Reconstructing Quasar Spectra and Measuring the Lyα Forest with SPENDERQ

Anonymous Author(s)
Affiliation
Address
`email`

Abstract

Quasar spectra carry the imprint of foreground intergalactic medium (IGM) through absorption systems. In particular, absorption caused by neutral hydrogen gas, the "Lyα forest," is a key spectroscopic tracer for cosmological analyses used to measure cosmic expansion and test physics beyond the standard model. Despite their importance, current methods for measuring Lyα absorption require making strong assumptions on the shape of the intrinsic quasar continuum that bias Lyα analyses. We present SPENDERQ, a ML-based approach for reconstructing intrinsic quasar spectra and measuring the Lyα forest from observations. SPENDERQ uses the SPENDER spectrum autoencoder to learn a compact and redshift-invariant latent encoding of quasar spectra, combined with an iterative procedure to identify and mask absorption regions in the spectra. We apply SPENDERQ to 28,000 quasar spectra in the Early Data Release of the Dark Energy Spectroscopic Instrument and illustrate that it can reconstruct the intrinsic spectra of quasars, including the detailed features of broad emission lines (e.g., Lyβ, Lyα, SiIV, CIV, and CIII). Our method ignores dense absorption features in the Lyα forest and recovers the quasar continuum. SPENDERQ provides a new data-driven approach for unbiased Lyα forest measurements in cosmological, quasar, and IGM studies.

1 Introduction

Quasars or quasi-stellar objects (QSOs) are luminous active galactic nuclei fueled by gravitational accretion onto supermassive black holes at the centers of galaxies. As the most luminous extragalactic sources in the known universe, quasars are one of the main ways to study the cosmic large-scale structure in the early universe. Their spectra serve as cosmic lighthouses that enable us to probe the properties of the early universe through absorption from objects in their foreground. In particular, neutral hydrogen in the Inter-Galactic Medium (IGM) imprints a dense collection of absorption lines, blueward of the $\lambda = 1216$ Å Lyα emission line, that make up the so-called "Lyα forest".

As a tracer of neutral hydrogen, the Lyα forest traces the matter distribution and clustering in the Universe. On large cosmological scales, this enables us to use the Lyα forest to infer the expansion history of the Universe, using the Baryon Acoustic Oscillation feature in the clustering as a "standard ruler" [e.g., 1–4]. They serve as an essential tracer over the redshift range $2 < z < 3$, where we currently do not have other reliable spectroscopic probes. Lyα absorption also serves as a unique probe of clustering on the smallest scales, down to few megaparsecs. This makes the Lyα forest one of the most promising tracers for precisely testing physics beyond the standard model: e.g., measuring neutrino mass [e.g., 3] and probing the dark sector [e.g., 5, 6]. Outside of cosmology, Lyα forests also enable us to probe properties of the IGM (its temperature, density, and ionization state) in the early Universe. Given their broad cosmological and astrophysical applications, the Lyα forest is one of the main tracers that will be observed by upcoming major spectroscopic galaxy surveys, such as the Dark Energy Spectroscopic Instrument [DESI; 7, 8].

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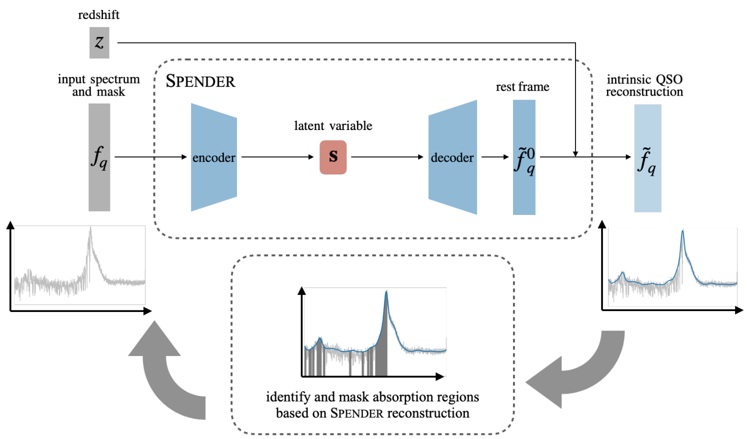

Figure 1: SPENDERQ combines the SPENDER autoencoder with an iterative procedure for masking absorption regions. It uses SPENDER to learn a compact and redshift-invariant latent encoding and reconstruction of the intrinsic quasar spectra (top). Then, it uses the reconstruction to mask absorption regions in the spectra for the next iteration (bottom). As additional absorption regions are masked with each iteration, SPENDERQ reconstructions converge to the intrinsic quasar spectra.

A critical bottleneck in any Lyα analysis is the fact that accurate knowledge of the original intrinsic quasar spectra is necessary to measure the Lyα forest and the full amplitude of its absorption. Yet, we only observe quasar spectra with Lyα absorption. As a result, the quasar continuum must be inferred from the absorbed spectra with only pieces of the unabsorbed spectra. This is only made more difficult by the higher neutral hydrogen fraction and density at higher redshifts. For some quasars, we observe little to none of their intrinsic spectra.

The current state-of-the-art[1] entirely forgoes deriving the intrinsic quasar spectra, $C_q(\lambda)$. Instead, it derives the product $\overline{F}(\lambda)C_q(\lambda)$, i.e. the intrinsic spectrum multiplied by the mean transmission fraction, which corresponds to expected flux of the continuum, and It further assumes that the product equates to a universal function in rest-frame, $\overline{C}(\lambda/(1+z_q))$, and a polynomial with two free parameters (a_q, b_q): $\overline{F}(\lambda)C_q(\lambda) = \overline{C}(\lambda/(1+z_q))(a_q + b_q \log \lambda)$ [4]. This assumption severely restricts the shape of the quasar continuum in the Lyα region. Moreover, the procedure has been shown to bias the flux transmission field, $\delta_q(\lambda) = f_q(\lambda)/(\overline{F}(\lambda)C_q(\lambda)) - 1$, and, thus, Ly$\alpha$ clustering measurements [e.g., 9–14].

We present SPENDERQ, a new method for reconstructing the intrinsic quasar spectra and measuring the Lyα forest. SPENDERQ leverages the SPENDER autoencoder architecture [15] to learn compact and redshift-invariant latent space representations of intrinsic quasar spectra. Since the foreground IGM are not correlated with the background quasars, SPENDER is especially well-suited for being insensitive to foregrounds and reconstructing the intrinsic quasar spectra. SPENDERQ further combines SPENDER with an iterative procedure for identifying and masking Lyα absorption to further improve the fidelity of our reconstructions and Lyα forest measurements. Our method is entirely data-driven and does not require any calibration on simulated data, where limitations in the simulations can degrade and bias performance. Moreover, our method relaxes current assumptions on the shape of the quasar continuum to produce unbiased Lyα forest measurements.

2 Data

We use quasar spectra observed during the DESI Survey Validation (SV) campaign, made publicly available in the Early Data Release [16][2]. SV was conducted before the start of the main DESI survey to evaluate its scientific program [17]. The data includes spectra observed during all phases of SV. The quasar spectra were reduced using the Fuji version of the DESI spectroscopic data reduction pipeline [18]. The spectra span the wavelength range of 3600 - 9824 Å with 7,781 spectral elements.

[1] picca: (https://github.com/igmhub/picca/)
[2] https://data.desi.lbl.gov/doc/releases/edr/vac/qso/

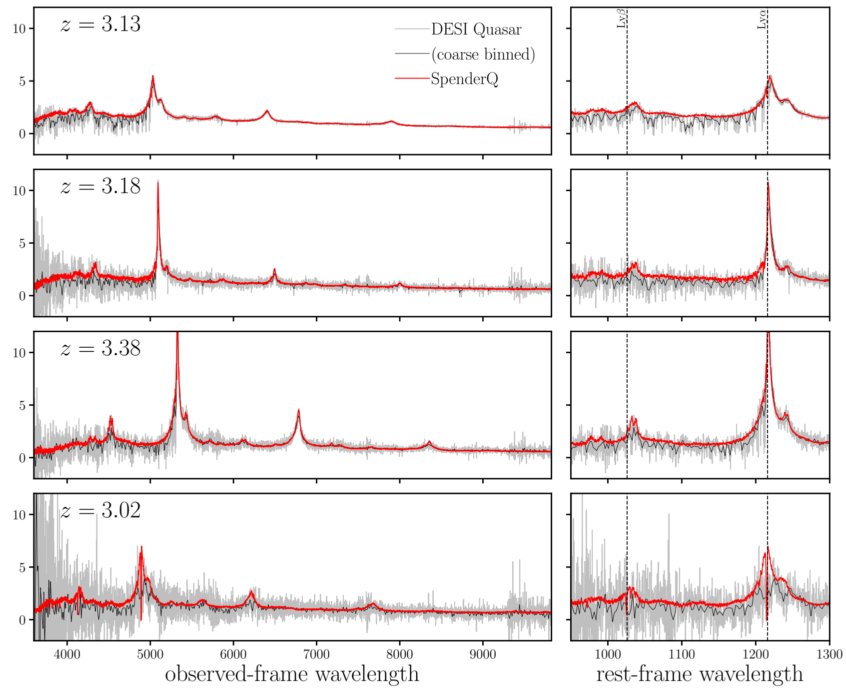

Figure 2: SPENDERQ reconstructed intrinsic quasar spectra (red) compared to the observed DESI quasar spectra (gray). The left panels present the full spectra over the observed-frame wavelength. The right panels present the Lyα region in rest-frame wavelength; we mark the Lyα and Lyβ wavelengths in black dashed. We include a coarsely rebinned quasar spectra in black for reference. We plot randomly selected high redshift, $z > 3$, quasars with higher signal-to-noise to showcase the full Lyα region and for clarity.

To construct our sample of quasar spectra, we start with the extended quasar catalog designed for the DESI Lyα group[3]. It contains all objects detected as quasar from all surveys in the EDR and from both the bright and dark-time programs. Hence, it includes quasar targets as well as non-quasar targets, which were spectroscopically classified as quasars. The catalog pipeline is described in [19] and validated in [20]. We limit our quasar spectra to those with measured spectroscopic redshifts between the range $2.1 < z < 3.5$. This selection ensures that all of the quasars have some wavelength overlap. In total, our sample consists of 28,435 quasar spectra.

Before applying SPENDERQ, we normalize the spectra to reduce their dynamical range. We divide them by the median spectral flux within the rest-frame wavelength λ = 1600 - 1800 Å, which roughly corresponds to the wavelengths between the CIV and CII emission lines, where there is little absorption overall from CIII.

3 Method

SPENDERQ uses the SPENDER autoencoder within an iterative framework for improving the fidelity of the intrinsic quasar spectrum reconstruction. We use SPENDER to learn a compact and redshift-invariant encoding of the intrinsic quasar spectra. We use the same architecture as described in [15] with a 10-dimensional latent space and a rest-frame model spans the wavelength λ = 800 - 3170 Å with 9,780 spectral elements.

The foreground IGM does not correlated with the background quasars, which means that the absorption features in the spectra do not correlate with the intrinsic quasar spectra. In principle, this implies that SPENDER will not learn the absorption features since the absorptions are effectively random artifacts in the spectra. However, SPENDER, on its own, will learn the average *observed* spectrum,

[3] `https://data.desi.lbl.gov/public/edr/vac/edr/qso/v1.0/QSO_cat_fuji_healpix_for_lyalpha.fits`

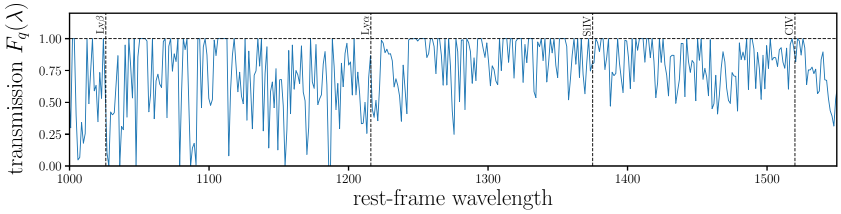

Figure 3: Transmission spectrum, $F_q(\lambda)$, estimated using SPENDERQ in rest-frame for the same quasars as the top panel in Fig. 2. We mark the wavelengths of the Lyβ, Lyα, SiIV, and CIV emission lines for reference. $F_q(\lambda)$ indicates the redshift and amount of IGM in the foreground of the observed quasar. Accurate $F_q(\lambda)$ is necessary for unbiased Lyα cosmological analyses and will improve studies of both quasars and IGM.

including absorption, and therefore underestimate the overall quasar continuum because absorption, treated as random noise, is neither additive nor does it have a mean of zero.

To account for this effect, we combine SPENDER with an iterative procedure for identifying spectral elements with noticeable absorption. At every iteration and for each observed quasar, we coarsely rebin its observed spectrum, $f_q(\lambda)$, and the corresponding SPENDER reconstruction, $\tilde{f}_q(\lambda)$. Then, we identify spectral elements where f_q lies significantly below $\tilde{f}_q$. For the Lyα region, $\lambda < 1216(1+z_q)$ Å, we use a threshold of 1.5σ, where σ corresponds to the observed uncertainty. Above $\lambda > 1216(1+z_q)$ Å, we use a threshold of 3σ. We use a lower threshold for the Lyα region as it has a higher density of absorption. If the observed spectrum lies more than the threshold below the reconstruction, the spectral elements are masked, which means that we set their weights to zero in the MSE loss calculation of the the next training epoch. We repeat the iterations until the reconstructed quasar spectra converge to an estimate of the intrinsic spectrum $\widetilde{C}_q(\lambda)$, which we find to occur after roughly four iterations. We present a schematic illustration of the SPENDERQ approach and architecture in Fig. 1.

4 Results & Discussion

We present the reconstructed intrinsic quasar spectra derived using SPENDERQ in Fig. 2. We compare the SPENDERQ reconstructions (red) to the observed DESI quasar spectra (gray). The spectra and reconstructions are plotted over the full observed-frame wavelength range in the left panels while the right panels focus on the Lyα region in rest-frame wavelength. All spectra are normalized (Section 2). For reference, we mark the Lyα and Lyβ emission line wavelengths in black dashed and include a coarsely rebinned spectra in black. The quasars are randomly selected $z > 3$ quasars with higher signal-to-noise to showcase the full Lyα region and clarity.

Overall, SPENDERQ accurately reconstructs the quasar spectra over the full observed wavelength range. This is especially clear above the Lyα region ($\lambda \gtrsim 1200(1+z)$ Å), where absorption features are rarer. The broad emission lines of Lyα, SiIV, CIV, and CIII are well reconstructed in all of the selected quasars, even the asymmetric profiles of Lyα. In the Lyα region, while quantitative validation is limited without knowing the true continuum, the SPENDERQ reconstructions successfully ignore absorption features in the spectra. This is especially evident in a comparison with the coarsely binned spectra. Even among the few quasars in Fig. 2, the reconstructed quasar continuum shows significant variation, which suggest that the first-order polynomial fit in the current methods is insufficient.

We also present an estimated transmission spectrum, $F_q(\lambda) = f_q(\lambda)/\widetilde{C}_q(\lambda)$, as the primary quantity of interest for IGM studies, in Fig. 3. While we do not know the true transmission spectrum along this sightline, its reconstruction is qualitatively plausible. In subsequent work, we will apply SPENDERQ to state-of-the-art simulated quasar spectra and validate the performance of SPENDERQ with quasar spectra for which we assume to know the ground truth. Afterward, we will apply it to DESI quasar spectra beyond the EDR. DESI has recently completed 3 years of observations and will soon publicly release its Year 1 observations. This dataset will include >130,000 quasar spectra, a sample >4× larger than the one used in this work. The significantly large sample will further improve SPENDERQ performance.

References

[1] N. G. Busca, T. Delubac, J. Rich, S. Bailey, A. Font-Ribera, D. Kirkby, J. M. Le Goff, M. M. Pieri, A. Slosar, É. Aubourg, J. E. Bautista, D. Bizyaev, M. Blomqvist, A. S. Bolton, J. Bovy, H. Brewington, A. Borde, J. Brinkmann, B. Carithers, R. A. C. Croft, K. S. Dawson, G. Ebelke, D. J. Eisenstein, J. C. Hamilton, S. Ho, D. W. Hogg, K. Honscheid, K. G. Lee, B. Lundgren, E. Malanushenko, V. Malanushenko, D. Margala, C. Maraston, K. Mehta, J. Miralda-Escudé, A. D. Myers, R. C. Nichol, P. Noterdaeme, M. D. Olmstead, D. Oravetz, N. Palanque-Delabrouille, K. Pan, I. Pâris, W. J. Percival, P. Petitjean, N. A. Roe, E. Rollinde, N. P. Ross, G. Rossi, D. J. Schlegel, D. P. Schneider, A. Shelden, E. S. Sheldon, A. Simmons, S. Snedden, J. L. Tinker, M. Viel, B. A. Weaver, D. H. Weinberg, M. White, C. Yèche, and D. G. York. Baryon acoustic oscillations in the Lyα forest of BOSS quasars. , 552:A96, April 2013.

[2] Anže Slosar, Vid Iršič, David Kirkby, Stephen Bailey, Nicolás G. Busca, Timothée Delubac, James Rich, Éric Aubourg, Julian E. Bautista, Vaishali Bhardwaj, Michael Blomqvist, Adam S. Bolton, Jo Bovy, Joel Brownstein, Bill Carithers, Rupert A. C. Croft, Kyle S. Dawson, Andreu Font-Ribera, J. M. Le Goff, Shirley Ho, Klaus Honscheid, Khee-Gan Lee, Daniel Margala, Patrick McDonald, Bumbarija Medolin, Jordi Miralda-Escudé, Adam D. Myers, Robert C. Nichol, Pasquier Noterdaeme, Nathalie Palanque-Delabrouille, Isabelle Pâris, Patrick Petitjean, Matthew M. Pieri, Yodovina Piškur, Natalie A. Roe, Nicholas P. Ross, Graziano Rossi, David J. Schlegel, Donald P. Schneider, Nao Suzuki, Erin S. Sheldon, Uroš Seljak, Matteo Viel, David H. Weinberg, and Christophe Yèche. Measurement of baryon acoustic oscillations in the Lyman-α forest fluctuations in BOSS data release 9. , 2013(4):026, April 2013.

[3] Andreu Font-Ribera, Patrick McDonald, Nick Mostek, Beth A. Reid, Hee-Jong Seo, and Anže Slosar. DESI and other Dark Energy experiments in the era of neutrino mass measurements. *Journal of Cosmology and Astro-Particle Physics*, 05:023, May 2014.

[4] Hélion du Mas des Bourboux, James Rich, Andreu Font-Ribera, Victoria de Sainte Agathe, James Farr, Thomas Etourneau, Jean-Marc Le Goff, Andrei Cuceu, Christophe Balland, Julian E. Bautista, Michael Blomqvist, Jonathan Brinkmann, Joel R. Brownstein, Solène Chabanier, Edmond Chaussidon, Kyle Dawson, Alma X. González-Morales, Julien Guy, Brad W. Lyke, Axel de la Macorra, Eva-Maria Mueller, Adam D. Myers, Christian Nitschelm, Andrea Muñoz Gutiérrez, Nathalie Palanque-Delabrouille, James Parker, Will J. Percival, Ignasi Pérez-Ràfols, Patrick Petitjean, Matthew M. Pieri, Corentin Ravoux, Graziano Rossi, Donald P. Schneider, Hee-Jong Seo, Anže Slosar, Julianna Stermer, M. Vivek, Christophe Yèche, and Samantha Youles. The Completed SDSS-IV Extended Baryon Oscillation Spectroscopic Survey: Baryon Acoustic Oscillations with Lyα Forests. , 901(2):153, October 2020.

[5] Hengameh Bagherian, Melissa Joseph, Martin Schmaltz, and Eashwar N. Sivarajan. Stepping into the Forest: Confronting Interacting Radiation Models for the Hubble Tension with Lyman-α Data. *arXiv e-prints*, page arXiv:2405.17554, May 2024.

[6] Vid Iršič, Matteo Viel, Martin G. Haehnelt, James S. Bolton, Margherita Molaro, Ewald Puchwein, Elisa Boera, George D. Becker, Prakash Gaikwad, Laura C. Keating, and Girish Kulkarni. Unveiling dark matter free streaming at the smallest scales with the high redshift Lyman-alpha forest. , 109(4):043511, February 2024.

[7] DESI Collaboration, Amir Aghamousa, Jessica Aguilar, Steve Ahlen, Shadab Alam, Lori E. Allen, Carlos Allende Prieto, James Annis, Stephen Bailey, Christophe Balland, Otger Ballester, Charles Baltay, Lucas Beaufore, Chris Bebek, Timothy C. Beers, Eric F. Bell, José Luis Bernal, Robert Besuner, Florian Beutler, Chris Blake, Hannes Bleuler, Michael Blomqvist, Robert Blum, Adam S. Bolton, Cesar Briceno, David Brooks, Joel R. Brownstein, Elizabeth Buckley-Geer, Angela Burden, Etienne Burtin, Nicolas G. Busca, Robert N. Cahn, Yan-Chuan Cai, Laia Cardiel-Sas, Raymond G. Carlberg, Pierre-Henri Carton, Ricard Casas, Francisco J. Castander, Jorge L. Cervantes-Cota, Todd M. Claybaugh, Madeline Close, Carl T. Coker, Shaun Cole, Johan Comparat, Andrew P. Cooper, M.-C. Cousinou, Martin Crocce, Jean-Gabriel Cuby, Daniel P. Cunningham, Tamara M. Davis, Kyle S. Dawson, Axel de la Macorra, Juan De Vicente, Timothée Delubac, Mark Derwent, Arjun Dey, Govinda Dhungana, Zhejie Ding, Peter Doel, Yutong T. Duan, Anne Ealet, Jerry Edelstein, Sarah Eftekharzadeh, Daniel J. Eisenstein, Ann Elliott, Stéphanie Escoffier, Matthew Evatt, Parker Fagrelius, Xiaohui Fan, Kevin Fanning, Arya

Farahi, Jay Farihi, Ginevra Favole, Yu Feng, Enrique Fernandez, Joseph R. Findlay, Douglas P. Finkbeiner, Michael J. Fitzpatrick, Brenna Flaugher, Samuel Flender, Andreu Font-Ribera, Jaime E. Forero-Romero, Pablo Fosalba, Carlos S. Frenk, Michele Fumagalli, Boris T. Gaensicke, Giuseppe Gallo, Juan Garcia-Bellido, Enrique Gaztanaga, Nicola Pietro Gentile Fusillo, Terry Gerard, Irena Gershkovich, Tommaso Giannantonio, Denis Gillet, Guillermo Gonzalez-de-Rivera, Violeta Gonzalez-Perez, Shelby Gott, Or Graur, Gaston Gutierrez, Julien Guy, Salman Habib, Henry Heetderks, Ian Heetderks, Katrin Heitmann, Wojciech A. Hellwing, David A. Herrera, Shirley Ho, Stephen Holland, Klaus Honscheid, Eric Huff, Timothy A. Hutchinson, Dragan Huterer, Ho Seong Hwang, Joseph Maria Illa Laguna, Yuzo Ishikawa, Dianna Jacobs, Niall Jeffrey, Patrick Jelinsky, Elise Jennings, Linhua Jiang, Jorge Jimenez, Jennifer Johnson, Richard Joyce, Eric Jullo, Stéphanie Juneau, Sami Kama, Armin Karcher, Sonia Karkar, Robert Kehoe, Noble Kennamer, Stephen Kent, Martin Kilbinger, Alex G. Kim, David Kirkby, Theodore Kisner, Ellie Kitanidis, Jean-Paul Kneib, Sergey Koposov, Eve Kovacs, Kazuya Koyama, Anthony Kremin, Richard Kron, Luzius Kronig, Andrea Kueter-Young, Cedric G. Lacey, Robin Lafever, Ofer Lahav, Andrew Lambert, Michael Lampton, Martin Landriau, Dustin Lang, Tod R. Lauer, Jean-Marc Le Goff, Laurent Le Guillou, Auguste Le Van Suu, Jae Hyeon Lee, Su-Jeong Lee, Daniela Leitner, Michael Lesser, Michael E. Levi, Benjamin L'Huillier, Baojiu Li, Ming Liang, Huan Lin, Eric Linder, Sarah R. Loebman, Zarija Lukić, Jun Ma, Niall MacCrann, Christophe Magneville, Laleh Makarem, Marc Manera, Christopher J. Manser, Robert Marshall, Paul Martini, Richard Massey, Thomas Matheson, Jeremy McCauley, Patrick McDonald, Ian D. McGreer, Aaron Meisner, Nigel Metcalfe, Timothy N. Miller, Ramon Miquel, John Moustakas, Adam Myers, Milind Naik, Jeffrey A. Newman, Robert C. Nichol, Andrina Nicola, Luiz Nicolati da Costa, Jundan Nie, Gustavo Niz, Peder Norberg, Brian Nord, Dara Norman, Peter Nugent, Thomas O'Brien, Minji Oh, Knut A. G. Olsen, Cristobal Padilla, Hamsa Padmanabhan, Nikhil Padmanabhan, Nathalie Palanque-Delabrouille, Antonella Palmese, Daniel Pappalardo, Isabelle Pâris, Changbom Park, Anna Patej, John A. Peacock, Hiranya V. Peiris, Xiyan Peng, Will J. Percival, Sandrine Perruchot, Matthew M. Pieri, Richard Pogge, Jennifer E. Pollack, Claire Poppett, Francisco Prada, Abhishek Prakash, Ronald G. Probst, David Rabinowitz, Anand Raichoor, Chang Hee Ree, Alexandre Refregier, Xavier Regal, Beth Reid, Kevin Reil, Mehdi Rezaie, Constance M. Rockosi, Natalie Roe, Samuel Ronayette, Aaron Roodman, Ashley J. Ross, Nicholas P. Ross, Graziano Rossi, Eduardo Rozo, Vanina Ruhlmann-Kleider, Eli S. Rykoff, Cristiano Sabiu, Lado Samushia, Eusebio Sanchez, Javier Sanchez, David J. Schlegel, Michael Schneider, Michael Schubnell, Aurélia Secroun, Uros Seljak, Hee-Jong Seo, Santiago Serrano, Arman Shafieloo, Huanyuan Shan, Ray Sharples, Michael J. Sholl, William V. Shourt, Joseph H. Silber, David R. Silva, Martin M. Sirk, Anze Slosar, Alex Smith, George F. Smoot, Debopam Som, Yong-Seon Song, David Sprayberry, Ryan Staten, Andy Stefanik, Gregory Tarle, Suk Sien Tie, Jeremy L. Tinker, Rita Tojeiro, Francisco Valdes, Octavio Valenzuela, Monica Valluri, Mariana Vargas-Magana, Licia Verde, Alistair R. Walker, Jiali Wang, Yuting Wang, Benjamin A. Weaver, Curtis Weaverdyck, Risa H. Wechsler, David H. Weinberg, Martin White, Qian Yang, Christophe Yeche, Tianmeng Zhang, Gong-Bo Zhao, Yi Zheng, Xu Zhou, Zhimin Zhou, Yaling Zhu, Hu Zou, and Ying Zu. The DESI Experiment Part I: Science,Targeting, and Survey Design. *arXiv:1611.00036 [astro-ph]*, October 2016.

[8] DESI Collaboration, Amir Aghamousa, Jessica Aguilar, Steve Ahlen, Shadab Alam, Lori E. Allen, Carlos Allende Prieto, James Annis, Stephen Bailey, Christophe Balland, Otger Ballester, Charles Baltay, Lucas Beaufore, Chris Bebek, Timothy C. Beers, Eric F. Bell, José Luis Bernal, Robert Besuner, Florian Beutler, Chris Blake, Hannes Bleuler, Michael Blomqvist, Robert Blum, Adam S. Bolton, Cesar Briceno, David Brooks, Joel R. Brownstein, Elizabeth Buckley-Geer, Angela Burden, Etienne Burtin, Nicolas G. Busca, Robert N. Cahn, Yan-Chuan Cai, Laia Cardiel-Sas, Raymond G. Carlberg, Pierre-Henri Carton, Ricard Casas, Francisco J. Castander, Jorge L. Cervantes-Cota, Todd M. Claybaugh, Madeline Close, Carl T. Coker, Shaun Cole, Johan Comparat, Andrew P. Cooper, M.-C. Cousinou, Martin Crocce, Jean-Gabriel Cuby, Daniel P. Cunningham, Tamara M. Davis, Kyle S. Dawson, Axel de la Macorra, Juan De Vicente, Timothée Delubac, Mark Derwent, Arjun Dey, Govinda Dhungana, Zhejie Ding, Peter Doel, Yutong T. Duan, Anne Ealet, Jerry Edelstein, Sarah Eftekharzadeh, Daniel J. Eisenstein, Ann Elliott, Stéphanie Escoffier, Matthew Evatt, Parker Fagrelius, Xiaohui Fan, Kevin Fanning, Arya Farahi, Jay Farihi, Ginevra Favole, Yu Feng, Enrique Fernandez, Joseph R. Findlay, Douglas P. Finkbeiner, Michael J. Fitzpatrick, Brenna Flaugher, Samuel Flender, Andreu Font-Ribera, Jaime E. Forero-Romero, Pablo Fosalba, Carlos S. Frenk, Michele Fumagalli, Boris T. Gaen-

sicke, Giuseppe Gallo, Juan Garcia-Bellido, Enrique Gaztanaga, Nicola Pietro Gentile Fusillo, Terry Gerard, Irena Gershkovich, Tommaso Giannantonio, Denis Gillet, Guillermo Gonzalez-de-Rivera, Violeta Gonzalez-Perez, Shelby Gott, Or Graur, Gaston Gutierrez, Julien Guy, Salman Habib, Henry Heetderks, Ian Heetderks, Katrin Heitmann, Wojciech A. Hellwing, David A. Herrera, Shirley Ho, Stephen Holland, Klaus Honscheid, Eric Huff, Timothy A. Hutchinson, Dragan Huterer, Ho Seong Hwang, Joseph Maria Illa Laguna, Yuzo Ishikawa, Dianna Jacobs, Niall Jeffrey, Patrick Jelinsky, Elise Jennings, Linhua Jiang, Jorge Jimenez, Jennifer Johnson, Richard Joyce, Eric Jullo, Stéphanie Juneau, Sami Kama, Armin Karcher, Sonia Karkar, Robert Kehoe, Noble Kennamer, Stephen Kent, Martin Kilbinger, Alex G. Kim, David Kirkby, Theodore Kisner, Ellie Kitanidis, Jean-Paul Kneib, Sergey Koposov, Eve Kovacs, Kazuya Koyama, Anthony Kremin, Richard Kron, Luzius Kronig, Andrea Kueter-Young, Cedric G. Lacey, Robin Lafever, Ofer Lahav, Andrew Lambert, Michael Lampton, Martin Landriau, Dustin Lang, Tod R. Lauer, Jean-Marc Le Goff, Laurent Le Guillou, Auguste Le Van Suu, Jae Hyeon Lee, Su-Jeong Lee, Daniela Leitner, Michael Lesser, Michael E. Levi, Benjamin L'Huillier, Baojiu Li, Ming Liang, Huan Lin, Eric Linder, Sarah R. Loebman, Zarija Lukić, Jun Ma, Niall MacCrann, Christophe Magneville, Laleh Makarem, Marc Manera, Christopher J. Manser, Robert Marshall, Paul Martini, Richard Massey, Thomas Matheson, Jeremy McCauley, Patrick McDonald, Ian D. McGreer, Aaron Meisner, Nigel Metcalfe, Timothy N. Miller, Ramon Miquel, John Moustakas, Adam Myers, Milind Naik, Jeffrey A. Newman, Robert C. Nichol, Andrina Nicola, Luiz Nicolati da Costa, Jundan Nie, Gustavo Niz, Peder Norberg, Brian Nord, Dara Norman, Peter Nugent, Thomas O'Brien, Minji Oh, Knut A. G. Olsen, Cristobal Padilla, Hamsa Padmanabhan, Nikhil Padmanabhan, Nathalie Palanque-Delabrouille, Antonella Palmese, Daniel Pappalardo, Isabelle Pâris, Changbom Park, Anna Patej, John A. Peacock, Hiranya V. Peiris, Xiyan Peng, Will J. Percival, Sandrine Perruchot, Matthew M. Pieri, Richard Pogge, Jennifer E. Pollack, Claire Poppett, Francisco Prada, Abhishek Prakash, Ronald G. Probst, David Rabinowitz, Anand Raichoor, Chang Hee Ree, Alexandre Refregier, Xavier Regal, Beth Reid, Kevin Reil, Mehdi Rezaie, Constance M. Rockosi, Natalie Roe, Samuel Ronayette, Aaron Roodman, Ashley J. Ross, Nicholas P. Ross, Graziano Rossi, Eduardo Rozo, Vanina Ruhlmann-Kleider, Eli S. Rykoff, Cristiano Sabiu, Lado Samushia, Eusebio Sanchez, Javier Sanchez, David J. Schlegel, Michael Schneider, Michael Schubnell, Aurélia Secroun, Uros Seljak, Hee-Jong Seo, Santiago Serrano, Arman Shafieloo, Huanyuan Shan, Ray Sharples, Michael J. Sholl, William V. Shourt, Joseph H. Silber, David R. Silva, Martin M. Sirk, Anze Slosar, Alex Smith, George F. Smoot, Debopam Som, Yong-Seon Song, David Sprayberry, Ryan Staten, Andy Stefanik, Gregory Tarle, Suk Sien Tie, Jeremy L. Tinker, Rita Tojeiro, Francisco Valdes, Octavio Valenzuela, Monica Valluri, Mariana Vargas-Magana, Licia Verde, Alistair R. Walker, Jiali Wang, Yuting Wang, Benjamin A. Weaver, Curtis Weaverdyck, Risa H. Wechsler, David H. Weinberg, Martin White, Qian Yang, Christophe Yeche, Tianmeng Zhang, Gong-Bo Zhao, Yi Zheng, Xu Zhou, Zhimin Zhou, Yaling Zhu, Hu Zou, and Ying Zu. The DESI Experiment Part II: Instrument Design. *arXiv:1611.00037 [astro-ph]*, October 2016.

[9] Naim Göksel Karaçaylı, Andreu Font-Ribera, and Nikhil Padmanabhan. Optimal 1D Ly α forest power spectrum estimation - I. DESI-lite spectra. , 497(4):4742–4752, October 2020.

[10] Naim Göksel Karaçaylı, Nikhil Padmanabhan, Andreu Font-Ribera, Vid Iršič, Michael Walther, David Brooks, Enrique Gaztañaga, Robert Kehoe, Michael Levi, Pierros Ntelis, Nathalie Palanque-Delabrouille, and Gregory Tarlé. Optimal 1D Ly α forest power spectrum estimation - II. KODIAQ, SQUAD, and XQ-100. , 509(2):2842–2855, January 2022.

[11] Naim Göksel Karaçaylı, Paul Martini, Julien Guy, Corentin Ravoux, Marie Lynn Abdul Karim, Eric Armengaud, Michael Walther, J. Aguilar, S. Ahlen, S. Bailey, J. Bautista, S. F. Beltran, D. Brooks, L. Cabayol-Garcia, S. Chabanier, E. Chaussidon, J. Chaves-Montero, K. Dawson, R. de la Cruz, A. de la Macorra, P. Doel, A. Font-Ribera, J. E. Forero-Romero, S. Gontcho A. Gontcho, A. X. Gonzalez-Morales, C. Gordon, H. K. Herrera-Alcantar, K. Honscheid, V. Iršič, M. Ishak, R. Kehoe, T. Kisner, A. Kremin, M. Landriau, L. Le Guillou, M. E. Levi, Z. Lukić, A. Meisner, R. Miquel, J. Moustakas, E. Mueller, A. Muñoz-Gutiérrez, L. Napolitano, J. Nie, G. Niz, N. Palanque-Delabrouille, W. J. Percival, M. Pieri, C. Poppett, F. Prada, I. Pérez-Ràfols, C. Ramírez-Pérez, G. Rossi, E. Sanchez, H. Seo, F. Sinigaglia, T. Tan, G. Tarlé, B. Wang, B. A. Weaver, C. Yéche, and Z. Zhou. Optimal 1D Ly α forest power spectrum estimation - III. DESI early data. , 528(3):3941–3963, March 2024.

[12] Corentin Ravoux, Marie Lynn Abdul Karim, Eric Armengaud, Michael Walther, Naim Göksel Karaçaylı, Paul Martini, Julien Guy, Jessica Nicole Aguilar, Steven Ahlen, Stephen Bailey, Julian Bautista, Sergio Felipe Beltran, David Brooks, Laura Cabayol-Garcia, Solène Chabanier, Edmond Chaussidon, Jonás Chaves-Montero, Kyle Dawson, Rodrigo de la Cruz, Axel de la Macorra, Peter Doel, Kevin Fanning, Andreu Font-Ribera, Jaime Forero-Romero, Satya Gontcho A Gontcho, Alma X. Gonzalez-Morales, Calum Gordon, Hiram K. Herrera-Alcantar, Klaus Honscheid, Vid Iršič, Mustapha Ishak, Robert Kehoe, Theodore Kisner, Anthony Kremin, Martin Landriau, Laurent Le Guillou, Michael Levi, Zarija Lukić, Christophe Magneville, Aaron Meisner, Ramon Miquel, John Moustakas, Eva-Maria Mueller, Andrea Muñoz-Gutiérrez, Lucas Napolitano, Jundan Nie, Gustavo Niz, Nathalie Palanque-Delabrouille, Will Percival, Ignasi Pérez-Ràfols, Matthew Pieri, Claire Poppett, Francisco Prada, César Ramírez Pérez, Graziano Rossi, Eusebio Sanchez, David Schlegel, Michael Schubnell, Hee-Jong Seo, Francesco Sinigaglia, Ting Tan, Gregory Tarlé, Ben Wang, Benjamin Weaver, Christophe Yèche, and Zhimin Zhou. The Dark Energy Spectroscopic Instrument: one-dimensional power spectrum from first Ly α forest samples with Fast Fourier Transform. , 526(4):5118–5140, December 2023.

[13] Roger de Belsunce, Oliver H. E. Philcox, Vid Iršič, Patrick McDonald, Julien Guy, and Nathalie Palanque-Delabrouille. The 3D Lyman-α forest power spectrum from eBOSS DR16. , 533(3):3756–3770, September 2024.

[14] Marie Lynn Abdul Karim, Eric Armengaud, Guillaume Mention, Solène Chabanier, Corentin Ravoux, and Zarija Lukić. Measurement of the small-scale 3D Lyman-α forest power spectrum. , 2024(5):088, May 2024.

[15] Peter Melchior, Yan Liang, ChangHoon Hahn, and Andy Goulding. Autoencoding Galaxy Spectra. I. Architecture. , 166(2):74, August 2023.

[16] DESI Collaboration, A. G. Adame, J. Aguilar, S. Ahlen, S. Alam, G. Aldering, D. M. Alexander, R. Alfarsy, C. Allende Prieto, M. Alvarez, O. Alves, A. Anand, F. Andrade-Oliveira, E. Armengaud, J. Asorey, S. Avila, A. Aviles, S. Bailey, A. Balaguera-Antolínez, O. Ballester, C. Baltay, A. Bault, J. Bautista, J. Behera, S. F. Beltran, S. BenZvi, L. Beraldo e Silva, J. R. Bermejo-Climent, A. Berti, R. Besuner, F. Beutler, D. Bianchi, C. Blake, R. Blum, A. S. Bolton, S. Brieden, A. Brodzeller, D. Brooks, Z. Brown, E. Buckley-Geer, E. Burtin, L. Cabayol-Garcia, Z. Cai, R. Canning, L. Cardiel-Sas, A. Carnero Rosell, F. J. Castander, J. L. Cervantes-Cota, S. Chabanier, E. Chaussidon, J. Chaves-Montero, S. Chen, X. Chen, C. Chuang, T. Claybaugh, S. Cole, A. P. Cooper, A. Cuceu, T. M. Davis, K. Dawson, R. de Belsunce, R. de la Cruz, A. de la Macorra, J. Della Costa, A. de Mattia, R. Demina, U. Demirbozan, J. DeRose, A. Dey, B. Dey, G. Dhungana, J. Ding, Z. Ding, P. Doel, R. Doshi, K. Douglass, A. Edge, S. Eftekharzadeh, D. J. Eisenstein, A. Elliott, J. Ereza, S. Escoffier, P. Fagrelius, X. Fan, K. Fanning, V. A. Fawcett, S. Ferraro, B. Flaugher, A. Font-Ribera, J. E. Forero-Romero, D. Forero-Sánchez, C. S. Frenk, B. T. Gänsicke, L. Á. García, J. García-Bellido, C. Garcia-Quintero, L. H. Garrison, H. Gil-Marín, J. Golden-Marx, S. Gontcho A Gontcho, A. X. Gonzalez-Morales, V. Gonzalez-Perez, C. Gordon, O. Graur, D. Green, D. Gruen, J. Guy, B. Hadzhiyska, C. Hahn, J. J. Han, M. M. S. Hanif, H. K. Herrera-Alcantar, K. Honscheid, J. Hou, C. Howlett, D. Huterer, V. Iršič, M. Ishak, A. Jacques, A. Jana, L. Jiang, J. Jimenez, Y. P. Jing, S. Joudaki, R. Joyce, E. Jullo, S. Juneau, N. G. Karaçaylı, T. Karim, R. Kehoe, S. Kent, A. Khederlarian, S. Kim, D. Kirkby, T. Kisner, F. Kitaura, N. Kizhuprakkat, J. Kneib, S. E. Koposov, A. Kovács, A. Kremin, A. Krolewski, B. L'Huillier, O. Lahav, A. Lambert, C. Lamman, T. W. Lan, M. Landriau, D. Lang, J. U. Lange, J. Lasker, A. Leauthaud, L. Le Guillou, M. E. Levi, T. S. Li, E. Linder, A. Lyons, C. Magneville, M. Manera, C. J. Manser, D. Margala, P. Martini, P. McDonald, G. E. Medina, L. Medina-Varela, A. Meisner, J. Mena-Fernández, J. Meneses-Rizo, M. Mezcua, R. Miquel, P. Montero-Camacho, J. Moon, S. Moore, J. Moustakas, E. Mueller, J. Mundet, A. Muñoz-Gutiérrez, A. D. Myers, S. Nadathur, L. Napolitano, R. Neveux, J. A. Newman, J. Nie, R. Nikutta, G. Niz, P. Norberg, H. E. Noriega, E. Paillas, N. Palanque-Delabrouille, A. Palmese, Z. Pan, D. Parkinson, S. Penmetsa, W. J. Percival, A. Pérez-Fernández, I. Pérez-Ràfols, M. Pieri, C. Poppett, A. Porredon, S. Pothier, F. Prada, R. Pucha, A. Raichoor, C. Ramírez-Pérez, S. Ramirez-Solano, M. Rashkovetskyi, C. Ravoux, A. Rocher, C. Rockosi, A. J. Ross, G. Rossi, R. Ruggeri, V. Ruhlmann-Kleider, C. G. Sabiu, K. Said, A. Saintonge, L. Samushia, E. Sanchez, C. Saulder, E. Schaan, E. F. Schlafly, D. Schlegel, D. Scholte, M. Schubnell, H. Seo, A. Shafieloo,

R. Sharples, W. Sheu, J. Silber, F. Sinigaglia, M. Siudek, Z. Slepian, A. Smith, M. T. Soumagnac, D. Sprayberry, L. Stephey, J. Suárez-Pérez, Z. Sun, T. Tan, G. Tarlé, R. Tojeiro, L. A. Ureña-López, R. Vaisakh, D. Valcin, F. Valdes, M. Valluri, M. Vargas-Magaña, A. Variu, L. Verde, M. Walther, B. Wang, M. S. Wang, B. A. Weaver, N. Weaverdyck, R. H. Wechsler, M. White, Y. Xie, J. Yang, C. Yèche, J. Yu, S. Yuan, H. Zhang, Z. Zhang, C. Zhao, Z. Zheng, R. Zhou, Z. Zhou, H. Zou, S. Zou, and Y. Zu. The Early Data Release of the Dark Energy Spectroscopic Instrument. , 168(2):58, August 2024.

[17] DESI Collaboration, A. G. Adame, J. Aguilar, S. Ahlen, S. Alam, G. Aldering, D. M. Alexander, R. Alfarsy, C. Allende Prieto, M. Alvarez, O. Alves, A. Anand, F. Andrade-Oliveira, E. Armengaud, J. Asorey, S. Avila, A. Aviles, S. Bailey, A. Balaguera-Antolínez, O. Ballester, C. Baltay, A. Bault, J. Bautista, J. Behera, S. F. Beltran, S. BenZvi, L. Beraldo e Silva, J. R. Bermejo-Climent, A. Berti, R. Besuner, F. Beutler, D. Bianchi, C. Blake, R. Blum, A. S. Bolton, S. Brieden, A. Brodzeller, D. Brooks, Z. Brown, E. Buckley-Geer, E. Burtin, L. Cabayol-Garcia, Z. Cai, R. Canning, L. Cardiel-Sas, A. Carnero Rosell, F. J. Castander, J. L. Cervantes-Cota, S. Chabanier, E. Chaussidon, J. Chaves-Montero, S. Chen, X. Chen, C. Chuang, T. Claybaugh, S. Cole, A. P. Cooper, A. Cuceu, T. M. Davis, K. Dawson, R. de Belsunce, R. de la Cruz, A. de la Macorra, J. Della Costa, A. de Mattia, R. Demina, U. Demirbozan, J. DeRose, A. Dey, B. Dey, G. Dhungana, J. Ding, Z. Ding, P. Doel, R. Doshi, K. Douglass, A. Edge, S. Eftekharzadeh, D. J. Eisenstein, A. Elliott, J. Ereza, S. Escoffier, P. Fagrelius, X. Fan, K. Fanning, V. A. Fawcett, S. Ferraro, B. Flaugher, A. Font-Ribera, J. E. Forero-Romero, D. Forero-Sánchez, C. S. Frenk, B. T. Gänsicke, L. Á. García, J. García-Bellido, C. Garcia-Quintero, L. H. Garrison, H. Gil-Marín, J. Golden-Marx, S. Gontcho A Gontcho, A. X. Gonzalez-Morales, V. Gonzalez-Perez, C. Gordon, O. Graur, D. Green, D. Gruen, J. Guy, B. Hadzhiyska, C. Hahn, J. J. Han, M. M. S. Hanif, H. K. Herrera-Alcantar, K. Honscheid, J. Hou, C. Howlett, D. Huterer, V. Iršič, M. Ishak, A. Jacques, A. Jana, L. Jiang, J. Jimenez, Y. P. Jing, S. Joudaki, R. Joyce, E. Jullo, S. Juneau, N. G. Karaçaylı, T. Karim, R. Kehoe, S. Kent, A. Khederlarian, S. Kim, D. Kirkby, T. Kisner, F. Kitaura, N. Kizhuprakkat, J. Kneib, S. E. Koposov, A. Kovács, A. Kremin, A. Krolewski, B. L'Huillier, O. Lahav, A. Lambert, C. Lamman, T. W. Lan, M. Landriau, D. Lang, J. U. Lange, J. Lasker, A. Leauthaud, L. Le Guillou, M. E. Levi, T. S. Li, E. Linder, A. Lyons, C. Magneville, M. Manera, C. J. Manser, D. Margala, P. Martini, P. McDonald, G. E. Medina, L. Medina-Varela, A. Meisner, J. Mena-Fernández, J. Meneses-Rizo, M. Mezcua, R. Miquel, P. Montero-Camacho, J. Moon, S. Moore, J. Moustakas, E. Mueller, J. Mundet, A. Muñoz-Gutiérrez, A. D. Myers, S. Nadathur, L. Napolitano, R. Neveux, J. A. Newman, J. Nie, R. Nikutta, G. Niz, P. Norberg, H. E. Noriega, E. Paillas, N. Palanque-Delabrouille, A. Palmese, Z. Pan, D. Parkinson, S. Penmetsa, W. J. Percival, A. Pérez-Fernández, I. Pérez-Ràfols, M. Pieri, C. Poppett, A. Porredon, S. Pothier, F. Prada, R. Pucha, A. Raichoor, C. Ramírez-Pérez, S. Ramirez-Solano, M. Rashkovetskyi, C. Ravoux, A. Rocher, C. Rockosi, A. J. Ross, G. Rossi, R. Ruggeri, V. Ruhlmann-Kleider, C. G. Sabiu, K. Said, A. Saintonge, L. Samushia, E. Sanchez, C. Saulder, E. Schaan, E. F. Schlafly, D. Schlegel, D. Scholte, M. Schubnell, H. Seo, A. Shafieloo, R. Sharples, W. Sheu, J. Silber, F. Sinigaglia, M. Siudek, Z. Slepian, A. Smith, M. T. Soumagnac, D. Sprayberry, L. Stephey, J. Suárez-Pérez, Z. Sun, T. Tan, G. Tarlé, R. Tojeiro, L. A. Ureña-López, R. Vaisakh, D. Valcin, F. Valdes, M. Valluri, M. Vargas-Magaña, A. Variu, L. Verde, M. Walther, B. Wang, M. S. Wang, B. A. Weaver, N. Weaverdyck, R. H. Wechsler, M. White, Y. Xie, J. Yang, C. Yèche, J. Yu, S. Yuan, H. Zhang, Z. Zhang, C. Zhao, Z. Zheng, R. Zhou, Z. Zhou, H. Zou, S. Zou, and Y. Zu. The Early Data Release of the Dark Energy Spectroscopic Instrument. , 168(2):58, August 2024.

[18] J. Guy, S. Bailey, A. Kremin, Shadab Alam, D. M. Alexander, C. Allende Prieto, S. BenZvi, A. S. Bolton, D. Brooks, E. Chaussidon, A. P. Cooper, K. Dawson, A. de la Macorra, A. Dey, Biprateep Dey, G. Dhungana, D. J. Eisenstein, A. Font-Ribera, J. E. Forero-Romero, E. Gaztañaga, S. Gontcho A Gontcho, D. Green, K. Honscheid, M. Ishak, R. Kehoe, D. Kirkby, T. Kisner, Sergey E. Koposov, Ting-Wen Lan, M. Landriau, L. Le Guillou, Michael E. Levi, C. Magneville, Christopher J. Manser, P. Martini, Aaron M. Meisner, R. Miquel, J. Moustakas, Adam D. Myers, Jeffrey A. Newman, Jundan Nie, N. Palanque-Delabrouille, W. J. Percival, C. Poppett, F. Prada, A. Raichoor, C. Ravoux, A. J. Ross, E. F. Schlafly, D. Schlegel, M. Schubnell, Ray M. Sharples, Gregory Tarlé, B. A. Weaver, Christophe Yéche, Rongpu Zhou, Zhimin Zhou, and H. Zou. The Spectroscopic Data Processing Pipeline for the Dark Energy Spectroscopic Instrument. , 165(4):144, April 2023.

[19] Edmond Chaussidon, Christophe Yèche, Nathalie Palanque-Delabrouille, David M. Alexander, Jinyi Yang, Steven Ahlen, Stephen Bailey, David Brooks, Zheng Cai, Solène Chabanier, Tamara M. Davis, Kyle Dawson, Axel de laMacorra, Arjun Dey, Biprateep Dey, Sarah Eftekharzadeh, Daniel J. Eisenstein, Kevin Fanning, Andreu Font-Ribera, Enrique Gaztañaga, Satya Gontcho A Gontcho, Alma X. Gonzalez-Morales, Julien Guy, Hiram K. Herrera-Alcantar, Klaus Honscheid, Mustapha Ishak, Linhua Jiang, Stephanie Juneau, Robert Kehoe, Theodore Kisner, Andras Kovács, Anthony Kremin, Ting-Wen Lan, Martin Landriau, Laurent Le Guillou, Michael E. Levi, Christophe Magneville, Paul Martini, Aaron M. Meisner, John Moustakas, Andrea Muñoz-Gutiérrez, Adam D. Myers, Jeffrey A. Newman, Jundan Nie, Will J. Percival, Claire Poppett, Francisco Prada, Anand Raichoor, Corentin Ravoux, Ashley J. Ross, Edward Schlafly, David Schlegel, Ting Tan, Gregory Tarlé, Rongpu Zhou, Zhimin Zhou, and Hu Zou. Target Selection and Validation of DESI Quasars. , 944(1):107, February 2023.

[20] David M. Alexander, Tamara M. Davis, E. Chaussidon, V. A. Fawcett, Alma X. Gonzalez-Morales, Ting-Wen Lan, Christophe Yèche, S. Ahlen, J. N. Aguilar, E. Armengaud, S. Bailey, D. Brooks, Z. Cai, R. Canning, A. Carr, S. Chabanier, Marie-Claude Cousinou, K. Dawson, A. de la Macorra, A. Dey, Biprateep Dey, G. Dhungana, A. C. Edge, S. Eftekharzadeh, K. Fanning, James Farr, A. Font-Ribera, J. Garcia-Bellido, Lehman Garrison, E. Gaztañaga, Satya Gontcho A Gontcho, C. Gordon, Stefany Guadalupe Medellin Gonzalez, J. Guy, Hiram K. Herrera-Alcantar, L. Jiang, S. Juneau, N. G. Karaçaylı, R. Kehoe, T. Kisner, A. Kovács, M. Landriau, Michael E. Levi, C. Magneville, P. Martini, Aaron M. Meisner, M. Mezcua, R. Miquel, P. Montero Camacho, J. Moustakas, Andrea Muñoz-Gutiérrez, Adam D. Myers, S. Nadathur, L. Napolitano, J. D. Nie, N. Palanque-Delabrouille, Z. Pan, W. J. Percival, I. Pérez-Ràfols, C. Poppett, F. Prada, César Ramírez-Pérez, C. Ravoux, D. J. Rosario, M. Schubnell, Gregory Tarlé, M. Walther, B. Weiner, S. Youles, Zhimin Zhou, H. Zou, and Siwei Zou. The DESI Survey Validation: Results from Visual Inspection of the Quasar Survey Spectra. , 165(3):124, March 2023.