S2 - Estimating the magnetic field strength in a sunspot

Task

Estimate the magnetic field strength in a sunspot, using the Zeeman splitting of spectral lines.

Observation

The observation will be performed with the solar telescope in the "Einsteinturm".

Data reduction

[Data reduction for data taken before 2016:](#)

Login at the [Laboratory Course computer](#). Copy the observational data (TIFF files) from the directory `~/data/<date>` to your own directory (see [name conventions](#)). Use the command `ls` to view the directory's content. After the copying there should be at least two TIFF files, possibly with names that represent the meaning of the image.

The TIFF images can be viewed in *ImageMagick* with the console command

```
display filename.TIF
```

(The default contrast settings are generally unfavorable, as the image appears extremely dark.)

We use [GDL](#) for the data reduction. The program need to do the following steps:

- Convert TIFF to FITS
- Read-in the FITS file
- Rearrange the byte order of the 16-bit numbers (First check if this is required for data from the Einsteinturm!)
- Rotate the images for further data reduction in Python (the dispersion must be oriented horizontally/in X direction), i.e. rotate the image matrix
- Save the converted and rotated image as FITS files

Luckily, the required program (`konvert.pro`) is already prepared and can be found in the scripts directory. Copy it to your own directory. At the end of this program a few lines need to be adjusted. Use a text editor, i.e.

```
kate konvert.pro &
```

to open the script and change the parameters that describe the input files (filenames, dimensions). To

compile the program, start *GDL*

```
gdl
```

then compile the program via

```
gdl> .compile konvert.pro
```

The program itself is started in *GDL* by calling the program name, which in this case should be

```
gdl> konvert
```

The program converts and rotates the images, then saves the FITS files. They can be viewed (outside of *GDL*) with

```
ds9 filename.fits &
```

The image should be clearer and rotated in comparison to the TIFF file.

Analysis

The analysis can be performed with the Python script *comparespecs.py* that is already known from S1. The input (filename, lines) need to be adjusted accordingly. Use an editor of your choice. Note, that both spectra are in one file now. Mind that pixel errors can best be avoided by averaging over a number of lines of the image, but choose the regions with the maximal splitting.

Save the script and execute it by

```
./comparespecs.py
```

This will produce a PostScript file with the overlaid spectra which can be viewed with

```
gv speccmp.ps &
```

To avoid overwriting the output of S1 it is possible to change the filename of the output. Determine the shift of the Zeeman components $\Delta \lambda$. The wavelength calibration is done using telluric oxygen lines (see Table below). The magnetic field strength can then be calculated:

$B[\mathrm{T}] = \frac{4\pi m_\mathrm{e} c}{e} \cdot \frac{\Delta \lambda}{g\lambda_0^2} = 2.142\cdot 10^7\cdot\frac{\Delta \lambda[\mathrm{nm}]}{g\lambda_0^2[\mathrm{nm}^2]} = 2.142\cdot 10^4\cdot\frac{\Delta \lambda[\mathrm{pm}]}{g\lambda_0^2[\mathrm{nm}^2]}$

with the wavelengths λ_0 and the Landé factor g:

	$\lambda_0\,[\mathrm{nm}]$	
Fe	630.151	$g = \frac{5}{3}$
Fe	630.250	$g = \frac{5}{2}$

	$\lambda_0\,[\mathrm{nm}]$	
O$_2$	630.200	
O$_2$	630.276	

Protocol

Note, a joined protocol shall be created for S1 and S2.

The protocol is expected to contain the basic theory of the Zeeman effect. The above formula is to be derived. Discuss the importance of the Zeeman effect for this laboratory course. Search for an image of the investigated sunspots in the SOHO-Archive. Classify the sunspot following the Waldmeier (Zurich) scheme. Calculate the magnetic field strength in the sunspot and discuss its plausibility in regard to comparison values.

Overview: Laboratory courses