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A Single Line Emitter Identified in an Unbiased Search with JWST/NIRSpec: Multiobject Coronagraphy for Slitless Spectroscopy

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Abstract

We report the detection of a previously unknown object with a single emission line within the Hubble Ultra Deep Field, using a new JWST NIRSpec technique called Multiobject Coronagraphy for Slitless Spectroscopy (MOCSS) with the G140M/F100LP observing mode. The MOCSS technique involves opening almost all the shutters on the NIRSpec microshutter array, while simultaneously closing the shutters that lie on top of known low-redshift objects, facilitating a wide-field slitless spectroscopic search without contamination from bright objects. This observational technique has enabled the detection of a strong emission line in four different dither positions and in two position angles, and thus cannot be artificial. This line is detected at $1.60\ \mu\text{m}$ with a line flux of $[2.5 \pm 0.3] \times 10^{-18}\ \text{erg s}^{-1}\text{cm}^{-2}$ and an FWHM of $13.2 \pm 2.0\ \text{\AA}$, and does not correspond to any known source with some of the deepest Hubble Space Telescope and JWST imaging in existence. Based upon the absence of imaging detection, we place a lower limit on the observed frame equivalent width (EW) of $7620\ \text{\AA}$ on this object, which strongly limits the number of possible lines that this line can be. Given the wavelength, an EW limit that is near the ceiling of expectation, and the lack of other lines in the bandpass, this line cannot be easily explained by [O II] at $z = 3.29$, [O III] at $z = 2.20$, H α at $z = 1.44$, and Ly α at $z = 12.16$. We discuss possible active galactic nucleus and transient phenomena that could explain the finding.

Unified Astronomy Thesaurus concepts: Emission line galaxies (459); James Webb Space Telescope (2291); Reionization (1383); Early universe (435); Primordial galaxies (1293)

1. Introduction

The James Webb Space Telescope (JWST) has ushered in a new era in the search and study of the furthest and faintest objects in the Universe. Spectroscopically identified ultraviolet (UV) emission lines in these high- z sources can constrain both the conditions of the interstellar medium in the first galaxies and determine the contribution of faint active galactic nuclei (AGN) to the galaxy population (e.g., M. Castellano et al. 2022; M. Curti et al. 2023; S. Fujimoto et al. 2023; M. Tang et al. 2023; M. Llerena et al. 2025). UV emission lines are important diagnostics of the star formation, gas density, metallicity, dust content, the baryon cycle, and ionization properties of galaxies (e.g., A. Vidal-García et al. 2017; N. Byler et al. 2018; L. J. Kewley et al. 2019; M. Llerena et al. 2022; M. Mingozzi et al. 2024; M. J. Hayes et al. 2025).

Wide Field Slitless Spectroscopy (WFSS) observing modes have enabled the discovery of previously unknown emission-line sources as far back as the Epoch of Reionization (EoR; e.g., T. Treu et al. 2022; J. Matthee et al. 2023; M. A. Malkan et al. 2025; F. Sun et al. 2025). The Near-Infrared Imager and Slitless Spectrograph (NIRISS) WFSS observing mode does just this, but only has a resolution of $R \sim 100$, meaning it cannot capture emission lines with equivalent width (EW) below $\sim 10\ \text{\AA}$. The Near Infrared Camera (NIRCam) WFSS observing mode has a higher resolution of $R \sim 1000$, but at $\lambda > 2.4\ \mu\text{m}$. Unfortunately, it is the $1 < \lambda < 2.5\ \mu\text{m}$ regime that hosts $z > 6$ UV emission lines. In this wavelength range, the highest-resolution ($R \gtrsim 1000$ with G140M and G140H) spectroscopic instrument is the Near Infrared Spectrograph (NIRSpec; P. Jakobsen et al. 2022). However, typical NIRSpec observations require a preselection of targets unlike slitless spectroscopic modes, which introduces biases to the spectroscopic samples based upon magnitudes and/or colors, and prohibits the identification of unknown emission-line objects. Therefore, we have pioneered a new NIRSpec technique, Multiobject Coronagraphy



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for Slitless Spectroscopy (MOCSS), where we open all shutters in the microshutter assembly (MSA) except those on known low- z targets, thereby obtaining WFSS spectroscopy without contamination from unwanted bright objects. This allows us to search for never before seen faint and high- z emission lines without object preselection, at $R \sim 1000$ in the $\sim 1\text{--}2\ \mu\text{m}$ wavelength range. The lack of preselection bias is a very important characteristic for such a survey to have, so that the most recent puzzling discoveries of the high- z Universe are not subject to some kind of observational bias.

In this paper, we present a previously unknown line emitter within the MOCSS Hubble Ultra Deep Field (HUDF) survey, corresponding to no known source. In Section 2, we summarize the MOCSS HUDF observation strategy and data reduction process. In Section 3, we present the methodology for identifying the line emitter. In Section 4, we present the emission line and discuss the possible origins and implications of the line. Our conclusions are outlined in Section 5. We assume a flat Λ CDM Planck Collaboration et al. (2020) cosmology and use the AB magnitude system (J. B. Oke & J. E. Gunn 1983).

2. Observations and Data Reduction

The HUDF (overlapping with the Great Observatories Origins Deep Survey-South (GOODS-S); S. V. W. Beckwith et al. 2006; K. E. Whitaker et al. 2019) is a well-studied field, known for its exceptional wavelength coverage and depth of observations. This includes 11-band Hubble Space Telescope (HST) imaging (S. V. W. Beckwith et al. 2006; R. J. Bouwens et al. 2010; R. S. Ellis et al. 2013; H. I. Teplitz et al. 2013; M. J. Hayes et al. 2024) and both short-wavelength and long-wavelength imaging from the JWST/NIRCam (D. J. Eisenstein et al. 2026; C. C. Williams et al. 2023) and NIRISS (NGDEEP; M. B. Bagley et al. 2024).

The MOCSS HUDF survey, JWST-3290 (PIs: Hayes and Scarlata), was conducted in JWST Cycle 2. The primary overview of the MOCSS survey and will be discussed in a future paper. Here we present a summary of the MOCSS observation strategy and the data reduction process.

MOCSS observations were obtained with NIRSpec G140M/F100LP disperser/filter pairing, which nominally covers the wavelength range between 0.97 and $\sim 1.89\ \mu\text{m}$ at $R \sim 1000$. Instead of using the standard Multiobject Spectroscopy (MOS) observing mode, all shutters were left open to enable a slitless spectroscopic campaign.

To minimize contamination from bright, low- z sources and because the primary goal of the MOCSS survey is to detect faint emission lines in the EoR ($z \gtrsim 6.9$), we masked all sources with flux detected at $\lambda < 9600\ \text{\AA}$, identified in HUDF HST F814W images (K. E. Whitaker et al. 2019), by closing shutters that lie on top of these objects. Accounting for failed shutters and intentionally closed shutters to mask $z < 6.9$ galaxies, $\gtrsim 90\%$ of the MSA area was left open.

The HUDF was observed at two orientations (offset by $\sim 89^\circ$), with eight separate exposures per orientation (for a total of 16 exposures). We created a dither pattern optimized to ensure uniform illumination of the field. The dither pattern consists of four-point dither pattern of one-half of a shutter, followed by one large shift ($\sim 21''$) to cover the NIRSpec chip gap where a second four-point dither pattern of one-half of a shutter each takes place.

Table 1
Details of the MOCSS Observations

Exposure	Orientation	Stack	R.A. Offset (arcsec)	Decl. Offset (arcsec)
1	1	A	0	0
2	1	A	0.26	0.81
3	1	A	0.52	1.61
4	1	A	0.77	2.42
5	1	B	-15.97	14.62
6	1	B	-15.71	15.42
7	1	B	-15.45	16.23
8	1	B	-15.20	17.03
9	2	C	0	0
10	2	C	0.91	-0.24
11	2	C	1.81	-0.48
12	2	C	2.72	-0.72
13	2	D	16.79	13.88
14	2	D	17.70	13.64
15	2	D	18.60	13.40
16	2	D	19.51	13.15

Note. Information about each exposure in the dither pattern. Each group of four exposures are aligned and stacked, resulting in stacks A, B, C, and D. The R.A. and decl. offsets are calculated with respect to exposure 1 for all orientation 1 objects, and exposure 9 for all orientation 2 objects.

Each of the 16 exposures was row-by-row sky subtracted using a custom algorithm. This is required because in each row, the value of the background depends on the number of shutters opened in that specific row (which varies depending on the number of shutters that were closed to mask sources in each row). The 16 exposures were divided into four groups (called groups A, B, C, and D) corresponding to each of the small dither groups and orientations (see Table 1 for dither information). Dispersed images were aligned relative to the first exposure within each group (e.g., exposure 5 for group B) to ensure proper alignment of spectral traces across all exposures. We then created deep dispersed images for each group by error-weighted mean combining these aligned images. In this process, for each group we also obtain the standard deviation per aligned pixel into a σ map.

The results of this procedure are a set of four dispersed, sky-subtracted images that we use in the next section to detect emission lines.

3. Methodology

In standard slitless spectroscopy, direct images of the field are used to extract the spectra of known sources. In this work, we instead identify emission lines directly in the dispersed images (as done, e.g., in D. Kashino et al. 2023; A. Runnholm et al. 2025).

3.1. Emission-line Detection

Candidate emission lines in the dispersed images were identified using the Python library for Source Extraction and Photometry (SEP) package (K. Barbary 2016; E. Bertin & S. Arnouts 1996). We use SEP.BACKGROUND to create a spatially variable background image using 32×32 pixel background boxes. We retain only sources with more than five contiguous pixels with flux above a threshold of $3\sigma_{\text{rms}}$. Each detector stack includes $\sim 200\text{--}300$ candidate emission lines.

Real emission lines are expected to move in a very specific way between different stacks. Within a single orientation, real lines would appear in both stacks, offset by the large dither that corresponds to about 200 pixels in the dispersion direction and 2 pixels in the cross-dispersion direction. This shift may not be exact across the entire field of view due to wavelength- and position-dependent distortions that are not fully captured by the dither correction and can introduce additional offsets. We visually inspect the identified candidates, to ensure that they are not located near the edge of the detector and exhibit the morphology expected for emission lines. We classify sources as genuine emission-line detections if their centroids in the two groups lie within 4 pixels of the expected position. This procedure yields 21 and 21 emission-line candidates for orientations 1 and 2, respectively (for a total of 42).

3.2. Matching Emission-line Candidates in Different Orientations

The emission lines identified in the two orientations and described in the previous section do not have unique wavelength assignments. This ambiguity is the reason the field was observed at two different dispersion angles. In slitless observations, the wavelength corresponding to a given pixel in the dispersed image depends on the position of the source within the field of view. Consequently, the same pixel can be associated with different wavelengths for different objects. A selected emission-line target should correspond to a single source position and wavelength solution that is consistent across both orientations. We applied this criterion to the lists of emission-line candidates identified in Section 3.1. Specifically, we do the following.

1. For each orientation, we mapped each emission-line candidate to every possible MSA shutter that could host the source of that line. Note that each host shutter corresponds to a different wavelength for the line.
2. We retain in the final list of secure lines any lines that map to the same shutter in both orientations, with wavelength agreement within 6 Å (i.e., roughly the G140M’s dispersion)

3.3. Spectral Extraction

The criteria outlined in the previous section yield seven secure emission-line candidates. Six of the seven emission lines have well-defined hosts; galaxies identified in the JWST Advanced Deep Extragalactic Survey (JADES; D. J. Eisenstein et al. 2026; see Section 4.1). In addition to these sources, many of the remaining emission lines not seen in both orientations are constrained from being multiline emitters, found in ancillary spectroscopy, and from being found in three out of four stacks (with the emission line in the remaining stack falling in the chip gap, out of wavelength coverage, or falling just below the SEP detection threshold). In total $\gtrsim 75\%$ of the 42 emission lines are robustly identified and have known hosts. These source will be discussed in the future MOCSS overview paper.

However, there is one remaining emission line that is seen in both orientations that has no identifiable host in JADES and originates from a sky position of R.A. = $53^{\circ}.13127$ and decl. = $-27^{\circ}.78908$. This position is confirmed after spectral extraction from the pixel to R.A. + decl. + wavelength

transformation in the extracted 2D spectra. This position corresponds to an emission-line wavelength of 16004 ± 1 Å.

To search for secondary emission lines associated with this object, we extracted the spectra at both orientations by running the JWST Stage 2 pipeline on the stacked dispersed images. The pipeline version used in this extraction was the JWST v1.19 pipeline (H. Bushouse et al. 2025). We used the `jwst_1413.pmap` reference file in the JWST Calibration References Data System (CRDS; P. Greenfield & T. Miller 2016) and included the latest S-flat images (released 2025 summer). The Stage 2 pipeline applies instrumental corrections and calibrations to the count-rate products that result in fully calibrated exposures. The pipeline steps of MASTER_BACKGROUND, PATHLOSS, and BARSHADOW are skipped, as they are either not required or would result in inaccurate corrections given our observing strategy.

The JWST spectroscopic flux calibration is computed from observations of a point source and includes an aperture correction for flux loss due to the finite shutter size in the dispersion direction. Our observations, however, do not suffer from this limitation (as neighboring shutters are opened along the dispersion direction). Accordingly, the flux calibration should be corrected to account for only the fraction of light lost because of the shutter bars. To estimate this number, we used the Python package STPSF (M. D. Perrin et al. 2014) to compute a model point-spread function at $1.6 \mu\text{m}$ and then simulated the spectrum of a point source through three adjacent shutters. We find that the flux loss is only 3.3%.

The extracted 1D spectra in each of the four stacks can be seen in Figure 1. The top panel shows the full 1D spectral extraction while the inset zooms in on the location of the emission line at $1.60 \mu\text{m}$. We also compute, in each wavelength bin, the weighted mean of the spectra from the four stacks. The resulting spectrum is shown as the black curve in Figure 2. We generate 1000 realizations of the spectra from each of the four stacks by drawing values from a Gaussian distribution centered at f_{ν} and a standard deviation equal to the error on f_{ν} . We take the median of the four spectra (one per each stack) in every wavelength bin for all 1000 realizations; the standard deviation of the median distribution in each wavelength bin is taken as the error on the final spectrum. The bottom row of Figure 1 shows cutouts of the dispersed images centered at the emission-line position in each stack.

3.4. Emission-line Measurement

We fit a Gaussian to the detected emission line with SCIPY.OPTIMIZE.LEASTSQ (P. Virtanen et al. 2020) using a Levenberg–Marquardt algorithm. A Monte Carlo (MC) approach is used to estimate the error on the line flux: First, we created 1000 realization of the spectrum by drawing values from a Gaussian distribution centered at f_{λ} and a standard deviation equal to the error on f_{λ} . Then, we refit the Gaussian model to the 1000 realization of the spectrum and computed the error on the line flux as the dispersion of the derived line flux distribution. This measurement yield an integrated line flux of $[2.5 \pm 0.3] \times 10^{-18} \text{ erg s}^{-1} \text{ cm}^{-2}$. We also measure the line flux in each stack individually, which is presented in Table 2. The same MC Gaussian fitting procedure is used to derived the FWHM of the line, found to be 13.2 ± 2.0 Å in the observed frame.

We can use the line flux measurement together with the noise level to estimate a lower limit on the line EW. Measuring

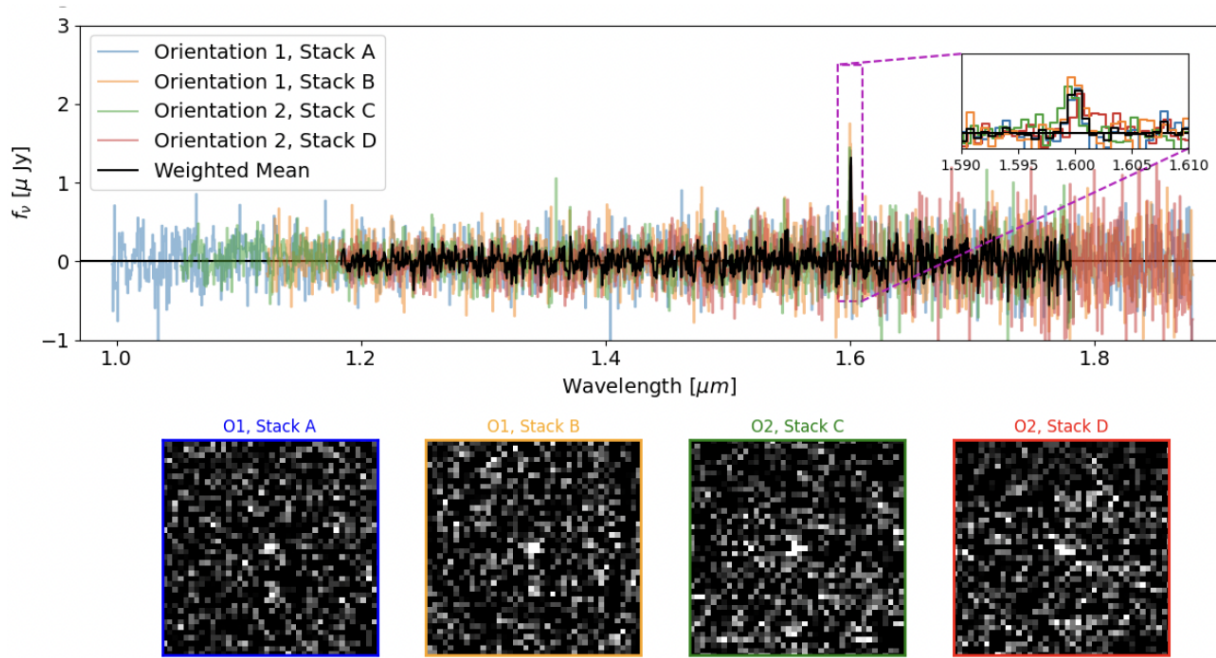


Figure 1. Single emission-line candidate matched in all stacks and orientations. Top: the 1D spectrum of the line in the four stacks. The black line is the weighted mean of the four individual stacks (and is only plotted in the wavelength range where all four stacks overlap). The inset zooms in on the location of the emission line. Bottom: the direct, SEP-identified detector images of the line in each of the four stacks (where O1 = orientation 1 and O2 = orientation 2).

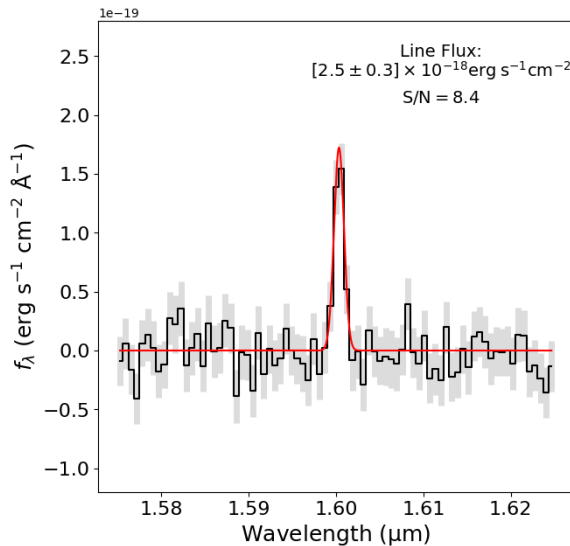


Figure 2. Weighted-mean line of the four stacks (black) with a Gaussian fit to the emission line (red). The associated uncertainty on each point is highlighted in gray. This strong emission line peaks at 1.60 μm , and corresponds to the location of R.A. = 53.13127 and decl. = -27.78908.

the noise as the standard deviation of the weighted-mean spectrum in the wavelength regime covered by all four stacks, we find that $\sigma_{f_\lambda} = 2.0 \times 10^{-20} \text{erg s}^{-1} \text{cm}^{-2} \text{\AA}^{-1}$. This corresponds to a 3σ lower limit on the observed line of $\text{EW} > 41 \text{\AA}$. As we will see in the next section, however, the nondetection in imaging could imply a much larger EW limit.

4. Discussion

In this section we address the possible origin of the emission line.

4.1. Emission-line Host, or Lack Thereof

Figure 3 shows a cutout of the JADES F150W NIRCам image centered at the inferred position of the source responsible for the emission line. The image reaches a 5σ depth of 4.6 nJy (within a $0.3''$ diameter aperture, corresponding to a limiting 3σ magnitude of 30.3; M. J. Rieke et al. 2023). The figure also shows the positions of the reference shutters used for the spectral extraction in each of the four stacks. Although the green and red shutters appear more offset from one another than the blue and yellow shutters, this is a consequence of the source position inferred by the orientation matching code (Section 3.2), which places the source near the boundary between two shutters. This does not affect our analysis because the dithering strategy causes the spectrum from each stack to sample flux from a larger region than that covered by the reference shutter alone. This is illustrated in Figure 3, where the faint green shutters indicate the positions of the other three dithers that contribute flux to the extracted spectrum for stack C.

It is clear that there is no source at the positions of the shutters in the image shown in Figure 3, despite the image being among the deepest images ever obtained by JWST. Three sources (marked in pink in the figure) appear to be within $1''$ from the putative position of the line host, but too far to be directly responsible for the emission line. In Sections 4.3 and 4.4 we discuss possible scenarios where these objects could still help the understanding of this line. Information about these neighboring sources can be found in Table 3.

The lack of detection in the broadband image is surprising, because the F150W filter fully encompasses the wavelength of the emission line. Indeed the line flux alone would be sufficient to produce a detectable signal in the F150W observations. This nondetection places a strong lower limit on the EW of the line. The 5σ depth of 4.6 nJy corresponds to a 3σ continuum limit of $f_\lambda = 3.23 \times 10^{-22} \text{erg s}^{-1} \text{cm}^{-2} \text{\AA}^{-1}$. Combining this limit

Table 2
Properties of the Emission Line When Measured Individually in Each Stack and the Combined Stack

Stack	Flux ($\text{erg s}^{-1} \text{cm}^{-2}$)	Significance	FWHM ($\text{\AA}$)	Central Wavelength ($\text{\AA}$)	Date of Observation
A	$[2.3 \pm 0.5] \times 10^{-18}$	4.7σ	10.7 ± 2.9	16006 ± 2	23 Aug 2023
B	$[3.5 \pm 0.6] \times 10^{-18}$	6.1σ	14.5 ± 3.2	16003 ± 1	24 Aug 2023
C	$[2.9 \pm 0.7] \times 10^{-18}$	4.5σ	14.9 ± 5.4	16001 ± 2	19 Nov 2023
D	$[2.9 \pm 1.2] \times 10^{-18}$	2.5σ	23.3 ± 14.4	16006 ± 2	19 Nov 2023
Combined	$[2.5 \pm 0.3] \times 10^{-18}$	8.4σ	13.2 ± 2.0	16004 ± 1	...

Note. There is a time period of about 88 days between observations in orientation 1 (stacks A and B) and orientation 2 (stacks C and D). Given the lack of detection for this source in JADES deep NIRCIm imaging, the 5σ upper limit on the line flux based on the nondetection would be $\sim 1.1 \times 10^{-18} \text{ erg s}^{-1} \text{cm}^{-2}$.

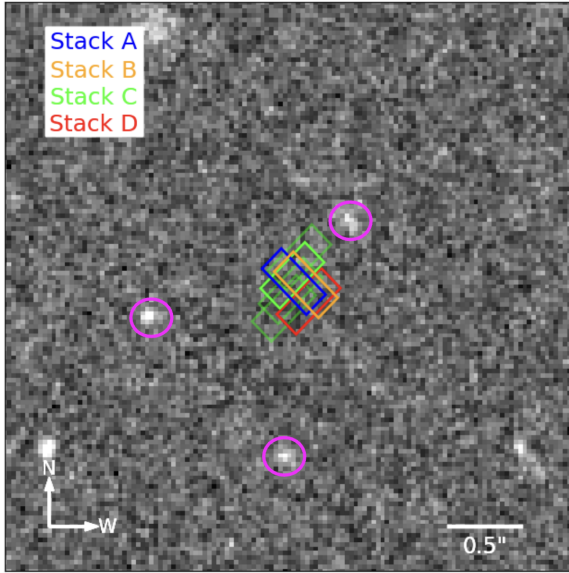


Figure 3. Location of the line-emitting source in NIRCIm F150W imaging, with north at the top of the image, and east on the left side of the image. The source location corresponds to no known source in the JADES catalog. The pink circles indicate the nearest sources identified in JADES. The shutter imprints show the location of the reference shutter in each stack used for spectral extraction (blue for stack A, yellow for stack B, green for stack C, and red for stack D). To clarify that each shutter represents a stack, for stack C (green), we also plot faint shutters representing the three other exposures for that stack.

with the measured line flux yields a lower limit on the observed-frame EW of $7620 \text{ \AA}$.

4.2. Interpretation as Star-forming Galaxy

The emission line at $1.60 \mu\text{m}$ cannot be readily explained by any Galactic source. If the emission line originates in an extragalactic source, its redshift depends on the line identification. Here we use constraints based on the absence of additional lines as well the inferred line EW and FWHM to explore possible strong line identifications.

Figure 1 shows that there are no additional emission lines in the wavelength range covered by the spectrum, which has a 3σ line flux limit that varies from ~ 8.2 to $\sim 10.6 \times 10^{-19} \text{ erg s}^{-1} \text{cm}^{-2}$ depending on the wavelength. The constraints from the EW limit will depend on the redshifts of the objects. In Table 4, we list strong emission lines that are commonly detected in the spectra of galaxies: $\text{H}\alpha$, $[\text{O III}]$, $[\text{O II}]$, and $\text{Ly}\alpha$ (no other potential emission lines theoretically

Table 3
The Nearest JADES-identified Sources to the Line Emitter

R.A. (deg)	Decl. (deg)	Location Relative to Line Emitter	z_{phot}	F150W (nJy)
53.131165	-27.788930	Northwest	$0.22^{+3.11}_{-0.09}$	4.75 ± 1.33
53.131584	-27.789105	East	$6.03^{+0.04}_{-0.29}$	4.69 ± 1.40
53.131301	-27.789367	South	$0.19^{+2.60}_{-0.03}$	3.57 ± 0.95

Note. These three source correspond to the pink circles in Figure 3. In Figure 3, the northwest JADES galaxy is to upper right, the east galaxy is to the left, and the south galaxy is to the bottom of the figure. These neighboring galaxies could host an ionizing source that is illuminating a cloud of gas that is the source of the emission line. Sky coordinates are in epoch J2000.

get within a factor of 10 of the EW of this object). For each line, we compute and list the galaxy's properties that would result from that line identification. In the next sections, we discuss each possible identification individually.

4.2.1. Interpretation as $[\text{O II}]$

Should the line detected in the JWST spectrum be interpreted as the $[\text{O II}]$ 3727, 3729 $\text{\AA}$ doublet, the redshift would be $z_{[\text{O II}]} = 3.29$ and $\text{EW}_{[\text{O II}]} \gtrsim 1770 \text{ \AA}$. In the rest-frame, the $[\text{O II}]$ 3727, 3729 $\text{\AA}$ doublet is separated by $\sim 2.7 \text{ \AA}$, or $11.6 \text{ \AA}$ in the observed frame, potentially resolvable in the $\sim 10 \text{ \AA}$ resolution spectra. The doublet ratio, $R_{[\text{O II}]} = I_{3729}/I_{3726}$, depends sensitively on the electron density, varying from ~ 1.5 in the low-density regime to ~ 0.35 in the high-density regime (G. J. Ferland et al. 2017; C. M. Gunasekera et al. 2025). Reproducing the narrow line width, therefore, requires high-density gas with $n_e \gtrsim 10^4 \text{ cm}^{-3}$. At this density, $[\text{O II}]$ will be suppressed by collisional deexcitation of O^+ ions. In addition, the implied rest-frame EW is extremely large, exceeding a few hundred angstroms, which has not been observed in $[\text{O II}]$ emitters (e.g., D. W. Hogg et al. 1998; R. Yan et al. 2006; C. Ly et al. 2012; B. Cedrés et al. 2021). Thus, the properties of this emission line cannot easily be reconciled with the $[\text{O II}]$ interpretation.

4.2.2. Interpretation as $[\text{O III}]$

Should the line be $[\text{O III}]$ 5007 $\text{\AA}$, the redshift would be $z_{[\text{O III}]} = 2.20$ and $\text{EW}_{[\text{O III}]} \gtrsim 2380 \text{ \AA}$. Large EWs for $[\text{O III}]$ have been observed (e.g., K. N. K. Boyett et al. 2022; S. Fujimoto et al. 2023; M. Tang et al. 2023; R. Endsley et al. 2025; M. Llerena et al. 2025), potentially indicating the

Table 4
Common Strong Emission Lines and Their Respective Rest Wavelengths That Could Be the Emission Line Found in the MOCSS Survey

Emission-line Candidates	Rest Vacuum Wavelength (Å)	z	Rest EW Lower Limit (Å)	Line Luminosity $\log_{10}(\text{erg s}^{-1})$	Rest FWHM (Å)
H α	6564.61	1.44	3130	$40.5^{+0.1}_{-0.1}$	5.4 ± 0.8
[O III]	5008.24	2.20	2380	$41.0^{+0.1}_{-0.1}$	4.1 ± 0.6
[O II]	3729.88	3.29	1770	$41.4^{+0.1}_{-0.1}$	3.1 ± 0.4
Ly α	1215.67	12.16	580	$42.7^{+0.1}_{-0.2}$	1.0 ± 0.1

Note. For each common emission line, we also list the corresponding redshift of the emission-line source and the lower limit on the rest EW of the line (based on the lack of detection in imaging), the line luminosity, and rest FWHM should it match that emission line. The EW limits are very large given the lack of imaging detection baseline, near or above the theoretical and observational maximum in all cases, making it challenging for these emission lines to explain this emission line.

presence of a highly obscured AGN, for which only the “narrow-line” region is detected (see Section 4.3). However, if this line were [O III] $\lambda 5007$, the accompanying [O III] $\lambda 4959$ line should be detected at 15864 Å. Based on the fixed doublet flux ratio, we would expect this line to have signal-to-noise ratio ≈ 2.9 . While this would not represent a strong detection, Figure 2 shows no apparent feature at 15864 Å, where we measure a 3σ upper flux limit of $\sim 9.4 \times 10^{-19} \text{ erg s}^{-1} \text{ cm}^{-2}$. Additionally, no H β emission is detected at 1.55 μm , where there is a 3σ line flux depth of $\sim 9.2 \times 10^{-19} \text{ erg s}^{-1} \text{ cm}^{-2}$. Thus, the [O III] interpretation remains disfavored.

4.2.3. Interpretation as H α

If this line were H α , the galaxy would be at $z_{\text{H}\alpha} = 1.44$ and the $\text{EW}_{\text{H}\alpha} \gtrsim 3130 \text{ Å}$. This EW would be close to the theoretical maximum for a zero-age starburst: for example, the maximal $\text{EW}_{\text{H}\alpha}^{\text{rest}}$ reached by a zero-age starburst is $\sim 3200 \text{ Å}$ (5 Myr old population, with $Z = 0.02 Z_{\odot}$, and an initial mass function (IMF) with $\alpha = 1.5$ using STARBURST99 models (C. Leitherer et al. 1999; H. Shim et al. 2011). The measured line flux corresponds to a line luminosity of $3.3 \times 10^{40} \text{ erg s}^{-1}$. Using the R. C. Kennicutt & N. J. Evans (2012) calibration, this implies a star formation rate (SFR) of $\sim 0.2 M_{\odot} \text{ yr}^{-1}$. Given the upper limit in the F115W flux, the stellar mass of this object must be below $\sim 10^6 M_{\odot}$, implying a specific SFR $\gtrsim 200 \text{ Gyr}^{-1}$, placing the source above the low-mass extrapolation of the star-forming main sequence at $z \sim 1.44$ (e.g., K. G. Noeske et al. 2007; E. J. Nelson et al. 2016; R. M. Mérida et al. 2026). It is worth noting that we do not see [O III] 5007 Å at 12217 Å, where there is a 3σ line flux depth of $\sim 9.5 \times 10^{-19} \text{ erg s}^{-1} \text{ cm}^{-2}$. There is also no [N II] 6548, 6583 Å, [S II] 6717, 6731 Å, [O I] 6300 Å, and He I 5876 Å, all of which would appear in this wavelength range, but these lines would likely be much fainter than H α .

The [O III] lines may or may not be intrinsically produced, as their strength depends sensitively on the ionizing spectrum and the gas-phase metallicity. If the starburst is effectively zero age (as implied by the large $\text{EW}_{\text{H}\alpha}$), the ionizing photon flux must be high, leading to a substantial O^+ photoionization rate. In this case, strong [O III] emission would generally be expected unless the metallicity is sufficiently low. A low metallicity could also account for the absence of detectable [N II] and [S II] emission, provided these lines are intrinsically weak and fall below the noise level. However, a low nebular O/H abundance would imply minimal dust attenuation. In that scenario, H β should be observed close to its intrinsic Case B recombination value, yet no such emission is detected. This

tension further disfavors an H α interpretation for this emission line.

Contrary to metal lines, if the line is H α , H β must be intrinsically produced. H β would be seen at 11865 Å if the line is H α . Assuming Case B recombination at 10^4 K , the minimum intrinsic H β flux would be $8.6 \times 10^{-19} \text{ erg s}^{-1} \text{ cm}^{-2}$, near the 3σ line flux upper limit of $\sim 9.7 \times 10^{-19} \text{ erg s}^{-1} \text{ cm}^{-2}$ measured at this wavelength. Assuming the same FWHM as H α in velocity space, an H β line with this flux would be detected at a significance of 2.7σ . Although this would represent only a marginal detection, the spectrum shows no evidence of a feature at the expected wavelength.

There are two possibilities to weaken the H β flux with respect to the H α . First, attenuation due to dust can significantly suppress the observed H β /H α ratio, making a nondetection of H β plausible. The second option is that the Case B recombination approximation may not be an appropriate assumption. Some recent evidence suggests that high values of the H α /H β ratio could be due to large amount of dense excited gas, producing absorption in the Balmer transitions (C. Scarlata et al. 2024).

4.2.4. Interpretation as Ly α

Finally, another alternative is Ly α , at a redshift of $z_{\text{Ly}\alpha} = 12.2$ and a rest-frame $\text{EW}_{\text{Ly}\alpha} \gtrsim 580 \text{ Å}$. If this line is Ly α , then no other strong emission lines would fall within the G140M/F100LP spectral coverage, which would explain the lack of detection of other lines. Ly α emission has been detected at even higher redshifts ($z \sim 13$; e.g., JADES-GS-z13-1-LA; J. Witstok et al. 2025), demonstrating that such a scenario is not observationally implausible.

However, JADES-GS-z13-1-LA differs substantially from the line emitter from this work. JADES-GS-z13-1-LA galaxy exhibits a well-detected continuum redward of the Lyman break ($f_{\nu} \sim 6 \text{ nJy}$ in F200W), corresponding to an absolute UV magnitude of $M_{\text{UV}} \approx -18.5$. In contrast, our line emitter lacks a comparable continuum detection. Furthermore, JADES-GS-z13-1-LA has a lower limit on the rest-frame EW of $\gtrsim 40 \text{ Å}$, significantly smaller than the lower limit of $\gtrsim 580 \text{ Å}$ inferred for this emission line. Such an extreme $\text{EW}_{\text{Ly}\alpha}$ would make this line emitter highly unusual. A rest-frame EW of $\gtrsim 580 \text{ Å}$ implies a very young and metal-poor stellar population (e.g., D. Schaerer 2003; N. Kashikawa et al. 2012). For example, at zero age and $Z = 1/20 Z_{\odot}$, STARBURST99 models can produce $\text{EW}_{\text{Ly}\alpha} \sim 500 \text{ Å}$ for a Salpeter IMF with an extreme slope of $\alpha = 0.5$ (S. Malhotra & J. E. Rhoads 2002).

Additionally, interpreting the line as Ly α would require minimal attenuation by the intergalactic medium (IGM), which

would be remarkable at $z = 12.16$. At this redshift, the IGM is inferred to be $\gtrsim 90\%$ neutral (S. Bruton et al. 2023), and ionized bubbles are not expected to be very extended (e.g., M. J. Hayes & C. Scarlata 2023; H. Umeda et al. 2024), unless the sight line happens to probe an unusually large ionized region. In the case of this line emitter, its faintness implies that it cannot, by itself, ionize a sufficiently large bubble to allow $\text{Ly}\alpha$ transmission. Sustaining such a bubble would instead require a substantial overdensity of nearby galaxies, such as a forming protocluster, capable of producing the necessary ionizing photon budget (W. Hu et al. 2021; T.-Y. Lu et al. 2024). Although none of the neighboring sources have photometric redshifts consistent with $z_{\text{phot}} \sim 12.16$, protoclusters can extend over several physical megaparsecs and could, in principle, lie partially outside the current field of view.

Taken together, the extreme EW requirement and the need for efficient $\text{Ly}\alpha$ transmission through a highly neutral IGM both present significant challenges for a $\text{Ly}\alpha$ interpretation of this line.

4.3. Interpretation as an Active Galactic Nucleus

Given that star formation alone does not well explain this emission line, an AGN provides an alternative interpretation. In principle, any of the emission lines considered above could be powered by AGN activity. AGN typically reside in chemically enriched environments and are characterized by strong metal emission lines (e.g., C. R. Mulcahey et al. 2022). If this line were interpreted as $[\text{O III}]$ or $\text{H}\alpha$, we would expect prominent accompanying metal lines within the observed wavelength range. In particular, in the $\text{H}\alpha$ scenario, an enhanced $\text{He I } \lambda 5876$ recombination line would be expected (e.g., Y. Almog & H. Netzer 1989). The absence of such strong metal features therefore argues against a classical AGN interpretation.

In contrast, if the line were isolated $\text{Ly}\alpha$, the situation is somewhat different. Rest-frame EWs as large as $\sim 500 \text{ \AA}$ have been observed in faint quasars (Y. Matsuoka et al. 2019; Y. Harikane et al. 2022; Y.-H. Lin et al. 2022). However, the narrow width of this line places additional constraints on an AGN interpretation. The feature is unresolved in the MOCSS data at $R \sim 1000$, implying a velocity width of $\lesssim 300 \text{ km s}^{-1}$. The emission line could therefore arise from the narrow-line region of an AGN.

AGN variability can in principle produce artificially large inferred EWs. For example, during a “changing-look” event, the hot accretion-disk continuum may fade rapidly while the line-emitting gas remains luminous for longer timescales (S. Komossa et al. 2026), temporarily boosting the observed EW. Moreover, a rapid “switch-on” scenario is unlikely in this case: producing significant line variability on the $\sim 1 \text{ yr}$ timescale between the imaging and spectroscopic observations (see Section 4.4) would require emission from the compact broad-line region, which is inconsistent with the observed narrow line width.

An alternative possibility is that an AGN located in one of the three neighboring sources listed in Table 3 is powering the emission line. In this scenario, ionizing radiation from the AGN could illuminate a separate cloud of gas at the position of this line emitter.

This type of “light echo” configuration, analogous to systems such as “voorwerps” and “green beans,” allows for

extremely large observed EWs, since the ionizing source need not be cospatial with the line-emitting gas (C. J. Lintott et al. 2009; R. Trainor & C. C. Steidel 2013; S. Cantalupo et al. 2014; R. L. Davies et al. 2015; M. V. Maseda et al. 2018; K. N. Sanderson et al. 2024). The neighboring sources to the northwest and south of the line emitter’s position have large uncertainties in their photometric redshifts, and their allowed z_{phot} ranges overlap with the redshifts at which this emission line could be interpreted as $\text{H}\alpha$, $[\text{O III}]$, or $[\text{O II}]$. However, even in this externally illuminated scenario, the $[\text{O III}]$ and $\text{H}\alpha$ interpretations remain problematic, as they would still predict the presence of additional strong emission lines that are not observed.

4.4. Interpretation as a Transient

In principle, the emission line alone should be sufficiently bright to produce a detectable signal in the broadband JADES F150W filter, even in the absence of any underlying continuum, so the lack of a corresponding imaging detection remains puzzling. To quantify this, we simulated the expected observed flux in F150W by generating synthetic photometry of the emission line using the SYNPHOT Python package (STScI Development Team 2018). Convolution of the emission-line spectrum with the NIRC2 F150W transmission curve yields an expected flux density of 5.5 nJy , corresponding to an observed magnitude of $m_{\text{F150W}} \sim 29.6$, assuming no continuum contribution. This is approximately 0.7 mag brighter than the nominal JADES limiting magnitude, implying that the source should have been detected in the imaging data. The line flux of the emission line would need to be $\sim 1.1 \times 10^{-18} \text{ erg s}^{-1} \text{ cm}^{-2}$ or smaller to be absent in JADES imaging. As discussed in Section 3.3, the line flux may be overestimated by $\sim 3.3\%$, but such a correction is insufficient to reconcile the predicted flux with the nondetection. This might indicate that a transient better explains the nondetection in the imaging data.

The MOCSS observations were obtained on 2023 August 23 (orientation 1) and 2023 November 19 (orientation 2), while the JADES imaging used for comparison (Figure 3) was acquired on 2022 October 8–10. Thus, there is approximately a 1 yr gap between the imaging and spectroscopic data. In a transient scenario, the constraints on the observed EW derived from the JADES nondetection would no longer apply, since the emission line may simply not have been present at the time of the imaging. Under this assumption, we take the maximum allowed continuum level to be σ_f . In this case, the 3σ lower limit on the observed EW is $\text{EW}_{\text{obs}} \gtrsim 41 \text{ \AA}$. This corresponds to rest-frame limits of $\text{EW}_{[\text{O II}]} \gtrsim 10 \text{ \AA}$, $\text{EW}_{[\text{O III}]} \gtrsim 13 \text{ \AA}$, $\text{EW}_{\text{H}\alpha} \gtrsim 17 \text{ \AA}$, and $\text{EW}_{\text{Ly}\alpha} \gtrsim 3 \text{ \AA}$. Therefore, in a transient interpretation, extremely large EWs are no longer required to explain the emission line. However, transient scenarios introduce their own challenges in accounting for the observed properties of this emission line.

One possibility is a flaring star in the Milky Way (i.e., at $z = 0$). Flaring stars can exhibit hydrogen Brackett-series transitions in emission (e.g., W. S. Howard et al. 2023). In particular, the Brackett (13–4) transition at $1.61 \text{ }\mu\text{m}$ lies close to the wavelength of the MOCSS emission line. However, this interpretation predicts the presence of additional Brackett lines, including Br12 at $1.64 \text{ }\mu\text{m}$, which is not observed. The absence of this feature effectively rules out a flaring-star scenario.

Another possibility is a Type II_n supernova, which is characterized by narrow emission-line features (e.g., F. Taddia et al. 2013). These narrow lines arise when the supernova blast wave shocks dense circumstellar material previously ejected by the progenitor through substantial mass loss. The transient could be a supernova at $z \sim 0.25$, potentially associated with a low-surface-brightness disk component of one of the nearby JADES sources (two neighboring objects have best-fit photometric redshifts near $z \sim 0.25$). In this scenario, this emission line could be identified as Pa β . However, this interpretation predicts the presence of Pa γ at $1.37 \mu\text{m}$. Assuming Case B recombination, the expected flux ratio is Pa β /Pa $\gamma \sim 1.6$, implying that Pa γ should be detected at $>3\sigma$ significance. That said, supernovae make a lot of dust, which could preferentially attenuate the Pa γ line and make it appear weaker.

Another possible transient explanation is a tidal disruption event (TDE). A TDE occurs when a supermassive black hole tidally disrupts a star, producing a luminous flare (E. C. Kool et al. 2020; G. Cannizzaro et al. 2022; G. Leloudas et al. 2022). At late times, TDE spectra can exhibit strong H α emission accompanied by weak continuum, as well as a wide range of observed H α /H β line ratios (P. Charalampopoulos et al. 2022). In luminous, dust-obscured TDEs, optically thick gas can suppress forbidden emission lines such as [O III], while dust attenuation can reduce the strength of H β (C. Panagiotou et al. 2023). In such a scenario, H α could plausibly be observed in isolation within the wavelength range, without detectable [O III] or H β .

The two MOCSS orientations were observed at separate epochs approximately 88 days apart, yet the measured line fluxes are consistent between the two observations. While this does not exclude a transient origin—since some TDEs evolve on longer timescales—it does argue against a rapidly moving solar system object.

5. Conclusion

In this study, we report the identification of a unique emission line using a new NIRSpec observing strategy, MOCSS. This technique involves opening nearly all shutters in the NIRSpec MSA while selectively closing those that coincide with known galaxies. This approach enabled high-resolution ($R \sim 1000$) spectroscopy over $0.97\text{--}1.89 \mu\text{m}$ in the HUDF, resulting in the discovery of a strong emission line at $1.6 \mu\text{m}$.

The line is robustly detected in multiple dithers and in two independent orientations, with a signal-to-noise ratio of 5.4 and no detectable continuum. There is no corresponding source in existing JADES NIRCам imaging. Based on this nondetection, the inferred observed EW is extremely large ($\text{EW}_{\text{obs}} \sim 7620 \text{ \AA}$), implying that, if real and persistent, the source would have to be a very young and metal-poor galaxy.

However, none of the plausible line identifications, [O II], [O III], H α , or Ly α , provide a fully satisfactory explanation, whether or not an AGN is invoked. Transient scenarios also face significant challenges, although they would naturally explain the lack of an imaging counterpart and would relax the extreme EW constraints.

Regardless of its true nature—whether an extremely low-metallicity, primeval galaxy at $z \sim 12.2$, a distant AGN in a fading phase, or an extreme metal-poor source at $z \sim 1.4$ —this

object is highly unusual and probes extreme physical conditions.

Follow-up observations are essential to confirm the redshift and determine the physical origin of the emission. JWST/NIRSpec integral field unit (IFU) observations would be particularly powerful, enabling simultaneous spectroscopy of both this line emitter and nearby galaxies. Deeper, more sensitive spectroscopy could reveal additional emission lines and definitively establish the redshift and nature of the source.

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