EXPLORE THE SUN

# SUNSTRUCK

# TEACHER RESOURCE
## INFORMATION

# SUNSTRUCK
# AN INTEGRATED SOLAR EDUCATIONAL EXPERIENCE

## TEACHER RESOURCES

Background

Sun Earth Relationship

Sun's Energy-Nuclear Fusion

Light-Photons/distance traveled

Space Weather and its impact on our technology

- Sunspots
- Solar Flare
- Coronal Mass Ejection
- Solar Wind

Sun's Effect on the weather on Earth

Global Warming

Other Stars-Hertzsprung-Russell Diagram

## KIT

Solar filter telescope-8" DOB

Sunspotter

Solar Viewers (enough for 30 students)

Build Your Own Telescope kits (enough for 30 students)

# BACKGROUND

About 4.6 billion years ago, our solar system didn't exist. Our star, the Sun, was just about to be born out of a molecular cloud that was over 600 trillion kilometers wide. This cloud was made up of mostly hydrogen and helium gas with some interstellar dust. Nearby an explosion occurred causing part of the cloud to collapse and become more dense and massive. It eventually grew so massive that it collapsed under its own gravity. This formed a proto-star. This is the first stage of the life cycle of a star.

This young star gradually became so hot and dense that hydrogen atoms were fused together at its core. This fusion creates helium and energy. The energy is heat and light which explodes outward. This is the true birth of our Sun.

There are six areas: the core, the radiative zone, the convective zone, the photosphere, the chromosphere, and the corona. The photosphere or surface of the sun is a 500 kilometer thick region from which most of the Sun's radiation escapes outward and is detected as the sunlight we see.

Eventually over many years, the planets formed and our solar system formed into what we see today. One of those planets is Earth. Earth is in the habitable zone in the solar system. This means that it is not too close or too far away from the sun. It is in a position that allows for life as we know it to exist. Life can exist here because of the sun's interaction with the Earth and its atmosphere. The connection between the Sun and the Earth drive the seasons, ocean currents, weather and climate.

The sunlight arrives on Earth 8 minutes after it leaves the sun. The sun's light warms the Earth. As the heat increases, the air and water temperatures rise. The water evaporates into a gas called water vapor. As the water vapor cools, it forms clouds. The clouds release water back to the Earth in the form of precipitation. Thus the water cycle is created. This is also the basis for our weather on Earth. As the air is heated, the warm air rises higher in the atmosphere, so the colder air rushes to fill the empty space which results in wind. This wind is known as the jet stream. The warm and cold air masses flow along the jet stream and our weather on Earth is created.

The Sun plays another important role in the life cycle of animals and plants. All living things depend on the Sun for both heat and light energy. Sunlight plays a major role in the process of photosynthesis. This process occurs in green plants from the tiny phytoplankton in the oceans to the tallest trees on Earth. These green plants contain chlorophyll. It is the chlorophyll that uses the sun's light during photosynthesis. During photosynthesis plants use carbon dioxide, water and sunlight and produce oxygen which is essential for life on Earth.

# SUN-EARTH RELATIONSHIP

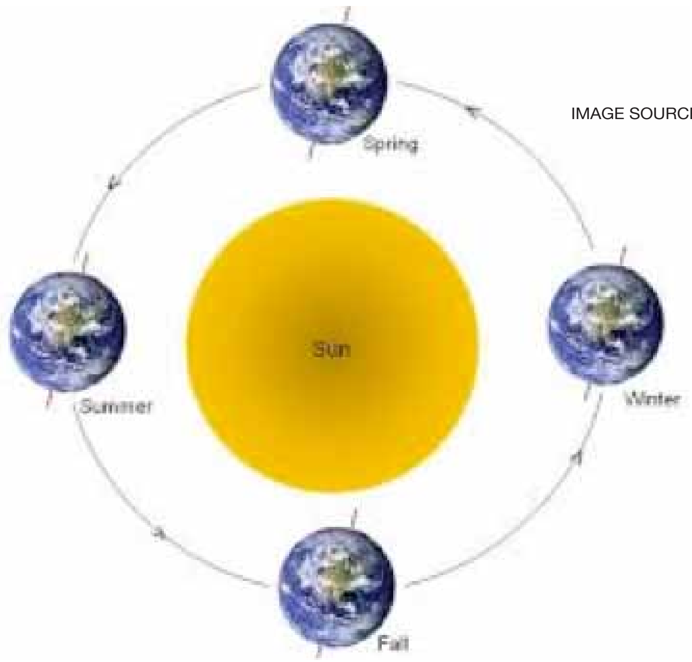



IMAGE SOURCE: SCIENCEBUDDIES.ORG

## SEASONS

Earth’s orbit is not a perfect circle. It is a bit lop-sided. During part of the year, Earth is closer to the Sun than at other times. However, in the Northern Hemisphere, we are having winter when Earth is closest to the Sun and summer when it is farthest away! Compared with how far away the Sun is, this change in Earth's distance throughout the year does not make much difference to our weather.

## WHY DO WE HAVE DIFFERENT SEASONS ON EARTH?

Earth's axis is an imaginary pole going right through the center of Earth from "top" to "bottom." Earth spins around this pole, making one complete turn each day. That is why we have day and night, and why every part of Earth's surface gets some of each. Earth has seasons because its axis doesn't stand up straight.

As Earth orbits the Sun, its tilted axis always points in the same direction. So, throughout the year, different parts of Earth get the Sun’s direct rays. Sometimes it is the North Pole tilting toward the Sun (around June) and sometimes it is the South Pole tilting toward the Sun (around December).
It is summer in June in the Northern Hemisphere because the Sun's rays hit that part of Earth more directly than at any other time of the year. It is winter in December in the Northern Hemisphere, because that is the time of year when it is the South Pole's turn to be tilted toward the Sun.

## HOW FAR AWAY IS THE SUN FROM EARTH?

Earth’s perihelion (point closest to Sun) = 91,400,000 miles from Sun

Earth’s aphelion (point farthest from Sun) = 94,500,000 miles from Sun

While that is a difference of over 3 million miles, relative to the entire distance, it isn’t much.

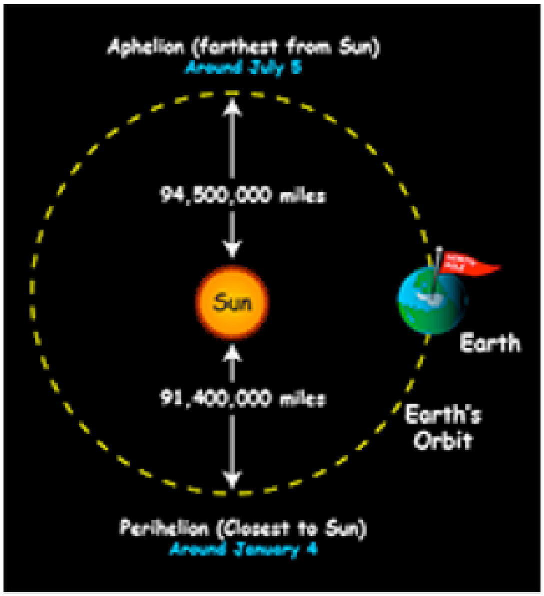



PHOTO COURTESY OF NASA.GOV

Aphelion, when the Earth is farthest from the Sun, occurs in July and perihelion, when we are closest, occurs in January. For those of us who live in the Northern Hemisphere where it’s summer in July and winter in January, that seems backwards, doesn’t it? That just goes to prove that Earth's distance from the Sun is not the cause of the seasons.

SEASONS

## CLASSROOM ACTIVITY

NASA-Reason for the Seasons lesson plan - Click HERE

NASA-Seasons and Cloud Cover - Click HERE

# SUN'S ENERGY

How does the Sun produce energy? The Sun produces energy by the nuclear fusion of hydrogen into helium in its core.  Since there is a huge amount of hydrogen in the core, these atoms stick together and fuse into a helium atom. This energy is then radiated out from the core and moves across the solar system. However, how is the energy transferred from the Sun's core to the Earth and the other objects in our solar system?

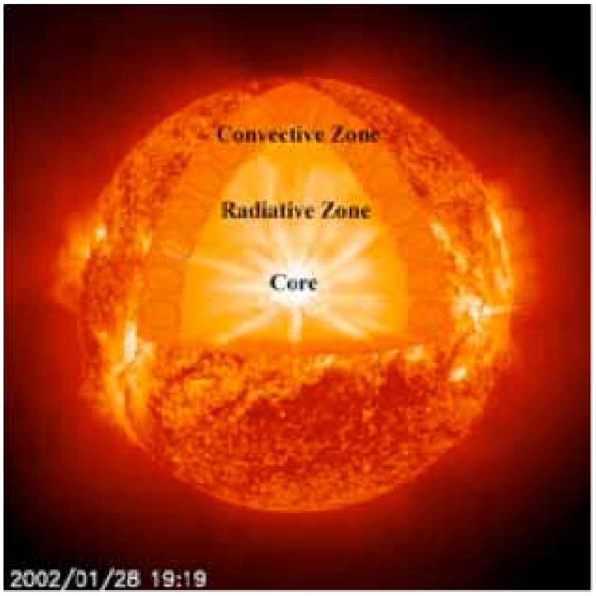


PHOTO COURTESY OF NASA.GOV

Energy is produced by nuclear fusion during a series of steps called the proton-proton chain, converting hydrogen to helium. The core is the only part of the Sun that produces an appreciable amount of heat through fusion (99%). The rest of the star is heated by energy that is transferred outward from the core and the layers just outside. The energy must then travel through many layers to the solar photosphere before it escapes into space sunlight.

The next layer of the Sun is the radiative zone. Here solar material is hot and dense enough that thermal radiation (energy moving in waves in this case heat) is all that is needed to transfer the intense heat outward. There is no thermal convection. The material grows cooler as altitude increases. Heat is transferred because ions of hydrogen and helium emit photons that travel a small distance and then are reabsorbed.

The next layer is the convective zone. Here the solar plasma is not dense enough or hot enough to transfer the heat of the interior through radiation. Thermal convection occurs here as thermal columns carry hot material to the next layer, the photosphere. Once the material cools off in the photosphere, it plunges back to the base of the convection zone and receives more heat from the top of the radiative zone.

# LAYERS OF THE SUN

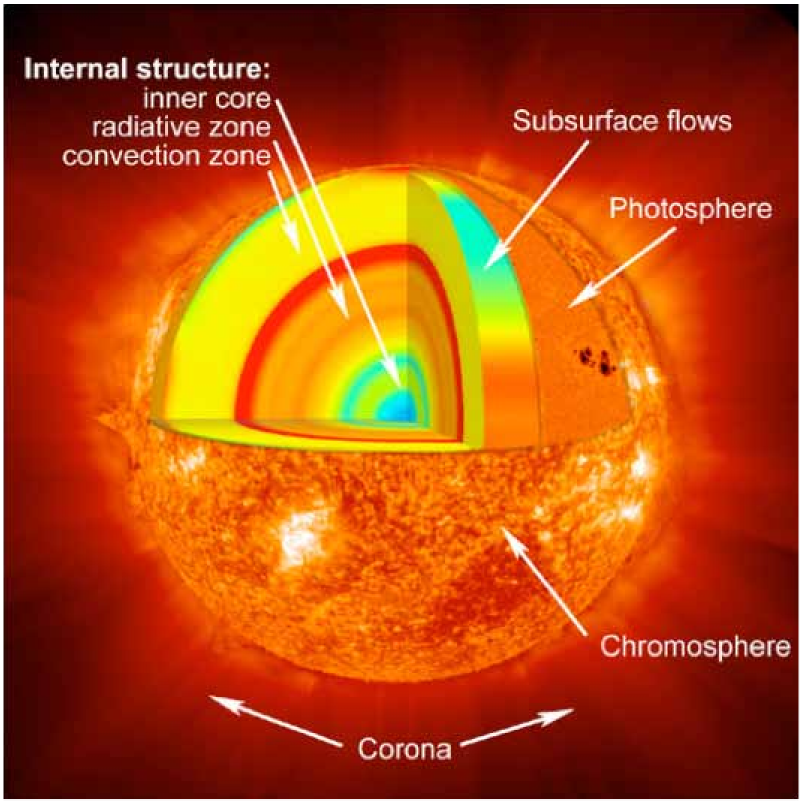



PHOTO COURTESY OF NASA.GOV

At the surface of the Sun, the temperature has dropped. The turbulent convection of this layer of the Sun causes an effect that produces magnetic north and south poles all over the surface of the Sun.

Lastly, the photosphere, the surface of the Sun, is where visible sunlight is free to move into space. The energy then travels to the other bodies in the solar system. Here on Earth the atmosphere filters some of the UV rays, but allows a portion of that energy to pass. The energy bounces off of the surface and is then reflected back by the atmosphere. After this bounce the Earth absorbs some of the energy and our planet is heated.

# LIGHT (PHOTON) FROM THE SUN

Photons are tiny little particles of light, far too small to see individually. All light is made of photons (FOE-tahns). The earliest photons probably appeared about fifteen billion years ago, during the Big Bang. Unlike electrons, photons have no mass, so they can travel at the speed of light (about 186,000 miles per second) - that's why we call it the speed of light.

Photons behave in some ways like particles and in other ways like waves. It's not just visible sunlight that is made of photons, but also many other kinds of waves including radio waves, television broadcasts, x-rays, and the ultraviolet (UVA and UVB) rays that give you sunburns. The difference between light and these other kinds of waves depends on the size of the wave - the wavelength. Very short waves are x-rays and ultraviolet rays. Visible light like sunlight is made of medium-length waves. Radio and television waves are very long waves. All of these waves are made of photons.

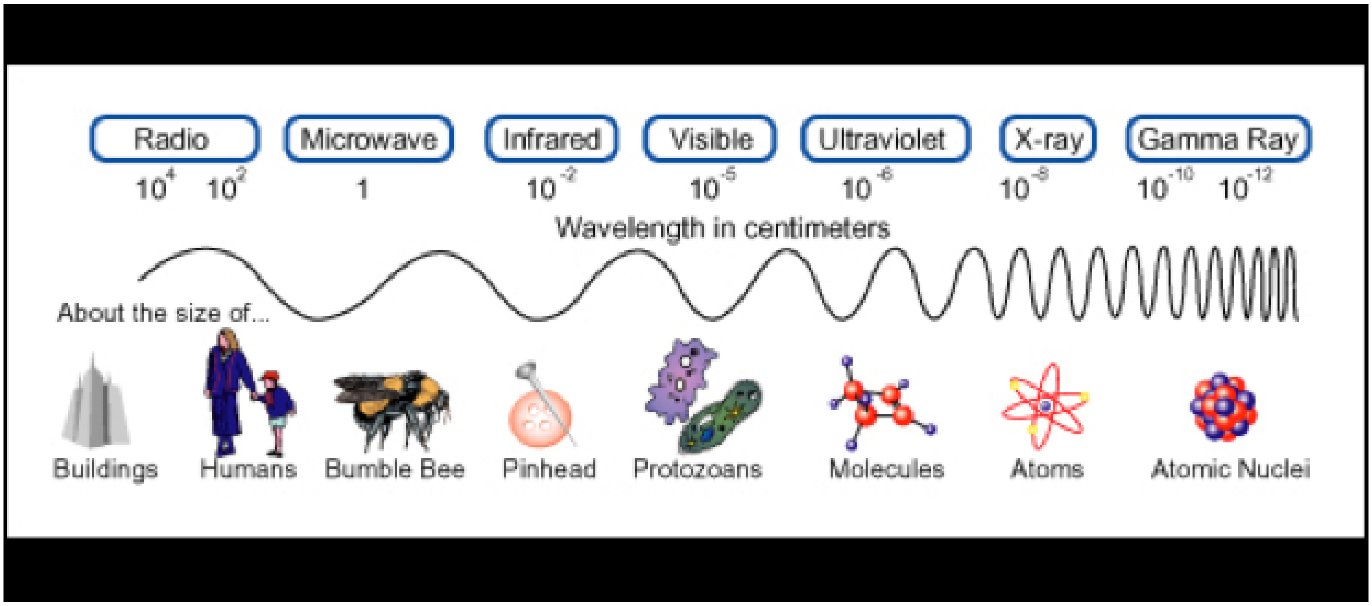
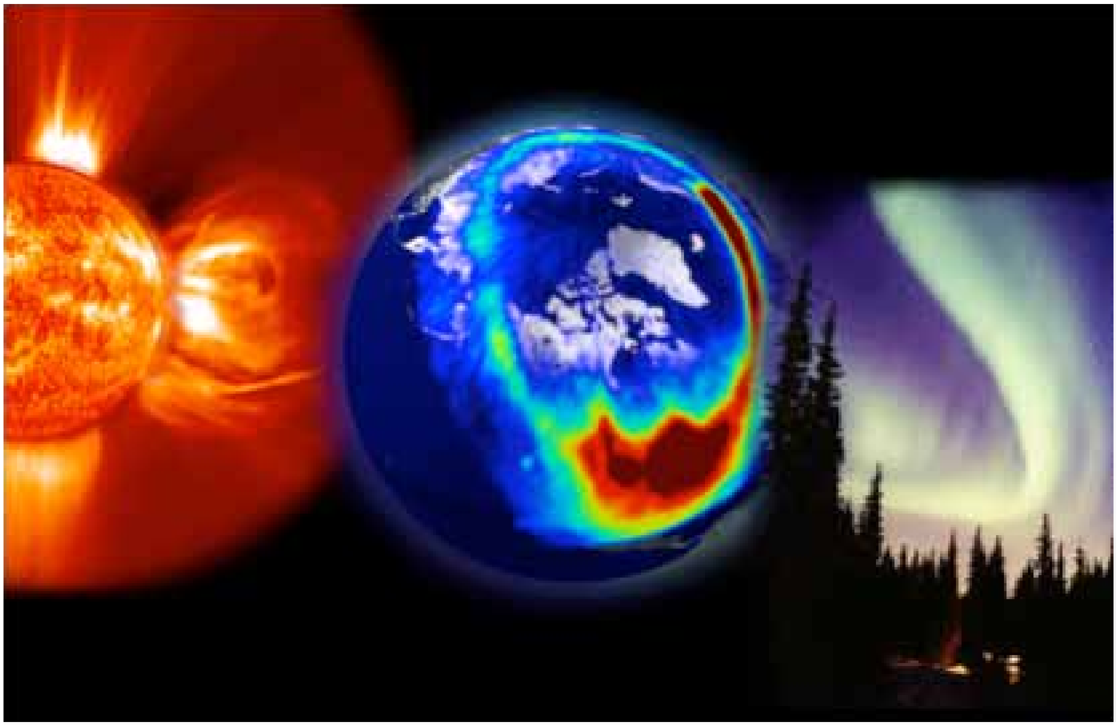



PHOTO COURTESY OF NASA.GOV

If a photon moves in short wavelengths, like x-rays or ultraviolet rays, then that photon has more energy. That's why you have to be careful how much x-ray radiation or UV rays you get, or you'll get radiation sickness or sunburn. If the wavelength is longer, then that photon will have less energy - that's why it's not dangerous to stand in the way of radio or television broadcasts. When photons bump into other atoms, some of their energy can get the electrons in those atoms moving faster than they were before causing heat. This is why you get hot sitting in the sun.

# SPACE WEATHER

What is space weather? Space weather occurs when there is a storm on the Sun. When a solar storm travels through space it impacts the Earth's magnetosphere. Solar storms can affect technology we use in our everyday life. Energy and radiation from solar flares and coronal mass ejections can: harm astronauts in space, damage electronics on spacecraft, cause auroras and interrupt electrical power grids on Earth.



Picture of a solar storm, aurora from space and aurora on Earth

PHOTO COURTESY OF NASA.GOV

The Sun produces sunspots and solar storms over an 11-year cycle which is driven by the reversal of its magnetic poles over this time period. Solar storms (coronal mass ejections and solar flares) occur most often and more powerfully during this period of solar maximum.

## SPACE MATH
## CLASSROOM ACTIVITY (ONLINE)

Click HERE

This is an entire unit on space weather mathematical problems. It incorporates many math concepts for a variety of students and their abilities.

# SUNSPOTS

Sunspots are regions on the solar surface where the Sun's magnetic fields are most intense. These areas appear dark because they are cooler than the surrounding area (photosphere). The dark region is called the umbra and the surrounding area is called the penumbra. However, they are only dark in appearance. If you removed the surrounding bright background-penumbra- the umbra would still glow brightly.

Sunspots can be quite large and be seen by the naked eye. Sunspots often form in groups normally with up to 10, but some have up to 100, which is relatively rare. Sunspots develop and last from hours to months and travel on the Sun's surface by its rotation. This was discovered by Galileo in his observations of the sun.

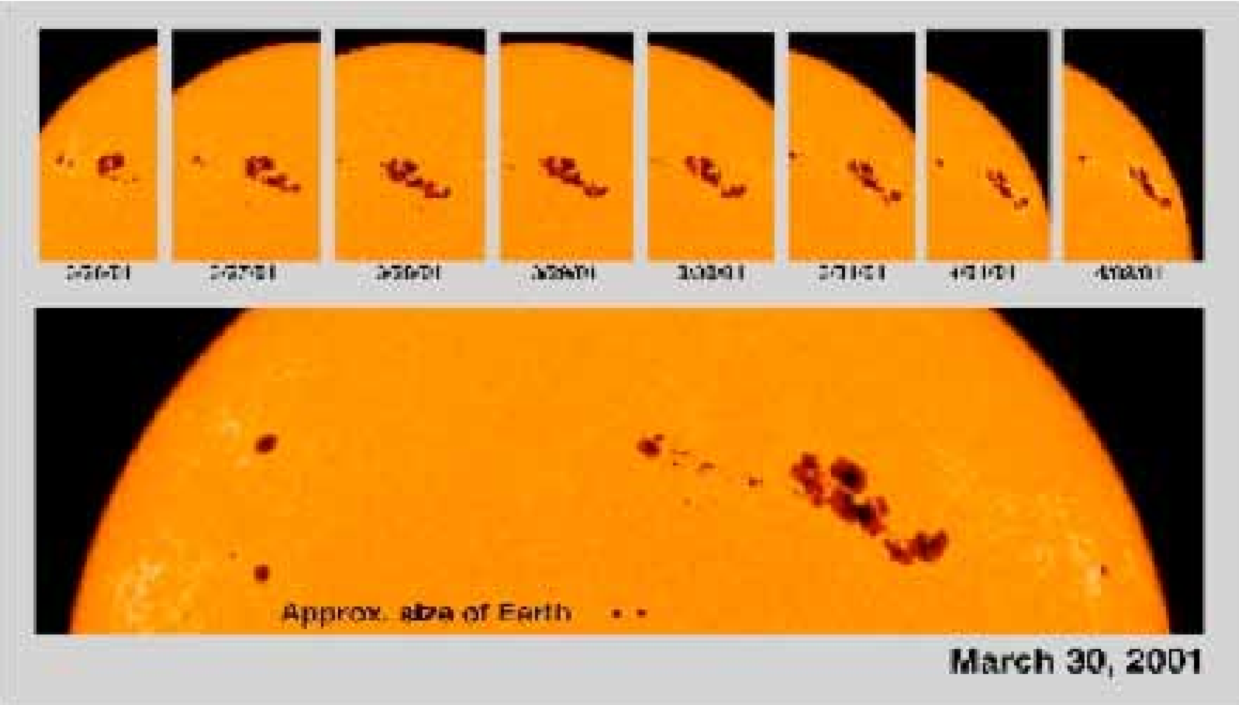



PHOTO COURTESY OF NASA.GOV

SUNSPOT INTERACTIVE ACTIVITY LINK

**CLASSROOM PROGRAM**

Click HERE

Materials Needed: Paper copies, access to web, pencils, mapping grid (enough for each pair of students)

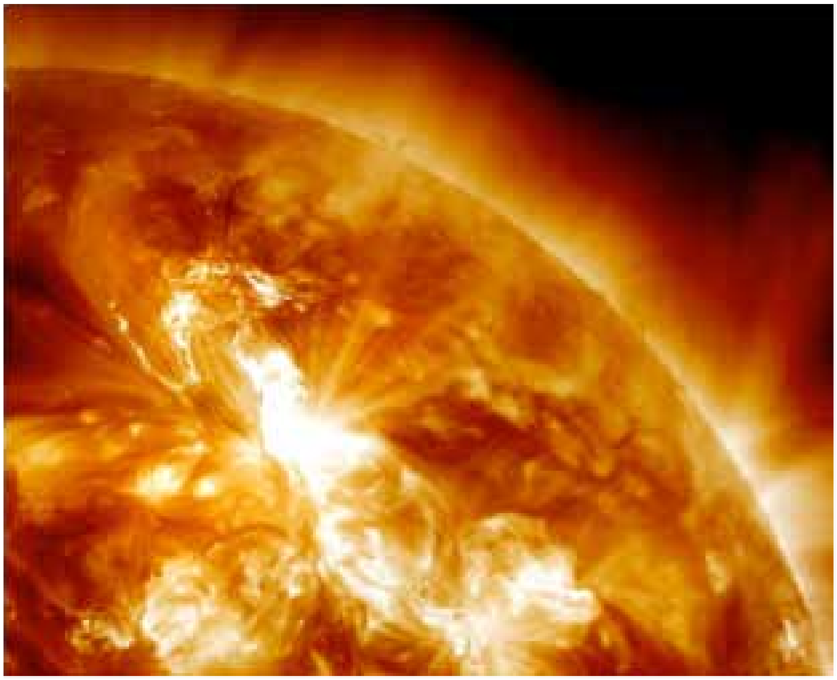
USING SUNSPOTTER

**OUTSIDE OBSERVATIONS**

# SOLAR FLARE

A solar flare is a sudden, rapid, and intense variation in brightness on the sun's surface. A solar flare occurs when magnetic energy has built up in the sun's atmosphere and is suddenly released. The amount of energy released is equivalent to 100-megaton hydrogen bombs exploding at the same time!

There are typically three stages of a solar flare. First is the precursor stage, where the release of magnetic energy is triggered. During this stage the soft x-ray emission can be detected. The second is the impulsive stage where radio waves, hard x-rays, and gamma rays are detected. In the third stage or decay stage the soft x-ray emission starts to decay. The length of these stages can be just a few seconds or as long as an hour.



M9 Solar Flare

PHOTO COURTESY OF NASA.GOV

Solar flares extend out to the Corona. The corona is the outermost atmosphere of the Sun. Solar flares and sunspots are located within strong magnetic fields which are called active regions. The frequency of the flares coincides with the Sun's eleven year cycle. When the solar cycle is at a minimum, active regions are small and rare with few solar flares.

Solar flares cannot be seen by the human eye. Flares are in fact difficult to see against the bright photosphere. Specialized scientific instruments are used to detect the radiation emissions during a flare. The radio and optical emissions from flares can be observed with telescopes on Earth.

# CORONAL MASS EJECTIONS

Coronal mass ejections (or CMEs) are huge bubbles of gas threaded with magnetic field lines that are ejected from the Sun over the course of several hours. Although the Sun's corona has been observed during total eclipses of the Sun for thousands of years, the existence of coronal mass ejections was unrealized until the Space Age. During a natural eclipse of the Sun the corona is only visible for a few minutes at most, too short a period of time to notice any changes in coronal features. A coronagraph produces an artificial eclipse of the Sun by placing an "occulting disk" over the image of the Sun. With ground based coronagraphs only the innermost corona is visible above the brightness of the sky. From space the corona is visible out to large distances from the Sun and can be viewed continuously.

Corona Mass Ejection

PHOTO COURTESY OF NASA.GOV

Coronal Mass Ejections disrupt the flow of the solar wind and produce disturbances that strike the Earth, sometimes with catastrophic results. The Large Angle and Spectrometric Coronagraph (LASCO) on the Solar and Heliospheric Observatory (SOHO) has observed a large number of CMEs.

Coronal mass ejections are often associated with solar flares and prominence eruptions but they can also occur in the absence of either of these processes. The frequency of CMEs varies with the sunspot cycle. At solar minimum we observe about one CME a week. Near solar maximum we observe an average of 2 to 3 CMEs per day.

# SOLAR WIND

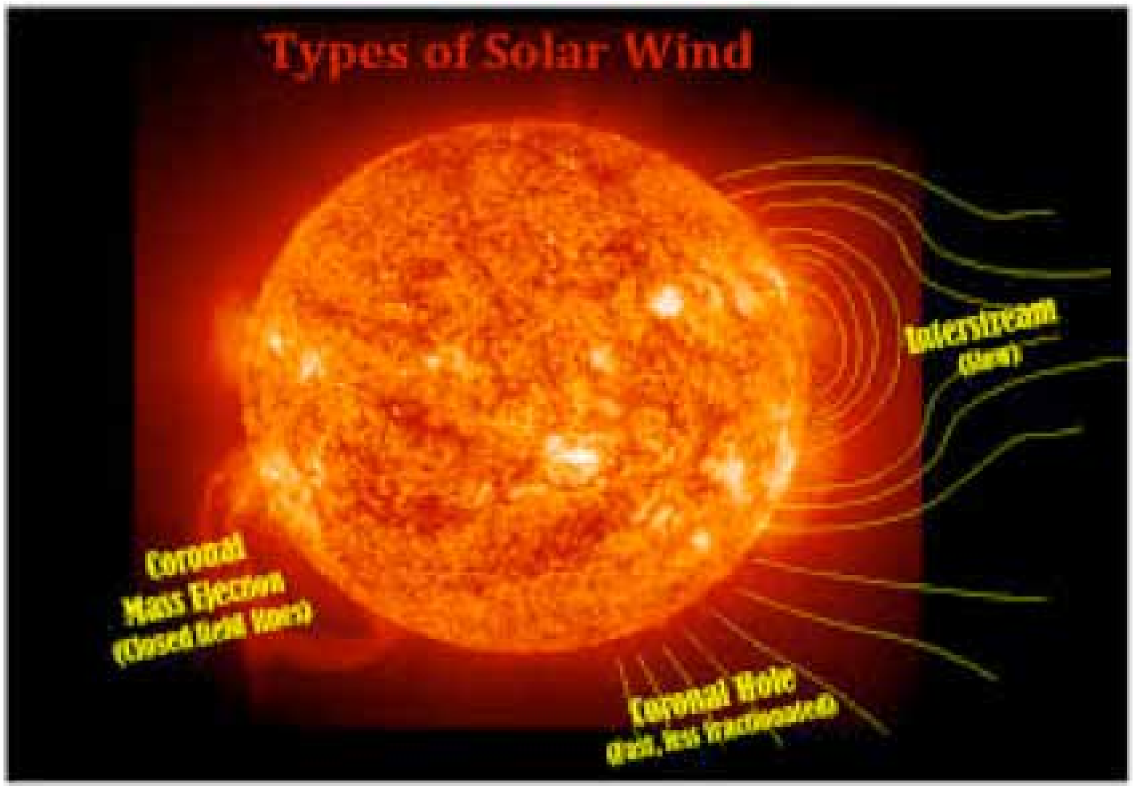



PHOTO COURTESY OF NASA.GOV

The solar wind streams off of the Sun in all directions at speeds of about 400 km/s (about 1 million miles per hour). The source of the solar wind is the Sun's hot corona. The temperature of the corona is so high that the Sun's gravity cannot hold on to it. Although we understand why this happens we do not understand the details about how and where the coronal gases are accelerated to these high velocities.

The solar wind is not uniform. Although it is always directed away from the Sun, it changes speed and carries with it magnetic clouds (interacting regions where high speed wind catches up with slow speed wind) and composition variations. These high and low speed streams interact with each other and alternately pass by the Earth as the Sun rotates. These wind speed variations buffet the Earth's magnetic field and can produce storms in the Earth's magnetosphere.

# SUN'S EFFECT ON EARTH'S WEATHER

PHOTO COURTESY OF NASA.GOV

The energy that the Earth receives from the Sun is the basic cause of our changing weather. Solar heat warms the huge air masses that comprise large and small weather systems. The day-night and summer-winter cycles in the weather have obvious cause and effect. The effects of currently observed changes in the Sun - small variations in light output, the occurrence of solar particle streams and magnetic fields are very small in the Earth's lower atmosphere or troposphere where our weather actually occurs. The search for Sun-weather relations is complicated by the presence of many non-solar influences on both short- and long-term weather patterns. Volcanic eruptions can inject huge amounts of dust and ash into the atmosphere, cutting off some of the Sun's light and heat. Changes in the amount of carbon dioxide in the atmosphere, as a result of volcanic eruptions or the burning of coal and oil, affect the amount of heat absorbed by the atmosphere. Even small variations in the Earth's orbital motion around the Sun from year to year may cause significant changes in the weather. In looking for direct effects of solar activity on the weather we must first take into account the many non-solar effects that are going on simultaneously.

# GLOBAL WARMING

Many researchers believe the steady rise in sunspots since the late seventeenth century may be responsible for as much as half of the 0.6 degrees of global warming over the last 110 years (IPCC, 2001). Since pre-industrial times, it's thought that the Sun has given rise to a global heating similar to that caused by the increase of carbon dioxide in the atmosphere. If the past is any indication of things to come, solar cycles may play a role in future global warming.

Sunspot cycles may sway global warming either way. If long-term cycles in solar radiation reverse course and the Sun's spots begin to disappear over the next century, then the Sun could partially counter global warming. On the other hand, if the average number of spots rises, the Sun could serve to warm our planet even more. The Sun's 11-year cycles may dampen or amplify the effects of global warming on a year-to-year basis.

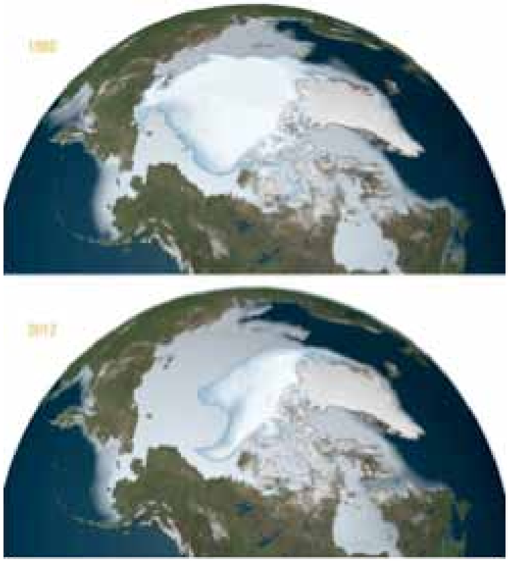


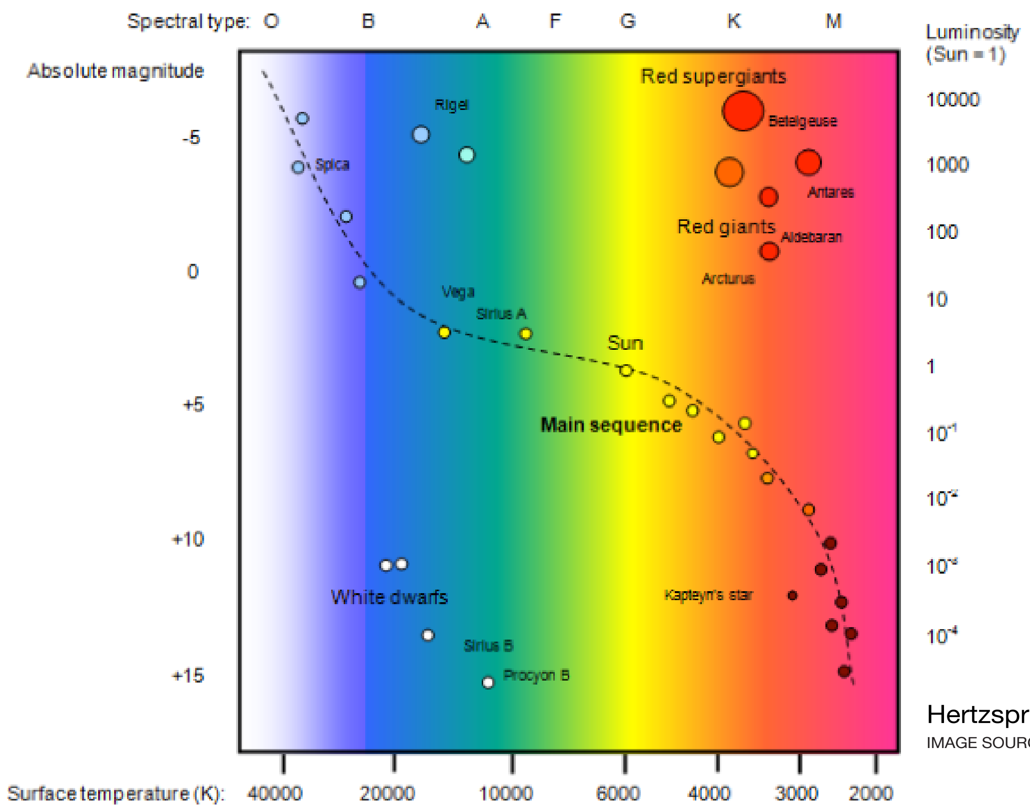
IMAGE SOURCE: GEOLOGYPAGE.COM

The Sun's effect on global warming can mostly be attributed to variations in the near-infrared and visible wavelengths of solar radiation. These types of radiation are absorbed by the lower atmosphere, the oceans, and the land. Ultra violet radiation, on the other hand, interacts strongly with the ozone layer and the upper atmosphere.

The impacts of changing ultra violet solar radiation may be substantial. Since ultra violet radiation creates ozone in the stratosphere, the changes in ultra violet levels can affect the size of the ozone hole. Absorption of ultra violet radiation by the ozone also heats up the stratosphere. Many scientists suspect that changes in stratospheric temperatures may alter weather patterns in the troposphere. Finally, an increase in the amount of ultra violet radiation could impact human health, increasing the incidence of skin cancer, cataracts, and other Sun-exposure-related issues.

# OTHER STARS

The Hertzsprung–Russell diagram (HR diagram) was first used in 1912. Ejnar Hertzsprung from Denmark and Henry Norris Russell from the Unites States, both discovered that the brightness of a star depends on the surface temperature of the star. They came up with the Hertzsprung-Russell diagram that explains the brightness, temperature and classes of stars.




Hertzsprung–Russell diagram
IMAGE SOURCE: SCHOOLPHYSICS.CO.UK

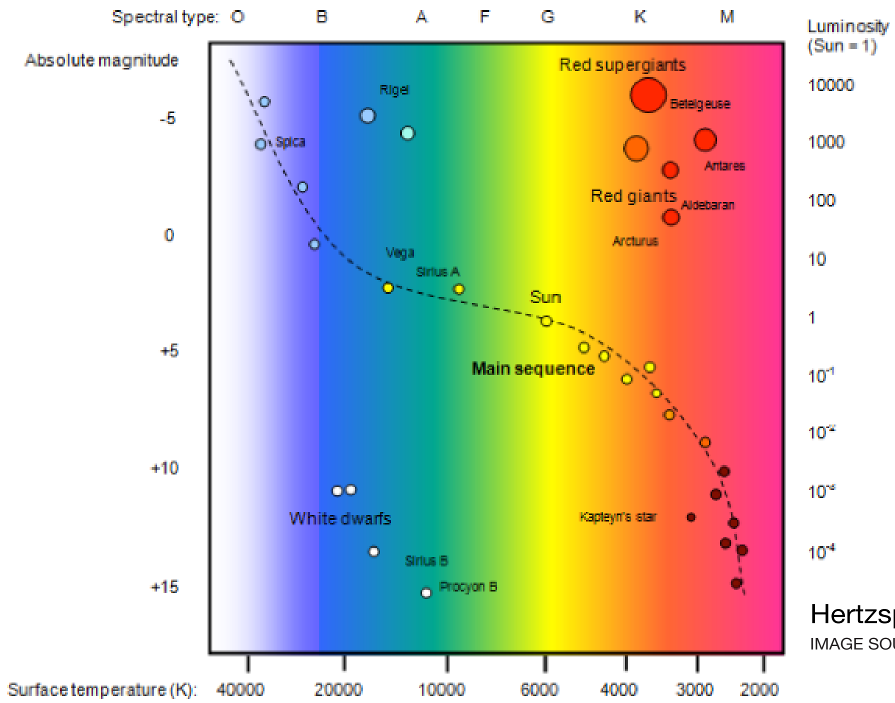
The scale on the left shows the absolute magnitude. Absolute magnitude is a calculated brightness of a star. Luminosity is the brightness of a star by its appearance.

The scale across the top represents the spectral class of stars, or color of stars and is depicted by the letters O, B, A, F, G, K, and M. These letters represent the following colors:

**O** – Blue **B** – Blue/White **A** – White **F** - White/Yellow **G** – Yellow **K** – Orange **M** - Red

Across the bottom of the scale is the temperature of the stars measured in Kelvin. Zero Kelvin equals -273 degrees Celsius, -459 degrees Fahrenheit.

Most stars in our universe are main sequence stars, including our sun Sol. Notice how the biggest stars are the brightest but not the hottest. The white dwarf stars are near the end of their life and losing much of their brightness but they are very hot.




Hertzsprung–Russell diagram
IMAGE SOURCE: SCHOOLPHYSICS.CO.UK

## TRY THIS!

1. Can you find Sol? ______________________ What spectral class is it? ______________________
2. Can you find Antares? ______________________ What spectral class is it? ______________________
3. What is the absolute magnitude of white dwarfs? ______________________
4. What is the temperature of red giants? ______________________
5. What class is Spica? ______________________
6. What class is Sirius A? ______________________
7. How bright is Vega? ______________________
8. Name a star on the Main Sequence? ______________________

# REFRACTOR TELESCOPES
## HANDS-ON ACTIVITY

# SOLAR FILTER TELESCOPE
## TEACHER DEMONSTRATION