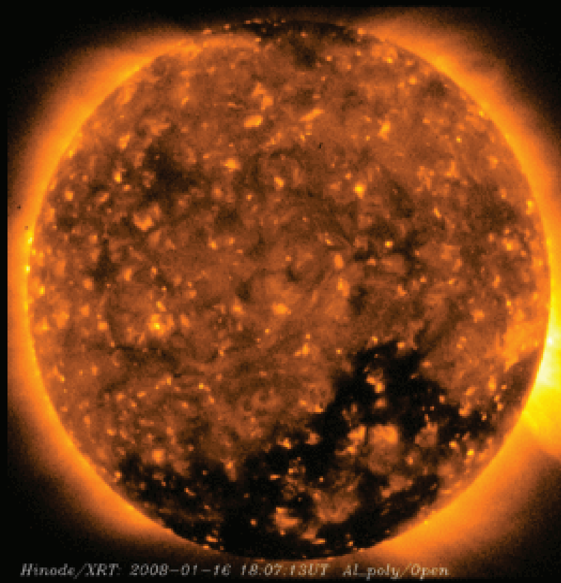
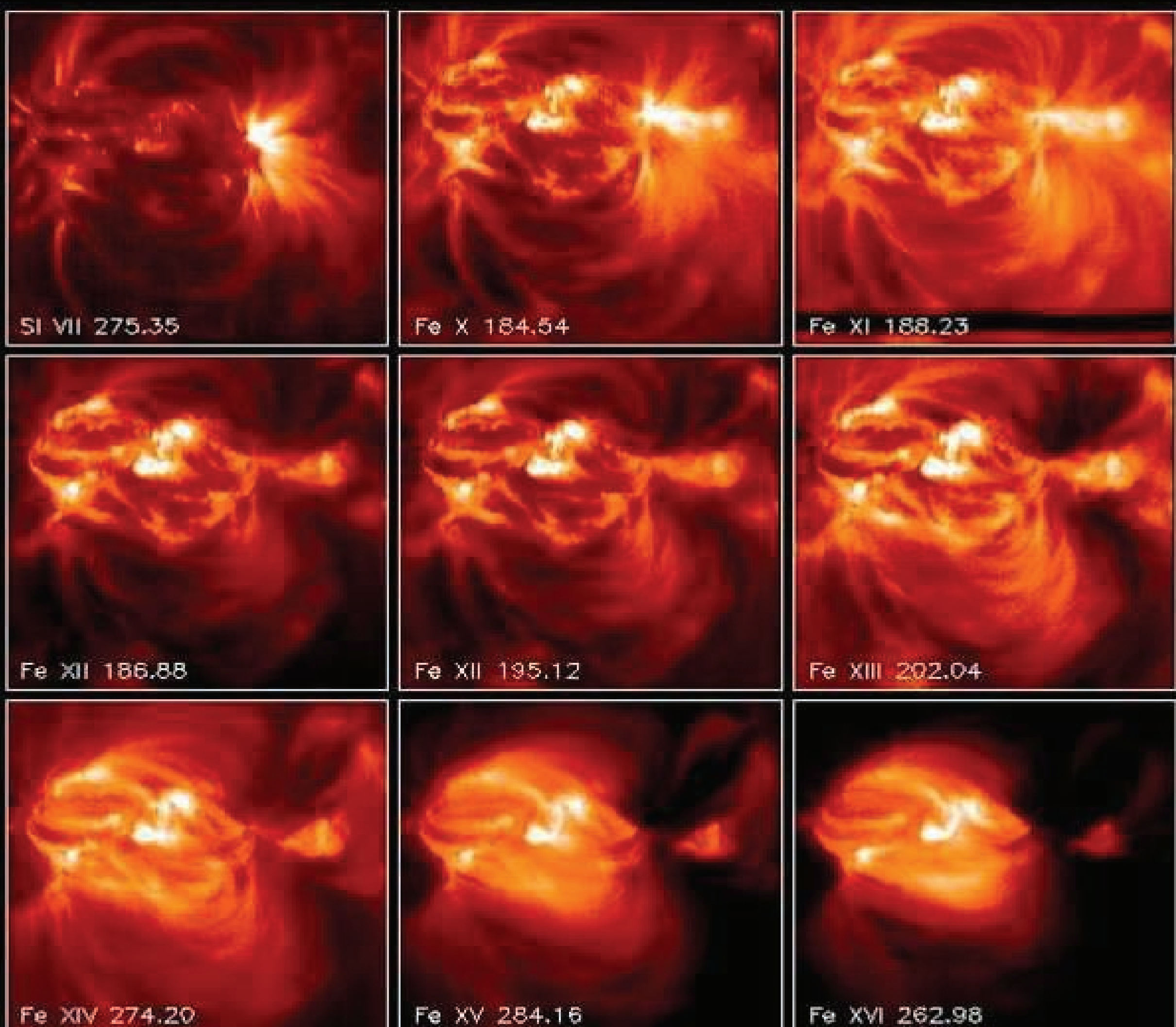
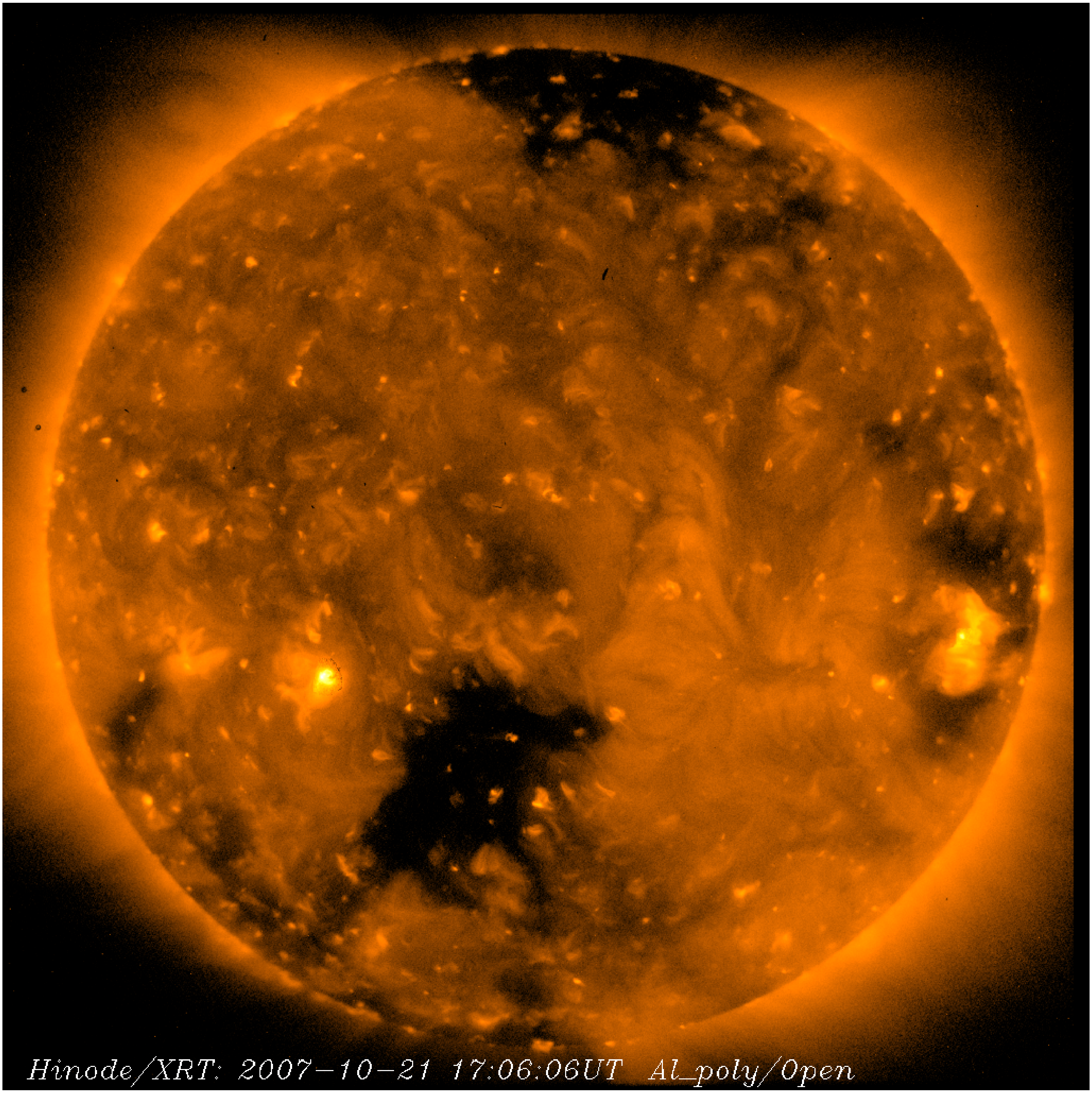
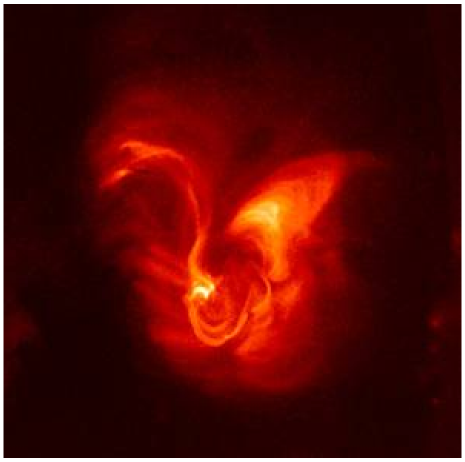
National Aeronautics and Space Administration





Hinode Math





The Hinode satellite was launched on September 22, 2006 and began taking images of the sun through x-ray light. The goal was to study the intense releases of magnetic energy which cause solar flares and the heating of the sun's corona.

These two images show the full-sun on October 21, 2007, revealing the orange glows of million-degree solar plasmas, along with coronal 'holes'. The small points of light are active regions, such as the one to the left, in which magnetic energy is released to heat the local solar gases.

By using the Hinode Extreme Ultraviolet Imaging Spectrometer (EIS), solar scientists hope to understand the physical conditions that lead to these violent releases of energy.

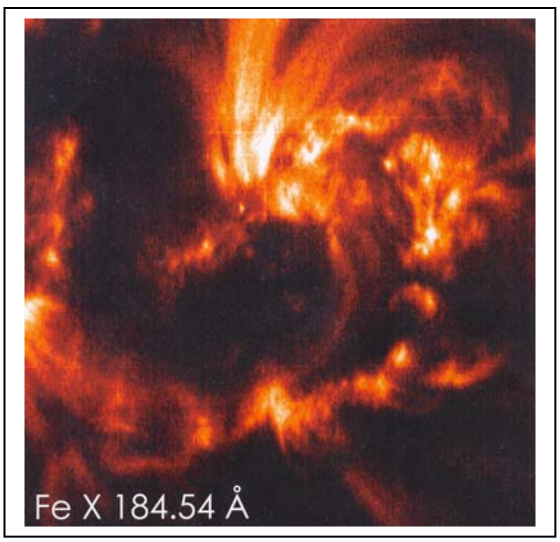
This collection of activities is based on a weekly series of space science problems distributed to thousands of teachers during the 2006-2008 school year. The problems were designed to be authentic glimpses of modern science and engineering issues that come up in designing satellites to work in space, and to provide insight into the basic phenomena of the Sun-Earth system.

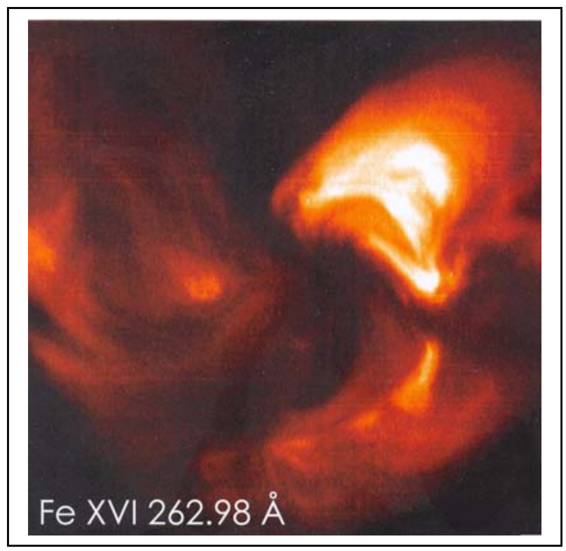
The problems are designed to be 'one-pagers' consisting of a Student Page, and Teacher's Answer Key. This compact form was deemed very popular by participating teachers.

This booklet was created by the Naval Research Laboratory, Hinode EIS-Education and Public Outreach Project.

Dr. Sten Odenwald ***(Catholic University: Space Math @ NASA)***

Dr. George Doschek (NRL, *Hinode*/EIS Co-I)





These images, provided by the EIS Imaging Spectrometer, show the locations of solar plasma near an active region, with temperatures near 950,000 K (left) and 1,600,000 K (right).

Images such as these can be assembled into detailed movies that help solar physicists study the heating and movement of plasmas within intense solar magnetic fields.

For more weekly classroom activities about the Sun-Earth system visit the NASA website,

http://spacemath.gsfc.nasa.gov

Add your email address to our mailing list by contacting Dr. Sten Odenwald at

sten.f.odenwald@nasa.gov

Table of Contents

How to Use This Resource

Teachers continue to look for ways to make math meaningful by providing students with problems and examples demonstrating its applications in everyday life. Space Math offers math applications through one of the strongest motivators-Space. Technology makes it possible for students to *experience* the value of math, instead of just reading about it. Technology is essential to mathematics and science for such purposes as *"access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information."* 3A/M2 authentic assessment tools and examples. The NCTM standards include the statement that "Similarity also can be related to such real-world contexts as photographs, models, projections of pictures" which can be an excellent application for all of the Space Math applications.

Hinode Math is one in a series of booklets developed by Space Math @ NASA, designed to be used as a supplement for teaching mathematical topics. The problems can be used to enhance understanding of the mathematical concept, or as a good assessment of student mastery.

An integrated classroom technique provides a challenge in math, science and, as in this scenario, technology classroom, through a more intricate method for using **Hinode Math**. Read the scenario that follows:

Ms. Black teaches a class about the use of technology. She integrates math and science in her class; she was excited when she saw the possibilities in the Hinode Math book. She wanted her students to learn about the technology that is used on a single spacecraft to research space, in this case the Sun. She challenged each student team with math problems from the Hinode Math book. The students were to use the facts available in the Hinode Math book to develop an observing the Sun bulletin board display. What we can learn through the use of Technology!
NASA's YouTube gives some additional information that students can use, http://www.youtube.com/watch?v=DSfAI6_7bjU

Hinode Math can be used as a classroom challenge activity, assessment tool, enrichment activity or in a more dynamic method as is explained in the above scenario. It is completely up to the teacher, their preference and allotted time. What it does provide, regardless of how it is used in the classroom, is the need to be proficient in math. It is needed especially in our world of advancing technology and physical science.

Topics and Alignment with Mathematics Standards

Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Area	x					x									
Volumes									x						
Decimals	x	x	x	x	x	x	x	x		x	x	x	x	x	x
Scale drawings		x	x	x	x	x	x	x		x	x				x
Geometry				x	x	x		x		x	x				
Scientific Notation						x			x				x	x	x
Unit Conversions	x			x	x				x	x	x	x			
Distance; speed x time				x	x	x		x				x			
Solving for X												x			
Graph Analysis													x	x	x

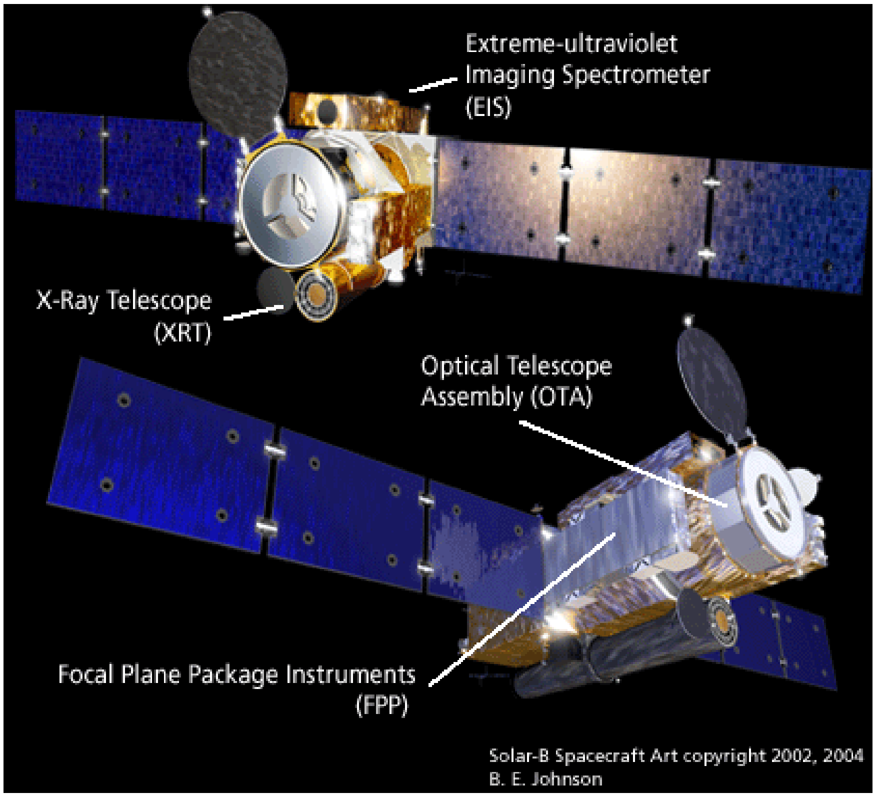
Applicable Standards (AAAS Project:2061 Benchmarks).

(3-5) - Quantities and shapes can be used to describe objects and events in the world around us. 2C/E1 --- Mathematics is the study of quantity and shape and is useful for describing events and solving practical problems. 2A/E1 **[Relevant problems: 2, 3, 7]**

(6-8) Mathematicians often represent things with abstract ideas, such as numbers or perfectly straight lines, and then work with those ideas alone. The "things" from which they abstract can be ideas themselves; for example, a proposition about "all equal-sided triangles" or "all odd numbers". 2C/M1 **[Relevant problems: 1, 4, 5, 6, 8, 10, 11]**

(9-12) - Mathematical modeling aids in technological design by simulating how a proposed system might behave. 2B/H1 ---- Mathematics provides a precise language to describe objects and events and the relationships among them. In addition, mathematics provides tools for solving problems, analyzing data, and making logical arguments. 2B/H3 ----- Much of the work of mathematicians involves a modeling cycle, consisting of three steps: (1) using abstractions to represent things or ideas, (2) manipulating the abstractions according to some logical rules, and (3) checking how well the results match the original things or ideas. The actual thinking need not follow this order. 2C/H2 **[Relevant problems: 9, 12, 13, 14, 15]**

Hinode Satellite Power



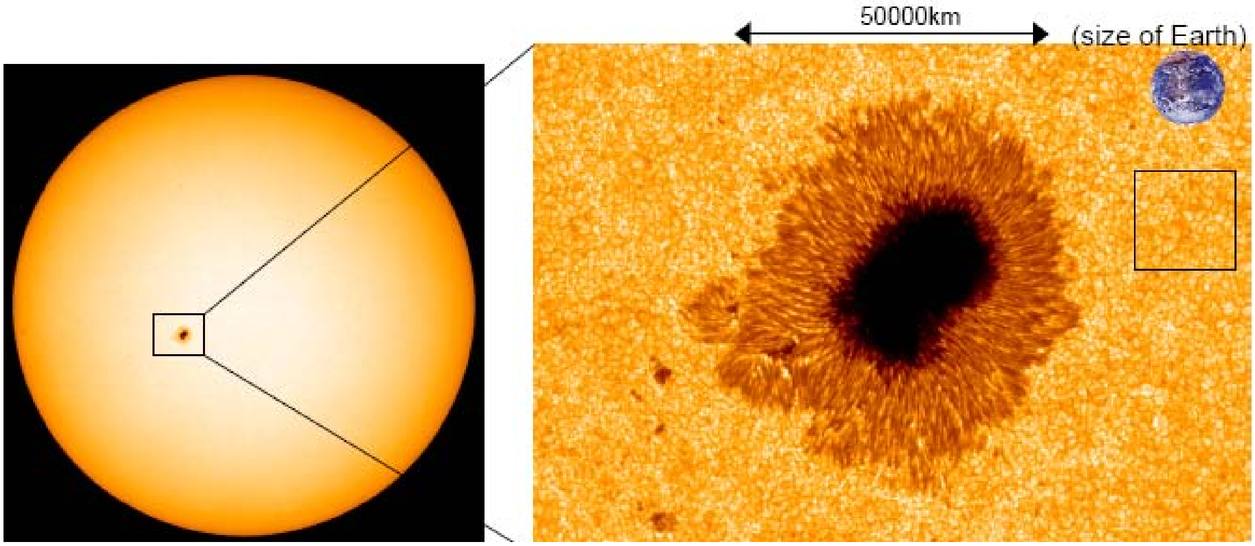
The Hinode satellite weighs approximately 700 kg (dry) and carries 170 kg of gas for its steering thrusters, which help to maintain the satellite in a polar, sun-synchronous orbit for up to two years. The satellite has two solar panels (blue) that produce all of the spacecraft's power. The panels are 4 meters long and 1 meter wide, and are covered on both sides by solar cells.

Problem 1 - What is the total area of the solar panels covered by solar cells in square centimeters?

Problem 2 - If a solar cell produces 0.03 watts of power for each square centimeter of area, what is the total power produced by the solar panels when facing the sun? Can the satellite supply enough power to operate the experiments which require 1,150 watts?

Problem 3 - Suppose engineers decided to cover the surface of the cylindrical satellite body with solar cells instead. If the satellite is 4 meters long and a diameter of 1 meter, how much power could it produce if only half of the area was in sunlight at a time? Can the satellite supply enough power to keep the experiments running, which require 1,150 watts?

Hinode - Close-up of a Sunspot



After a successful launch on September 22, 2006 the Hinode solar observatory caught a glimpse of a large sunspot on November 4, 2006. An instrument called the Solar Optical Telescope (SOT) captured this image, showing sunspot details on the solar surface.

Problem 1 - Based on the distance between the arrow points, what is the scale of the image on the right in units of kilometers per millimeter?

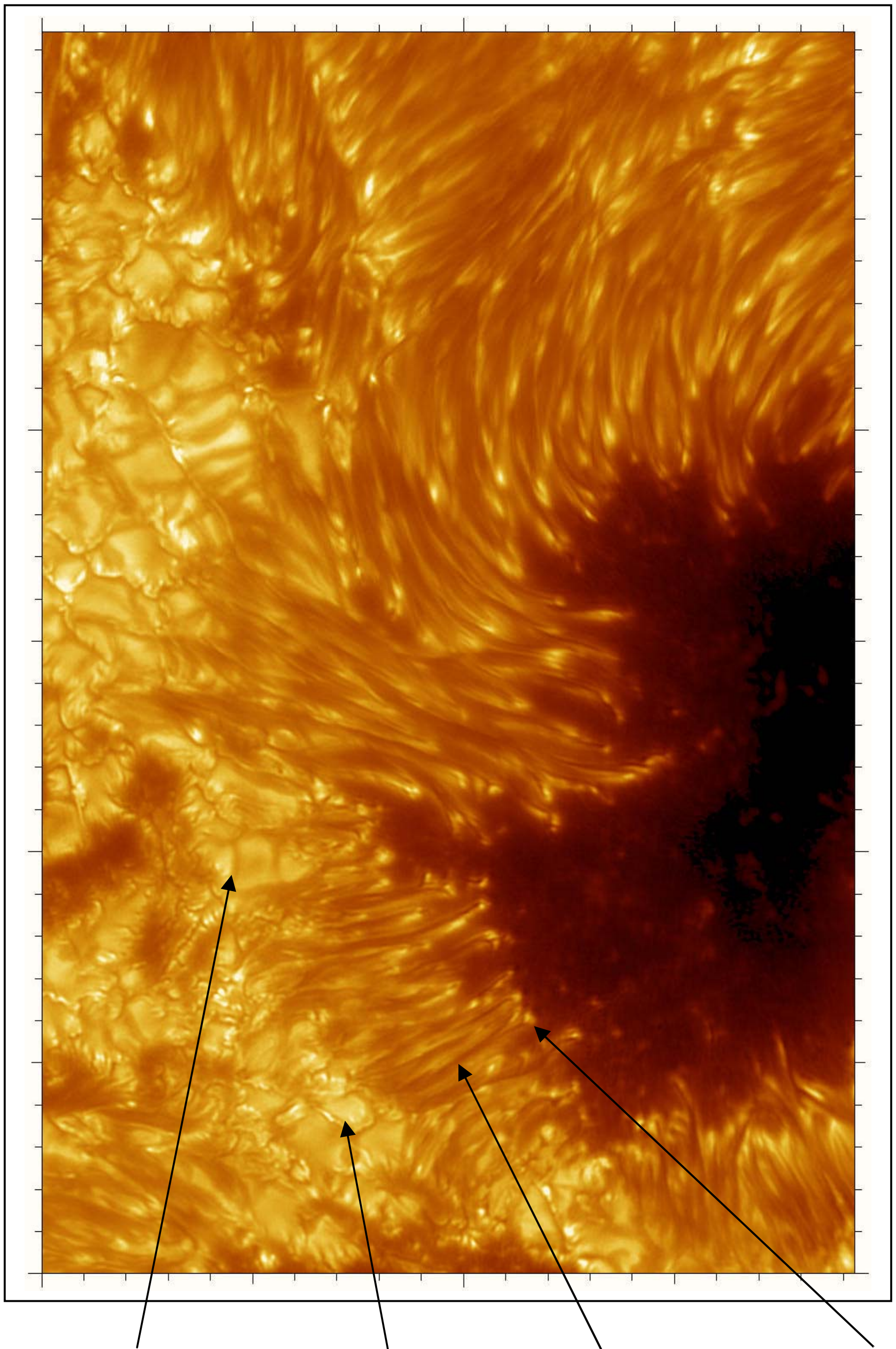
Problem 2 - What is the size of the smallest detail you can see in the image?

Problem 3 - Compared to familiar things on the surface of Earth, how big would the smallest feature in the solar image be?

Problem 4 - The gold-colored textured surface is the photosphere of the sun. The texturing is produced by heated gas that is flowing up to the surface from the hot interior of the sun. The convecting gases form cells, called granulations, at the surface, with upwelling gas flowing from the center of each cell, outwards to the cell boundary, where it cools and flows back down to deeper layers. What is the average size of a granulation cell within the square?

Problem 5 - Measure several granulation cells at different distances from the sunspot, and plot the average size you get versus distance from the spot center. Do granulation cells have about the same size near the sunspot, or do they tend to become larger or smaller as you approach the sunspot?

The sun is our nearest star. From Earth we can see its surface in great detail. The images below were taken with the 1-meter Swedish Vacuum Telescope on the island of La Palma, by astronomers at the Royal Swedish Academy of Sciences (http://www.astro.su.se/groups/solar/solar.html). The image to the right is a view of sunspots on July 15, 2002. The enlarged view to the left shows never-before seen details near the edge of the largest spot. Use a millimeter ruler, and the fact that the dimensions of the left image are 19,300 km x 29,500 km, to determine the scale of the photograph, and then answer the questions. See the arrows below to identify the various solar features mentioned in the questions.

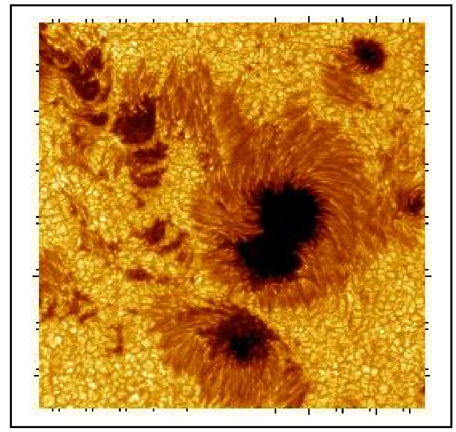


Granulation Boundary

Solar Granulation

Dark Filament

Bright Spot



Question 1 - What is the scale of the image in km/mm?

Question 2 – What is the smallest feature you can see in the image?

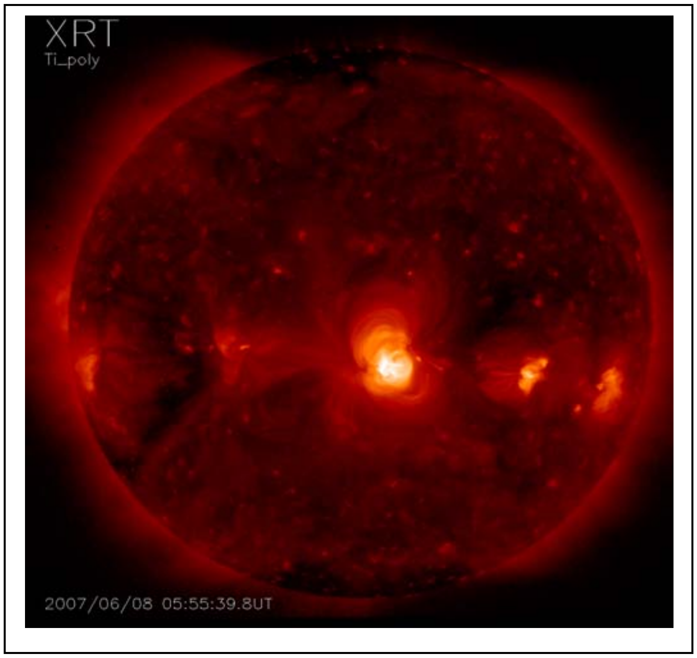
Question 3 – What is the average size of a Solar Granulation region?

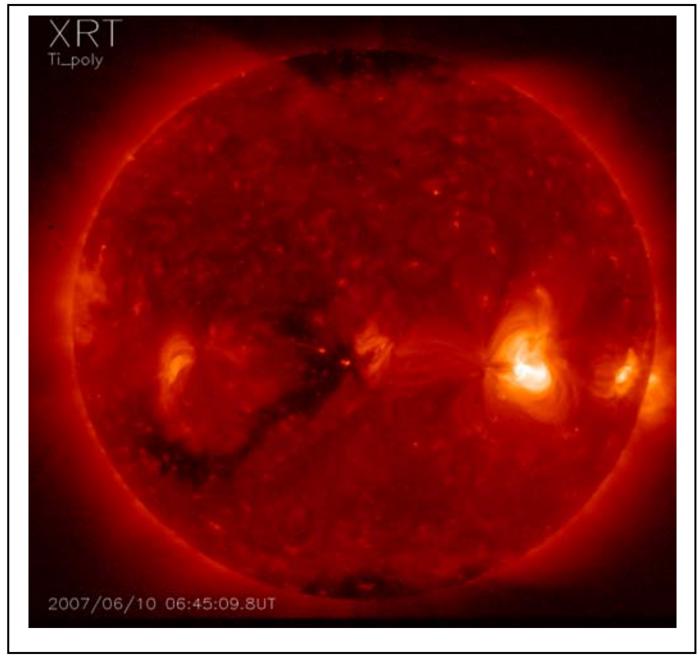
Question 4 – How long and wide are the Dark Filaments?

Question 5 – How large are the Bright Spots?

Question 6 – Draw a circle centered on this picture that is the size of Earth (radius = 6,378 km). How big are the features you measured compared to familiar Earth features?

How fast does the sun spin? 4





The sun, like many other celestial bodies, spins around on an axis that passes through its center. The rotation of the sun, together with the turbulent motion of the sun's outer surface, work together to create magnetic forces. These forces give rise to sunspots, prominences, solar flares and ejections of matter from the solar surface.

Astronomers can study the rotation of stars in the sky by using an instrument called a spectroscope. What they have discovered is that the speed of a star's rotation depends on its age and its mass. Young stars rotate faster than old stars, and massive stars tend to rotate faster than low-mass stars. Large stars like supergiants, rotate hardly at all because they are so enormous they reach almost to the orbit of Jupiter. On the other hand, very compact neutron stars rotate 30 times each second and are only 40 kilometers across.

The X-ray telescope on the Hinode satellite creates movies of the rotating sun, and makes it easy to see this motion. A sequence of these images is shown on the left taken on June 8, 2007 (Left); June 10 2007 (Right) at around 06:00 UT.

Although the sun is a sphere, it appears as a flat disk in these pictures when in fact the center of the sun is bulging out of the page at you! We are going to neglect this distortion and estimate how many days it takes the sun to spin once around on its axis.

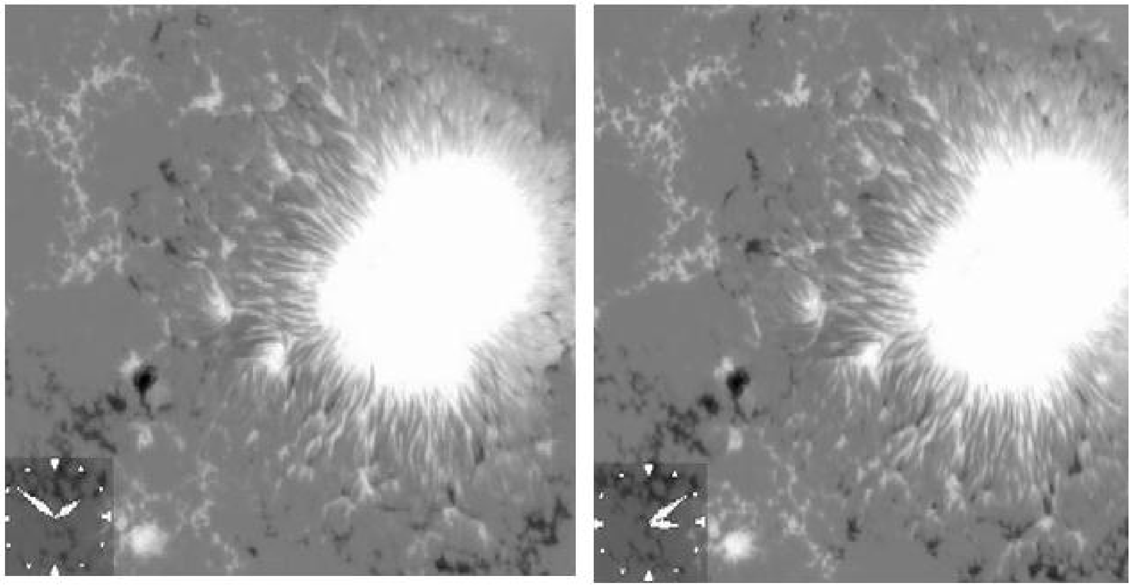
The radius of the sun is 696,000 kilometers.

Problem 1 - Using the information provided in the images, calculate the speed of the sun's rotation in kilometers/sec and in miles/hour.

Problem 2 – About how many days does it take to rotate once at the equator?

Inquiry Question: What geometric factor produces the largest uncertainty in your estimate, and can you come up with a method to minimize it to get a more accurate rotation period?

Moving Magnetic Filaments Near Sunspots



These two images were taken by the Hinode solar observatory on October 30, 2006. The size of each image is 34,300 km on a side. The clock face shows the time when each image was taken, and represents the face of an ordinary 12-hour clock.

Problem 1 - What is the scale of each image in kilometers per millimeter?

Problem 2 - What is the elapsed time between each image in; A) hours and minutes? B) decimal hours? C) seconds?

Carefully study each image and look for at least 5 features that have changed their location between the two images. (Hint, use the nearest edge of the image as a reference).

Problem 3 - What direction are they moving relative to the sunspot?

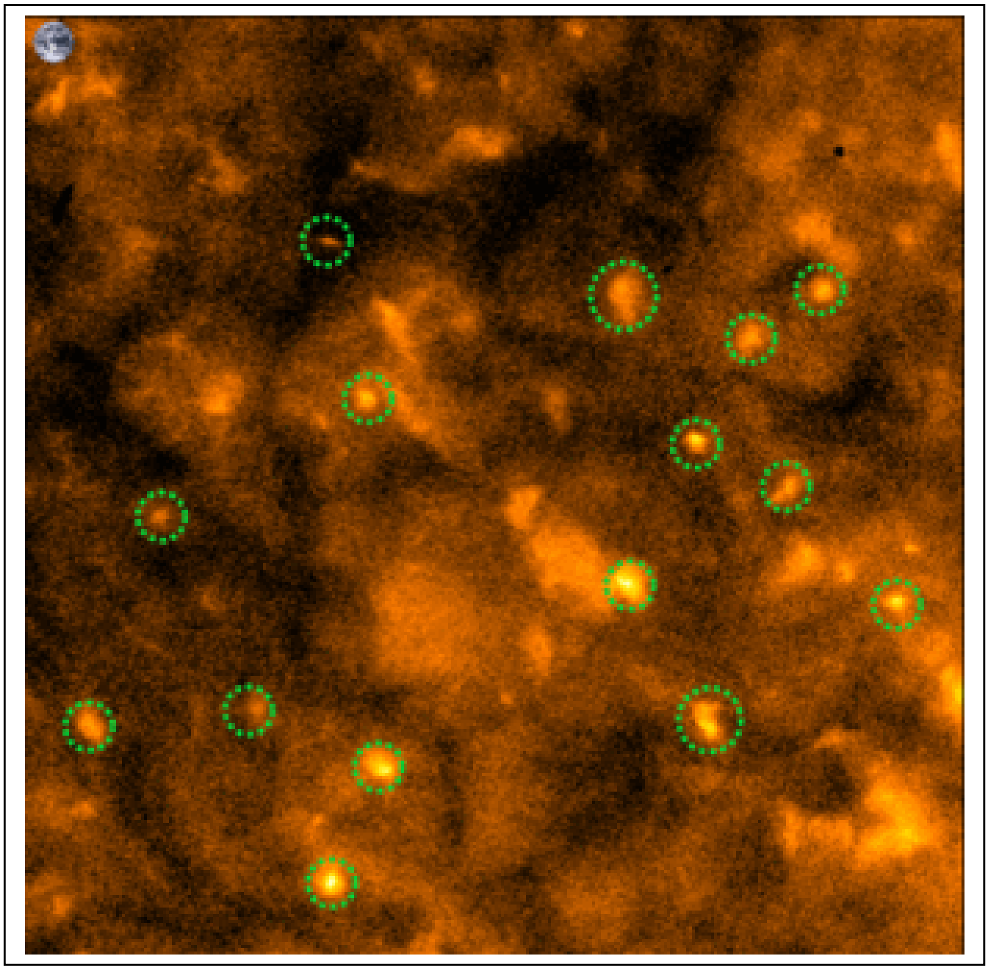
Problem 4 - How far, in millimeters have they traveled on the image?

Problem 5 - From your answers to questions 1, 2 and 4, calculate their speed in kilometers per second, and kilometers per hour.

Problem 6 - A fast passenger jet plane travels at 600 miles per hour. The Space Shuttle travels 28,000 miles per hour. If 1.0 kilometer = 0.64 miles, how fast do these two craft travel in kilometers per second?

Problem 7 - Can the Space Shuttle out-race any of the features you identified in the sunspot image?

Hinode Sees Mysterious Solar Micro-flares



The Sun's surface is not only speckled with sunspots, it is also dotted with intense spots of X-ray light called 'X-ray Bright Points'. Although sunspots can be over 100,000 kilometers across and easily seen with a telescope, X-ray Bright Points are so small even the largest solar telescope only sees a few of them with enough detail to reveal their true shapes. X-ray Bright Points release their energy by converting tangled magnetic fields into a smoother ones. This liberates large quantities of stored magnetic energy. For that reason, these Bright Points can be thought of as micro-flares.

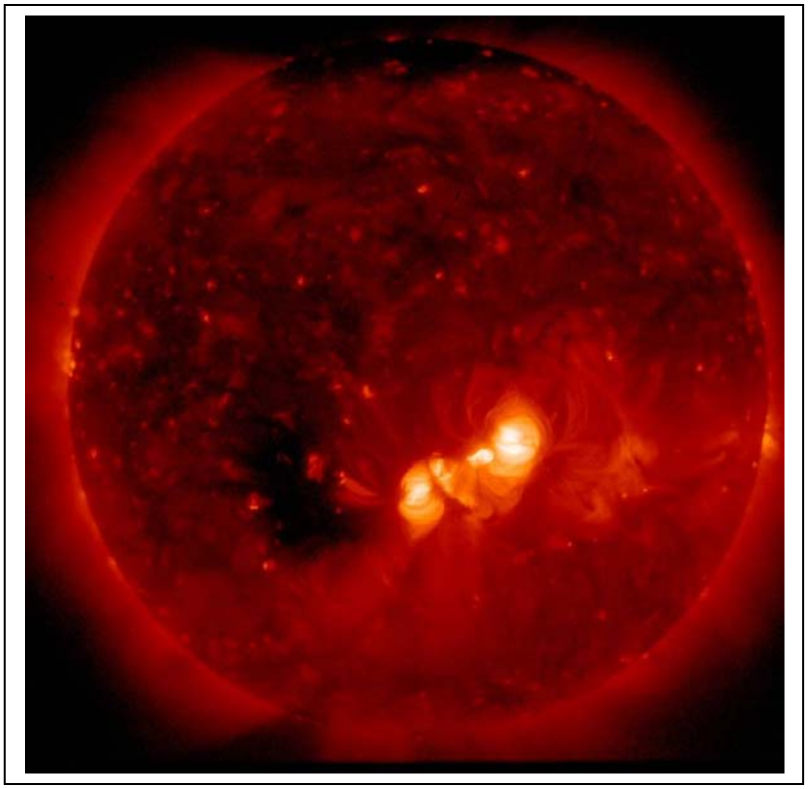
Hinode's X-ray Telescope (XRT) can now see the details in some of the Bright Points and allow scientists to see small magnetic loops. In the image above, individual bright points are circled in green. A few of them can be resolved into tiny magnetic loops. These data were taken on March 16, 2007. The image is 300 x 300 pixels in size. Each pixel views an area on the sun that is 1 arcsecond x 1 arcsecond on a side.

Problem 1: If the diameter of the Sun is 1800 arcseconds, and has a radius of 696,000 km, what is the scale of the above image in A) kilometers per arcsecond? B) kilometers/millimeter?

Problem 2: What are the dimensions, in kilometers, of the smallest circled Bright Point in the image?

Problem 3: How many Bright Points cover the solar surface if the above picture is typical?

The Hinode satellite views the sun

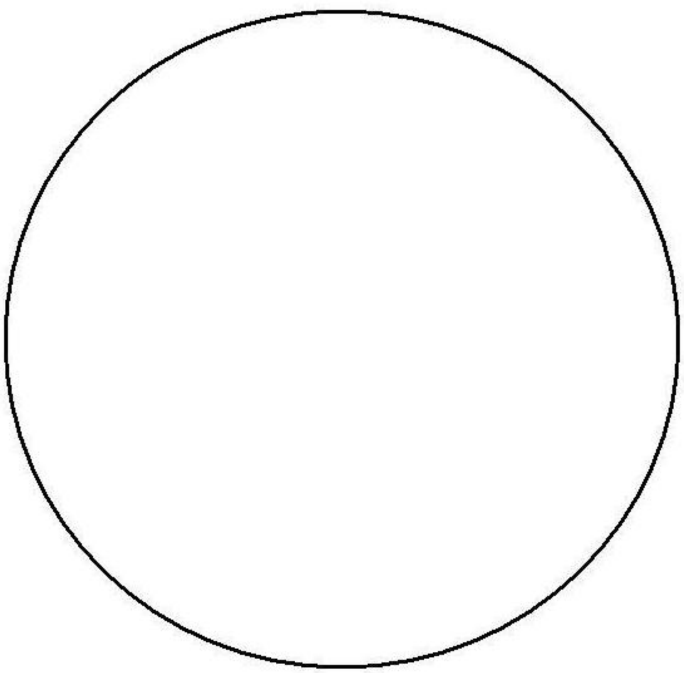


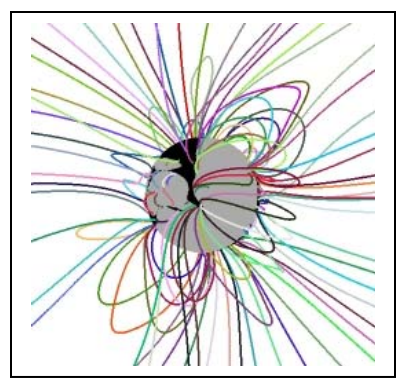
This image was taken by the X-Ray Telescope (XRT) on the Hinode solar observatory in December, 2006. It shows the complex magnetic structure over a large sunspot called Active Region AR930. You can also see large numbers of bright 'freckles' - each representing a small micro-flare.

The large black 'holes' are places in the corona of the sun where high-temperature gas is free to escape from the sun, and so there is little gas to illuminate these regions of the solar corona. This is because in these 'coronal holes' magnetic field lines open out to interplanetary space. Closed field lines near the surface act like magnetic bottles and keep the heated plasma close to the sun, creating the bright areas (red and yellow colors).

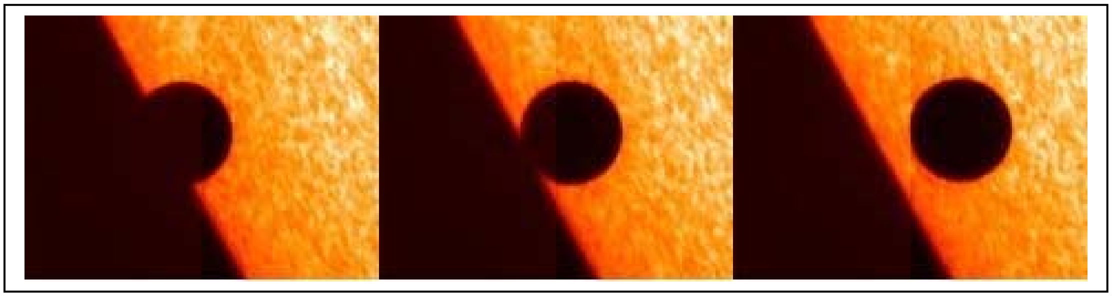
Using a black pen or pencil, try your hand at predicting what the magnetic field lines look like using the clues from Hinode picture!

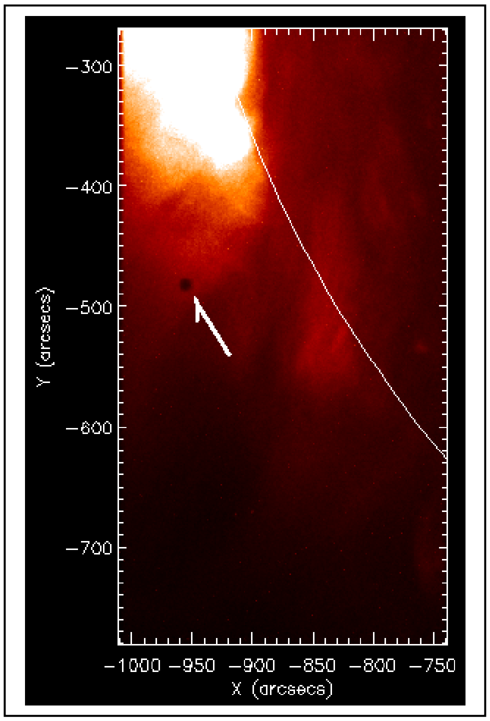
Below is an example of a field line model calculated from an image by the SOHO satellite.





The Transit of Mercury





Every few times a century, the planet Mercury and Earth are lined up in such a way that Mercury passes across the disk of the sun as seen from Earth. The last time this happened was on November 8, 2006, and the next time this will happen will be on May 9, 2016. Since they were first observed in the 1600's, astronomers have studied them intently to learn more about Mercury, and to determine how far the sun is located from Earth. In recent times, astronomers no longer view these transits with much interest since the information that provide can be found by other more direct means. Still, when transits occur, astronomers turn their telescopes, now located in space, to watch the spectacle.

Top) Transit of Mercury obtained with Solar Optical Telescope (SOT) on the Hinode satellite on November 8, 2006. Left) Image obtained with the EUV Imaging Spectrometer (EIS). Solid curve indicates solar limb. The arrow shows the location of Mercury seen against the solar corona.

Problem 1: If the diameter of Mercury as viewed from Earth during the transit was 10 arcseconds, and the diameter of the sun at that time was 1900 arcseconds, what would be the diameter of the circle in the Hinode EIS image in centimeters that would represent the solar disk at this scale?

Problem 2: At the time of the transit, Mercury was about 55 million kilometers from the sun and about 92 million kilometers from Earth. How large, in arcseconds, would Mercury have appeared if it were at the distance of the Sun at this time?

Problem 3: How old will you be when the next Transit of Mercury happens?

Inquiry Problem: Why are transits of Mercury so rare?

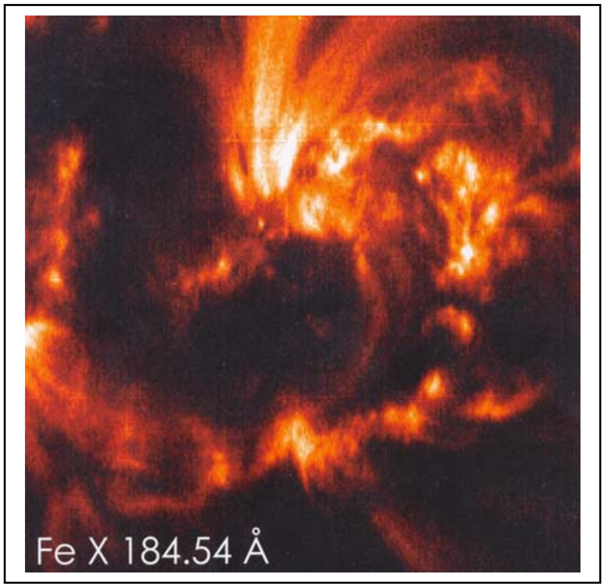
Hinode Studies Loopy Sunspots!

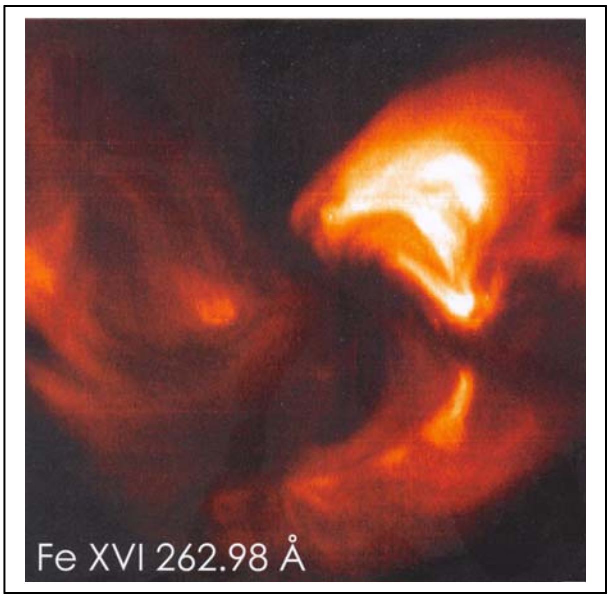
The solar surface is not only a hot, convecting ocean of gas, but is laced with magnetism. The sun's magnetic field can be concentrated into sunspots, and when solar gases interact with these magnetic fields, their light lets scientists study the complex 'loopy' patterns that the magnetic fields make as they expand into space. The above image was taken by NASA's TRACE satellite and shows one of these magnetic loops rising above the surface near two sunspots. The horseshoe shape of the magnetic field is anchored at its two 'feet' in the dark sunspot regions. The heated gases become trapped by the magnetic forces in sunspot loops, which act like magnetic bottles. The gases are free to flow along the lines of magnetic force, but not across them. The above image only tells scientists where the gases are, and the shape of the magnetic field, which isn't enough information for scientists to fully understand the physical conditions within these magnetic loops. Satellites such as Hinode carry instruments like the EUV Imaging Spectrometer, which lets scientists measure the temperatures of the gases and their densities as well.

Problem 1: The Hinode satellite studied a coronal loop on January 20, 2007 associated with Active Region AR 10938, which was shaped like a semi-circle with a radius of 20,000 kilometers, forming a cylindrical tube with a base radius of 1000 kilometers. What was the total volume of this magnetic loop in cubic centimeters assuming that it is shaped like a cylinder?

Problem 2: The Hinode EUV Imaging Spectrometer was able to determine that the density of the gas within this magnetic loop was about 2 billion hydrogen atoms per cubic centimeter. If a hydrogen atom has a mass of 1.6×10^{-24} grams, what was the total mass of the gas trapped within this cylindrical loop in metric tons?

Hot Gas and Cold Gas





The Hinode Extreme Ultraviolet Imaging Spectrometer (EIS) sorts the light from the Sun into a spectrum. It works in a part of the spectrum far beyond the visible light we see, and which can only be studied from space. The atmosphere of Earth absorbs this light, so satellite telescopes have to be placed in orbit to study this light.

Very hot gas near the sun produces this light, and by carefully measuring it, scientists can deduce the exact temperature, density and speed of motion of the gas that produces it. When atoms are heated, they produce specific wavelengths of light, called spectral lines.

The two pictures were taken of the same active region (AR-10940) over a sunspot on February 2, 2007, and are exactly overlapping images. The size of each square image is about 200,000 km on a side.

The top picture is produced by ionized iron atoms (Fe X) in which 9 of the 26 iron electrons have been removed. The light is from a single line at a wavelength of 184.54 Angstroms. The bottom picture is from ionized iron atoms (Fe XVI) in the same region, which have lost 15 of their 26 electrons, and is from the light from a single line at 262.98 Angstroms.

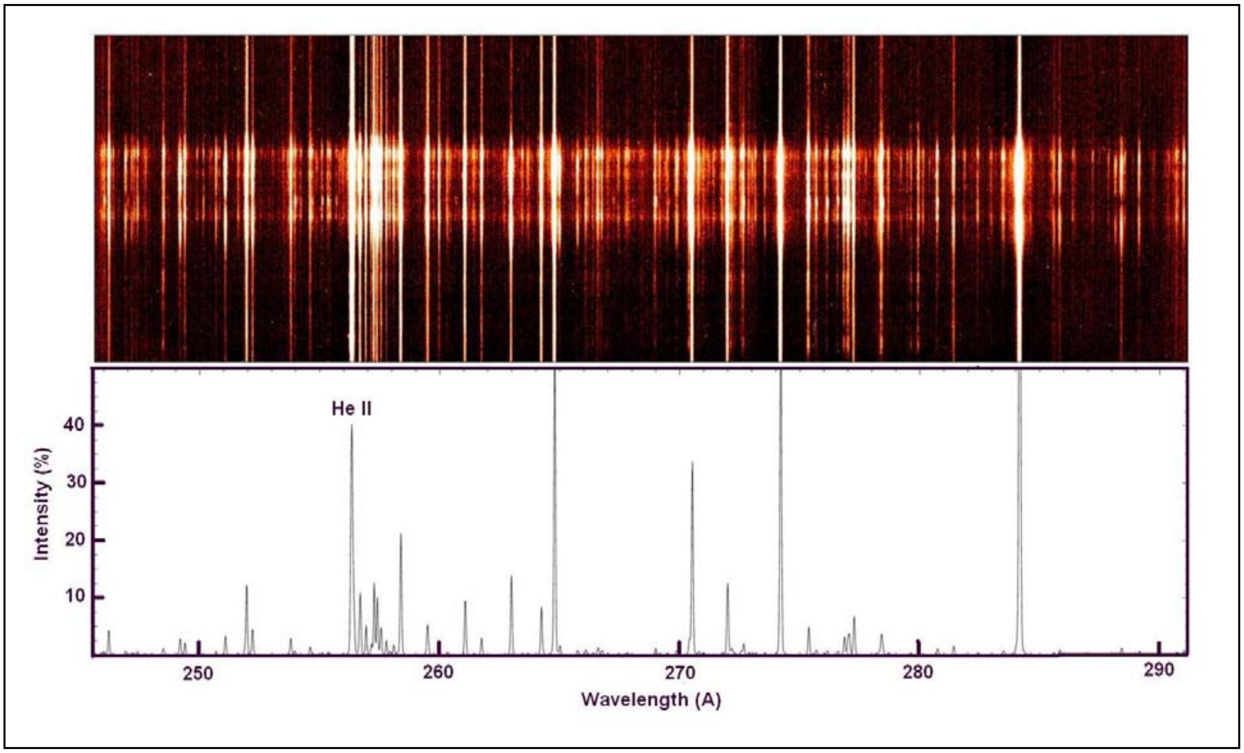
The Fe X emission is produced in plasma with a temperature of 950,000 K. The Fe XVI emission is produced in plasma with a temperature of 2,600,000 K.

Problem 1 - From the information, what is the scale of the images in kilometers per millimeter?

Problem 2 - Of the two gas temperatures, at which gas temperature do you find the smallest clumps, and about how big are they?

Problem 3 - At which temperature do you think the gas is more easily confined by the magnetic fields near this sunspot?

Find the mystery lines...if you can!



This is an image from the Hinode satellite's Extreme Ultraviolet Spectrometer (EIS). The graph below the spectrum provides the wavelength scale and line locations for the Hinode image. Each line in the bottom graph has an intensity that is indicated by its length along the vertical axis of the figure. The most intense lines have a value of 30 % of larger. The helium II (He II) line is about 40% on this intensity scale. The table to the right gives the wavelengths of some spectral lines that fall within the wavelength range of the figure. Let's use this information to identify a 'mystery line' in the above spectrum.

The scale of the horizontal axis is 0.31 Angstroms/millimeter For example, the difference in wavelength between He II and the next strong line to the right of He II is 27 mm or 27 x 0.31 = 8.4 Angstroms. Since the wavelength of He II is 256.32 Angstroms and the scale increases in wavelength to the right, the wavelength of the mystery line is 256.32 + 8.4 = 264.7 A. the table to the right suggests that this is the ion iron-14 (Fe XIV).

Problem 1 - From the wavelengths of the tabulated lines, calculate from the graph scale where these lines should be in the Hinode spectrum. Match up the tabulated lines with the lines shown in the above figure. Which lines can you match up?

Problem 2 - A careful count will show that there are about 127 lines in the above spectrum. What percentage of lines in the Hinode solar data are not identified in the table?

Table 1: List of ionic lines

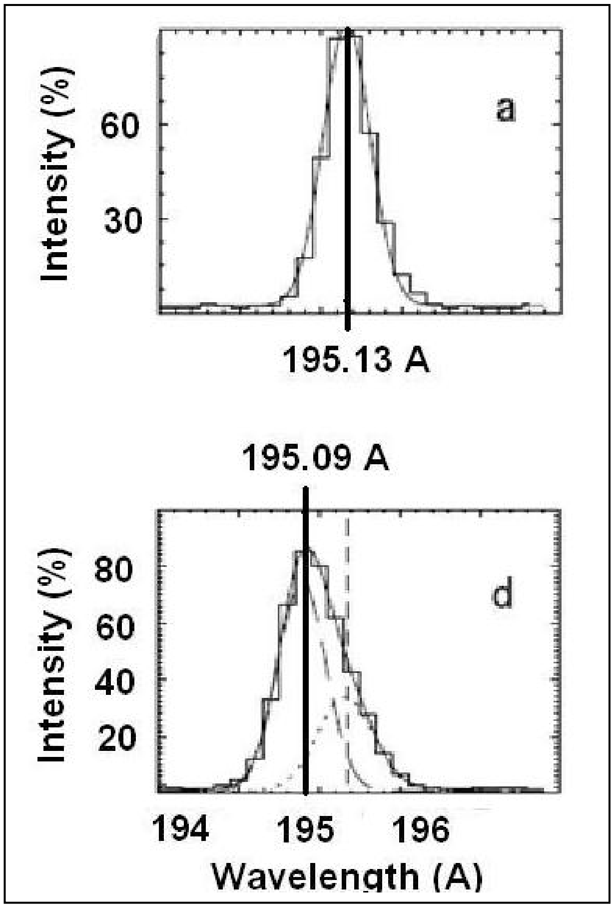
Ion	Wavelength
He II	256.32 A
Fe XVI	262.98
S X	264.23
Fe XIV	264.79
Si VII	275.35
Fe XV	284.16

Note: Wavelengths are given in the traditional Angstrom (A) units used by spectroscopists in which 10 Angstroms = 1 nanometer

Ionic Notation: The naming convention for atoms that have lost some of their electrons (to be come ions) is as follows for the case of iron (Fe) which has 26 electrons:

Fe I - neutral atom
Fe II - 1 electron lost
Fe III - 2 electrons lost
Fe IV - 3 electrons lost
…
Fe XIV - 13 electrons lost
Fe XV - 14 electrons lost
…
Fe XXVII - All 26 electrons lost

Using the Doppler Shift to Study Gas



When a fire truck races towards you, the siren sounds at a higher pitch than when it races away. This is called the Doppler Shift, and it can also be used to measure the speed of a gas cloud near the sun.

The Hinode Extreme Ultraviolet Imaging Spectrometer (EIS) sorts the light from the sun into a spectrum. When atoms are heated, they produce specific wavelengths of light, called spectral lines. The wavelengths of some of these lines, such as the one produced by iron atoms, are known precisely. By measuring the wavelengths shift of one of these iron lines, solar physicists can use the Doppler Shift to measure how fast the gas was moving on the sun. Here's how they do it!

The figure to the left shows the intensity of the light produced by a particular iron atom in the sun's spectrum. The top panel shows the light produced by a cloud that was at rest near the solar surface at a wavelength of 195.13 Angstroms. The bottom panel shows the light from a similar plasma cloud that was in motion during a solar flare on December 13, 2006. Notice that the wavelength of the light in the moving cloud is 195.09 Angstroms.

The plots were published by Dr. Shinsuke Imada and his co-investigators in the *Publications of the Astronomical Society of Japan* (v. 59, pp. 759).

Problem 1 - What is the wavelength for the FeXII emission line for: A) the gas at rest: λ(rest)? B) What is the wavelength for the gas in motion: λ(moving)?

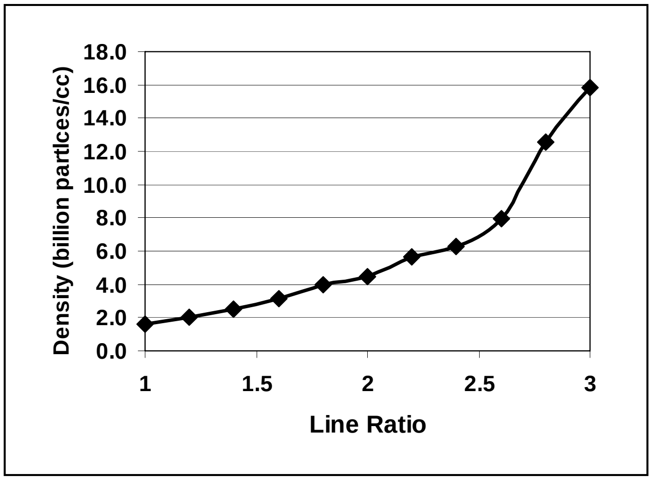
Problem 2 - The Doppler Formula relates the amount of wavelength shift to the speed of the gas according to

$$V = 300{,}000 \text{ km/sec} \times \frac{\lambda(\text{rest}) - \lambda(\text{moving})}{\lambda(\text{rest})}$$

From the information in the two panels, what was the speed of the plasma during the solar flare event?

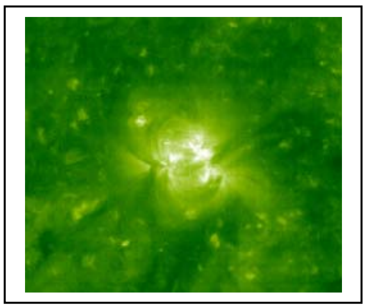
Problem 3 - From the location of the peak of the moving gas, is the gas moving towards the observer (shifted to shorter wavelengths), or away from the observer (shifted to longer wavelengths)?

Problem 4 - From your answer to Problem 3, during a flare, is the heated plasma flowing upwards from the solar surface, or downwards to the solar surface? Explain your answer by using a diagram.

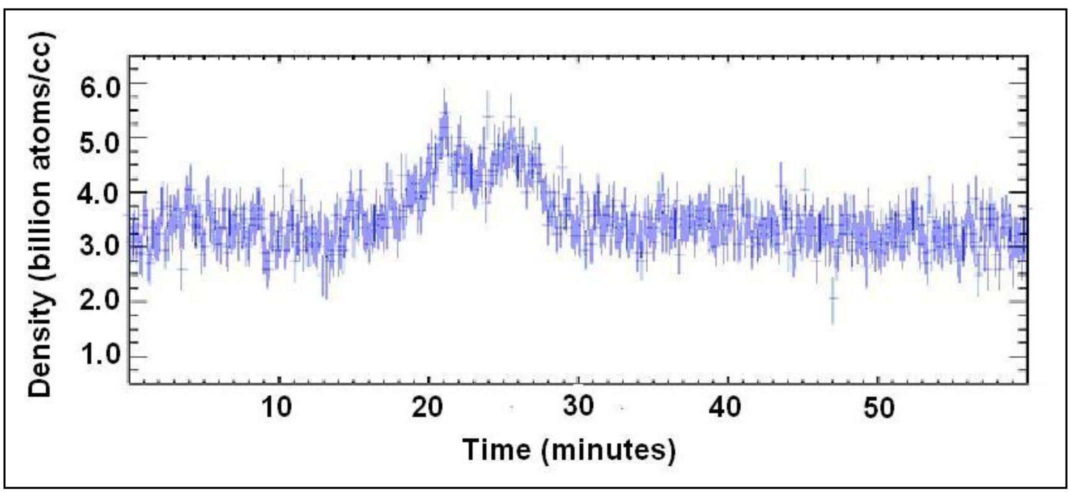


The Hinode EIS instrument can detect the individual 'fingerprint' lines from dozens of elements. Each line has its own unique wavelength. The intensity of an atomic line can be used to learn about the properties of the gas near the solar surface.

Two particular atomic lines produced by the element iron appear at wavelengths of 203.8 and 202.0 Angstroms. The ratio of the intensities of these two lines can be converted into a measurement of the density of the gas producing them, as shown in the figure to the left.



For example, if the intensity of the Fe XII line at 203.8 Angstroms were measured to be 300 units, and the line at 202.0 Angstroms were measured to be 150 units, the ratio yields 300/150 = 2.0. From the figure, a value of '2.0' on the horizontal axis, corresponds to a density of about 4.0 billion atoms per cubic centimeter on the horizontal axis.

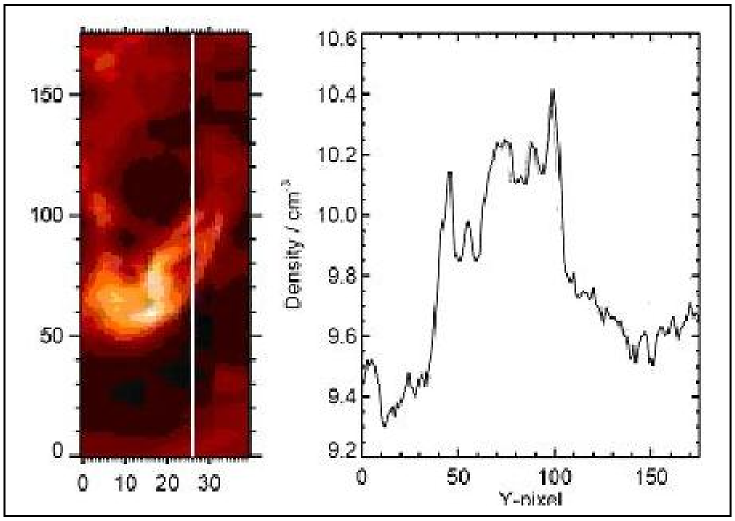


Problem 1 - The figures (above) were adapted from an article by Dr. Peter Young at the Rutherford Appleton Laboratory in England. The photograph shows an active region on the sun spotted by Hinode. The graph is the density measured by the EIS instrument near the center of the active region during 60 minutes. A) To the nearest integer, what is the average density of the region during the last 20 minutes of the study? B) About what is the average line ratio that corresponds to the average density?

Problem 2 – A) To the nearest integer, what is the maximum density that was recorded during the 60-minute time period? B) About how many minutes was this plasma density maintained above 4 billion atoms/cc during the flare event?

Density Structure of an Active Region

The Hinode EIS instrument has been used to study many active regions in order to determine how the density of the plasma varies through each region. One of these studies was reported by solar physicist Dr. Peter Young from the Rutherford Appleton Laboratory in England in August 2007. Below-left is an image of a coronal loop with the X and Y axes indicating the pixel number in each direction. The white line is a slice through the data at an X-pixel value of 26, and reveals the density variation in the vertical Y direction shown in the graph on the right. The density is rendered on the vertical axis in terms of the base-10 logarithm of the density value so that '10' means 10^{10} particles/cm^3



The gas densities are found by observing the same region of the sun at two different wavelengths emitted by the iron atom at a temperature near 1.5 million degrees K. *The ratio of the light intensity emitted at these two wavelengths is directly related to the density of the gas producing the light.* This shows how spectroscopy can provide vastly more information about the sun and solar activity, than what you would get from a single image alone.

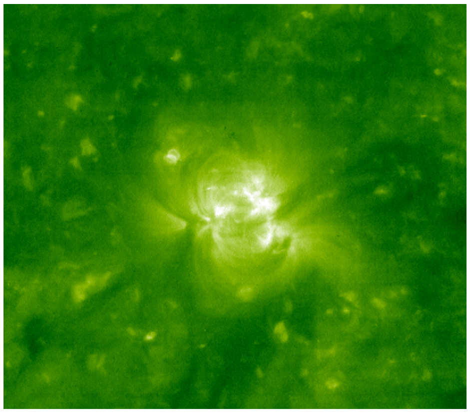
Problem 1 - About what is the average density of the gas in the dark regions covered by the pixels in the range from Y=10 to Y=30? Convert answers to normal decimal units of density in scientific notation.

Problem 2 - About what is the average density of the gas in the dark regions covered by the pixels in the range from Y=140 to Y=170? Convert answers to normal decimal units of density in scientific notation.

Problem 3 - The dark regions not involved with bright coronal loop are glimpses of the surface of the sun. If higher gas densities tend to be found closer to the solar surface, in which part of the image not including the bright coronal loop may we be looking at a deeper layer of the solar atmosphere?

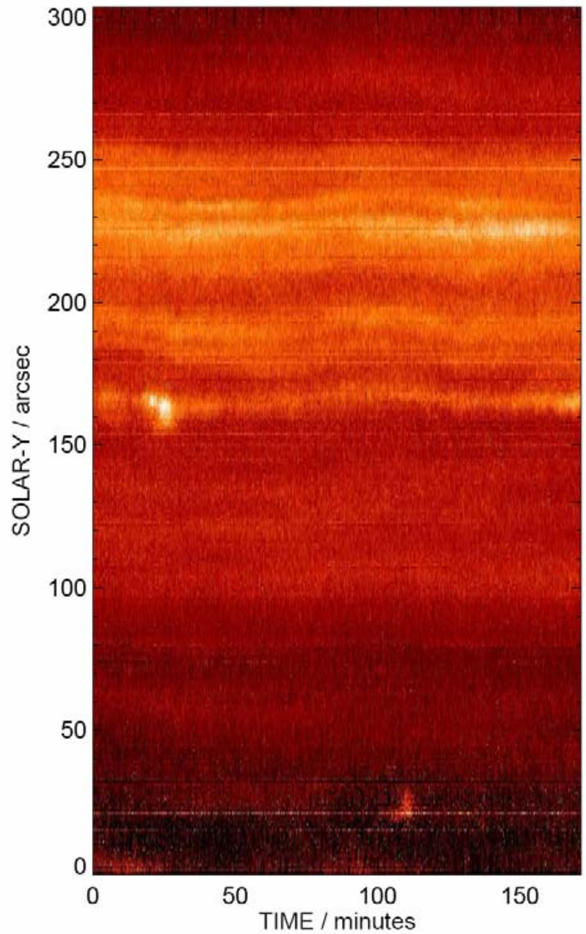
Problem 4 - About what is the density of the three ribbon-like features at Y= 70, Y=90 and Y=100? Convert answers to normal decimal units of density in scientific notation.

Plasma Speeds in Active Regions



The Hinode EIS instrument can study a single slice of an active region and detect subtle changes in position over time. The image above shows an active region near a sunspot, and reveals its 'bar magnet' magnetic field loops.

The strip plot to the right shows the motion of the plasma sliced vertically along the center line of the active region, over a span of about 200 minutes. The vertical axis gives the location of the plasma in units of arcseconds, where one arcsecond equals a physical distance of 725 kilometers on the solar surface.



Individual features in the upper image appear as bands on the strip plot. The slope of the band is a measure of the speed of motion of the gas.

Problem 1 - The scale of the vertical axis is in angular units of arcseconds. At the distance of the sun, one arcsecond corresponds to 725 kilometers. Select the bright feature near Y=160 arcseconds. What is the change in the Y-position during the period from A) 0-50 minutes? B) 50 - 100 minutes? C) 100-150 minutes? (Hint: Use a millimeter to calculate the scale of the vertical axis in kilometers/mm)

Problem 2 - From your answer to Problem 1, what is the average speed of this feature during each 50-minute period from A to C in kilometers per second?

Problem 3 - About how soon after the start of the data did the flare occur in this feature, and how long did it last? [The flare is the sudden brightening in the data that occurs near Y=160]

A note from the Author:

Hi again!

This booklet will introduce you to the Hinode satellite, and a few of its many discoveries. Many of the problems involve the basic skill of measuring the size of an image, and converting the measurement into an actual physical unit (kilometers, seconds, etc). Most students can successfully perform this activity by grade-5 when they have become familiar with decimal-math and division.

Calculating the scale of an image is a critical operation in just about any scientific investigation. You know all those pretty pictures that NASA loves to show you of planets, stars and galaxies? Well before an astronomer can make any sense of them, he has to be able to figure out how many millimeters on the image/photograph corresponds to a meter, kilometer or even a light-year in actual physical units. Otherwise, you have no clue how big the object is that you are investigating! Also, it is a fun exercise to see what the smallest detail in an image is in physical units.

The Hinode satellite creates many images of the sun at various sizes to study phenomena as big as the sun, or as small as a micro-flare. The X-ray and optical imager are good for establishing a size to things, and the movies give us a sense for how quickly or slowly things occur. But the satellite can do much more than this!

The Extreme Ultraviolet Imaging Spectrometer dissects the ultraviolet light from the sun, and is able to use the 'fingerprints' of various atoms producing light, to work out the density, temperature and speed of the various phenomena being studied. You cannot get this information by just looking at a picture of the sun. Solar scientists need this kind of information in order to mathematically model how a phenomenon changes in time, how the gases flow, and how magnetic energy heats the various gases found near sunspots and other active regions on the sun.

Ironically, spectroscopy is the unsung hero of solar and astrophysics. Students that view dazzling pictures of nebula, galaxies, planets and solar storms instinctively enjoy these images because they represent an image, like a photograph of a house, mountain or lake. It is very easy to explain what the image represents because we have many familiar examples of the same kind of data in our family photo albums!

Spectroscopy is different. It is a technology that sorts the electromagnetic spectrum by wavelength. Each atom produces its own 'fingerprint' lines of light that resemble a bar code. Scientists can read this bar code, and even take a picture of the sun by the light from one particular 'bar'. The relative intensities of the different spectral bars or 'lines', can be used to calculate the density and temperature of the gas that is producing it. Some of the problems in this book will give students a taste of how this kind of information is used to more clearly understand how solar flares and other phenomena on the sun are 'put together'.

Enjoy!!

Sincerely,
Dr. Sten Odenwald
NASA Astronomer

Internet Resources

The Hinode Mission education page - A variety of resources that explain solar flares, space weather, and many of the basic solar science terms encountered in this math guide.

http://solarb.msfc.nasa.gov/for_educators/index.html

Space Math @ NASA – A collection of over 200 individual math problems covering nearly all aspects of solar science, astronomy, astrophysics and engineering.

http://spacemath.gsfc.nasa.gov

The human and technological impacts of solar storms and space weather - A guide to the many issues that occur in studying how the sun affects the many human and technological systems we rely upon, and how they can be disturbed or damaged by solar storms.

http://www.solarstorms.org

NOAA space weather forecasting center – This website gives up to the minute forecasts of solar storms and flares, and is used by thousands of agencies and institutions across the country and world.

http://www.noaa.sec.gov/SWN

NASA Student Observation Network:Tracking a Solar Storm – This is a hands-on educational resource and tool that allows students to monitor space weather and make their own forecasts.

http://son.nasa.gov/tass/index.htm

Elementary Space Mathematics Primer – This is a short math guide that covers workin g with positive and negative numbers, scientific notation, graph analysis, and simple algebra, in the context of authentic astronomy mathematics problems.

http://image.gsfc.nasa.gov/poetry/MathDocs/spacemath.html

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