Winds of Change: Investigating Variability in Quasars with Outflows

Michael Carrasco, Dr. Mariana Lazarova
University of Northern Colorado, Department of Physics and Astronomy, 2026

Abstract

Active Galactic Nuclei are galaxies with a supermassive black hole that is actively taking in surrounding gas and matter. Quasars are a subset of Active Galactic Nuclei (AGN) that are extremely luminous, that are thought to be powered by radiation from the accretion disk of a central supermassive black hole. The light from the accretion disk of its central supermassive black hole outshines all the stars in its host galaxy and appears 'quasi-star' like, hence the name 'quasar'. About ten percent of quasars are classified as Broad Absorption Line (BAL) quasars because their spectra exhibit broad, blue-shifted deep absorption lines due to high-velocity gas outflows toward the observer, almost certainly originating from the inner region of the quasar. An even smaller subset of quasars are classified as Low-ionization Broad Absorption Line (LoBAL) quasars because the ions showing outflows, such as Mg II, have low-ionization potential. The purpose of this research is to trace any variability in the observed optical spectra in a small sample of 22 Low-ionization Broad Absorption Line (LoBAL) quasars within redshift 0.5-0.6.

What is a Quasar?

Quasars are galaxies that host a supermassive black hole that is actively taking in stellar material. As the matter falls into the black hole, an accretion disk is formed that outshines its entire host galaxy. This light is so bright that it appears like a star would, hence the name 'quasar.' **Figure 1.** below is an image from the James Webb Space Telescope of quasar J0100+2802, located between the constellations of Pisces and Andromeda. The quasar is the pink dot with the diffraction spikes in the center of the image.[1]

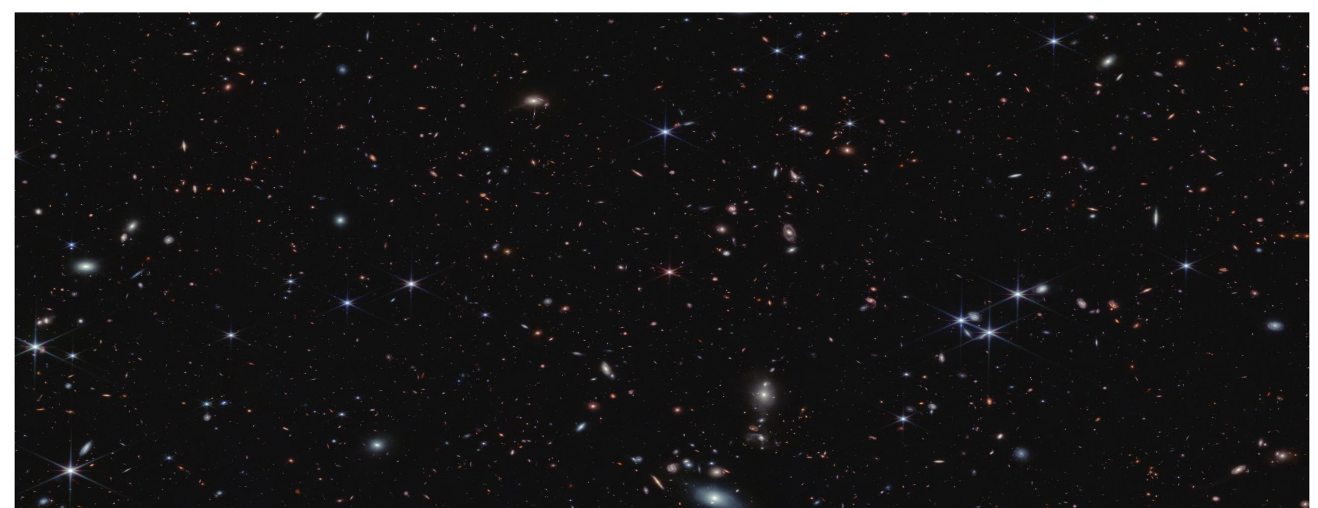


Figure 1. JWST image of quasar J0100+2802, it is the pink 'star' with the diffraction spikes in the center of the image.

Method

For this research, we downloaded data from the Sloan Digital Sky Survey[2] (SDSS) for our set of 22 LoBAL quasars. Out of our 22 quasars, only 7 of them had observations from SDSS that covered multiple epochs that ranges from the year 2000 to the year 2018. These seven quasars were: SDSS J025026.66+000903.4 **(Figure 2.)**, SDSS J083525.98+435211.2 **(Figure 3.)**, SDSS J085053.12+445122.5 **(Figure 4.)**, SDSS J102802.32+592906.6 **(Figure 5.)**, SDSS J114043.62+532439.0 **(Figure 6.)**, SDSS J161425.17+375210.7 **(Figure 7.)**, SDSS J170341.82+383944.7 **(Figure 8.)**. We used the Astropy[3] package of Python in order to read the Flexible Image Transport Systems (FITS) file and extract the spectral data of our objects. We then redshifted the spectra so that our graphs were in our objects' rest frame. We overplotted two spectra from two different epochs on the same graph to spot obvious differences, subtracted the recent observation (green spectrum) from the oldest observation (black spectrum) on a graph below our overplotted spectra. We finally zoomed in on the Mg II region, 2800 Å, of the spectral difference to see if there were any significant changes over time. We used a package in Astropy called 'Convolution' to get a Gaussian line smoothing of our raw data, the red line overplotted on the raw spectral difference.

Data

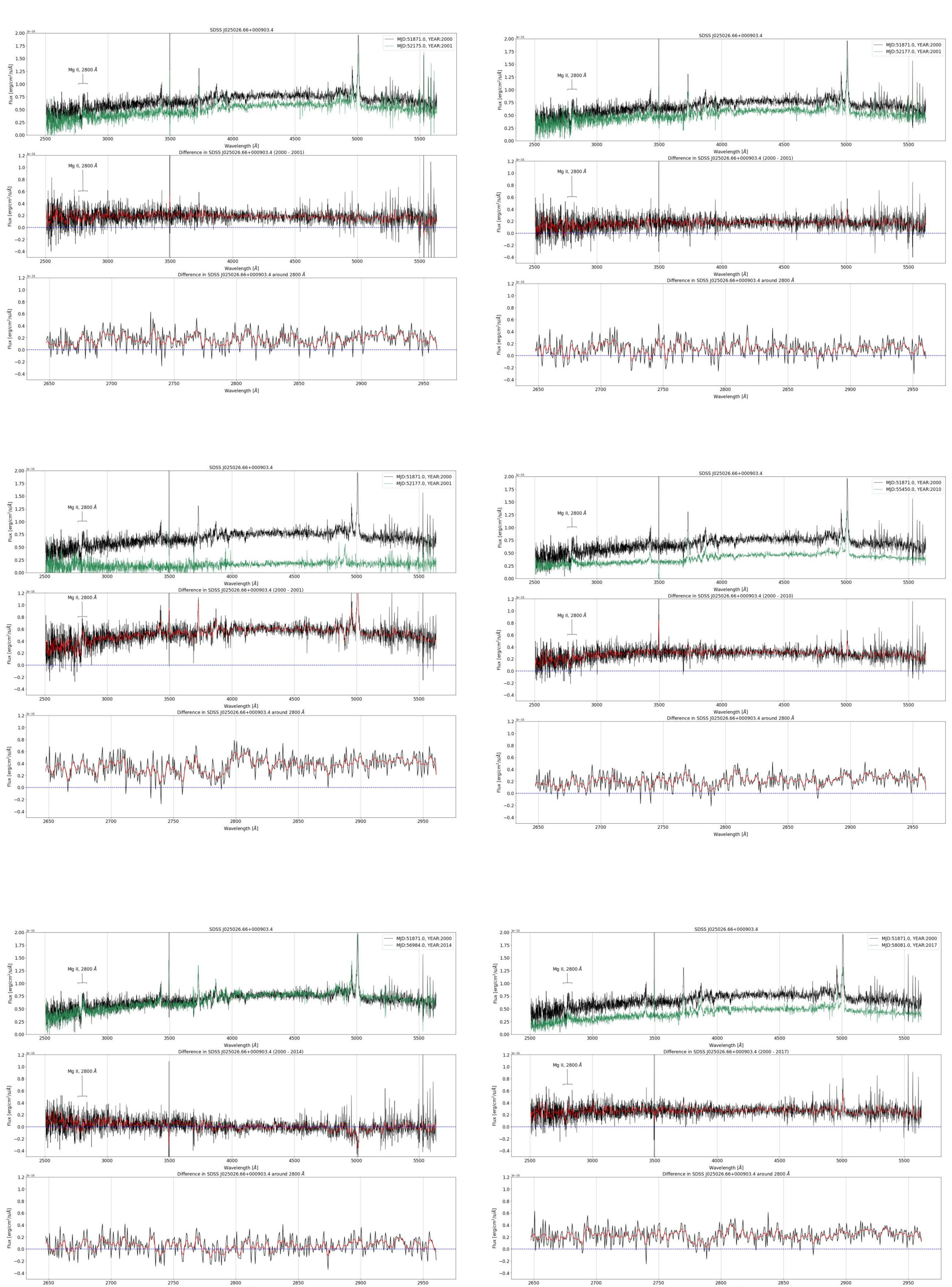


Figure 2. LoBAL quasar SDSS J025026.66+000903.4 and its observations in different epochs ranging from 2000-2017. There is some evidence of dust extinction in the Mg II region (2800Å).

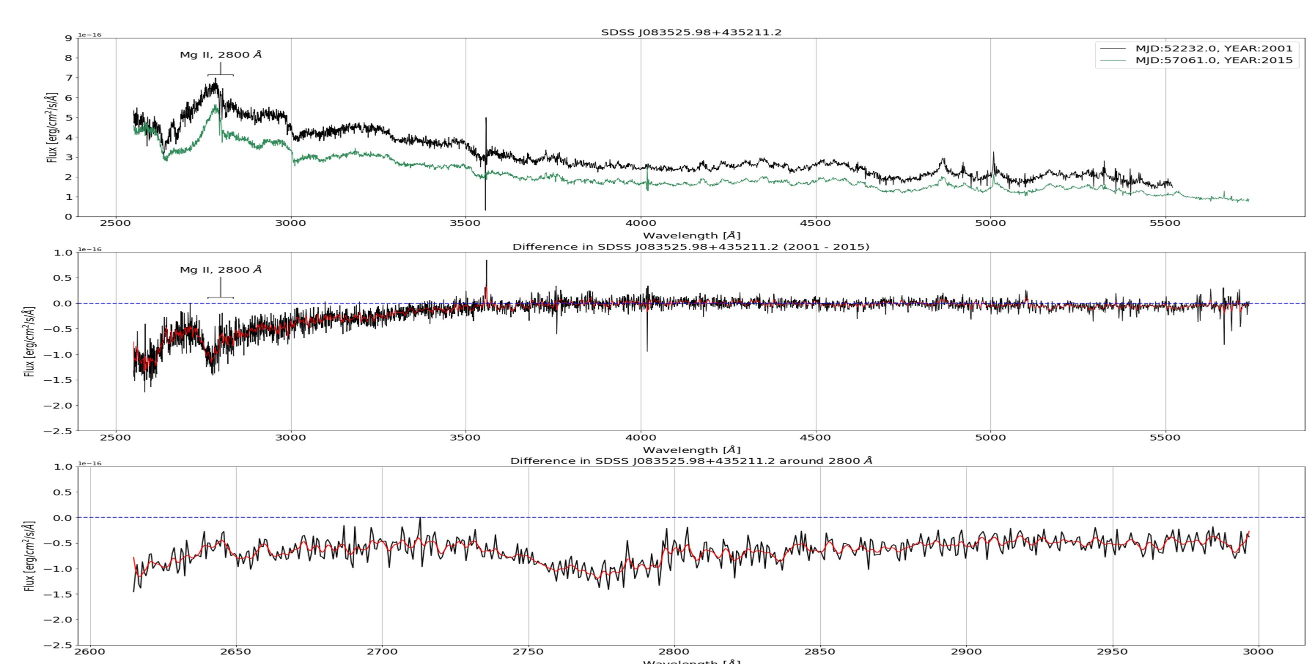


Figure 3. LoBAL quasar SDSS J083525.98+435211.2. Notice evidence of dust extinction in the Mg II region (2800 Å).

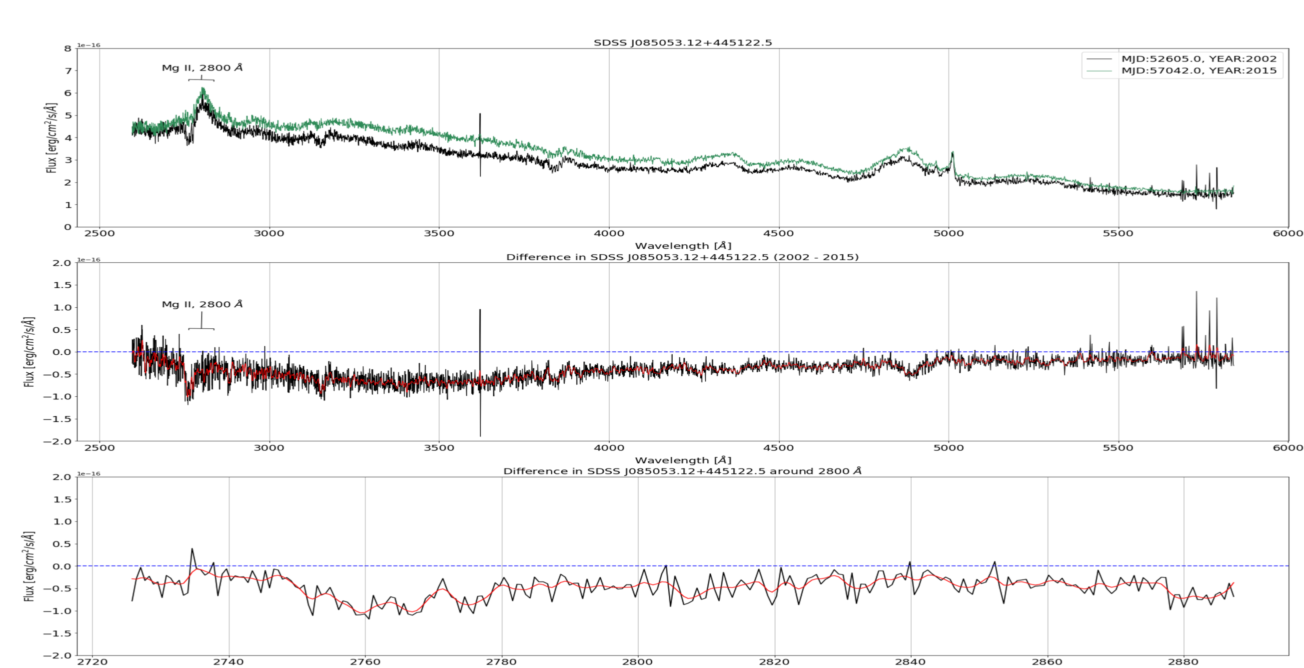


Figure 4. LoBAL quasar SDSS J085053.12+445122.5. There is not much difference in the Mg II region (2800 Å).

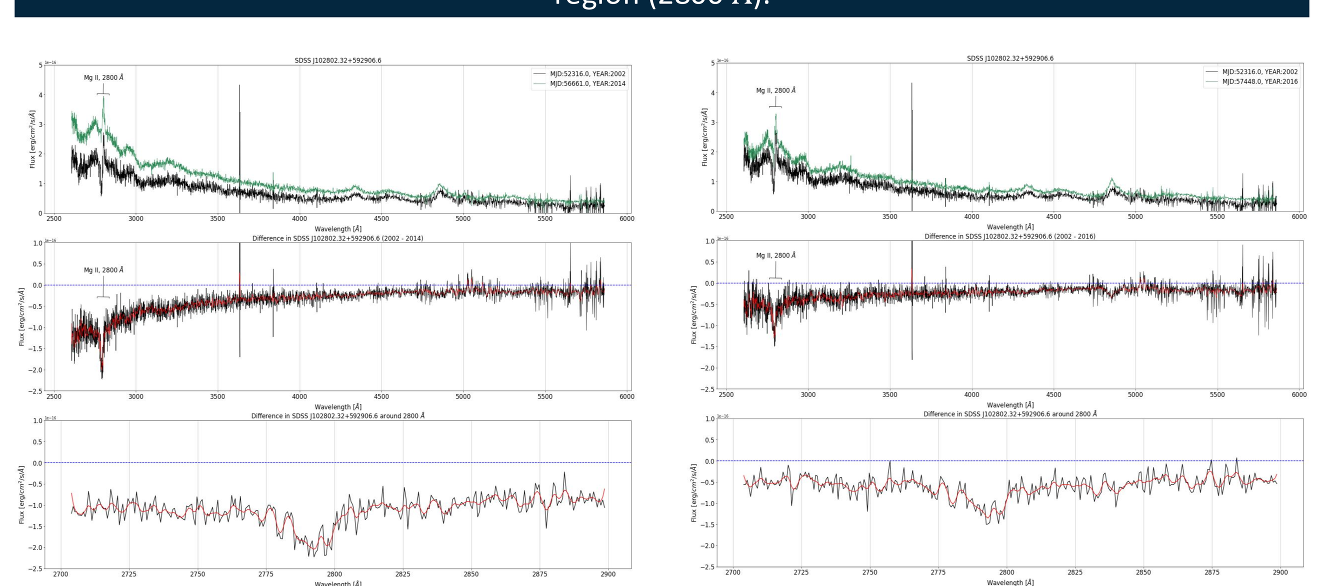
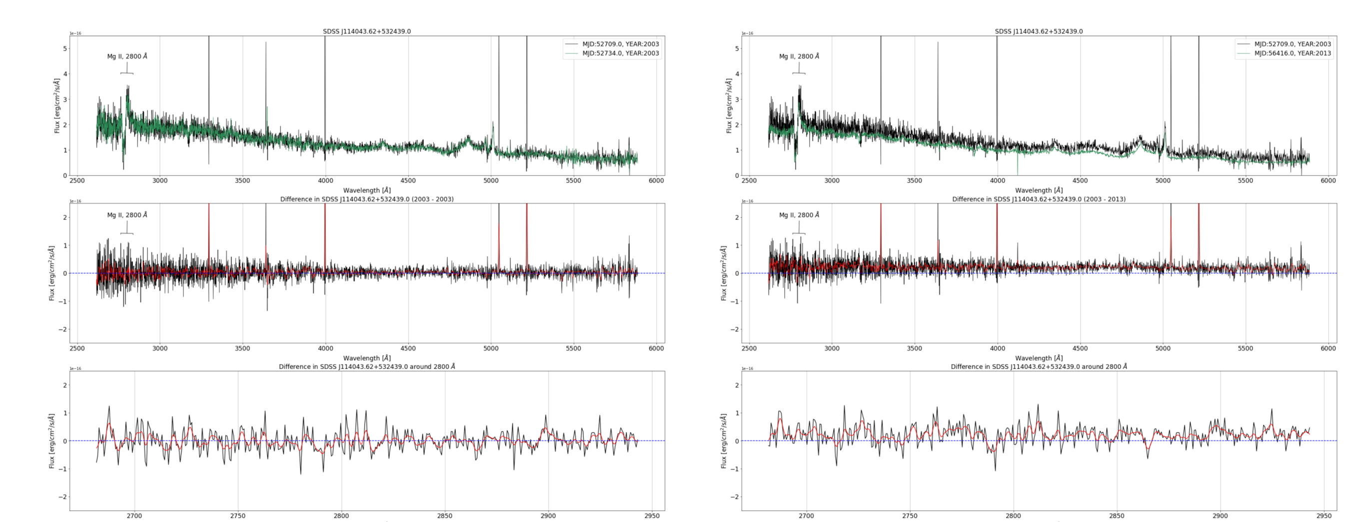


Figure 5. LoBAL quasar SDSS J102802.32+592906.6. Notice evidence of dust extinction in the Mg II region (2800 Å).



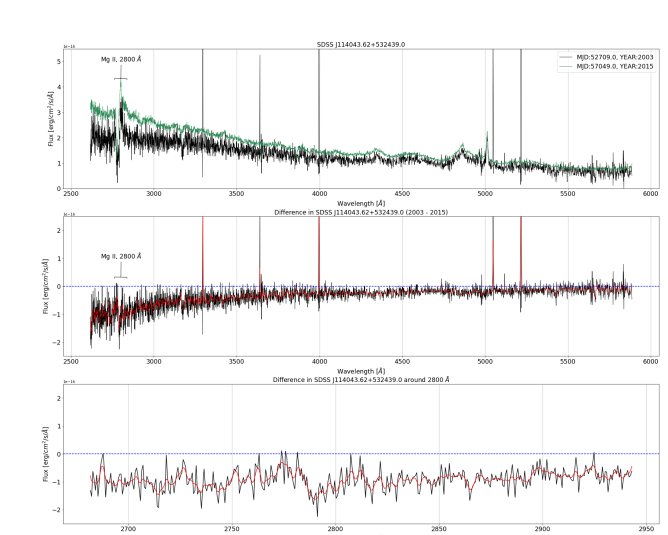


Figure 6. LoBAL quasar SDSS J114043.62+532439.0 shows no change in the Mg II region (2800 Å), [Above], until 2015 where there is evidence of dust extinction in the Mg II region, [Left].

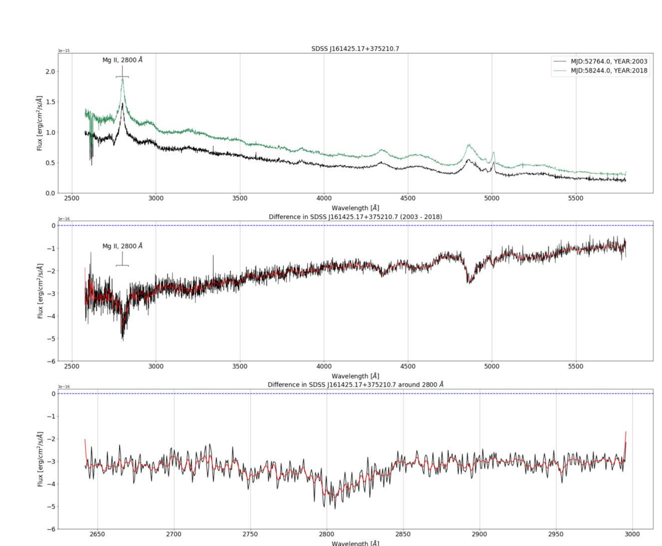


Figure 7. LoBAL quasar SDSS J161425.17+375210.7 exhibits evidence of dust extinction in the Mg II region (2800 Å).

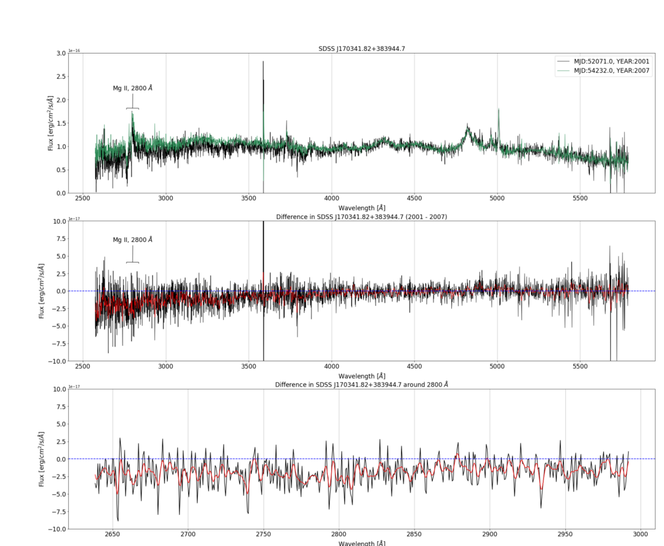


Figure 8. LoBAL quasar SDSS J170341.82+383944.7 shows no change in its optical spectrum.

Acknowledgements

To the Sloan Digital Sky Survey for archiving this data. To the Astropy Documentation page for providing tutorials on how to use their package. And to Dr. Mariana Lazarova, without her support and expertise, I would have never completed this. Thank you Dr. L.

Resources

1. Image: NASA, ESA, CSA, Simon Lilly (ETH Zurich), Daichi Kashino (Nagoya University), Jorryt Matthee (ETH Zurich), Christina Eilers (MIT), Rob Simcoe (MIT), Rongmon Bordoloi (NCSU), Ruari Mackenzie (ETH Zurich); Image Processing: Alyssa Pagan (STScI), Ruari Mackenzie (ETH Zurich)
2. Almeida, et al. (2023). *The Eighteenth Data Release of the Sloan Digital Sky Surveys: Targeting and First Spectra from SDSS-V.* SDSS Science Archive Server. https://dr18.sdss.org/optical/plate/search.
3. Astropy. (2025). *User Guide.* [Tutorial]. Astropy - A community Python Library for Astronomy. https://docs.astropy.org/en/stable/index_user_docs.html.