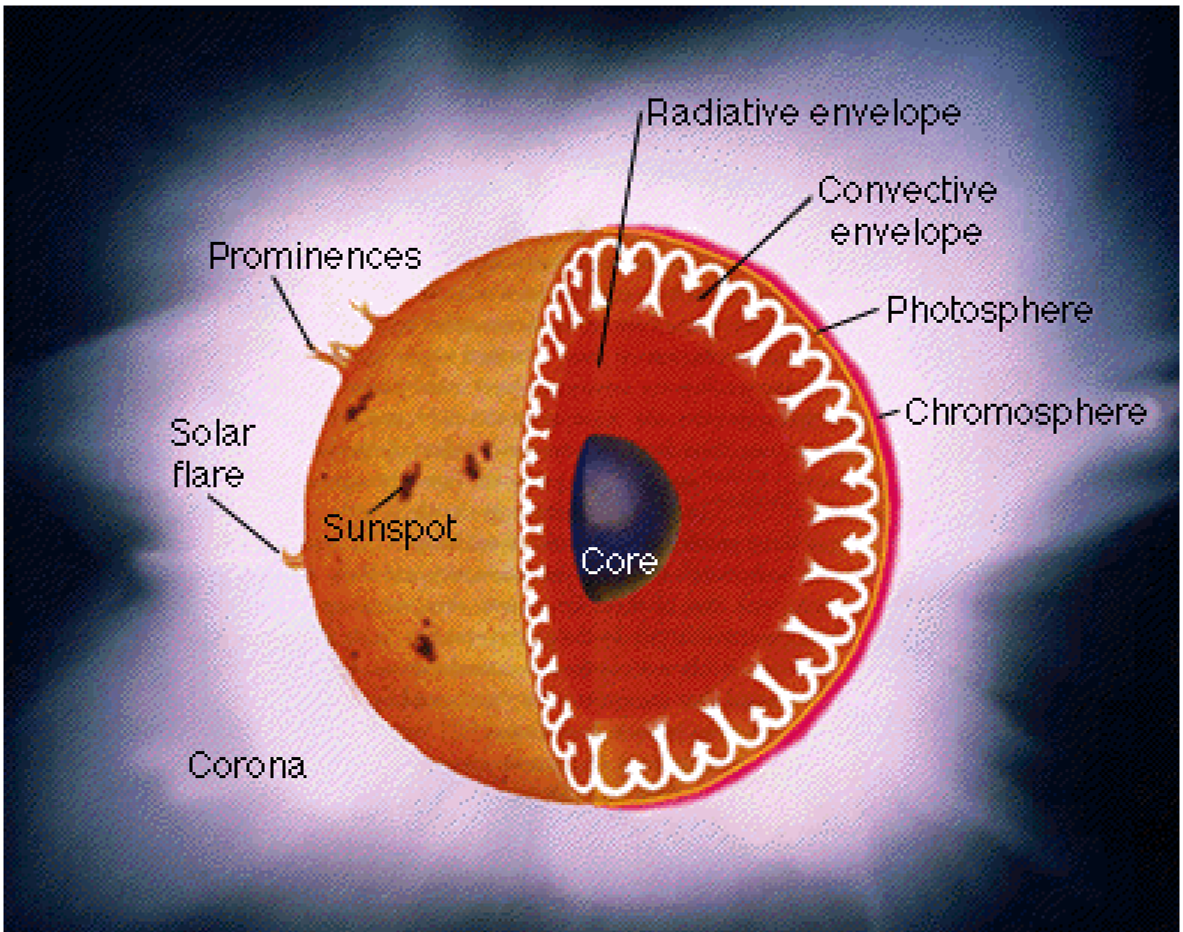
Introduction to the Sun, Solar Activity, and the SRT

The Layers of the Sun

Although the Sun is completely gaseous, it has many different layers in its structure. The density and temperature change drastically as you go from the center to the outermost regions. For example, in the core a piece the size of your two thumbs would have about as much mass as a six pack of soda. At the other extreme, the outermost layer, the corona, the density is only about 1×10^{-15} grams/cm^3. This value is close to laboratory vacuum densities here on Earth.

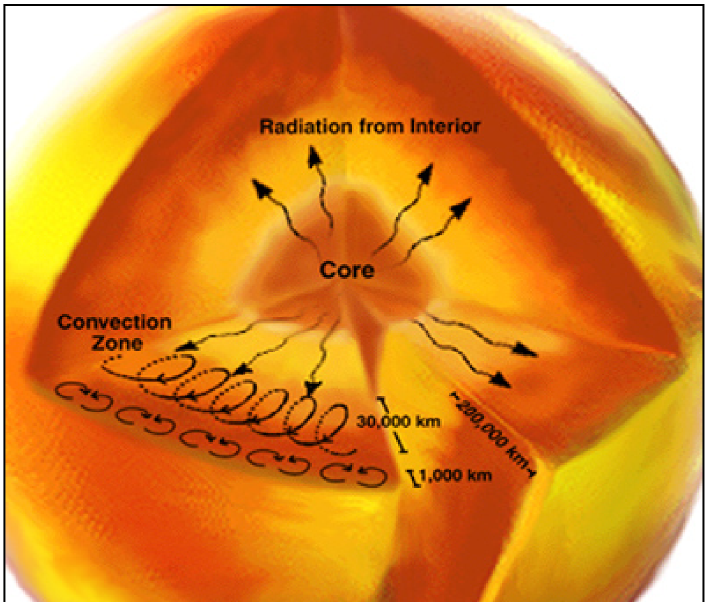


http://solar.physics.montana.edu/YPOP/Spotlight/SunInfo/Images/convect.gif

The temperature patterns are also perplexing. The core is more than 15 million Kelvin due to the fusion of hydrogen to helium. Moving away, the temperature drops to about 6000 degrees at the photosphere, the surface of the Sun. The puzzling thing is that the temperature then rises again to more than 2 million Kelvin in the corona which lays the furthest layer from the core. Researchers are currently investigating why this is so.

The Sun's Energy Source, the Core

Two properties are needed for nuclear fusion: high temperature and high density. The core has both. It is more than 15 million Kelvin and is tightly-packed and dense.



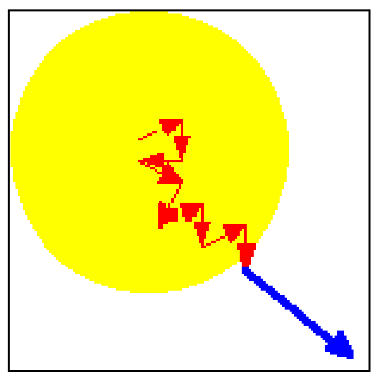
http://www.windows.ucar.edu/sun/Solar_interior/Sun_layers/Convection_zone/sun_conv_big_jpg_image.htmlun_paths_2.html

The intense heat destroys the internal structure of hydrogen and breaks it into its constituent parts: protons, electrons and neutrons. Neutrons have no electric charge, do not interact with their surroundings, and leave the core fairly quickly. The positively charged protons and the negatively charged electrons remain in the core and drive the reactions which fuel the Sun. The core is made up of a sea of protons and electrons and is called plasma.

The high temperature provides the protons and electrons with a large amount of kinetic energy: they move around quite quickly. This motion, combined with the high density of the plasma, causes the particles to continuously slam into one another creating nuclear fusion and energy.

Radiation zone

Heat energy travels from the core to the outer regions. For a star, the most efficient means of transferring energy near the core is by radiation. Consequently, the region surrounding the core of the Sun is known as the radiation zone. Energy is transferred by its interaction with the surrounding atoms.



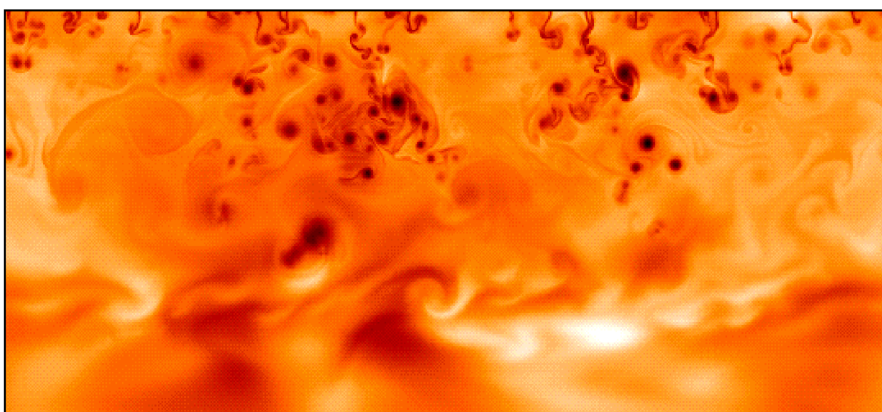
Imagine standing in a crowded gym with each person holding an empty glass. There is a sink on one end of the gym and someone at the opposite end wants a drink, but because the gym is so crowded, no one can move. The person nearest the sink can fill his/her glass with water and pour it into the glass next to them. This process could continue until the water is passed across the gym. This is similar to the Sun's energy being passed from atom to atom until it reaches the end of the radiation zone.

One important difference between our analogy and what takes place in the Sun is that in the gym we would pass the water in such a way that it always moves towards the other side. Atoms do not do this. In fact, there is no direct communication between one end of the radiation zone and the other. Instead, the Sun's heat energy is passed randomly from atom to atom. Sometimes it moves outward, sometimes inward and just often it moves side to side. It takes over 170,000 years for the energy released in the Sun's core just to get out of the radiation zone!

The "Boiling Zone"

Once out of the radiation zone, the energy needs a new transport mechanism to continue its journey to the surface because outside of the radiation zone the temperature is relatively cool, now only 2 million Kelvin as opposed to 5 million in the radiation zone. At this temperature the atoms will absorb energy, but because things are cool and dense, the atoms do not release it so readily. Consequently the transfer of energy by radiation slows down significantly.

The most efficient means of energy transfer is now convection. The hotter material near the top of the radiation zone (the bottom of the convection zone) rises up and the cooler material sinks to the bottom. As the hot material reaches



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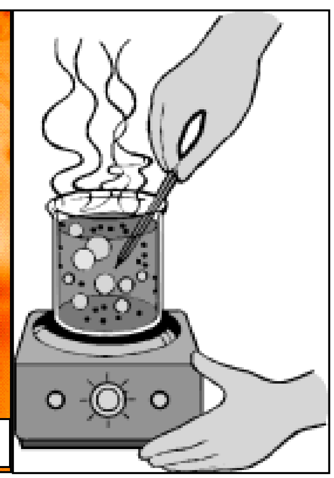
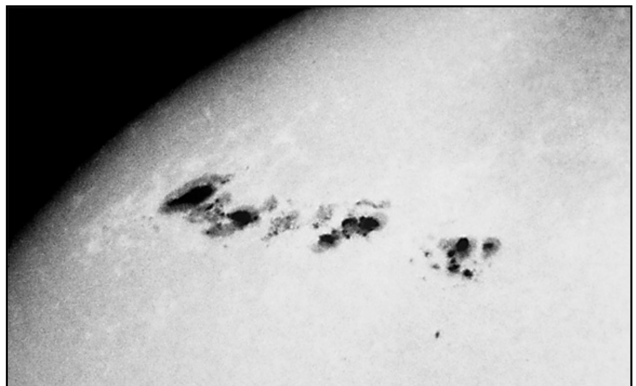


the top of the convection zone it begins to cool and sink, and as it sinks, it heats up again and will rise. This produces a rolling motion much like that in a pot of boiling water. The hot material follows a direct path through the convective zone and the energy is transferred much faster than by radiation. Taking only a little more than a week for the hot material to carry its energy to the top of the convection zone.

The Photosphere

There is a depth on the Sun in which the gas is so dense that we can not see through it. Because the Sun is completely made of gas and there is no hard surface like there is on Earth, we call the apparent surface of the Sun the photosphere.

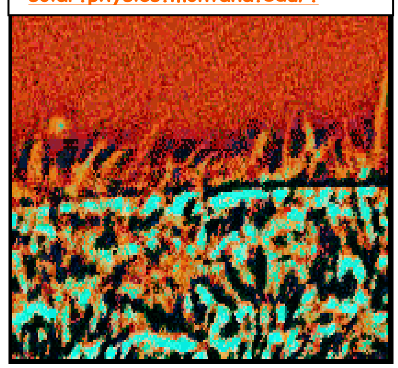
Energy is transported through the photosphere by radiation. Although the temperature of the photosphere is cool, about 5800 Kelvin, the gas is thin enough that the atoms absorb and release energy. In fact, most of the light that we receive from the Sun on Earth is energy that was released by atoms in the photosphere, taking just over eight minutes to reach the Earth.



http://www.astropix.com/HTML/G_SUN/SUNSPOTS

When the Sun is viewed through a solar telescope, dark spots can be observed on the surface. These continuously changing dark regions are called sunspots. The spots appear dark to the eye because they are cooler than the surrounding gas although they are still quite hot! The photosphere has a temperature of about 5800 Kelvin and a typical sunspot has a temperature about 3500 Kelvin. A sunspot's life can be as short as an hour or two or as long as several months. The number of sunspots that can be seen on the surface of the Sun increases and decreases in a regular pattern, known as the solar cycle, with a maximum number of Sunspots occurring every 11 years.

solar.physics.montana.edu/.



The Chromosphere

Above the photosphere a layer of gas, approximately 2000 km thick, is known as the chromosphere. In the chromosphere energy continues to be transported by radiation. Hydrogen atoms absorb energy from the photosphere and most of the energy is then emitted as red light.

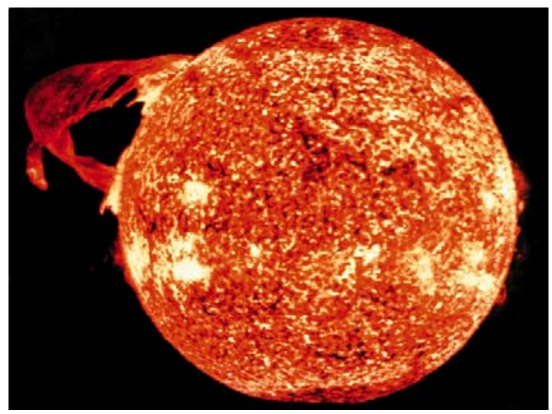
An interesting feature of the chromosphere is its jagged outer layer which is constantly changing. The motion is much like flames shooting up several thousands kilometers and then falling again. These spiky, dancing flames are called spicules.

The Corona

http://spdf.gsfc.nasa.gov/education.html

The outermost layer of the Sun is called the corona. It gets its name from the crown-like appearance evident during a total solar eclipse. The corona stretches far out into space and, in fact, particles from the corona reach the earth's orbit. The corona is very thin and faint and therefore can only be seen from earth during a total solar eclipse or by using a coronagraph telescope which simulates an eclipse by covering the bright solar disk. The shape of the corona is mostly determined by the magnetic field of the Sun.

Solar Flares



A solar flare occurs as a sudden, rapid, and intense variation in Sun's radiation intensity and occurs when magnetic energy has built up in the Sun's atmosphere and is suddenly released. Radiation is emitted across the entire electromagnetic spectrum, from radio waves to gamma rays. Large flares can emit energy ten million times greater than the energy released from a volcanic explosion. On the other hand, it is less than one-tenth of the total energy emitted by the Sun every second.

The frequency of flares coincides with the Sun's eleven year cycle. When the solar cycle is at a minimum, active regions are small and rare and few solar flares are detected. These increase in number as the Sun approaches the maximum part of its cycle. The Sun will reach its next maximum in the year 2011 or 2012.

Name ____________________ **Period** ________ **Date** ______________

Detecting Solar Flares using the SRT

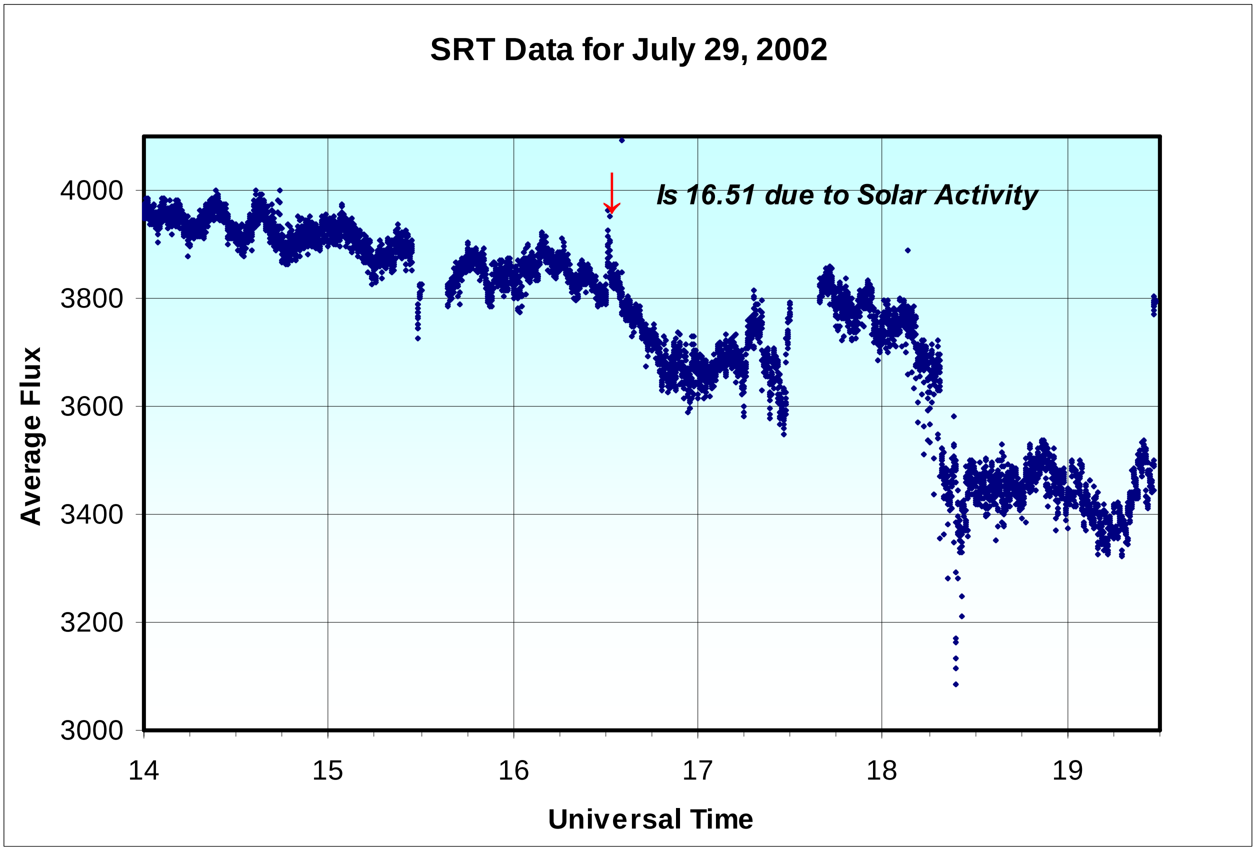
Data from the Small Radio Telescope (SRT) will be examined to determine if we are measuring solar activity. The description below of the SRT can be found at the Haystack website: **http://www.haystack.mit.edu/edu/undergrad/srt/index.html**

> Haystack Observatory has developed a small radio telescope (SRT) capable of continuum and spectral line observations in the L-band (1.42 GHz or 21-cm). This inexpensive radio astronomy kit provides everything needed to introduce students and amateur astronomers to the field of radio astronomy. A radio telescope is an excellent teaching tool as it involves the combined technologies of microwave engineering and digital computing. Its use involves astronomy, digital signal processing, software development, and analysis.
>
> The SRT is a standard seven-foot diameter satellite television dish mounted on top of a fully motorized mount. This unique mounting arrangement allows the observer to perform total power measurements and contour mapping. Software has been provided for controlling the antenna and selection of sources. Data reduction can be performed using existing radio astronomy software packages or left as an exercise for the student.

The SRT is Haystack's portable radio telescope designed for high school students so that they can measure the 21-cm line (1420 MHz). If the radio telescope is centered on the Sun, it will measure the hydrogen spin-spin transition. When there is a solar storm, this line becomes more intense. So by monitoring this line, we can detect a solar storm. The graph on the next page was generated from data collected July 29, 2002 during a solar maximum.

Name ____________________ **Period** ________ **Date** ______________

Detecting Solar Flares using the SRT



Notice how the intensity fluctuates as a function of time. When a solar flare occurs the intensity should suddenly increase.

1. Do you see any sudden jumps on the average flux or intensity? Identify these locations on your graph.

2. Does the data from the SRT provide enough information in order to determine whether this is caused by solar activity or is just instrumental noise? Explain.

3. What other information might be useful in order to make a good judgment? Solar flares emit energy across the entire electromagnetic spectrum. The SRT is only sensitive to radio waves. To answer the question, these two websites will be helpful. Go into the archives to see what happened in July 29, 2002.
http://www.sec.noaa.gov/alerts/archive.html or
http://www.spaceweather.com

4. Is the spike around 16.5 hours due to solar activity or is it just an instrumental "hiccup?" Explain your answer.