



SCIENCE ARCHIVES AND VO TEAM

# →ESAC VOSPEC SCIENCE TUTORIAL

## COMPARING SPECTRA OF THE SUN AND SIMILAR STARS



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European Space Astronomy Centre (ESAC) Tutorial

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# THE EXPERIMENT

## → THE AIM

The overall goal of this tutorial is to compare a spectrum of the Sun, taken by the SOHO satellite, with spectra from two similar type stars: Alpha Centauri and Capella.

## → PERFORMING THE EXPERIMENT

### Tools Used

**VOSpec:** This is an ESA Virtual Observatory tool used for multi wavelength spectral analysis. It has access to spectra, theoretical models, experimental photometry services and atomic and molecular line databases in the VO.

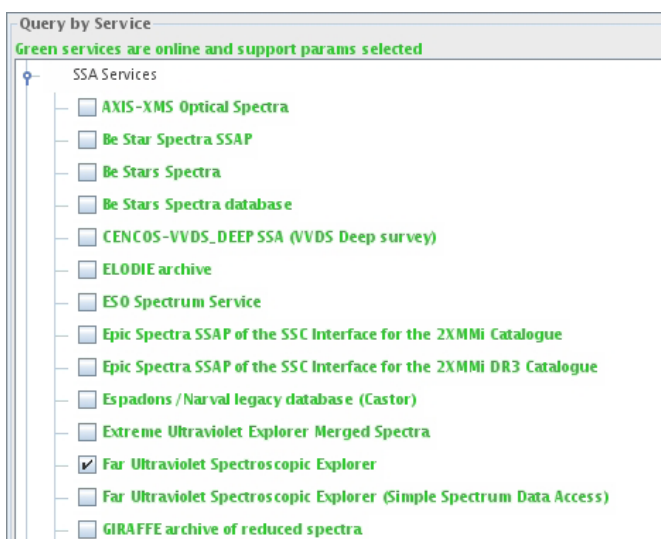
### Loading and Saving Spectra

1. Open VOSpec by visiting <http://www.sciops.esa.int/index.php?project=SAT&page=vospec> and clicking on the 'Webstart' link.

2. In the Target field type 'Capella' and click the 'Query' button. The **Server Selector** window opens.



3. Select the Observational Spectra Services, in the left-hand side of the window in the 'Query by Service' region, by opening up the Observational Spectra Services tree. Select the service called 'Far Ultraviolet Spectroscopic Explorer'

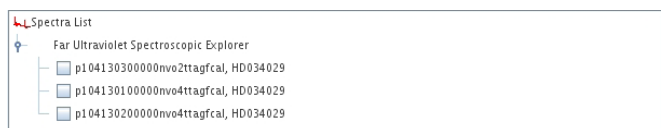


4. Click the 'Query' button.



The spectra are then loaded into the 'Spectra List' region in the lower part of the main VOSpec window.

5. Open up the tree structure to display the three available spectra.



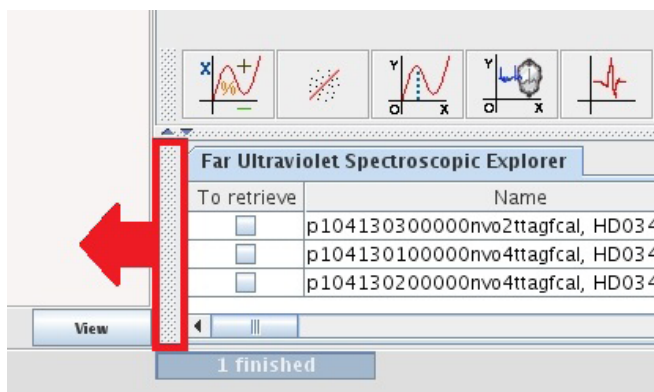
6. This list can also be viewed as a table by clicking the 'Tree/Table view' icon on the top right of the main VOSpec window.



7. Change the view to table. Expand the 'Name' column to show the full name. Click on the Name column and other columns and see how they can be sorted.

To retrieve	Name	Distance (degr...)	ssa:dataset.datamodel	ssa:curation.publisher
<input type="checkbox"/>	p104130300000nvo2ttagfcal, HD034029	0.00301496783...	Spectrum-1.0	MAST
<input type="checkbox"/>	p104130100000nvo4ttagfcal, HD034029	0.00301496783...	Spectrum-1.0	MAST
<input type="checkbox"/>	p104130200000nvo4ttagfcal, HD034029	0.00301496783...	Spectrum-1.0	MAST

This view can be detached into its own separate window by clicking the left region and dragging it out.



To reattach the view, simply close the window.

8. Select one of the spectra in the table and click the 'RETRIEVE' button



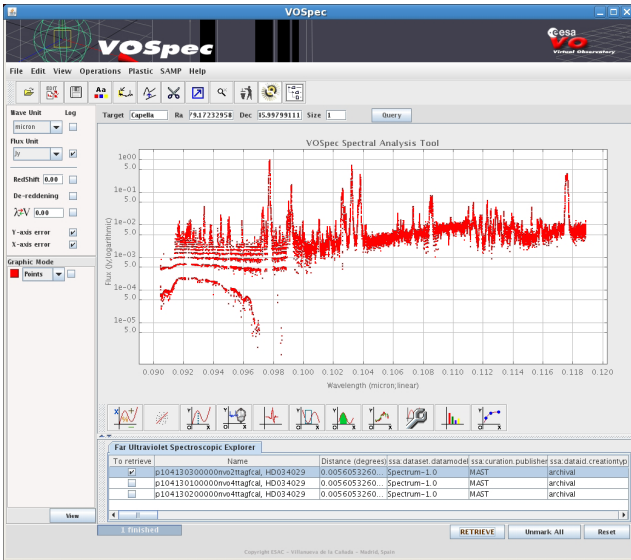
9. Select one of the spectra in the table and click the 'RETRIEVE' button

The spectrum is now displayed in the main VOSpec window.

10. On the left hand side, towards the top, untick the 'Log' box next to the 'Wave Unit'.



Once unticked the spectrum will redisplay with the x-axis (the wavelength axis) in linear, instead of logarithmic scale.

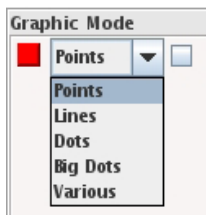


Note, the wavelength is shown in microns (micrometres), which are one millionth the size of a metre, or one thousandth the size of a millimetre.

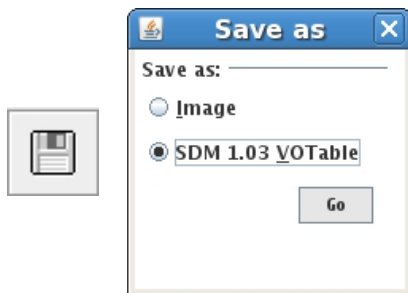
**11.** Try zooming in and out of the spectrum. Zoom in by clicking the left mouse button and dragging from top left to bottom right. Zoom out in a similar way by clicking the left mouse button and dragging from bottom right to top left, or by clicking the 'Unzoom' icon, located in the top menu and from the View dropdown menu.



**10.** Try changing how the spectra are drawn, e.g. from points to lines, to dots.



**11.** Save the spectrum by selecting **File -> Save** as in the main menu (or by clicking the save icon), select '**SDM 1.03 VOTable**' and click the 'Go' button. Save the spectrum as '**Capella.xml**'.



**12.** Click the 'Reset' button in the main VOSpec window.

### Repeating the process for Alpha Centauri.

Now we will repeat the same for the star Alpha Centauri:

**13.** In the target field type '**Alpha Cen**' and click the 'Query' button.

**14.** When the **Server Selector** window opens. Select the Observational Spectra Services, in the left-hand side of the window in the '**Query by Service**' region, by opening up the Observational Spectra Services tree. Select the service called '**Far Ultraviolet Spectroscopic Explorer**'.

**15.** Click the 'Query' button.

The spectra are again loaded into the 'Spectra List' region of the main VOSpec window.

**16.** Change the view to table and expand the '**Name**' column to show the full name. Also expand the '**Distance (degrees)**' column. This distance refers to the difference between the coordinates of the star (i.e. where the star is located in the sky) and the coordinates of each spectrum (i.e. where the telescope was pointing when it took the spectrum).

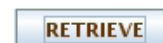
**17.** Sort the distance column so that the lowest value is the first in the list.

To retrieve	Name	Distance (degrees)	ssa.dataset.datamodel	ssa.curation.published
<input checked="" type="checkbox"/>	p104260100000mvo2ttagfcal, HD128620	0.019976653125123058	Spectrum-1.0	MAST
<input type="checkbox"/>	p104250100000mvo2ttagfcal, HD128621	0.05342573250597556	Spectrum-1.0	MAST
<input type="checkbox"/>	g081010200000mvo2ttagfcal, HD128620	0.08786701771045592	Spectrum-1.0	MAST
<input type="checkbox"/>	h096010100000mvo2ttagfcal, aCenA-viss1	0.10157186119066532	Spectrum-1.0	MAST

Do you see the difference in the names of the first two spectra? One has **HD128620** in the name and the other has **HD128621**. This is another name for a star (HD and then a number) and originates from the first large astronomical catalogue of stars, the Henry Draper (HD) Catalogue. HD128620 is another name for Alpha Centauri. HD128621 is another name for Alpha Centauri B, the companion star of Alpha Centauri.

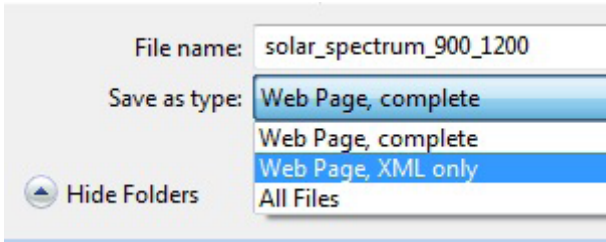
**18.** Since we are concentrating on the spectra from Alpha Centauri (HD128620), click on the first spectrum in the list, as shown in the image above.

**19.** Click the '**RETRIEVE**' button



The spectrum will again be displayed in the main VOSpec window.

**20.** Load a spectrum of the Sun and the spectrum from Capella you saved earlier: Firstly download this spectrum of the sun called **solar\_spectrum\_900\_1200.xml** and save it in the same folder as your Capella spectrum. This can be done by visiting: [http://www.rssd.esa.int/SD/ESAVO/docs/solar\\_spectrum\\_900\\_1200.xml](http://www.rssd.esa.int/SD/ESAVO/docs/solar_spectrum_900_1200.xml), right clicking and then selecting 'Save Webpage As'. When the 'Save As' window opens, make sure to select 'Web-page, XML only' from the dropdown menu before clicking 'Save'.



**21.** Next, select **File -> Open Spectrum** in the main VOSpec menu (or click on the 'Open Spectrum' icon).

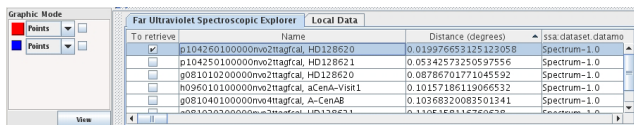


**22.** Browse to the folder you saved your Sun and Capella spectra in, select the spectrum of Capella and click the 'Open' button.

**23.** A window called 'Edit Spectra' opens. All that needs to be done here is to click the 'Accept' button.

Your loaded spectrum of Capella is now displayed along with the spectrum of Alpha Centauri.

**24.** To see which spectrum is which, click on one of them in your table, the spectral list.



When you do this, one of the coloured squares in the graphic mode region increases in size. Therefore, as shown above, the red spectrum is the Alpha Centauri spectrum, and the blue the Capella spectrum.

You can also press the coloured squares in the Graphic Mode region and display just that spectrum, plus the spectrum is highlighted in the table list. Or hover over the coloured squares and the name of the spectrum will appear.

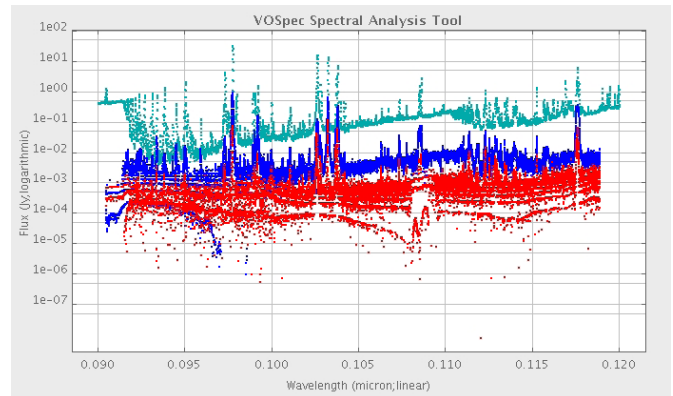
**25.** Click the 'View' button, in the bottom left corner, to view all the spectra again.

**26.** Now open the spectrum you downloaded of the Sun by selecting **File -> Open Spectrum** in the main menu (or click on the 'Open Spectrum' icon).

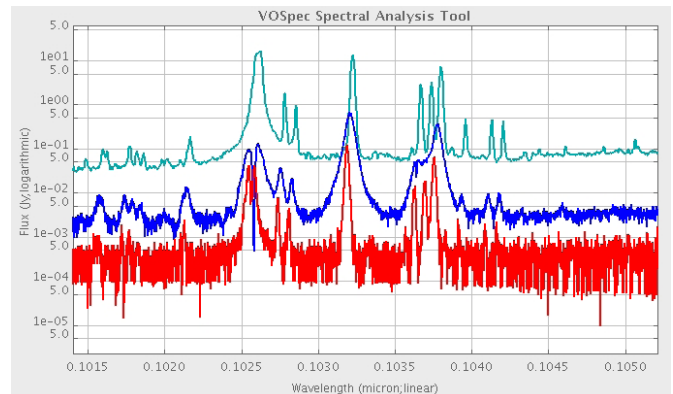
**27.** When the Edit Spectra window opens, click the 'Accept' button.

All three spectra are now displayed in the main VOSpec window.

**Note for astronomers and astronomy students:** This solar spectrum is not actually in Flux (Janskys), but is uncalibrated and is in counts per detector pixel. It is displayed here with the flux calibrated spectra for easier identification of spectroscopic lines.



**28.** Change in the Graphic Mode the points to lines and then zoom into the central region with the three strong emission lines (between 0.100 and 0.105 microns).

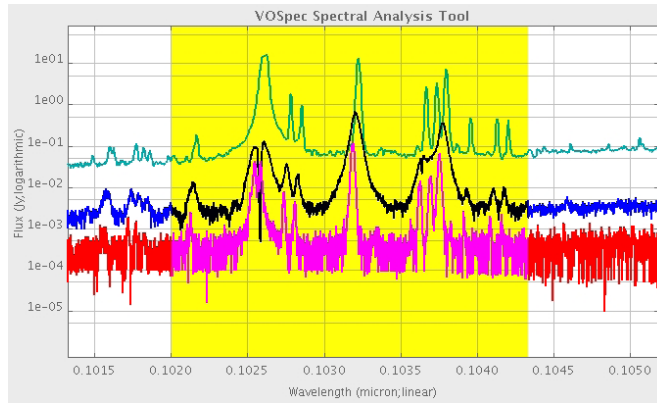


The top spectrum is from the Sun, the middle from Capella and the bottom from Alpha Centauri. There are only emission lines present in this wavelength region. **What differences and similarities do you see in the spectra from the three stars?**

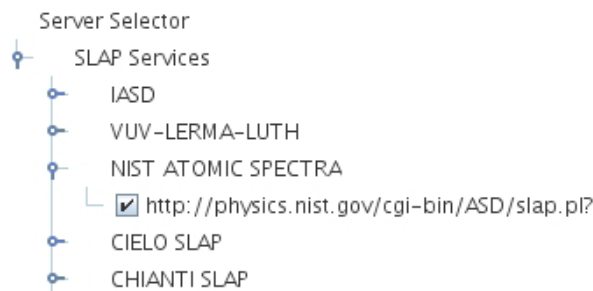
**29.** Now we are going to identify some lines. Select from the main menu **Operations -> SLAP** (or click on the SLAP icon).



30. Drag your mouse across the spectra so that the region turns yellow.

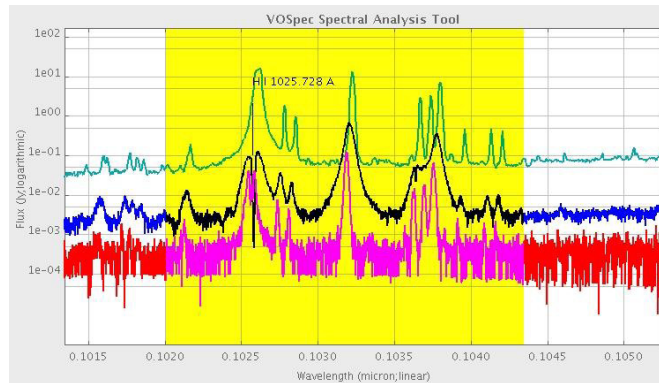


31. The Slap Viewer window will open. Open up the **SLAP Services** tree and select the **NIST ATOMIC SPECTRA SLAP** service.

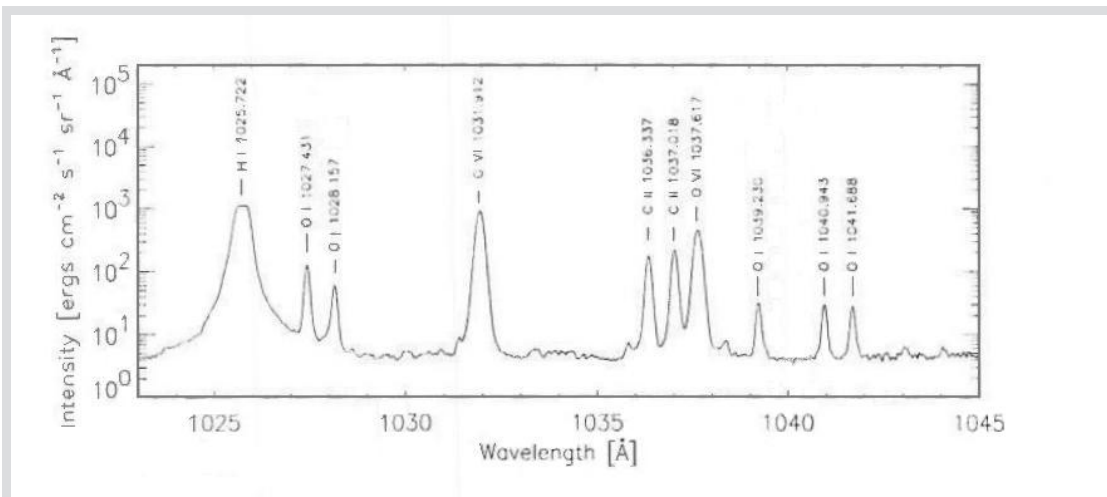


32. Click the 'Select' button. A table then loads in the lower region of the window, in the **Slap Services Output** panel.

33. Go back to the main VOSpec window and move your mouse across the spectra. The line identifications, from the loaded database, are shown on the spectra.



34. See if you can identify any of the lines using this database and comparing with the image below, which contains the line identifications for the Sun. (1 micron = 10000 Angstroms, or Å).



→ Spectrum of the sun in the far-ultraviolet, from 1020 to 1045 Angstroms, from the SOHO/SUMER instrument (Brekke et. al., 1997, Solar Physics, 175, 349). SUMER (Solar Ultraviolet Measurement of Emitted Radiation) is a spectrograph operating in the range from 400 to 1610 Angstroms, and measures plasma flows, temperature and density in the corona.



**Note:** The NIST ATOMIC SPECTRA service comes from the National Institute of Standards and Technology (NIST), in the US, and contains data for radiative transitions and energy levels in atoms and atomic ions. Data are included for observed transitions of 99 elements and energy levels of 56 elements, as observed on Earth. This database contains many lines we would not expect to see from stars. Also, it does not contain lines from the highly ionized oxygen ion O VI.

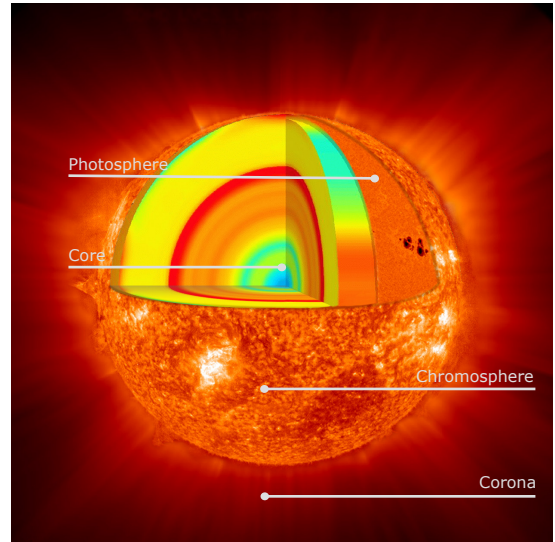
### → FROM WHERE DO THE FAR INFRARED EMISSION LINES ORIGINATE?

These emission lines arise from the very hot solar corona.

The corona is a region around the Sun, extending more than one million kilometres from its surface, where the temperature can reach two million degrees! In fact, the OVI lines that we looked at in this tutorial are formed at ~290,000 degrees!

→ For background on the Solar Atmosphere, see the ESA outreach page: <http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=2546>

→ For an introduction to the Solar Corona see the NASA outreach page: [http://imagine.gsfc.nasa.gov/docs/science/mysteries\\_11/corona.html](http://imagine.gsfc.nasa.gov/docs/science/mysteries_11/corona.html)





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