SCIENCE ARCHIVES AND VO TEAM

→ESAC VOSPEC SCIENCE TUTORIAL

COMPARING SPECTRA OF THE SUN AND SIMILAR STARS

THEORY SECTION

Tutorial created by Luis Sánchez, ESAC SOHO Archive scientist,
adapted from the 'Tracking Sunspots' SOHO classroom exercise:
http://soho.esac.esa.ubt/classroom/docs/Spotexerweb.pdf
and modified for use with the SOHO Science Archive and Aladin
by Deborah Baines and Pedro Osuna.

Tutorial Theory Section Edited and Reformatted By: Olivia Carrington, as part of
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http://archives.esac.esa.int

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ESAC Science Archives and Virtual Observatory Team

European Space Agency
European Space Astronomy Centre (ESAC) Tutorial

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INTRODUCTION

→INTRODUCTION

The first telescope was made in Europe in 1608. Galileo, who first performed scientific observations in the early 1613, concluded that the Sun did indeed have spots. If, as others suggested, these spots are planets passing in front of the Sun, they'd be the same in the centre as near the edges. He noted changes in size and shape. Other scientists came to similar conclusions.

The first historical determination of differential solar rotation was in 1630 by Scheiner, and then again in 1843 by Schwabe. This is an example of how scientific advances can sometimes be lost to tradition, and are re-discovered much later.

With the launch of the Solar and Heliospheric Observatory (SOHO) we now have access to high quality images of the Sun and its spots. In this tutorial, the SOHO Science Archive will be used along wtih Aladin to create animations and analse images of the Sun in order to determine the solar differential rotation.

In this booklet, the background and theory needed to fully understand the tutorial is explored.

↑An artist's impression of the SOHO spacecraft in orbit around the Sun.

BACKGROUND AND THEORY

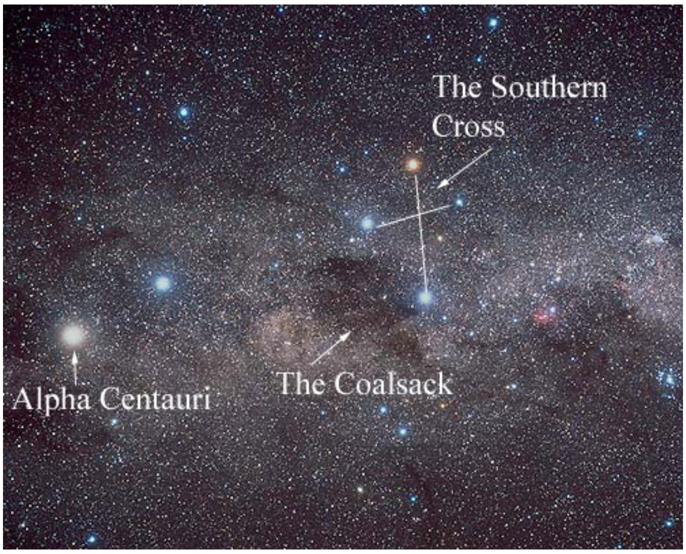
ALPHA CENTAURI

Alpha Centauri is the **second closest star to the Sun**, at 4.37 light years (1.34 parsecs) and the third brightest star in the sky. It is located in the Southern hemisphere, so we can not observe it in Europe.

This star is very similar to our sun in size, age and in temperature (it has the same spectral type = G2V).

The difference between Alpha Centauri and our Sun is that Alpha Centauri is actually a **binary system**, which means it has a companion star, called **Alpha Centauri B**.

Alpha Centauri B is slightly smaller than Alpha Centauri, and therefore fainter and cooler (spectral type = K1V), making it more an orange-yellow colour than the whiter Alpha Centauri A.



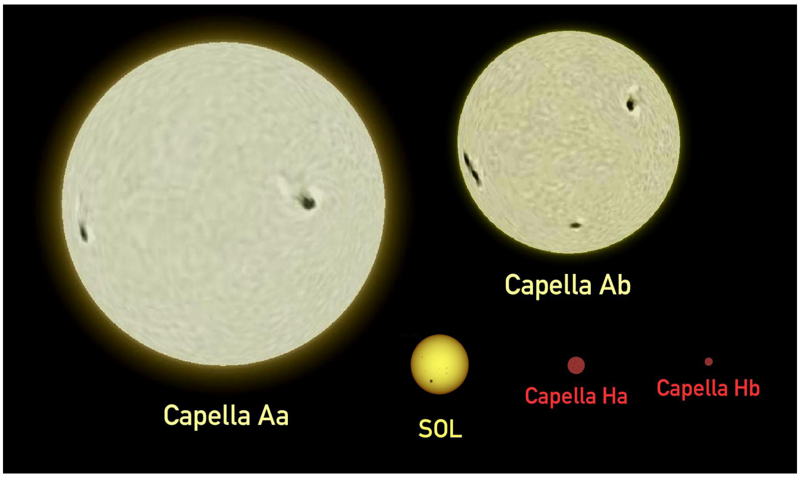
The orbit of the two stars is **eccentric** (not circular) and varies between a minimum of 11.2 astronomical units (about the distance from the Sun to Saturn) to a maximum of 35.6 astronomical units (about the distance from the Sun to Pluto).

CAPELLA

Capella is the sixth brightest star in the sky, the third brightest star in the Northern hemisphere (after Arcturus and Vega), and the brightest star in the constellation Auriga.

Although it appears to be a single star to the naked eye, it is actually a star system of **four stars in two binary pairs**.

The first pair consists of **two bright, large type-G giant stars**, both with a radius around 10 times the Sun's, in close orbit around each other (0.67 astronomical units, just under the distance from the Sun to Venus), and with an orbital period of approximately 104 days.



These two stars are thought to be cooling and expanding on their way to becoming red giants.

The second pair, around 10,000 astronomical units from the first, consists of **two faint, small and relatively cool stars**. The Capella system is relatively close, at only 42.2 light years (12.9 parsecs) from Earth.

SPECTROSCOPY

This section is adapted from the Caltech, IPAC outreach web pages: **http://www.ipac.caltech.edu/Outreach/Edu/Spectra/spec.html**:

Spectroscopy is a very important tool in astronomy. It is the detailed study of light from an object.

Light is energy that moves through space and can be thought of as either waves or particles. The distances between the peaks of the waves of light are called the light's **wavelength**. Light is made up of many different wavelengths. For example, visible light has wavelengths of about 1/10th of a micrometre.

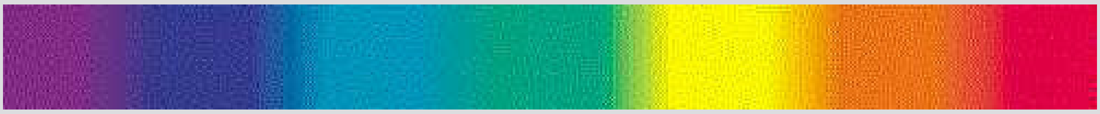
Spectrometers are instruments which spread light out into its wavelengths, creating a **spectrum**. Within this spectrum, astronomers can study **emission** and **absorption lines** which are the finger-prints of atoms and molecules. An emission line occurs when an electron drops down to a lower orbit around the nucleus of an atom and looses energy. An absorption line occurs when electrons move to a higher orbit by absorbing energy. Each atom has a **unique spacing of orbits** and can emit or absorb only certain energies or wavelengths. This is why the location and spacing of spectral lines is unique for each atom.

Astronomers can learn a great deal about an object in space by studying its spectrum, such as its composition (what it's made of), temperature, density, and its motion (both its rotation as well as how fast it is moving towards or away from us).

There are three types of spectra which an object can emit: **continuous**, **emission** and **absorption** spectra. The examples of these types of spectra shown below are for visible light as it is spread out from purple to red, but the concept is the same for any region of the electromagnetic spectrum (from gamma-rays through X-rays, ultraviolet, visible, infrared, millimetre, all the way to radio).

CONTINUOUS SPECTRA

Continuous spectra (also called a thermal or blackbody spectrum) are emitted by any object that radiates **heat** (has a temperature). The light is spread out into a continuous band with every wavelength having some amount of radiation. For example, when sunlight is passed through a prism, its light is spread out into its colours.

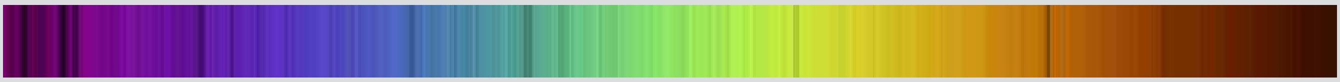


↑A continuous visible light spectrum

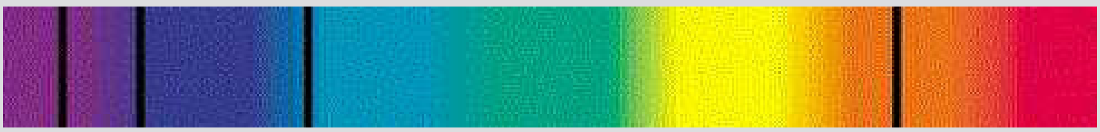
ABSORPTION SPECTRA

If you look more closely at the Sun's spectrum, you will notice the presence of dark lines. These lines are caused by the Sun's atmosphere absorbing light at certain wavelengths, causing the intensity of the light at this wavelength to drop and appear dark.

The atoms and molecules in a gas will absorb only certain wavelengths of light. **The pattern of these lines is unique to each element** and tells us what elements make up the atmosphere of the Sun. We usually see absorption spectra from regions in space where a cooler gas lies between us and a hotter source. We usually see absorption spectra from stars, planets with atmospheres, and galaxies.



↑Detailed image of our Sun's visible light spectrum



↑The absorption spectrum of hydrogen

EMISSION SPECTRA

Emission spectra occur when the atoms and molecules in a hot gas emit extra light at certain wavelengths, causing bright lines to appear in a spectrum. As with absorption spectra, **the pattern of these lines is unique for each element**. We can see emission spectra from comets, nebula and certain types of stars.

↑The emission spectrum of hydrogen

→GETTING STARTED

→You should now be able to proceed with the tutorial with enough relevant knowlege to understand it fully.

→In the tutorial, you will be using the VOSpec to compare spectra from the Sun with spectra from other, similar stars. On completion of the tutorial, you will have the knowledge necessary to compare spectra from other stars and planets with each other and have a further understanding of spectroscopy as a whole.

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