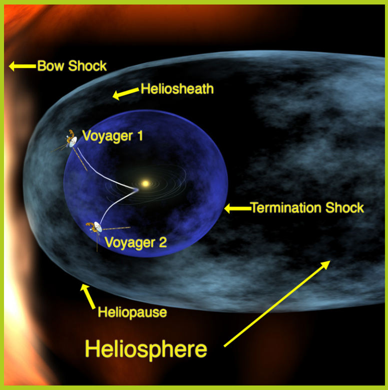
MAIN MENU

# ICE IN SPACE
# LESSON DIRECTORY

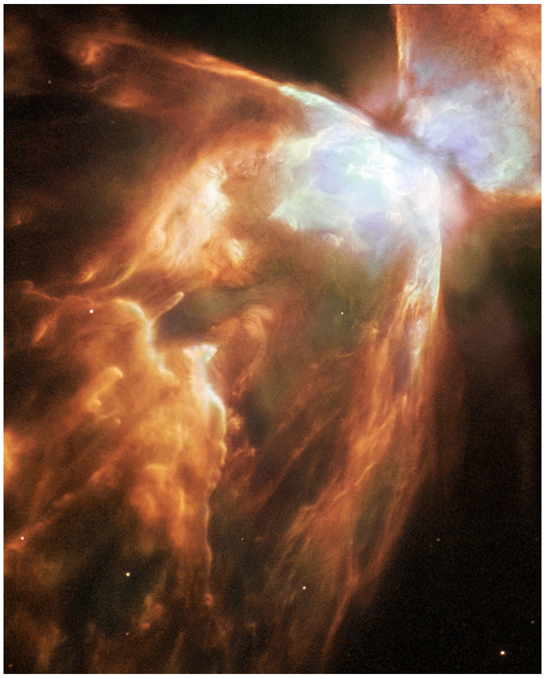


PHOTO GALLERY




This lesson develops pre-cursor understanding about space and how our Earth was formed along with the rest of the Solar System.

## SCIENCE & LITERATURE



Water ice is not only a product of star formation, but also part of the raw materials out of which star systems form, including our own. The discovery of the presence of ice in space suggests that water is more abundant in the universe than we once imagined.

> "Interstellar gas and dust, including ices and ice-and organic-mantled refractory dust grains, comprise the primary stuff from which the Solar System formed."
>
> —Louis J. Allamandola, et.al.,
> *Evolution Of Interstellar Ices*
> Space Science Reviews 90: 219–232, 1999.

> "The interstellar medium, with its molecules and dust particles, represents the raw material for forming future generations of stars which may develop planetary systems like our own."
>
> —J. Volp, European Space Agency
> Exo/Astrobiology Programme

> "In another discovery, Spitzer's infrared eyes have peered into the place where planets are born—the center of a dusty disc surrounding an infant star—and spied the icy ingredients of planets and comets. This is the first definitive detection of ices in planet-forming discs."
>
> —NASA News Release: 2004-275
> November 9, 2004

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## CONCEPT OVERVIEW

This lesson develops precursor understanding about space and how our Earth was formed along with the rest of our Solar System.

***Concepts:***

- Interstellar space
- Solar System formation
- Ice in space

***This lesson provides concrete experiences of:***

- Sharing ideas about space with others and drawing out science questions about space phenomena and space exploration events.
- Looking at space phenomena and space exploration events, observing and recording observations, specifically, viewing Hubble Space Telescope and ground-based pictures of molecular gas clouds.
- Enacting the solar nebular theory of how the Solar System formed and how ice was also formed in that process.

### PRE K–2 CONCEPTS

- Space includes all the stars, galaxies, and planets—even the Earth.
- Images of distant places in space show where new stars and solar systems are being formed.
- Special science instruments detect ice in space.
- The Solar System, including the Sun, the Earth, the Moon, all the planets, and other icy, rocky objects, formed in space a long time ago, about 4.6 billion years ago, from a whirling cloud and material from a supernova.

### GRADE 3–5 CONCEPTS

- Space includes all the stars, galaxies, and planets—even the Earth.
- Telescopes view star-forming events occurring in space.
- Special science instruments (infrared spectrometers) can detect ice in clouds in space and scientists can simulate these components in the laboratory.
- The solar nebular theory explains that the Solar System formed as a result of the interaction between a supernova event and an icy hydrogen-rich cloud, about 4.6 billion years ago.

## LESSON SUMMARY & OBJECTIVES

Awareness of space often begins in the encounter with the night sky. Even young children acquire notions about stars as distant places on vast unimaginable scales out in space. The imagery and language of space have become part of everyday experience. The lesson seeks to evoke students' already formed ideas and notions about space in order to move toward a scientific understanding of space and how Earth is situated as part of it.

***Objective 1: Notice that there are many ideas about space***

Human beings everywhere and in every time have wondered about space. Conceptions and attitudes about space have shaped whole civilizations. The era of space exploration began with the technological advances of the mid-twentieth century, and is expanding into the twenty-first century.

***Objective 2: Notice that scientific exploration of space tests ideas about space.***

The human and robotic exploration of space includes looking through telescopes, sending telescopes into space, sending orbiters around planetary objects, sending landers and rovers to explore the surfaces of other worlds, as well as sending astronauts to explore other worlds in person. Using all these technologies to explore the unknown and to retrieve data about space phenomena, scientists test their models and understandings about what space really is.

***Objective 3: Notice that the Solar System emerged out of a misty, icy cloud***

The solar nebular theory is the current scientific explanation of how the Solar System formed about 4.6 billion years ago. Similar processes have been observed in different places in space. Ice in the interstellar medium is one of the raw materials that form planets around star systems.

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## STANDARDS

### BENCHMARKS:

***4A The Physical Setting: The Universe***

GRADES 3–5, PAGE 63

- The Earth is one of several planets that orbit the Sun, and the Moon orbits around the Earth.

***11 B Common Themes and Models***

GRADE K–2, PAGE 268

- A model of something is different from the real thing, but can be used to learn something about the real thing.

GRADES 3–5, PAGE 268

- Seeing how a model works after changes are made to it may suggest how the real things would work if the same were done to it.
- Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representations can never be exact in every detail.

### NSES:

***Content Standard D Earth and Space Science: Earth in the Solar System***

GRADES 5–8, PAGE 160

- The Earth is the third planet from the Sun in a system that includes the Moon, the Sun, eight other currently recognized planets, and their moons, and smaller objects, such as asteroids and comets. The Sun, an average star, is the central and largest body in the Solar System.
- Most objects in the Solar System are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the Moon, and eclipses.

***Content Standard Unifying Concepts and Processes: Evidence, models, and explanation***

GRADES K–12, PAGE 117

- Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

***Content Standard A Science as Inquiry: Understanding about scientific inquiry***

GRADES 5–8, PAGE 148

- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.

***Content Standard D Earth and Space Science: Origin and evolution of the universe.***

GRADE 9–12, PAGE 190

- The origin of the universe remains one of the greatest questions in science. The “big bang” theory places the origin between 13 and 15 billion years ago, when the Universe began as a hot dense state; according to this theory, the universe has been expanding ever since.

GRADE 9–12, PAGE 189

- The Sun, the Earth, and the rest of the Solar System formed from a nebular cloud of dust and gas about 4.6 billion years ago. The early Earth was very different from the planet we live on today.

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## ESSENTIAL QUESTION

***What is space?***

What can we understand about space by considering our own experiences of the sky along with what we know about space? What can we say, draw, or write about space? What observations help us understand that ice is in space?

## ACTIVITY QUESTION

***How did the Solar System, including Earth, form in space?***

What evidence do we have about how the Solar System formed? How do we know that ice was part of that early formation process? What can we say, draw, or write about detecting ice in space?

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## BACKGROUND

***How did the Solar System form?***

The *Solar Nebular Theory* is the current explanatory model of the formation of the Solar System. While there are several variations in the details, and much that still needs to be learned, the basic explanation is widely accepted by scientists.

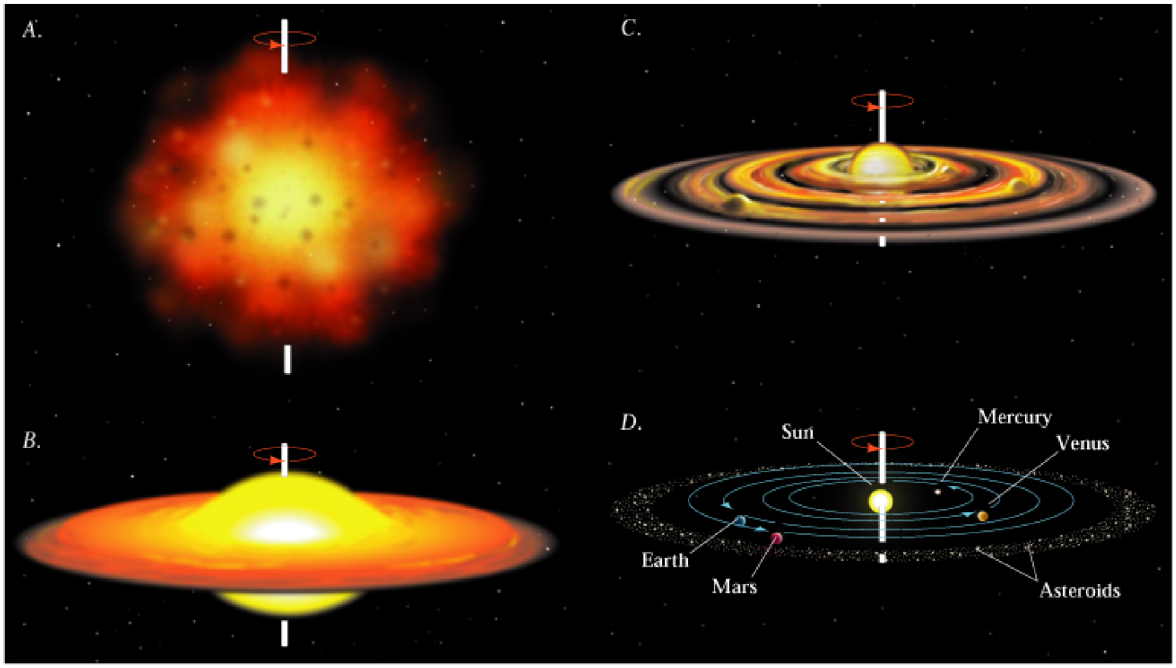
Key to illustration of the Solar Nebular Theory:

A. A supernova event stirs up a hydrogen-rich gas cloud.

B. Material gravitates toward the center becoming a protosun.

C. Through impacts, planets and objects accrete. Differences in gravity and density cause them to differentiate.

D. The Solar System we know today.






(This particular image of the Solar Nebular Theory is copyrighted by John Wiley & Sons)

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Stars are known to be composed mostly of hydrogen. Scientists infer that a large molecular cloud of hydrogen-rich gas was shocked by a supernova explosion of a nearby star, which sent things whirling. Eventually a disk of hot debris gravitated toward the center, the initial form of the Sun, the protosun. The root meaning of the Greek word *proto* means first.

***How do planets form?***
Planets may have formed as condensations of hot gaseous material into clumps that then swept up other debris by accretion until the interplanetary space was swept virtually clean by the orbital actions of the protoplanets. Another possibility is that as the gas whirled, variations in the density caused clumps that accreted to form the planets. By accretion or by condensation, or by some combination of the two processes, the planets formed. Rocky and icy debris cluttered the outer regions beyond. The exploration of primeval icy objects in space is partly intended to shed light on this story.

The Hubble Space Telescope and space-borne infrared telescopes (such as the Spitzer Telescope) have returned images that help us understand how our Solar System formed and more about the nature of molecular clouds in space.

Observations that show evidence of ice in space exploration images and in readings of interstellar space, suggest that water is not scarce, but abundant.

NASA is in the midst of several astrochemical investigations that are exploring interstellar ice models, especially at the NASA Ames Astrochemistry Laboratory. Scientists cannot travel to deep space to test how things work, but they can model interstellar conditions in the laboratory.

***What is an interstellar hydrogen cloud like?***
Within a hydrogen-rich cloud, the condition of the hydrogen determines what the ice mantles will look like. So, if the hydrogen is atomic then it will add to the less abundant elements, like carbon (C), oxygen (O), and nitrogen (N), making compounds like water ($H_2O$), methane ($CH_4$), methanol ($CH_3OH$), and ammonia ($NH_3$). If the hydrogen is molecular (as $H_2$) then the C, O and N have a chance to react with one another forming molecules like CO, $N_2$, and $O_2$. Once these ice mantles are exposed to radiation all kinds of reactions occur. Each compound absorbs infrared radiation differently.



It turns out that different elements absorb different wavelengths along the electromagnetic spectrum, of which visible light is a very small part. Wavelengths, such as the infrared, that our eyes cannot see, can be detected by special telescopes that use *spectrometers*. Comparisons between the infrared absorption bands seen by an infrared spectrometer through the telescope and as measured in the laboratory have been used to explore the possible range of molecules that compose these clouds. As a result infrared astronomers now know the composition of clouds many light years away.

Infrared observations, combined with realistic laboratory simulations, have revolutionized our understanding of interstellar ice and dust, are how star systems develop and emerge with planets as well.

***What is the evidence for ice in space?*** Initially, scientists did not expect to find evidence of ice circulating in interplanetary space. They thought water was scarce. But now, notions about the scarcity or abundance of ice in our Solar System or any solar system has been changing over the last few years. As scientists are better able to make observations with telescopes in the upper atmosphere and in Earth orbit, they have obtained data that they were not able to get from Earth itself.

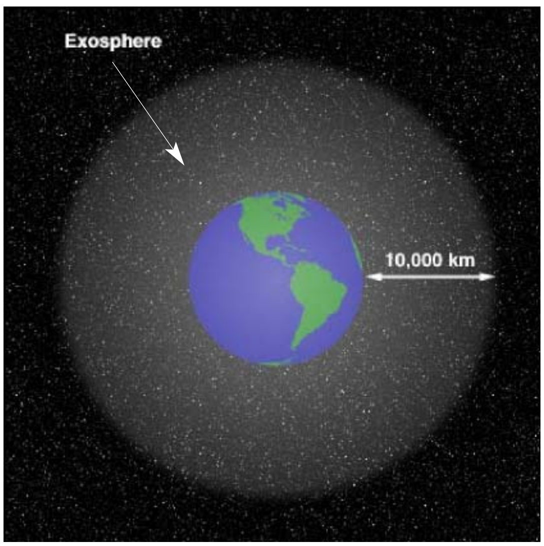
If water is abundant, perhaps the possibility of life is greater. So the search for life beyond Earth has focused on places where liquid water is present—in occlusions within icy comets, beneath the surface of ice-covered moons, in the past on Mars, and so forth. It turns out that hydrogen exists in abundance in cold gas clouds in interstellar space, the kind of place where stars and planets form. Infrared spectroscopy, able to pick up wavelengths corresponding to the presence of water ice, has established the presence of ice in these regions of interstellar space.

In between neighboring stars we find dense, optically dark, but infrared bright, molecular clouds that can transform into solar systems.

(Photo: NASA HST/Heritage)

With spectrometers, special instruments sensitive to different wavelengths of electromagnetic radiation, tuned to the infrared (IR), we can identify the molecules, but only if we observe from above 40,000 feet. At lower altitudes, water in the atmosphere obscures our view. So we must place the instrument in an airplane or into orbit.

Scientists at NASA Ames have created a laboratory environment that emulates interstellar space with clouds of ice crystals. When they exposed the clouds to simulated starlight, matching what would likely shine throughout interstellar space, they achieved a surprising result: nucleic acids, the building blocks of life's DNA, formed. If this result is borne out by further investigation, it may mean that the building blocks of life are as common as the clouds that can become solar systems.




***Where Does Space Begin?***

Even scientists will have different answers for this question. There is no clear cut boundary between the end of the atmosphere and the beginning of interplanetary space because the air gradually thins as you get higher and higher.

The Ansari X Prize was awarded to SpaceShipOne the first successful privately financed spaceship that reached space, defined as 100 kilometers (62.5 miles) up. NASA grants the status of astronauts to those who have reached at least 50 miles up. The Space Shuttle orbits at about 125 miles up. Some say space begins where the exosphere ends. The exosphere is the outermost region of the Earth's atmosphere, where atoms move fast but rarely collide because the density of atoms in this region is so low. The exosphere begins at 500 km (about 300 miles) and extends outward until it transitions with interplanetary space at roughly 10,000 km (about 6000 miles).

But you can also think of the Earth and all of us on Earth as traveling through space as part of the Solar System. So in a sense, we are all in space.

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## ACT OUT THE SCIENCE

**Mime Activity: *Movement Integration Mediating Experience***

This is the science story of how the Solar System formed, about 4.6 billion years ago. It brings together the various concepts mentioned in this activity, and can be used as an entry to the activity as well as an integrating activity.

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***The Science Story of The Solar Nebular Theory***

| Narrative | Movement | Concept |
|---|---|---|
| Now, let's explore how our Solar System formed!<br><br>FREEZE—Look, we can't go out of our Solar System into interstellar space—yet. So let's RE-create this dense molecular cloud in our own version of a NASA Astrochemistry Laboratory. | Move into an open area, inside or outside, imagining that each person is a particle of dust or a molecule composed in part of a hydrogen atom.<br><br>Let everyone move in a gentle floaty motion, arms outstretched. | The hydrogen gas cloud, a star-forming nebula, corresponds to part A in the figure of the solar nebular theory. |
| Imagine that we are each an atom of hydrogen or a cluster of atoms, as molecules, just floating around in a dense interstellar molecular cloud.<br><br>When we look out into the depths of interstellar space, in between neighboring stars we find dense, optically dark, but infrared bright, molecular clouds that can transform into solar systems.<br><br>We are a crowded mixture of molecules in many combinations of hydrogen and other kinds of atoms, floating around in space between two star systems.<br><br>We need EVERYONE in the middle of this open area to form (continued) | Have a group become an Infrared Spectrometer, tuning in to infrared wavelengths (perhaps with bodies angled and arms moving in a wave motion, and a flight team) | |

| Narrative | Movement | Concept |
|---|---|---|
| this massive hydrogen-rich cloud floating out in space. Nothing here but us molecules, frozen into mixed icy grain mantles: water ice, methanol ice, ammonia ice, carbon dioxide ice—interstellar ices.<br><br>This is the stuff that stars are made of, in the beginning, as a huge nebula, a molecular cloud just floating around minding its own business. | | |
| FREEZE—that's right, everyone freeze in place, of course we're now in interstellar space, and it is very cold, but right now, be still, because I need a volunteer—someone who'd like to be a star.<br><br>(Select participant volunteers) | The floating "Cloud" is randomly distributed within the open area. | Creates the relationship between the molecular cloud and a nova event that triggers the formation of the Solar System. |
| You are a nearby star, just about to perform a nova event—a star that has nearly used up all its hydrogen, and is about to transform in a release of energy in a massive expansion, an explosion, sending out shock waves and matter into the floating nearby nebula. | A proud and radiant "Star" stands nearby about to enact a nova event, readied to make a sudden bursting motion with the whole body involved. | |

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| Narrative | Movement | Concept |
|---|---|---|
| So here's a star—Shine a little starlight into this dense molecular cloud and Voilá, chemical reactions occur, creating nucleic acids, the building blocks of DNA, the spice of life. | "Star" makes a shining motion; "Cloud" vibrates with chemical reaction motions. | Modeling experiments at NASA Ames Astrochemistry Laboratory have shown that nucleic acids can result with the energy of starlight shining through a laboratory model of a dense molecular cloud. |
| READY, everyone?<br><br>Okay, when the star goes into its nova explosion, you begin to swirl; the shock waves have a direction; it's as if you are slowly stirred up; as you swirl, you connect up little by little with others—from time to time, I will call out for you to FREEZE in place. READY?<br><br>Okay, back to the floating around, the cold hydrogen gas cloud… then, suddenly, the star exhausts its hydrogen fuel, it loses its self-gravitation, and literally lets go of itself: it EXPLODES!!!! | "Cloud" suspends action to set up next phase: the nova event.<br><br>"Cloud" sets in motion again, slowly…<br><br>"Star" explodes with wild action, directing shock waves in a direction. Lead stirring up of cloud, swirling around a vague center. | Nova event sets star formation in motion. |
| FREEZE! Notice that some gravitational clumping has occurred (referring to some group students who have, by chance, clumped together). | Watch as action develops, students tend to "clump together" by chance. This can be used to label the objects forming in the early Solar System. | As the early sun forms a protodisk, corresponding to part B of the figure. |

| Narrative | Movement | Concept |
|---|---|---|
| This is the beginning of a protosun—the beginning of our Sun, the same Sun we see today in the sky!<br><br>CONTINUE… | Identify the Sun as a group that has already clumped together, or pull together students who are almost there. | Gradually, through a combination of impact, sweeping up debris, and accretion, clumping together, the disk differentiates into the prototypes of the bodies in the Solar System (Part C) and eventually to the Solar System we have today (Part D). |
| FREEZE! Notice that other clumps are forming, early planets and early moons, and on the outer fringe, eccentric objects like asteroids and comets—this is the picture of the early Solar System that continued developing into what we have today: the Solar System, including the Earth and all that is here, including we ourselves!<br><br>So indeed, we are stardust, one and all! | Identify other planetary bodies–planets, moons, asteroids, and comets–by the chance groupings and positions students move. | |



***Small Group Mime Activity: Movement Integration Mediating Experience***

Invite students to form small groups (about three to five students), to create their own mime and narrated story about interstellar ice drawn from the science literature and their own ideas. Encourage students to act out a sequence that results in new insights, looking for the clues that reveal how interstellar ices mixed with starlight and the energy of a nova event may be the raw materials to form a star system like our own.

## MATERIALS

In this lesson, students will experience images of stars forming in space and act out the story of the formation of the Solar System.

***For all activities, to record reflections, observations, calculations, etc.***

- Science Notebooks: writing and drawing utensils

***Space phenomena depicting nebulae and star-forming clouds***

- Gallery of images selected from NASA collection.



## DEMONSTRATION

The meaning of the word *space* is used in many different ways. Even scientists may define it slightly differently. One important starting place is to discover how students think about space.

The range of meaning of space may include:

- the space that objects take up
- the space around us
- the space we can move through
- the space beyond Earth's exosphere
- interplanetary space—the space between the planets of the Solar System
- interstellar space—the space between stars in the galaxy
- intergalactic space—the space between galaxies
- the spacetime continuum—the whole universe with all that it is composed of—including Earth and ourselves.

Share a brief space experience from your own life.

From the cultural heritage of star stories told through oral traditions, select a story to read that has a vivid space or Solar System experience as part of the story.

Refer to the space aspects of the story as "a space experience." Model the asking of a science question about the space experience. Encourage the students to ask science questions. Then ask the students to pose science questions and share their own space experiences.

### PRE K–2

***Coyote and the Stars (A Coyote Tale)***

Retold by Richard Shope

Out of the mist emerged the people, first their toes, then their feet, then their calves, then their knees, then their thighs, then their hips, then their stomach and ribs, then their chest and heart and lungs and back, then their shoulders and arms, hands and fingers, then their neck and mouths, their noses, their ears, heads and eyes. The people hovered in the mist, that was still dark and cold, and they waited.

The wise ones gathered on the sacred mountaintop at the edge of the darkness, all shrouded in mist. They carefully unwrapped a beautiful bundle, where sparkled an infinite number of crystals of all different shapes and colors, turquoise, ruby, emerald, opal, diamond, and quartz. One by one, reverently, slowly, the wise ones placed the crystals into the sky, where they began to shine a starry light through the swirling mist, where the people waited at the beginning place.

Coyote saw the wise ones from over the ridge. Coyote was curious and decided to come closer to see what they were doing.

"Coyote, go away," the wise ones urged.

"What are you doing? What are those starry sparkles?"

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"Coyote, leave us," the wise ones scolded. "The mist people are waiting in the darkness to emerge from the beginning place when we finish placing the stars where they belong in the skyspace."

"Can I help? That looks like fun! I want to put some stars in the skyspace."

"Coyote, leave us," the wise ones scolded sternly. "You must let us place the stars ourselves; we know the patterns they are to form. It is to be a map to guide the people through their lives. Go, now!"

Coyote backed away, but hid behind a yucca tree. He watched and ached at how slowly and stately the wise ones placed the crystals so carefully, so orderly, so…

Suddenly Coyote could stand it no longer. He rushed wildly to where the wise ones were and scooped up the bundle and flipped all the crystals every which way out into the dark chaos of the night skyspace. "Oops!"

The starry light shined through the mist, and the people emerged at the beginning place, and began to wander across the world and wonder at the meaning of the skyspace above them.

"Coyote, what have you done?" the wise ones wept. "Now the people emerging from the mist will always wonder, for the meaning of the skyspace is now confused with wandering planets, coursing comets, bright stars and dim stars, dark matter and black holes. The wise ones sadly shook their heads and in a splendor of light, shimmered away into the night."

But Coyote was not sorry. He stood proud of himself and laughed aloud. "Well, if the people will always wonder, all the better to be curious and figure it out for themselves!"

**LEAD A DISCUSSION** about this story that draws students to express their own ideas about stars and space. Guiding questions might include:

- What kind of patterns do we see in the night sky?
- How is looking at the stars a space experience?

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### 3–5

***The Fifth Sun (Classic Toltec Tale)***

Retold by Richard Shope

*The wise ones, representing all the powers of nature, were gathered at the meeting place, the great pyramid of the Sun, Teotihuacán. Rain, Thunder, Volcano, Mountain, Earthquake, Ocean, and Wind—all were present. The sacred flame was lit below as the Fourth Sun slowly extinguished in the West for the last time.*

*A proud wise one, decked in prominent blue and green quetzal plumes, stepped to the parapet, to leap, to become the next great Sun, the Fifth Sun, El Quinto Sol. As he leaned over the perilous height, he looked down. He was suddenly gripped with the fear of mortality and could no longer bring himself to leap.*

*Shocked, the other wises stood helplessly—if this once proud god refused to become the new Sun, darkness would rule. The sacred flame would become cold ash. The gods and the worlds they created would perish.*

*Amidst the confusion, stood Nanahuátzin (na-na-whót-zeen), the weakest, skinniest wise one, face cratered by the pox. Nanahuátzin moved without hesitance to leap from atop the pyramid of the sun. The sacred flame leaped up to embrace him and in a sweep of light, they rose together to become El Quinto Sol, the Fifth Sun, the very Sun that shines on us today.*

*Shamed by his weakness, and wishing to regain his glory, the once-proud wise one, leaped as well. The sacred flame leaped up to embrace him in a sweep of light, but now other wise ones were shocked again, there could not be two Suns shining. Quetzalcoatl, the morning star, summoned the Rabbit to leap high into the face of the second rising circle of light. The light diminished as the Rabbit tucked back her ears, leapt, and held tightly for all time. And to this day the children of Mexico and many other parts of the world, look up on nights of the Full Moon, and they see the Rabbit on the Moon, with her ears tucked back, looking out into the night.*

After the story, **LEAD A DISCUSSION** about the different meanings of the word space.

What questions about space and the Solar System emerge from this story? Guide discussion toward specific questions students have about space, using questions such as,

- Where does space begin?
- What is space?
- What fascinates you about space?
- What questions would you ask a space scientist?

Keep track of and record the questions and ideas that emerge. Connect these questions and ideas to the main activity.



# MAIN ACTIVITY

## PREPARATION

Devise exploratory zones about ice in space that guide students to ask:

- What is infrared?
- How did Herschel discover infrared?
- How does infrared help us see ice and other objects in space?
- How can we picture what the Solar System looks like?
- What do dense interstellar molecular clouds look like?

## TEACHING TIPS

***Explore***

As students view the images of star-forming nebula, explain that by connecting infrared features to the visible, we see evidence of processes of star formation. This tends to confirm the science story about how the Solar System formed. Explain that we also see evidence of the abundance of ice within such clouds in space.

***Diagnose***

Listen to student ideas about space. How big is space? Is Earth in space? What can we learn about the Solar System by studying images of star formation? Be prepared to help students gain precursor understanding about the scale of space. What do students consider a space experience?

***Design***

Have students work in active inquiry teams to generate questions that arise from the visits to the exploratory zones.

***Discuss***

How do scientists learn about space? What are the big questions scientists are asking about space through the current and future missions?

***Use***

This activity connects personal concepts about space to the world of scientific understanding about the formation of the Solar System out of an immense interstellar cloud.

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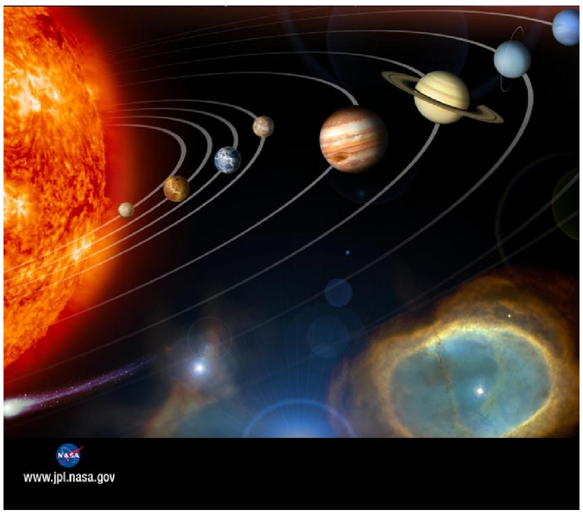
## WARM-UP AND PRE-ASSESSMENT

### *Create a Living Scale-Model of the Solar System*

This interactive demonstration requires some open area and can be adapted to the size of the space available. For young children, going out to Jupiter or Saturn may be enough to get the idea across.




Everyone stands up in an open area, arranged so as not to bump into anything or anyone. Invite a volunteer to be an Astronomical Unit. The abbreviation A.U. conveniently provides a pun to invite the first student volunteer. "A.U.! (Hey, you!) Over there, will you come over here? Please stretch out your arms to be our scale model of an Astronomical Unit!"

Explain that we are to imagine that the distance from fingertip to fingertip is the reach from the Sun to the Earth! The student's name might further personalize the scaled unit — "this is our Sarah Unit" or "our Juan unit." Then proceed to calibrate the A.U., marking the outstretched arms in tenths.

| OBJECT | DISTANCE FROM SUN |
|---|---|
| Sun | 0 A.U. |
| Mercury | 0.4 A.U. |
| Venus | 0.7 A.U. |
| Earth | 1.0 A.U. |
| Mars | 1.5 A.U. |
| Asteroid Belt | 2.8–3.0 A.U. |
| Jupiter | 5.2 A.U. |
| Saturn | 9.5 A.U. |
| Uranus | 19.2 A.U. |
| Neptune | 30 A.U. |
| Pluto | 39 A.U. |
| Kuiper Belt | 39–45 A.U. |
| Oort Cloud | 5,000–100,000 A.U. |
| Heliopause | 153–158 A.U. |

A.U. = Astronomical Units

As the student's arms are outstretched, begin at one end and let the class count aloud as the A.U. is calibrated into tenths, counting from 0 to 1 in tenths, marking off each relative distance along the outstretched arms from fingertip to fingertip.

Then, beginning with the Sun, invite students to play the parts of the Solar System, using the A.U. to measure out the placement out from the Sun. With the information from the Astronomical Unit table, invite students to assume the parts of the Sun and the planets, placing them at the proper distance beginning with Mercury and on out to Pluto and beyond.

***The Solar System and the Astronomical Unit (A.U.)***

For interplanetary distances we use the Astronomical Unit, a unit of measurement that corresponds roughly to the average distance between the Sun and Earth: about 93 million miles or 150 million kilometers. (Figures represent AVERAGE distance.)

The Sun will be placed at the zero point (at the fingertips), Mercury at 0.4 A.U. (in front of the shoulder nearest the Sun), Venus at 0.7 A.U. (in front of the other shoulder), and Earth (at the fingertips opposite the Sun). From there, it is a matter of measuring the distances using the outstretched arms of the Astronomical Unit until all of the planets are placed at the proper distance to scale.

We eventually have planets extending from very close (Mercury, Venus, Earth, and Mars) to the asteroid belt and beyond to the outer planets (Jupiter, Uranus, Neptune, and Pluto/Charon). From a cluster of cozy inner planets out to 30–50 A.U. to the cold Outer Planets, the layout is dramatic in scale. Comets reside as far out as 100 A.U. The heliopause, the extended reach of the Sun's influence is out past 150 A.U., the beginning edge of interstellar space.

*This is how the Solar System is today, but how did it form in the first place?*

## PROCEDURES

***Part 1. Discuss Ice in Space***

Lead a discussion about how students think scientists investigate space.

Guide students toward understanding the currently available tools of inquiry that detect ice in space: space-based infrared spectrometers, Hubble and Spitzer telescopes, and laboratory models of the conditions of interstellar space. Mention that the two Voyager spacecraft will be the first to visit space beyond the Solar System.

***Part 2. Explore how scientists investigate ice in space***

Select a series of images from Hubble and other images of nebulae where stars are forming and where ice has been detected.

Select images that describe how space scientists used infrared spectrometers and other instruments to detect evidence of ice crystals in space.

Invite students to visit each exploratory zone to make observations and generate questions.

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Explain how scientists combine observation of objects in space and work in the laboratory to understand how our Solar System formed.

Since objects in space such as planets, stars, and nebulae are so far away, we cannot conduct investigations experimentally. Instead, scientists try to create conditions in the laboratory that act as models of what they think is probably true about the processes they are interested in. Through such modeling, scientists are able to test out their proposed explanations, generating a pattern of data. From the work in the laboratory, they are able to think through what they ought to see in space that would either confirm or discount their idea.

*This table lists questions and explanations related to images of dense interstellar molecular (DISM) clouds.*

| Observations/Questions | Possible Explanations |
|---|---|
| a. What are they made of? | • Icy Grain Mantles<br>• The debris of stars that once were |
| b. What are icy grain mantles? | • Water ice crystals mixed with other ices |
| c. How do we observe them? | • Space-based Telescopes<br>• Infrared Spectrometers |
| d. How can we learn more about them? | • Create a simulation of conditions of interstellar clouds in the laboratory<br>• Look for verification of theoretical predictions |
| e. Photochemistry is the study of how light effects chemical reactions. What results have emerged from photochemistry experiments in the laboratory? | • By shining simulated starlight into a cloud chamber with a mix of gases that are found in DISM clouds, scientists have observed the formation of amino acids |
| f. How does starlight affect dense interstellar molecular clouds? | • It triggers chemical reactions, resulting in amino acids the basic building blocks of life |
| g. Can interstellar ice reach Earth? | • There is strong evidence that interstellar ice and amino acids formed in DISM clouds reach Earth |

For example, scientists have been trying to understand what it is like in interstellar space, the places in between neighboring stars. They have noticed clouds of dust and ices in space, and have created simulations, setting up similar conditions as they observe in space, but in the laboratory, on a smaller scale. By going back and forth between laboratory simulations and infrared observations, scientists feel confident that molecular clouds contain very simple ices in abundance: $H_2O$ (water ice), $CH_3OH$ (methanol ice), $NH_3$ (ammonia ice), CO (carbon monoxide ice), $CO_2$ (carbon dioxide or dry ice), and $H_2$ (hydrogen ice).

Invite students to reflect about their new ice in space experiences based on questions such as:

- *Draw and/or say what you think about ice in space?*
- *What can we learn by exploring ice in space?*

## DISCUSSION & REFLECTION

### *Reflections about Telling The Science Story*

Every culture in every time has oral traditions that explain the origin of the Sun, the Earth, the Moon, planets, comets, and stars. These oral traditions are living mythologies expressed poetically, mythopoetic explanations told as stories that reflect a people's values, yearnings, and questionings about their place in the universe.

Scientific theories reflect the reasoned considerations that explain why the laws of nature seem to hold. A law is a description of a pattern in the facts that holds true about a natural phenomenon. A theory must explain the underlying reason for the pattern as coherently as possible. To be accepted, a theory must meet various criteria. It must have predictive power. It must provide intellectual satisfaction. It must go beyond a just so story or a mythopoetic tradition. A theory must do so by directing its attention to the evidence for underlying cause. It must explain why the phenomenon is what it is and why it changes as it does by demonstrating the presence of and showing the nature of a causal connection.

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***The role of Analogy in Science Communication***

Analogy is a literary tool that plays a powerful role in the communication of scientific theory. When theoretical ideas are clearly expressed in terms of familiar imagery, the theory becomes more comprehensible. The selection of an apt analogy to explain a scientific theory is crucial, for the scientist attempts to express a process that cannot be directly observed. Understanding depends on the aptness of the analogy. For an analogy to convey a theory, the range of possibly inaccurate interpretations must also be considered, to ensure that the analogy serves the scientific explanation without confusion.

For example, stars and planets change through time in a sequence that resembles birth, life, and death. The theory of stellar evolution expresses the cycles of energy transformation as the "life cycle" of stars, an analogy that speaks to many cultures through the whole range of mythopoetic creation stories.

The rich cultural heritage of star stories can be a springboard for discussion that results in deeper understanding of the science story, the evolving scientific inquiry of natural phenomena.

The ancient Mesoamerican story about *El Quinto Sol, the Fifth Sun*, is a literary explanation about how the Sun and the Moon came to be. The same Toltec people who originally told this story also built stepped pyramids, aligned to events in the night sky, in the central valley of Mexico. They created great interlocking calendars based on detailed observations of the movements of the Sun, Moon, Venus, and Mars. They carved these laws in stone. They recorded them in richly colored almanacs. They laid out their great cities as reflections of these celestial patterns.

They made empirical observations, metaphysical beauty, ingenious engineering, precise mathematics, yet we have no evidence that they had expressions of theory, in the scientific sense that we mean today. Yet science questions can be drawn from such stories that were passed by oral literary traditions down through the generations. Where story and science meet is in analogy. Together in one mind, these two forms of organizing knowledge, the scientific and the literary, coalesce in a creative leap that can lead to insightful understanding.

The solar nebular theory is a causal explanation based on observations and an accumulation of data drawn from the fields of astronomy, physics, chemistry, and geology over many years. It seeks to explain the process of how the Solar System formed from a misty molecular cloud, inferred from the theory of stellar evolution. We cannot view the process directly, but we can see analogous processes as we view other stellar and nebular objects that appear to be in different stages of formation, in keeping with the feature of the theory. Scientists hope to learn more about this science story by observing planets around distant stars.

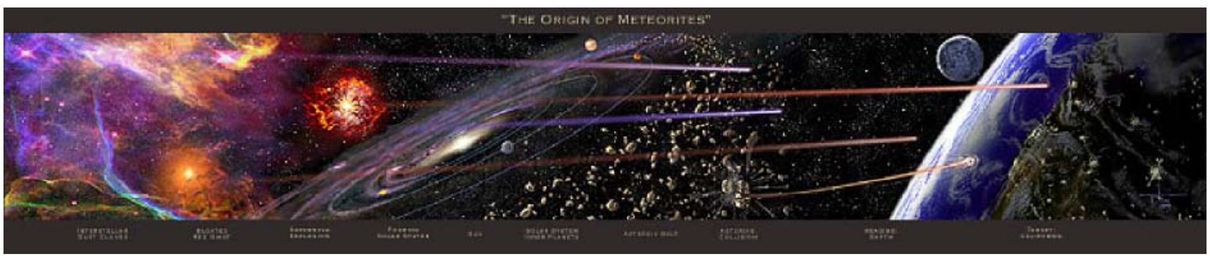
## CURRICULUM CONNECTIONS

The cultural history of human thought about space offers rich connections to literature and visual arts.

Space art has become a rich source of imagery that leads humanity to consider traveling into space. Create a gallery of space art and invite students to discuss how art helps or hinders our scientific understanding of space.

The Chabot Space & Science Center Mural: The Origin of Meteorites
By B.E. Johnson and Joy Day (http://imperialearth.com/meteor.html)

A digital mural, then painted by hand in acrylics on a 4' x 26' foot canvas, depicting the wonders of the Universe where the different classes of meteors have originated.




We are already traveling in space, via the spacecraft that send back images and data that allow our minds to construct the knowledge of space.

***Journey into Tomorrow***
by David A. Hardy

***View To The Future***
by Rick Guidice

NASA Space Art: http://vesuvius.jsc.nasa.gov/er/seh/advart.html

Invite students to create their own space art, short stories, skits that express their own feelings and understandings about space.

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## ASSESSMENT CRITERIA

***Exemplary***

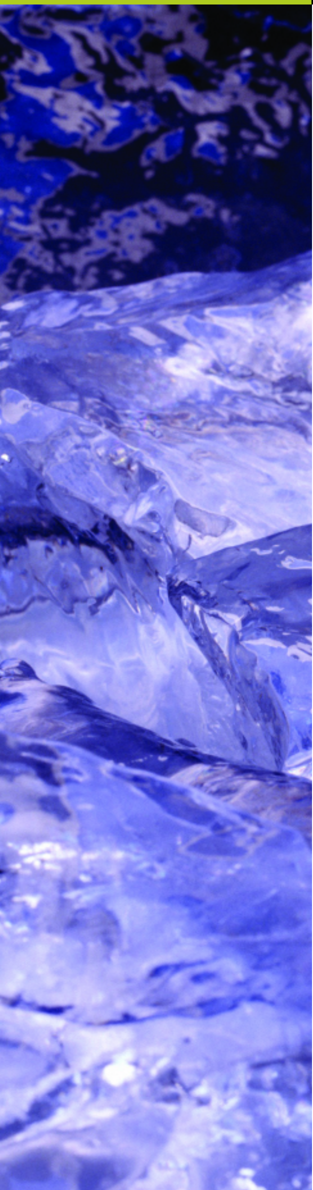
- Students write and illustrate a personal ice in space experience and share it dynamically with both a small group and the whole group.
- Students display drawings, constructions, and dynamic models drawn from their science notebooks and web-based research.
- Students identify and extend science questions drawn from direct observation and extended research about space, the Solar System, and interstellar ice.
- Students explore a rich range of observations about space and relate it to prior shared experiences.
- Students ask a rich and extensive range of questions about space, the solar and interstellar ice: nebulae, photochemistry, infrared observation, and icy grain mantles.
- Students extend learning by considering implications of interstellar ice as an explanation for the presence of organic compounds in the Solar System, interstellar space, and dense interstellar molecular clouds.
- Students relate ideas to the whole context of exploring ice in the Solar System.

***Emerging***

- Students write and illustrate a description of space, the relationship of the Solar System within it, and the presence of ice and other molecules in space, sharing it with both a small group and the whole group.
- Students pose basic science questions drawn from their observations and research of space, the Solar System and ice in space.
- Students succeed in observing examples of interstellar clouds where ice has been detected.
- Student display results using a variety of ways to represent examples of ice in space.
- Students ask a rich range of questions about the origin, structure and composition of space, the Solar System and interstellar ice.

***Formative***

- Students ask questions and express their own ideas about space.
- Students recognize features of the Solar System, such as the planets and the distances.
- Students discuss evidence for interstellar ice or describe the basic features of interstellar clouds.
- Students pose science questions drawn out of the context of observing and researching the presence of ice in space.



## RESOURCES

http://www.astrochem.org
The Astrochemistry Laboratory at NASA Ames

http://vesuvius.jsc.nasa.gov/er/seh/advart.html
NASA Space Art

http://imperialearth.com/meteor.html
Space Artists' work

http://coolcosmos.ipac.caltech.edu
NASA Spitzer Telescope's Education and Public Outreach website *The Infrared Universe* has many activities about infrared astronomy

http://heritage.stsci.edu/index.html
Hubble Heritage Page

***Images***
Link to image gallery