Spectroscopic analysis of quasar absorption lines

MSc - II Practical

I. Quasar absorption line spectroscopy

Intervening absorbers along the sightline towards a luminous object such as a quasar can be studied

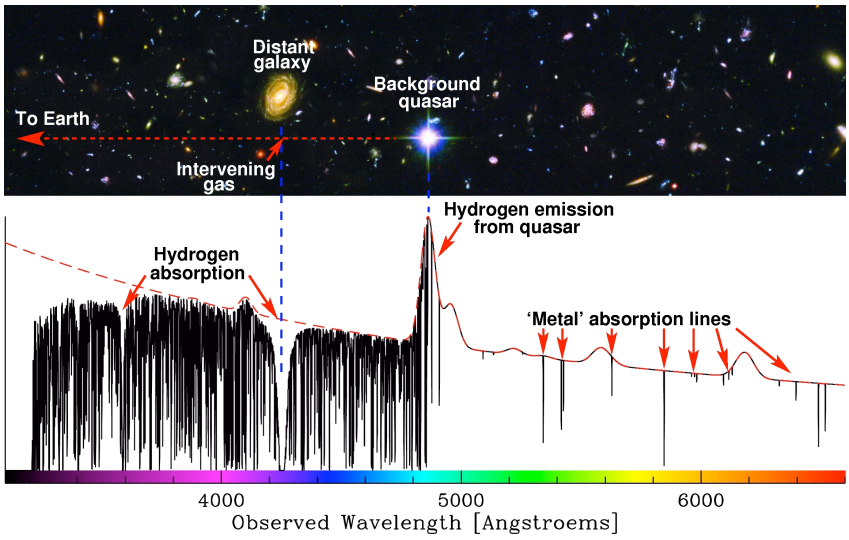

Figure 1: Credit: Pettini & Cooke (2012)

through their characteristic absorption lines in the spectrum of the background source. Such spectroscopic studies are commonly carried out at ultraviolet and optical wavelengths, and give insight into the physical properties of the absorbers such as metallicity, dust content, radiation field, density, etc. These absorbing clouds may be classified on the basis of their neutral gas content, with damped Lyman-α absorbers being the most neutral.

II. The data

For this practical, you will make use of spectra from the First Data Release (DR1) of the UVES Spectral Quasar Absorption Database (SQUAD). The database comprises of 467 high-resolution archival quasar spectra obtained using the Ultraviolet and Visual Echelle Spectrograph (UVES) at the Very Large Telescope in Chile.

Details about DR1 are presented in Murphy et al. (2018), published in *Monthly Notices of the Royal Astronomical Society*. The entire spectral database is hosted at `https://github.com/MTMurphy77/UVES_SQUAD_DR1`, along with details regarding the data and its usage. In particular, information about the structure of the FITS files can be found at `https://github.com/MTMurphy77/UVES_SQUAD_DR1/blob/master/Notes_FITS_Files.txt`.

III. Retrieving spectroscopic data from a FITS file

- Aim: Develop a Python code that reads a FITS file containing spectroscopic data, computes the wavelength array, writes the spectral data to an external data file and also plots the spectrum.
- The *astropy*, *numpy* and *matplotlib* packages will be needed.
- Get information about the FITS file structure and data [eg: hdu_list.info()]; hdu_list[0].header and hdu_list[0].data provide access to the header and data respectively.
- For wavelength calibration, use the values of the 'CRVAL1', 'CRPIX1' and 'CD1_1' header cards. The central wavelength of the first pixel is given by 'CRVAL1' in log-scale. The entire wavelength array can be determined using the relation $w[i] = w[0] \times 10^{([i+1]-CRPIX1)CD1\_1}$. Refer to `https://github.com/MTMurphy77/UVES_SQUAD_DR1/blob/master/Notes_FITS_Files.txt`.
- Check the dimensions of the array before and after calibration. Use the *reshape* command if needed.
- Use the *concatenate* command to combine the normalized flux and calibrated wavelength arrays.
- Save the data arrays to a file. Also, plot and save the entire spectrum to a file.
- The table below lists suggested quasars to perform this exercise.

Table 1: Suggested quasars for the exercise

Sr. no.	Object name
1	J010104-285801
2	J010311+131617
3	J004131-493611
4	J001306+000431
5	J012550-535225

IV. Identifying absorption lines and determining redshift

- Develop a Python code that reads in the spectral data from the data file output of the previous exercise and plots the data interactively. Use the *plt.show()* command for this.
- Zoom into various wavelength regions of the spectrum and identify absorption features, starting with the conspicuous damped Lyman-α line.
- Note down the approximate observed central wavelength of the Lyman-α absorption line, and using the known rest wavelength of this transition, determine the redshift of the absorbing cloud. Use the relation $\lambda_{obs} = \lambda_{rest}(1 + z_{abs})$.
- At this redshift, check for the presence of commonly observed metal transitions in neutral gas such as those associated with Si II, Al III, Fe II, Cr II and Ni II.
- Rest wavelengths for the necessary transitions are available in the second column of the file named atom.dat, which has been provided to you. This file is part of a software package called VPFIT which is used to fit line profiles to absorption features.
- Identify at least five absorption lines in addition to the Lyman-α feature. Plot them clearly using suitable axes limits. The plots should be clearly labelled with the name of the species and the wavelength of the transition.
- You may refer to the plots in `https://github.com/MTMurphy77/UVES_SQUAD_DR1/blob/master/DLAs/DR1_DLAs.pdf` for comparison. One example is indicated below.

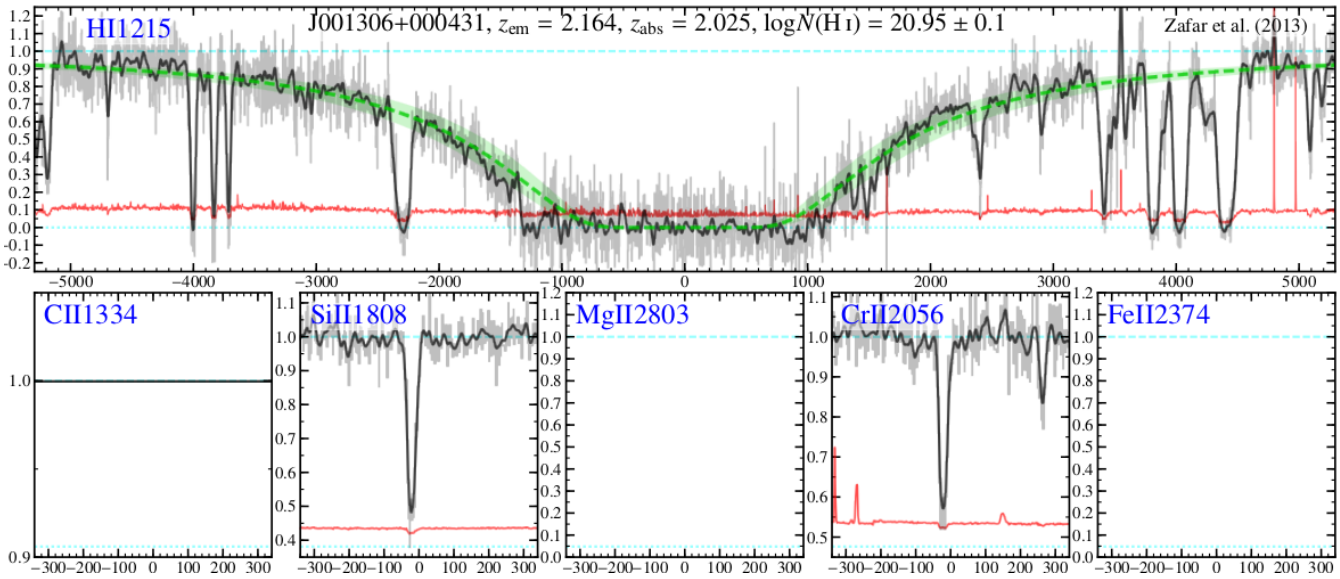

Figure 2: Absorption lines plotted in velocity space, Credit: `https://github.com/MTMurphy77/UVES_SQUAD_DR1/blob/master/DLAs/DR1_DLAs.pdf`

V. References

- Murphy, Kacprzak, et al. (2018)
- `https://github.com/MTMurphy77/UVES_SQUAD_DR1`
- Extragalactic Astronomy and Cosmology – An Introduction, by Peter Schneider