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Insights for Early Massive Black Hole Growth from JWST Detection of the [Ne v] λ3427 Emission Line

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Abstract

We use the narrow [Ne v] λ3427 emission line detected in the recently published JWST spectra of two galaxies, at $z \simeq 6.9$ and 5.6, to study the key properties of the active galactic nuclei (AGN) and the supermassive black holes (SMBHs) in their centers. Using a new empirical scaling linking the [Ne v] line emission with AGN accretion-driven (continuum) emission, derived from a highly complete low-redshift AGN sample, we show that the [Ne v] emission in the two $z > 5$ galaxies implies total (bolometric) AGN luminosities of order $L_{\rm bol} \approx (4\text{–}8) \times 10^{45}$ erg s^{-1}. Assuming that the radiation emitted from these systems is Eddington limited, the (minimal) black hole (BH) masses are of order $M_{\rm BH} \gtrsim 10^7\,M_\odot$. Combined with the published stellar masses of the galaxies, estimated from dedicated fitting of their spectral energy distributions, the implied BH-to-stellar mass ratios are of order $M_{\rm BH}/M_{\rm host} \approx 0.1$–1. This is considerably higher than what is found in the local Universe, but is consistent with the general trend seen in some other $z \gtrsim 5$ AGN. Given the intrinsic weakness of the [Ne v] line and the nature of the [Ne v]–to–$L_{\rm bol}$ scaling, any (rare) detection of the [Ne v] λ3427 line at $z > 5$ would translate to similarly high AGN luminosities and SMBH masses, thus providing a unique observational path for studying luminous AGN well into the epoch of reionization, including obscured sources.

Unified Astronomy Thesaurus concepts: Active galactic nuclei (16); High-redshift galaxies (734); Supermassive black holes (1663); AGN host galaxies (2017)

1. Introduction

Quasars detected at $z \gtrsim 6$, which now total hundreds of sources, have challenged our understanding of supermassive black hole (SMBH) formation and early growth, inspiring models in which SMBHs grow from massive seeds and/or through exceptionally efficient, super-Eddington accretion (e.g., K. Inayoshi et al. 2020; X. Fan et al. 2023; and references therein). However, until recently, there were relatively few observations of lower-luminosity and/or obscured active galactic nuclei (AGN) at these early epochs, although such sources are expected to be (intrinsically) far more abundant (e.g., Y. Ni et al. 2020; R. Gilli et al. 2022; A. Peca et al. 2023; J.-T. Schindler et al. 2023).

The James Webb Space Telescope (JWST) is revolutionizing our ability to study high-redshift AGN and SMBHs. Not only has it provided measurements of the host galaxies and larger-scale environments of previously known quasars (e.g., X. Ding et al. 2023; M. Yue et al. 2024b), but crucially, it has also detected several types of AGN that were previously unseen at $z \gtrsim 5$. These include broad-line AGN candidates now detected out to $z \gtrsim 10$ (V. Kokorev et al. 2023) and to considerably lower luminosities and/or black hole (BH) masses compared with the luminous quasars probed before (Y. Harikane et al. 2023; D. D. Kocevski et al. 2023; H. Übler et al. 2023; L. J. Furtak et al. 2024; X. Lin et al. 2024; I. Juodžbalis et al. 2025; A. J. Taylor et al. 2025); an abundant population of so-called "little red dots"—many of which appear to harbor AGN based on the presence of broad emission lines (albeit with properties that are still under intense discussion; e.g., J. E. Greene et al. 2024; J. Matthee et al. 2024); and several obscured AGN identified either through multiwavelength emission (e.g., Á. Bogdán et al. 2024; E. Lambrides et al. 2024a) or narrow emission lines of highly ionized species (e.g., J. Chisholm et al. 2024; G. Mazzolari et al. 2025; J. Scholtz et al. 2025). Many of these systems exhibit BH-to-host masses that are significantly higher than what is seen in the local Universe, reaching $M_{\rm BH}/M_* \approx 0.1$ (e.g., Y. Harikane et al. 2023; H. Übler et al. 2023; L. J. Furtak et al. 2024; I. Juodžbalis et al. 2024, 2025; R. Maiolino et al. 2024). These discoveries motivated an intensive discussion regarding the origin and (surprisingly high) abundance of such systems.

Here, we study two star-forming, low-mass galaxies that were recently claimed to host AGN based on emission lines measured from JWST spectroscopy (J. Scholtz et al. 2025, S25 hereafter; J. Chisholm et al. 2024, C24 hereafter). We argue that these galaxies harbor intrinsically luminous AGN based on the published measurements of the [Ne v] $\lambda3427$ emission line. This line is commonly used as a robust AGN tracer (e.g., N. L. Zakamska et al. 2003; R. Gilli et al. 2010; S. Yuan et al. 2016; D. Vergani et al. 2018), as it requires an ionizing source reaching $\gtrsim$100 eV—much higher than what stellar populations can typically provide (e.g., S. Satyapal et al. 2021; N. J. Cleri et al. 2023; and references therein, for detailed discussion).

We describe the data available for the two galaxies in Section 2. In Section 3 we derive estimates of the intrinsic, accretion-powered luminosities of the AGN that drive the high-ionization line emission in these galaxies. We discuss the implications for early SMBHs and their host galaxies in Section 4, before concluding in Section 5. All the luminosities mentioned in this Letter are (re)calculated assuming a flat ΛCDM cosmology, with $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_\Lambda = 0.7$, and $\Omega_M = 0.3$.

2. Two AGN-hosting Galaxies at $z \sim 5.5$–7

This work focuses on two galaxies with narrow [Ne v] $\lambda3427$ emission lines identified in recently published JWST/NIRSpec-based studies. Table 1 lists the key properties of the two galaxies—including those reported in the papers presenting their [Ne V] measurements (C24, S25) and those derived throughout the present study. We stress that the two studies that presented the galaxies have already analyzed their spectra and provided significant evidence for their AGN nature, based on their luminous [Ne V] line emission. Below we revisit some of these arguments and further strengthen this basic conclusion.

These two galaxies are the only $z > 5$ cases we are aware of where the robust detection and measurement of the [Ne V] line were made public. Given that these are drawn from large samples of hundreds of high-redshift galaxies with JWST spectroscopy, they are likely not representative of the overall galaxy population. Recently, two additional galaxies were claimed to present some [Ne V] emission, as reported by M. Curti et al. (2025; GS-z9-0 at $z = 9.43$) and by M. Tang et al. (2025; GS-81034 at $z = 5.39$). In both these cases, the [Ne V] line is only marginally detected, with a signal-to-noise ratio of $S/N \simeq 3$ (varying across reduction methods). We therefore prefer not to include these galaxies in our study (but see possible implications mentioned in Section 5).

2.1. NG-GS-10013609

NG-GS-10013609 (GS-10013609 hereafter), at $z = 6.931$, is part of a sample of 42 galaxies with AGN emission line signatures presented by S25, based on JWST/NIRSpec observations carried out as part of the JWST Advanced Deep Extragalactic Survey (D. J. Eisenstein et al. 2023). The narrow (FWHM $\simeq 215\,\mathrm{km\,s^{-1}}$) [Ne v] $\lambda3427$ line is robustly detected, with a luminosity corresponding to $L_{[\mathrm{Ne\,V}]} = 1.9 \times 10^{41}\,\mathrm{erg\,s^{-1}}$. Other lines of interest that are robustly detected include C III] $\lambda1909$, [Ne III] $\lambda3870$, Hβ, and [O III] $\lambda5007$ (see Table 1; F. D'Eugenio et al. 2025). The basic galaxy properties were derived by fitting the NIRSpec/PRISM spectra that are part of JADES, using the BEAGLE code (J. Chevallard & S. Charlot 2016). This analysis yielded a stellar mass of $\log(M_*/M_\odot) = 7.7^{+0.06}_{-0.07}$ and a star formation rate of SFR $\approx 4\,M_\odot\,\mathrm{yr^{-1}}$. R. Maiolino et al. (2025) derived a 3σ upper limit on the (rest-frame) 2–10 keV luminosity of $L(2\text{–}10\,\mathrm{keV}) < 5.3 \times 10^{42}\,\mathrm{erg\,s^{-1}}$.

As for the AGN nature of GS-10013609, we first note that S25 classified it as an AGN (and thus included it in their sample) based on the mere detection of [Ne v] $\lambda3427$.[14] Further evidence for an AGN in this source comes from its location in the C III]/He II $\lambda1640$ versus [Ne V]/C III] diagnostic diagram (Figure 5 in S25; following A. Feltre et al. 2016), as well as in the [O III]/Hβ versus [Ne V]/[Ne III] diagnostic diagram put forward by N. J. Cleri et al. (2023). The latter is shown in Figure 1, illustrating how most low-redshift AGN from the Burst Alert Telescope (BAT) AGN Spectroscopic Survey (BASS) DR2 catalog (M. J. Koss et al. 2022; K. Oh et al. 2022) fall in the "AGN" region. Finally, the high $L_{[\mathrm{Ne\,V}]}$ itself provides further support for an AGN, as we discuss below.

Table 1
Properties of the Two AGN

Property	GS-10013609	GN 42437	References[a]
Key spec. reference	S25	C24	
α(J2000.0) (d)	53.117303	189.17219	(1)
δ(J2000.0) (d)	−27.764082	+62.30564	(1)
z	6.931	5.58724	(1)
D_L (Gpc)	68.236	53.128	(2)
M_{UV} (mag)	−18.7	−19.1	(1)
$\log M_*$ ($M_\odot$)	$7.7^{+0.06}_{-0.07}$	7.9 ± 0.2	(1)
$F_{[\mathrm{Ne\,V}]}$ (10^{-19} erg s^{-2} s^{-1})	3.37 ± 0.75	2.35 ± 0.35	(1)
$F_{[\mathrm{N\,III}]}$ (10^{-19} erg s^{-2} s^{-1})	3.46 ± 0.36	9.0 ± 0.7	(1)
$F_{\mathrm{H}\beta}$ (10^{-19} erg s^{-2} s^{-1})	5.83 ± 0.27	20.2 ± 0.7	(1) [b]
$F_{[\mathrm{O\,III}]}$ (10^{-19} erg s^{-2} s^{-1})	33.04 ± 0.33	115.3 ± 3.1	(1)
$\log L_{[\mathrm{Ne\,V}]}$ (erg s^{-1})	41.27	40.90	(2)
$\log L_{[\mathrm{OIII}]}$ (erg s^{-1})	42.27	42.59	(2)
$\log L_{\mathrm{bol}}(L_{[\mathrm{Ne\,V}]})$ (erg s^{-1})	45.9	45.6	Equation (1), (3)
$\log L_{\mathrm{bol}}(L_{[\mathrm{OIII}]})$ (erg s^{-1})	45.8	46.1	Equation (2), (4)
$\log M_{\mathrm{BH,min}}$ ($M_\odot$)	7.75	7.38	Equation (1) and $L_{\mathrm{bol}} \leqslant L_{\mathrm{Edd}}$
$M_{\mathrm{BH,min}}/M_*$	≈1.1	≈0.32	(1, 2)

Notes.
[a] **References.** (1) The relevant original papers: S25 and/or F. D'Eugenio et al. (2025) for GS-10013609, and C24 for GN 42437, (2) this work, (3) R25, (4) T. M. Heckman et al. (2004).
[b] For GN 42437, Hβ was not measured directly, so instead we list the $F_{\mathrm{H}\beta}$ derived by combining the $F_{[\mathrm{O\,III}]}$ and the [O III]/Hβ values tabulated in C24.

2.2. GN 42437

GN 42437 is a $z = 5.58724$ galaxy for which deep JWST/NIRSpec spectroscopy was obtained as part of a study of

[14] This is the only source in the S25 sample where [Ne v] $\lambda3427$ is robustly detected.

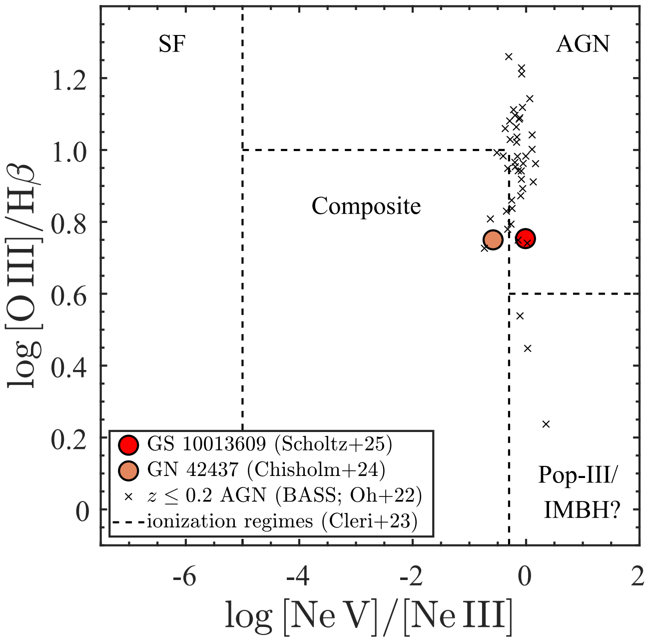

Figure 1. The [Ne v] λ3427/[Ne III] λ3870 vs. [O III] λ5007/Hβ line ratio diagnostic diagram, with regions dominated by various ionization mechanisms marked following N. J. Cleri et al. (2023). The two galaxies under study (large colored symbols) are consistent with AGN-driven photoionization, albeit with some contribution from other sources for GN 42437. Low-redshift, bona fide narrow-line AGN (black crosses; drawn from BASS/DR2; K. Oh et al. 2022) have similar line ratios to those of the two high-redshift galaxies we study here. We argue that the high [Ne V] line luminosity, that is $L_{\rm [Ne\,V]}$ itself, should also be considered when interpreting the ionization mechanism.

several epoch-of-reionization galaxies in the GOODS-North (GN) field (JWST Project ID: 1871, PI: Chisholm). The exquisite NIRSpec spectrum of GN 42437 revealed many emission lines, including [Ne V], [Ne III], [O III], and He II λ4686. Specifically, the narrow (FWHM $\simeq$ 174 km s^{-1}) [Ne v] λ3427 line has a luminosity of $L_{\rm [Ne\,V]} = 7.9 \times 10^{40}$ erg s^{-1}.[15] The deep JWST/NIRCam imaging available from the First Reionization Epoch Spectroscopically Complete Observations project (FRESCO; P. A. Oesch et al. 2023), combined with past Hubble Space Telescope imaging and using the `BAGPIPES` spectral fitting code (A. C. Carnall et al. 2018), yielded $\log(M_*/M_\odot) = 7.9 \pm 0.2$ and SFR $\simeq 10\,M_\odot$ yr^{-1}. C24 further reported an upper limit on the X-ray emission of L(2–10 keV) $< 4.5 \times 10^{43}$ erg s^{-1}.

C24 employed photoionization modeling and line ratio diagnostic diagrams, concluding that the emission lines in GN 42437 can only be explained with a dominant BH-accretion-based ionizing source. However, a significant contribution from stars, perhaps as much as $\approx$2/3 of the hydrogen ionizing radiation, cannot be ruled out. The potentially "composite" nature of GN 42437 can be demonstrated by the [Ne V]/[Ne III] versus [O III]/Hβ diagnostic diagram in Figure 1. We note that GN 42437 is located very close to the pure AGN region in that diagram, where we also find a nonnegligible fraction ($\sim$16%) of the low-redshift, bona fide BASS AGN.

Importantly, we argue that the [Ne V] line luminosity (i.e., $L_{\rm [Ne\,V]}$), and not just line ratios, provides further support for an AGN in this system. Specifically, if most of the high [Ne V] luminosity, corresponding to roughly $\approx 5 \times 10^7\,L_\odot$, is not due to an AGN, it implies an exceptionally large (and/or massive) population of Population III stars and/or intermediate-mass black holes (IMBHs), the existence of which cannot be further supported by the data in hand. As a reference for the high $L_{\rm [Ne\,V]}$ of GN 42437 we mention two recent studies of this line in low-redshift galaxies. First, over 80% of the $\sim$150 [Ne V]-detected sources in the recently published study of [Ne v] λ3427 emission in BASS AGN (T. Reiss et al. 2025, R25 hereafter) have a $L_{\rm [Ne\,V]}$ that is lower than that of GN 42437. Second, among the 60 [Ne V]-emitting galaxies in the Coronal Line Activity Spectroscopic Survey (CLASS; M. Reefe et al. 2023)—all of which can be independently classified as AGN—about 13% have a $L_{\rm [Ne\,V]}$ that is lower than that of GN 42437. Moreover, all the [Ne V]-emitting CLASS AGN are found in hosts with $M_* \gtrsim 5 \times 10^9\,M_\odot$, that is, $\gtrsim$2 dex higher than what is estimated for GN 42437. Thus, even for those systems in the local Universe where [Ne V] is as luminous as, or lower than, what is seen in GN 42437, if we were to suspect a significant non-AGN contribution to $L_{\rm [Ne\,V]}$, this would correspond to galaxies with significantly larger populations of (young) stars than the data for GN 42437 allow.[16]

3. AGN Energetics

We next estimate the bolometric AGN luminosities, $L_{\rm bol}$, of the two galaxies under study. We focus on the recently published scaling between $L_{\rm [Ne\,V]}$ and the (intrinsic), accretion-driven, AGN radiation, as traced by the ultrahard X-ray luminosity in the 14–195 keV band, L_{14-195}, which was described in R25. The R25 study is based on a large sample of low-redshift, ultrahard X-ray selected narrow-line AGN from BASS/DR2 (M. J. Koss et al. 2022), which have high-quality optical spectroscopy. The ultrahard X-ray band used to define the sample and to link [Ne V] line emission with AGN continuum radiation is essentially unaffected by obscuration. The specific scaling suggested in R25, $\log L_{14-195} = \log L_{\rm [Ne\,V]} + 3.75$, represents the median value found among the [Ne V]-detected sources in the R25 sample, with no correction of the [Ne V] emission for source dust attenuation, and has a scatter of 0.45 dex. Combining this scaling with a simple, universal bolometric correction of $L_{\rm bol} = 8 \times L_{14\text{-}195}$ (see also M. J. Koss et al. 2022; K. K. Gupta et al. 2024), R25 conclude that $L_{\rm bol}$ can be estimated directly from $L_{\rm [Ne\,V]}$ following

$$\log L_{\rm bol} = \log L_{\rm [Ne\,V]} + 4.65\,. \quad (1)$$

All of the [Ne V]-detected narrow-line AGN in R25 have $\log(L_{\rm bol}/L_{\rm [Ne\,V]}) > 3.3$ and only <5% (<18%) have $\log(L_{\rm bol}/L_{\rm [Ne\,V]}) < 3.65$ (4.15, respectively). Also, the [Ne V] line luminosities and widths of the two galaxies under study are well within the range covered by the R25 sample. Therefore, the scaling we adopt here should not be considered biased (high). We verified that using the more elaborate, nearly linear relation linking $L_{\rm [Ne\,V]}$ and continuum AGN emission presented in R25 (their Equation (1)), or their [Ne V] $- L_{2-10}$ scaling, would not affect our results. Given the large scatter in all these scaling relations, we prefer to use the former, simpler Equation (1). With this scaling, we obtain $L_{\rm bol} \simeq 8.5 \times 10^{45}$ and 3.6×10^{45} erg s^{-1} for GS-10013609 and GN 42437

[15] We rely on the observed line fluxes from C24, uncorrected for attenuation, so as to be consistent with what is available for GS-10013609.

[16] We note that the $L_{\rm [Ne\,V]}$ of GS-10013609 is similar to the median value among the CLASS AGN.

(respectively). AGN bolometric corrections have a significant scatter, and may also vary with certain AGN properties (e.g., R. V. Vasudevan & A. C. Fabian 2007; F. Duras et al. 2020; K. K. Gupta et al. 2024; and references therein). However, using more elaborate bolometric corrections is not warranted here, given the kind of approximate argumentation we pursue. Combining the 0.45 dex scatter on the scaling between [Ne V] and AGN continuum emission (R25) and the scatter on bolometric corrections deduced from the BASS sample of 0.4 dex (K. K. Gupta et al. 2024), the uncertainty on our [Ne V]-based estimates of $L_{\rm bol}$ is ~0.6 dex.

To illustrate the effect of relying on other narrow emission lines from high-ionization species on our assessment of AGN energetics in these two galaxies, we use scaling relations suggested for the [O III] λ5007 line. The large Sloan Digital Sky Survey study of T. M. Heckman et al. (2004) suggested

$$\log L_{\rm bol} = \log L_{\rm [O III]} + 3.54\,. \quad (2)$$

The X-ray informed study of T. M. Heckman et al. (2005) reported a scatter of ≈0.5 dex on the scaling between $L_{\rm [O III]}$ and AGN X-ray emission; however, more recent studies found that this scatter could be larger, exceeding 0.6 dex (e.g., S. Berney et al. 2015; Y. Ueda et al. 2015; K. Oh et al. 2022). This is expected, as [O III] may be contaminated by galaxy-scale star forming regions and/or reflect past episodes of SMBH accretion. Notwithstanding these limitations, Equation (2) yields $L_{\rm bol}$([O III]) $\approx 6.3 \times 10^{45}$ and 1.4×10^{46} erg s^{-1}, for GS-10013609 and GN 42437 (respectively). These differ from the [Ne V]-based estimates of $L_{\rm bol}$ by −0.13 and +0.55 dex (respectively). If we instead use the [O III] + Hβ prescription of H. Netzer (2009, Equation (1) there), we obtain $L_{\rm bol}$ estimates that differ from our [Ne V]-based estimates by either −0.6 dex (for GS-10013609) or +0.1 dex (for GN 42437). For reference, we note that the studies presenting the two sources have also provided rough estimates of $L_{\rm bol}$, based on the [O III] and Hβ lines. S25 estimated $L_{\rm bol} \simeq 10^{44}$ erg s^{-1} for GS-10013609, which is significantly lower than our [Ne V]-based estimate (by 2 dex; citing M. Hirschmann et al. 2025, in preparation). For GN 42437, C24 estimated $L_{\rm bol}$ to be as high as $L_{\rm bol} \simeq 10^{45}$ erg s^{-1} based on the H. Netzer (2009) prescription(s), but assuming only 1/3 of $L_{\rm [O III]}$ is due to an AGN. This is in excellent agreement with our [Ne V]-based $L_{\rm bol}$ estimate, if we instead assume that 100% of $L_{\rm [O III]}$ is due to an AGN.

In what follows, we focus on $L_{\rm [Ne V]}$ and Equation (1) as the primary method to estimate the bolometric AGN luminosities for the two galaxies. This is motivated by the higher ionization potential needed for [Ne V] (compared with [O III]), making it a high-purity AGN tracer, as well as the possibly closer distance of the [Ne V]-emitting gas to the ionizing AGN central engine. We note that the metallicity in the line-emitting regions of the $z > 5$ galaxies under study may be lower than in the low-redshift samples used to calibrate the aforementioned scaling relations, as suggested by various analyses of $z > 5$ galaxies with JWST spectroscopy (see, e.g., D. P. Stark et al. 2025 and references therein). However, a lower metallicity would result in a higher $L_{\rm bol}/L_{\rm line}$, and so would imply a yet higher $L_{\rm bol}$ given the measured $L_{\rm [Ne V]}$ (or $L_{\rm [O III]}$) we use. This is exemplified in the works by N. J. Cleri et al. (2023) and J. D. McKaig et al. (2024), which looked specifically into how [Ne v] λ3427 line emission may be affected by various properties of the ionized gas and incident radiation, including low metallicity.

Our main conclusion therefore is that the luminous narrow [Ne V] line emission observed in GS-10013609 and GN 42437 implies that they highly likely harbor obscured (i.e., "Type-II") AGN with bolometric luminosities of order $L_{\rm bol} \gtrsim 3 \times 10^{45}$ erg s^{-1}. This is higher than what was deduced by the previous studies of these galaxies (S25 and C24).

Given the high $L_{\rm bol}$ we infer from [Ne V], the upper limits on X-ray emission from the two galaxies imply extremely high bolometric-to-X-ray radiation ratios, $L_{\rm bol}/L_{2\text{-}10} \gtrsim 80$ for GN 42437 and $\gtrsim$1600 for the higher-$L_{\rm [Ne V]}$ GS-10013609. These are (far) higher than what is seen in large samples of lower redshift (X-ray selected) AGN, where $L_{\rm bol}/L_{2\text{-}10} \lesssim 50$ (e.g., F. Duras et al. 2020; K. K. Gupta et al. 2024). At face value, the implied X-ray weakness of the two AGN we study is in line with what is seen in other samples of JWST-detected $z > 5$ AGN (T. T. Ananna et al. 2024; M. Yue et al. 2024a; R. Maiolino et al. 2025), which has been interpreted to be caused either by significant obscuration by dense circum-nuclear gas (e.g., R. Maiolino et al. 2025) or by X-ray weak spectral energy distributions (SEDs) originating from super-Eddington accretion flows (e.g., E. Lambrides et al. 2024b). In this context, our two AGN are clearly capable of producing copious amounts of >0.1 keV radiation, given their intense [Ne V] emission, which could in principle be interpreted as further support of high line-of-sight obscuration toward the central X-ray source. We caution, however, that the X-ray weakness of our two AGN, and other JWST-detected sources targeted by Chandra, concerns the rest-frame ultrahard X-ray radiation (rest frame >10 keV), while the spectral regime probed (indirectly) by the [Ne V] emission is much softer. Interpreting the strong line emission and weak X-ray continuum emission of our AGN thus requires a more detailed spectral analysis, which is beyond the scope of the present Letter (see, e.g., E. Lambrides et al. 2024b for a specific example spectral model for [Ne V]-weak AGN).

4. Implications for Early SMBH Growth

What sort of SMBHs could be driving the luminous AGN in the two galaxies we study, which seem to have $L_{\rm bol} \gtrsim 3 \times 10^{45}$ erg s^{-1}, and what might this mean for early SMBH growth and galaxy evolution?

First, assuming that the two sources under study radiate through Eddington-limited accretion, one can deduce a lower limit on $M_{\rm BH}$ by harnessing the Eddington limit itself, namely (for solar metallicity gas)

$$M_{\rm BH} \gtrsim M_{\rm BH,min} \equiv (L_{\rm bol}/1.5 \times 10^{38}\ {\rm erg\ s^{-1}})\, M_\odot\,. \quad (3)$$

Since the gas metallicity in the two AGN could be lower than solar, we note that for pure (ionized) hydrogen gas the Eddington luminosity would be slightly lower (by ≈0.08 dex), and the resulting $M_{\rm BH,min}$ would be slightly higher (by the same amount). For the two galaxies discussed here, Equation (3) yields $M_{\rm BH} \gtrsim 5.6 \times 10^7$ and $2.4 \times 10^7\,M_\odot$ for GS-10013609 and GN 42437 (respectively).

However, there are reasons to suspect that AGN accretion flows may sustain much higher accretion rates, above the classical Eddington limit. This is particularly the case for $z \gtrsim 5$ SMBHs, which had to grow to their high masses within a limited period (see, e.g., review by K. Inayoshi et al. 2020).

Importantly, several studies have shown that even in (extremely) super-Eddington accretion flows, i.e., when $\dot{M} > > \dot{M}_{\rm Edd}$, the emerging radiation is expected to "saturate" at $L_{\rm bol} \approx$ few $\times L_{\rm Edd}$ (e.g., M. A. Abramowicz et al. 1988; J. C. McKinney et al. 2014; A. Kubota & C. Done 2019). If we adopt the commonly used scaling of $L_{\rm bol} \simeq L_{\rm Edd} \times (1 + \ln[\dot{M}/\dot{M}_{\rm Edd}])$ (M. A. Abramowicz et al. 1988), this would imply $M_{\rm BH,min}$ values that are lower than those mentioned above by a factor of $\approx$5.6$\times$ (i.e., 0.75 dex) for accretion rates with $\dot{M} = 100 \times \dot{M}_{\rm Edd}$. Even in such an extreme case, the implied lower limits on $M_{\rm BH}$ for the two galaxies are of $\gtrsim 4 \times 10^6\,M_\odot$.

To get a sense of the maximal BH mass, $M_{\rm BH,max}$, we may assume that the extreme-UV emitting accretion flow that is required for producing [Ne V] lines can only exist if $L/L_{\rm Edd} \gtrsim 0.01$. This is indeed the range seen in many samples of persistent, radiatively efficient AGN (e.g., A. Schulze et al. 2015; T. T. Ananna et al. 2022; and references therein). Using this lower limit on $L/L_{\rm Edd}$ would naturally yield $M_{\rm BH,max} = 100 \times M_{\rm BH,min}$, that is, $\approx 5.6 \times 10^9$ and $2.4 \times 10^9\,M_\odot$ for GS-10013609 and GN 42437 (respectively). The two [Ne V]-detected galaxies should therefore have SMBH masses in the range of roughly $M_{\rm BH} \sim (5\text{–}600) \times 10^7$ and $(2\text{–}300) \times 10^7\,M_\odot$ for GS-10013609 and GN 42437 (respectively). We emphasize that these are rough estimates, which are susceptible to significant (systematic) uncertainties on the assumptions taken to derive them. Any variation or uncertainty on the $L_{\rm bol}$ estimates would naturally propagate, linearly, to $M_{\rm BH,min}$ and $M_{\rm BH,max}$.

The C24 study of GN 42437 also considered several estimates of $M_{\rm BH}$, based either on the width of (narrow) emission lines and assuming the local $M_{\rm BH}$–σ_* relation, or on their estimates of $L_{\rm bol}$ and requiring $L_{\rm bol} = L_{\rm Edd}$. The former approach assumes that the $M_{\rm BH}$–σ_* relation does not evolve with redshift. The latter approach is, in principle, similar to our argumentation; however, we note that the C24 estimates of $L_{\rm bol}$ had to account for the potential contribution of young stars to the lower-ionization Balmer and [O III] lines, while our analysis relies solely on the exceptionally luminous [Ne V] line, which has minimal contribution from young stars (if at all; Figure 1). In any case, the C24 $M_{\rm BH}$ estimates range between $M_{\rm BH}({\rm C24}) \approx 10^6$ and $10^7\,M_\odot$, which is lower than our estimates by $\approx$0.4–1.5 dex.

The BH masses we derived above for the two galaxies under study are, by themselves, not exceptional. Indeed, many known $z > 5$ quasars have masses in the range $M_{\rm BH} \sim 10^{8-9}\,M_\odot$ (X. Fan et al. 2023 and references therein). Recent JWST discoveries pushed the lower end of the SMBH mass range among fainter broad-line AGN even further (e.g., Y. Harikane et al. 2023; J. E. Greene et al. 2024; R. Maiolino et al. 2024; A. J. Taylor et al. 2025). The two galaxies discussed here are, however, narrow-lined, meaning that their (rest-frame) optical SEDs are dominated by stars, and not by the AGN, providing reasonably robust estimates of stellar masses (see Table 1 and the original papers S25 and C24). Given the high AGN luminosities implied by the high-ionization line emission, one may actually suspect these stellar masses are overestimated, if the (rest-frame) optical SED is indeed contaminated by some continuum AGN emission.

Figure 2 shows the two galaxies on the $M_{\rm BH}$–$M_{\rm host}$ plane, in addition to several other (samples of) sources, including both relic and active systems in the local Universe, and $z \gtrsim 5$ AGN of various luminosities and from different types of surveys

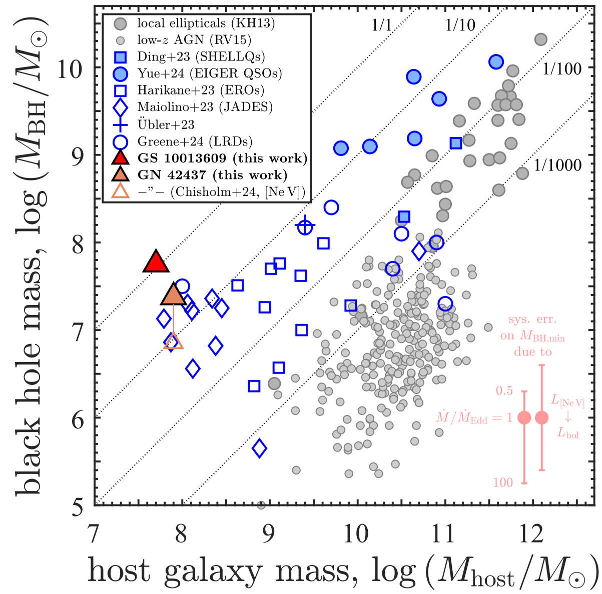

Figure 2. The SMBH–host mass plane with the [Ne V]-based constraints for the two $z > 5$ AGN studied here. We plot the two lower limits on BH masses, $M_{\rm BH,min}$ (colored triangles), derived by scaling the [Ne V] line emission to $L_{\rm bol}$ (via Equation (1)) and assuming $L_{\rm bol} \leqslant L_{\rm Edd}$. The systematic uncertainties associated with this scaling (0.6 dex), and with the assumption of $L_{\rm bol} = L_{\rm Edd}$ (see text), are illustrated by the large pink marker (bottom-right corner). For GN 42437, we also plot an alternative estimate (lower open triangle), assuming that only one-third of the ionizing radiation is due to an AGN, as suggested by C24 (a highly conservative assumption for [Ne V]; see text). We include for comparison several other samples from the local and distant ($z > 5$) Universe (see legend): local ellipticals (from J. Kormendy & L. C. Ho 2013; large gray circles), low-z broad-line AGN (from A. E. Reines & M. Volonteri 2015; small gray circles); luminous $z \gtrsim 6$ quasars selected from ground-based, wide-field optical–near-infrared surveys (from M. Yue et al. 2024b and X. Ding et al. 2023; filled blue symbols); and several fainter, broad-line AGN identified in various spectroscopic JWST studies (from Y. Harikane et al. 2023; H. Übler et al. 2023; R. Maiolino et al. 2024; and J. E. Greene et al. 2024; open blue symbols). Diagonal dotted lines denote BH-to-stellar mass ratios of $M_{\rm BH}/M_* = 1$: 1000, 100, 10, and 1. The two sources studied here appear to have extremely high mass ratios, $M_{\rm BH}/M_* \approx 0.1$–1.

(i.e., from large-area quasar searches and JWST deep fields). Taking the lower values of $M_{\rm BH,min}$ derived above and the published M_* estimates, we derive lower limits on the BH-to-host mass ratios of $M_{\rm BH}/M_* \gtrsim 1.1$ and 0.3 for GS-10013609 and GN 42437 (respectively). Even if we assume that only one-third of the ionizing radiation in GN 42437 comes from an AGN, and scale down $L_{\rm bol}$ and $M_{\rm BH,min}$ by the corresponding factor,[17] we obtain $M_{\rm BH}/M_* \approx 0.1$ (see lower open triangle in Figure 2). We stress that this significant scaling down of $L_{\rm bol}$ represents an extremely conservative choice, given the challenge of non-AGN sources to affect the part of the ionizing radiation that drives [Ne V] emission.[18] In comparison, C24 concluded $M_{\rm BH}/M_* \simeq 0.01$ for GN 42437, based on their lower $M_{\rm BH}$ estimates for that source (see their Figure 10).

The mass ratios we derive for the two galaxies are obviously extremely high. For comparison, the typical mass ratio among relic systems in the local Universe is $M_{\rm BH}/M_* \sim 1/100$–500, and there is only limited evidence for the typical ratio to increase at high redshift, although there are a few exceptions

[17] That is, scale the [Ne V]-based $L_{\rm bol}$ estimate down by one-third.

[18] In other words, even if only one-third of the total ionizing radiation comes from an AGN, still the vast majority of the radiation that drives [Ne V] is expected to come from an AGN, and thus the $L_{\rm [Ne\,V]}$-based estimate of $L_{\rm bol}$ should in principle be scaled down by a factor that is smaller than $\times$3.

(e.g., X. Ding et al. 2020; H. Suh et al. 2020; and references therein). In the early Universe, $z \gtrsim 5$, there are again conflicting claims for and against a significantly elevated $M_{\rm BH}/M_*$ (compared with $z \simeq 0$). Recent JWST data revealed increasingly smaller SMBHs, which appear to be "overmassive" compared with their host galaxies (see the low-redshift $M_{\rm BH}/M_*$; e.g., Y. Harikane et al. 2023; L. J. Furtak et al. 2024; I. Juodžbalis et al. 2024, 2025; R. Maiolino et al. 2024). There is, however, an ongoing debate regarding whether such elevated $M_{\rm BH}/M_*$ ratios are representative of the intrinsic values for the underlying, not-yet-accessible population of $z \gtrsim 5$ AGN (see, e.g., J. Li et al. 2025 versus F. Pacucci et al. 2023).

Regardless of the complete distribution of $M_{\rm BH}/M_*$, every system with $M_{\rm BH}/M_* \gtrsim 0.1$ raises the question of how the SMBH could have grown so efficiently (compared with the stellar component of its host). While there are several models that try to address this challenge (see, e.g., P. Natarajan et al. 2024 and references therein), testing them would require larger samples and a better understanding of the space densities of $z > 5$ AGN with certain $M_{\rm BH}$ and (enhanced) $M_{\rm BH}/M_*$ ratios. Indeed, as further near-infrared spectroscopy of high-z galaxies is pursued with JWST, it is possible that additional [Ne V]-emitting AGN would be identified. We stress, however, that the intrinsic weakness of the [Ne V] line is such that any [Ne V]-detected system would imply a rather luminous AGN. Specifically, as noted in R25, [Ne V] line detections down to the highest sensitivity expected for JADES would correspond to AGN luminosities of order $\gtrsim 10^{45}$ erg s^{-1} (combining Figure 9 in D. J. Eisenstein et al. 2023 and Equation (1)), therefore making such sources rare. For example, if the recently reported detection of [Ne V] in a $z = 9.43$ galaxy (M. Curti et al. 2025) is indeed reliable,[19] then that source would yield $L_{\rm bol} \approx 2.3 \times 10^{45}$ erg s^{-1}, and thus $M_{\rm BH,min} \approx 1.5 \times 10^7 \, M_\odot$ and $M_{\rm BH}/M_* \gtrsim 0.1$, merely 500 Myr after the Big Bang.

5. Concluding Remarks

We have demonstrated how the mere detection of (narrow) [Ne V] λ3427 line emission in spectroscopic JWST observations of $z \gtrsim 5$ galaxies can provide not only a unique opportunity to uncover (obscured) AGN but also to reveal (over)massive BHs, complementing the more common approach that focuses on broad-line AGN. Specifically, we argue that two $z \gtrsim 5$ galaxies with [Ne V] detected in their JWST/NIRSpec spectra may be harboring AGN with luminosities of order $L_{\rm bol} > 10^{45}$ erg s^{-1}, based on a newly established scaling relation that links $L_{\rm [Ne\,V]}$ to $L_{\rm bol}$, calibrated using a highly complete, low-redshift sample of narrow-line AGN. We further argued that such AGN, selected solely on their [Ne V] emission, could be powered by SMBHs with masses of at least $M_{\rm BH} \gtrsim 10^7 \, M_\odot$ if they are accreting at Eddington-limited rates, or larger if they their accretion rates are lower. Combined with the available estimates of the stellar masses of their hosts, we derived extremely high BH-to-host mass ratios of $M_{\rm BH}/M_{\rm host} \approx 0.1$–1.

The only way to avoid this latter conclusion is if (i) these AGN are accreting at rates significantly higher than the Eddington limit—which we think would be interesting given its potential significance to early SMBH growth and the rarity of evidence for such accretion; (ii) their hosts include an exceptionally significant contribution from accreting IMBHs (again, a novelty; see C24); (iii) their host masses are exceptionally underestimated—which we think is unlikely, but may have implications for other high-redshift galaxies for which M_* is deduced in similar ways; and/or (iv) they are exceptionally luminous in the extreme-UV/soft X-ray regime, compared with other parts of their AGN-related SEDs (i.e., UV-optical and/or hard X-rays), in a way that is not observed in low-redshift AGN with similar high-ionization line emission.

Whatever may be the case for the two objects we studied, our analysis exemplifies how deep spectroscopy of galaxies in the early Universe, aiming for detecting certain (rare and weak) emission lines, can yield insights regarding the earliest phases of SMBH growth.

[19] Note that this marginal detection required 72 hr of on-source integration.

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