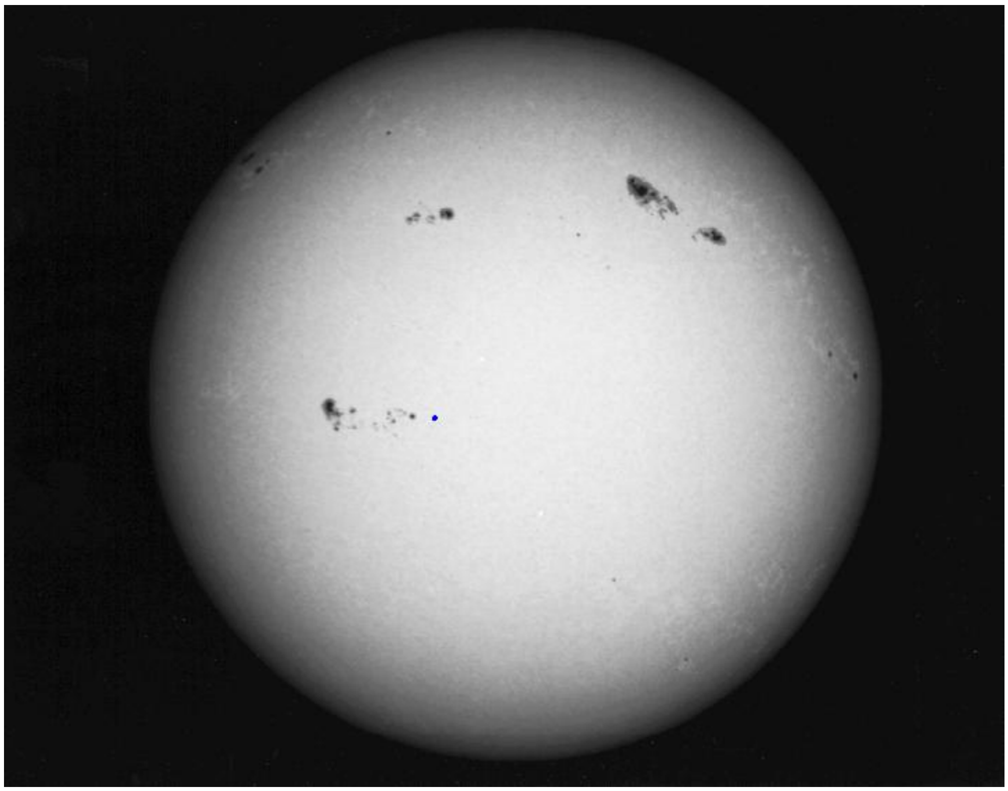
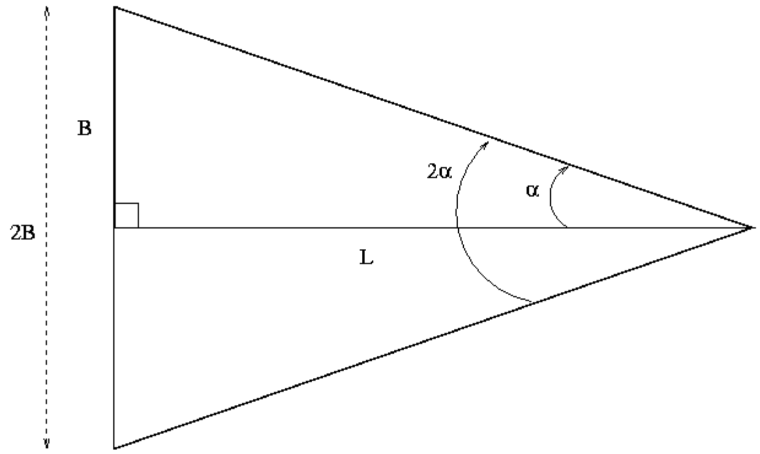
Our Sun: the view from outside

1. The Sun is hot. Really hot. The visible "surface" of the Sun, called the **photosphere**, has a temperature of about 5800 Kelvin. That's equivalent to roughly 10,000 Fahrenheit. Any solid substance placed in the photosphere would rapidly melt and evaporate into gas.
2. The Sun is big. Really big.



See that little blue dot near the center, just to the right of the large sunspot group? That's how big the Earth would be if it were sitting in front of the Sun.

You can get a rough idea for the size of the Sun by using a little geometry -- exactly the same geometry you would use for parallax:



Q: The Sun subtends an angle of about one-half of one degree, as seen from the Earth.

What is the average distance between Sun and Earth?

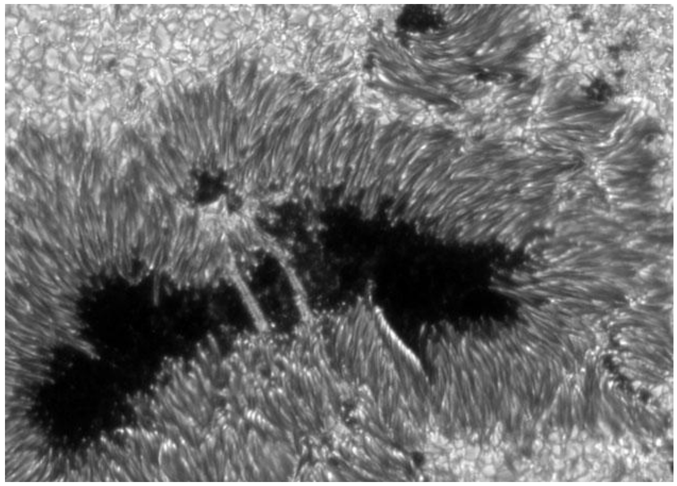
What is the radius of the Sun?

If you want the exact numbers, for the Sun or any major body in the solar system, I recommend The Nine Planets WWW site.

But there's more to see, if one looks very closely, and especially if one looks with different eyes.

Sunspots

If one examines the photosphere with a big optical telescope from a site with very clear and steady air, one notices several features:

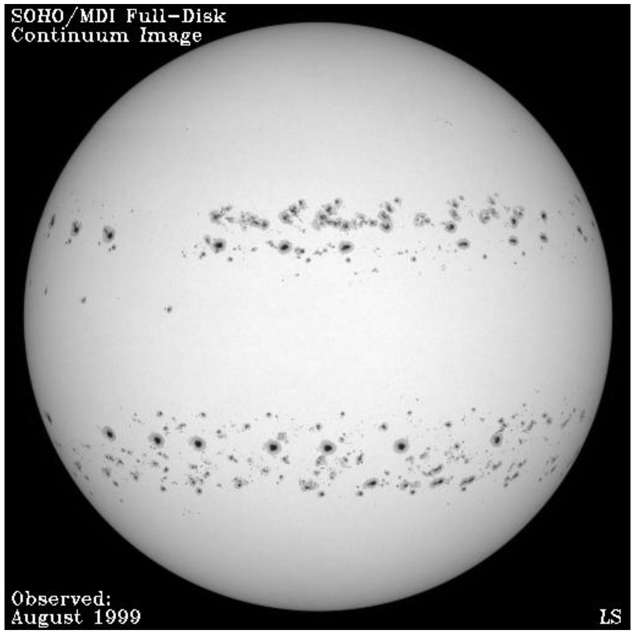


Dark spots appear scattered over the photosphere. These **sunspots** are regions in which the temperature is just a little bit cooler than the surroundings: roughly 4000 K, versus 5800 K. Because they are cooler, they emit less radiation, and therefore look, well, darker than the hot gas around them.

Q: Sunspots emit roughly ________ as much light as the surrounding photosphere.

8%   23%   48%   69%

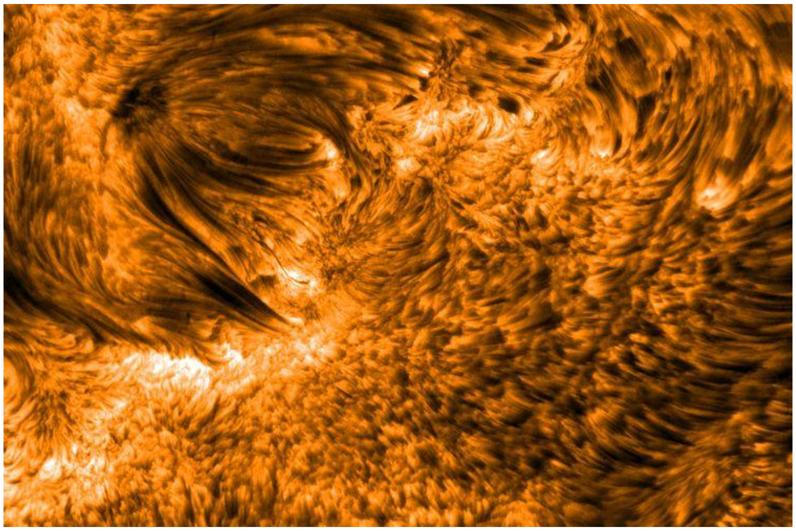
If you watch the Sun over a period of several weeks, you can see the sunspots move across its disk.



Strangely enough, spots near the Sun's equator make one complete revolution *faster* than those near the Sun's poles. How can that happen? It can't on a solid body, like the Earth, but there's no problem if the body is gaseous. Don't forget: we don't see the SURFACE of the Sun, we see its OUTER ATMOSPHERE.

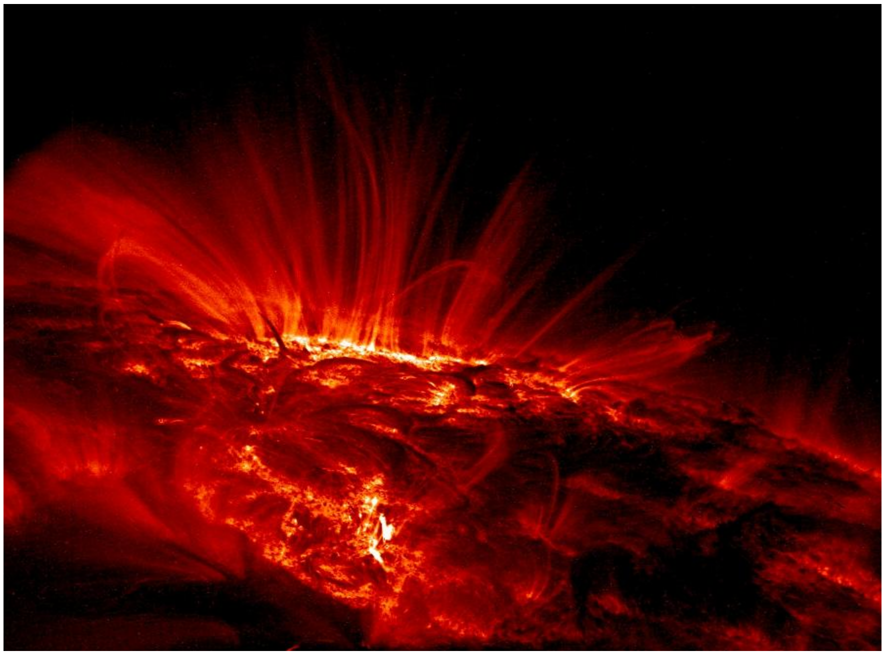
- Just how long does it take portions of the Sun to rotate? Do the Solar Rotation Extra Credit project and find out.

Why are sunspots cooler than the rest of the photosphere? The answer has something to do with magnetic fields. Because different portions of the Sun rotate at different rates, the large-scale magnetic field of the Sun gets tangled up, like an unruly ball of string. Occasionally, a section of the field pops up from below the photosphere, arcs gracefully above the surface, and dives back down. Where it cuts through the photosphere, we see a sunspot. The strong magnetic fields near sunspots force gas to flow along the field lines, making tube-like structures called spicules:



Credit: SST, Royal Swedish Academy of Sciences, LMSAL

This picture of a sunspot pair near the limb of the Sun was recorded by the TRACE spacecraft.



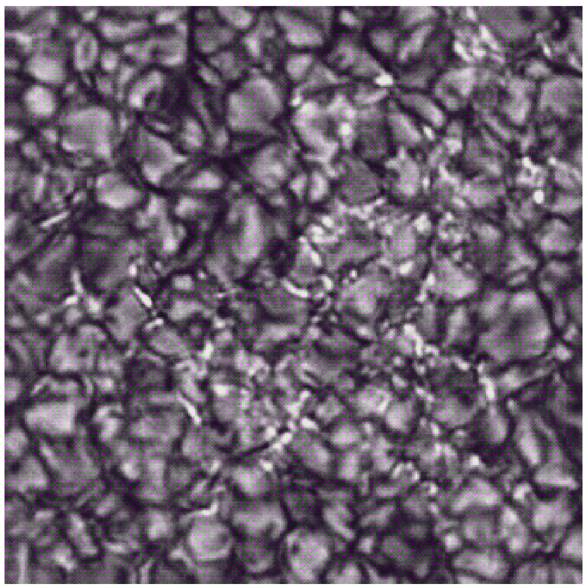
In this ultraviolet image, gas at the level of the photosphere is dark, indicating a temperature of thousands of degrees. But flowing high above the photosphere, along the lines of the magnetic field, gas is heated (somehow) to temperatures of over one million degrees. It emits ultraviolet and X-ray radiation.

Q: If the gas above sunspots is so much hotter,

it should emit more radiation than the cool
gas below. So why do sunspots appear dark?

Granulation

The photosphere is a dynamic place even far from sunspots. High-resolution photographs show that the gas isn't a uniform brightness, but broken up into "little" cells called **granules.**



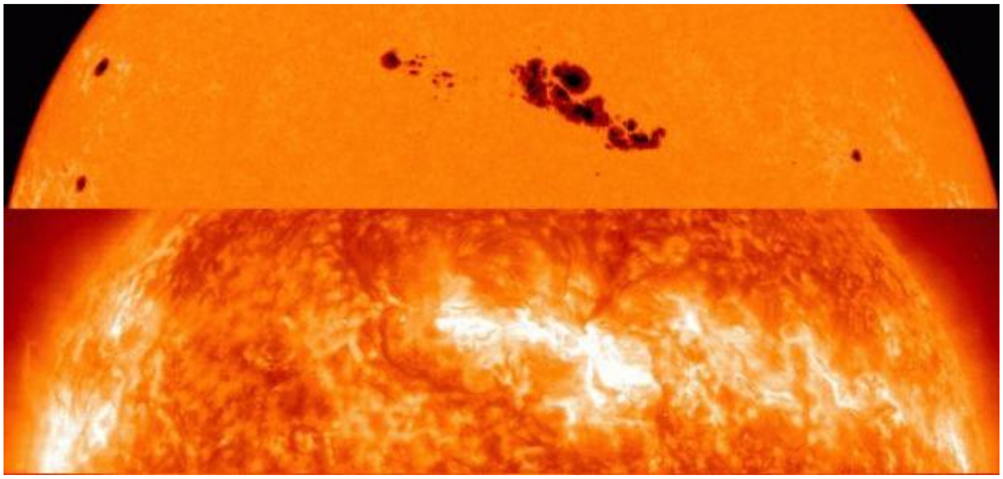
The granules "boil", exactly like water in a hot pot --

- Watch an MPEG movie of granules in action

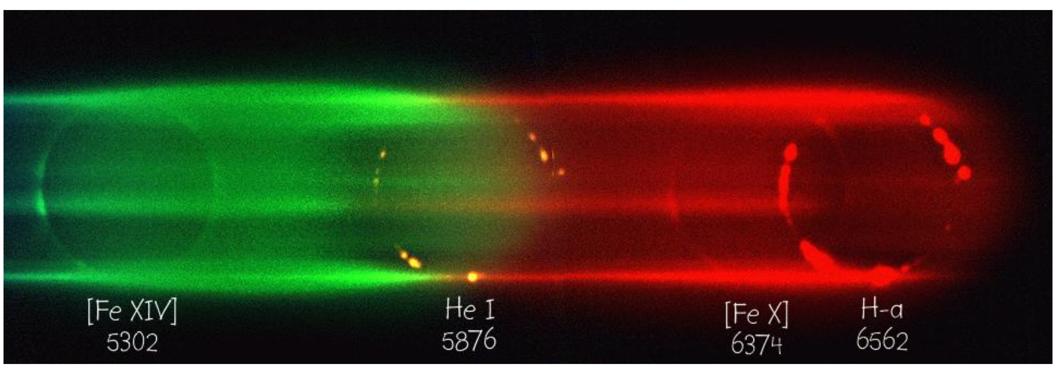
-- and for exactly the same reason: **convection.** Here's how it works: the interior of the Sun heats up gas in the photosphere. A hot blob of gas expands a bit and becomes slightly less dense than its surroundings. As a result, it rises upwards, like a hot-air balloon. Eventually, after radiating its heat into space, the gas cools off, and falls back down towards the interior.

The chromosphere

The Sun's atmosphere becomes less dense as one moves outwards and upwards. Above the photosphere is a layer called the **chromosphere.** The gas here is hotter than that in the photosphere, probably because of energy transferred to the gas by strong areas in the Sun's magnetic field. In this simultaneous pair of images, which show the same portion of the Sun's photosphere (top) and chromosphere (bottom), note how much brighter -- hotter -- the gas in the chromosphere is over the sunspot groups.



As light from the photosphere flies out into space, some of it is absorbed by atoms in the chromosphere. The dark lines in the solar spectrum are created in this region of the solar atmosphere, which gives us more information about this thin layer than any other portion of the Sun.



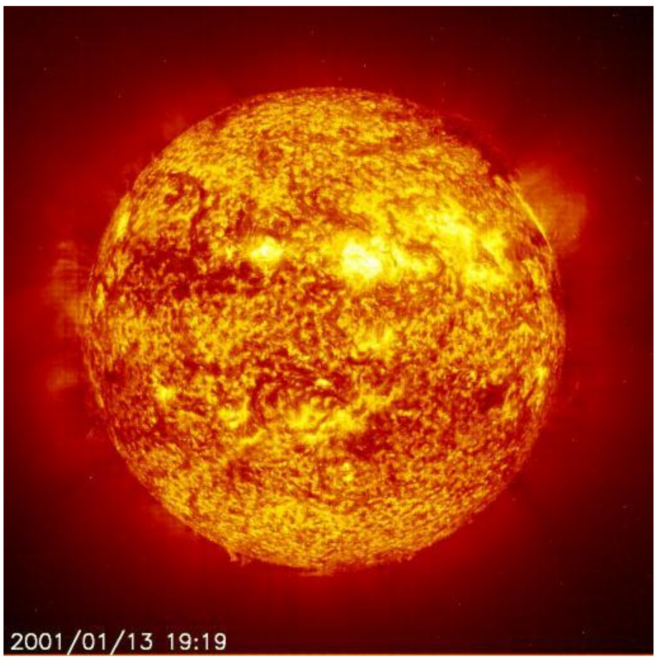
Taken by the Fosbury team during the solar eclipse, 11 Aug 1999.

Back in the nineteenth century, astronomers studying the optical spectrum of the Sun found several lines which did not correspond to any elements tested in their laboratories. One of these lines, in the yellow portion of the spectrum, was especially bright in **prominences** and other portions of the solar atmosphere above the photosphere (in other words, in the chromosphere). In 1868, English astronomer Joseph Norman Lockyer who evidently was a bit of an egotist, judging by this little poem written by one of his contemporaries:

And Lockyer, and Lockyer,
grows cockier, and cockier,
for he thinks he's the owner
of the solar corona

guessed that this line was due to an element which hadn't yet been discovered on Earth: he suggested the name "Helium", from the Greek word for the Sun. Most other astronomers thought he was wrong, and the yellow line simply due to some common element in an unusual energy state. But in 1895, William Ramsey isolated small amounts of an inert gas after processing uranium compounds. This new gas had a line at exactly the same wavelength as Lockyer had observed in the Sun -- and so it was given the name proposed for it almost three decades earlier.

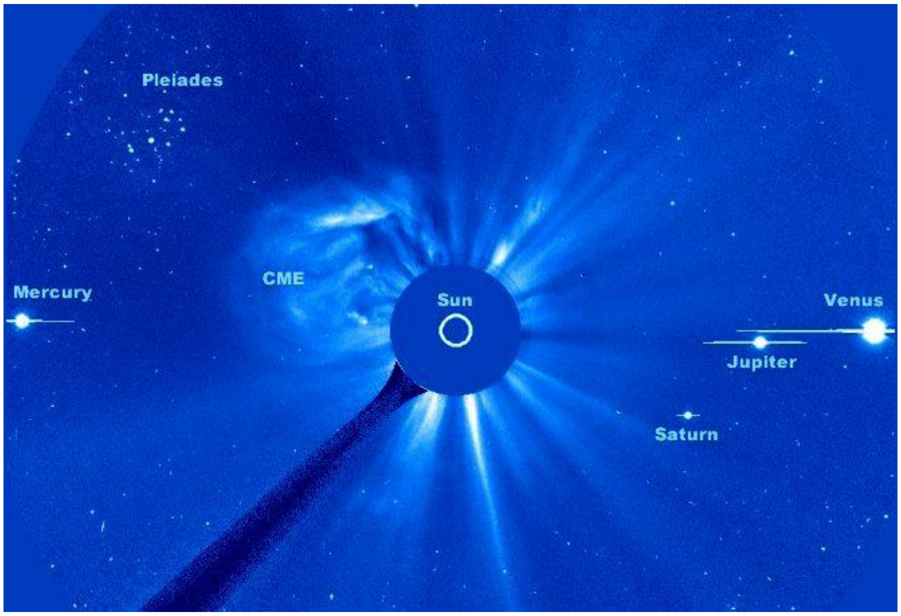
The picture below is taken at the same yellow wavelength of light emitted by helium atoms; it shows details in the chromosphere.



The corona

Even further above the photosphere lies the **solar corona**, most easily visible during a total solar eclipse. The term comes from a Latin word for "crown" -- can you see why?

The corona extends from above the chromosphere to far, far beyond the visible extent of the Sun. Even though it is further from the hot stellar interior than the chromosphere, the temperature of the very thin gas in this portion of the solar atmosphere is even hotter: millions of degrees. Most of the radiation emitted by the corona is in the form of X-rays, which do not penetrate the Earth's atmosphere. Fortunately, there are several spacecraft which have unobstructed views. SOHO, for example, can use its LASCO camera to take wide-angle pictures of the corona in X-rays.



Titanic explosions called **solar flares** send hot gas shooting outwards into space at high speed, as the movie below shows:

- Movie of Coronal Mass Ejection on Jan 15, 1996

If the flare happens on a portion of the Sun facing the Earth, the ejected material will take several days to fly through space.

Q: How long does it take light to travel from the Sun to the Earth?

Q: If particles ejected from one flare take 3 days to reach the Earth, what is their average speed through space? Express in m/s, and as a fraction of the speed of light.

When the energetic particles run into the Earth's atmosphere, they can cause it to glow softly, creating an **aurora.**

Image courtesy of Phil Hoffman

Source: http://spiff.rit.edu/classes/phys230/lectures/sun_gross/sun_gross.html