# Analysis of multiwavelength observations of Active Galaxies

## Introduction

Due to the expansion of the Universe, all distant extragalactic objects get farther away from each other with a speed that increases with distance. Within a cosmological model, measuring the red shift of the spectrum allows us, in principle, to estimate its distance. If e.g., the apparent magnitude or the angular diameter of an object are known, it is possible to determine its absolute magnitude or its angular size.

In this exercise we will determine the redshift of a sample of Active Galactic Nuclei (AGN) from their absorption and emission lines. The presence and intensities of the lines in the spectra allow to do Astrophysics, in the sense of investigating the physical conditions of the material responsible for its emission. In this exercise we will measure the width of some of these lines, to learn something about the conditions of the material producing them.

## Exercise

The spectra will be analysed individually. The spectra will be plotted using the application of GUIspec, which will be run from Linux or Windows following the teacher's instructions. The files with the data for each object will be in the same directory as the application. Each spectrum will be loaded into the application, which includes its own help files. Fluxes are in $f_\lambda$ in units of erg/cm$^2$/s/Å.

To start with, the general shape of the spectrum should be compared with the continuum of the spectra shown in Figures. This will give a first indication of the type of object under study. AGN and galaxy masks can also be used. They can be found under the menu Masks→AGN and Masks→ES0.

### Determination of the redshift

After that the obvious emission lines (if any is present) should be examined, checking if they match the lines in Table 1. The application also allows to do this easily using the menu Masks→Plot AGN lines, and the scroll bar z. When the brightest emission lines are identified, the fainter ones should also be checked. For each object, the redshift and the observed lines should be recorded.

For the objects with a galaxy continuum, common galactic absorption lines can also be checked against using the menu Masks→Plot Gal lines. In this process it is important to take into account the presence of atmospheric absorption lines, mainly around 7600 and 6360 Å. The application can mark their ranges, in the menu Tasks→Plot atm. lines.

### Line widths

For the objects with emission lines, the parameters of the main lines (those in Table 1) should be measured, particularly their width. This can be done within the application: pressing *m* both sides of the line and *g* in line centre, the application fits a gaussian, giving the line parameters in an additional window.
You can also use Tools→"Fit straight line plus gaussian to 1$^{st}$ selected spectrum over visible range" to fit a linear continuum and a gaussian. The line parameters will be

displayed in an additional window. The observed wavelength of the line centre is GC, and its width is GS.

To translate the width of the line to the Full Width at Half Maximum (FWHM), it should be taken into account that FWHM=2(2Ln2)$^{1/2}$ GS. Assuming that all this width is due to the Doppler effect of the clouds responsible for the emission of the lines, it is possible to calculate their speed Δv=FWHM×c/GC. Δv should be calculated for the main permitted and forbidden lines.

## Black Hole Masses

In the cases where broad line components have been detected for $H_\beta$ and MgII, the mass of the SMBH should be calculated as follows:

$$M_{BH}(H_\beta) = 1.05 \times 10^8 \left(\frac{L_{5100}}{10^{46}\mathrm{erg/s}}\right)^{0.65} \left[\frac{FWHM(H_\beta)}{10^3\mathrm{km/s}}\right]^2 M_\odot$$

$$M_{BH}(MgII) = 5.6 \times 10^6 \left(\frac{L_{3000}}{10^{44}\mathrm{erg/s}}\right)^{0.62} \left[\frac{FWHM(MgII)}{10^3\mathrm{km/s}}\right]^2 M_\odot$$

where $L_{5100}$ and $L_{3000}$ are the accretion disk luminosities at rest-frame 5100Å and 3000Å. To compute the luminosities a Cosmology Calculator such as
http://www.astro.ucla.edu/~wright/CosmoCalc.html
could be used.

After the mases are derived, they should be compared to estimate the reliability of the technique.

## Optical appearance and X-ray emission properties

From the results obtained in previous sections it should be possible to predict the expected optical colours (blue/red objects) and morphology (point like vs. extended) of the AGN. An optical image should be associated with each AGN.

Finally, it is also possible to use the results to predict whether photoelectric absorption should be expected in X-rays. An X-ray spectrum should be associated with each AGN.

## Report

After the exercise a report must be written, with the following sections:
1. Summary: a paragraph explaining the goal of the exercise, the techniques used and the results obtained
2. Methods: a brief explanation of the means used, as well as of the observational and statistical techniques used
3. Results: numerical values obtained, presented as tables and plots. A plot for each spectrum analysed must be included showing the following information: absorption and emission lines for AGN and galaxies (both lines and the corresponding labels); redshift; atmospheric bands.

**The criteria used to carry out each part of the exercise must be well justified.**

| Tabla 1: Common emission and absorption lines | |
|---|---|
| **Line** | **Wavelength (rest frame Å)** |
| Lyman alfa | 1216 |
| SiIV | 1397 |
| CIV | 1548 |
| CIII] | 1908 |
| MgII | 2798 |
| [OII] | 3726,3729 |
| CaII H&K, abs | 3933.7,3968.5 |
| Banda G, abs | 4298,4304,4310.4 |
| H gamma (also abs) | 4340.5 |
| [OIII] | 4363 |
| H beta (also abs) | 4861.3 |
| [OIII] | 4958.9,5006.8 |
| MgI, abs | 5168.6,5175.4,5183 |
| NaI, abs | 5890,5895.9 |
| Atmospheric abs. | 6277.85-6312.71 |
| H alfa (also abs) | 6562.8 |
| Atmospheric abs. | 6868.71-6926.41 |
| Atmospheric abs. | 7595.04-7692.72 |

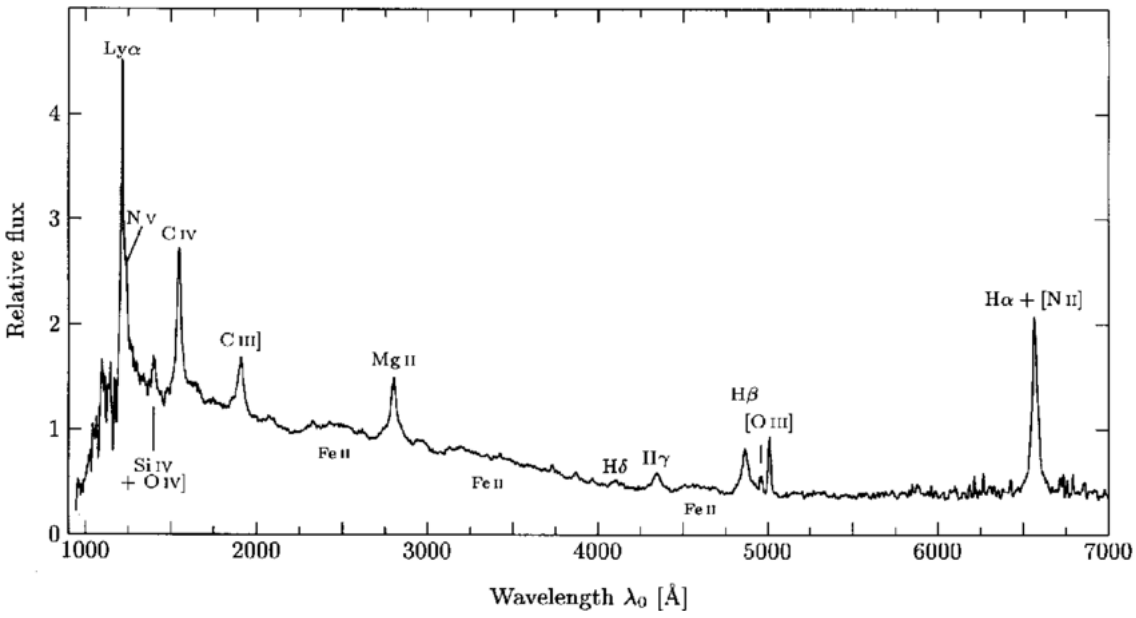


Figure 1: rest frame spectrum of an AGN, with the main broad and narrow emission lines marked.

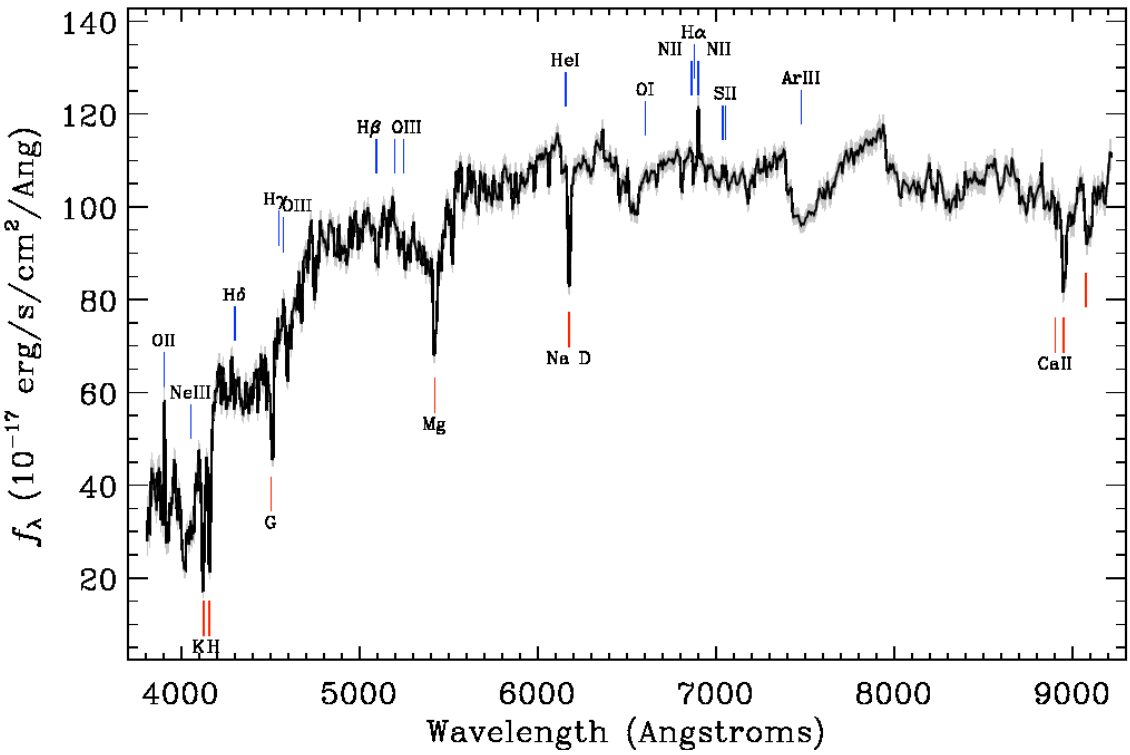


Figure 2: rest frame spectrum of an elliptical galaxy, with the main emission (blue) and absorption (red) lines marked.

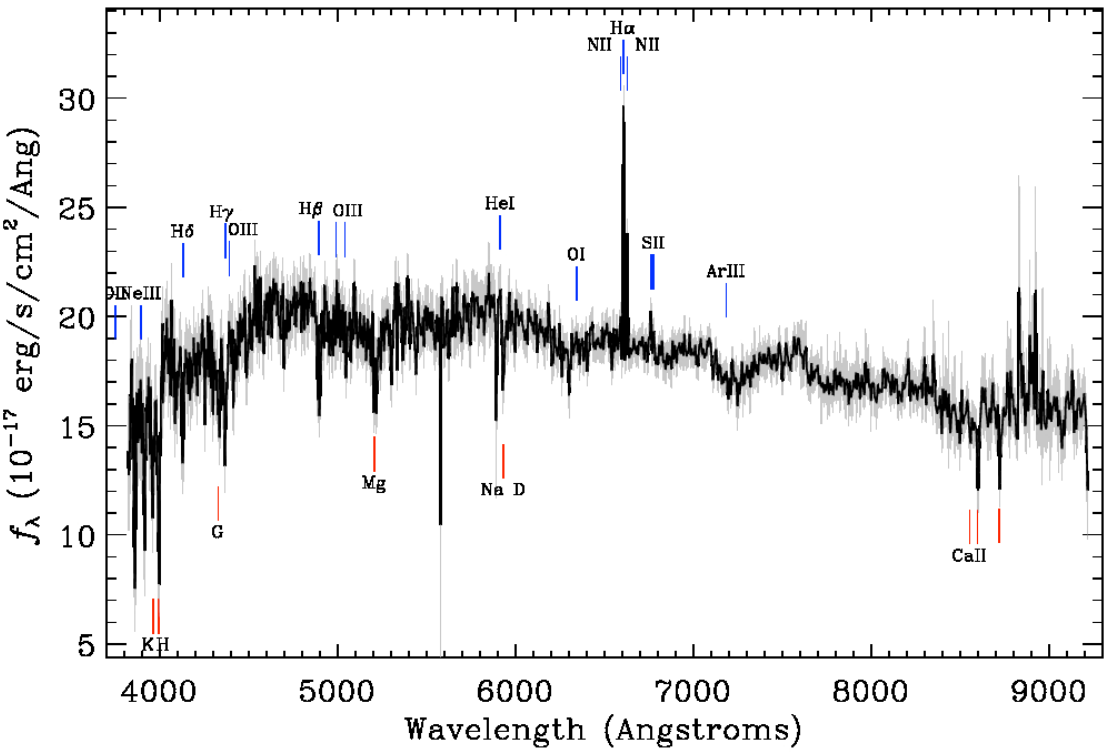


Figure 3: rest frame spectrum of a spiral galaxy, with the main emission (blue) and absorption (red) lines marked.