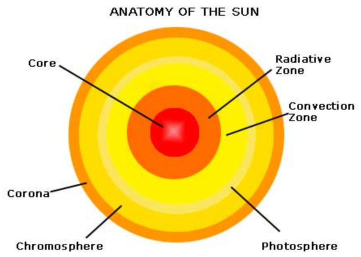
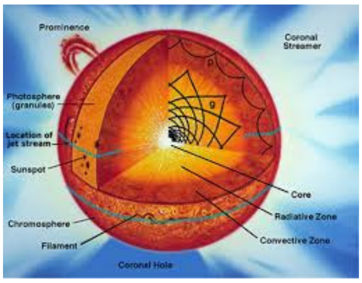
Sun – Part 13 - structure 2





Solar structure

Solar atmosphere
Normally overwhelmed by sunlight, this is visible during totality of a solar eclipse. Illogically, it is much hotter than the Sun's surface, with temperatures increasing with increasing distance. These high temperatures, particularly in the corona, show that the solar atmosphere is heated by something other than direct heat conduction from the photosphere.

One possible explanation is the presence of Alfvén waves, transverse waves that occur in regions containing a magnetic field and a plasma. The ionised, highly conducting plasma material is 'frozen' into the magnetic field and forced to take part in its wave motion. However, Alfvén waves do not easily dissipate in the corona and cannot fully explain its very high temperatures. Heating by flares and other large scale solar emission phenomena is perhaps a stronger possibility, but is still being investigated.

Chromosphere
About 9,000 km thick, this forms the lowest of the three parts of the solar atmosphere. Its name, meaning 'colour', reflects its visibility as a coloured flash at the start and end of a solar eclipse. Temperatures increase with altitude, from around 5,500 K at the upper photosphere, to around 20,000 K near the top.

Transition region
Temperatures rise rapidly from around 20,000 K to close to 1,000,000 K in this thin region, which is about 200 km in depth. The increase is facilitated by full ionisation of helium ions in the transition region, which significantly reduces radiative cooling of the plasma. This region does no occur at a defined altitude. It forms a nimbus around chromopsheric features eg spicules, filaments, and is in constant, chaotic motion.
The region is not easily visible from Earth, but is easily observed in space by instruments sensitive to the ultraviolet part of the spectrum.

Corona
The average temperatures in the corona, the outer part of the solar atmosphere, and the origin of the solar wind, is 1-2 million K, but it can reach 8-20 million K in the hottest regions. Explanation for these temperatures is incomplete, but at least some is known to be from magnetic reconnection.

Coronal streamers are tapered patterns visible in corona when the Sun is covered. They are formed by outward flow of plasma which is shaped by the Sun's magnetic field lines and extend millions of kilometres into space. This extended solar atmosphere has a volume much greater than that of the Sun itself.

Waves at the outer surface of corona with randomly blow away from the Sun are the origins of the solar wind. This continuous outflow of ionised gas energy from the corona consists of electrons, protons and, to a lesser extent, nuclei of elements like helium

Heliosphere

This is the tenuous outermost part of the solar atmosphere. Filled with solar wind plasma, it is defined to begin at the distance where the flow of the solar wind becomes superalfvénic ie where flow becomes faster than the speed of Alfvén waves. This occurs at approximately 20 solar radii (0.1 AU).

Temperatures and dynamic forces in the heliosphere cannot affect the shape of the corona because information can only travel at the speed of Alfvén waves. The solar wind travels continuously outwards through this region, forming the solar magnetic field into a spiral shape until it impacts the heliopause**.** more than 50 AU from the Sun. In December 2004, Voyager 1 passed through a shock front thought to be part of the heliopause. Both Voyagers recorded higher levels of energetic particles as they approached this boundary.

Links between solar surface and atmosphere

Solar prominences are large, bright gaseous features which reach outwards from the Sun's surface, often in a loop shape. Anchored in the photosphere, they extend out into corona. First described in the 14th century Laurentian Codex in a description of the May 1185 solar eclipse as 'flame like tongues of live embers', they typically extend over many 1,000s of kilometres. The largest on record is estimated to have been around 800,000 km long (over half the Sun's diameter). Some are so powerful that they throw out matter from the Sun into space at speeds of 600->1,000 km/s.

While the corona consists of extremely hot ionised gases (plasma) which do not emit much visible light, prominence plasma is typically 100 times cooler and denser than coronal plasma, and more visible. They form over timescales of about 1 day and may last a few days or persist in the corona for several weeks or months. Some break apart and may give rise solar flares or coronal mass ejections. Ongoing, intensive research is still being undertaken in order to identify how and why solar prominences and other solar emission features form.

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