

OPEN ACCESS

The Quasar SDSS J140821.67+025733.2 Does Not Contain a 196 Billion Solar Mass Black Hole

Hengxiao Guo¹  and Aaron J. Barth¹ 

Published January 2021 • © 2021. The Author(s). Published by the American Astronomical Society.

Research Notes of the AAS, Volume 5, Number 1

Citation Hengxiao Guo and Aaron J. Barth 2021 *Res. Notes AAS* 5 2

¹ Department of Physics and Astronomy, 4129 Frederick Reines Hall, University of California, Irvine, CA 92697-4575, USA

Hengxiao Guo  <https://orcid.org/0000-0001-8416-7059>

Aaron J. Barth  <https://orcid.org/0000-0002-3026-0562>

Received December 2020

Accepted January 2021

Published January 2021

<https://doi.org/10.3847/2515-5172/abd7f9>

Black hole physics; Supermassive black holes; Quasars

 Journal RSS

Sign up for new issue notifications

Create citation alert

Abstract

The black hole in the quasar SDSS J140821.67+025733.2 has been reported to have a mass of $1.96 \times 10^{11} M_{\odot}$ based on measurements from the SDSS DR12 Quasar Catalog. As a result, references to this object as the most massive known black hole in the universe have recently appeared in scientific articles and in popular media including Wikipedia. We show that this extremely high mass estimate is incorrect, resulting from a faulty measurement of the C IV line width. From a new measurement of the Mg II line width, we derive an estimate of $M_{\text{BH}} \approx 8 \times 10^9 M_{\odot}$.

Export citation and abstract

[BibTeX](#)

[RIS](#)

◀ **Previous** article in issue

Next article in issue ▶



1. Introduction

What is the most massive known black hole (BH) in the universe? This answer to this question is relevant for constraining BH growth models (Natarajan & Treister 2009; King 2016) and is also of interest in popular astronomy. The largest BH mass published in recent work is that of the quasar SDSS J140821.67+025733.2 (J1408+0257 hereafter) at $z=2.055$. In the Kozłowski (2017) catalog of 280,000 quasar BH mass estimates, J1408+0257 is listed as having $M_{\text{BH}}=1.96 \times 10^{11} M_{\odot}$. This is an extremely high value, five times greater than the most massive BH detected by stellar dynamics (Mehrgan et al. 2019). The extraordinary BH mass reported for J1408+0257 has recently been used as a constraint on dark matter models (Zu et al. 2020) and has been featured in popular web sites including an article about the quasar on Wikipedia. However, other published estimates for this object are much lower: for example, Shen et al. (2011) find $M_{\text{BH}}=(4-6) \times 10^9 M_{\odot}$. To check whether the extreme mass estimate from Kozłowski (2017) is plausible, we reexamined the quasar's spectrum and mass determination.

2. The SDSS Spectrum and BH Mass

Quasar J1408+0257 has been observed spectroscopically twice by the Sloan Digital Sky Survey (SDSS) and its properties are tabulated in the SDSS Data Release 7 (Schneider et al. 2010; Shen et al. 2011) and Data Release 12 (DR12Q; Pâris et al. 2017) Quasar Catalogs. Quasar BH masses are determined using the single-epoch virial estimator,

$$\log \left(\frac{M_{\text{BH}}}{M_{\odot}} \right) = a + b \log \left(\frac{\lambda L_{\lambda}}{10^{44} \text{ erg s}^{-1}} \right) + 2 \log \left(\frac{\text{FWHM}}{\text{km s}^{-1}} \right), \quad (1)$$

where FWHM refers to the width of either MgII or CIV and λL_{λ} is the continuum luminosity at either 1350 or 3000 Å, along with empirical determinations of a and b for MgII and CIV (McLure & Dunlop 2004; Vestergaard & Peterson 2006). The Kozłowski (2017) BH masses are based on DR12Q data for MgII and/or CIV, and Kozłowski (2017) notes that the CIV-based masses must be used with caution because of known problems with CIV as a virial mass indicator.

For J1408+0257, DR12Q does not include FWHM (MgII), and the mass estimate is based on the DR12Q value of FWHM (CIV)=22965 kms⁻¹, an extreme value that ranks in the uppermost 0.05 percentile of CIV line widths in the catalog. For comparison, Shen et al. (2011) list FWHM (CIV) = 6820±3581 kms⁻¹.

Kozłowski (2017) noted that the CIV widths in the Shen et al. (2011) catalog, which were measured via multicomponent fits, appeared to be more accurate than those in DR12Q, which were determined from a principal component analysis. To correct for the disagreement between these two catalogs, Kozłowski (2017, see their Equation (2)) introduced an empirical transformation to bring the DR12Q FWHM (CIV) values into statistical agreement with DR7 values for objects in common between the two catalogs. This transformation converted the already extreme DR12Q value of FWHM (CIV) into a revised width of 39,694 kms⁻¹. Combined with $L_{1350}=10^{46.744} \text{ erg s}^{-1}$, this yields $M_{\text{BH}}=1.96 \times 10^{11} M_{\odot}$, which Kozłowski (2017) noted as the largest BH mass in the DR12Q sample.

Given the large disagreement between the DR7 and DR12Q data for J1408+0257, a reassessment of the DR12 measurements is warranted. Figure 1 displays the SDSS BOSS spectrum. The quasar's spectrum is somewhat unusual,

an automated measurement algorithm would encounter difficulty in measuring its emission-line parameters.

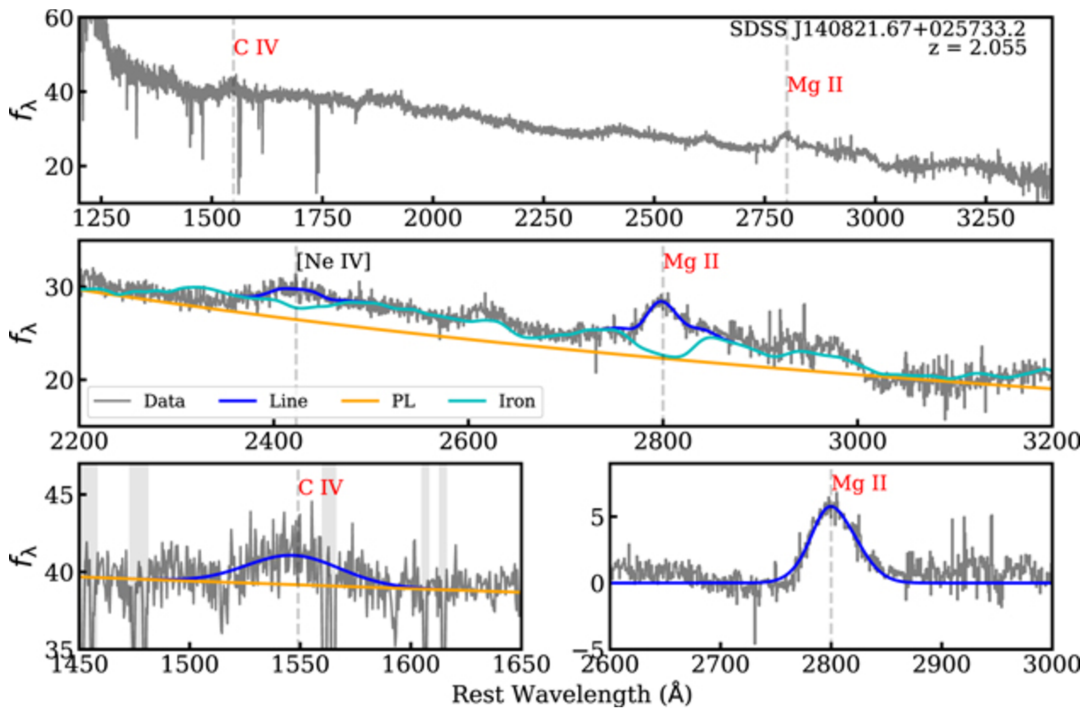


Figure 1. Top: the extinction-corrected BOSS spectrum. Middle and Bottom left: the spectral fit for the C IV and Mg II regions. Bottom right: continuum-subtracted Mg II profile and fit. The light gray bands denote the masked narrow absorption lines.

To carry out new measurements, we fit a spectral model to the C IV and Mg II regions (rest wavelengths 1430–1800 and 2200–3200 Å, respectively) using the software PyQSOFit (Guo et al. 2018). The model is a linear combination of a power-law continuum, a broadened Fe II emission template (Vestergaard & Wilkes 2001), and single Gaussians for the emission lines. Figure 1 displays the fits to these two spectral regions. The derived continuum luminosity is $L_{1350 \sim 1450} = 10^{46.72 \pm 0.01} \text{ erg s}^{-1}$ and $L_{3000} = 10^{46.76 \pm 0.02} \text{ erg s}^{-1}$, consistent with the values used by Kozłowski (2017). We obtain $\text{FWHM} = 9578 \pm 1508 \text{ km s}^{-1}$ and $5195 \pm 112 \text{ km s}^{-1}$ for C IV and Mg II, respectively, where the uncertainties are estimated by carrying out 100 Monte Carlo simulations with Gaussian random noise added. The much larger C IV line width reported in DR12Q is incompatible with the data.

We can then estimate M_{BH} using Equation (1). Following Kozłowski (2017), we adopt $(a, b) = (0.66, 0.53)$ for C IV (Vestergaard & Peterson 2006) and $(a, b) = (0.74, 0.62)$ for Mg II (McLure & Dunlop 2004). This yields $M_{\text{BH, Mg II}} = 10^{9.89 \pm 0.02} M_{\odot}$ and $M_{\text{BH, C IV}} = 10^{10.10 \pm 0.13} M_{\odot}$. The uncertainties are 1σ statistical values resulting from the propagated measurement uncertainties; systematic errors are not included but may be ~ 0.6 dex (Vestergaard & Peterson 2006).

We take $M_{\text{BH, Mg II}}$ as the best estimate since it should be more reliable than the C IV-based mass, considering issues such as outflows that are known to affect the C IV line (as described by Kozłowski (2017)). Further corrections to $M_{\text{BH, C IV}}$ can be applied (e.g., Coatman et al. 2017) but we do not consider these effects here. This revised BH mass estimate is similar to the values ($M_{\text{BH, Mg II}} = 10^{9.6} M_{\odot}$, $M_{\text{BH, C IV}} = 10^{9.77} M_{\odot}$) from Shen et al. (2011), but it is a factor of ~ 25 smaller than that from Kozłowski (2017), owing to the large difference in C IV line widths used to compute M_{BH} . We also visually inspected the spectra of objects with $\text{FWHM}(\text{C IV}) > 30,000 \text{ km s}^{-1}$ in DR12Q. All appeared to be normal quasars with line widths $< 10,000 \text{ km s}^{-1}$, suggesting that C IV-based BH masses for other objects with extremely large line widths in

3. Conclusions

Our measurement of the MgII width in the quasar SDSS J1408+0257 indicates that it contains a highly massive BH with $M_{\text{BH}} \approx 8 \times 10^9 M_{\odot}$, but this value is well below the largest BH masses detected with stellar dynamics. The extreme value of $1.96 \times 10^{11} M_{\odot}$ found in earlier work was simply the result of an incorrect measurement of its CIV width in the DR12Q catalog, amplified by a correction method that exacerbated the overestimate of mass. This case serves as a reminder that caution is warranted when deriving physical conclusions from large catalogs of automated measurements, particularly for objects with unusual or extreme properties.

This work has been supported by NSF grant AST-1907290.

Facility: Sloan. -

-
- [↑](#) Coatman L., Hewett P. C., Banerji M. *et al* 2017 *MNRAS* **465** 2120
[Crossref](#) [ADS](#) [Google Scholar](#)

 - [↑](#) Guo H., Shen Y. and Wang S. 2018 *PyQSOFit: Python Code to Fit the Spectrum of Quasars, Astrophysics Source Code Library* ascl:1809.008
[Google Scholar](#)

 - [↑](#) King A. 2016 *MNRAS* **456** L109
[Crossref](#) [ADS](#) [Google Scholar](#)

 - [↑](#) Kozłowski S. 2017 *ApJS* **228** 9
[IOPscience](#) (<https://iopscience.iop.org/0067-0049/228/1/9>) [Google Scholar](#)

 - [↑](#) McLure R. J. and Dunlop J. S. 2004 *MNRAS* **352** 1390
[Crossref](#) [ADS](#) [Google Scholar](#)

 - [↑](#) Mehrgan K., Thomas J., Saglia R. *et al* 2019 *ApJ* **887** 195
[IOPscience](#) (<https://iopscience.iop.org/0004-637X/887/2/195>) [ADS](#) [Google Scholar](#)

 - [↑](#) Natarajan P. and Treister E. 2009 *MNRAS* **393** 838
[Crossref](#) [ADS](#) [Google Scholar](#)

 - [↑](#) Pâris I., Petitjean P., Ross N. P. *et al* 2017 *A&A* **597** A79
[Crossref](#) [ADS](#) [Google Scholar](#)

 - [↑](#) Schneider D. P., Richards G. T., Hall P. B. *et al* 2010 *AJ* **139** 2360
[IOPscience](#) (<https://iopscience.iop.org/1538-3881/139/6/2360>) [ADS](#) [Google Scholar](#)

 - [↑](#) Shen Y., Richards G. T., Strauss M. A. *et al* 2011 *ApJS* **194** 45
[IOPscience](#) (<https://iopscience.iop.org/0067-0049/194/2/45>) [ADS](#) [Google Scholar](#)

 - [↑](#) Vestergaard M. and Peterson B. M. 2006 *ApJ* **641** 689
[IOPscience](#) (<https://iopscience.iop.org/0004-637X/641/2/689>) [ADS](#) [Google Scholar](#)



[↑](#) Zu L., Feng L., Yuan Q. and Fan Y.-Z. 2020 *EPJP* **135** 709

[Crossref](#)

[ADS](#)

[Google Scholar](#)

Export references:

[BibTeX](#)

[RIS](#)

