A Brief Column for the Beginning Stargazer Introducing a New Astronomical Term Each Month

Astronomy is rich with terminology. This column will help beginning stargazers ease into the world of astronomy by *briefly introducing* a new but *basic astronomical term* (word, acronym or abbreviation) each month. This list, which began January 1999 with the letter ***a***, is alphabetical but uses successive letters for each month's entry. (We will return to the letter ***a*** after twenty-six months.)

Word of the Month for November 2000

Wolf sunspot number (also the *Zürich sunspot number*) A measure of *sunspot activity* on the solar disk, taking into account both the number of individual spots and sunspot groups. It was introduced in 1848 by J. Rudolph.Wolf, a Swiss astronomer, who helped confirm the sunspot cycle. (See *sunspots* at end for more information about "sunspots.")

Both the Wolf and Zürich sunspot numbers are obsolete having been replaced by the *International Sunspot Number* (R) on January 1, 1981:

$$R = k\,(10g + s),$$

where k is an observatory reduction constant (approximately one), g is the number of sunspot groups, and s is the total number of individual spots. The factor k (usually less than one) represents the observing conditions and telescope, and was equal to one for Wolf's observations at Zürich. It is determined each day without reference to preceding days.

Relative sunspot numbers are now based on observations from a network of about twenty-five observing stations with the observatory in Locarno, Switzerland used as a reference station to preserve continuity with the older Wolf numbers. The Sunspot Index Data Centre in Brussels publishes an International values of R (http://sidc.oma.be/index.php3). In addition, the NOAA Space Environment Center (http://www.sec.noaa.gov/) computes a daily "Boulder Sunspot Number." This number is usually about 25 percent higher than the Belgium International Sunspot Index. (Both the Boulder and the International numbers are calculated from the same basic formula, but incorporate data from different observatories.)

Monthly values of R are combined to give a 12-month moving average (R_0), also known as the *smoothed* sunspot number. For a solar cycle, the minium and maximum value of R_0 denote sunspot minimum and maximum respectively. Minimum to minimum values determine the length of the sunspot cycle. The largest annual mean number (190) occurred in 1957.

Note: The Sun is now near maximum activity for the current solar cycle and interest in the Sun is therefore high. Consequently, the following material is included to give additional information about sunspots.

sunspots Small looking dark areas on the Sun are called *sunspots*. Typical sunspots are about the size of the Earth although some become much larger. The big sunspot that appeared during the week of 2000 September 17, largest in the previous nine years, was about three to four times the Earth's diameter. This sunspot (really group) could be easily seen with the naked eye (using a safe, solar filter, of course).

Spots often form in pairs or isolated clusters or groups. At any given time hundreds of sunspots may occur or virtually none at all. For example, the earth facing side of the solar disk had almost no spots during the week prior to the appearance of the large sunspot in September 2000! The absence of spots was striking because this event occurred near the middle of the current sunspot cycle (#23 since Wolf began counting cycles with the solar maximum of 1750).

Sunspots are typically seen only at low solar latitudes, in roughly parallel zones, on opposite sides of the Sun's equator. They are rarely seen on the Sun's equator.

The average number of sunspots occurring on the Sun actually waxes and wanes in an approximate eleven year sunspot cycle. At the beginning of a new sunspot cycle, the sunspot zones are found at a solar latitude of approximately thirty degrees north and south of the Sun's equator. As the sunspot cycle progresses, the sunspot forming regions slowly shift toward the equator of the Sun. Thus, sunspots forming near the beginning of a new cycle are generally observed about thirty degrees from the Sun's equator. And sunspots observed near the end of the cycle are found at lower latitudes, about five degrees from the Sun's equator.

The changing positions of new sunspots from the solar equator lead to a well-known graph showing the latitudes of sunspots during the solar cycle. This graph is called the "butterfly diagram" because the collection of plotted points looks like a butterfly!

A common misconception is that sunspots migrate toward the Sun's equator as they evolve. They don't. Instead, when new spots develop, they usually form closer to the equator as the sunspot cycle progress through the years. Sunspots remain at approximately the same solar latitude where they first form but then move westward on the solar disk as the Sun rotates.

Sunspots may last from a day to a hundred days. Nevertheless, most sunspots are short-lived lasting only a week or so. Since the Sun spins (rotates) on its axis only once in about four to five weeks, many sunspots do not last for even one solar rotation. (The Sun is gaseous and does not rotate with a single period—the rotation period is about 25 days at the solar equator and exceeds five weeks near the Sun's poles.)

The sunspot cycle typically lasts about eight to fourteen years. The eleven year period often quoted for the sunspot cycle is therefore only a rough number. Actually, the solar cycle is approximately twenty-two years when one takes into account the magnetic reversal of sunspot group "polarities." Sunspots often develop in pairs with a leading and a following spot. For example, if the leading spot is a north magnetic pole, the trailing spot is a south magnetic pole. All sunspot groups from the same cycle have the same magnetic arrangement in the Sun's northern hemisphere. Sunspot groups in the opposite (southern) hemisphere have the reverse polarity. Using our previous example, the leading spot will thus be a south pole and the trailing spot a north pole.

During the next sunspot cycle, the magnetic polarities reverse themselves—the spots that had north magnetic polarities now have south polarities and vice versa. So, the Sun really needs about twenty-two years to complete a "solar cycle." Often the new sunspot cycle will commence before the old cycle ends. Therefore, sunspots from the new cycle are seen at mid-solar latitudes while sunspots from the old cycle appear closer to the Sun's equator. And, of course, the magnetic polarities of the "old cycle" spot pairs are reversed from the magnetic polarities of the "new cycle" spot pairs!

The physics of sunspots is very complex. Although theories about sunspots are still subject to debate, they seem to form when the Sun's magnetic field lines break through to the Sun's surface causing a disruption in the normal flow of hot gases. The Sun's rotation wraps and distorts magnetic field lines, an effect more pronounced near the equatorial regions of the Sun.

Sunspot magnetic fields are about one thousand times stronger than the magnetic field of the normal solar surface, which itself has a magnetic field several times stronger than the Earth's magnetic field. The darker, central regions of sunspots become cooler than the Sun's surface by approximately 1,500 Kelvins (about 2,000 Fahrenheit degrees). So, sunspots emit less light than the usual solar surface and appear dark only in comparison to the brighter, surrounding areas. (The surface of the Sun that we see has a temperature of approximately 5,800 Kelvins or about 10,000 F.)

Thus, if one could view a sunspot by itself, it would appear to glow brightly!

For more information about sunspots and the solar cycle, see http://www.sunspotcycle.com/. ☼

References. J. Mitton 1991, *Concise Dictionary of Astronomy* (Oxford Univ. Press); I. Ridpath 1997, *A Dictionary of Astronomy* (Oxford Univ. Press); *Explanatory Supplement to the Astronomical Almanac*, 1992, ed. P.K. Seidelmann.