Exercises related to the lecture on stellar atmospheres

Idea

In these exercises we want to get a flavor of how spectral lines are formed in stellar atmospheres, more specifically what effects the abundance has on line strength. To this end, we will run a spectral synthesis with the SYNTHE code developed by R.L. Kurucz (see documentation directory). The code is "research grade", meaning that it is actually used in research projects. SYNTHE is able to synthesize a piece of stellar spectrum based on a previously calculated 1D stellar atmosphere model. We are not calculating the atmosphere model here, we focus on the spectral synthesis. Potentially, SYNTHE can take a large number of lines into account provided by extensive line lists.

The material provided in the exercises is actually a subset of the complete ATLAS/SYNTHE suite which is available from `atmos.obspm.fr` . Have a look at the site in case you would like to obtain the complete distribution. Technically, the binaries distributed for the exercises have been compiled for a 64bit Linux system.

Exercise 1: Synthesis of a piece of the solar spectrum

The `exercise` directory contains an ATLAS model of the Sun called `asunodfnew.mod`. The shell script `synthe.csh` is set-up to run a small piece of the solar spectrum around the Na D lines in the range 585–595 nm. Run the script, and try to understand (roughly) how it works. For that, have a look at the section on SYNTHE in the "Atlas_Cookbook". Load the file

```
../documentation/atlas\_cookbook/Atlas_Cookbook.html
```

into a browser. The script `synthe.csh` generates a lot of diagnostic output that we ignore here – assuming that the synthesis is successful. The final result of the synthesis is put into the files

```
t5777g444a00p00_w585_595_r1.dat
t5777g444a00p00_w585_595_r2.dat
t5777g444a00p00_w585_595_r3.dat
```

These are ASCII files containing the wavelength, absolute flux including lines, absolute continuum flux, and normalized flux in four columns. The three files are for three different rotational velocities assumed for the Sun. Now, we would like to visualize the result. You may use your favorite plotting tool for this purpose. The file `sun_neckel_585_595.txt` contains an observed solar spectrum from the solar atlas of Neckel & Labs (1984, Sol. Phys. 90, p. 205) for comparison. It has the same format as the output files of the SYNTHE script.

Instead of using your plotting tools, we have also provided a simple PYTHON script for plotting purposes. First copy (or link) one of the output files to the generic file name `tmp.dat`. Then invoke IPYTHON and run the script `plotspec.py`:

```
shell> ipython
In [1]: %run plotspec
In [2]: plot2(syn,obs)
```

Note, that the plot window allows to zoom and pan.

- Can you locate the Na D lines?
- Are you content with the correspondence between synthesis and observations?
- Do you have an explanation for potential differences?

Exercise 2: Calculating the curve-of-growth of an iron line and check the solar iron abundance

We want to check whether the iron abundance assumed in the synthesis is compatible with the observations. The iron abundance can be found in the model file `asunodfnew.mod` as non-normalized number fraction. Except for H and He logarithms are given. The iron abundance in the file corresponds to A(Fe)=7.42 on the scale A(H)=12 (why?). The file `sun_spectrum_bass2000.pdf` contains an annotated solar spectrum. Select a suitable (clean and isolated) iron line in the wavelength range available in the observed spectrum. Measure its equivalent width. For this you can use the function `ew` in the Python script:

```
shell> ipython
In [1]: %run plotspec
In [2]: print ew(obs, <lower wavelength bound>, <higher wavelength bound>)
```

Then calculate a curve-of-growth for the line. You can do this by running several syntheses changing the iron abundance in the model atmosphere file. However, alternatively it is faster to generate a new line file containing various versions of the line with different oscillator strength. The idea here is that to good approximation the equivalent width of a line depends on the product $gf\epsilon$ (ϵ is the abundance) only. The new fake lines should not fall on top of the original line so that it is necessary to displace them in wavelength (a bit). The continuum is not changing much over the 10 nm of the synthesis window so that the involved error is very small.

- Which abundance fits the strength of the observed line best?
- Change the extra microturbulence in the `synthe.csh` script to zero. Does it change your result?