SOHO Michelson Doppler Imager
Stanford University – NASA

The One

The Only

The Sun Cake!

Developed by: Barbara J. Edmunds and Amy Jackson
Redesigned by: Barbara J. Edmunds

"What is a sun cake?" you ask in all innocence. Well, it is perhaps the best (and most delicious) model of the sun that has ever been developed! Years after learning about the sun incorporating the use of a sun cake, students retain the basic composition and what happens in each zone.

National Science Standards

Unifying Concepts and Processes Standard – Evidence, models, and explanation.
K-4 – Standard D – Objects in the sky
5-8 – Standard D – Earth in the Solar System
9-12 – Standard D – Energy in the Earth System

Objectives

Students will:

- See and understand that the sun is comprised of zones using a model
- Discuss the function of each zone
- Learn about the solar flares, solar prominences and sun spots
- Discuss the cyclic nature of the sun
- Eat their way though each zone

Grades

3nd – Adult (up to 48 people)

Time

About 2-3 hours making model.
About 30-60 minutes activity.
About 30 minutes clean up (combined cooking and lesson).

Materials

Non-consumable supplies

- oven
- 1 metal mixing bowl about 8-10 liters (32-40 cups) referred to as "large"
- 2 metal mixing bowls about 4-5 liters (16-20 cups) referred to as "medium"
- 2 metal mixing bowls about 2.5-3 liters (10-12cups) referred to as "small"

- hot pads
- cooling rack
- large serrated knife
- sponge(s)
- large mixer

Consumable supplies
- 2 angel food cake mixes
- 2 gingerbread cake mixes
- 2 brownie mixes
- oil (amount as specified on the brownie mix directions)
- extra oil for brownie and gingerbread bowls (to prevent sticking while baking)
- eggs (amount as specified on the brownie mix directions)
- water
- 2 cans cream cheese or white frosting
- 1 can chocolate fudge frosting
- about 1 oz yellow food coloring
- toothpicks or bamboo skewers (to test for doneness)
- 1 sm package chocolate chips
- red whip licorice
- aluminum foil
- platter – larger than the opening of largest metal mixing bowl (Or as an alternative, get a large cardboard box, cut it down and cover with aluminum foil.)
- birthday candles
- matches
- paper plates
- plastic forks
- napkins

Preparations

1. I always start with the angel food cake. (If you have two ovens, see step 3 first.) You will need two racks; one rack for the cake, and another rack above it to steady the "medium" mixing bowl. This mixing bowl will create a well in the angel food cake batter as it rises around the "medium" bowl. (See the photograph of the oven.) Preheat your oven. Even though you have two cake mixes baking in the "large" mixing bowl, the "medium" mixing bowl acts like a bunt cake pan, and this cake will do just fine at its regular temperature. It may increase the amount of time it takes to bake, but only 5-10 minutes. You can use the "large" mixing bowl as the mixing bowl. Add both packages of angel food cake mix, and follow the directions on the back of the box,

remembering to double everything. Mix will. (Do NOT oil the "large" mixing bowl. Egg whites will not whip up if any oil or egg yolks traces get into the batter.) When the oven has reached temperature, set the "medium" mixing bowl in the middle of the "large" mixing bowl on top of the angel food cake batter. Do NOT oil the bottom of the "medium" bowl. It will not stick on the angel food. Bake the time specified on the box, and check with the toothpick or skewer. If it comes out clean, your angel food cake is done. If not, bake for an additional 5 minutes at a time until done. Take out of the oven and cool on the rack.

2. I make the gingerbread cake next. You can time this so that you begin to make this cake about the time the angel food cake is suppose to come out. You may need to adjust the oven temperature, depending on the mix you are using. You need to adjust the rack. I usually raise the bottom rack up one notch. Even though you have two cake mixes baking in the "medium" mixing bowl, the "small" mixing bowl will act like a bunt cake pan, and this cake will do just fine at it's regular temperature. It may increase the amount of time it takes to bake, but only 5-10 minutes. You can use the "medium" mixing bowl as the mixing bowl. Add both packages of gingerbread cake mix, and follow the cake directions on the back of the box, remembering to double everything. Mix well. Oil the bottom of the "small" bowl. Set the "small" mixing bowl in the middle of the "medium" mixing bowl on top of the gingerbread cake batter. Bake the time specified on the box, and check with the toothpick or skewer. If it comes out clean, your gingerbread cake is done. If not, bake for an additional 5 minutes at a time until done. Take out of the oven and cool on the rack.

3. I usually bake the brownies last because they take a long time to bake. If you have two ovens, start the brownies with your angel food cake. If not, you can time this so that you begin to make the brownies about the time the gingerbread cake is suppose to come out. You will need to adjust the oven temperature by reducing the temperature 25ºF from the temperature stated on the brownie directions. You need to slow down your oven to allow the inside of the brownies to cook without burning the outside. It will increase the time it takes to bake them. You will be using the "small" mixing bowl. You can use the "small" mixing bowl as the mixing bowl. Add both packages of brownie mix, and follow the directions on the back of the box, remembering to double everything. Mix will. Bake the time specified on the box, and check with the toothpick or skewer. It won't be done. Continue to bake for an additional 10-15 minutes at a time until done, being careful not to over bake. If you are concerned that the outside is baking too fast, turn down the oven an additional 25ºF. When the toothpick or skewer comes out clean, take out of the oven and cool on the rack.

4. Cool overnight. To assemble the sun cake, start with the brownies. Set them upside down in the center of your platter or cardboard covered with aluminum foil. (To get out of the bowl, I use a rather flexible knife, and just keep working it a little further down the sides until it finally is free from the bowl.) This is the core of the sun.

Next, the radiative zone is the ginger bread. By spinning the "small" mixing bowl gently, it will work free from the top of the batter. Use the same knife technique until the gingerbread is free. It is more delicate than the brownies, so work it free, and have it gently drop on the brownies, lining up the well in the gingerbread with the brownies. You will need to frost the gingerbread to represent the interface layer. This represents the area where the magnetic fields are generated. The angel food cake, the convective zone, will then need to be placed on top of the frosting on the gingerbread. Great care must be taken in order to free the angel food cake, and not mess up the chocolate frosting too much! In one of the small mixing bowls add the 2 cans of white frosting and add yellow food color until it is the perfect shade of sun yellow. Too much and it looks orange. Not enough, and it just doesn't look sunny. Frost the outside of the angel food cake. Make peaks in the frosting (very important for our model.) Add chocolate chips for sun spots (I always add way to many because I like chocolate), and red licorice for the solar flares. You may have to push the licorice into the cake until it sticks out satisfactorily. Licorice whips are also the solar prominances. Push both ends of the licorice into the cake to create arcs. Add the candles.

5. Make a tent with the aluminum foil to cover the cake.

Activity

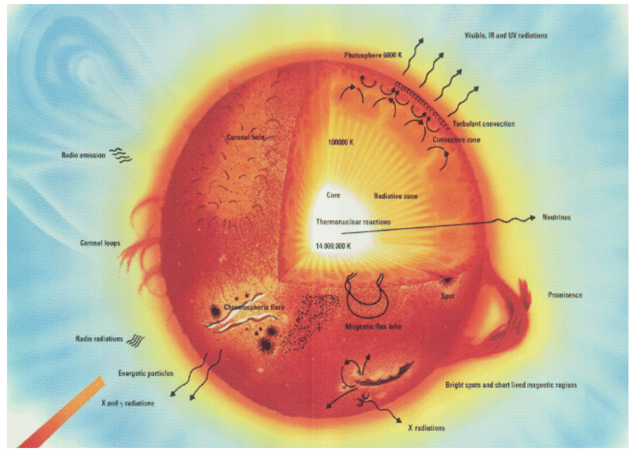
I think that the sun cake is the best way to end an astronomy/solar system science unit. You can review the material that they have learned about our own Sun or stars in general, or go into detail about the composition of the sun. The discussion should emphasize the National Science Standard or your state standard for your grade level.

Class discussion:
Stars are made up of zones. Each zone has a different function in the anatomy of a star. This is the model of our sun. (Cut the cake in half and open it so that the students can see each of the interior zones. Light the candles.)

<u>Core</u> (brownies) It can be 15 million degrees at the core of our sun. It is so hot because of the tremendous pressure exerted by the total mass of the sun pressing down on it. This hot, dense zone is where nuclear fission occurs. The sun takes some of its mass and changes it into energy – light energy. (Be sure to understand the difference between mass and weight and density. Definitions are at the end of this section.)

<u>Radiative Zone</u> (gingerbread) Light, after it has been converted from matter, reaches the radiative zone. It can spend millions of years passing through this section of the sun, because it gets bounced all around like a pin ball.

<u>The Interface Layer or Tachocline</u> (chocolate fudge frosting) Until very recently, not much was known about this layer. It is thought that the tremendous magnetic field of the sun is generated in this layer, and there are sudden changes in both the fluidity and the chemical composition of this area.



http://www.solarviews.com/cap/sun/sundiag.htm
NASA/ESA - 3 January 1995

<u>Convection Zone</u> (angle food) The outer layer of the sun is hotter towards the interior and cooler at the surface. This creates huge cells of rising hot plasma. Remember, hot air rises and cold air sinks; hot water rises and cold water sinks. Same with plasma. Hot plasma rises and cold (relatively speaking) plasma sinks. (This is an optional activity for students to work in groups.) It is best if you have a tray and sponge for each group. Fill a baby food jar with very hot tap water. Add a drop of red food coloring. Place that jar in the middle of the tray. Fill another baby food jar with cold water. Add a drop of blue food coloring. Cut the side of a 3x5" index card to measure 3x3" square. Slowly add more water to the blue jar until you can see a bulge of water over the rim of the jar. Put the index card on top of the blue jar. Pick up the blue jar and turn it upside-down holdin the index card. Just flip the jar over. Don't hesitate. If the jar is tilted but not turned over completely, the water will not hold the index card, and the water will spill out. Lay the blue jar with the square card carefully onto the top of the red jar. Tap the card gently with your finger. (Don't poke it. You want the card to be flat and form a seal with the water and the jar.) Have someone hold onto both jars while another person very slowly and carefully pull the card out. Watch what happens. Empty both jars. Rinse them. Repeat each step but put the jar with the blue-colored cold water on the bottom and put the card on top of the jar with the red-colored hot water. Turn the red jar upside-down and put it on top of the blue jar. This can be very messy! Also, practice this before you present it. It is so much easier to explain.

<u>Chronosphere</u> (surface of the angel food) An invisible layer of plasma at the edge of the sun is the end of the convective zone and the beginning of the photosphere.

<u>Granules or Supergranules</u> (peaks in frosting) The surface of the sun has a granular look from the hot plasma rising in California-sized bubbles and the cool plasma sinking.

<u>Photosphere</u> (yellow frosting) This is what we see. It is "only" 10,000 degrees, but it is so bright that we cannot see either the chronosphere or the corona.

<u>Sun Spots</u> (chocolate chips) The sun is blemished with cool, darker spots known as sun spots. Not only are they cooler, but they have very strong magnetic fields associated with them. And for every sun spot, there is a mate. Like any magnet, one spot is the "north pole," and its mate is the "south pole." There is an 11 year cycle associated with sun spots. They peak in number. During that time, we can see more aurora borealis or aurora australis. Then they subside, and the sun can appear with almost no spots. The 11 year cycle is not constant. About 300 years ago, there was no peak for about 75

years. No one knows why that happened.

Solar Flares (licorice whips sticking straight out) Solar flares are explosions from the sun that are not pulled back by the strong magnetic fields.

Solar Prominances (licorice whips that make arcs) Sometimes the far end of a solar flare is pulled back to the sun by the strong magnetic field. They make beautiful arcs. (This is an optional demonstration or you could find enough materials for all students to work in groups and do this as an activity.) Using metal filings on a piece of cardstock paper, pass a strong magnet (preferably a strong horseshoe magnet) underneath and view the effect. The shavings will line up in the geometry of the surrounding magnetic field. Fill a large, transparent container with mineral oil, and mix in the metal shavings. Wait until the viscous liquid has stopped moving. Carefully lower the horseshoe magnet into the middle of the liquid. Students can observe the 3D magnetic fields. (It is possible that once the magnet is in place to secure it with wire to the top of the container so you won't have to hold it.)

Corona (candles) During a total solar eclipse, the corona is the illuminated halo that surrounds the sun. It can be millions of miles for the surface, and is about 2 million degrees. Astrophysists can explain why the surface of the sun is so much cooler (10,000 degrees compared to 2,000,000 degrees), but it is very hard to understand.

Definitions

- Density is how tightly the atoms, molecules and/or matter are packed together.
- Mass is how much stuff there is all together.
- Pressure is how much the air, gas, liquid atmosphere above you pushes on you.
- Volume is how much space matter needs.
- Weight is how much gravity pulls matter down.

Example: I have some feathers and gold. Gravity is pulling down equally on them, and they both weigh one pound. The feathers and the gold are therefore equal mass (they are both 1 pound.) On the International Space Station, they will still have equal mass, even though they won't weigh anything up there. There is no pressure in space, but the Space Station creates some artificial pressure. Back on Earth, 100 feet down in the ocean, the water weighs more than the air, so there is more pressure pushing down on them. All this time, my feathers have much more volume than my gold. My gold is compact, but my feathers take up a lot of space.

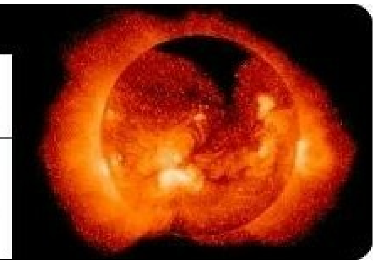
Background

Who could say it better than NASA. So, included is an article on solar zones and some other excellent sites. Have fun, learn lots, and ENJOY!

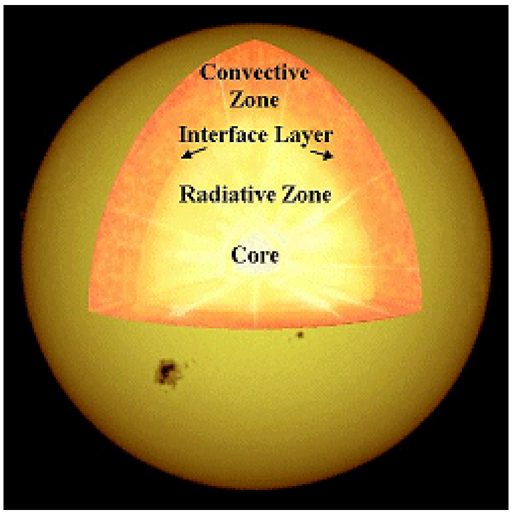
You can also use the model to create the layers of the Earth or other planets. This is a great site for research on planetary layers:
http://www.windows.ucar.edu/openhouse/open_house.html

Solar Physics

Science Directorate
Marshall Space Flight Center



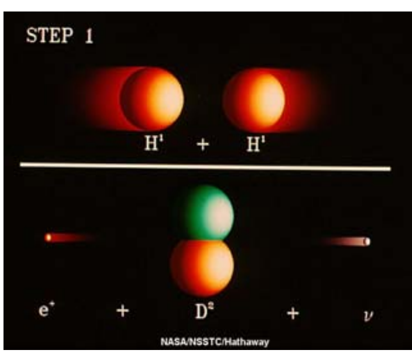
The Solar Interior

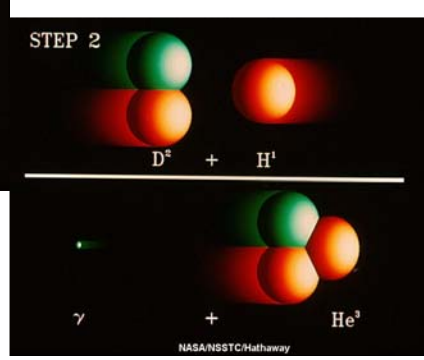


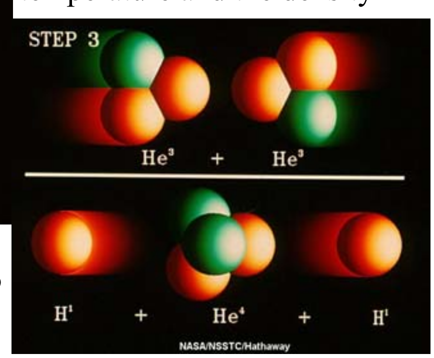
The solar interior is separated into four regions by the different processes that occur there. Energy is generated in the core. This energy diffuses outward by radiation (mostly gamma-rays and x-rays) through the radiative zone and by convective fluid flows (boiling motion) through the outermost convection zone. The thin interface layer (the "tachocline") between the radiative zone and the convection zone is where the Sun's magnetic field is thought to be generated.

The Core

The Sun's core is the central region where nuclear reactions consume hydrogen to form helium. These reactions release the energy that ultimately leaves the surface as visible light. These reactions are highly sensitive to temperature and density. The individual hydrogen nuclei must collide with enough energy to give a reasonable probability of overcoming the repulsive electrical force between these two positively charged particles. The temperature at the very center of the Sun is about 15,000,000° C (27,000,000 ° F) and the density is about 150 g/cm³ (about 10 times the density of gold or lead). Both the temperature and the density decrease as one moves outward from the center of the Sun. The nuclear burning is almost completely shut off beyond the outer edge of the core (about 25% of the distance to the surface or 175,000 km from the center). At that point the





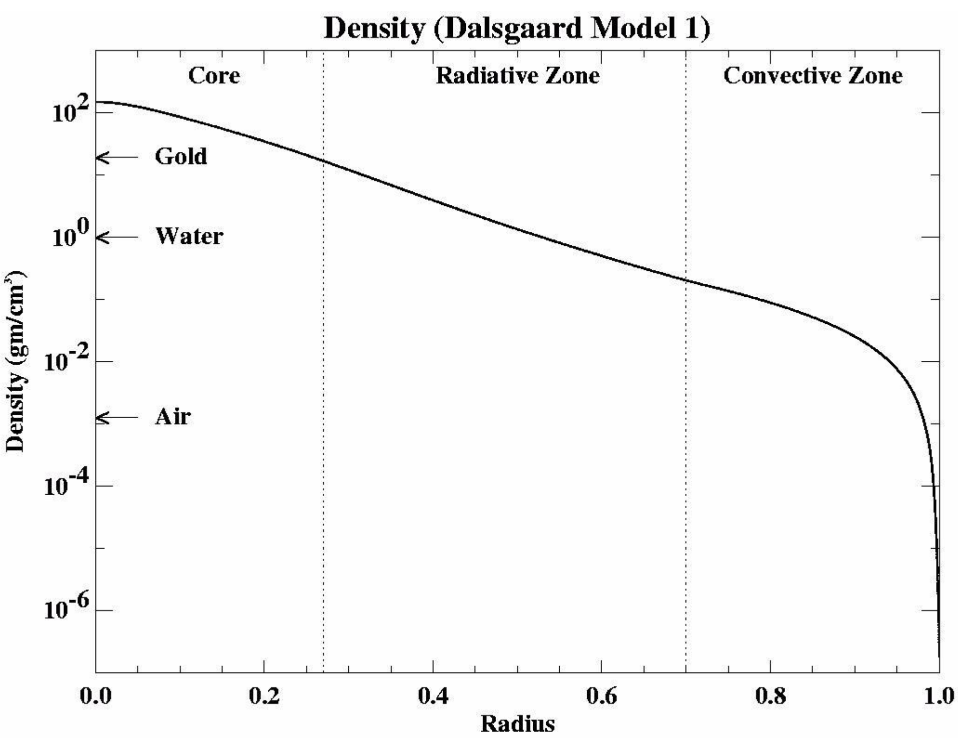


temperature is only half its central value and the density drops to about 20 g/cm³.

In stars like the Sun the nuclear burning takes place through a three step process called the proton-proton or pp chain. In the first step two protons collide to produce deuterium, a positron, and a neutrino. In the second step a proton collides with the deuterium to produce a helium-3 nucleus and a gamma ray. In the third step two helium-3s collide to produce a normal helium-4 nucleus with the release of two protons.

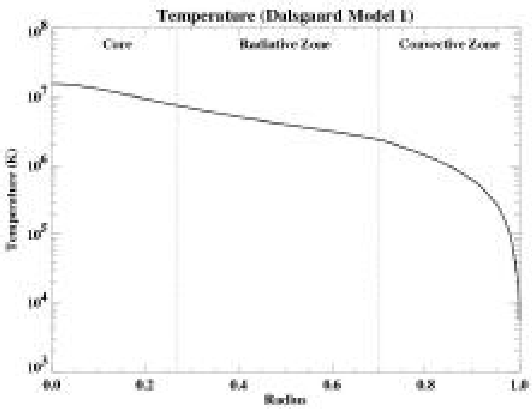
In this process of fusing hydrogen to form helium, the nuclear reactions produce elementary particles called neutrinos. These elusive particles pass right through the overlying layers of the Sun and, with some effort, can be detected here on Earth. The number of neutrinos we detect is but a fraction of the number we expect. This problem of the missing neutrinos was one of the great mysteries of solar astronomy but now appears to be solved by the discovery of neutrino masses.

The Radiative Zone



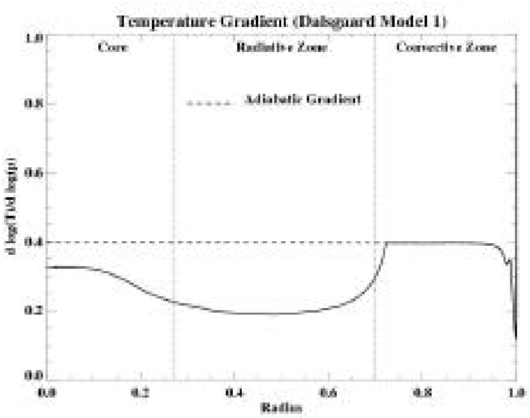
The radiative zone extends outward from the outer edge of the core to the interface layer or tachocline at the base of the convection zone (from 25% of the distance to the surface to 70% of that distance). The radiative zone is characterized by the method of energy transport - radiation. The energy generated in the core is carried by light (photons) that bounces from particle to particle through the radiative zone. Although the photons travel at the speed of light, they bounce so many times through this dense material that an individual photon takes about a million years to finally reach the interface layer. The density drops from 20 g/cm³ (about the density of gold) down to only 0.2 g/cm³ (less than the density of water) from the bottom to the top of the radiative zone. The temperature falls from 7,000,000° C to about 2,000,000° C over the same distance.

The Interface Layer (Tachocline)



The interface layer lies between the radiative zone and the convective zone. The fluid motions found in the convection zone slowly disappear from the top of this layer to its bottom where the conditions match those of the calm radiative zone. This thin layer has become more interesting in recent years as more details have been discovered about it. It is now believed that the Sun's magnetic field is generated by a magnetic dynamo in this layer. The changes in fluid flow velocities across the layer (shear flows) can stretch magnetic field lines of force and make them stronger. This change in flow velocity gives this layer its alternative name - the tachocline. There also appears to be sudden changes in chemical composition across this layer.

The Convection Zone



The convection zone is the outer-most layer of the solar interior. It extends from a depth of about 200,000 km right up to the visible surface. At the base of the convection zone the temperature is about 2,000,000° C. This is "cool" enough for the heavier ions (such as carbon, nitrogen, oxygen, calcium, and iron) to hold onto some of their electrons. This makes the material more opaque so that it is harder for radiation to get through. This traps heat that ultimately makes the fluid unstable and it starts to "boil" or convect. Convection occurs when the temperature gradient (the rate at which the temperature falls with height or radius) gets larger than the adiabatic gradient (the rate at which the temperature would fall if a volume of material were moved higher without adding heat). Where this occurs a volume of material moved upward will be warmer than its surroundings and will continue to rise further. These convective motions carry heat quite rapidly to the surface. The fluid expands and cools as it rises. At the visible surface the temperature has dropped to 5,700° K and the density is only 0.0000002 gm/cm^3 (about 1/10,000th the density of air at sea level). The convective motions themselves are visible at the surface as granules and supergranules.

You can find the original article on the Marshall Spaceflight Center website:
http://science.msfc.nasa.gov/ssl/pad/solar/interior.htm
Other good sites for solar information are:
http://science.nasa.gov/headlines/y2002/18jan_solarback.htm
http://science.msfc.nasa.gov/headlines/y2000/ast03apr_1m.htm
Other excellent astronomy sites:
http://science.nasa.gov/headlines/news_archive.htm
http://www.nasa.gov/gallery/photo/