of BLAGN observed in the EGS field (Kocevski et al. 2023; Taylor et al. 2025b; Brooks et al. 2025).

To determine the best fit $H\alpha$ model, we utilize the Bayesian information criterion (BIC) to compare model

goodness-of-fit and determine if extra fit parameters (absorption, free broad line center, etc) are needed to best describe the broad $H\alpha$ line profile. Here, the BIC is defined as $BIC = \chi^2 + k \ln(N)$, where k is the number of model free parameters, and N is the number of data points included in the fits. We start our iterative fitting process with the fiducial narrow-line-only $H\alpha + [NII]\lambda 6548, 6583$ profile. We then add additional fit components as determined by the ΔBIC . We require a $\Delta BIC > 6$ to accept the added fit component and then update our “fiducial” model. In total, each spectra is fit with 8 different $H\alpha$ line profile models, shown in Figure 3. In total, an LRD could be fit with up to 12 free parameters to describe its broad $H\alpha$ profile; this 12-parameter model would include a narrow Gaussian, a broad Gaussian convolved with an exponential profile, and an absorption component. The broad and narrow component line centers are allowed to vary.

All LRDs have ΔBIC evidence for broad $H\alpha$ emission. A complete list of the best models for each LRD and the ΔBIC values with respect to the best fit model for $H\alpha$ are given in Figure 3. The line profiles for OCEANS sources with fits that have significant absorption components are shown in Figure 4 and we show the remaining OCEANS LRD sample in Figure 5. Our final sample includes 4 absorbers and 6 non-absorbers.

We fit $H\beta$ profiles with a narrow-only fiduciary model and include an optional broad $H\beta$ component when the ΔBIC prefers the addition over the single Gaussian-only model. We include an absorption component in the $H\beta$ fit, with the same parameters allowed for the $H\alpha$ profile, in the case that an absorption feature is visibly apparent. We require a 3σ detection of a broad $H\beta$ component.

3.2. Previous Observations of OCEANS LRDs in the Literature

A few of the LRDs in our sample have been previously noted in the literature. OCEANS 169045 was originally identified as the low-luminosity AGN CEERS 2782 in Kocevski et al. (2023). We confirm the source’s broad $H\alpha$ emission here and show that, even in this LRD whose broad $H\alpha$ component is sub-dominant, the source is best fit with exponential wings. Additionally, we recover broad $[\text{OIII}]\lambda 5008, 4960$ in this source indicating the host galaxy may be experiencing an outflow that was missed by previous lower resolution observations of the source in CAPERS, RUBIES, and CEERS programs. The broad $[\text{OIII}]$ in OCEANS 169045 is broad but not comparable in intensity to the broad $H\alpha$ feature, which is consistent with a galactic outflow broadening the line. We do not recover Balmer absorption in the source.

OCEANS 35829 was observed by The High-Redshift+Ionization) Line Search (THRILS) [program ID 5507, PIs: T. Hutchison & R. Larson] (Hutchison et al. 2025) as THRILS 46403 and is a noted Balmer absorber discussed in Lambrides et al. (2025) and D’Eugenio et al. (2025b), which identified the absorption at medium spectral resolution. We recover Balmer absorption here from two OCEANS pointings of the source, two of which capture $H\beta$ and one of which captures $H\alpha$.

OCEANS 20504 was observed in the RUBIES program as RUBIES 42046 and was identified as a Balmer-absorbing LRD at medium-resolution (Kocevski et al. 2025; Taylor et al. 2025b). We recover broad $[\text{OIII}]$ emission in this source that is much weaker and narrower than the broad $H\alpha$ component, pointing to a galactic outflow also present in the system.

4. ABSORBER PROPERTIES

We explore the properties of Balmer-line absorption as tied to spectral resolution and the properties of the absorbers themselves.

4.1. Selection Effects

We contextualize Balmer-line absorbing LRDs by interpreting their detection through the lens of their spectroscopic resolution. We find a higher incidence

of absorption features at higher resolution, note high-resolution data successfully recovers absorption lines in lower-luminosity LRDs, and report two low luminosity absorbing LRDs.

4.1.1. Spectral Resolution and Absorption-Line Detection

We identify 4 absorbing LRDs in OCEANS data, two of which were previously identified as absorbers (OCEANS 35829 in (D’Eugenio et al. 2025b; Lambrides et al. 2025) and OCEANS 20504 in Taylor et al. (2025b)). Figure 6 shows an example of Balmer-absorption missed by previous spectroscopy. The target had low-resolution (prism) and medium-resolution (G395M) in RUBIES, and was not identified as a potential target with absorption in any previous studies. We plot the RUBIES G395M spectra in red, the OCEANS spectra in black, and the OCEANS spectra degraded to resolution that matches the RUBIES observation in blue. The absorption is too narrow ($\sigma_{abs} = 64 \text{ km s}^{-1}$) to recover at G395M resolution. We note another absorber, OCEANS 100424, which similarly has narrow absorption ($\sigma_{abs} = 52 \text{ km s}^{-1}$) that was not recoverable from a RUBIES observation of the source. We note that OCEANS 102364, shown in Figure 6, is among the bluest LRDs from Figure 12. With an absorption line ~ 5 pixels wide, the absorption would have been undetected at any lower resolution.

Balmer-line absorption in LRDs was first identified in medium-resolution NIRSpec spectroscopy from the RUBIES program, noted in several studies (de Graaff et al. 2025b; Hviding et al. 2025; Matthee et al. 2024; Taylor et al. 2025b; Kocevski et al. 2025). We review the detection fraction of LRD absorption in NIRSpec follow-up surveys contextualized by their survey resolution in Figure 7. Absorber percentages for other spectroscopic survey papers are plotted in blue and the fraction for this survey is plotted with a red star. We give the binomial standard error for the detection fractions and report a rule-of-three error ($3/N$) for a null detection among N sources. We also note that other observations of LRDs with deep, G395H spectroscopy have revealed Balmer absorption (D’Eugenio et al. 2026; Kokorev et al. 2025; Torralba et al. 2025; Wang et al. 2025) and low-resolution spectroscopy has revealed absorption in the extreme “cliff” sources (Naidu et al. 2025; Taylor et al. 2025a) but we exclude single objects from this figure.

We include one study of LRDs that used low-resolution ($R \sim 100$) NIRSpec prism spectroscopy (Greene et al. 2024). The work noted no Balmer-line absorption in the 17 LRDs surveyed. At medium-resolution ($R \sim 1000$), surveys find Balmer-absorption in 10 – 20% of LRDs with Kocevski et al. (2025) finding

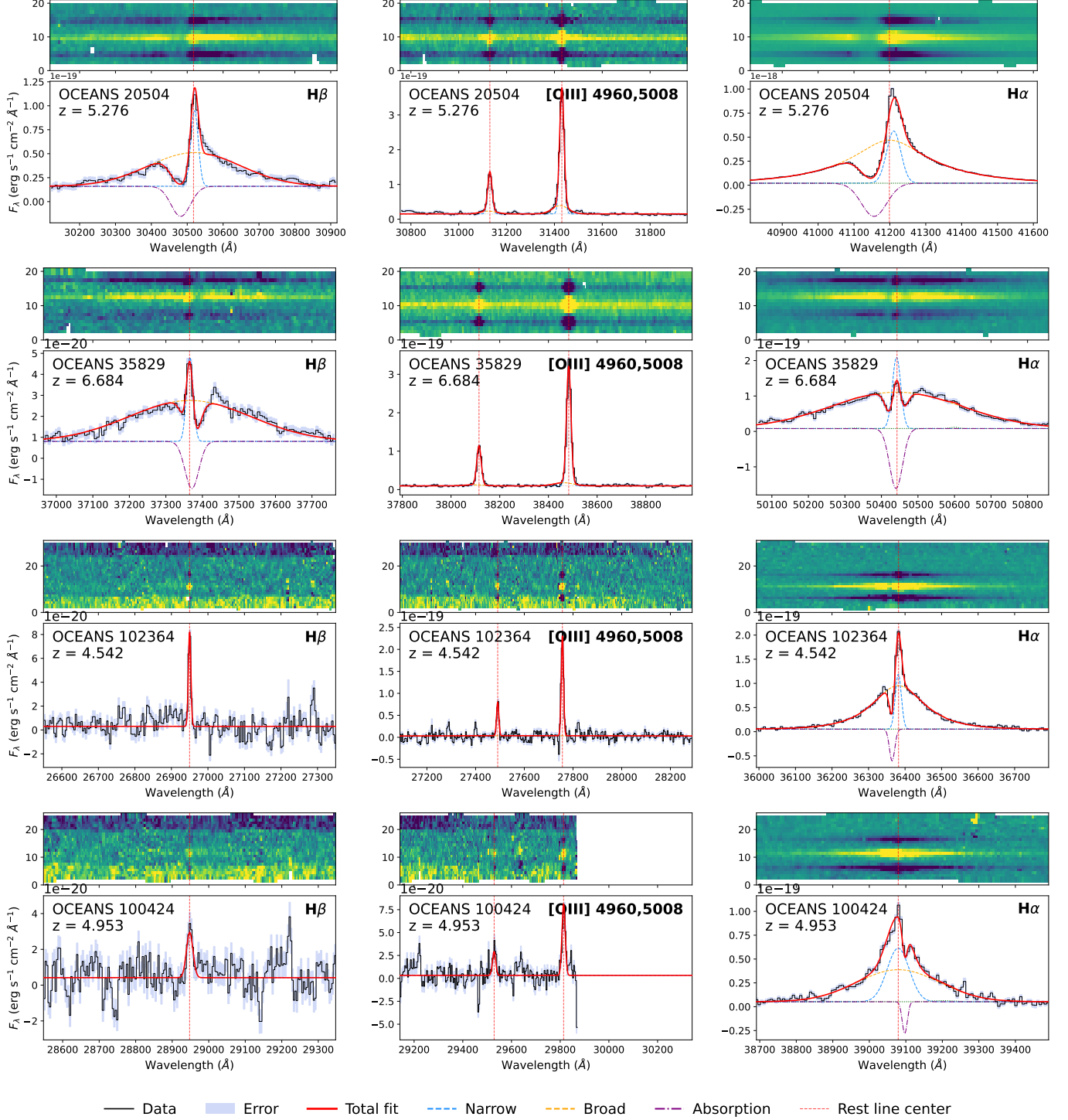


Figure 4. LRDs with H α absorption features from OCEANS. Each row in the figure represents a single source in OCEANS. First column insets are H β , second are [OIII] λ 4960,5008, and third are H α . The OCEANS spectrum is plotted in black and error is plotted as the light blue shaded region. Each inset has the total fit that gives the preferred Δ BIC described in Section 2. Narrow H α is plotted with a light blue dotted line, broad Gaussian or exponential profiles are plotted as orange dashed lines, [NII] contribution is plotted as a green dashed line, and absorption is plotted as a purple dot-dashed line. Insets for non-absorbing LRDs can be found in Figure 5.

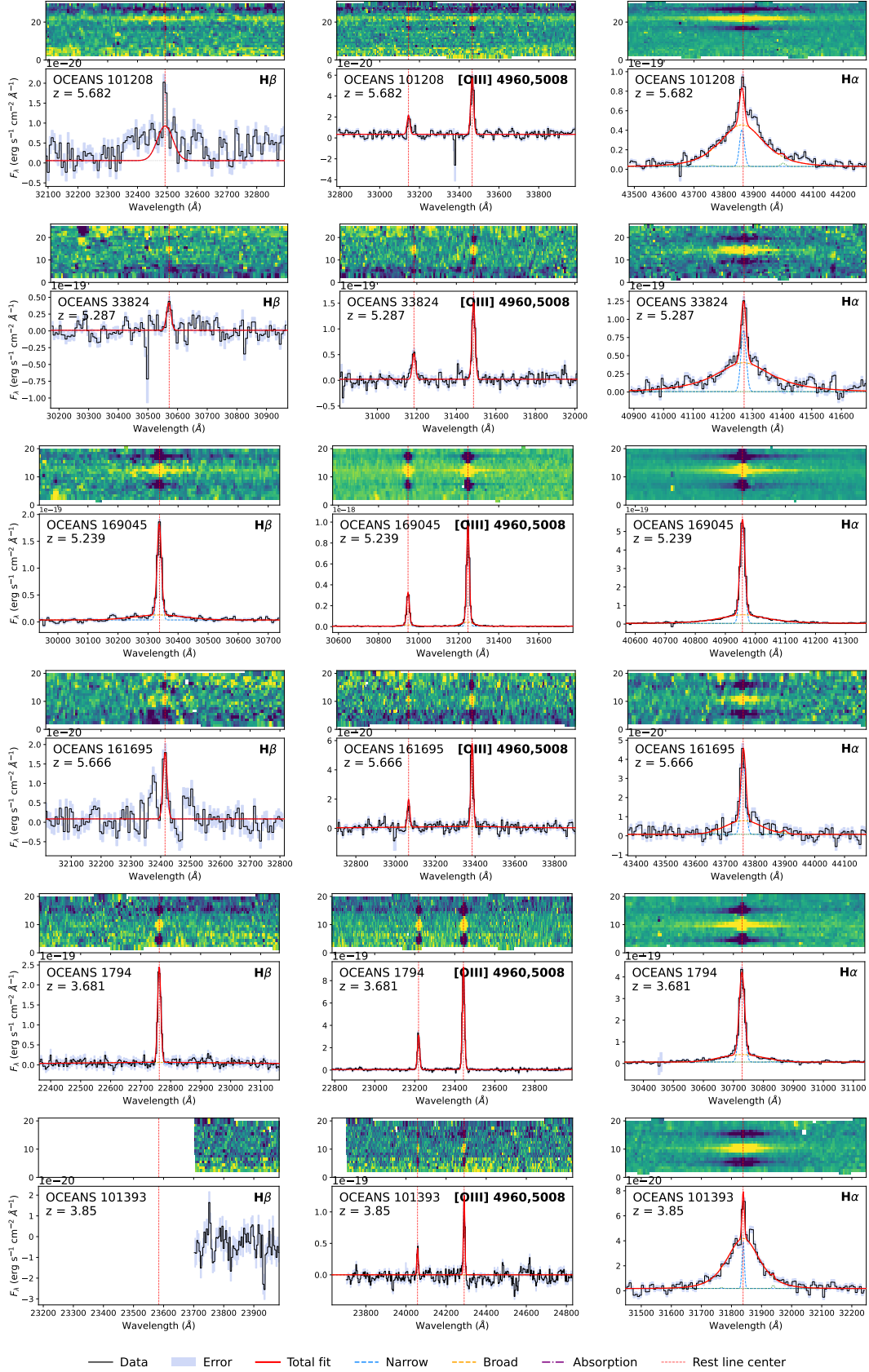


Figure 5. LRDs with broad H α emission and no absorption from OCEANS. Each row in the figure represents a single source in OCEANS. First column insets are H β , second are [OIII] λ 4960,5008, and third are H α . The OCEANS spectrum is plotted in black and error is plotted as the light blue shaded region. Each inset has the total fit that gives the preferred Δ BIC described in Section 2. Narrow H α is plotted with a light blue dotted line, broad Gaussian or exponential profiles are plotted as orange dashed lines, [NII] contribution is plotted as a green dashed line, and absorption is plotted as a purple dot-dashed line. Redshift and source IDs are listed in the legends.

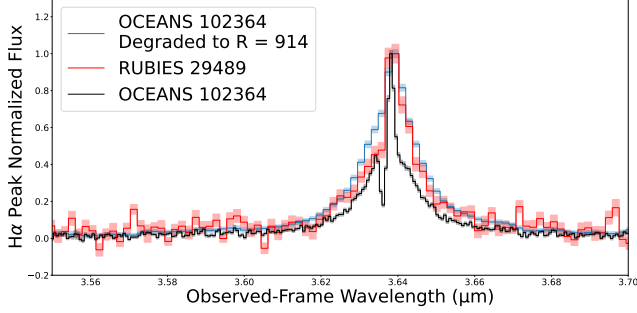


Figure 6. G395M (RUBIES) and G395H (OCEANS) coverage for a sources with an absorption feature only recovered in high-resolution spectroscopy. High-resolution OCEANS 102364 spectrum in black, medium-resolution RUBIES 28489 spectrum in red, and the OCEANS spectrum degraded to the RUBIES resolution for an $H\alpha$ line at $z = 4.54$ in blue.

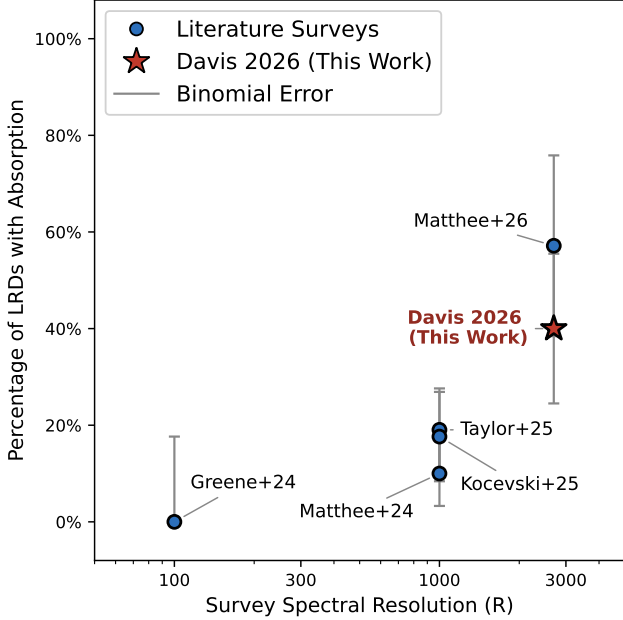


Figure 7. The fraction of LRDs with Balmer absorption in various surveys as a function of spectral resolution. At prism resolution ($R \sim 100$), LRD surveys do not recover absorption (Greene et al. (2024), 0/17). Of the surveys with medium-resolution ($R \sim 1000$) coverage (Taylor et al. (2025b) (4/21), Matthee et al. (2024) (2/20), and Kocevski et al. (2025) (3/17)), typically 10-20% of LRDs have Balmer line absorption. We note that Taylor et al. (2025b) and Kocevski et al. (2025) utilized the same RUBIES dataset. In this work (4/10) and Matthee et al. (2026) (4/7), which both utilize high-resolution ($R \sim 2700$) NIRSpect spectroscopy, absorption is recovered in ~ 40 -60% of LRD targets and the samples do not overlap.

3 in 17, Matthee et al. (2024) finding 2 in 20, and Taylor et al. (2025b) finding 4 in 21. At high-resolution ($R \sim 2700$), absorption is detected in 50 – 60% of LRDs, with Matthee et al. (2026) finding 4 in 7 and this work finding 4 in 10. This climbing recovery rate with increased spectral resolution points to better recovery of absorption at higher spectral resolution.

Such Balmer-absorption has been noted in $< 1\%$ of Sloan Digital Sky Survey (SDSS) Quasars (Leighly et al. 2025; Wang & Xu 2015) but is observed with increased frequency in LRDs. Selection effects are not likely to impact the SDSS samples ($R = 2000$) and so Balmer-absorption must be uniquely common in LRD systems through some mechanism absent in most $z < 1$ SDSS quasars. This points to Balmer-line absorption as a fundamental property of some LRDs. We further investigate Balmer absorption as a function of LRD properties in Section 4.2.

Davis et al. (2026) showed that BLRs at $3 < z < 7$ are better recovered from medium-resolution NIRSpect spectroscopy when sources are targeted with increased exposure times (up from ~ 1 hour to ~ 8 hours) in the THRILS program. This approach successfully recovered 5 broad-line AGN originally targeted by the RUBIES program that were missed by previous searches for broad-line AGN within the RUBIES data (Hviding et al. 2025; Taylor et al. 2025b). This approach, however, failed to recover any Balmer absorption in the targets with deep follow-up spectroscopy. Increased spectral resolution instead may be the driving observational effect that improves Balmer-line absorption recovery fractions since we do recover more absorption in the higher-resolution data.

4.1.2. Flux and Luminosity Selection Effect

We further investigate if LRD luminosity or flux influence absorber occurrence to probe whether LRDs are more likely to absorb if they are intrinsically brighter or if we observe absorption increasingly with detected flux. A correlation between absorption and flux might be associated with lower spectral signal-to-noise causing non-detection of absorption in fainter sources. We define both flux and luminosity at $5100\text{\AA}$ which probes the rest-optical continuum, where the LRD “engine” is predicted to dominate the emission (Kocevski et al. 2025), while avoiding emission-line contamination. We measure the continuum from the low-resolution prism data. All OCEANS absorbers were previously observed by RUBIES and so can be directly compared.

Flux measurements, $\nu F_\nu(5100)$, are plotted against the redshift distributions for OCEANS and RUBIES in the top panel of Figure 8. We draw horizontal lines for

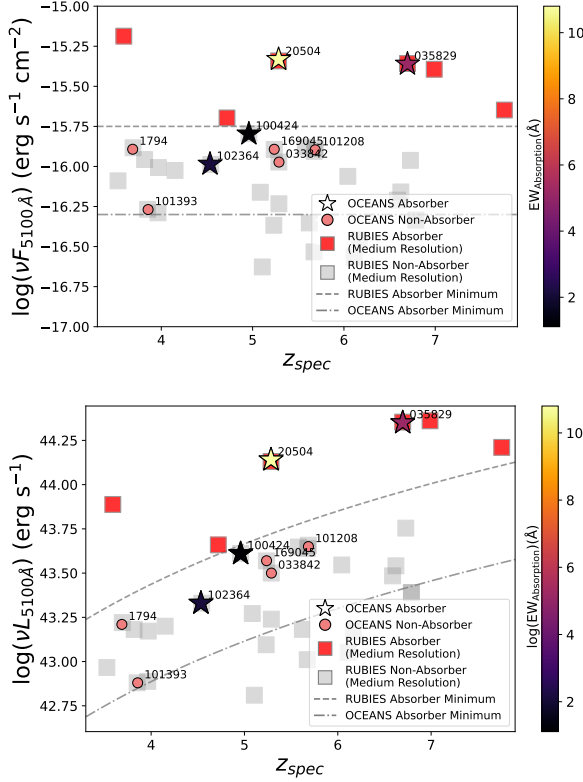


Figure 8. The luminosities and fluxes of LRDs observed by OCEANS and/or RUBIES programs in UDS and EGS. Squares indicate the medium-resolution RUBIES sample. Stars indicate OCEANS absorbers and circles indicate OCEANS LRDs without absorption. **Top:** Redshift vs $\nu F_{\nu,5100}$ for both samples. We draw lines at the lowest flux absorber, dashed for RUBIES and dash-dotted for OCEANS. **Bottom:** Redshift vs $\nu L_{\nu,5100}$. We plot the flux-constraining lines from the top panel of this figure in Luminosity space.

the dimmest detected absorber in both RUBIES and OCEANS. Luminosity measurements, $\nu L_{\nu}(5100)$, are plotted for LRDs in the RUBIES + OCEANS spectroscopic samples in the bottom panel of Figure 8. We re-draw the dimmest detected absorber lines from the flux plot in luminosity space.

In the RUBIES data, the line tracing the dimmest source works as an effective separator, with all detected absorbers falling brighter than where the line lies in both plots. In the OCEANS data, the line is less of a clear delineator. The least-luminous absorbing OCEANS LRD is both the second least-luminous in the OCEANS sample and one of the least-luminous LRDs to be observed in either program. Furthermore, the LRDs between the RUBIES and OCEANS threshold lines are close to evenly split between absorbers and non-absorbers.

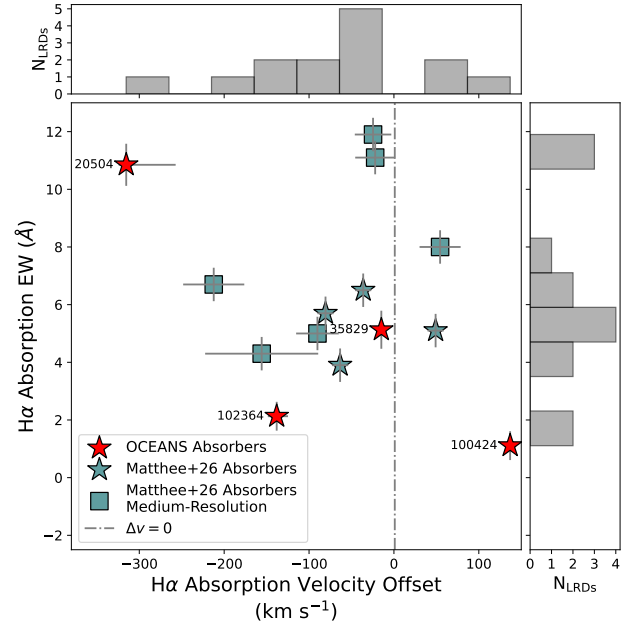


Figure 9. The velocity offset and rest frame EW of the $H\alpha$ absorption in the OCEANS (red) and (Matthee et al. 2026) (blue) samples. High-resolution absorption detections (G395H and/or 235H) are marked with stars and medium-resolution (G395M) detections are marked with squares. We find a median EW of 5.3 Å and a median velocity offset of -49 km s^{-1} . Population distributions are given along each axis.

We note that OCEANS 100424 and 102364 are among the least-luminous LRDs ever observed to have Balmer-line absorption. Both have bluer continuum slopes and optical colors (see Figure 12). These sources are a first look at absorption in low-luminosity LRDs and their typical absorption properties point to Balmer-line absorption as a more common phenomenon in LRDs than implied by medium-resolution spectroscopic data, which tends to recover only more luminous sources with broader absorption features.

4.2. Balmer Absorption Properties

We investigate the absorption-line properties of OCEANS LRDs. In this section, we include the sample of LRDs from Matthee et al. (2026), removing two duplicate sources in favor of high-resolution OCEANS spectroscopy (OCEANS 20504, 35829). Figure 9 shows absorption EW and velocity offset for all LRDs including sources with high-resolution spectra (stars) and medium-resolution spectra (squares). Histograms along both axes indicate sample distributions. The population has a median absorption EW of 5.3 Å and a median velocity offset of -49 km s^{-1} . Figure 9 shows both EW

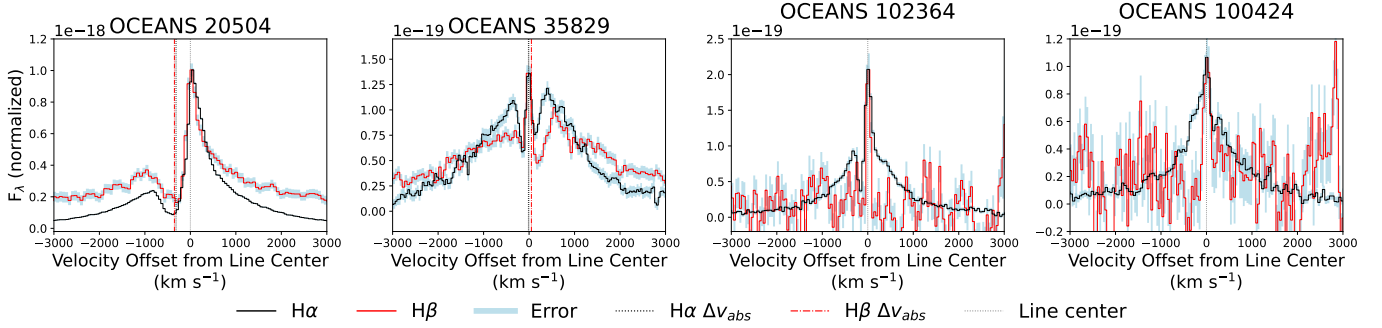


Figure 10. $H\alpha$ (black) and $H\beta$ (red) line profiles for the OCEANS absorbing LRDs. $H\beta$ is scaled to $H\alpha$ peak flux for profile comparison. Two absorbers have recovered absorption in their $H\beta$ line profiles (left two) and two do not (right two) but are consistent with low signal-to-noise observations of $H\beta$. OCEANS 20504 and 35829 were both observed in multiple MSA pointings (see the Appendix) and the spectra displayed here are co-added. We note that the $H\alpha$ line in OCEANS 35829 fell in a chip gap for all but one of the MSA pointings that targeted it but $H\beta$ was detected in all observations.

and velocity offset for all absorbers in the sample. The population has weak ($EW < 12 \text{ \AA}$) absorption and tends to be modestly blueshifted. The majority (11/14 in the combined sample) of the absorption lines are blueshifted, consistent with outflowing gas that is viewed in the foreground of the LRD emission source. Four of these absorbers are best fit with Gaussians convolved with exponential wings (see the Appendix) implying either dense gas is scattering the photons (Inayoshi & Maiolino 2025; Rinaldi et al. 2025; Naidu et al. 2025) and/or the BLR is highly stratified (Madau et al. 2026; Tang et al. 2026; Ji et al. 2026).

4.2.1. $H\alpha$ and $H\beta$ Absorption Profile Comparison

Figure 10 shows the velocity offsets of $H\alpha$ and $H\beta$ for the two dual-absorbing OCEANS LRDs (left two) and the line profiles for the other two absorbing OCEANS LRDs with only $H\alpha$ absorption (right two). $H\alpha$ profiles are plotted in black and $H\beta$ in red. For dual absorbers, the absorption velocity offsets are indicated with vertical lines.

In both OCEANS 20504 and 35829, the $H\alpha$ and $H\beta$ profiles are similar. The absorption features share comparable profile shapes and depths relative to the emission lines with the exception of their velocity offsets which we discuss further here. The two absorbing LRDs that do not have $H\beta$ absorption also do not have broad $H\beta$ lines, consistent with the $H\beta$ from the central engine being lost to low signal to noise. OCEANS 20504 and 35829 are the most luminous LRDs in the OCEANS sample and are the only OCEANS LRDs with dual absorption. This points to intrinsic luminosity or flux detection as a potential constraint for detecting absorption in multiple Balmer lines.

The absorption in OCEANS 20504 has both velocity offsets and absorption EWs that are consistent between $H\alpha$ and $H\beta$ ($H\alpha \Delta v = -315^{+58}_{-8.9} \text{ km s}^{-1}$, $H\beta \Delta v$

$= -351^{+39}_{-35} \text{ km s}^{-1}$, $H\alpha \text{ EW} = 11^{+0.73}_{-0.27} \text{ \AA}$, and $H\beta \text{ EW} = 6.0^{+0.64}_{-0.61} \text{ \AA}$). The large absorption velocity offset further implies the absorbing medium in OCEANS 20504 is spatially located in an outflowing region rather than interspersed within the emitting regions as demonstrated in OCEANS 35829. Such agreement in velocity offset as well as absorption width ($H\beta \sigma_{abs} = 266^{+27}_{-26} \text{ km s}^{-1}$, $H\alpha \sigma_{abs} = 260^{+10}_{-7} \text{ km s}^{-1}$) implies that the absorption profiles have similar shapes for both lines. This consistency implies that the absorbing medium is located further from the system center than the Balmer emitting regions.

OCEANS 35829, also called “Irony” (D’Eugenio et al. 2025b) and “GlimmIr” (Lambrides et al. 2025), has OCEANS Balmer absorption measurements of $H\alpha \Delta v = -14^{+5.7}_{-6.4} \text{ km s}^{-1}$, $H\beta \Delta v = 51^{+26}_{-18} \text{ km s}^{-1}$, $H\alpha \text{ EW} = 5.1^{+1.1}_{-0.66} \text{ \AA}$, and $H\beta \text{ EW} = 3.7^{+1.4}_{-0.58} \text{ \AA}$. We find that the EWs are statistically consistent between the two Balmer lines and measure a velocity offset between the absorption features of $65 \pm 19 \text{ km s}^{-1}$, lower than the velocity offsets reported at medium resolution ($206 \pm 10 \text{ km s}^{-1}$ in D’Eugenio et al. (2025b) and $152 \pm 20 \text{ km s}^{-1}$ in Lambrides et al. (2025)), but still a true velocity offset. Our values are in agreement with the Lambrides et al. (2025) measurement to $\sim 3\sigma$ and the D’Eugenio et al. (2025b) measurement to $\sim 6\sigma$, implying that absorption velocity offsets can be identified with medium-resolution NIR-Spec spectroscopy but high-resolution is essential to constrain offsets between lines.

Our OCEANS co-add has a median signal to noise per pixel of 11 around the $H\beta$ emission line and a velocity width per pixel of 50 km s^{-1} , allowing allows us to measure a line centroid to $\sim 1/2$ the pixel width ($\sim 25 \text{ km s}^{-1}$). The $H\alpha$ offset of -14 km s^{-1} is near-zero in velocity offset but the $H\beta$ velocity offset, and therefore the reported difference in absorption velocity shift between $H\alpha$ and $H\beta$, is statistically significant.

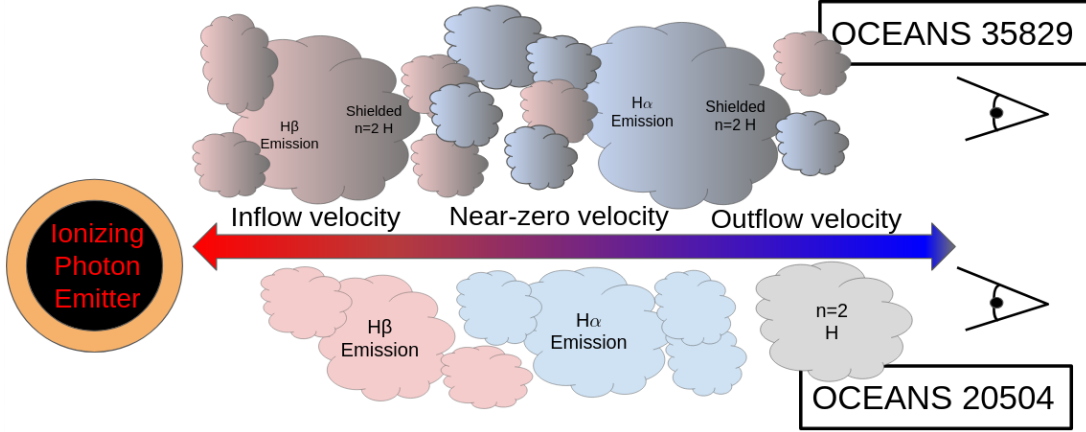


Figure 11. Cartoon of absorbing-medium locations for OCEANS 35829 and OCEANS 20504 which have absorption velocity offsets implying $n=2$ absorbing hydrogen is co-located with $H\alpha$ and $H\beta$ emission regions which are radially stratified. This source contrasts the implied location of the absorbing medium location for OCEANS 20504 which has absorption velocity offsets implying $n=2$ absorbing hydrogen is located primarily outside of the emitting region.

Balmer line-dependent velocity offsets have been noted in Balmer emission for low- z quasars, attributed to emission that is radially stratified and subject to different kinematics (see Fries et al. 2024; Villafaña et al. 2024). In contrast, Balmer-line absorption features typically share velocity offsets. Of note, one SDSS quasar with offset Balmer-line emission does not have offset Balmer-line absorption (Wang & Xu 2015). Several SDSS identified quasars and other LRDs have detected Balmer absorption lines but their velocity offsets between Balmer lines are consistent (Aoki et al. 2006; Hall 2007; Juodžbalis et al. 2024; Leighly et al. 2025; Shi et al. 2016, 2017).

We present another possibility; that the absorbing medium is co-located with the emitting regions in OCEANS 35829. Our cartoon model is sketched in Figure 11. We turn to known properties of nearby AGN to explain the system. Partial covering can produce optical depths that vary radially in BLRs, demonstrated in AGN along a single column density without invoking kinematically distinct absorbers (Leighly et al. 2019, 2025). The absorption at different velocity offsets can be explained by the tendency of $H\beta$ emission to occur closer to a SMBH than $H\alpha$ emission (evident by virial stratification of emission established in Korista & Goad (2004)) with a radially distributed absorbing medium that has different optical depths driven by the covering fraction. In this framework, colder clumps of absorbing media where $n = 2$ is thermally populated are co-spatially located with the Balmer emitting regions.

This may present as self-shielding clouds in the BLR where the side facing the emission source is subject to photoionization (with $H\alpha$ or $H\beta$ emission ratios depending on proximity to the SMBH) while the side facing away from the ionizing photon emitting source is

shielded and absorption dominates in this region. Such self-shielding clump structures exist in the torus around AGN (Nenkova et al. 2008). OCEANS 35829 may represent an LRD with a unique viewing angle, capturing two absorbing $H\alpha$ and $H\beta$ dominated clouds co-located with the emission regions, that drives the observed velocity offsets.

Velocity offsets of $H\alpha$ and $H\beta$ emission imply either a strong temperature or density gradient because $H\alpha$ and $H\beta$ relative emission strengths are highly dependent on such gradients (Inayoshi & Maiolino 2025; Osterbrock 1989). However, absorption requires hydrogen in the $n = 2$ state which is sensitive to the local physical conditions, with any single absorbing region subject to a single population state, making departures from standard velocity offsets more complicated than for Balmer emission.

Balmer absorption can be sensitive to temperature and density gradients, for example in the photospheres of white dwarfs where Balmer lines have absorption velocity offsets of $\sim 10\text{\AA}$, and extreme densities ($\log(n_e) \approx 17 - 18\text{ cm}^{-3}$) (Tremblay & Bergeron 2009) drive Stark broadening. This is beyond what is realistic for LRD environments and direct line measurements from the medium-resolution data of this source imply densities of $\log(n_e) \approx 4 - 5$ (D’Eugenio et al. 2025b), implying no single medium along the line-of-sight can create the observed velocity offsets. An alternative explanation requires an absorbing medium parameterized as distinct absorbers with non-standard optical depth weights with different velocity offsets driven by kinematic turbulent “breathing modes” which preferentially velocity shift $H\beta$ absorption redward relative to $H\alpha$ absorption (see D’Eugenio et al. (2025b) for a complete discussion of this model).

Dual-line absorption in LRDs provides a critical look at absorption velocity offsets that are difficult to measure from lower-resolution spectroscopy. While we recover only two dual-absorbers in OCEANS spectroscopy, the sources have distinct kinematically implied absorption structures. This could represent a viewing angle effect, where LRDs viewed from an angle capturing an outflow have $n = 2$ hydrogen located primarily in the outflowing gas and LRDs viewed from an angle that do not capture strong outflows have $n = 2$ hydrogen primarily co-located with emitting regions. Alternatively, OCEANS 35829 and 20504 could represent systems in different evolutionary phases, although they have similar UV to Optical colors and Balmer breaks in Figure 12, implying they have some systemic similarities. Future studies utilizing high-resolution NIRSpec spectroscopy will be essential to probe the kinematic nature of the absorbing gas in LRDs.

4.2.2. Balmer Absorption Along the LRD Sequence

We investigate trends with color and absorption velocity offset first reported in Matthee et al. (2026) and look for other trends with Balmer break and net-to-narrow emission ratios in Figure 12. We include measurement uncertainties reported in the Appendix for the OCEANS absorbers and assign the median error from the OCEANS population to the Matthee et al. (2026) sources for EWs. Each dataset is fit by a weighted least-squares method and we report null probability p -values from Spearman correlation coefficients from `scipy` where a p -value < 0.05 is a statistically significant trend.

The leftmost panels in Figure 12 compare absorption velocity offset and EW to net-to-narrow emission which we define as the ratio of total (broad+narrow+absorption) flux to the narrow-line flux. In both cases, we find no significant trend among the absorbers. This net-to-narrow measurement is an efficient probe of LRD engine to host galaxy emission, with higher ratios implying the LRD central engine dominates over the host galaxy. A lack of correlation with either absorption property suggests that the dominance of the host galaxy has little to no influence on the absorption properties in LRDs.

The middle panels of in Figure 12 compare both velocity offset and EW to UV-to-optical color ($f_{\nu,5500}/f_{\nu,3600}$). The LRDs in the OCEANS sample have UV-to-optical flux ratios between 3 and 10, consistent with the center of the distribution of the Matthee et al. (2026) sources. We find significant correlations with both EW ($p = 0.037$) and velocity offset ($p = 0.034$). The trends imply that LRDs with redder colors

(and therefore stronger optical continua with respect to the UV) have higher EW and outflows with redder velocities. The UV-to-optical color traces the shape of the optical continuum which is highly sloped and best fit by a black-body radiative profile in many cases (de Graaff et al. 2025c). This trend could also trace the shape, and therefore temperature, of the black body.

We also compare absorption properties directly with the strength of the Balmer break. The rightmost panels of Figure 12 compare velocity offset and absorption EW to Balmer break strength ($f_{\nu,4100}/f_{\nu,3600}$). Balmer absorption arises from hydrogen in the $n = 2$ state at a narrow range of gas states where Hydrogen excitation is stable. This same hydrogen gas drives the absorption causing the Balmer break observed in LRDs and so we investigate the kinematic offset of the $n = 2$ hydrogen through interpreting the absorption features.

The color used to define the Balmer break is similar to the color used to define the UV-to-optical ratio, and so exhibits similar trends, but probes the presence of $n = 2$ hydrogen in the system more directly. We find a significant correlation with velocity offset ($p = 0.011$) but not with EW ($p = 0.55$). A lack of trend with EW could point to absorption strength being independent of available gas, but could also point to viewing angle and partial covering of the absorbing clouds, analogous to BALQSOs (e.g. Leighly et al. (2019, 2025); Trump et al. (2006)) However, it may also imply that absorbing EW is highly model dependent and therefore difficult to constrain.

The positive trends between LRD color and absorption velocity are the strongest among any of the explored trends. This implies that LRDs with stronger Balmer breaks have absorbing gas with close to zero velocity or modestly redshifted while LRDs with less pronounced Balmer breaks have more $n = 2$ hydrogen in outflows. This is consistent with our cartoon model in Figure 11, where more available $n = 2$ hydrogen implied by stronger Balmer breaks and redder colors means more available gas to drive the absorption. LRDs with modest absorption have $n = 2$ gas primarily at larger radii while stronger breaks see absorbing gas included at smaller radii.

In other words, LRDs with less available $n=2$ hydrogen tend to have that gas physically located further from the central SMBH in outflows, rather than co-located with emitters. This absorbing gas has a radial velocity gradient with closer gas preferring to infall while further gas outflows. Thus, redder LRDs tend to have absorption with near-zero or modestly red velocity offsets associated with more absorbing gas that is closer to the central engine. Such a model implies that Balmer break

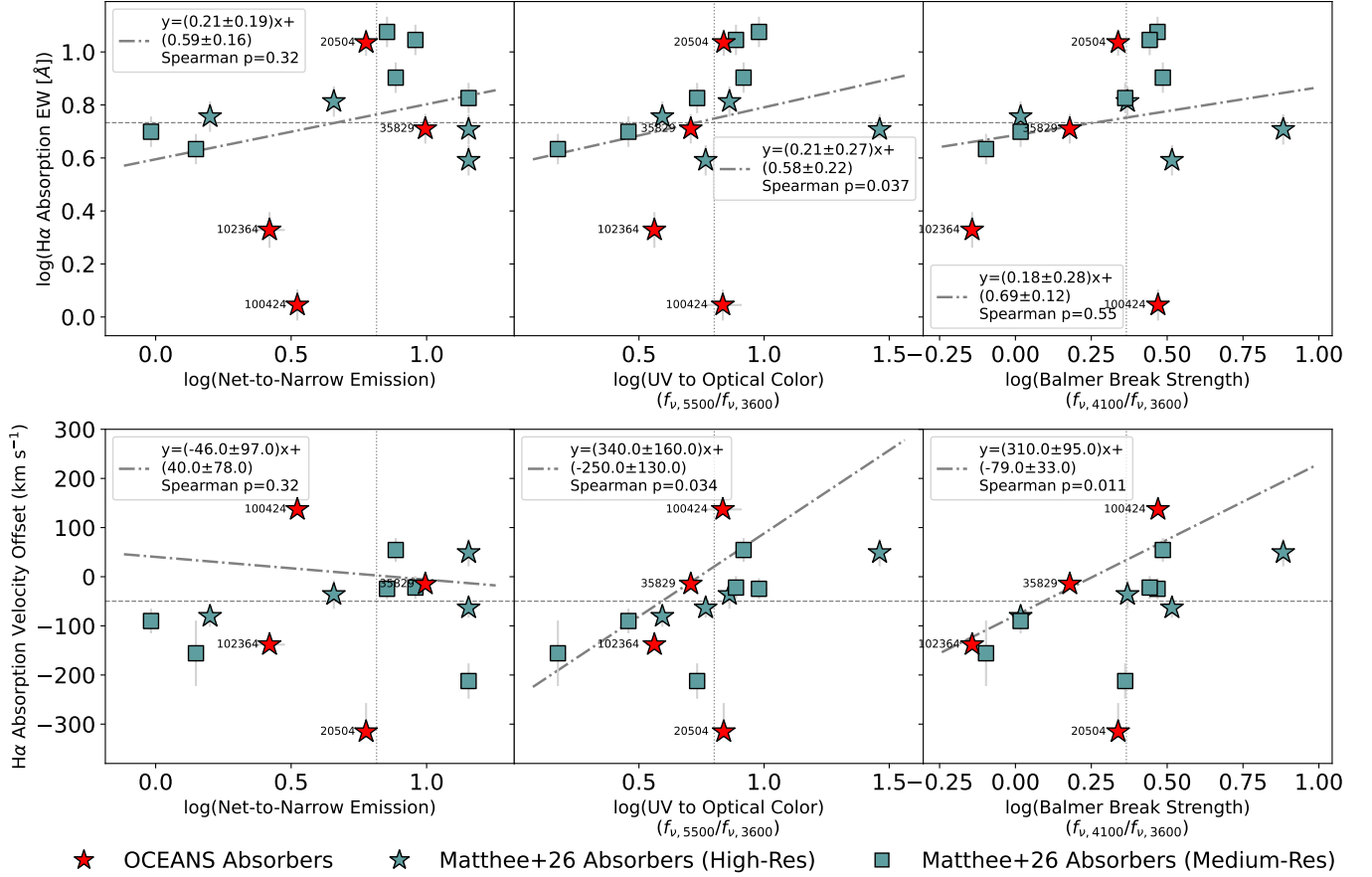


Figure 12. Absorption velocity offset from the systemic redshift (top row) and Absorption EW (bottom row) vs net-to-narrow emission (column 1), UV-to-Optical color (column 2), and Balmer break strength (column 3) for the OCEANS and Matthee et al. (2026) absorbing LRDs. OCEANS data (G395H and G235H) is represented by red stars, high resolution absorbers (G395H and/or 235H) from (Matthee et al. 2026) are represented by blue stars, and medium-resolution (G395M) absorbers from (Matthee et al. 2026) are represented by blue squares.

strength and UV-to-optical color are good tracers of the amount of absorbing gas along the line-of-sight. Absorption EW is sensitive to optical depth effects along the line-of-sight and carries less direct information about the amount of absorbing gas. This is further supported by our cartoon model which requires the absorbing gas be co-located with the broad emission gas and thus have a much lower covering fraction.

This picture may describes OCEANS 100424, our only significantly redshifted $\text{H}\alpha$ absorber in OCEANS. The source has a Balmer break among the highest in the combined sample, and the highest in the OCEANS sample, but the smallest absorption EW. OCEANS 100424 may have most of this $n = 2$ hydrogen near the system center, where it is infalling. Such deep $n = 2$ hydrogen would be subject to a high line-of-sight optical depth and so we measure less Balmer-line absorption EW.

OCEANS 20504 may represent another extreme of the outflow scenario. It has UV-to-optical colors near the middle of the population distribution and a Balmer

break that is similarly near the median, but high-EW, high-velocity outflowing $n = 2$ gas. This implies that some strong Balmer breaks can occur without the presence of shielded clumps, as in our cartoon of OCEANS 35829, but can instead also be driven by strong outflows along the line of sight, consistent with our cartoon model of this source.

These two sources contrast the remaining blueshifted absorbing LRDs which follow the trend line, with the bluest velocity shifts tending to correlate with milder Balmer breaks. Such LRDs may have $n = 2$ hydrogen located primarily in the outflowing gas (more consistent with the cartoon model of OCEANS 20504) that lies beyond the Balmer broad-line emitting regions. One such LRD, OCEANS 102364 is one of the bluest LRDs in the sample. Further, this represents one of the most blueshifted outflows among the LRDs and has the weakest Balmer break in the full sample. This implies outflows in an LRD with one of the weakest absorbing cocoons.

Balmer-line absorption in LRDs is a critical probe of the kinematics of hydrogen gas that drive the Balmer break spectral feature in LRDs. Although the number of Balmer-line absorbing LRDs is low, future high-resolution spectroscopic observations will expand this population and build a broader picture of the dynamic environments of excited hydrogen in LRDs.

5. SUMMARY AND FUTURE WORK

The OCEANS high-resolution spectroscopy program provides a new look at LRDs with Balmer absorption. The OCEANS sample was compiled from an amalgamation of targets in CEERS, and so we select LRDs that (1) satisfy the photometric criteria in Barro et al. (2026), (2) are compact in rest-optical light, and (3) have broad $H\alpha$ and/or $H\beta$. We identify 10 LRDs from the OCEANS data, 4 of which have Balmer-line absorption.

Higher-resolution spectroscopy yields an increased recovery fraction for absorption features in LRDs, up to 40 – 60% at $R \sim 2700$ from 10 – 20% at $R \sim 1000$. This recovery is partly dependent on optical continuum flux for medium-resolution surveys. However, high-resolution surveys like OCEANS may probe the fraction of absorbers more efficiently as demonstrated through our recovery of absorption features lost in sources observed at lower spectral resolution. Absorption in LRDs tends to be near-zero in absorption velocity with a median velocity offset of -49 km s^{-1} and median absorption EW of $5.3 \text{ \AA}$.

OCEANS recovers two Balmer-absorbing LRDs with absorption in both $H\alpha$ and $H\beta$, both observed at high-resolution for the first time here. One source, OCEANS 20504 (also called RUBIES 42046) has absorption profiles consistent with a significant portion of the $n = 2$ hydrogen occupying an outflow along the line of sight. The second dual-absorbing source, OCEANS 35829 (also called “Irony” (D’Eugenio et al. 2025b) and “GlimmIr” (Lambrides et al. 2025)) has statistically significant velocity offsets for $H\alpha$ and $H\beta$ absorption. The source is presented here in high spectral resolution for the first time. We present a cartoon model that requires an absorbing medium co-located with $H\alpha$ and $H\beta$ emission regions along the line of sight to explain the observation. We also note OCEANS 102364 as an LRD with

Balmer absorption but a weak break and relatively blue UV-to-optical colors.

Trends relating absorption properties to LRD properties are explored to probe the nature of Balmer absorption along the LRD sequence. We report that LRD engine contribution compared to galaxy contribution to Balmer emission lines does not relate with observed absorption properties, implying the strengths of the LRD-powered broad emission lines have little correlation with the relative galaxy strength. We also report and discuss trends relating absorption velocity offset to UV-to-optical colors and Balmer break strength and absorption EW to UV-to-optical color. Our strongest trends relate absorption velocity offset to Balmer break strength and UV-to-optical colors, implying LRDs with more available absorbing gas tend to have that gas more centrally located.

This work highlights the additional information gained by observing LRDs in high-resolution modes, giving a more comprehensive picture of the $n = 2$ hydrogen present in LRDs driving the strong Balmer breaks. Future work on LRDs in CEERS and other fields will require additional high-resolution follow-up spectroscopy to build population distributions and probe the absorbing fraction fully across the LRD sequence.

Facility: JWST (NIRCam, NIRSpec)

Software: Astropy (Astropy Collaboration et al. 2013, 2018, 2022), Matplotlib (Hunter 2007), NumPy (Harris et al. 2020), Pandas (pandas development team 2020; Wes McKinney 2010), Scipy (Virtanen et al. 2020)

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6. APPENDIX

We include additional information about our LRD population. Table 2 lists the OCEANS IDs and gives matches to other surveys as well as target coordinates, OCEANS pointings, and lists the best-fit models for H α line profiles. The Δ BIC fits to all possible profile shapes are shown in Figure 3. Table 3 give the H α line properties for the OCEANS LRDs inferred by their fits. Table 5 provides similar information for the [OIII] fits and give systemic redshifts.

Table 2. LRD Target Descriptions

OCEANS ID	Alternative ID	RA (deg)	Dec (deg)	Pointing	Best Fit Model
020504	RUBIES 42046	214.795369	52.788845	1, 4	Exponential + Absorption
035829	CAPERS 11585/THRILS(ID)	214.892249	52.877403	2, 3, 6	Gauss+ Abs
102364	CAPERS 19300/RUBIES 29489	215.022070	52.920786	5	Exp + Abs + Offset Gaussian
101393	RUBIES 37032	214.849381	52.811828	4	Exp + Abs
100424	RUBIES 42232	214.886799	52.855377	3	Gauss+ Abs
169045	RUBIES 50052/CAPERS 11320/CEERS 2782	214.823454	52.830277	4	Exp + Abs + Offset Gaussian
033842	RUBIES 60935	214.923373	52.925588	2	Exp
101208	RUBIES 37124	214.990980	52.916522	2, 5	Exp + Offset Gaussian
161695	CEERS 1345	214.889684	52.832978	3, 6	Gauss
001794	CAPERS 24745	214.814779	52.748950	1	Exp + Offset Gaussian

Table 3. H α emission and absorption-line properties. Absorption velocity offset is measured relative to the systemic redshift.

OCEANS ID	F_{narrow} (erg s $^{-1}$ cm $^{-2}$)	F_{broad} (erg s $^{-1}$ cm $^{-2}$)	F_{abs} (erg s $^{-1}$ cm $^{-2}$)	Δv_{abs} (km s $^{-1}$)	σ_{abs} (km s $^{-1}$)	EW_{abs} (Å, rest)
20504	$2.61 \pm 0.78 \times 10^{-17}$	$1.50 \pm 0.04 \times 10^{-16}$	$-3.06^{+0.13}_{-0.44} \times 10^{-17}$	$-315^{+58}_{-9.0}$	$260^{+10}_{-6.9}$	$11^{+0.73}_{-0.27}$
35829	$5.95 \pm 5.94 \times 10^{-18}$	$4.63 \pm 0.07 \times 10^{-17}$	$-7.71^{+2.11}_{-5.88} \times 10^{-18}$	$-14^{+5.7}_{-6.4}$	$105^{+12}_{-9.8}$	$5.1^{+1.1}_{-0.66}$
102364	$2.53 \pm 0.46 \times 10^{-18}$	$1.80 \pm 0.03 \times 10^{-17}$	$-1.40^{+0.26}_{-0.45} \times 10^{-18}$	-138^{+13}_{-10}	$64^{+7.0}_{-5.8}$	$2.1^{+0.33}_{-0.24}$
100424	$4.30 \pm 0.43 \times 10^{-18}$	$9.48 \pm 0.50 \times 10^{-18}$	$-5.45^{+0.73}_{-0.78} \times 10^{-19}$	$137^{+7.3}_{-6.9}$	$52^{+6.2}_{-5.6}$	$1.1^{+0.15}_{-0.14}$
101393	$3.90 \pm 16.40 \times 10^{-19}$	$5.81 \pm 1.15 \times 10^{-18}$	...	...	...	...
101208	$7.70 \pm 1.21 \times 10^{-19}$	$8.65 \pm 0.36 \times 10^{-18}$	...	...	...	...
33842	$1.90 \pm 0.19 \times 10^{-18}$	$1.12 \pm 0.07 \times 10^{-17}$	...	...	...	...
169045	$1.05 \pm 0.01 \times 10^{-17}$	$1.05 \pm 0.03 \times 10^{-17}$	...	...	...	...
161695	$7.63 \pm 0.81 \times 10^{-19}$	$1.09 \pm 0.17 \times 10^{-18}$	...	...	...	...
1794	$8.58 \pm 0.18 \times 10^{-18}$	$6.15 \pm 0.32 \times 10^{-18}$	...	...	...	...

Table 4. H β emission and absorption-line properties. Absorption velocity offset is measured relative to the systemic redshift.

OCEANS ID	F_{narrow} (erg s ⁻¹ cm ⁻²)	F_{broad} (erg s ⁻¹ cm ⁻²)	F_{abs} (erg s ⁻¹ cm ⁻²)	Δv_{abs} (km s ⁻¹)	σ_{abs} (km s ⁻¹)	EW _{abs} (Å, rest)
20504	$2.05 \pm 0.24 \times 10^{-18}$	$1.14^{+0.06}_{-0.06} \times 10^{-17}$	$-2.12^{+0.27}_{-0.30} \times 10^{-18}$	-35^{+38}_{-35}	266^{+27}_{-26}	$6.0^{+0.64}_{-0.61}$
35829	$9.13 \pm 13.45 \times 10^{-19}$	$8.17^{+0.27}_{-0.29} \times 10^{-18}$	$-1.11^{+0.24}_{-1.31} \times 10^{-18}$	51^{+26}_{-18}	153^{+23}_{-30}	$3.7^{+1.4}_{-0.58}$
102364	$6.10 \pm 0.82 \times 10^{-19}$	...	...	...	...	...
100424	$4.66 \pm 1.43 \times 10^{-19}$	...	...	...	...	...
101393	...	...	...	...	...	...
101208	$1.86 \pm 1.34 \times 10^{-19}$	...	...	...	...	...
33842	$5.57 \pm 1.89 \times 10^{-19}$	...	...	...	...	...
169045	$3.11 \pm 0.10 \times 10^{-18}$	$1.98^{+0.29}_{-0.28} \times 10^{-18}$	...	...	...	...
161695	$2.31 \pm 0.92 \times 10^{-19}$	$4.09^{+1.74}_{-1.63} \times 10^{-19}$	...	...	...	...
1794	$3.35 \pm 0.07 \times 10^{-18}$	...	...	...	...	...

Table 5. [O III] $\lambda\lambda 4960, 5008$ emission-line properties. OCEANS 101393 does not have [O III] line coverage and so we use the narrow H α peak to calculate a systemic redshift.

OCEANS ID	$F_{\text{narrow}}^{[\text{OIII}]5008}$ (erg s ⁻¹ cm ⁻²)	$F_{\text{broad}}^{[\text{OIII}]5008}$ (erg s ⁻¹ cm ⁻²)	$F_{\text{narrow}}^{[\text{OIII}]4960}$ (erg s ⁻¹ cm ⁻²)	$F_{\text{broad}}^{[\text{OIII}]4960}$ (erg s ⁻¹ cm ⁻²)	$z_{[\text{OIII}]5008}$
20504	$7.74^{+0.14}_{-0.13} \times 10^{-18}$	$2.01^{+0.14}_{-0.15} \times 10^{-18}$	$2.57^{+0.04}_{-0.04} \times 10^{-18}$	$6.68^{+0.48}_{-0.49} \times 10^{-19}$	5.276
35829	$6.98^{+0.07}_{-0.07} \times 10^{-18}$	$8.24^{+1.09}_{-1.10} \times 10^{-19}$	$2.32^{+0.02}_{-0.02} \times 10^{-18}$	$2.74^{+0.36}_{-0.37} \times 10^{-19}$	6.684
102364	$2.69^{+0.07}_{-0.07} \times 10^{-18}$	...	$8.94^{+0.24}_{-0.24} \times 10^{-19}$	...	4.542
100424	$1.30^{+0.07}_{-0.07} \times 10^{-18}$	...	$4.31^{+0.23}_{-0.22} \times 10^{-19}$	...	4.953
101393	$1.15^{+0.05}_{-0.05} \times 10^{-18}$	...	$3.84^{+0.16}_{-0.16} \times 10^{-19}$	...	3.850
101208	$9.84^{+0.33}_{-0.33} \times 10^{-19}$	...	$3.27^{+0.11}_{-0.11} \times 10^{-19}$	...	5.682
33842	$3.09^{+0.12}_{-0.12} \times 10^{-18}$	...	$1.03^{+0.04}_{-0.04} \times 10^{-18}$	...	5.287
169045	$1.64^{+0.01}_{-0.01} \times 10^{-17}$	$3.08^{+0.12}_{-0.12} \times 10^{-18}$	$5.45^{+0.04}_{-0.04} \times 10^{-18}$	$1.02^{+0.04}_{-0.04} \times 10^{-18}$	5.239
161695	$8.92^{+0.34}_{-0.35} \times 10^{-19}$	...	$2.97^{+0.11}_{-0.12} \times 10^{-19}$	...	5.666
1794	$1.33^{+0.01}_{-0.01} \times 10^{-17}$	...	$4.41^{+0.03}_{-0.03} \times 10^{-18}$	...	3.681