Practical No :- 01
Spectroscopic Analysis of Quasar Absorption Lines

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Abstract

This report details the analysis of quasar absorption lines using spectral data from the UVES SQUAD DR1 database. The study involves retrieving, calibrating, analyzing, and identifying absorption features in quasar spectra to determine physical properties of intervening absorbers.

1 Introduction

Quasar absorption line spectroscopy provides insights into the physical properties of intervening gas clouds along the line of sight towards quasars. This practical utilizes high-resolution spectral data from the UVES Spectral Quasar Absorption Database (SQUAD), obtained from the Very Large Telescope (VLT) in Chile. The aim is to analyze absorption features such as damped Lyman-α lines and associated metal transitions.

2 Data Source and Preparation

The spectral data used in this practical is sourced from the First Data Release (DR1) of the UVES SQUAD database. Detailed information about the data structure and FITS files can be found at `https://github.com/MTMurphy77/UVES_SQUAD_DR1`. The data comprises 467 quasar spectra obtained using the Ultraviolet and Visual Echelle Spectrograph (UVES).

2.1 Procedure:

- Use Python with astropy, numpy, and matplotlib libraries to read and calibrate the FITS files.

```
import numpy as np
from matplotlib.pyplot import *
from astropy.io import fits
import pandas as pd
```

- Compute the wavelength array using 'CRVAL1', 'CRPIX1', and 'CD1_1' header values.

```
file = '/home/gauravbhoir147/Practicals/ISM/J010104-285801.fits'
HDUList = fits.open(file)
HDUList.info()
HDUList[0].header
HDUList[2].header

# Extract the header and data from the primary HDU
header = HDUList[0].header
data = HDUList[0].data

# Extract the necessary header values for wavelength calibration
crval1 = header['CRVAL1']
crpix1 = header['CRPIX1']
cd1_1 = header['CD1_1']
flux = header['ARRAY1']
z = header['UP_ZEM']
wl = 1215.6701*(1+z)
print(wl)
```

```
# Determine the number of pixels
npix = data.shape[1]

# Compute the wavelength array
i = np.arange(npix)
w0 = 10**crval1  # Central wavelength of the first pixel in linear scale
w = w0*10**((np.arange(npix) + 1 - crpix1) * cd1_1)
```

- Reshape and concatenate flux and wavelength arrays. Save the data to external files.
- Plot the calibrated spectrum and identify absorption features interactively.

```
def plot_spectrum(w, flux, xs=None, xm=None, ys=None, ym=None):
    """
    Plot spectroscopic data.

    Parameters:
    - w (array-like): Array of wavelengths.
    - flux (array-like): Array of flux values.
    - xs (float, optional): Minimum value for x-axis limit.
    - xm (float, optional): Maximum value for x-axis limit.
    - ys (float, optional): Minimum value for y-axis limit.
    - ym (float, optional): Maximum value for y-axis limit.
    """
    figure(figsize=(10, 6))
    plot(w, flux, label='Spectrum')
    xlabel('Wavelength')
    ylabel('Flux')
    title('Spectroscopic Data')
    legend()
    grid(True)

    # Set xlim if provided
    if xs is not None and xm is not None:
        xlim(xs, xm)

    # Set ylim if provided
    if ys is not None and ym is not None:
        ylim(ys, ym)

    show()
plot_spectrum(w,data[0,:])
```

3 Identifying Absorption Lines and Redshift Determination

- Focus on prominent lines such as Si II, Fe II, Cr II and Ni II.
- Determine the redshift (z_{abs}) of absorbers using the relation $\lambda_{obs} = \lambda_{rest}(1 + z_{abs})$.
- Identify additional absorption lines associated with neutral gas (e.g., Si II, Al III, Fe II, Cr II, Ni II) using rest wavelengths from 'atom.dat'.

4 Spectral Lines

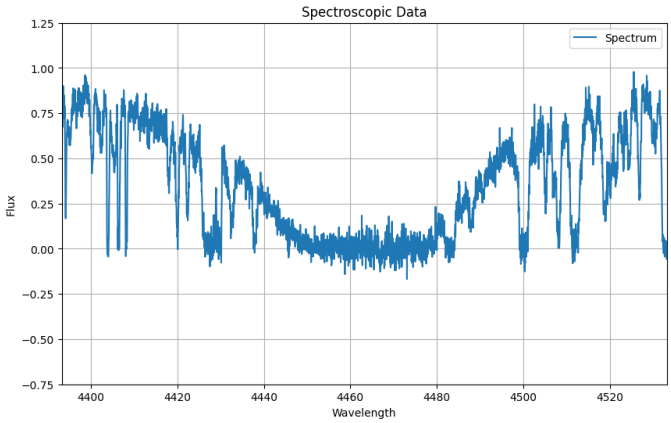

Figure 1: Spectral line of Damped Lyman Alpha

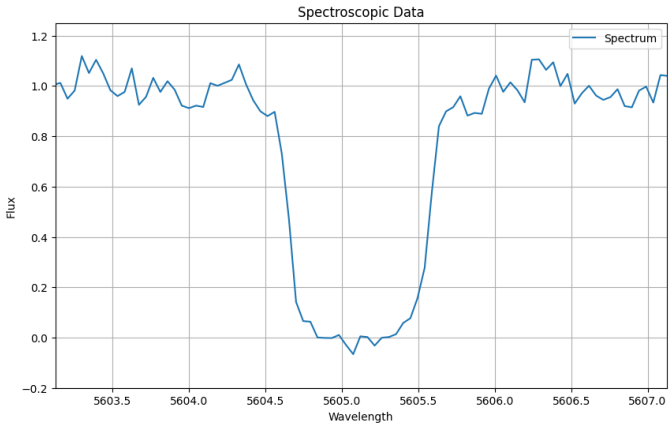

Figure 2: Spectral line of Si-II at wavelength 1526 Å

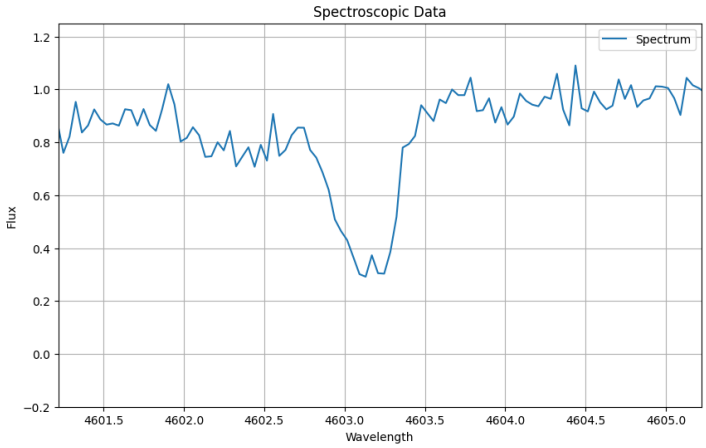

Figure 3: Spectral line of S-II at wavelength 1253.811 Å

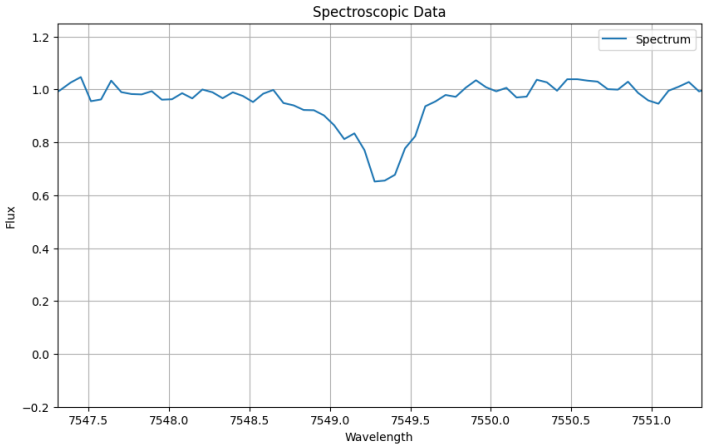

Figure 4: Spectral line of Cr-II at wavelength 2056.2576 Å

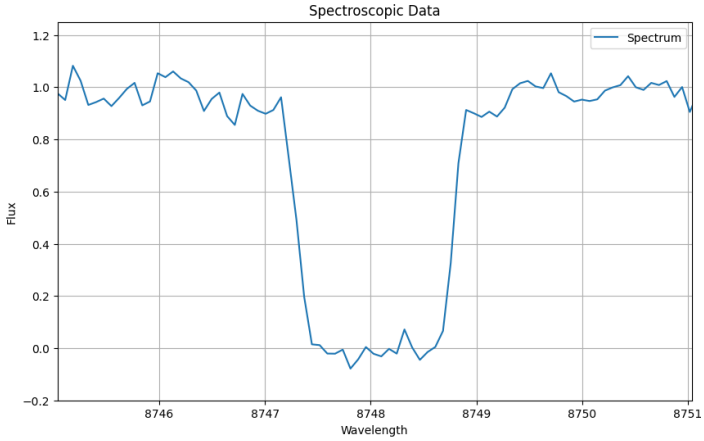

Figure 5: Spectral line of Fe-II at wavelength 2382 Å

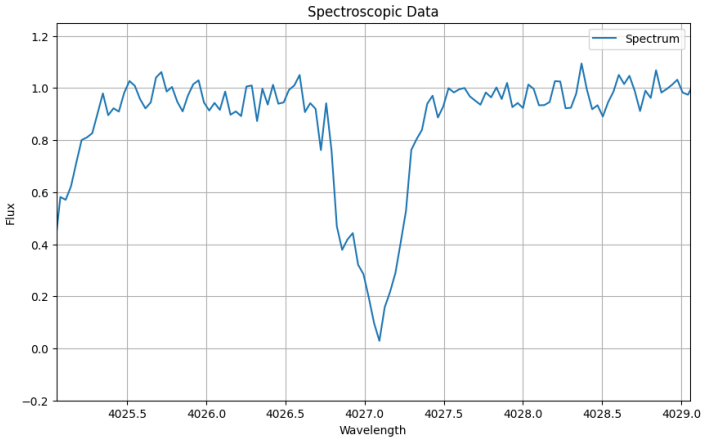

Figure 6: Spectral line of Fe-II at wavelength 1096 Å

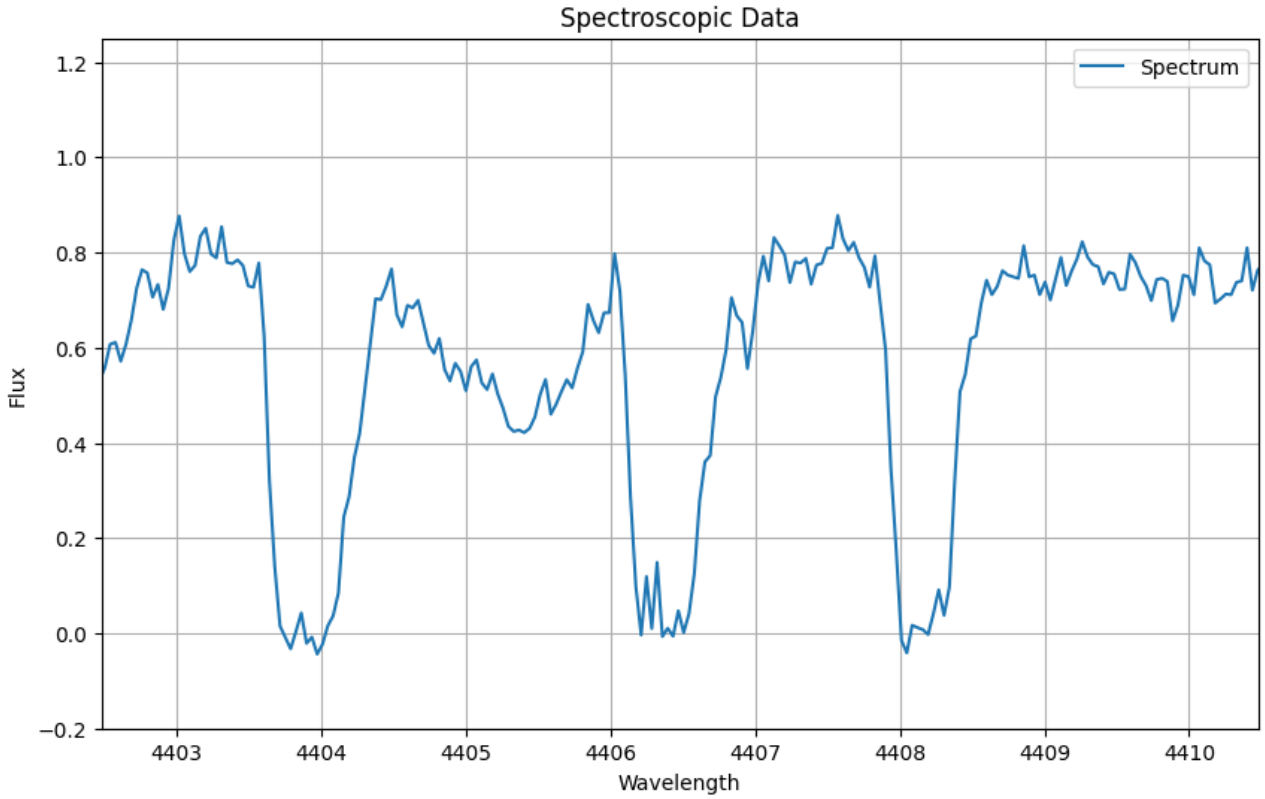

Figure 7: The nitrogen triplets at wavelength of 1200.7098 Å, 1200.2233 Å& 1199.5496 Å

5 Results and Discussion

- From this practical we analyzed and interpret the identified absorption features.
- Compare with known spectra and absorption line catalogs.
- From the above figures we can see the prominent lines of Damped-Lyman alpha,Si-II,S-II,Fe-II and Cr-II.
- by observing the dip of the absorption line we can comment on the density of the element in our case we can see the the density of S-II in wavelength 1253 Åis less than the density of S-II in wavelength 1259.519 Å
- As for the metallicity we can see many absorption lines from the metals such as Fe, Si, Cr, Mn, Na and many more hence we can conclude that the ISM between the quasar and earth is metal rich ISM.

6 References

- Murphy, Kacprzak, et al. (2018), Monthly Notices of the Royal Astronomical Society.
- UVES SQUAD DR1 Database, `https://github.com/MTMurphy77/UVES_SQUAD_DR1`
- Schneider, P., Extragalactic Astronomy and Cosmology – An Introduction.