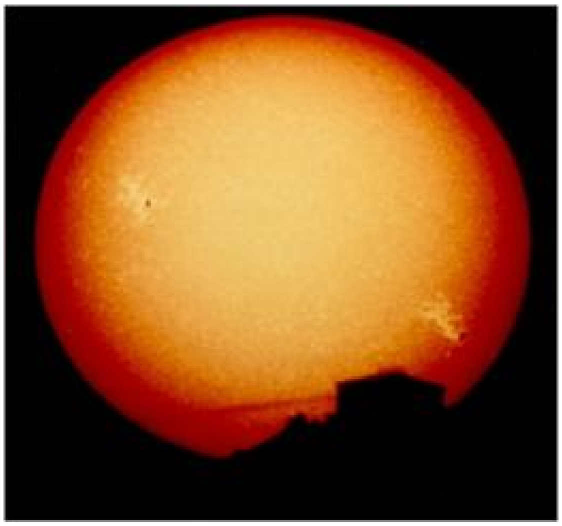
The rhythm of our star

February 15 2010



When we look at the Sun we cannot penetrate beyond its outer surface, the photosphere, which emits the photons that make up the radiation we can see. So how can we find out what is inside it?

Imagine a metal box. If it is a long way from us we cannot tell whether it is full or empty. Yet if we can tap it, the sound that we hear will tell us about its contents: it will be deeper if the box is full, and hollow-sounding if not. The human brain can tell one substance from another, and gain information about what it is, from the sound it makes.

Seismology works in a similar way: the way that waves travel through the interior of an object tells us about its structure. The "signature" of sound waves as they travel through a particular type of material is unique, and it changes as the material changes. This makes it easy to tell whether a sound is travelling through air or water, for example. The science of Seismology is not earthbound - it has travelled to the stars. The methods it uses to gather information about stars are basically the same as they are on Earth. The first sound to be heard was the "song" of the Sun, because it is near to us and therefore easy to observe. That is how Helioseismology was born.

Our star, like others, is a gaseous incandescent sphere. We can compare the way it makes sounds to what happens when a clarinet is played. Blowing into the mouthpiece makes it vibrate, changing the air and creating sound waves that become trapped inside the instrument. The Sun does something similar. Turbulence in its outer layers produces changes in the gas and creates sounds, in the same way as the mouthpiece of a clarinet. The resulting sound waves (they originate from just below the visible surface in a layer some 200 or 300 kilometres thick, which is very thin given that the Sun's radius is 700,000 km) remain inside the star and resonate like a musical instrument.

Do you find this surprising? The stars provide natural cavities for sound waves, just like musical instruments. We cannot hear the sounds because they are in empty space and have nothing to travel through to reach us. However, as the gassy materials in a star are compressed and expand they make the star oscillate, and this oscillation can be detected. This is the visible manifestation of sound waves as they move across the interior of a star, and studying them gives us information about the layers it contains.

The proximity of the Sun, which is just 150 million kilometres away, means that we can detect not only waves that are travelling right across it but also much more localised waves with very short wavelengths.

Analysing these lets us observe the movement of plasma in the first few thousand kilometres beneath the surface, to see how it rises, falls and is altered by the Sun's magnetic field.

Sunspots are one of the best known features of the Sun, but until now little has been known about the activity that takes place beneath them. It was known only that sunspots are magnetic phenomena, are a reliable indicator of solar activity, and that they follow an eleven year cycle during which they increase and decrease in size. When the Sun is very active it gives off large amounts of matter as electrically charged particles that can be hazardous to space missions, damage communications satellites and cause power cuts. On a less practical level, they also cause the beautiful polar auroras on Earth.

Our star rotates on its axis every 27 days, which means that part of it is always hidden from observers on Earth. "Seeing" what happens on the Sun's back and building models to forecast the composition of the regions we can see is important for our understanding of the effects of activity in the Sun. Seismology provides us with a tool for this. Using an observation technique known as *farside* we can determine the position of sunspots on the hidden side of the Sun. Irene González-Hernández, a scientist at the NOAO (*National Optical Astronomical Observatory*) said during her address to the 4th International HELAS Conference in Lanzarote (Canary Islands) that: "activity in the farthest regions of the Sun can be observed by looking at waves in the nearer regions. We make a model of the way these waves are propagated from the *farside* to the *frontside* and compare it to what we are observing. When the data being received do not conform to the model we know that the waves are passing through a zone that has a strong magnetic field or sunspot".

González-Hernández also said that data from the GONG (*Global Oscillation Network Group*) telescope network, which has seven stations across the globe to observe the Sun continuously without stopping at "nightfall", is used for this. The first network of telescopes acting in "relay" was the University of Birmingham's BiSON network in the 1980s. BiSON's first instrument, which is still in operation, was built in Tenerife in 1977.

Another instrument used for *farside* observation is the MDI (*Michelson Doppler Imager)* on the SoHO (*Solar and Heliospheric Observatory*) satellite, which has been the most successful mission ever launched to study the Sun and is a product of collaboration between the European and North American space agencies (ESA and NASA). MDI will soon have some help: next week NASA will launch the SDO (*Solar Dynamics Observatory*), with the HMI (*Helioseismic and Magnetic Imager*) instrument on board.

The most significant advances in the SDO over SoHO, or rather the advantages of the HMI over the MDI, were spelt out in Lanzarote by Richard Bogart of Stanford University: "higher resolution, wider coverage and the ability to measure the magnetic fields." For the first time we will continuously observe the whole of the Sun, which will allow us to track whole-system structures as they develop: from below the surface, through the surface fields and the structures of the corona.

Since its beginnings thirty years ago, Helioseismology has been listening to the great mass of resonances that is the Sun. The Sun's properties never seem to stop "changing" as we discover more about it. Is it typical of other stars? In many ways it seems not, but to know for certain we will have to wait to see what research tells us in the years ahead.

Source: Instituto de Astrofisica de Canarias