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Stephen James O'Meara's
Excerpt
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CHAPTER 1

The Sun: angel of light

The Sun, with all those planets revolving around it and dependent on it, can still ripen a bunch of grapes as if it had nothing else in the universe to do.

– Galileo Galilei

WARNING!

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- **Do *not* look at the Sun with your unaided eyes for any prolonged period of time.**
- **Do *not* use sunglasses, smoked glass, CDs, DVDs and CD-ROMs, film negatives, or polarizing filters, to look at the Sun; they are not safe for the purpose!**
- **Do *not* look at the Sun directly through binoculars without them being covered with specifically designed filters – filters that cover the objective lenses at the front end of the binoculars and let only about one part in 100,000 through, reflecting the rest.**
- ***Never* leave unattended mounted binoculars (without filters) pointed at the Sun, since even an instant's viewing could be devastating to someone's eyesight.**
- **Do *not* use solar filters at the eyepiece end of your binoculars. The focused light can burn through, or crack, the filters.**
- **Purchase solar filters only from reputable dealers.**
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When the ancients finished their nightly musings under the stars, and the Sun brought the light of day, the answer to at least two astronomical questions (what is a star, and what purpose does it serve?) was burning brightly before them. The Sun is the nearest star to the Earth. It is the center of our Solar System and our true Angel of Light.

The Sun is with us every day and will be with us long into the future. Earth cannot escape its gravitational embrace. We are are destined to circle our star year after year, lifetime after lifetime. The Sun affects our moods, warms our bones, and burns our skin. Its light influences the way we see the world and how artists express their feelings. Without the Sun, the sky would not be blue, breezes would not blow, and rains would not fall. All usable energy on Earth – including oil and coal – is directly, or indirectly, manufactured by the Sun. Plants convert sunlight into food, which enables them to stay healthy and grow. All animals, including humans, need plants, air, and water to survive. Simply put, the Sun is the most important star in the sky; without it, life on Earth would not exist.

Little wonder then that Sun worship has prevailed throughout recorded history. The first Egyptian pyramid, the Step Pyramid at Saqqara, was dedicated to the Sun; its shape may reflect the step-like appearance of the setting or rising Sun during certain mirage conditions. Some of the largest neolithic and pre-Columbian structures in the world – including the Great Pyramid of Giza, Stonehenge, and Machu Picchu – have intimate alignments with the rising and setting Sun, whose position shifts seasonally

along the east and west horizons like a slowly swinging pendulum.

Ancient peoples recognized not only the importance of the Sun's position along the horizon but also its divine power as the creator and nurturer of all living things. Researchers have found depictions of Sun gods and goddesses on nearly every continent. Among the oldest are reliefs of various Egyptian deities carrying the solar disk atop their heads, such as Hathor, the supreme mother of pharaohs. Hathor is often depicted carrying the ankh, which, like the Sun, symbolizes eternal life or resurrection; the ankh's figure may, in fact, depict the Sun cresting the horizon. The images above show (counterclockwise from from upper left) the Step Pyramid, the rising Sun distorted by mirages, Hathor, and the ankh.

The most ancient Mayan deity identified in archaeological records is the Sun God. Many early peoples revered the Sun as the father of all gods or the mother of light and life, such as Australia's aboriginal Sun goddess *Yhi*. The pharaohs of Egypt believed they were descendants of the Sun god *Ra*. In ancient Greece, the Sun gods *Helios*, and later *Apollo*, fathered all other Greek gods. Likewise, chiefs of Sonabait, who once ruled the Timor region of Indonesia, regarded themselves as the "children of the Sun." And in Japan, the "Great Divinity Illuminating Heaven" was *Amaterasu*, from whom the imperial Japanese family claims descent. One would be hard pressed to find an ancient culture that did not recognize the Sun as a deity or source of omnipotent power.

The solar powerhouse

Meet the Sun

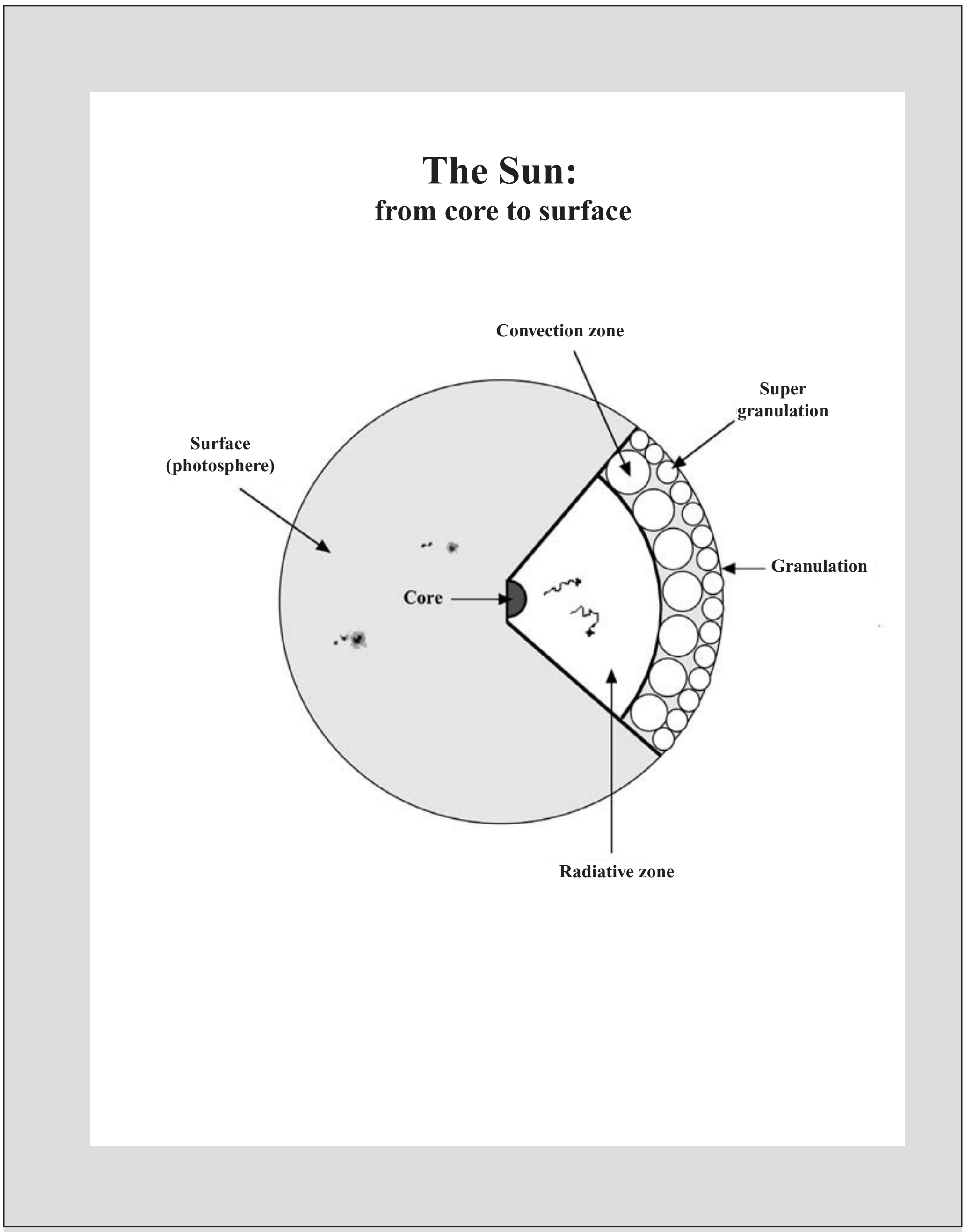
Magnitude:	–27
Spectral type:	G2 (yellow dwarf)
Age:	~4.6 billion years
Diameter:	1,400,000 km (870,000 miles)
Surface temperature:	5,785 K (10,000 °F)
Rotation period (equator):	24 days 6 hours
Inclination of axis:	7° 15′
Mean distance (from Earth):	150,000,000 km (93,000,000 miles)

The brightest and closest star in our sky, the Sun (from the Latin, *Sol*) is an enormous glowing sphere of gas at an average distance of 150 million km (93 million miles), or 1 astronomical unit (AU).[1] With a diameter of about 1.4 million km (870,000 miles), the Sun is so large that you could line, side by side, 109 Earths across its equator. If Earth were the size of a baseball, the Sun would be a sphere about 60 meters (200 feet) smaller than the 365-meter-wide (1,197-foot-wide) London Millennium Dome, and about 46 meters (150 feet) larger than the 256-meter-wide (840-foot-wide) Georgia Superdome!

[1] The Earth's orbit around the Sun is not a perfect circle, but an ellipse. Earth's distance varies from about 147 million km (91.3 million miles) around January 3, to about 152 million km (94.4 million miles) when farthest away around July 7.

Open the Sun like a chest, and you could fit 1,300,000 Earths inside. Actually, the Sun is not a perfect sphere. Scientists using NASA's Ramaty High Energy Spectroscopic Imager (RHESSI) spacecraft have measured the roundness of our star with unprecedented precision, and found that during years of high solar activity, the Sun becomes more oblate, i.e. flattened at the poles. For instance, during its peak activity in 2004, the Sun increased its 1.4-million-km (870,000-mile) equatorial diameter by about 13 km (8 miles). It's a puny anomaly, despite which, the Sun is still the biggest and smoothest object in the Solar System – perfect at the 0.001 percent level.

While the Sun is enormous in size, the gases that comprise it – hydrogen and helium (99.9%) and some heavier elements (0.1%) – are so light that a teaspoonful of its matter would be, on average, about one-fourth as light as a teaspoonful of Earth's, or about the density of water.



The gases radiate at extremely high temperatures. At the surface, the Sun's heat measures 5,785 K (10,000 °F), or 4.5 times as hot as molten lava. Place the Earth on the "surface" of the Sun and it will vaporize straight away.

The Sun's surface temperature is refreshingly cool compared to the 15.6 million degrees Celsius (28 million degrees Fahrenheit) temperature found at the Sun's core. Here gases are packed so tightly (thousands of tons per square inch) that the nuclei of hydrogen atoms fuse (combine) into heavier helium atoms. Through this process of "hydrogen burning," some 600 million tons of hydrogen are converted into helium every second, a power equivalent to 100 billion hydrogen bombs exploding every second.

The energy radiating outward from the Sun's core is so hot that we'd need X-ray eyes to see it! This energy doesn't just erupt to the surface and spew out into space. It can spend several hundred thousand years inside the Sun, in a region called the "radiative zone," where it is continually absorbed and re-emitted, until it ultimately breaks free and rises to to a region known as a convection zone, where convection is a sort of boiling. As these heated gases approach the surface, they cool to surface temperature and emit visible light. (Most of the light actually comes from electrons attaching and detaching from neutral hydrogen atoms on the solar surface.) They also start to sink until heat from the upper layer of the radiative zone makes them buoyant once again. We see this surface action as granulation, which is described in more detail on page 8. Gases in the Sun's convective zone and surface, then, churn turbulently like boiling water.

While the Sun radiates into space more than half a million tons of energy each second from its surface, only a fraction of that amount reaches the Earth. Still, the solar energy we receive each minute is roughly equal to the amount of electrical energy we artificially generate on Earth each year.

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As viewed through proper and safe solar filters, the Sun actually has three levels of atmosphere visible to the naked eye and binoculars. The *photosphere* (lowest level of the three) is the Sun's visible surface, which we can see on any clear day. Its fantastic brilliance overpowers the weak emission emanating from the other two levels. (The photosphere is described in great detail beginning on page 7.)

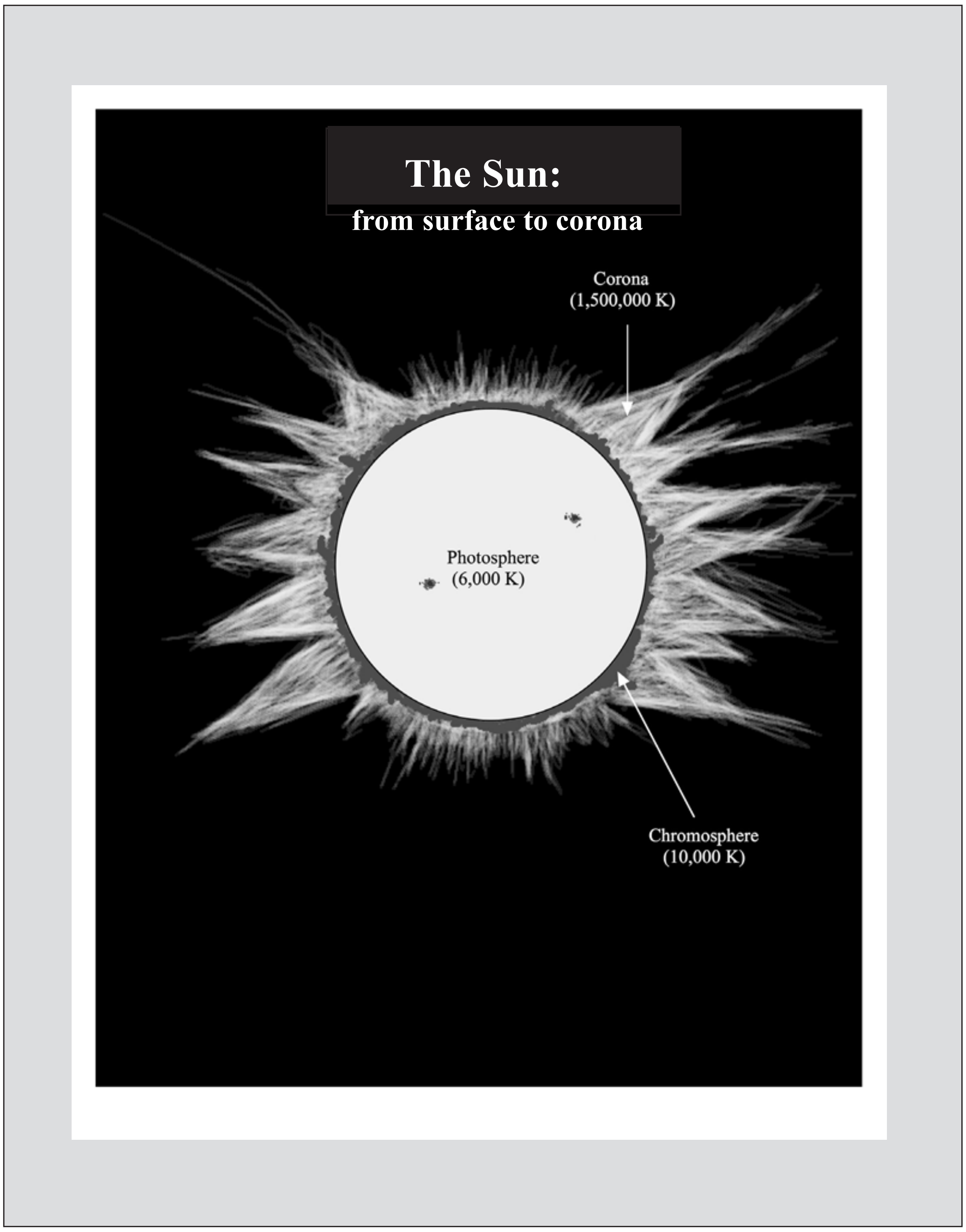
The *chromosphere* (middle level) is a spiky 10,000-km-wide (1,200 mile-wide) veneer of gas (less than 1 percent of the Sun's diameter) lying just above the photosphere. Its name, derived from the Greek word *chromos* (color), means "sphere of color." Nineteenth-century astronomers gave it this name because it appears as a thin layer of intense red light around the Moon's black silhouette at the beginning and the end of the total phase of a total solar eclipse. The color comes from the chromosphere's hydrogen gas, the strongest emission of which is hydrogen-alpha in the red part of the Sun's spectrum.[2]

The chromosphere has a temperature of about 5,600 °C (10,000 °F) near its base and 50,000 °C (90,000 °F) at its top. The structure varies from the fine to the majestic. The subtlest features are small jets of gas, called spicules, that bristle up from the Sun's limb like fine neck hair on a cold day. In the nineteenth century, they were sometimes referred to as "burning prairies." Actually, they're transparent magnetic pipes (hundreds of thousands of them at any time) filled with plasma moving at speeds of 50,000 km (31,000 miles) per hour. The features are short-lived, lasting only a few minutes, squirting up and falling down like fairy fountains.

The chromosphere's most majestic features are its *prominences*. These prodigious eruptions of dense gas can lift off from a section of the Sun's limb (i.e. entire circumference) in a variety of forms – from fiery tongues to fantastic hedgerows. These plasma clouds can be held suspended by the Sun's magnetic field for hours or weeks; some seem to appear in concert with violent eruptions of solar flares (see page 18). Many prominences rise into the Sun's outer atmosphere, the ethereal *corona*, whose temperature suddenly rises to nearly 1.7 million degrees Celcius (3 million degrees Fahrenheit). While the photosphere is visible to us every clear day, naked-eye and binocular observers can see the chromosphere and corona only when the Moon covers the photosphere during a total or annular solar eclipse. (Again, I must stress that the details in the chromosphere and corona cannot be seen through binoculars unless you're observing a total or annular solar eclipse. Failure to use proper methods when observing the Sun may result in permanent eye damage, retinal burns, or blindness.) The appearance of prominences and the corona will be discussed in greater detail in Chapter 3.

Despite all the Sun's glory and grandeur compared to earthly standards, the Sun is just an average star. We have found stars much larger than the Sun and many much

[2] If you ever graduate to a telescope (and I encourage you to do so one day), you can supplement your solar viewing with a hydrogen-alpha filter, which will reveal the Sun's chromosphere and open a door to a new and ever-changing world of solar wonder. A world where spicules, plages, flares, and prominences suddenly burn forth in crimson splendor. For hydrogen-alpha viewing, consider Coronado's Personal Solar Telescope (PST), which costs around $500 to $600.



smaller; we have also found stars much hotter than the Sun and others much colder. Considering the hundreds of billions of stars in our galaxy alone – and there are trillions upon trillions of galaxies, each with billions upon billions of stars, in the Universe – our Sun has no outstanding qualities . . . except for one: if it weren't for the size of this unassuming star and its distance from Earth, you would not be around to read these words. The Sun, say Leon Golub and Jay Pasachoff in their 2001 book *Nearest Star: The Surprising Science of Our Sun* (Harvard University Press, Cambridge, Massachusetts; London, England) is our "Goldilocks," meaning that it creates the conditions "just right" for life to flourish on Earth. Is it surprising then we still worship the Sun today in our own private ways?

Like anything that burns energy, the Sun's lifetime is limited. Our star has been consuming its nuclear fuel for nearly five billion years. But it does so very conservatively; the Sun is expected to burn for another five billion years before exhausting its hydrogen supply and will begin to die. Today, as anyone on a cloudless day can see, the Sun's light is still very intense; intense enough that anyone foolish enough to stare directly at it for any length of time without proper eye protection risks damaging (or losing) his or her eyesight!

How to observe the Sun safely

The Sun offers safety-conscious observers highly detailed views of the only star resolvable from Earth. Keeping track of the Sun's ever-changing features can keep one pleasantly occupied for a lifetime. But before I explore the visual splendor of the Sun with you, let's look at two

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simple and inexpensive ways you can view it in complete safety.

Projection

The safest and simplest way to view the Sun is to project its image through one lens of your binoculars onto a large white, or light-gray, card or piece of cardboard. No filters are required for this method because you *never* look through the binoculars. Start by capping one of the binoculars' front objective lenses and turning your back to the Sun. Holding the binoculars in one hand, point the uncovered objective lens toward the Sun behind you. With your free hand, place the card about a foot from the binocular's eyepiece. To achieve proper alignment, use the shadow of the binoculars as a guide. Simply move the binoculars around until the Sun's image appears on the card within the binocular's shadow. Focus on the Sun's limb until it looks sharp.

Once you master this technique, repeat the procedure while either bracing the binoculars against something sturdy (like a table, chair, or wall), or propping up and supporting the paper at the appropriate angle (the Sun's projected image should appear circular not elliptical) so that you can hold the binoculars with both hands. Of course, if the binoculars can be mounted on a tripod, by all means do so!

WARNING!

***Never* leave unattended mounted binoculars pointed at the Sun, especially in a public setting; someone may become curious, take a peek, and burn his or her eyes.**

The further you hold the card from the eyepiece, the larger the Sun's image. With my 7 × 50 and 10 × 50 binoculars, I like to view a disk that is about 5 to 8 cm (2 to 3 inches) across, which requires placing the card some 50 to 80 cm (20 to 30 inches) away from the eyepiece. When I hold the card about 50 cm (20 inches) away from the eyepiece of 25 × 100 binoculars, I get a beautiful image of the Sun some 10 cm (4 inches) across. Experiment until you find the distance that gives you the best view with your binoculars.

You can increase the apparent contrast between the projected image and its surroundings by using a front shield. I made one out of a piece of cardboard with two holes large enough to slip objective mounts through. Wearing sunglasses to look at the projected image will help cut down on the glare reflecting off the white card to your eyes; or use a light gray card.

Try to keep the observations brief enough so that the Sun's heat is not concentrated for long periods of time on the optical system. I generally project an image for a minute or two, then turn the binoculars away from the Sun before repeating the observation a few minutes later.

Welder's glass

Proper solar filters are designed to reflect or absorb a specific amount of ultraviolet, visible, and infrared energy – namely one part in 100,000 of light transmitted – for safe solar viewing. One of the most common and inexpensive filters in the Sun observer's arsenal is a shade number 14 welder's glass, which is widely available for a few dollars

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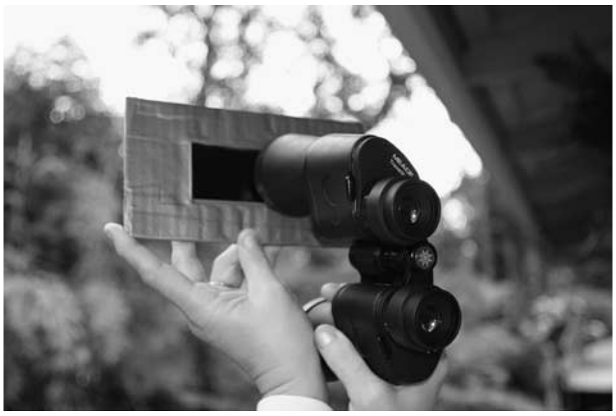


from welder supply shops; you can find one in any local phone directory. The glass comes in a variety of sizes and shapes. All those of shade #14 convey an agreeable green image of the Sun.

A 10-cm-square (4-inch-square) glass allows you to observe the Sun with your unaided eyes; make sure the glass covers both eyes at all times. You can also use the glass to cover the *front* of your binocular objectives. (If the filter is large enough to cover only one binocular objective, *remember to cap the other objective!*). But make sure the filter is securely mounted, and that it doesn't fall off or blow loose while you are looking through the binoculars.

If you purchase a smaller, rectangular welder's glass, I suggest you mount the filter in a cardboard frame that fully covers the binocular objective. The poor optical quality of the glass yields a soft and slightly distorted binocular image. I have observed the Sun with welder's glass both with unaided eyes and in front of binocular objectives for more than a quarter century and have never hurt my eyes, but I am always especially careful when looking at the Sun. The images above show the welder's glass in a cardboard frame (left) and the proper way to hold it up to one front objective (right), as my wife, Donna demonstrates. Always remember to cap the unused objective!

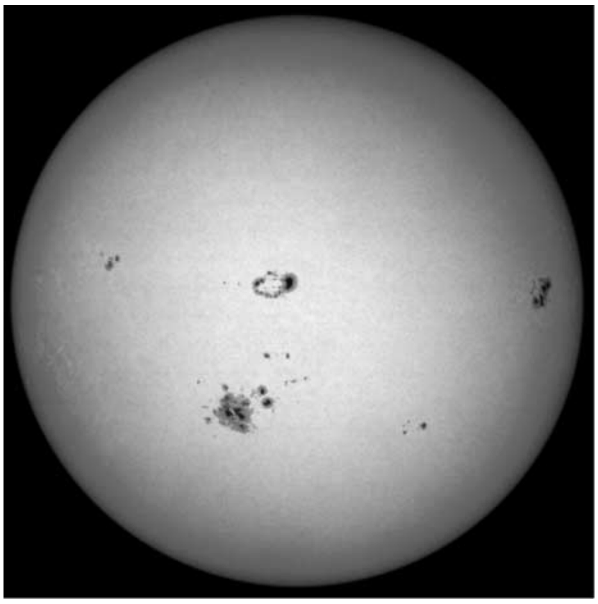
Mounted filters

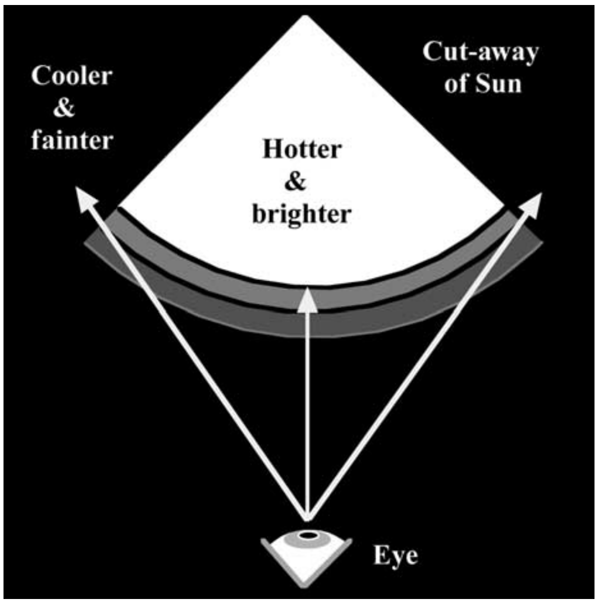
Many reputable telescope dealers sell special metal-coated glass or mylar filters in mounted cells that fit snugly over, or screw tightly to, most binocular objectives. Like the shade #14 welder's glass, special, mounted solar filters take out the infrared energy. Note that some other filters – including ordinary photographic filters (even so-called neutral density ones) – don't! Always be sure to use a safe and special solar filter!

Using special, cell-mounted filters allow you to look directly at the Sun in comfort and safety with binocular vision! (Always check the filters for surface damage before using them; for instance, mylar – a very thin plastic film with a coating of aluminum – can be easily punctured or ripped.) I used Orion® full-aperture glass solar filters, which are mounted in aluminum cells. The filter's glass elements are machine-polished and triple-coated with an advanced nickel–chromium alloy that gives the Sun a soothing amber hue. With no optical distortions, the Sun appears as a pleasingly crisp disk with sharp detail, especially through 25 × 100 binoculars. The photo below shows the 25 × 100 binoculars with the solar filters on; on top of them I piggybacked a pair of 10 × 50 *unfiltered* binoculars for size comparison. Again, make sure that any filters are securely mounted or properly taped on; be careful that they don't come loose.

The photosphere

Photosphere, meaning "sphere of light," is derived from the Greek word, *photos*, for light. The Sun has no solid surface, but we commonly refer to the photosphere as its everyday, visible surface. It is what we see when the Sun rises each morning and sets each afternoon. It is the face we see when the Sun's image is projected onto a card, or when we view it directly through properly filtered binoculars. When we look at the photosphere through our filters, we're seeing light fleeing from the Sun's turbulent surface; like all light and radio waves, it is traveling at a speed of 300,000 km (186,000 miles) per second. This light must travel some 150 million km (93 million miles) before reaching our eyes eight minutes later. Consequently, whenever we look at the Sun's filtered disk, we see it as it was eight minutes in the past.





Limb darkening

When you project the Sun's image, or look at its filtered disk through binoculars, survey the intensity of light from the disk's center to its limb. The Sun's surface brightness drops off gradually, then more severely, as you look closer to the limb. The effect is called *limb darkening*, and it is one of the perennial features of the white-light Sun.

Limb darkening is the visible effect on light as it rises from the base of the convection zone to the cooler surface of the Sun's photosphere. As the diagram above (right) shows, when we look directly at the Sun's center, we look a bit into the convection zone – very near its cool top. When we look at the Sun's limb, we do not look at all into the convective zone; instead, we look obliquely through only the cooler upper layers of the photosphere. Since cool gas does not glow as intensely as hot gas, the Sun's limb appears darker than it does at its center; it also appears very slightly redder; in the black-and-white image above (left), limb darkening appears as a darker shade of gray.

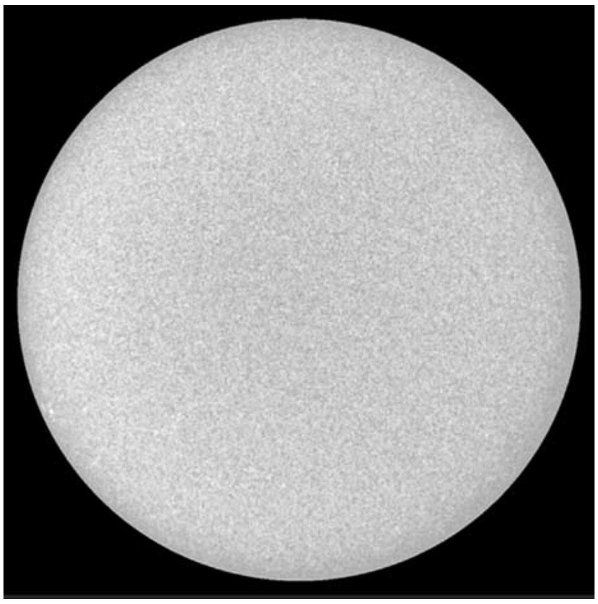
Granulation

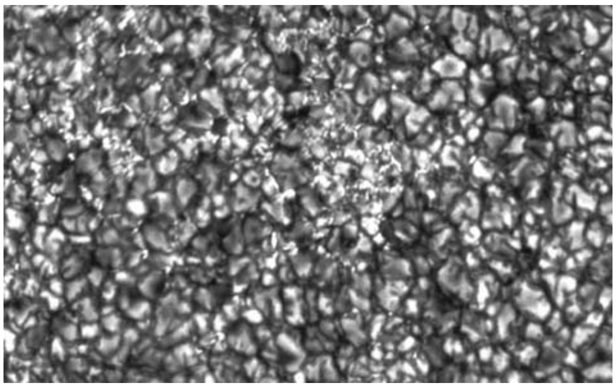
If you concentrate on the filtered Sun's surface and let your eye flit around the binocular field of view, you may see that the Sun's photosphere is not smooth. It has a fine, granular texture. The detail becomes especially apparent when one is using large filtered binoculars that magnify at least 20× and the atmosphere is very stable.

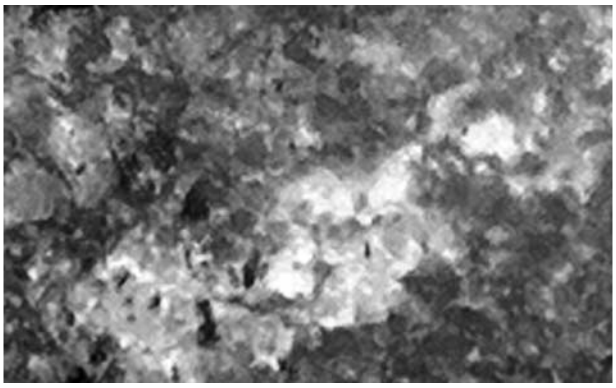
The image at right is a white-light SOHO satellite image that shows the Sun's mottled surface texture on a totally spotless day in December, 2008. Expect a softer view through your binoculars. You'll find that with time as you observe, the granulation stands out ever more prominently. And once you get sight of it, it's hard not to see it again; remember, the longer you look, the more prominent the granular texture will seem.

Two astute observers – Danish Astronomer Royal Thomas Bugge (1740–1815) and the German-born British observer William Herschel (1738–1822) – appear to have noticed the Sun's granular texture around the same time in 1792. Interest in the phenomenon led many observers to better describe and decipher what they were seeing. One famous interpretation blossomed in 1861, when Scottish engineer/observer James Nasmyth (1808–1890) announced to the Literary and Philosophical Society of Manchester that the Sun's photosphere was dappled with small, elongated features, shaped like willow leaves. He described the leaves as crossing one another in all directions and constantly moving.

This announcement led to a "vehement controversy," George F. Chambers tells us in his 1904 book *The Story of the Solar System* (D. Appleton and Company; New York), which led to the use of other expressions, such as "'rice grains,' 'sea beach,' and 'straw thatching,'" to describe the phenomenon. Chambers thought all these words were too precise to be taken literally; though, "on the whole," he admits, "'rice grains' is not altogether a bad







expression . . . " But it wasn't until 1864, when another Englishman, William Rutter Dawes (1799–1868), coined the term "granulated," which formed the word we still use today.

Inspired by observations by William Herschel (who called them "forrows" which were bordered by "indentations") astronomers began to theorize that the granules were the summits of leaping flames (prominences) all over the Sun's surface – an idea that carried over into the twentieth century! These theories were not far from the truth.

Today we know that solar granules – several million of which are visible at any given time – mark the places where huge (several-hundred-km-wide) bubbles of hot gas are rising up from the base of the hot convection zone and erupting onto the Sun's surface; the granules remain intact for only about 15 minutes or so before they fragment, merge with other granules, or sink, cool, and fade, only to be replaced with new bubbles of hot, rising gas. We see this perpetual activity as a slowly shifting "rice grain" pattern across the entire face of the Sun. So the granules are the convection regions that I discussed earlier.

Look closely with your filtered binoculars and you'll see that each bright luminous patch is separated from its neighbors by less dark *intergranular lanes*, where cooling gases descend. So the surface looks like a bubbling broth of rice pudding seen from afar. Because the Sun is so distant, the individual "grains" can be a challenge to see through small, filtered, handheld binoculars. Granulation is best seen with a direct view through mounted binoculars whose objectives are covered with safe solar filters.

Through mounted 10 × 50 binoculars capped with solar filters, I can "sense" granulation when I slowly move the Sun around in the binocular field of view, or gently tap the tube. Tube tapping is an old observing trick. When you stare directly at an object without shifting your gaze, vision fades (which is why the eye has natural rapid eye movements). Tube tapping provides slight motions, allowing the object in view to sweep back and forth across the eye's photoreceptors, so that continuous (non-fading) images are sent to the brain for processing. (That's why it's easier to see a gnat in flight than when it's resting, say, on a leaf.)

Although I do not see *individual* grains clearly through 10 × 50 binoculars, I do get fleeting impressions of a hyperfine roughness across the entire Sun's face, superimposed on which are some more obvious blemishes, which may be clusters of granulation. The Sun does have larger-scale supergranulation cells which can measure some 16,000 to 32,000 km (10,000 to 20,000 miles) in diameter – but you don't really see those in white light. Actually, the average size of a solar granulation is *about* 1.5 arcseconds across, which is near the limit of 10 × 50 binoculars and often below the steadiness of the air above you.[3]

I get the same impression, though one much more difficult to savor, when I use 10 × 50 binoculars to project the Sun's image onto a card; be sure to make the Sun's image as big as possible and focus the binoculars until the disk appears sharp. Success, however, also requires mounting your binoculars (with a Sun shield) on a tripod, projecting the Sun's image onto a white or gray card, blocking any extraneous light, and moving the card around so that the Sun's sandpaper texture is not confused with the tiny fibers making up the card or paper you're holding.

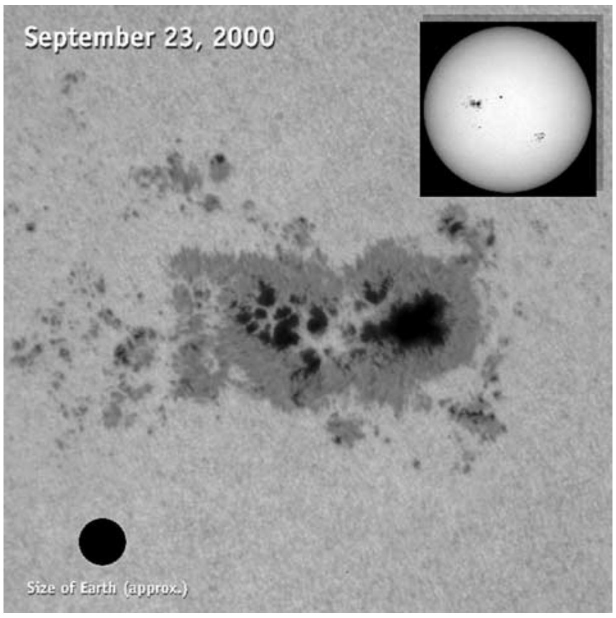
Fine solar granulation is definitely visible when I look directly through the mounted 25 × 100 binoculars with safe solar filters. The individual grains are fantastically small, looking like heaps of hot and cooling molten flecks. Indeed, I have seen molten rock bubbling in the throat of a volcanic vent and have noticed that it is eerily similar to seeing these roiling clouds of hot gases that rise to the surface of the Sun. The images above show a high-resolution image of the Sun's granulation (left) taken with the Swedish 1-meter (40-inch) Solar Telescope and processed

[3] Resolving power is defined as an instrument's ability to see fine detail, like granulation on the Sun. To determine your instrument's resolving power, divide 4.56 by the aperture in inches. The answer, known as Dawes' limit, gives you the resolution in arcseconds (″). One arcsecond is 1/60 of an arcminute (′), or 1/3600 of a degree. (The Sun measures about 30′ across.) A pair of 50-mm (2-inch) binoculars can resolve details to 2.3″ (aside from limits caused by Earth's turbulent atmosphere), while a pair of 100-mm (4-inch) binoculars can detect features as small as 1.2″. But this limit applies to bright points of light seen against a dark background. The eye can resolve finer details through the same instrument used in the daytime! So solar granulation is indeed within the grasp of 50-mm binoculars, and certainly resolvable in 100-mm binoculars.

in a computer, which shows *much* more detail than you'll see in your binoculars (but knowing what you're actually seeing is part of the imagination side of astronomy). To the right is an image showing the surface of a molten lava lake for comparison. Through 25 × 100 binoculars, the granules can be spied with a direct gaze and without any tube tapping. Looking at these granular features and thinking about the action forming them truly makes the Sun come alive.

Sunspots

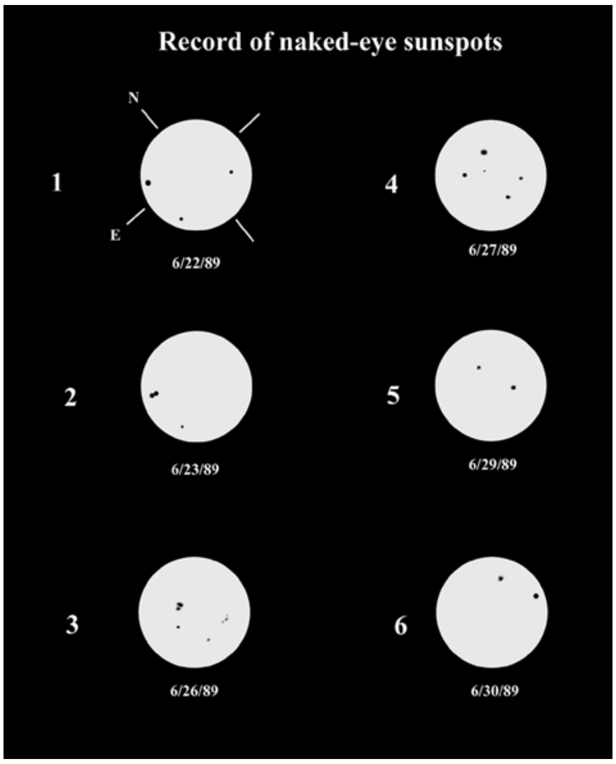
As exciting as it is to see solar granulation, nothing on the Sun's surface compares to catching sight of its dark spots. These mysterious clouds of gas can range in size from about 2,400 km (1,500 miles) across to a colossal 48,000 km (30,000 miles) across; the latter size being great enough to swallow four Earths. The image below shows a close-up of a large sunspot group with an artificial silhouette of the Earth for comparison. It also shows a full-disk, white-light SOHO image of the Sun, which represents well the detail one can see through filtered binoculars.



Large sunspots (as well as some smaller ones) are visible to the unaided eyes through a safe solar filter. It's also possible to see them without a filter when the Sun is near setting and the atmosphere is especially contaminated with dust or other pollutants, which can greatly dim the Sun's brightness. Many ancients made their observations of the Sun in this latter way.

In a 1995 *Quarterly Journal of the Royal Astronomical Society* (volume 36, pp. 397–406), Xu Zhen-tao (Purple Mountain Observatory, China), F. R. Stephenson (University of Durham, UK), and Jiang Yao-taio (Nanjing University, China) noted that Chinese skywatchers in the Shang Dynasty (from about 1500–1050 BC) habitually observed the low Sun. According to their interpretation of inscriptions on oracle bones (animal bones and turtle shells inscribed with a primitive form of Chinese characters), they also made the "earliest written records of sunspots." For instance, one inscription says, "There was *ri zhi* in the western sky, will it bring a disaster?" The authors note that *ri* means "the Sun," while they interpret *zhi*, to mean "a black spot" or "black vapor." Using a welder's glass or other safe viewing filter, you too can keep vigil on the Sun and record naked-eye spots.

Below is an illustration of a record of naked-eye sunspots as seen through a #14 welder's glass; it's based on a page from one of my notebooks. The sketches here show the naked-eye Sun in June 1989, near sunspot maximum – a time when sunspot activity peaks in its roughly 11-year cycle. (The cycle is described in more detail on page 14.)



Optical sunspots

The invention of the telescope in 1608, and Galileo's turning a telescope skyward in 1609, brought the heavens into a new light. (These telescopes were no better than a good pair of binoculars today.) With the telescope, the spotted Sun was soon noticed by several European observers at about the same time. Galileo Galilei (1564–1642), was one of them. In a letter dated June 12, 1612, the great Italian observer wrote to his patron Giuliano de'Medici that "celestial discoveries are not yet at an end, it is about