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Finnish Heidi has been interested in the cosmos since an early age. Having lived and worked in a variety of locations, from the snowy Arctic Circle to the sunny Canary Islands, Heidi describes her decision to become a professional astronomer as a "jump into the unknown". She is keen to challenge the conception of astronomers being eccentric professors glued to their telescopes!

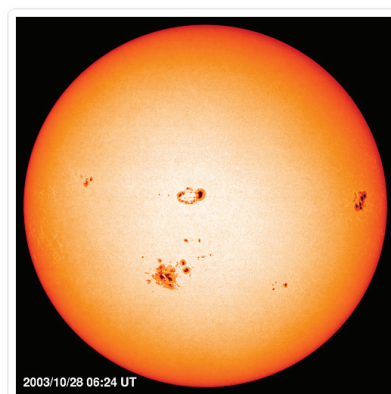
The Sun may appear as a perfect sphere in the sky, but it actually has blemishes called sunspots. Their nature was a mystery until modern science was challenged to explain their nature and workings. Now, astronomers have a new task: determine whether other stars have the same phenomena!

Sunspots and starspots: magnetic islands larger than our planet

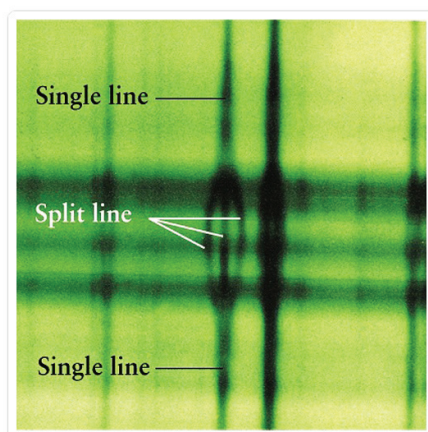
If you glance at the Sun through fog, clouds or darkened glass you will usually see a perfect white disk (never look at the Sun directly because of the damage it will do to your eyes!) On occasions though you would see dark patches on this smooth surface. Usually these so-called sunspots are so small that you would see them only with the aid of a telescope, but occasionally large spots occur, many times larger than the Earth. These are even visible to the naked eye.

Dark or light?

Even though sunspots appear dark they still radiate light, and actually they are brighter than the full Moon. They just appear dark when compared to the rest of the Sun. What is causing this apparent darkness? When scientists first started regular observations of sunspots, after the development of the telescope in the early 17th Century, their origin was already hotly debated. Some thought that they were clouds in the solar atmosphere, others that they were small bodies orbiting the Sun. Still, quite soon scientists agreed that they were actually something that was in the Sun itself, but it took couple of hundred years before people really started to understand what sunspots are.



Solar disk observed by MDI (Michelson Doppler Imager) instrument on-board the SOHO (Solar and Heliospheric Observatory) spacecraft. The image shows what the Sun looked like in visible light on October 28, 2003. Several large sunspot groups are seen on the solar surface. The three biggest groups are all rare naked eye sunspots, with the biggest one occupying an area equal to about 15 Earths.
Image credit: SOHO.



In the presence of magnetic field, spectral lines that are normally at a single wavelength become split into two or three components. Here observations of spectral lines inside a sunspot (split lines) and in the surrounding solar surface (single line) are shown.
Image credit: NOAO.

Mysterious magnetism

In 1908 the magnetic origin of sunspots was discovered by an American astronomer, George Ellery Hale. In the presence of a magnetic field, spectral lines are split into several components. Hale used this so-called Zeeman effect to show that sunspots harbour very strong magnetic fields. The Earth's magnetic field at the equator is approximately 0.3 Gauss; the field in sunspots can be as high as 3000 Gauss. In the normal solar atmosphere material is transported from the hot interior; causing an outward flow of heat and energy. In sunspots, the magnetic field acts as a valve hindering the normal heat transportation. Some of the transportation still occurs and thus the sunspot is still hot, approximately 4000 degrees Celsius, but even though this temperature sounds very hot, it still is about 2000 degrees Celsius less than the rest of the solar surface.

Modern telescopes can make extremely detailed pictures of the Sun, resolving structures that are less than 100 kilometres in size. When looking at a sunspot with such high resolution, one starts to see an amazing amount of detail.

Large sunspots consist of two main parts: the darker inner region called umbra, and the lighter outer region called penumbra. Still, even the dark penumbra is not completely dark, it can host bright points or lanes, which are called umbral dots and light bridges. In the centre of the sunspot the magnetic field is at its strongest and comes straight out of the Sun (or goes directly in). When moving away from the centre of the spot the magnetic field weakens fast.

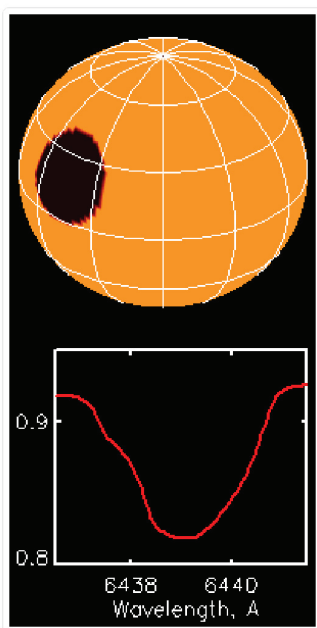


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A common phenomenon?

Do stars other than our Sun also show spots? Or is our own star just a special case? This question is difficult to answer. Stars are very far away from us, and thus they are seen from Earth just as points of light. Even with the largest modern telescopes, it is impossible to make direct images of the surface of stars. The only exception to this are the close-by supergiants, very large stars that have diameters dozens of times that of the Sun. Images of the surface of supergiants, like Betelgeuse (the very bright red star in the constellation of Orion), are available. In these images the resolution is quite poor, and only structures that are very much larger than our Sun can be seen. So, what can be done if one really wants to see spots on other stars?

The most detailed information on stellar surfaces can be obtained using Doppler imaging. This is an indirect method in which high resolution spectra are obtained at many different times during the rotation of the star. The high resolution spectra shows the shape of the spectral lines in great detail, and the exact shape of the spectral line depends on many physical parameters, among them the temperature. Therefore, if spots having a different temperature than the rest of the stellar surface are on the surface when the star is observed, a change in the shape of the spectral line is seen. If the observations are repeated while the star rotates, a detailed map of the surface temperature, so-called Doppler image, can be created.



The principles of Doppler imaging. The detailed shape of the observed spectral line profile changes when a spot of different temperature is seen on the surface. A map of the surface temperature can be obtained when the star is observed at many different rotational phases, and the movement of the "bumps" in spectral lines is followed in detail. Image credit: Dr. Svetlana Berdyugina.

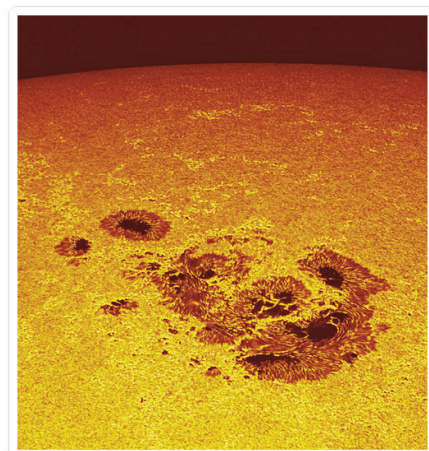
Surprise discoveries

With the Doppler images, starspots can be studied in detail. For some stars observations over several years exist, enabling us to also study the starspot evolution with time. One of the most striking discoveries with Doppler imaging is the latitude range at which the spots can occur. In our Sun the spots occur very close to the equator, at most 35 degrees away from it. On other stars spots are frequently seen at very high latitudes, 50-65 degrees away from the equator, and even at the rotational poles themselves. Another surprise discovery was the sheer size of the spots. Some spots on giant stars (old stars having diameters several times that of the Sun) are larger than the Sun itself. Still, even the resolution of Doppler images does not allow us to see whether these large spots are one huge spots, or a group of smaller spots.

Another interesting observations is that on the Sun the spots live only for a relatively short time, usually days and at most some weeks, while on some other stars spots have been observed at the same location for several years. This of course does not necessarily mean that it would have to be exactly the same spot staying there the whole time; spots could die and new ones form in the same location.

One has to keep in mind that so far all the methods for seeing spots on other stars than our Sun allow us to only see very large spots. With the current instruments and observing techniques one would not be able to detect even the largest sunspots on distant stars.

Still, our observations of other stars provides very interesting, and sometimes surprising, pictures of magnetic surface structures on stars make astronomy such an exciting field of research. It provides both amazing visual images and important tools to unveil the secrets of the Universe.



A detailed image of the largest sunspot seen in the earlier figure with the full solar disk. These observations have been obtained with the Dutch Open Telescope on La Palma, Spain, on November 2, 2003. The complexity of this huge sunspot group is breathtaking. Image credit: Dutch Open Telescope.

This feature article was written as part of the Cosmic Diary Cornerstone project for the International Year of Astronomy 2009. To find out more, check out www.cosmicdiary.org and www.astronomy2009.org.