Origins of the Solar System and the Astronomer's Periodic Table

Grade Range: 6-8

Teaching Time: five to six, 45-minute periods

Module: Origins

Lesson: Origins of the Solar System and the Astronomer's Periodic Table

Activities:

Ia How did the Solar System Form?; Ib: Walk this Way – A Kinesthetic Model of Solar System Formation

IIa: The Astronomer's Periodic Table ; IIb *Modeling the Composition of the Solar System, Earth, and Jupiter with Beads*.

III: Demonstration: Making a Frost Line – A Model of Early Solar System Structure

IV: Walk this Way *AGAIN* – Extending the Kinesthetic Model of Solar System Formation

Advanced Planning

1. Ensure that you have access to a computer with the ability to project multimedia and images using presentation and video software such as PowerPoint, KeyNote, and Quicktime.
2. Review Activity IIb *Modeling the Composition of the Solar System, Earth, and Jupiter with Beads*. **Decide to provide teams with either 30 or 300 beads. You will need 17 distinct colors.**
3. Review the advanced preparation and steps for the teacher demonstration
4. Collect and organize materials
5. Copy student pages
6. Download the video, *James Webb Space Telescope: Planetary Evolution*, from the NASA Internet site, *Portal to the Universe*

Materials

Teacher Materials

- Computer with Internet access and the ability to project images and multimedia
- Access to presentation software such as PowerPoint or Keynote and QuickTime or RealPlayer
- Access to a large, open space such as the gym or athletic field
- Slideshow, *Origins of the Solar System and the Astronomer's Periodic Table*
- Video: *James Webb Space Telescope: Planetary Evolution*, from the internet site, Portal to the Universe
- (Optional) 4 traffic cones and several hundred feet of kite string
- Transparencies, markers, and overhead projector ***OR*** poster paper and markers
- Flashlight

Materials for Demonstration

- Water in a spray bottle
- Candle or source of heat that is localized, not dispersed
- Support Structure – chip and dip platter
- Ceramic surface – Platter or large plate of a dark color to contrast with the color of ice
- Matches

Student Materials

Beads Per Team (Assuming ***100*** Beads per Earth, Jupiter, Universe per team**)**

Number of Beads	Element/Compound represented by bead	Color Code
150	Hydrogen	
47	Helium	
32	Iron	
31	Oxygen	
15	Silicon	
14	Magnesium	
3	Sulfur	
2	Calcium	
2	Nickel	
1	Aluminum	
2	Other/trace elements	
0.5	Carbon	
0.3	Water	
0.3	Ammonia	
0.3	Methane	

- Student Pages: *Origins of the Solar System Comic Strip* and *Modeling Composition with Beads*
- Paper
- Pencil
- Ruler
- (3) per pair, self-sealing plastic bags
- Calculator
- Colored pencils of the same hue as the beads

Learning Outcomes

- Kinesthetically model the evolution of our solar system from a nebula to its current state
- Interpret data tables and charts regarding the chemical composition of the Universe, the variation in composition and abundance of elements and compounds in gas giants and terrestrial planets
- Use mathematics to convert percent to whole numbers
- Use simple materials to represent the proportion of elements and compounds that compose Earth, Jupiter, and the Universe
- Represent and communicate composition of the solar system, terrestrial and gas giants

- Represent and communicate the formation and differentiation of the solar system into a star, terrestrial planets and gas giants

Prior Knowledge & Skills

- General knowledge of astronomy and structures within the Universe: nebula, solar systems, stars, and planets
- General knowledge of the periodic table of the elements
- Ability to convert units of measurement
- Ability to calculate volume (optional)

What Students Do

The Juno Origins Module engages students in activities that explore planetary and solar system formation. The activities in this module address the composition and events of early solar system formation. Students use data sets (data, images, and multimedia resources) to perform comparative planetology while investigating the composition and formation of planets and our solar system.

In Activity I students brainstorm their current knowledge about the formation of the solar system. After exploring current beliefs, students role-play the movement of gas and dust particles during the initial stages of solar system formation. Activity II provides students with an astronomer's perspective of the composition of the Universe. Students use mathematics and simple materials (colored beads) to model the composition of a nebula, the Earth, and Jupiter. Based upon their models, students compare and contrast the compositions of nebula, terrestrial planets, and gas giants. Activity II is followed by a teacher demonstration. Using simple materials the teacher demonstrates the role of temperature in the differentiation of the early solar system into two types of planets, terrestrial and gas giants and the formation of a frost line that separates the two types of planets. In the last activity, students expand upon Activity I. Using the knowledge gained from Activities II and the demonstration, students act out additional stages in solar system formation – the differentiation of the solar system into a star, terrestrial planets, and gas giants.

The Juno Origins Module contains an **overarching activity** designed to help students reflect on and summarize their understanding of the origins and the formation of the solar system. Throughout this series of activities students keep a visual journal to highlight the main concepts they explore. The students record their ideas in the form of a comic strip, drawing and captioning new panels at the close of each activity. Each panel represents important ideas or concepts they learned.

Rationale

This series of integrated activities employs multiple learning styles to allow all students to gain knowledge and demonstrate their understandings of the origins of the solar system and the differentiation of the planets into terrestrial and gas giants. The activities anchor abstract scientific concepts to concrete student experiences through kinesthetic and visual representations. The kinesthetic role-play provides students the opportunity to internalize stages of the solar system. The on-going documentation of their learning, in the form of a comic strip, allows students to consolidate and communicate the body of knowledge developed through the collection of activities that comprise this lesson. The integrated nature of the activities leads students through increasingly challenging concepts at a gradual pace, each idea building upon the previous.

Curriculum Connections

The Juno Origins Module contains one lesson with several integrated activities that explore the origins, composition, and evolution of our solar system from an interstellar cloud to differentiated planets. Using kinesthetic activities and models crafted from simple materials students model the stages of solar system evolution, planetary composition, and the process of differentiation of the solar system into a star, terrestrial planets, and gas giants (*Walk this Way, Walk this Way AGAIN,* and *Making a Frost Line: A Model of Early Solar System Structure*). Mathematical calculations provide the basis for modeling the composition of stars, Earth, and Jupiter using simple materials (*Modeling the Composition of the Solar System, Earth, and Jupiter with Beads*).

Juno Mission Connection

Theories about solar system formation all begin with the collapse of a giant cloud of gas and dust, or nebula, most of which formed the infant sun. Like the sun, Jupiter is mostly hydrogen and helium, so it must have formed early, capturing most of the material left after our star came to be. How this happened, however, is unclear. Did a massive planetary core form first and gravitationally capture all that gas, or did an unstable region collapse inside the nebula, triggering the planet's formation? Differences between these scenarios are profound.

Even more importantly, the composition and role of icy planetesimals, or small proto-planets, in planetary formation hangs in the balance – and with them, the origin of Earth and other terrestrial planets. Icy planetesimals likely were the carriers of materials like water and carbon compounds that are the fundamental building blocks of life.

Unlike Earth, Jupiter's giant mass allowed it to hold onto its original composition, providing us with a way of tracing our solar system's history. Juno will measure the amount of water and ammonia in Jupiter's atmosphere and determine if the planet actually has a solid core, directly resolving the origin of this giant planet and thereby the solar system. By mapping Jupiter's gravitational and magnetic fields, Juno will reveal the planet's interior structure and measure the mass of the core.

Instruments and Data

Juno's Microwave Radiometer – MWR – will determine the abundance of water deep in Jupiter's atmosphere and obtain measurements of ammonia as well. These observations will allow scientists to determine whether the water abundance on Jupiter is three times that of the Sun or nine times that of the Sun. These differences in abundances help constrain ideas about the formation of the planet.

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's history
- 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
2. The Nature of Mathematics
    A. Patterns and Relationships
    B. Mathematics, Science, and Technology
    C. Mathematical Inquiry

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
9. The Mathematical World
    A. Numbers
    B. Symbolic Relationships
    C. Shapes
    D. Uncertainty
    E. Reasoning
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 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
- Benchmark 3: Knows characteristics of the Sun and its positioning the Universe.
- Benchmark 6: Knows that the Universe consists of many billions of galaxies (each containing many billions of stars) and that incomprehensible distances (measured in light years) separate these galaxies and stars from one another and from the Earth

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 2: Knows that elements often combine to form compounds
- Benchmark 4: Knows that substances containing only one kind of atom are elements and do not break down by normal laboratory reactions; over 100 different elements exist

- Benchmark 8: Knows that substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties

Standard 10: Understands forces and motion

- Benchmark 1. Understands general concepts related to gravitational force
- Benchmark 4. Understands effects of balanced and unbalanced forces on an object's motion
- Benchmark 5. Knows that an object that is not being subjected to a force will continue to move at a constant speed and in a straight line

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

Number & Operations

- Work flexibly with fractions, decimals, and percents to solve problems
- Understand and use ratios and proportions to represent quantitative relationships
- Develop an understanding of large numbers and recognize and appropriately use exponential, scientific, and calculator notation

Measurement

- Understand both metric and customary systems of measurement;
- Understand relationships among units and convert from one unit to another within the same system;
- Understand, select, and use units of appropriate size and type to measure angles, perimeter, area, surface area, and volume.

Process Standards

- Problem Solving
- Communication
- Connections
- Representation

McREL Compendium of Standards and Benchmarks

Mathematics

Standard 1: Uses a variety of strategies in the problem-solving process

- Benchmark 2: Uses a variety of strategies to understand problem-solving situations and processes
- Benchmark 5. Represents problem situations in and translates among oral, written, concrete, pictorial, and graphical forms
- Benchmark 6. Generalizes from a pattern of observations made in particular cases, makes conjectures, and provides supporting arguments for these conjectures
- Benchmark 9. Uses a variety of reasoning processes to model and to solve problems

Standard 2: Understands and applies basic and advanced properties of the concepts of numbers

- Benchmark 1. Understands the relationships among equivalent number representations
- Benchmark 7. Understands the concepts of ratio, proportion, and percent and the relationships among them

Standard 3: Uses basic and advanced procedures while performing the processes of computation

- Benchmark 1: Adds, subtracts, multiplies, and divides integers, and rational numbers.
- Benchmark 4. Selects and uses appropriate computational methods for a given situation
- Benchmark 5. Understands the correct order of operations for performing arithmetic computations
- Benchmark 6. Uses proportional reasoning to solve mathematical and real-world problems
- Benchmark 8. Knows when an estimate is more appropriate than an exact answer for a variety of problem situations

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

- Benchmark 5. Understands the concepts of precision and significant digits as they relate to measurement
- Benchmark 8. Selects and uses appropriate estimation techniques (e.g., overestimate, underestimate, range of estimates) to solve real-world problems

Standard 9: Understands the general nature and uses of mathematics

- Benchmark 2. Understands that mathematicians often represent real things using abstract ideas like numbers or lines; they then work with these abstractions to learn about the things they represent

Common Core State Standards for Mathematics

Ratios and Proportional Relationships

- Understand ratio concepts and use ratio reasoning to solve problems.

The Number System

- Compute fluently with multi-digit numbers and find common factors and multiples.

Ratios and Proportional Relationships

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

Origins of Solar System and the Astronomers Periodic Table

Note to the Teacher

The lesson guide parallels the slideshow, *Origins of the Solar System and the Astronomers' Periodic Table*. 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.

Assessing Prior Knowledge

1) Before beginning the module or one of the lessons, a **KWL** (What the Students Know, What the Students Want to Learn, and What the Students Learned) could be utilized in order to assess students' level of prior knowledge, misconceptions, and interest regarding the origins of our solar system. Either as a whole class or individually, the teacher could ask students to complete the **K** and **W** portions of the **KWL**. At the end of the module or lesson, the teacher can conduct the **L** portion of the **KWL** to formatively assess student knowledge and to address any misconceptions.

2) As this lesson may contain unfamiliar vocabulary for the students, several vocabulary development strategies could be helpful. The teacher may choose to use a Concept Definition Map or a Frayer model. Examples of these strategies are included at the end of this lesson.

Introducing the Lesson

Explain to students that in this lesson, they will study the formation and composition of the solar system and compare and contrast the two types of planets that formed – terrestrial and gas giants – using Earth and Jupiter as prime examples of each.

Activity Ia: How did the Solar System Form?

Explain to students that they will view images of space to review their existing knowledge of the formation of stars and solar systems and to begin to study the process.

Orienting Students to Images of Objects from Space

If your students are not familiar with images of astronomical objects, take the time to orient them to the images. The notes included with each slide provide an explanation of the image and features to notice.

Corresponding Slide Number	Instructional Steps
1-3	1. Using the slideshow, *Origins of the Solar System and the Astronomer's Periodic Table*, show students several images of nebulae. Prompt a discussion about solar system formation by asking and recording students answers to the questions: • What do you think these images represent? *Note: Help students to articulate their responses by asking them follow-up questions that probe their reasoning.* • How do you think the solar system formed? *Note: At this point in the lesson, let students brainstorm responses. The lesson addresses this question through a series of activities.* 2. If students struggle to interpret the images, point out some of the features such as bright points of light (developing stars) and interstellar clouds (masses of gas and dust). 3. Explain that the cloud collapses upon itself. The collapse of the cloud forms stars and sometimes solar systems.
4	1. Pause slide show. Play the video, James Webb Space Telescope: Planetary Evolution. 2. The video lasts 3:20 minutes. Watch it through with or without pausing, as appropriate for your class. 3. Review the video by discussing the following questions with students: • Where do stars form? *Answer: In gas clouds or nebula called "stellar nurseries".* • What are "proto-stars"? *Answer: Young stars.* • In what order do scientists think planets form? *Answer: Gas giants form earlier than terrestrial planets.*

Activity Ib: Walk this Way – A Kinesthetic Model of Solar System Formation

Explain to students that they will work together to model the collapse of a gas cloud and formation of a solar system. Explain that each student will represent a particle of dust or gas that makes up a nebula.

> **Digital Opportunity**
> Have a student film the movement of the class from start to finish. Use the film to view changes in the pattern of movement.

1. Take the class to a large, open space, free of hazardous obstacles.
   - *If the space does not contain walls define and mark its boarders.*
2. Explain the rules of behavior for each atom/student. (*Note: These rules represent a simplification of the movement of the materials in a nebula.)*
3. If you are outside define the borders of the space.
   Ask students to spread out within the space. Students should stand at least an arm's

length from their neighbors.

4. To ensure a random start direction, ask students to briefly and ***slowly*** spin in place before they start walking.
5. Observe students to ensure that they are following the rules and behaving in a safe manner.
6. Allow students to collide once or twice. Ask them to pause in their walking. Confirm that they are following the rules to avoid true collisions.
7. Ask one or more volunteers to describe the general motion of the individuals in the group and to explain the role of each individual. *(At this stage most students will be facing and thus walking in different directions. The individuals in the group should be moving in many directions, creating a sense of random movement of particles.)*
8. Indicate that students should begin moving again. Allow them to walk and collide several times. *(After each collision, more and more students should walk in the same direction. Over time, the movement of the students should become organized such that they circle a central point.)*
9. Call a halt to the game once all or most of the individuals are walking in the same direction.
10. As a class, discuss the changes in the movement and the pattern that arose. Students should note that the movement began as random and ended with all/most of the individuals walking in the same direction. Explain that during the collapse of a nebula to form a solar system, the particles in the cloud eventually begin to move in the same direction, rotating around a central point.
11. Return to the classroom.

RULES

- Students must walk slowly
- Students start by walking in a random direction.
- Define a "collision" as walking into another person or the walls/boarder of open space. Explain that before colliding individuals ***must stop without touching***
- Explain that each person turns 45 degrees to their right and continues walking
- Explain that students should continue walking and colliding until given the command to stop.

Summarize and Reflect: Origins of the Solar System Comic Strip

Throughout this lesson, students will return to the construction of a comic strip to record and consolidate the main concepts addressed by each activity.

Corresponding Slide Number	Instructional Steps
5	1. As a class, summarize the main concepts that have been addressed through discussion and activity thus far. List the main points on the board. 2. Distribute and review the student page, *Origins of the Solar System Comic Strip*. Explain to students that they will create a comic strip to

	represent the main scientific concepts they learn from each activity in this module. 3. Using an overhead transparency or large sheet of paper, model creating a panel for the comic strip. • Draw the borders of a panel. • Invite students to volunteer ideas for images and text for the first panel in the comic strip. Suggest that students refer to the list generated above. • Select one idea and draw and caption the panel. 4. Provide students with drawing paper, pencils, coloring supplies, and rulers to draw their own panels to represent the main ideas and concepts associated with solar system composition and formation. • (Modification) For students who find it challenging to draw, allow them to cut and paste images from magazines into their comic strip panels. Students can write the captions or print them from a computer. 5. (Optional) Individuals can share their work with the class or within small groups. Encourage students to *briefly* explain their panels with the goal of demonstrating the main ideas each student identified and their individual methods for expressing the concepts. 6. Collect or have students store their comic strips for later use.

Activity IIa: The Astronomer's Periodic Table

Explain to students that in this activity they will use mathematics and simple materials to create models that represent the composition of a nebula. Remind students that in the previous activity, they viewed images and role-played the behavior of the materials that constitute a nebula.

Corresponding Slide Number	Instructional Steps
6-14	1. Ask students, *"What is the composition of the Universe?"* Point out that the gas cloud that collapsed to form the solar system produced the Sun, terrestrial planets, and gas giants along with a number of other objects. Ask students to consider what these objects (stars and planets) are made of. Record their ideas on the board. 2. Review or introduce the periodic table of the elements to your students. Explain that the table represents known natural and synthetic pure chemicals. 3. Next, introduce the concept of the "The Astronomer's Periodic Table". Explain that if the periodic table were organized based on observations of the composition of the Universe, hydrogen would be the most abundant followed by helium. 4. Use slides 11-14 to help students visualize the composition of the Universe. Ask students to closely examine the charts. Ask students to interpret the images and explain what each represents. 5. Slide 11: Key Questions and Observations to Discuss • How is the data organized? *Answer: The pie chart expresses the amount of each element in parts per million atoms of hydrogen.* • Why use parts per million atoms of hydrogen? *Answer: The concentration of hydrogen in the Universe is so great and the concentration of other elements so minimal, that we compare a million atoms of hydrogen to a few atoms of other elements.* • What are the abundances of some of the elements in comparison to hydrogen? *Answer: There are 68,000 atoms of helium for every 1,000,000 atoms of hydrogen, the second most common element in the Universe. Of the ten most abundant elements in the Universe, eight (oxygen through sulfur) occur in such small amounts that a separate pie chart shows their abundance in parts per million.* 6. Slide 12: Key Questions and Observations to Discuss • How is the data presented on this chart? *Answer: In this*

	table, the number of atoms of hydrogen is compared to one atom of each element. This provides a ratio of hydrogen atoms to atoms of other elements. For example, the ratio of atoms of helium to hydrogen is 1:15 whereas the ratio of sulfur to hydrogen is 1:52,632. • How does this representation help us understand the composition of the Universe? *Answer: This chart provides a different way to visualize the composition of the Universe. It shows the proportion of hydrogen to one atom of each of the other elements.* 7. Slide 13: Key Questions and Observations to Discuss • What does this slide show? *Answer: This slide provides a different way to visualize proportion of hydrogen atoms to oxygen atoms (1449:1), in the Universe. Oxygen is the third most abundant element in the Universe. Even so, there are 1,449 hydrogen atoms for each oxygen atom.* • Why do you think the slide shows oxygen and not one of the other elements? *Answer: Oxygen was chosen because 1,449:1 is a challenging ratio to depict but, not as challenging as other proportions. Also, oxygen is an element that students should recognize from their studies. Oxygen makes up about 21% of the atmosphere of Earth and about 30% of the mass of Earth.* 8. Slide 14: (Optional) If students find it difficult to grasp the comparisons presented in the other images, remind them that they already know a lot about proportion. They compare denominations of currency daily.

Activity IIb: Modeling the Composition of the Universe, Earth, and Jupiter with Beads

Explain to students that in this activity they will use beads to represent the various elements and/or compounds that compose the Earth, Jupiter, and the Universe as a whole.

Corresponding Slide Number	Instructional Steps
15-17	1. Explain to students that the composition of the Earth, Jupiter, and the Universe vary. Ask students to compare and contrast the compositions listed on slide 15. 2. Distribute and review the student page, *Modeling Composition with Beads*. Explain that in this activity, students will compare and contrast the composition of Earth, Jupiter, and the Universe. Explain that they will represent the composition of each with beads – each bead represents a unique element or compound. 3. As a class, review the tables on the student pages. Each table shows the abundance, by percent, of several elements and/or compounds for Earth, Jupiter, and the Universe. 4. Explain that students will calculate the number of beads for each element or compound and place that number of beads in each bag. ***5.*** Assign each element or compound a specific bead (either color or shape). ***Beads will vary based upon available resources.*** 6. Assign students to work in pairs or small groups. 7. Orient students to the location and distribution methods for the materials. 8. Allow time for students to calculate the number of beads for each substance and to place these beads in their respective bags. Remind students to check their calculations, complete the table, including creating a key to indicate the bead assigned to each element or compound. 9. Once teams have constructed their bags and completed their responses to each question call the class to attention to review student work. Ask for volunteers to share their responses to the questions and share their process for calculating the number of beads of each type per bag.

Summarize and Reflect

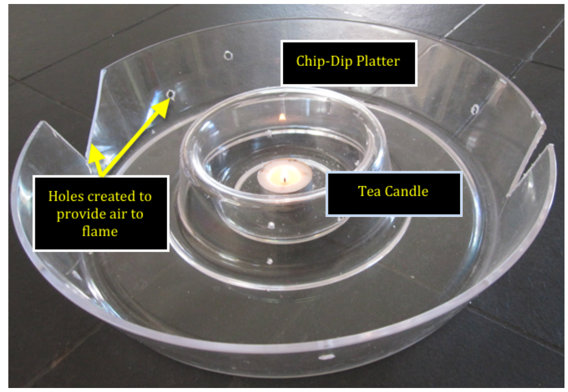
Ask teams to tape or pin their bags to the wall of the classroom. Allow students to circulate around the room to view the composition of each bag. This provides students with the opportunity to compare their efforts to those of their peers and to compare results. Ideally, each set of three bags would be identical.

Ask students what might account for any variation between the sets of bags. Students may recognize that all the sets of bags should be identical. Variations in the bags might result from miscalculations or miscounting on the part of individuals.

Origins of the Solar System Comic Strip

1. Explain to students they will update their comic strip with additional panels that depict the main ideas they have addressed since they last worked on the comic strip.
2. As a class, brainstorm and list the main ideas addressed since students last worked on their comic strip. Key concepts from this activity include:
   - The composition of the Universe, Earth, and Jupiter are very different.
   - 74% of the Universe is hydrogen; helium (24%) is second most common element ***by mass*** and the remaining elements occur in trace amounts.
   - If the periodic table were revised to reflect the relative amounts of each element, it would appear very different.
3. Discuss ideas for images and text to place in the new panels to represent the composition and distribution elements throughout Earth, Jupiter, and the Universe and the idea of the Astronomer's Periodic Table.
4. Redistribute or ask students to take out their *Origins of the Solar System Comic Strip.* Allow time for students to update their comic strips and to reflect on recently acquired knowledge.
5. (Optional) Ask individuals to share their work with the class or within smaller groups. Encourage students to briefly explain their panels with the goal of demonstrating the main ideas each student depicted and their individual methods for expressing the concepts.
6. Collect or ask students to store their comic strips for later use.

Demonstration: Making a Frost Line – A Model of Early Solar System Structure



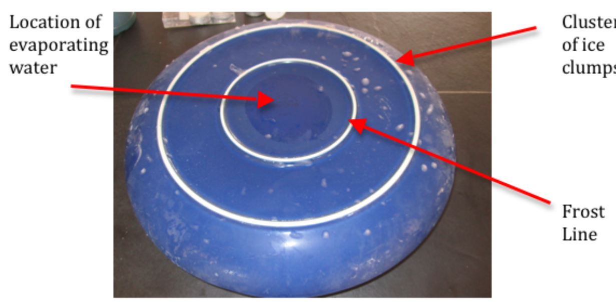
Advanced Preparation

1. Spray the dark ceramic platter with a fine mist of water.
2. Without disturbing the water droplets set the platter in the freezer.
3. Allow the water to freeze to the platter. (The time will vary from 5-30 minutes depending upon the temperature of your freezer).

To Do and To Notice

Demonstration Procedures

1. Light the candle and place it within the center of the support structure (chip-dip platter)
2. Remove the platter from the freezer.
3. Center the platter over the flame and on support structure.
4. Monitor the candle to ensure it remains lit throughout the next several minutes.
5. (Optional) Take a series of photographs to record changes in the pattern of ice on the surface of the platter.



To Notice: Observe the initial pattern of frozen water on the surface of the platter.
To Do: Observe and record changes in the pattern of the frozen water. If you have access to a digital camera, take a series of photographs to use for review and reflection.
To Notice: Observe that the frozen water droplets initially appear as small, fine, individual clumps of ice equally distributed across the surface of the platter. As the temperature of the ceramic plate increases some of the ice melts and the resulting water evaporates. The ice closest to the candle flame, at the center of the platter melts first while ice at a distance from the flame remains solid longer.

What is Going On?

The demonstration **models** the process of solar system differentiation. Heat transferred from the candle warms the platter. The platter conducts the heat from above the flame outward toward the rim. Ice above or nearest the source of heat melts and evaporates first. The result is that the area closest to the flame becomes barren of water while ice clumps remain toward the rim of the platter. This process models the formation of a frost line early in the evolution of the solar system. Early in the formation of the solar system, the Sun ignited. It began to produce energy through thermonuclear fusion. The energy radiated outward from the Sun. Volatile elements nearer the Sun were forced beyond the frost line where they condensed and added to the formation of gas giants. Heavier, terrestrial material remained nearer the Sun in the inner solar system.

Summarize and Reflect: Origins of the Solar System Comic Strip

1. Explain to students that based upon class discussion and the demonstration of the formation of a frost line, students will update their comic strip with additional panels.
2. As a class, brainstorm and list the main ideas addressed during the demonstration and since students last worked on their comic strips. Key concepts from this activity include:
   - Differentiation of the planets into two types – terrestrial and gas giants
   - Differentiation occurs due to temperature variation
   - Heat from the newly "ignited" Sun drives the more volatile elements beyond the frost line
   - Elements that condense at higher temperatures remained closer to the Sun to form terrestrial planets
   - Elements that condensed in the cooler regions of the solar system, beyond the frost line formed gas giants
3. Discuss ideas for images and text to place in the new panels. Help students to plan ways to depict the frost line, the variations in temperature, and any new ideas they have about the distribution of elements and compounds throughout the solar system.
4. Redistribute or ask students to take out their *Origins of the Solar System Comic Strip.* Allow time for students to update their comic strips to reflect recently acquired knowledge.
5. (Optional) Ask individuals to share their work with the class or within smaller groups. Encourage students to *briefly* explain their panels with the goal of demonstrating the main ideas each student identified and their individual methods for expressing the concepts.
6. Collect or ask students to store their comic strips for later use.

Activity III: Walk this Way *AGAIN* – Extending the Kinesthetic Model of Solar System Formation

Explain to students that they will repeat the kinesthetic exercise of nebula collapse and solar system formation. In this role-play students will add steps to express the stages of solar system formation based upon the knowledge gained from activities II and III.

The purpose of repeating and extending this activity is to depict the differentiation of the solar system into a star, terrestrial planets, and gas giants. To do this, students must also address the challenge of modeling the proportion of the various elements and compounds with only 25-30 students.

1. As a class, review students *Origins of the Solar System Comic Strip.* The comic strip is a visual representation of the kinesthetic activity. It serves as a "storyboard" for the role-play.
2. Remind students that the first time they performed *Walk this Way*, they acted out only early stages of solar system formation: steps a-c, at right. They reached the stage where the majority of the material in the nebula circled a central point.
3. Explain that students will repeat the *Walk this Way*, adding the next steps of solar system formation: differentiation into a star and two types of planets.
4. As a class, discuss *if or how* a group of students can accurately represent the composition of the nebula when 74% is hydrogen and the remainder helium and trace amounts of other elements. Ask students:
   - "How or can we represent the relative composition of the nebula with the students in our class? *Answer: It is difficult to represent the composition accurately with so few individuals.*
5. "If the nebula is 74% hydrogen, *estimate* how many students would represent hydrogen?" *Answer: Estimates will vary with class size. In a class of 30 students the hydrogen would be represented by 23 individuals.*
6. There are several possible approaches for representing the composition of the nebula that formed our solar system. We recommend the following options:

Sample Comic Strip Concepts

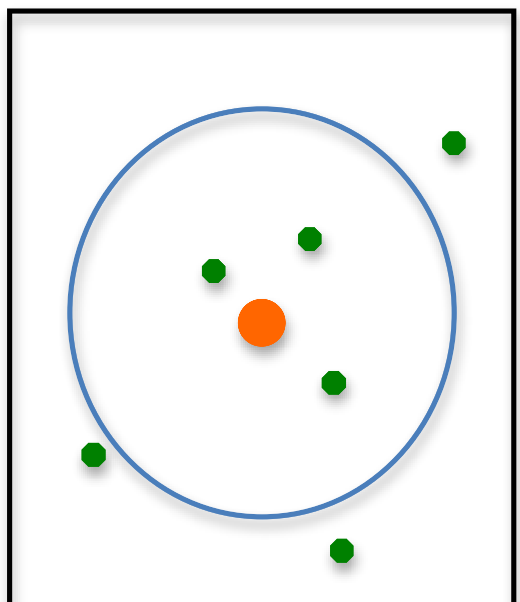
a. The solar system and planets formed from a nebula. A nebula is an interstellar cloud of gas and dust
b. The particles of gas and dust in a nebula move randomly at first
c. As the nebula collapses, the particles begin to move in a more organized fashion, they circle a central point.
d. The Universe is composed of hydrogen, helium, and trace amounts of other elements
e. The solar system contains a star and two types of planets: terrestrial and gas giants
f. Terrestrial planets and gas giants have very different compositions
g. Once the Sun becomes massive enough it initiates thermonuclear fusion. This creates heat and a solar wind that "blow" the more volatile elements (H and He) beyond the frost line where they condense.
h. Elements that remain solid at higher temperatures concentrated nearer the Sun and formed terrestrial planets
i. The more volatile elements concentrated beyond the frost line to form gas giants

i. Acknowledge that it is difficult to accurately represent the composition of the nebula with only 30 students. *Explain that* Walk this Way *is a model of solar system evolution, not composition*, thus the exact proportions of elements is less important than the stages of solar system formation. Assuming a class size of about 30, assign 15 students to represent hydrogen, 7 students to represent helium, and one student to represent each of the elements: oxygen, carbon, neon, nitrogen, magnesium, silicon, iron, and sulfur. **Remind students that these numbers do not represent the actual composition.**

ii. Work with a team of students. Invite 100 or more students to perform the activity, *Walk this Way*. Assign 74 of them to portray hydrogen, 24 to portray helium, and one each to represent each of the eight remaining elements. **Remind students that these numbers do not represent the actual composition.**

Once you have selected a method to represent the composition of the Universe, assign students to represent specific elements. Return to the open space and walk students through steps 2-9 of Activity Ib.

1. Upon reaching step 9, ask students to halt their movement.
2. Assign one student to play the Sun. Explain that this individual represents the Sun. Place the Sun in the center of the rotating pack of students.
3. **Add a new rule.** Explain that instead of colliding, when they meet, students will link arms and walk together, rotating around the Sun. Ask students to resume their movement following this and past rules. Allow students to walk around the Sun until several distinct groups form.
4. Halt student movement and ask them to observe how students are arranged in groups or clumps. Ask students:
   - What do the clumps of represent? *Answer: The clumps represent a concentration of gas and dust particles. The clumps will eventually form planets.*
   - What is the composition of the clumps? *Answer: Currently, the clumps are a mixture of various elements. Proportionally, most clumps will contain more hydrogen and helium.*
   - Since we know that the solar system contains two types of planets, terrestrial and gas giants, what do you think happens next? *Answer: The materials must differentiate with the most volatile, hydrogen and helium, condensing on the far side of the frost line to form gas giants while the denser materials condense nearer the Sun to form terrestrial planets.*

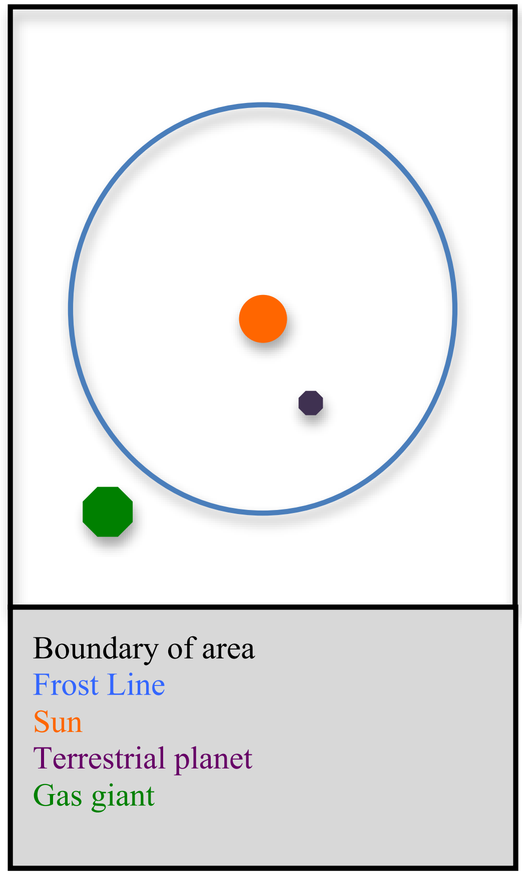


Boundary of area
Frost Line
Sun
Students/clumps of dust and gas

8. Define the location of the frost line as half way

from the Sun to the boundary of the space you are using. Your students and the space should appear similar to the image at right.

9. **Add a new rule.** Hand the Sun a flashlight. Explain that when the flashlight turns on, all but one atom of hydrogen and helium are "blown" beyond the frost line where they condense into one large group. All the remaining elements condense into one group on the Sun-side of the frost line. Allow students to resume their movement following this and past rules.
10. **Have the Sun turn on the flashlight.** Allow the students who represent hydrogen and helium to concentrate on the far side of the frost line. Allow the remaining students to concentrate on the near side of the frost line. Ask the students:
    - What do you think the turning on of the flashlight represents? *Answer: Turning on the flashlight represents the point in time when the Sun becomes massive enough to initiate thermonuclear fusion and create a solar wind. The wind sweeps the volatile elements past the frost line where they condense into gas giants, leaving the materials closer to the Sun to form terrestrial planets.*
    - What three objects does the class now represent? *Answer: The students should now form three objects: a star, a terrestrial planet, and a gas giant.*
    - What is the composition of each group? *Answer: The Sun is hydrogen and helium, the terrestrial planet is composed of the dense elements plus a little hydrogen and helium, and the gas giant is made of hydrogen and helium.*
    - Why do we have only one terrestrial planet and one gas giant? *Answer: It is difficult to model all the planets in the solar system with so few students*



Reflect & Summarize: Origins of the Solar System Comic Strip

1. Explain to students that they will review their comic strips to ensure that the panels represent all the key concepts addressed by the activities thus far. Note that the concepts address in the demonstration, *Making a Frost Line: A Model of Early Solar System Structure* and the second round of *Walk this Way* explore the same ideas, differentiation of the solar system into a star, terrestrial planets, and gas giants and the organization of the solar system by temperature differences, in different ways. As a result, new panels are optional.

2. Redistribute or have students take out their comic strips. Have students review their comic strips to ensure that they have completely represented the main ideas learned through each of the activities thus far in the lesson.
3. Collect or have students store their comic strips for later use.

Assessment Opportunities

This set of activities provides opportunities to assess students for knowledge and skills in multiple ways.

Activity 1a: How did the Solar System Form?

Formative assessment:
During the activity, the teacher could use the **Observation Rubric #1** to quickly assess student ability to communicate concepts and content to peers.

Activity 1b: Walk this Way – A Kinesthetic Model of Solar System Formation

Formative assessment:
During the activity, the teacher could use the **Observation Rubric #2** to quickly assess student ability to communicate concepts and content to peers and his/her participation in the whole group activity.

Activity 2a: The Astronomer's Periodic Table

Formative assessment:
During the activity, the teacher could use the **Observation Rubric #1** to quickly assess student ability to communicate concepts and content to peers.

Activity 2b: Modeling the Composition of the Universe, Earth, and Jupiter with Beads

Formative assessment:
During the activity, the teacher could use the **Observation Rubric #2** to quickly assess student ability to communicate concepts and content to peers and his/her participation in the activity.

Summative assessment:
The teacher can use the **Teacher Answer Key** to score student responses to the student worksheet *Modeling Composition with Beads*.

Activity 3: Walk this Way AGAIN – Extending the Kinesthetic Model of Solar System Formation

Formative assessment:
During the activity, the teacher could use the **Observation Rubric #2** to quickly assess student ability to communicate concepts and content to peers and his/her participation in the activity.

Origins Module Assessment

The teacher can use the **Comic Strip Rubric** to score student work.

Extensions

1. Using similar data, have students compare the composition of the Earth to the composition of other planets both terrestrial and gas giants.
2. Have students compare and contrast the various shapes and dimensions of solar systems throughout the galaxy using images from the Hubble and other space telescopes.
3. Have students investigate the current methods of identifying extrasolar planets, planets that orbit other stars. Have students explain why it is challenging to locate small planets, like Earth, whereas it is easier to identify gas giants, like Jupiter.
4. Use the background information on how scientists arrive at an estimate of the volume of the solar system to have students calculate the volume of the nebula from which our system formed.

Resources

Lin, Douglas N.C., The Chaotic Genesis of Planets, Scientific American, May 12, 2008.

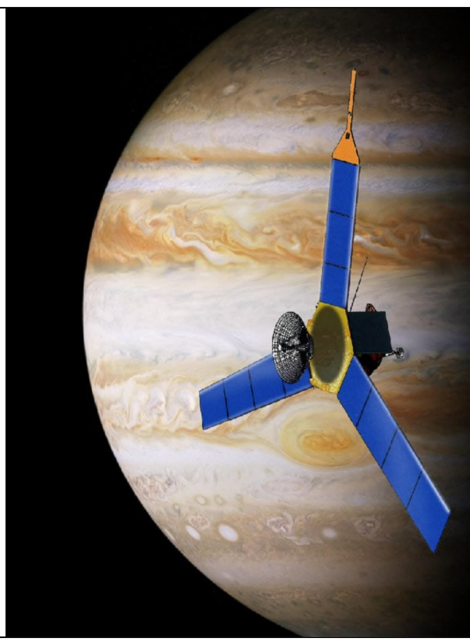
Background Information

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.

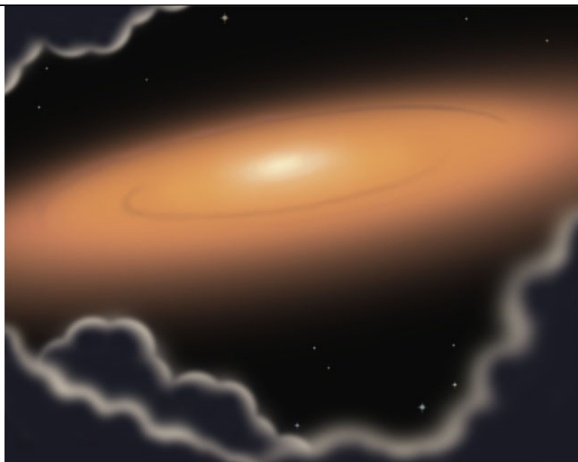
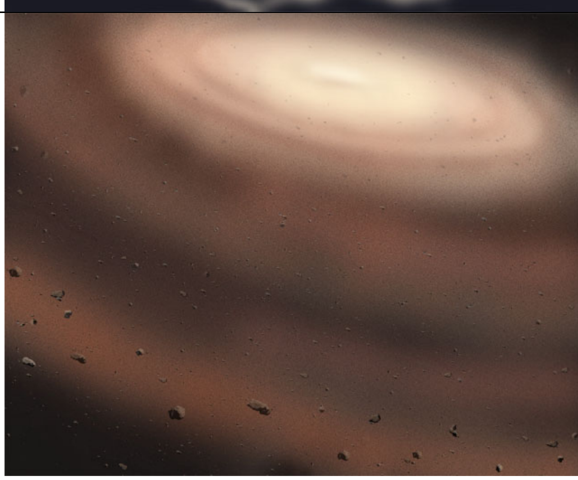
NASA's Juno mission to Jupiter is scheduled to launch in 2011 and will investigate not only the deepest mysteries of its unique personality, but it also will plumb the secrets of our solar system's origins.

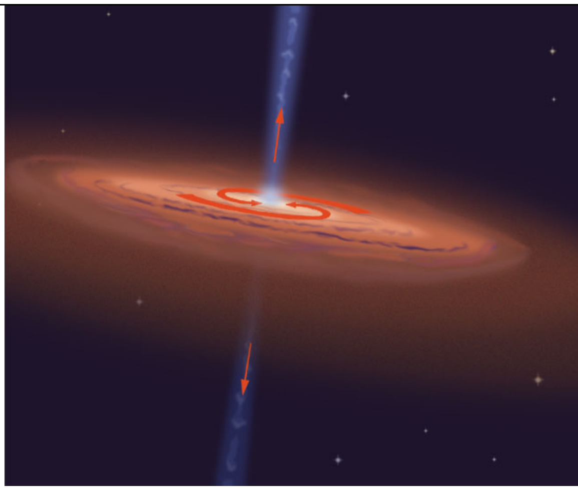


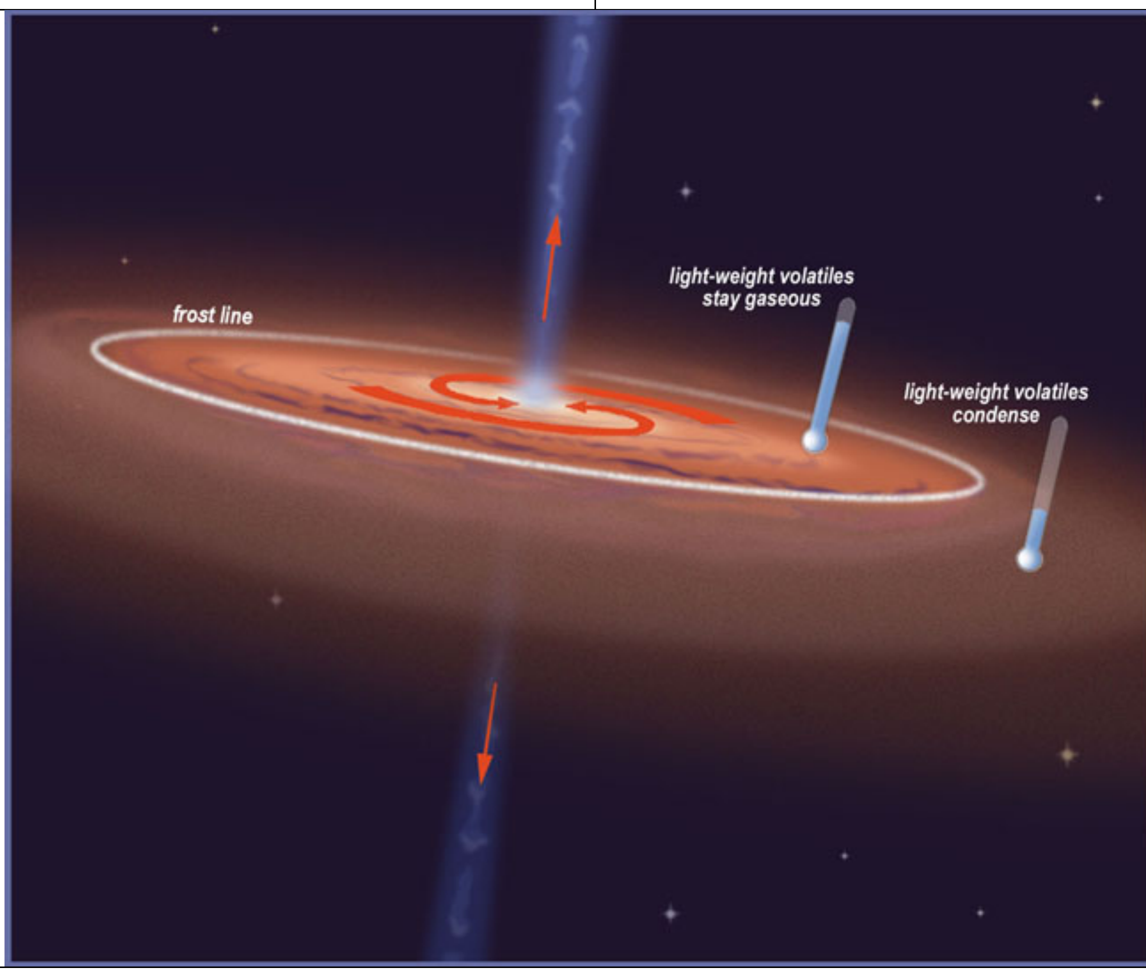
NASA's Juno mission will investigate Jupiter's interior, atmosphere, magnetosphere, and origins. By discovering clues about Jupiter's unique personality, the Juno mission will reveal answers about our solar system's birth. This artist's rendering shows the Juno spacecraft in front of Jupiter, where it will

arrive in 2016. Credit: NASA.

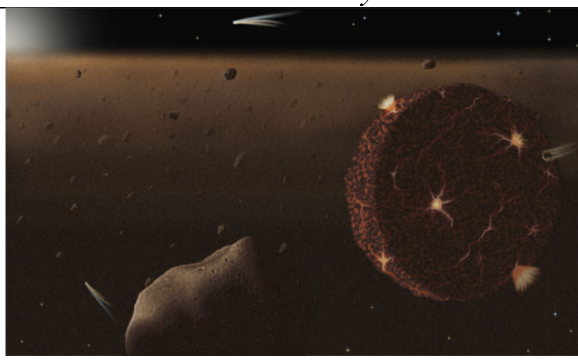
Our Solar System Was Born from a Cloud of Gas and Dust
Like all families, the members of our solar system family share a common origins story. Their story started even before our solar system formed 4.56 billion years ago. Their story started when the story started for every single thing in our Universe. Our Universe was born from the Big Bang about *13.5 billion* years ago. The first stars lived out their lives and eventually exploded, sending "star stuff" out into the cosmos. That original stellar material was recycled as another generation of stars, and many of these, too, exploded at the end of their lives. Our Sun is thought to be a third-generation star and our entire solar system is made of the recycled star stuff of previous star generations. Our Sun is a granddaughter of the very first stars!

	*Our solar system began forming about five billion years ago within a concentration of interstellar dust and hydrogen gas called a molecular cloud. The cloud contracted under its own gravity and our proto-Sun formed in the hot dense center. The remainder of the cloud formed a swirling disk called the solar nebula.* *Credit: Lunar and Planetary Institute.*
	*Within the solar nebula, dust and ice particles embedded in the gas moved, occasionally colliding and clumping together. Through this process, called "accretion," these microscopic particles formed larger bodies that eventually became planetesimals with sizes up to a few kilometers across. In the inner, hotter part of the solar nebula, planetesimals were composed mostly of silicates and metals. In the outer, cooler portion of the nebula, water ice was the dominant component.* *Credit: Lunar and Planetary Institute.*

	*The growing proto-Sun accumulated much of the original material from the nebula, leaving only a small portion to be incorporated into the planets.* The temperatures and pressures became so great at the center of the Sun that hydrogen atoms were forced together, combining to form helium. This nuclear reaction produced light as well as a stream of particles, called the "solar wind." These two outputs shaped the distinct destinies of the inner and outer planets. (We continue to enjoy the warmth provided by the Sun's light, and a weaker form of the solar wind persists today.) *Credit: Lunar and Planetary Institute.*



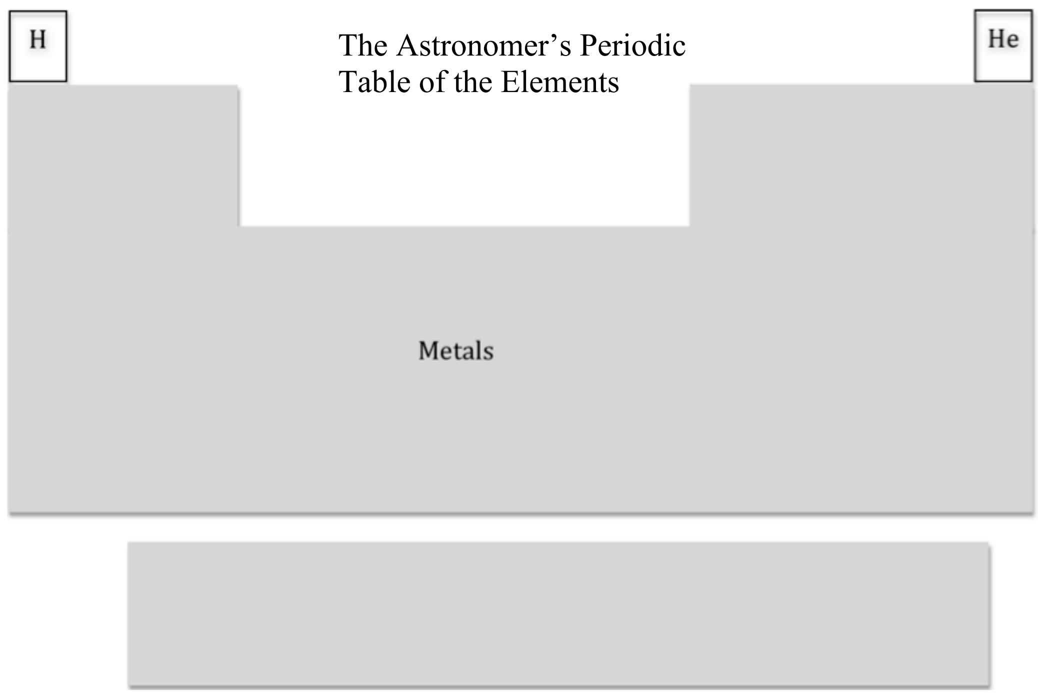
The Sun's light provided warmth to the objects in our solar system, especially to those in the inner solar system. There, it was too warm for lightweight volatiles, such as water and ammonia,

to condense. In addition, the solar wind pushed volatiles out of the inner solar system. When the volatiles reached the cold temperatures of the outer solar system — out beyond an Invisible boundary called the "frost line" — they condensed onto the nascent giant planets. Thus, the outer planets had rocks, metals, and volatiles available to accumulate, while the relatively warm, "windy" inner region was stripped of all but the densest materials, like rock and metal. *Credit: Lunar and Planetary Institute.*	
	*Planetesimals were massive enough that their gravity influenced each other's motions. This increased the frequency of collisions, through which the largest bodies grew most rapidly. Eventually, regions of the nebula were dominated by large protoplanets. The process of collision and accretion continued until only four large bodies remained in the inner solar system — Mercury, Venus, Earth, and Mars, the terrestrial planets. In the cold outer solar nebula, where our Sun's gravity was weaker, much larger protoplanets formed. The largest ones swept up other protoplanets, planetesimals, and nebular gas, leading to the formation of Jupiter, Saturn, Uranus, and Neptune.* *Credit: Lunar and Planetary Institute.*

Scientists still have many questions about our solar system's story, and Juno will help scientists begin to piece together the missing clues: How did the planets form quickly enough to escape the blast of the early Sun's intense solar wind, which would have swept gas and dust out of the growing planets' reach? Did the planets form in their present locations, or did the giant planets form closer to the Sun and, through complex gravitational interactions, migrate to their orbits of today?

The Astronomer's Periodic Table

Given the opportunity, astronomers might reorganize the periodic table of elements to reflect their observations of space. Approximately 99% of the ***volume*** of the Universe is composed of hydrogen. The next most abundant element, helium, comprises less than 1% of the Universe by volume. The remaining elements in the Universe occur in trace amounts. Some astronomers might even lump all elements other than hydrogen and helium into one group, the metals. The elements hydrogen and helium were created during the Big Bang. All other elements result from astrophysical events associated with stellar evolution.



It is difficult to convey the relative abundance of the ten most common elements in the Universe. It is hard for many to grasp a Universe composed of 99% hydrogen. Our reference point, the composition of Earth, complicates the situation. The Earth and its combination of solids, liquids, and gases composed of a variety of elements and compounds provides us with a very different experience than we would have elsewhere in space.

The tables and charts below provide several ways to express the proportion of hydrogen and helium to the other elements. All elements, helium through sulfur, are compared to hydrogen, the most abundant element in the Universe.

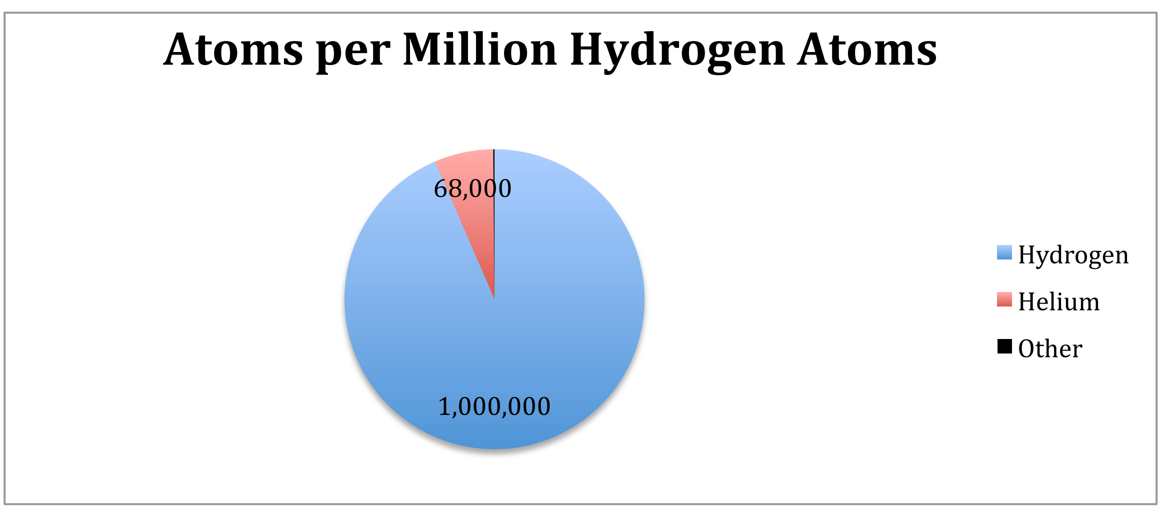
The Ten Most Abundant Elements in the Universe*

Element	Symbol	Atomic Number	Number of Atoms per Million Hydrogen Atoms	Number of Hydrogen atoms for each 1 atom of other elements
Hydrogen	H	1	1,000,000	
Helium	He	2	68,000	15
Oxygen	O	8	690	1,449
Carbon	C	6	420	2,381
Neon	Ne	10	98	10,204
Nitrogen	N	7	87	11,494
Magnesium	Mg	12	40	25,000
Silicon	Si	14	38	26,315
Iron	Fe	26	34	29,412
Sulfur	S	16	19	52,632

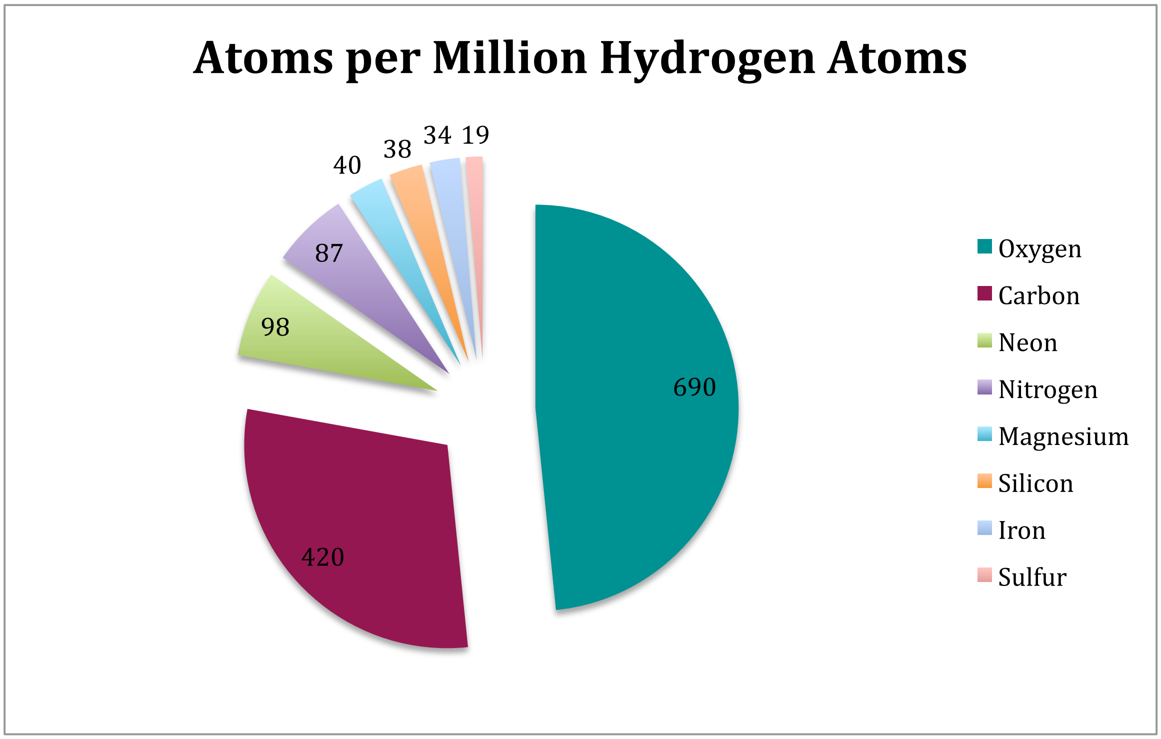
*Abundance by mole-fraction.

The table above lists the ten most abundant elements. One column compares the number of atoms of each element to 1,000,000 atoms of hydrogen, or ***parts per million***. The table also shows the number of atoms of hydrogen for each one atom of other elements. For example, for every 1,000,000 atoms of hydrogen there are 68,000 atoms of helium. The ratio of hydrogen to helium is 15:1. There are nineteen atoms of sulfur for each million atoms of hydrogen; a ratio of 52,632:1.

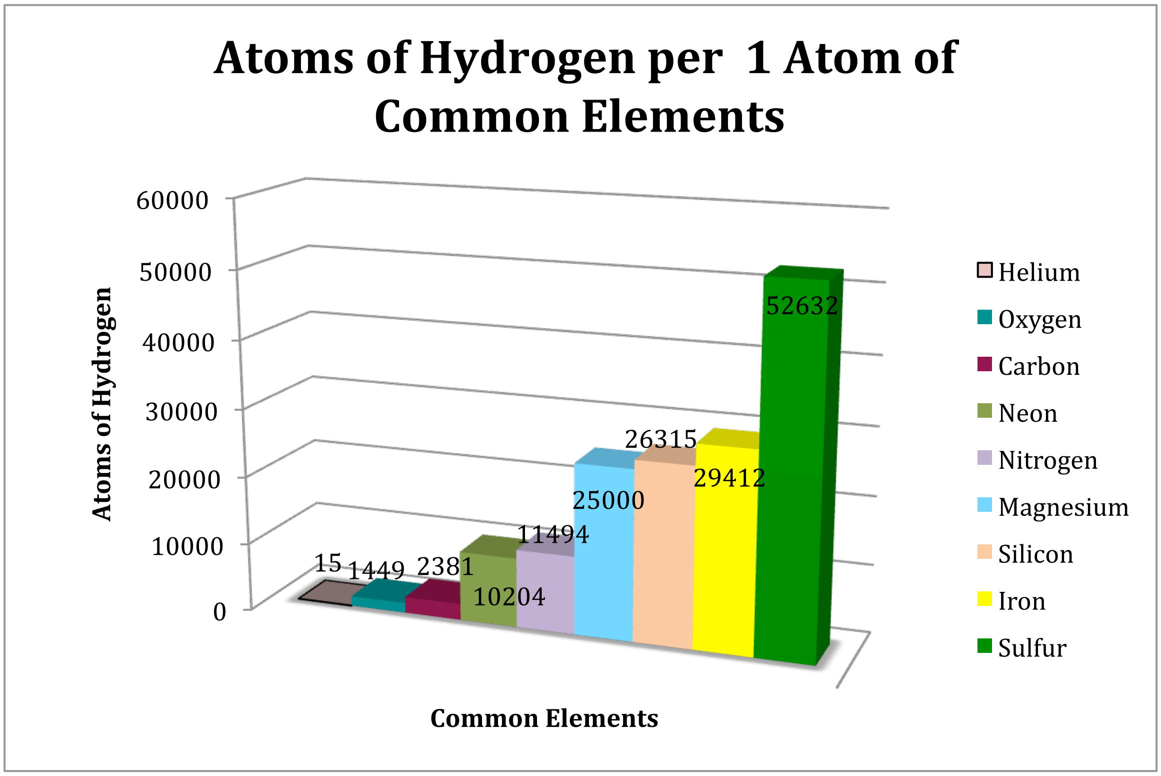
Charts provide a visual method for comparing the abundance of elements in the Universe. Different visual representations may help students to grasp the surprising lack of diversity in the composition of the Universe.



The above chart compares the number of atoms of helium (68,000) to 1,000,000 atoms of hydrogen. The remaining elements combined, listed as "other" are so few that the wedge that represents their portion of the chart appears as a line.



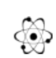
Here the "other" eight elements in the top ten appear in their own pie chart. As you can see, oxygen atoms while the third most abundant element in the Universe occur 690 times for every 1,000,000 atoms of hydrogen.



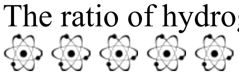
This chart compares one atom of each element to a corresponding number of atoms for hydrogen. There are 15 atoms of hydrogen to every one atom of helium. The ratio for hydrogen to sulfur is 52,632:1.

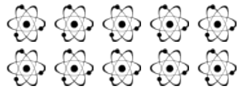
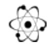
Students readily compare large numbers to small numbers when they manage money. Point out that they compare pennies to dollars. They know that there are 100 pennies for every 1 dollar. Can they calculate the number of pennies to a single, $100 dollar bill?

There are 100 pennies for each single dollar.
There are 100 single dollar bills for each $100 dollar bill.
Therefore, 100 pennies X 100 single dollars equals 10,000 pennies for a $100 bill; a ratio of 10,000:1

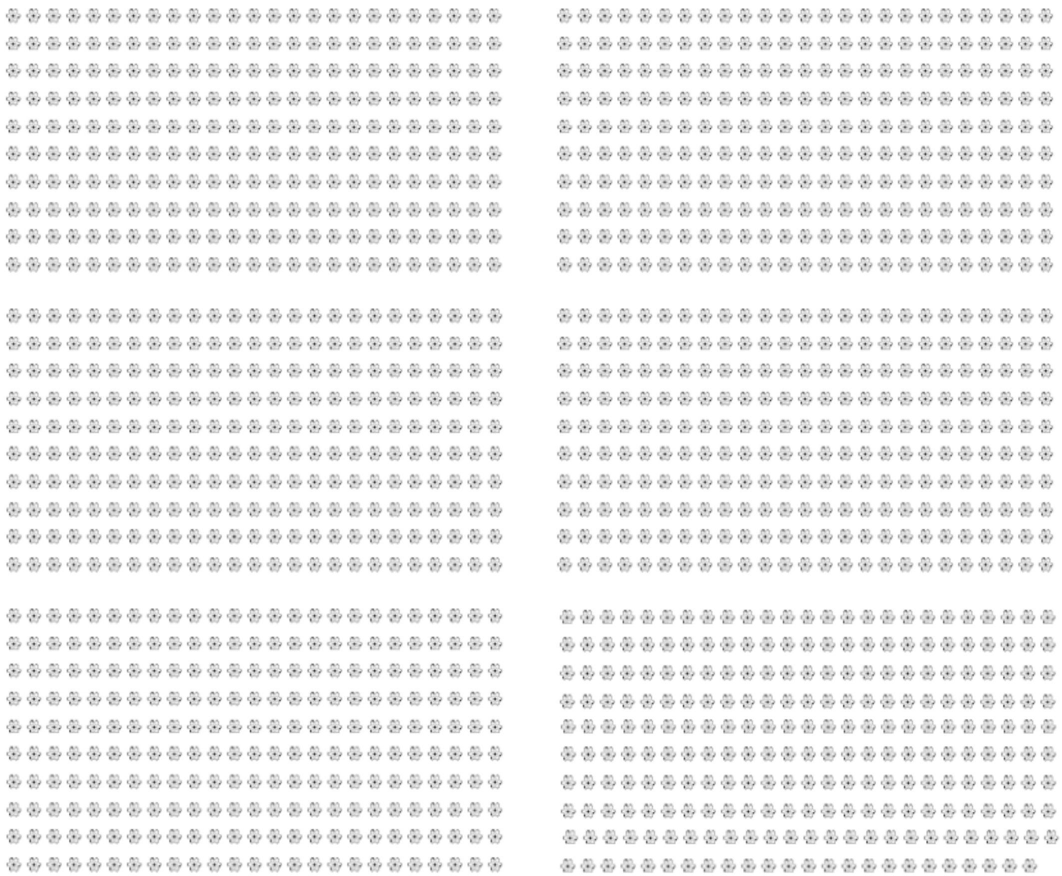
If students find it easier, have them draw the comparisons. In the images below, each  represents a single atom.

The ratio of hydrogen to helium appears as:



 to 

The Universe contains1,449 hydrogen atoms for each atom of oxygen:

 to 

In Activity IIb *Modeling the Composition of the Universe, Earth, and Jupiter with Beads* students compare the percent, by mass, of each element or compound found on Earth, Jupiter, and in the Universe. The composition of Earth is significantly different that that of Jupiter and the Universe. The similarity of compositions of Jupiter and the Universe suggest that Jupiter formed early in the evolution of the system and retained a composition more comparable to that of the nebula from which our solar system arose. Earth, located closer to the Sun and within the frost line, lost its more volatile compounds, creating a higher concentration of heavier elements and compounds.

How Much?: Describing Abundance

The abundance of an element (throughout the Universe) may be described in several ways: by mass, by volume, or relative to hydrogen. For example, helium:

24% by Mass
1% by Volume
68,000 atoms He to 1,000,000 atoms H (parts per million)

Composition of Earth, Jupiter, and the Universe by *Mass*

Element	Earth	Jupiter	Universe
Hydrogen		75.00%	75.00%
Helium		24.00%	23.00%
Oxygen	30%		1.00%
Nitrogen			0.10%
Iron	32%		0.11%
Sulfur	3%		0.05%
Aluminum	1%		
Calcium	2%		
Nickel	2%		
Silicon	15%		0.07%
Magnesium	14%		0.06%
Carbon			0.50%
Neon			0.13%
Argon			0.02%
Other	1%		
Compound			
Water		0.30%	
Ammonia		0.30%	
Methane		0.30%	
Other		0.10%	

How Big was the Nebula from which Our Solar System Formed?

The initial nebula from which our solar system formed was very large and had a low density. To estimate the size of the interstellar dust cloud from which our solar system formed, scientists make several assumptions. First, they assume that the mass of the nebula was 10^{32} kg or approximately 100 times greater than the mass of our Sun. Next they assume the temperature of the cloud and assign it a density. Temperature is given in degrees Kelvin.

	Scenario 1	Scenario 2
Temperature of Nebula	1000 K	10 K
Density of Nebula	10^{-12} kg/m^{-3}	10^{-18} kg/m^{-3}
Radius of Nebula	2,500 AU	250,000 AU

Recall that an astronomical unit, "AU", is equal to about 93 million miles (150 million kilometers), the distance from Earth to the Sun. Thus, the numbers for the radius of the nebula, shown above, demonstrate an enormous cloud. The distance from the Sun to Neptune is 2.8 billion miles (4.5 billion kilometers) or about 30 AU.

To help students understand the vast distances of space, consider the following table. The table shows travel times in days and years assuming a rate of travel of 500 mph or about the speed of a passenger airplane.

1 AU equals 93,000,000 miles.
93,000,000 miles/500 mph = 186,000 hours
186,000 hours/24 hours = 7,750 days
7,750 days/365 = 21 years

Point A to Point B	Distance	Days to Destination*	Years to Destination*
Earth to Sun	1 AU	7,750	21
Sun to Neptune	30 AU	232,500	630
Nebula Center to Rim for Temperature of 10 K	2,500 AU	19,375,000	53,082
Nebula Center to Rim for Temperature of 1000 K	250,000 AU	1,937,500,000	5,308,219

* Speed of a Passenger Airplane = 500 mph

Glossary