Aurora of Earth, Aurora of Jupiter: A Celestial Scavenger Hunt

Grade Range: Grades 6-8

Teaching Time: four to five, 45-minute periods

Module: Magnetospheres

Lesson: Aurora of Earth, Aurora of Jupiter: A Celestial Scavenger Hunt

Activities:

I. Observation and Description: Honing Critical Skills
II. Comparing and Contrasting Aurora and Magnetospheres
III. Scientific Illustration: Visually Representing Information

Lessons Recommended to Precede this Lesson

- The Northern Lights, Activities: 1, 2, and 7, published by NASA IMAGE Mission
- Patterns and Fingerprints, Project Spectra, LASP
- Modeling the Magnetospheres of Earth and Jupiter in 3 Dimensions
- Kinesthetic Magnetosphere

Advanced Planning

1. Ensure access to computers with the ability to play multimedia and images using presentation and video software such as PowerPoint, Keynote, QuickTime, or RealPlayer
2. Load the student PowerPoint to computers
3. Load video and/or audio files to the computers or ensure Internet access
4. Copy student pages: *Aurora of Earth, Aurora of Jupiter: A Celestial Scavenger Hunt*

Materials

Teacher M*aterials*

- *Computer with Internet access and the ability to* ***project*** images and multimedia
- Slideshow, *Art vs. Scientific Illustration*
- Access to presentation software such as PowerPoint or Keynote and QuickTime or RealPlayer

Student Materials

- Computer with the ability to access the Internet and play multimedia products requiring software such as PowerPoint, KeyNote, Quicktime, or RealPlayer
- (2) Images of similar objects (see pig images provided)
- Student slideshow: *Aurora on Earth, Aurora on Jupiter*
- Student Pages: *Aurora on Earth, Aurora on Jupiter: A Celestial Scavenger Hunt*
- Drawing paper
- Drawing implements

Learning Outcomes

As a result of this lesson, students will:

- Develop and enhance skills of observation and description in the context of comparing and contrasting the aurora and magnetosphere of Earth and Jupiter
- Compare and contrast the characteristics of Earth and Jupiter that result in the formation of aurora
- Articulate the similarities and differences between the auroras of Earth and Jupiter
- Explain at least three unique characteristics of the Jovian system that contribute to the nature and formation of aurora
- Explain two examples of how the Juno mission will improve our understanding Jovian auroras
- Use the Internet to source appropriate information about the aurora of Earth and Jupiter.
- Demonstrate the ability to distinguish art from scientific illustration by making a scientific illustration that compares and contrasts the auroras and magnetospheres of Earth and Jupiter.

Prior Knowledge and Skills

- The nature of the magnetospheres of Earth and Jupiter
- Electricity and magnetism
- Volcanic eruptions inject material into the atmosphere
- Ability to estimate and measure

What Students Do

The Juno Magnetosphere Module consists of three lessons that use a range of activities, from building models, to role-playing, and an Internet-based scavenger hunt to compare and contrast the nature of the magnetospheres and auroras of Earth and Jupiter.

In this lesson students use a variety of multimedia and Internet resources to compare and contrast characteristics of the aurora and magnetosphere of Earth with that of Jupiter. In Activity I, the teacher models how to completely and accurately make and record qualitative and quantitative observations of two similar images. In Activity II, students use a slideshow and scavenger hunt, to compare and contrast the aurora of Earth and Jupiter. They measure, observe, and record characteristics such as the shape, color, duration, size, and predictability of aurora and the magnetosphere for Earth and Jupiter. Students record their observations and measurements highlighting the similarities and differences between Terrestrial and Jovian systems. In Activity III, students visually communicate the results of their research. They make scientific illustrations of Earth and Jupiter emphasizing the aurora, magnetospheres, and other contributing characteristics to depict the similarities and differences of the two planetary systems.

Rationale

Much of our scientific understanding about distant objects comes from images collected by remote sensing equipment and computer modeling and simulation. Likewise, visual methods to convey information abound in science and other fields. It is important for students to learn to source and analyze information presented visually. Additionally, the ability to create scientific illustrations helps students to learn to convey information visually. The activities in this lesson encourage students to hone their skills of observation, description, and visual communication in the context of comparing and contrasting the aurora of Earth and Jupiter.

Curriculum Connections

The Juno Magnetosphere Module consists of three lessons that use a range of activities, from building models, to role-playing, and an Internet-based scavenger hunt to compare and contrast the nature of the magnetosphere and aurora of Earth and Jupiter. The lessons provide students with the opportunity to model the 3-dimensional nature and the size of magnetic fields surrounding planets (Modeling the Magnetospheres of Earth and Jupiter in 3-D), explore how the rate of spin of a planet effects magnetosphere stability (Kinesthetic Magnetosphere), research the causes of aurora and compare and contrast the characteristics of aurora of Earth and Jupiter.

Juno Mission Connection

Deep in Jupiter's atmosphere, under great pressure, hydrogen gas is squeezed into a fluid known as metallic hydrogen. At these great depths, the hydrogen acts like an electrically conducting metal that is believed to be the source of the planet's intense magnetic field. This powerful magnetic environment creates the brightest auroras in our solar system, as charged particles precipitate down into the planet's atmosphere. Juno will directly sample the charged particles and magnetic fields near Jupiter's poles for the first time, while simultaneously observing the auroras in ultraviolet light produced by the extraordinary amounts of energy crashing into the polar regions. These investigations will greatly improve our understanding of this remarkable phenomenon, and also of similar magnetic objects, like young stars with their own planetary systems.

Instruments and Data Collected

Juno will observe the aurora at infrared wavelengths with the Juno InfraRed Auroral Mapper – JIRAM – instrument. JIRAM will observe Jupiter at a few very specific wavelengths of infrared light and produce maps or images of Jupiter's aurora at each of those specific wavelengths. A team of researchers in Italy built JIRAM.

Currently, scientists observe Jupiter's aurora with telescopes on Earth. Juno will orbit around the poles of Jupiter producing the first complete observations of the planet. At its closest, Juno will be about 4,000 km above the cloud tops. This means we will have the most detailed infrared pictures available and other data, such as magnetic field, important to our understanding of the auroral processes.

The auroras of Jupiter result from powerful and complex processes in the magnetosphere. In order to understand what's behind the aurora, Juno has a group of instruments that will measure properties of the magnetosphere. JADE, the Jovian Auroral Distribution Experiment, will make measurements of the particles that exist in the region of the magnetosphere above the poles. The measurements will reveal the compositions and energies of the particles responsible for aurora. JEDI, an energetic particle detector, will measure the properties of the hydrogen, helium, oxygen, and sulfur ions in this same region. The WAVES instrument will determine the regions in the polar magnetosphere where the electrical currents exist. These currents are responsible for transporting particles from the magnetosphere to Jupiter's upper atmosphere, generating aurora. UVS, an ultraviolet spectrograph, will provide images of the aurora at UV wavelengths.

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National Standards and Benchmarks

This lesson has been mapped to middle school grade level mathematics and science content standards, benchmarks, and common core state standards as defined by:

- National Science Education Standards (National Research Council, National Academy Press, Washington, D.C., 1996); http://www.nap.edu/html/nses/html
- Benchmarks for Science Literacy (American Association for the Advancement of Science, Project 2061, Oxford University Press, New York, 1993, revised in 2009); http://www.project2061.org/publications/bsl/online.
- Principles and Standards for School Mathematics (2000-2004 by the National Council of Teachers of Mathematics); http://www.nctm.org/standards
- Mid-continent Research for Education and Learning compendium of standards and benchmarks for K-12 education; http://www.mcrel.org/standards-benchmarks/index.asp.
- Common Core State Standards for Mathematics (National Governors Association Center for Best Practices and the Council of Chief State School Officers, 2010); http://www.corestandards.org

National Science Education Standards

Science as Inquiry, Content Standard A:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science, Content Standard B:

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

Earth and Space Science, Content Standard D:

- Structure of the earth system
- Earth in the solar system

Science and Technology, Content Standard E:

- Understandings about science and technology

Science in Personal and Social Perspectives, Content Standard F:

- Science and technology in society

History and Nature of Science, Content Standard G:

- Science as a human endeavor
- Nature of science

AAAS Benchmarks for Science Literacy

1. The Nature of Science
   A. The Scientific Worldview
   B. Scientific Inquiry
   C. The Scientific Enterprise
3. The Nature of Technology
   A. Technology and Science
4. The Physical Setting
   A. The Universe

B. The Earth
C. Processes that Shape the Earth
D. The Structure of Matter
E. Energy Transformations
F. Motions
G. Forces of Nature

8. The Designed World
   D. Communication
   E. Information Processing

10. Historical Perspectives
    A. Displacing the Earth from the Center of the Universe

11. Common Themes
    A. Systems
    B. Models
    C. Constancy and Change
    D. Scale

12. Habits of Mind
    A. Values and Attitudes
    B. Computation and Estimation
    C. Manipulation and Observation
    D. Communication Skills

McREL Compendium of Standards and Benchmarks

Science

Standard 2: Understands Earth's composition and structure

- Benchmark 1: Knows that the Earth is comprised of layers including a core, mantle, lithosphere, hydrosphere, and atmosphere

Standard 3: Understands the composition and structure of the universe and the Earth's place in it

- Benchmark 1: Knows characteristics and movement patterns of the planets in our Solar System (e.g., planets differ in size, composition, and surface features; planets move around the Sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them)

Standard 8: Understands the structure and properties of matter

- Benchmark 1: Knows that matter is made up of tiny particles called atoms, and different arrangements of atoms into groups compose all substances
- Benchmark 3: Knows that states of matter depend on molecular arrangement and motion (e.g., molecules in solids are packed tightly together and their movement is restricted to vibrations; molecules in liquids are loosely packed and move easily past each other; molecules in gases are quite far apart and move about freely)

Standard 9: Understands the sources and properties of energy

- Benchmark 1. Knows that energy is a property of many substances (e.g., heat energy is in the disorderly motion of molecules and in radiation; chemical energy is in the arrangement of atoms; mechanical energy is in moving bodies or in elastically distorted shapes; electrical energy is in the attraction or repulsion between charges)
- Benchmark 2. Understands the law of conservation of energy (i.e., energy cannot be created or destroyed but only changed from one form to another)

- Benchmark 3: Knows that heat energy flows from warmer materials or regions to cooler ones through conduction, convection, and radiation A
- Benchmark 4: Knows how the Sun acts as a major source of energy for changes on the Earth's surface (i.e., the Sun loses energy by emitting light; some of this light is transferred to the Earth in a range of wavelengths including visible light, infrared radiation, and ultraviolet radiation)
- Benchmark 6: Knows that most chemical and nuclear reactions involve a transfer of energy (e.g., heat, light, mechanical motion, electricity) A
- Benchmark 9: Knows that only a narrow range of wavelengths of electromagnetic radiation can be seen by the human eye; differences of wavelength within that range of visible light are perceived as differences in color

Standard 11: Understands the nature of scientific knowledge

- Benchmark 1: Understands the nature of scientific explanations
- Benchmark 2: Knows that all scientific ideas are tentative and subject to change and improvement in principle, but for most core ideas in science, there is much experimental and observational confirmation
- Benchmark 3: Knows that different models can be used to represent the same thing and the same model can represent different things; the kind and complexity of the model should depend on its purpose
- Benchmark 4: Knows that models are often used to think about things that cannot be observed or investigated directly

Standard 12: Understands the nature of scientific inquiry

- Benchmark 1: Knows that there is no fixed procedure called "the scientific method," but that investigations involve systematic observations, carefully collected, relevant evidence, logical reasoning, and some imagination in developing hypotheses and explanations
- Benchmark 2. Understands that questioning, response to criticism, and open communication are integral to the process of science
- Benchmark 6. Uses appropriate tools (including computer hardware and software) and techniques to gather, analyze, and interpret scientific
- Benchmark 7. Establishes relationships based on evidence and logical argument

Standard 13: Understands the scientific enterprise

- Benchmark 1. Knows that people of all backgrounds and with diverse interests, talents, qualities, and motivations engage in fields of science and engineering; some of these people work in teams and others work alone, but all communicate extensively with others
- Benchmark 2. Knows that the work of science requires a variety of human abilities, qualities, and habits of mind
- Benchmark 3. Knows various settings in which scientists and engineers may work
- Benchmark 6. Knows ways in which science and society influence one another

NCTM Principles and Standards for School Mathematics

Measurement

- Understand both metric and customary systems of measurement
- Understand relationships among units and convert from one unit to another within the same system

Process Standards

- Connections
- Representation

McREL Compendium of Standards and Benchmarks

Mathematics

Standard 4: Understands and applies basic and advanced properties of the concepts of measurement

- Benchmark 4: Solves problems involving unites of measurement and converts answers to a larger or smaller unit within the same system (i.e., standard or metric)
- Benchmark 6. Selects and uses appropriate units and tools, depending on degree of accuracy required, to find measurements for real-world problems

Common Core State Standards for Mathematics

Grade 7

Ratios and Proportional Relationships

- Analyze proportional relationships and use them to solve real-world and mathematical problems.

Activity I: Observation and Description, Honing Critical Skills

Explain that in this exercise, students will practice observation and description to improve this critical scientific skill.

1. Display the images of the two pigs to the class. Use these images to model making detailed, complete, and accurate observations.
2. Project a T-Chart on the screen or wall. Use the T-Chart to record observations of the images.
3. Using a "Think-Aloud" approach, demonstrate how to make and record observations that compare and contrast the two pigs. "Thinking Aloud" requires the instructor to verbally express his/her thoughts as he/she compares and contrasts the images and records observations. For example, the teacher might verbalize the observation that both pigs have black hair, one in spots and the other in bands. Record and read aloud your specific observation.
4. After modeling an observation and description, invite students to volunteer their observations and the information to record when comparing the piglets. Encourage students to state their observations carefully with detail and precision.
    - IMPORTANT: If students do not suggest making ***quantitative*** measurements of the images, demonstrate that one can measure the size of various features directly from the images ***as long as the images are to scale***. (*Note: Use this opportunity to help students recognize that knowing the scale of an image is very important.)*
5. As a class, review all the observations and descriptions made of the two images. Revise those that require adjustments because they are incomplete or inaccurate.

Activity II: Comparing and Contrasting Aurora and Magnetospheres

Note to the Teacher

The lesson guide parallels the slideshow, *Aurora of Earth, Aurora of Jupiter: A Celestial Scavenger Hunt*. For those without the ability to project the presentation, it is recommended that you print hard copies of each slide and distribute them to students.

1. Explain to students that they will work in pairs to compare and contrast the auroras and magnetospheres of Earth and Jupiter.
2. Distribute and review the student handout, *Aurora of Earth, Aurora of Jupiter: A Celestial Scavenger Hunt*. Remind students to make and record detailed, complete, and accurate observations or measurements.
3. Form student pairs, seat students at computers with Internet access and direct students to the slideshow and additional multimedia resources selected for this lesson.
4. As students work, support their efforts to compare and contrast the systems of Earth and Jupiter. Help students to
   - Locate and interpret information
   - Make and record measurements and observations
5. Pose questions to help expand or extend their research and understanding as appropriate.
6. Reconvene class once teams have completed their research.

Summarize and Reflect

As a class, review each station. Help students to articulate the similarities and differences between aurora on Earth and Jupiter. Remind students to refer to their notes as they volunteer examples of what they learned from their research. Summarize student responses to the questions. Note that while both planets have similar features, they differ in degree, nature, and origin.

Activity II Assessment

Collect and review student work. Use the work to assess individuals' abilities to make and record observations and interpret information presented as text and visually. Use student contributions to class discussion to gage their ability to verbally communicate complex scientific ideas.

Activity III: Scientific Illustration: Visually Representing Information

Explain to students that scientific illustration represents an important method for communicating scientific concepts and information. Explain that scientific illustrations differ in their appearance and purpose from other types of illustrations.

> **Magnetosphere Module Lesson Integration**
> If your class completed Activity III of *Modeling the Magnetospheres of Earth and Jupiter in 3-D*, they may add the aurora of each planet to their drawings or refer to their drawings for this activity.

1. Use the slideshow, *Art vs. Scientific Illustration*, to illustrate the differences between art and scientific illustration. Select one or more slides. Each slide provides a pair of contrasting images, one a work of art and the other a scientific representation. Points to make or have students volunteer include but, are not limited to:
    - The purpose of art and scientific illustration differ.
    - Scientific illustrations convey information. They may have artistic appeal, too.
    - Works of art influence one or more of our senses, emotions, and intellect. Generally, art does not seek to convey knowledge or information
    - Scientific illustrations represent objects or phenomena literally. Art, generally, is a work of the imagination.
    - Scientific illustrations include text to convey details or orient the observer.
2. Following the discussion of art versus scientific illustration, distribute drawing paper to students.
3. Explain to students that their goal is to visually represent the most important similarities and differences between the aurora and magnetosphere of Earth and Jupiter in a scientific illustration.
4. Discuss whether or not the images should be drawn to scale or how to express astronomical scales on such relatively small pieces of paper.
5. Explain that they should draw such things as the magnetic field, aurora, and moons of each planet. Ask students to label each part of the drawing.
6. Encourage students to refer to the notes they took as they draw. Remind students that they are not graded on their artistic ability. If students still have access to the Internet, they may return to the computer to refer to original data.
7. Allow students to work in pairs or small groups as they produce individual drawings.
8. Call a halt to student work. Reconvene class. Ask students to hang their drawings either around the room or in the hallway. Provide time for students to review each other's work.

Summarize and Reflect

As a class, review the drawings. Ask students to volunteer to explain the information they selected to depict and how they represented the information. Compare and contrast various illustrations.

Activity III Assessment

Collect and review student illustrations. Use the illustrations to assess each individual's ability to visually communicate scientific information. The information they share provides insight into what content they felt was most important to communicate.

Extensions

This lesson introduces multiple topics and provides many opportunities for further study by individuals or teams. Help students to identify a topic and a method for presenting to their peers. Depending upon the students and resources, research could be presented in written, visual, or verbal forms. Encourage students to identify a topic that is of meaning to them. The following is a very short list of possible topics:

- Coronal mass ejections
- The nature and the dynamics of the Earth's core
- The moons of Jupiter
- Space weather
- Communication satellites and solar radiation

Background Information

The Origins and Causes of Aurora

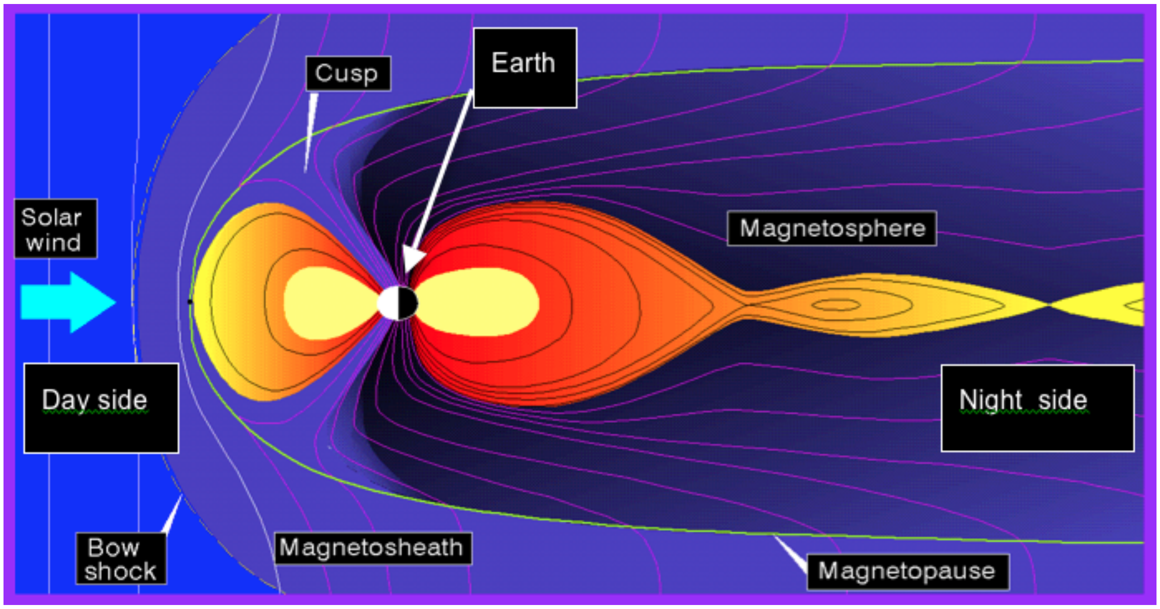


Figure 1: Artist depiction of the magnetosphere surrounding Earth.

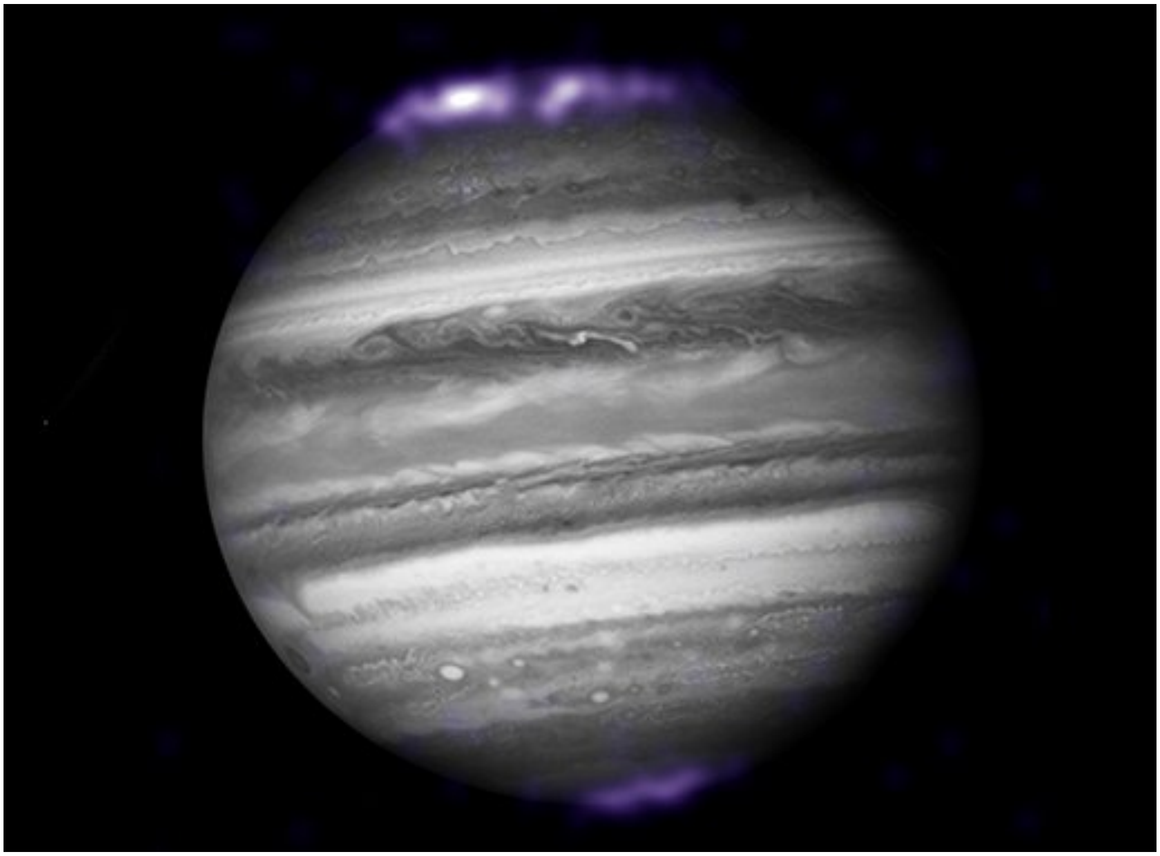
Solar storms (prominences and coronal mass ejections) cause material from the outer layer of the sun to shed into the solar system. This material – charged particles – travels through the solar system, embedded in the Sun's magnetic field. This tenuous structure of solar charged particles and magnetic field is called the "solar wind." When the solar wind encounters the magnetic field of a planet, let's say Earth's, the solar wind pushes against the magnetosphere, compressing it in the 'front' (the sunward side, the day side) and stretching it out in the 'back' (the side facing away from the sun, night side).

The solar and planetary fields interact. As a result Earth's magnetosphere becomes disrupted or rearranged. In an effort to return to equilibrium, potential energy stored in Earth's magnetic field is transferred to kinetic energy as charged particles – they become fast-moving. These particles, partly from the Sun and partly from Earth's own atmosphere, travel along Earth's magnetic field lines inwards toward Earth. The moving particles create magnetic-field-aligned electrical currents. Upon reaching Earth's ionosphere, the particles are boosted in energy to 6,000 volts or more and collide with nitrogen and oxygen atoms. These collisions emit radiation at specific wavelengths. We see the radiation emitted as aurora.

Jupiter's Aurora

The following was edited from the original. The original, *Big Auroras on Jupiter,* was produced for NASA Science News, on March 29, 2007 by Dr. Tony Phillips and is available at: http://science.nasa.gov/science-news/science-at-nasa/2007/29mar_bigauroras/

So you thought Northern Lights were big in Alaska? "That's nothing," says Randy Gladstone of the Southwest Research Institute in San Antonio, Texas. "Jupiter has auroras bigger than our entire planet."



Above: *X-ray auroras observed by the Chandra X-ray Observatory overlaid on a simultaneous optical image from the Hubble Space Telescope. [More]*

The purple ring traces Jupiter's X-ray auroras. Gladstone calls them "Northern Lights on steroids. They're hundreds of times more energetic than auroras on Earth."

Jupiter's auroras were discovered by the Voyager 1 spacecraft in 1979. A thin ring of light on Jupiter's nightside looked like a stretched-out version of our own auroras on Earth. But those early photos merely hinted at the power involved. The real action, astronomers soon learned, was taking place at high-energy wavelengths invisible to the human eye. In the 1990s, ultraviolet cameras on the Hubble Space Telescope photographed raging lights thousands of times more intense than anything ever seen on Earth, while X-ray observatories saw auroral bands and curtains bigger than Earth itself.

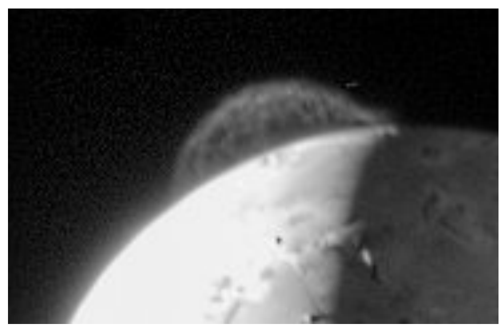
Jupiter's hyper-auroras never stop. "We see them every time we look," says Gladstone. You don't see auroras in Alaska every time you look, yet on Jupiter the Northern Lights always seem to be "on."

Gladstone explains the difference: On Earth, the most intense auroras are caused by solar storms. An explosion on the sun hurls a billion-ton cloud of gas in our direction, and a few days later, it hits. Charged particles rain down on the upper atmosphere, causing the air to glow red, green and purple. On Jupiter, however, the sun is not required. "Jupiter is able to generate its own lights," says Gladstone.

The process begins with Jupiter's spin: The giant planet turns on it axis once every 10 hours and drags its planetary magnetic field around with it. As any science hobbyist knows, spinning a magnet is a great way to generate a few volts—it's the basic principle of DC motors. Jupiter's spin produces 10 *million* volts around its poles.

"Jupiter's polar regions are crackling with electricity," says Gladstone, "and this sets the stage for non-stop auroras."

The polar electric fields grab any charged particles they can find and slam them into the atmosphere. Particles for slamming can come from the sun, but Jupiter has another, more abundant source nearby: the volcanic moon Io, which spews oxygen and sulfur ions (O^+ and S^+) into Jupiter's spinning magnetic field.



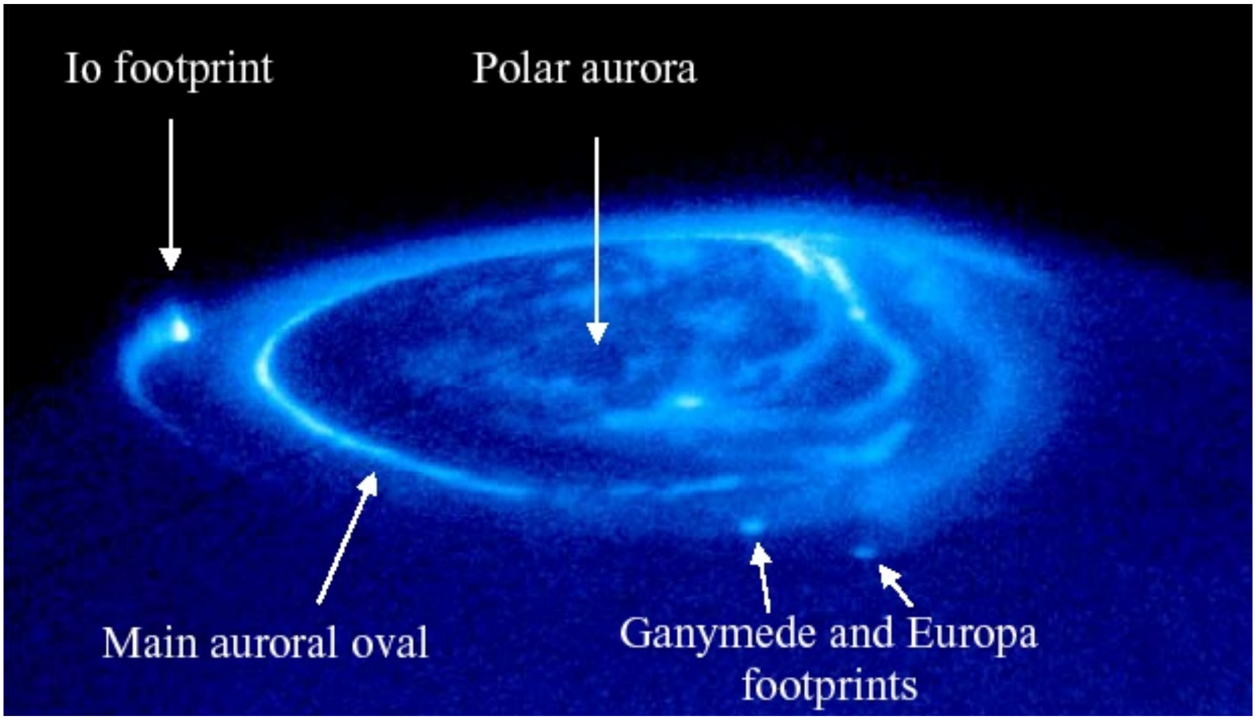
Right: A volcano on Io, photographed by New Horizons in Feb. 2007. [More]

Somehow, these ions make their way to Jupiter's poles where electric fields send them hurtling toward the planet below. Upon entering the atmosphere, "their electrons are first stripped away by molecules they run into, but as they slow down they start grabbing electrons back. The 'charge exchange reaction' produces intense X-ray auroras," he explains.

So Jupiter's Northern Lights are, in a sense, volcano powered. Mystery solved? Not quite. No one knows exactly how volcanic exhaust meanders from Io out through Jupiter's magnetosphere and back to Jupiter's poles. "We're still trying to figure it out," says Gladstone.

Three Jupiter Aurora:

Jupiter exhibits three auroras.
The moons of Jupiter, especially Io, and their atmospheres interact with the magnetosphere of Jupiter. Volcanic eruptions on Io inject ions of sulfur into Jupiter's atmosphere. These ions form a plasma torus, a doughnut-shaped cloud of ions and electrons, around Jupiter. The moons appear as bright spots. In addition, Jupiter has a steady oval or kidney-bean shaped steady aurora and variable aurora.



About the Io Torus

(**Source:** Lunar and Planetary Laboratory at the University of Arizona. URL: http://vega.lpl.arizona.edu/iotorus/)

The Io plasma torus is a ring-shaped cloud of ions and electrons surrounding the planet Jupiter. Electrons collide with the ions, which absorb energy from the collisions and release it again as ultraviolet light. This process resembles the light emission by neon lights and the aurora borealis (northern lights).

Neon lights, however, get their power from the man-made electrical power grid. What powers the Io plasma torus?

Only part of the answer to this question is known.

The Io plasma torus is created by ionizing neutral atmospheric gases such as sulfur dioxide. These ions are created by the ultraviolet part of sunlight and bombardment by the electrons of the plasma torus. These new ions and electrons are immediately accelerated to move with Jupiter's rotating magnetic field, and as a side effect the ions are heated to very high temperatures (tens of thousands of degrees), which is passed on to the electrons. Electrical currents are also driven by this acceleration process, forcing electrons to move at very high speeds. This energy leaves the system when the electrons excite the ions to give off this energy as ultraviolet light, which can be observed by telescopes.

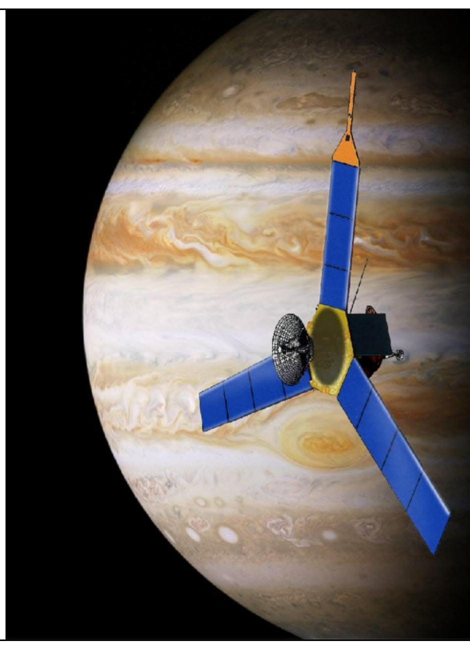
Because these ions and electrons, or plasma, come from Io and its accompanying donut-shaped cloud of escaped atmospheric gases, this plasma cloud is also donut-shaped. Because of its shape, it is called the Io plasma torus. It rotates with Jupiter with a 10 hour period, while Io and its accompanying neutral gas ring requires 42 hours to revolve around Jupiter. Because Jupiter's magnetic field is tilted, the Io plasma torus rotation has a wobble or shimmy, like a car tire with a bent hub.

Jupiter's Family Secrets

Our solar system is a family of planets, dwarf planets, comets, and asteroids orbiting our Sun, each harboring clues of our common origins, with their disparate compositions and characteristics.

How do scientists discover those secrets? Ancient civilizations studied the skies and noted the strange travelings of "wanderers," or "*planetes*" in Greek, which seemed to move against the background of familiar constellations. Telescopes allowed astronomers to view the *surfaces* of planets; spacecraft instruments now allow us to infer information about the *interiors* of planets. Instruments like radar, sophisticated compasses, orbital mapping devices, and others that detect wavelengths of light invisible to the human eye are some of the tools that allow spacecraft to explore other worlds.

NASA's Juno mission to Jupiter is scheduled to launch in 2011 and will investigate not only the deepest mysteries of its unique personality, but it also will plumb the secrets of our solar system's origins.



NASA's Juno mission to will investigate Jupiter's interior, atmosphere, magnetosphere, and origins. By discovering clues about Jupiter's unique personality, the Juno mission will reveal answers about our solar system's birth.

This artist's rendering shows the Juno spacecraft in front of Jupiter, where it will arrive in 2016.

Credit: NASA.

The Juno Mission Will Unlock Jupiter's Family Secrets

Cassini image of Jupiter. Credit: NASA/JPL/Space Science Institute .

At more than twice the mass of all the other planets combined, Jupiter is the patriarch of our planet family. It grew large enough to capture and hold onto the materials of the solar nebula, so its mixture of about 90% hydrogen and 10% helium by percent volume (with some methane, water, and ammonia mixed in) reflects the composition of the primordial mixture that produced all the planets. Yet, its composition is not *exactly* like the primordial mixture, leaving scientists uncertain about how exactly Jupiter, and by extension, the solar system, formed. Better understanding Jupiter's traces of methane, water, and ammonia will help scientists piece together exactly how a collection of gas and dust came to form the planets we see today.

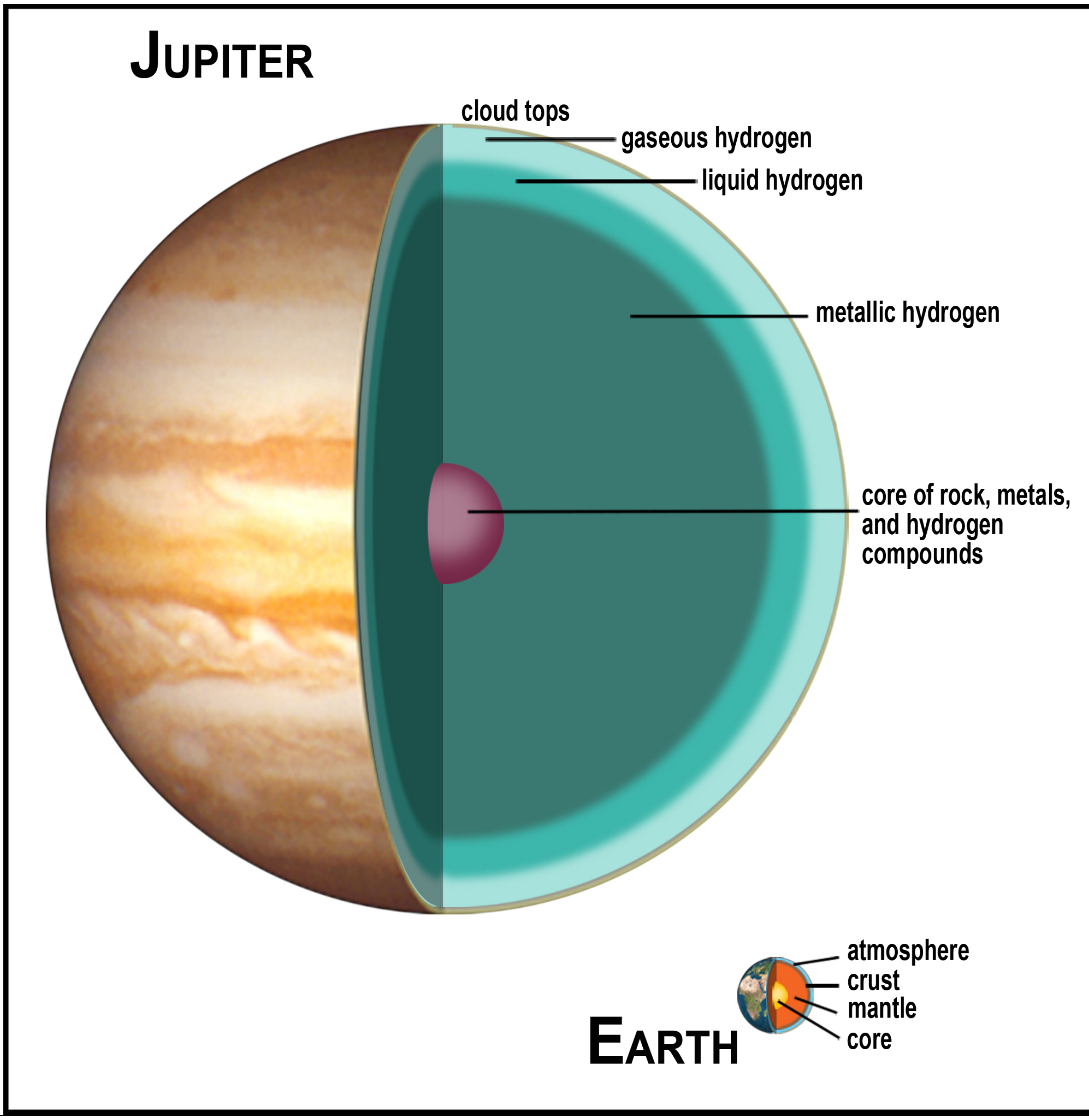
Juno will use a special set of "eyes," called microwave radiometers, to spy deep into Jupiter's atmosphere in wavelengths of light invisible to the human eye, and gather information about the trace components water and ammonia. By measuring how its orbit is very slightly altered by the gravity of the planet, Juno will infer just how massive Jupiter's core is to provide additional clues about how Jupiter captured heavy enough materials in its infancy to grow so large. The very stuff of Jupiter holds clues to understanding the story of our solar system's birth!

Jupiter's large magnetic field interacts with the solar wind to form an invisible magnetosphere. If we were able to see Jupiter's magnetosphere, it would appear from Earth as in this artist's depiction, larger than the Moon in the sky.

Credit: NASA.

Jupiter's Magnetosphere and Interior - Another shroud envelopes Jupiter, but this one is invisible to our eyes. Like Earth, Jupiter has a magnetic field. Earth's magnetic field is familiar to us through its effects: our compasses point to the magnetic poles; it protects our atmosphere from the blast of the solar wind; and particles interact with it to produce the auroras, or northern and southern lights. Similarly, Jupiter's magnetic field is detectable with compasses. It also produces beautiful auroras!

Both magnetic fields originate from processes deep in each planet's interior. Earth's is generated from the electric current caused by the flow of molten metallic material within its outer core. Jupiter's gases are crushed to such incredible pressures that they are forced beyond the common states of liquid, solid, or gas that we find on Earth. One such a layer inside Jupiter is *metallic* hydrogen, and the electric current caused by swirling movements in this substance produces a magnetic field so large that its tail end ("magnetotail") extends past the orbit of Saturn.

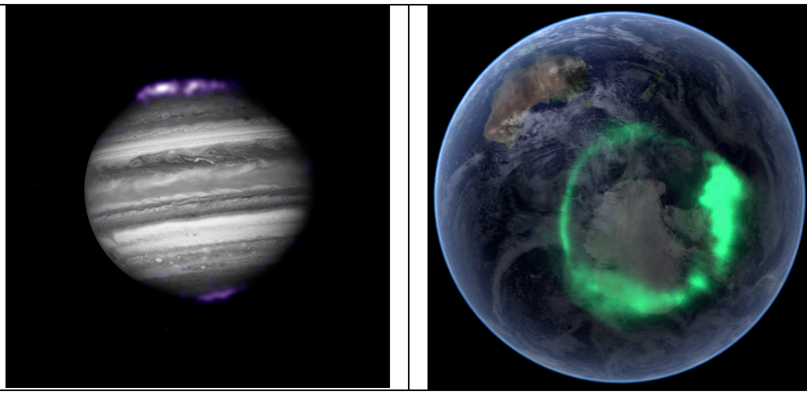


Liquid metallic hydrogen makes up most of Jupiter, as seen in this cut-away view of the plane's interior. There is a dense core at the planet's center, and it is slightly larger than the whole of Earth. The thick atmosphere merges seamlessly with a liquid hydrogen layer; there is no solid surface on Jupiter.

A similar cut-away view of Earth's interior shows its relatively thin atmosphere and dense interior. Both planets have layers and a core, but the composition of those layers is remarkably different.

Credit: Lunar and Planetary Institute.

Juno will map Jupiter's magnetic field with its own sophisticated version of a compass, called a magnetometer. Its unique polar orbit will carry it above the poles to study Jupiter's auroras and how the magnetic field slams invisible charged particles into the atmosphere to produce the beautiful lights.   Juno will measure the charged particles and the electric currents they create along the magnetic field lines. Juno will also “listen” for the radio signals given off by these particles as they move through the magnetic field. Its special “eyes” – an ultraviolet spectrometer – will “see” the aurora in a wavelength of light invisible to our eyes. JunoCam will take pictures of the planet, which scientists and students will use to study the poles.



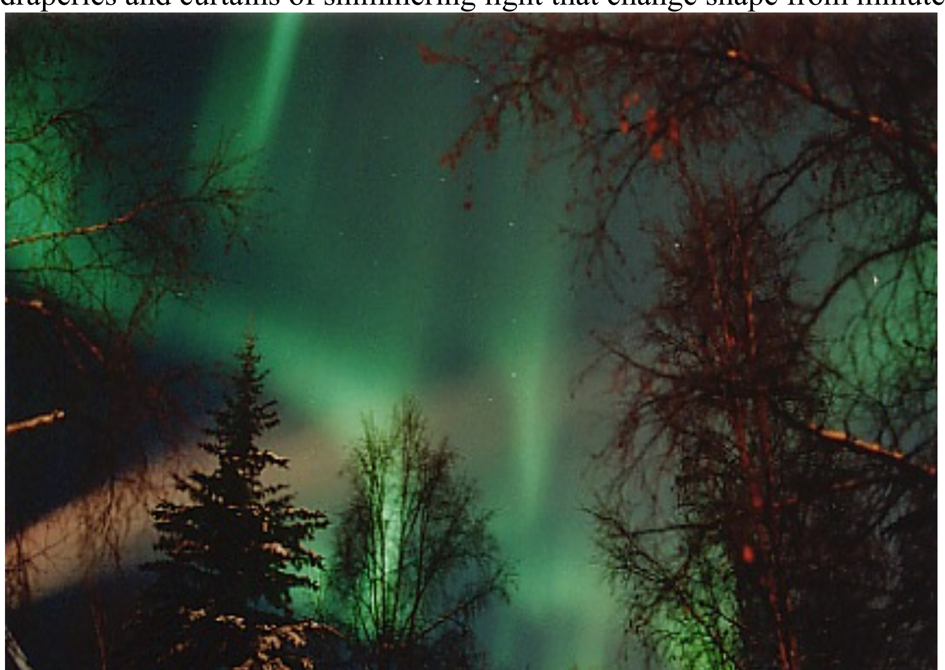
Jupiter (left) and Earth (right) both have auroras, or the northern and southern lights. Particles accelerated along the magnetic field lines of the planets slam into the upper atmospheres, generating curtains of glowing light. Planet images are not to scale. Credit: NASA.

Earth's Aurora

The following information was edited from the original. The original source, *The Aurora!,* is a NASA/IMAGE Resource in space science education available at:
http://image.gsfc.nasa.gov/poetry/educator/Aurora79.html

Description: Near the poles of Earth, observers have often seen glowing clouds shaped like curtains, tapestries, snakes, or even spectacular radiating beams. Northern Hemisphere observers call them the Northern Lights of Aurora Borealis. Southern Hemisphere observers call them the Southern Lights or Aurora Australis. Because most people, and land masses, are found north of the equator, we have a longer record of observing them in northern regions such as Alaska, Canada, Scandinavia, but sometimes as far south as the Mediterranian Sea or Mexico!

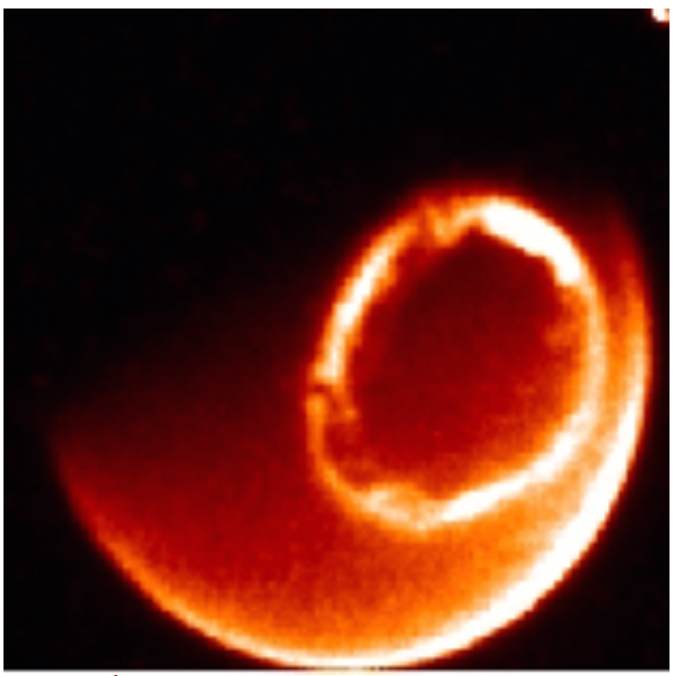
Sprinkle iron filings on a paper and put a magnet underneath. You will see lines of magnetism that seem to 'flow' towards the poles of the magnet. If you were a charged particle in space, you would be magnetically trapped on one of these lines of magnetism. As you flow down Earth's magnetic field into the north and south poles, you collide with atoms of oxygen and nitrogen. This gives off the colored lights you see in an aurora. What do you think these ovals of light look like from the ground if you were looking up at the sky? From space we can look down at an aurora and see that it actually looks like a crown of light! Scientists call this the Auroral Oval (see below satellite photo from IMAGE). If you were standing on the ground looking up at the night sky, you would only see a very small part of this halo. It would look like beautiful draperies and curtains of shimmering light that change shape from minute to minute!



- Watch a Aurora Movie
- Look at an Enlarged Picture

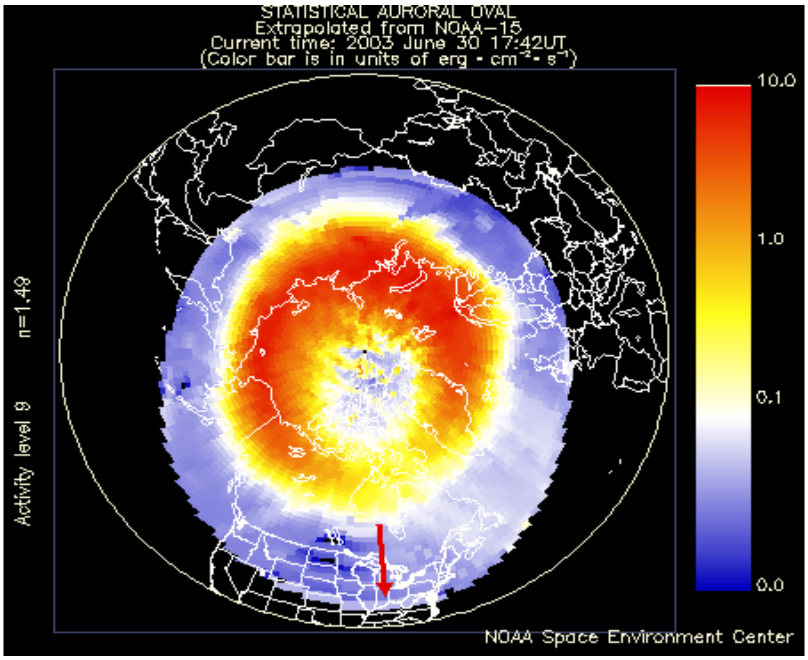
Causes: The most common explanation you will find in print is that particles from the Sun flow down the magnetic lines of force into the polar regions of Earth. They collide with oxygen and nitrogen atoms in the atmosphere which emit the colored lights we see in the aurora. This explanation is actually incorrect, although it is easy to describe in a few brief sentences, which is why it is popular in many textbooks.

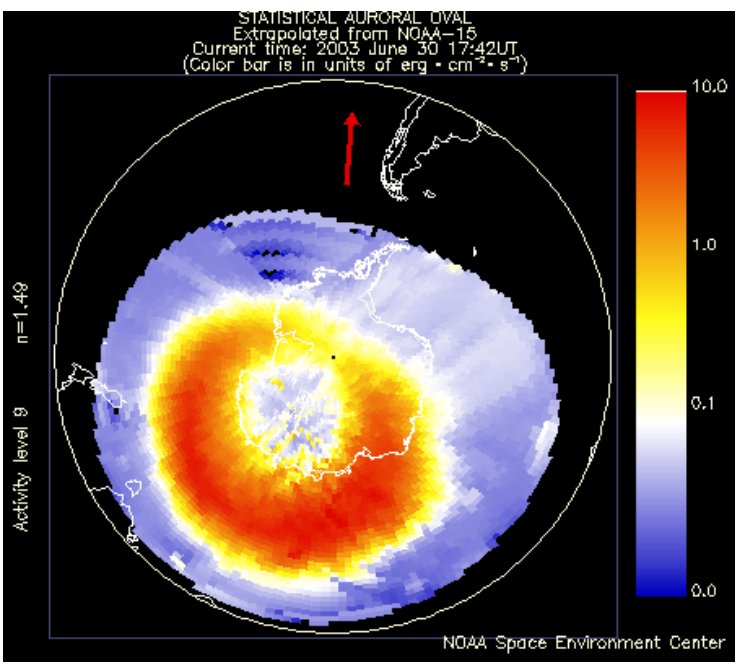
It has been known for decades that the correct explanation for why aurora occur involves distant regions of the magnetic field of night side of Earth (opposite direction from the Sun). Solar storms carry some of the Sun's magnetic field into space. When this magnetic field encounters Earth's magnetic field, it can sometimes cause Earth's field to rearrange itself and then reform. Potential energy that is stored in Earth's magnetic field converts to kinetic energy of fast-moving particles. These particles, partly from the Sun and partly from Earth that had previously been trapped in the magnetic field, flow inwards towards Earth along the polar magnetic field lines. As they encounter the ionosphere, they are boosted in energy to 6,000 volts or more, and then collide with nitrogen and oxygen atoms to produce the auroral light. There is no direct entry of solar particles into the polar regions to create the night-time aurora.



Watch an IMAGE Aurora Movie
Look at an Enlarged Picture

Properties: There are aurora over both poles of Earth almost every day, but they are mostly too faint to see. The two satellite views below show the aurora over the North (left) and South (right) polar regions on June 30, 2003. Notice how similar they are in shape and brightness - this shape similarity is what scientists call Auroral Conjugacy. Aurora are formed in the atmosphere at elevations from 100 to 1000 kilometers where the density of the air is very low. Enormous amounts of electrical energy are produced during an aurora when millions of amperes of electric currents pass through the atmosphere and generate nearly 900 billion watts of energy - mostly in heat but about a few percent in light.





Teacher Page
T-Chart for Activity I
Project this Image

Spotted Pig	Striped Pig


© SWNS


Ross Parry Photos

Figure 2 Arctic Hare, source: NOAA www.arctic.noaa.gov

Figure 3: Snowshoe Hare Source: National Park Service

Figure 4: Arctic Wolf Pup, Source - NOAA , www.arctic.noaa.gov


Figure 5: Red Wolf Pup, Source: U.S. Fish & Wildlife Service, www.fws.gov

Teacher Answer Key

Aurora of Earth, Aurora of Jupiter: A Celestial Scavenger Hunt

Directions

- Your teacher will provide you with the slideshow, *Aurora of Earth, Aurora of Jupiter: A Celestial Scavenger Hunt*
- Use the slides and the links to the Internet to compare and contrast the aurora of Earth and Jupiter.
- The slides are grouped by "*stations*" There are seven stations. Answer the questions for each station in the space provided below.
- Use additional, lined paper, if you need more room for your answers.

Station 1: Looking at Aurora

1. Find a place on the globe where you could go to see auroras. Explain your choice of location. *Answer*: *Auroras appear in the sky above the north and south magnetic poles of Earth. Generally, one must travel north or south of latitudes 60N/60S respectively to regularly see aurora. During major solar events, aurora have been seen as far south as Florida.*
2. What time of day is best to see auroras? *Answer*: *Auroras are visible after the sun has set.*
3. What time of year is best see auroras? *Answer*: *The majority of aurora activity takes place in the spring in the northern hemisphere and fall in the southern hemisphere.*
4. What color auroras occur on Earth? *Answer*: *The majority of auroras appear yellow-green and red. Some variations on these colors also occur.*
5. Oxygen and nitrogen produce different colors, pick one gas and find out which colors it contributes to the aurora. *Answer*: *Oxygen produces yellow-green and red light. Nitrogen produces red light.*

Station 2: More about Aurora

1. Describe at least two different shapes for aurora. *Answer*: *Auroras come in many shapes. From space, auroras appear as a ring. Ground observations show auroras as curtains, ribbons, corona, and many others. They may also change their shape during the period of observation.*
2. What are some possible explanations of the shapes of auroras? *Answer*: *Scientists are still attempting to understand the shapes. The different shapes of aurora are related to the configuration of the magnetosphere and its interaction with the solar wind (and variations in the solar wind). Different shapes may be related to different processes as different locations in Earth's magnetosphere.*
3. What can an aurora tell us about the Sun-Earth Connection? *Answer*: *Auroras indicate a Sun-Earth event. Charged particles from massive explosions on the Sun travel through space and enter Earth's magnetosphere causing energetic events. When the solar wind reaches Earth's magnetosphere, they interact and the charged particles are channeled into our upper atmosphere. These charged particles traveling into the atmosphere establish electrical currents in our upper atmosphere.*
4. What is the connection between auroras and the solar wind? *Answer*: *The solar wind drives the aurora. The solar wind disturbs the magnetosphere. The magnetosphere is*

distorted and out of balance. As the magnetosphere returns to balance, electrons in the atmosphere accelerate and crash into atoms of oxygen and nitrogen. As these excited atoms return to a neutral state they emit light.

Station 3: Do other Planets Make Aurora?

1. Which other planets in our solar system have the ingredients to make aurora? *Answer*: *Mercury, Earth, Jupiter, Saturn, Neptune, and Uranus. At Mars, the magnetic field is patchy and irregular. That's because it's due to terrestrial material near the surface that was permanently magnetized from a past planetary magnetic field. Correspondingly patchy and irregular aurora has been observed at Mars.*

Station 4: Comparing Planets

1. List at least three similarities or differences between Jupiter and Earth. *Answers will vary. Jupiter's visible wavelength aurora cannot be seen from Earth because the reflected sunlight is too bright. To see the aurora, you need to get to the night side of the planet, which we can do by spacecraft. The spacecraft, Galileo DID see the visible aurora on Jupiter's night side! Aurora are also visible in other wavelengths.*
2. Describe two ways that the moons of Earth and Jupiter differ. *Answers will vary. It is important to note that Earth's moon is geologically inactive while Io is active. Also, Io has an atmosphere whereas the Moon does not.*
3. Look at the aurora of Earth and Jupiter from space. Carefully describe two similarities and differences. *Answers will vary. Key differences include two auroral rings around Jupiter and bright spots within the Jovian aurora. In addition, the auroras on Jupiter are relatively constant phenomena rather than sporadic events as seen on Earth.*
4. Notice the bright spots in the image of Jupiter. What might cause these spots? *Answer*: *Jupiter's moons orbit within its magnetosphere. As a result, their atmospheres create disturbances in the aurora that appear as bright spots.*

Station 5: Composition of the Atmospheres

1. List some of the similarities and differences of the atmospheres of Earth and Jupiter. *Answer*: *The atmospheres of Earth and Jupiter differ in composition. Earth's atmosphere is primarily nitrogen and oxygen while the atmosphere of Jupiter is composed of mostly hydrogen and helium. Additionally, Earth is a terrestrial planet with a thin atmosphere. In contrast, Jupiter is a gas giant. It is difficult to define the boundary between the surface and the atmosphere of Jupiter. Little information for making this decision exists.*

Station 6: Comparing Magnetospheres

1. What is the composition of the core of Jupiter? *Answer*: *Jupiter's core is composed of liquid metal hydrogen. The enormous pressure from overlying layers compresses hydrogen into a liquid. The pressure also causes the liquid to take on properties of a plasma allowing electrons to flow creating a current. The liquid metal core creates the magnetosphere of Jupiter.*
2. How big is the magnetosphere of Jupiter? *Answers will vary. The magnetosphere of Jupiter is the largest object in the solar system. It extends to Saturn. The bow or front of the magnetosphere of Jupiter extends toward the Sun by approximately 3 million kilometers (about 1,860,000 miles.) The magnetotail, the night side of the magnetosphere extends 700 million kilometers (about 435,000,000 miles) behind the planet.*

3. Estimate how much larger Jupiter's magnetosphere is than Earth's? *Answer*: *Based upon the image provided, most students should estimate that Earth and its magnetosphere fit inside the diameter of one Jupiter. In fact, only the bow of Earth's magnetosphere fits within Jupiter. The bow of the Earth magnetosphere is 10 Earth's long or approximately the diameter of Jupiter.*
4. Summarize the answers to questions 1-4. *Answer*: *The Earth's magnetosphere is an extension of the magnetic field into space. The magnetosphere is very large. The bow of the magnetosphere, the side toward the Sun, extends for about 10 earth radii. The tail extends away from the Sun for about 1000 earth radii. We cannot directly observe the magnetosphere. We see the effects through aurora. New technologies have improved our ability to observe the magnetosphere itself. The Sun ejects matter into space as the solar wind. The solar wind crashes into the bow of the magnetosphere. Material from the solar wind may enter our magnetosphere and create aurora.*

Station 7: Adding the Energy

1. Slide 23 *Answers: #3, #2, #1.*
2. In your own words, explain how Io contributes to aurora on Jupiter. *Answers will vary. The volcanic activity of Io injects sulfur, as sulfur dioxide, into the atmosphere around Io. Io orbits within the magnetosphere of Jupiter. Therefore, the material erupted from volcanoes of Io enters the Jovian magnetosphere.*

Name:
Date:
Partner(s):

Aurora of Earth, Aurora of Jupiter: A Celestial Scavenger Hunt

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Station #1: Looking at Aurora
1. Find a place on the globe where you could go to see auroras. Explain your choice of location. 2. What time of day is best to see auroras? 3. What time of year is best see auroras? 4. What color auroras occur on Earth? 5. Oxygen and nitrogen produce different colors, pick one gas and find out which colors it contributes to the aurora.
Station #2: More about Aurora
1. Describe at least two different shapes of aurora. 2. What are some possible explanations of the shapes of auroras? 3. What can an aurora tell us about the Sun-Earth Connection? 4. What is the connection between auroras and the solar wind?
Station #3 Do Other Planets Make Aurora?
1. Which other planets in our solar system have the ingredients to make aurora?

Station # 4 Comparing Planets

1. List at least three similarities or differences between Jupiter and Earth.
2. Describe two ways that the moons of Earth and Jupiter differ.
3. Look at the aurora of Earth and Jupiter from space, carefully describe two similarities and differences.
4. Notice the bright spots in the image of Jupiter. What might cause these spots?

Station #5 Composition of the Atmospheres

1. List some of the similarities and differences of the atmospheres of Earth and Jupiter.

Station #6 Comparing Magnetospheres

1. What is the composition of the core of Jupiter?
2. How big is the magnetosphere of Jupiter?
3. How much bigger is Jupiter's magnetosphere than Earth's magnetosphere? (Hint: Use the picture to estimate the answer.)
4. Summarize the answers to questions 1-4.

Station #7 Adding the Energy

1. In your own words, explain how Io contributes to aurora on Jupiter.