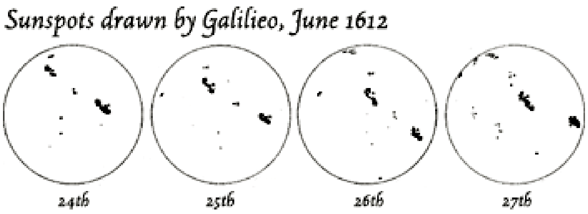
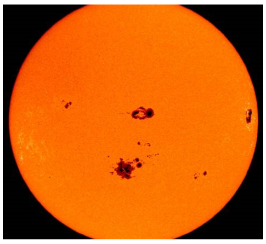
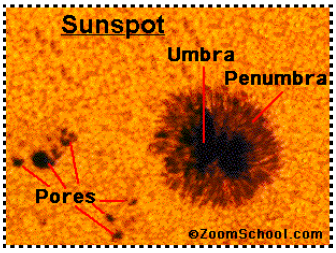
Sun series – Parts 21 – 31

Sun – Part 21 - Sunspots



These appear visibly as dark spots on the Sun's surface. They correspond to concentrations of magnetic field flux that inhibit convection, resulting in reduced surface temperatures compared with the surrounding photosphere. They usually appear in pairs, each member having opposite polarity.

Sunspot numbers are closely linked with the 11-year solar (sunspot) cycle and vary in number as the cycles progress. Their position also varies across the cycle. Early in cycle, sunspots appear at higher latitudes then move towards the equator as solar maximum approaches. The polarity of each of the magnetic field in each pair also changes with each 11-year cycle from North-South to South-North and back. Spots from two adjacent cycles, distinguished by the direction of their magnetic field can co-exist for some time.

Although magnetic pressure should tend to counter field concentrations, causing sunspots to disperse, they can live from a few days to several months. The largest spots usually last the longest. Satellite observations may provide an explanation for why sunspots are not shortlived. A powerful downdraft identified beneath each sunspot forms a rotating vortex that is believed to sustain the concentrated magnetic field. However, all eventually decay. Moving with the rotating Sun, they can travel at relative speeds of a few 100 m/s. Many expand and contract as the move across the Sun's surface, with sizes ranging from small pores of around 300 km to groups spanning up to 160,000 km diameters. They usually appear in groups.

Reflecting intense solar magnetic activity, sunspots often accompany secondary phenomena eg coronal loops. Most solar flares and coronal mass ejections also originate in magnetically active regions around visible sunspot groupings

Sunspot temperatures vary from 3,000-4,500 K. With surrounding surface temperatures of around 5,700 K, these cooler areas are visible as dark spots. They have two parts. In the darker central umbra, the magnetic field lines are almost vertical to the solar surface and temperatures are as much as 1,600 K lower than the photosphere. In the lighter, outer penumbra, lines are more angled and temperatures are around 500 K cooler. The penumbra accounts for around 70% of a spot's area.

They are self-perpetuating storms, apparently the visible counterparts of magnetic flux tubes in the convective zone which get 'wound-up' by the differential rotation of the Sun. If stress on tubes reaches a certain limit, they curl up and punctuate the Sun's surface. Because convection is inhibited at the puncture points, energy flux from the interior falls, and, with it, surface temperatures. All sunspots start as tiny dark pores and then may develop into small penumbra-less spots arranged in pairs. In a developing group, the spots become much larger and more separated in the first few days, reaching maximum complexity and area by the tenth day.

Monitoring sunspot numbers is central to study of solar activity. Initially introduced in 1848 by Swiss astronomer Rudolph Wolf, the so-called Wolf sunspot number system was replaced in 1855 by the more refined relative sunspot number. This is calculated by accounting for both the total number of individual spots and number of sunspot groups plus a factor k which represents the efficiency of the observer and telescope. In 1981, responsibility for generating the sunspot numbers during specific intervals was transferred from Switzerland to the Royal Observatory in Brussels. At this time, the index was renamed the International Sunspot Number. In America, two other sunspot number indices are also compiled.

Since the start of satellite measurements in 1979, sunspot numbers have been found to correlate with the intensity of solar radiation. Variations in solar intensity caused by the sunspot cycle are relatively small; around 0.1% of the solar constant.

Observation history The sunspots recorded during the Han dynasty in China (206 BCE – 220 CE) are possibly the earliest written records of these solar features. During the 12th century, the Arabic philosopher Averroes also described sunspots.

However, it was during the early 17th century that the development of the telescope allowed for improved understanding of sunspots. Galileo is the most famous person to observe sunspots through a telescope, but Thomas Hariot and others also made early telescopic observations. Galileo posited that the dark marks were on the surface of the Sun, not small objects passing between Earth and Sun, as had been proposed earlier. During the 1860s, the English solar physicist Norman Lockyer was first to study sunspots spectroscopically. He found Doppler shifts caused by convection currents in the Sun's gases.

Sunspots continue to be observed with both land-based and Earth-orbiting solar telescopes. Filtration and projection techniques are used on telescopes to allow for direct observation and camera imaging. Other specialised tools, including spectroscopes and spectroheliscopes, are also used to study sunspots. Also, use of artificial eclipses which block the central body of the Sun, allow for viewing of the solar edge and circumference as sunspots rotate through the horizon.

Due to its association with other solar activity, recording sunspot occurrence and behaviour can help predict space weather, the state of the ionosphere and conditions for shortwave radio propagation and satellite communication

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