Stellar Atmospheres, Ht 2002
Lab 2: The solar iron abundance

Lab report due: Tuesday, 29 October 2002

Goal:	Use SME to determine the solar iron abundance and the astrophysical *gf* values for some iron lines.
Tip:	Think about the questions in section 4 before you do the exercise!

1 Background

SME (Spectroscopy Made Easy) [5] is a tool for generating artificial spectra from atomic line lists, and for comparing these spectra to real observations. SME uses the Interactive Data Language IDL, which is commercial software for data analysis and visualization.

One thing for which SME is particularly useful is determining the abundances of elements in stellar atmospheres. This is done by adjusting a synthetic spectrum to match the observed spectrum of the star in question. Of course, this can only be done properly if the the spectral lines in the analysis are calculated using the correct atomic line parameters.

The Vienna Atomic Line Database (VALD) [4] is a database of atomic line lists from both theoretical and laboratory sources. The line lists are ranked according to their quality for each individual atomic parameter. Therefore, when you make a request to VALD, it will return the best data available for each parameter.

There are two ways of requesting data from VALD: via an e-mail service or a Web-based service. VALD will always respond via e-mail. *You need to register to use these services beforehand, so please sign up well before beginning these computer exercises.* More information about VALD, registration, and the different procedures for data extraction is available through the Web [1].

In this computer lab, you will use SME to generate synthetic spectra using atomic data from VALD. You will then be able to determine the iron abundance on the Sun by comparing those spectra to observations taken from the Kurucz Solar Atlas.

2 First steps

If you are working at a terminal other than sune, use secure shell to log on to sune (by typing `ssh sune`).

First, access the VALD Web interface [2] to extract a line list for the wavelength interval 6172–6181 Å. Use the "extract stellar" method with solar parameters (see

table below). Choose a microturbulence of 1 km s^{-1}, and a detection limit of five percent (0.05). The chemical composition defaults to solar. To be able to input the data easily into SME, you should request data in the VALD short format, with the default configuration. Please note that it can take up to 30 minutes before you receive the response from VALD containing your line list. Once you receive it, save it to a file and remove all the text lines before the one that contains the starting and ending wavelengths.

Solar parameters	
Teff	5770 K
log g	4.44
vmicro	1 km s^{-1}
vmacro	2 km s^{-1}
v sin i	1.66 km s^{-1}

To use SME on your system, you will need to install a few files in your current working directory. The batch file called `install_sme` that will take care of this. Copy it from `/u1/local/lab/stjarnatmos/Lab2/` into the directory in which you will run SME. Then run it by typing `./install_sme` in the terminal window.

3 Procedure

You are now ready to compute a spectral synthesis with SME. Launch IDL and SME automatically by typing the command `startsme`. At the Observatory there are a limited number of IDL licences available. Therefore, always quit SME and `exit` IDL when you are finished; do not leave IDL running if you do not need it!

1. Begin by generating a synthetic spectrum with fixed values. Choose the following settings:

Line Data	Select the line list you got from VALD.
Controls/Global parameters	Enter the solar parameters above and use a metallicity of [M/H] = 0, a radial velocity of 0.43 km s^{-1}, and set G6 to 2.5.
Controls/Model atmosphere	Choose "Single File" and "Find," then select /h3/piskunov/SYNTH/MODELS/sun.krz.
Observations	Choose "Segment of Kurucz solar atlas."
Jobs	Enter a name for this job, then hit RETURN. Make sure all parameters are set correctly by using **Review Current SME Request**.

Now you can compute the spectral synthesis by pressing **Save Request** and **Submit SME batch job**. The process runs in the background. You can check whether the computation is finished with **View SME Log File**.

When the computation is finished, go to the **Examine** menu, choose **Read SME structure from disk**, and read in your output spectrum, whose file name is the job name plus the file suffix `.out`. Then do **Plot Flux Profiles**.

Take a careful look at the spectra, especially at the iron lines. You can zoom in on parts of the plot by holding down the left mouse button while you select a portion of the plot. Return to normal size by hitting the **Unzoom** button. Note also that the plot is color-coded to show continuum points, line points, and points that should be ignored during any kind of fitting.

2. As you will see, the synthetic spectrum that you produced with the default parameters does not fit the observed iron lines on the Sun very well. But SME also allows you to select certain free parameters, for which it will determine the values that are most consistent with the observed spectrum. Try this option under **Controls/Free Parameters** and choose to solve for the iron abundance. Submit a new SME request. You can see what adjustments SME made during the fitting iterations by pressing **Examine** and **Print Free Parameters**. You can then also **Print** this output to a file called `sme_scratch.txt`. Compare your solution to the previous case. What happened, and why?

3. Repeat step 2, but this time ask SME to solve for both the iron abundance *and* the microturbulence `Vmic` simultaneously. Again, compare your solution to the previous case and explain what happened.

4. Return to the original solar abundance value and a microturbulence of 1 km s^{-1}. This time, fine tune the *gf* values by selecting individual iron lines from your spectrum and solving for their *gf* values. Analyze the remaining discrepancies.

5. Note that you can improve your fits even further by telling SME how to handle the different pixels in the observed spectrum. After reading either an input (`.inp`) or output (`.out`) file from disk, plot the flux profiles and put a checkmark in the **Edit mask** option. You can then ask SME to ignore certain points by selecting regions as "bad" pixels with the right mouse button (or reinstate them as "good" with the left mouse button). The **Switch to line/cont** button allows you to mark line and continuum regions with the right and left mouse buttons, respectively. Once you have edited the mask, try again to solve for the line broadening and the *gf* values for all strong lines. (Which parameter controls the broadening? Do you understand why?)

4 Written Report

Write a report in which you explain how the different atomic and stellar parameters influence the spectrum. Describe your strategy for determining the iron abundance and present your result.

In addition to this, take a moment to consider the program SME itself, which calculates the artificial spectrum by solving the radiative transfer equation. What are the implicit assumptions? What does this mean for your comparison of the artificial and observed spectrum? Below are more questions to consider, but feel free to comment on any other relevant points.

About the effects of atomic and stellar parameters on the shape of the spectral line[1]

1. Which atomic and stellar parameters determine the width of the line core?
2. Which parameters determine the strength of line wings at low (< 7000 K) and high (> 10000 K) effective temperatures?
3. What are micro- and macroturbulence? How do they affect line shapes? What is the relation between macroturbulence and surface gravity?
4. Describe the effect of stellar rotation on the shape and equivalent width of the spectral line.[2]
5. Describe the effect of the instrumental profile on the shape and equivalent width of the spectral line.
6. *Extra credit:* Use IDL or another such program to plot a doublet of identical Gaussians, separated by the FWHM. Then convolve them with (1) a rotational profile, and (2) another Gaussian that represents the instrumental profile. Compare the two results, and try to make a profile with three peaks. Why does this only work in one of the two cases?

About determining the solar iron abundance

1. What happened when you tried to solve simultaneously for the iron abundance and the microturbulence? Explain why.
2. The iron abundance cannot be solved simultaneously with the gf values. Discuss why. What other sets of parameters cannot be solved for simultaneously?

[1] Additional reading: Gray [3], chapter 13.
[2] Additional reading: Gray [3], chapter 17.

References

[1] http://www.astro.uu.se/∼vald/

[2] http://www.astro.uu.se/htbin/vald/

[3] D. F. Gray, *The Observation and Analysis of Stellar Photospheres*, Cambridge University Press, 1992.

[4] N. E. Piskunov, F. Kupka, T. A. Ryabchikova, W. W. Weiss, C. S. Jeffery, 1995, *A&AS* **112**, 525.

[5] J. A. Valenti & N. Piskunov, 1996, *A&AS* **118**, 595.

These computer exercises were written by Eric Stempels, and transferred to LaTeX and modified by Michelle Mizuno. They are based on notes by Nikolai Piskunov.