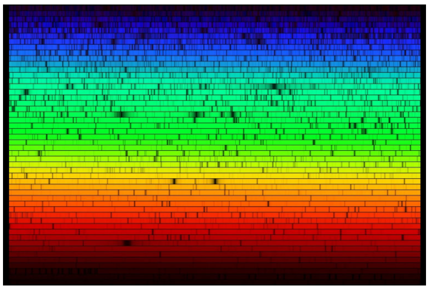
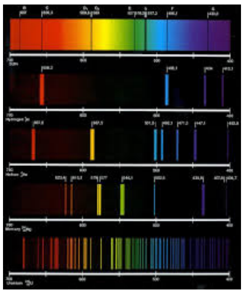
Sun – Part 8 - Spectroscopy 2


Sun's absorption spectrum S un's emission spectrum Bunsen and Kirchhoff

Fraunhofer lines are absorption lines, dark areas which occur when the energy from a radiative source is absorbed by the material or object. Absorption lines result when an electron moves to a higher energy level and needs an input of energy to do so. They are formed by cooler gas in the Sun's photosphere (outer layer) that absorbs radiation emitted by hotter gases below. Each line is a unique signature of the element or molecule that forms it, enabling the chemical composition of the star to be determined.

In contrast, emission lines are bright lines in particular wavelengths in a spectrum, given out by emitted hot or excited atoms. Emission lines result are formed when an electron drops from a higher to a lower energy level, with associated release of energy. They are the means by which scientists can determine the temperature, pressure and chemical composition of the emitting gas. They can appear on their own, or superimposed on an absorption spectrum eg from the hot gases round a star. Whether absorption or emission lines are observed depends on the type of material and its temperature relative to another emission source.

In the 1850s, the Swedish physicist and astronomer Anders Ångström, while using the fact that the simplest method of exciting a sample is to heat it to a high temperature, discovered the phenomenon of discrete emission lines. He also noted that the dark Fraunhofer lines in the solar spectrum had the appearance of a reversed emission spectrum ie they were absorption lines. In 1861, he began intensive study of the solar spectrum. A year later, combined photographic and spectrographic study of the Sun's emission spectrum led to him proving the presence of hydrogen in the Sun, among other elements.

These hydrogen lines were later named Balmer lines after the Swiss mathematician Johann Balmer who, in 1885, identified that the four visible hydrogen lines were part of a series that could be expressed in terms of integers. In 1868, Ångström published an atlas of solar spectrum and measurements which contained the wavelengths of over 1,000 spectral lines.

Advances in spectral analysis in chemistry were essential prerequisites to improved understanding of astronomical spectroscopy, including explanations for the phenomena behind the dark lines. Two of the scientists central to this were The German chemist Robert Bunsen and the German physicist Gustav Kirchhoff. In 1859, they started working together on emission spectra. Using advanced techniques, including a prototype spectroscope, they established the principles of spectral analysis while discovering several new elements during their study of the spectra of heated materials. This work established the direct link between chemical elements and their unique spectra.

Independently of Ångström, they identified that Fraunhofer lines indicated that light from the photosphere was being absorbed by at those wavelengths by the Sun's atmosphere. They also realised that one of the Fraunhofer lines was produced by sodium in the solar atmosphere, and that, therefore, other Fraunhofer lines revealed other elements present in the Sun. Kirchhoff also independently developed three laws relating to spectroscopy. These are:

- An incandescent solid, liquid or gas under high pressure emits a continuous spectrum
- A hot gas under low pressure emits a 'bright line' or emission line spectrum
- A continuous spectrum source viewed through a cool, low-density gas produces an absorption line spectrum

The work of Bunsen and Kirchhoff on the Sun's spectrum formed the foundation of astronomical spectroscopy and kick-started the work done by the English astronomer William Huggins and others. In the 1860s, William and Margaret Huggins used spectroscopy to determine that stars are composed of the same elements as those found on Earth. Their spectral analysis of celestial objects also enabled them to distinguish between features like nebulae and galaxies. They achieved this by identifying that nebulae eg Orion nebulae had the pure emission spectra characteristic of gas, while others eg Andromoeda galaxy had the spectral characteristics of stars. In 1864, they were the first take take a spectrum of a planetary nebula, the Cat's Eye Nebula.

Sources: Ridpath, I (Ed) (2012) Oxford dictionary of astronomy 2nd ed rev, www.en.wikipedia.org,