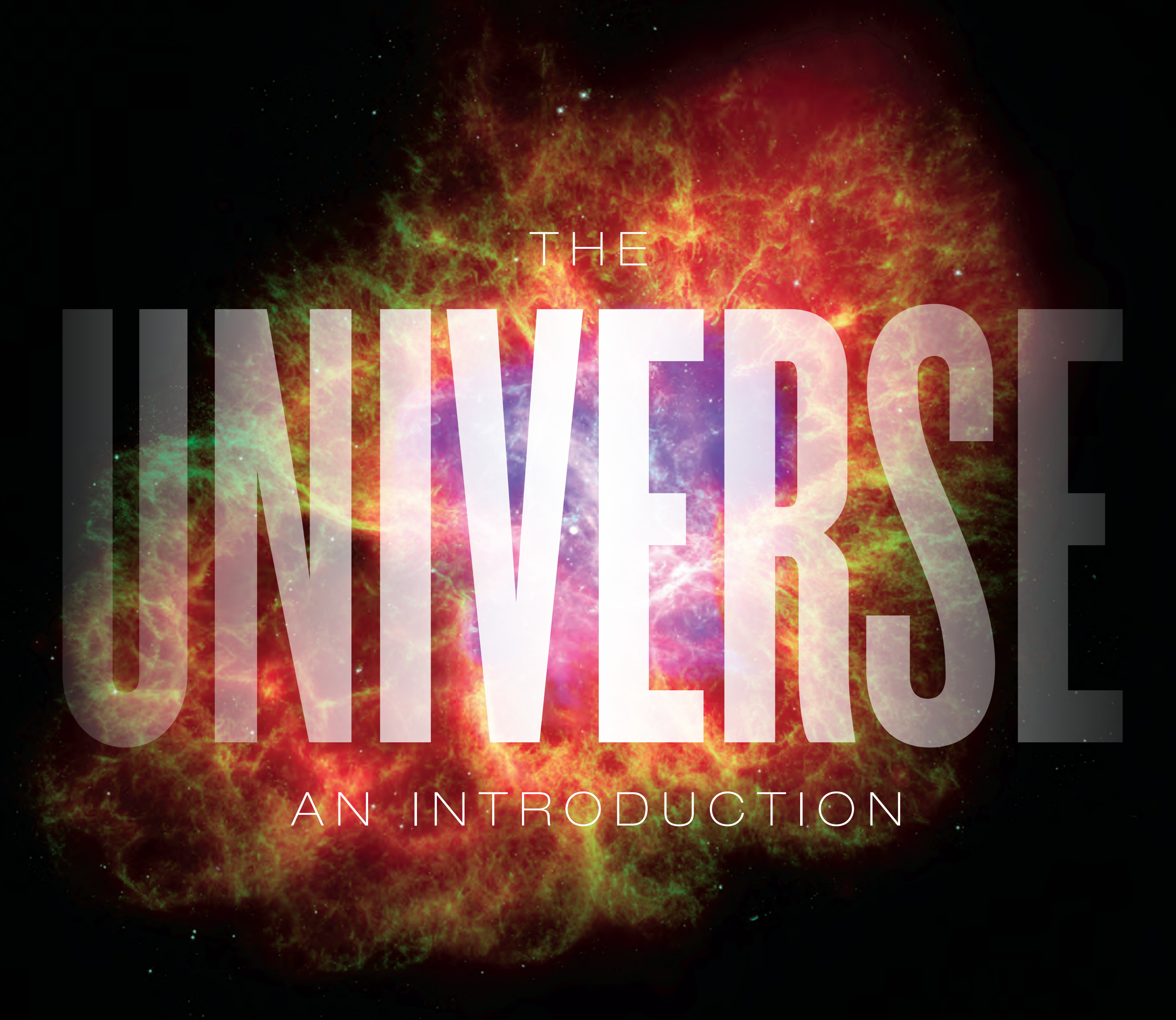
SMITHSONIAN

IN YOUR CLASSROOM

SPRING 2010

THE UNIVERSE

AN INTRODUCTION



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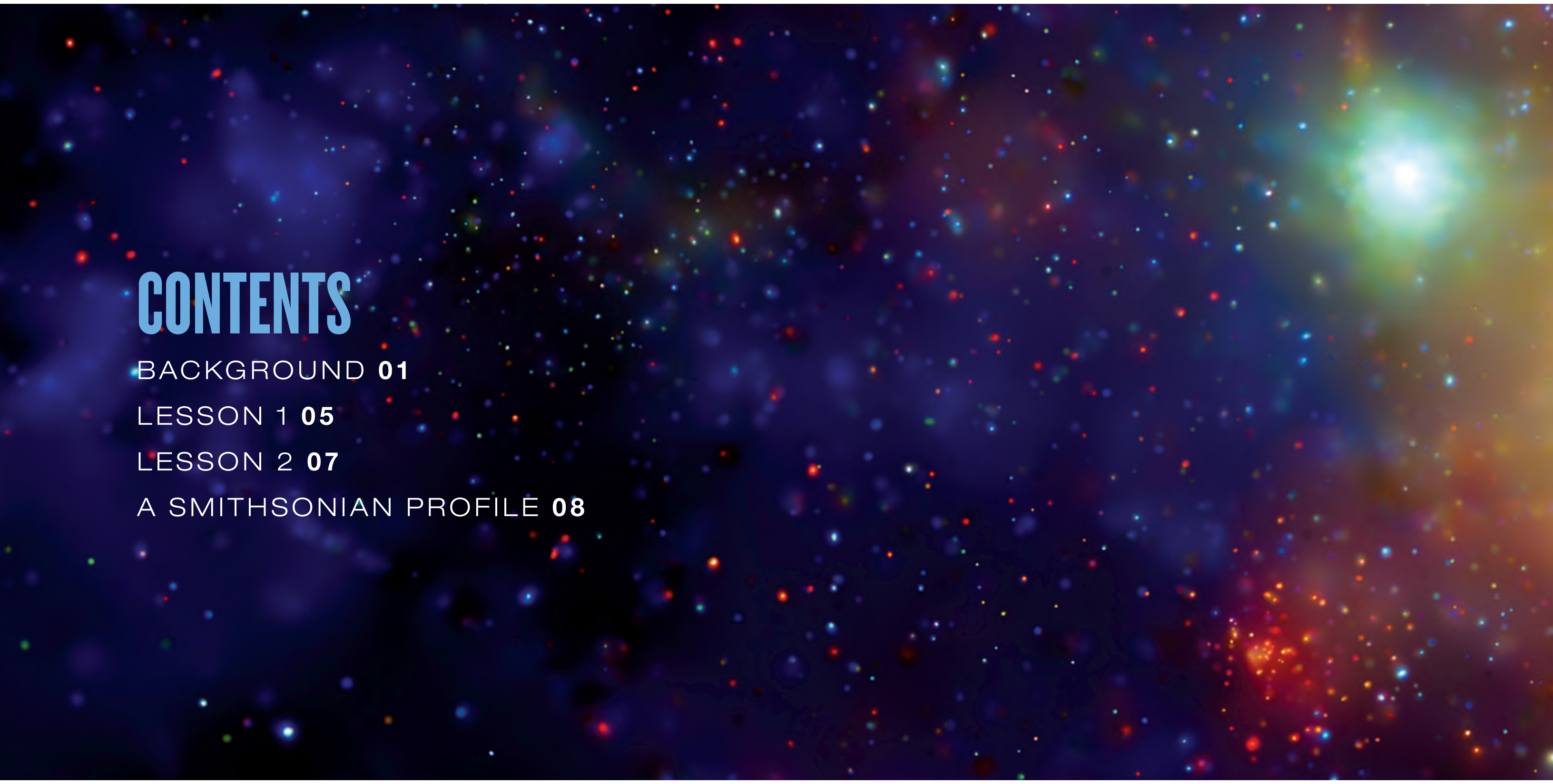

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Smithsonian in Your Classroom is produced by the Smithsonian Center for Education and Museum Studies. Teachers may duplicate the materials for educational purposes.

National Standards
The lessons in this issue address NAS National Science Content Standards for space science and NCTM National Mathematics Standards for the use of mathematics to solve problems.

State Standards
See how the lessons correlate to standards in your state by visiting smithsonianeducation.org/educators.

Illustrations
Cover, inside cover, pages 1–8, and pullout section (space images): National Aeronautics and Space Administration. *Page 9:* Christine Pulliam, Smithsonian Astrophysical Observatory.

Credits
Stephen Binns, writer; Michelle Knovic Smith, publications director; Darren Milligan, art director; Design Army, designer

Acknowledgments
Thanks to Mary Dussault, Alex Griswold, and Lisa Kaltenegger of the Smithsonian Astrophysical Observatory.

This issue of *Smithsonian in Your Classroom* is sponsored by

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The particle and the planet are subject to the same laws, and what is learned of one will be known of the other.

James Smithson,
in the will that founded the
Smithsonian Institution

BACKGROUND

COSMIC QUESTIONS

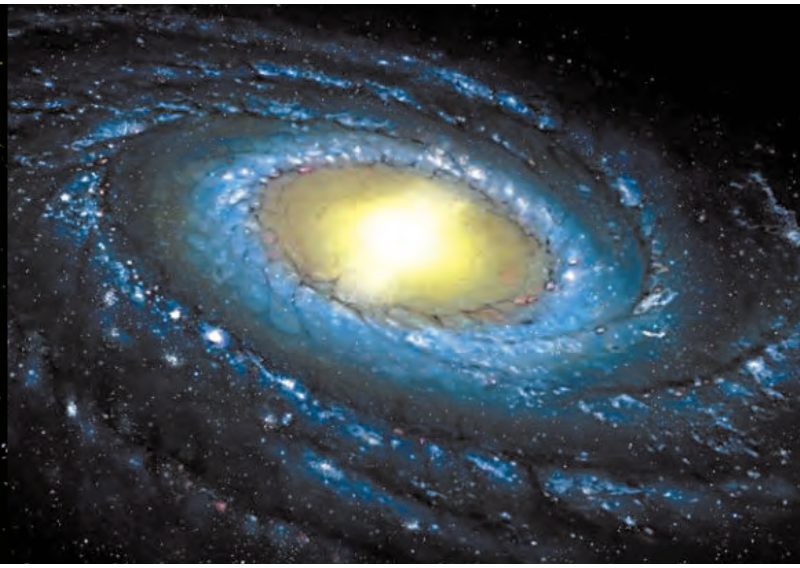
ASTRONOMY IS A SCIENCE THAT ASKS FUNDAMENTAL questions about the very fundament of things, the universe. *How big and how far away are the planets and stars? How did they form and when? How do they move and why?* Finding answers to those questions has been the highest adventure of the human mind, and yet the questions, in essence, are those of any child looking into the sky. The lessons in this issue address the questions, therefore, by first asking the students.

In Lesson 1, the class works together to arrange pictures from space according to the students' best ideas of size, distance, and age. This active introduction to the cosmos can be a pre-assessment for a unit on space science. Lesson 2 is a modeling exercise in which relationships in space are brought down to a scale of two inches. Both lessons are based on educational materials created by the Smithsonian Astrophysical Observatory, in cooperation with NASA. All images needed for the lessons are in the pullout section of the issue. They can also be downloaded from smithsonianeducation.org/universe.

The Smithsonian Astrophysical Observatory has deep roots in the history of the Smithsonian, as does astrophysics itself, the branch of astronomy concerned with matter and energy. In 1836, the United States found itself with a bequest from James Smithson, a deceased English scientist of independent means. The nation was to use the money to establish an institution of knowledge in Washington, D.C. Smithson, who had never visited the United States, gave no clear indication of what this institution should be. John Quincy Adams, then out of the White House and elected to Congress, urged strongly that it should be an observatory, what he called a "lighthouse of the skies." In 1890, the Smithsonian's third secretary, Samuel Pierpont Langley, built an observatory on the back lawn of our first museum, primarily for the study of solar energy. Langley is best known as an aviation pioneer who raced with the Wright brothers to build the first motorized flying machine. He was also an astronomer, one of the first to recognize astrophysics as its own field. In 1955, the Smithsonian's observatory relocated to Cambridge, Massachusetts, to combine its facilities with those of the Harvard College Observatory. Today, hundreds of scientists work together in the Harvard-Smithsonian Center for Astrophysics. In the development of ground and space telescopes, and in the study of the findings, they have helped to answer some of the questions posed in the lessons.

The issue includes a profile of one of the scientists, Lisa Kaltenegger, who is in the burgeoning business of "planet hunting"—the discovery of planets outside of our solar system. The first "exoplanet" was discovered in 1995. There have been hundreds of discoveries since. The work is bringing closer to the fore a question in the back of anyone's mind when looking at the sky: *Is anyone else out there?*

HUBBLE DEEP FIELD THE HUBBLE SPACE TELESCOPE BROUGHT US VIEWS OF GALAXIES FROM THE VISIBLE HORIZON OF THE UNIVERSE.



MILKY WAY THE DISK SHAPE OF OUR GALAXY IS SEEN IN THIS ILLUSTRATION. OUR SUN IS ABOUT HALFWAY OUT FROM THE GALACTIC BULGE IN THE CENTER. WE REVOLVE AROUND THE BULGE EVERY 250 MILLION YEARS.

FIRST THINGS FIRST: WHAT IS THE UNIVERSE?

Speaking generally, *universe* means everything—all we see and cannot see. When astronomers speak of the universe, they usually mean the *observable universe*—what technology has enabled us to see, or what physical laws will permit us to see as technology advances.

HOW BIG IS THE OBSERVABLE UNIVERSE?

Astronomers usually measure the far reaches of space in *light-years*. A light-year is the distance that light travels in one year, about 6 trillion miles. Our farthest views of space have come to us from the Hubble Space Telescope, launched by NASA in 1990. Hubble revealed galaxies more than 10 billion light-years away, or 60 billion trillion miles. Light in the form of radio waves has come to us from another few billion light-years beyond those galaxies.

WHAT IS A GALAXY?

A galaxy is an assembly of stars and related matter and gas, all held together by mutual gravity. We might think of a galaxy as a super megalopolis of stars. A more common analogy is that a galaxy is a vast island in space, separated from the others by millions of light-years.

Less than a century ago, we could speak of *the* galaxy, our own Milky Way, without ever pluralizing the word. The Milky Way got its name from its appearance to the naked eye. The galaxy has a disk shape. We are within the disk. Overhead, we get a sideways view: we see the disk as a band of so many stars that they appear as a creaminess of light. Scientists early in the twentieth century, Albert Einstein among them, believed that these stars—this galaxy—made up the whole of the universe. Beyond the galaxy was a void.

In 1917, the Wilson Observatory in Pasadena, California, erected a hundred-inch-wide telescope, the largest in the world. Missouri-born astronomer Edwin Hubble, namesake of the Hubble Space Telescope, went to Pasadena to study a *nebula*, a fuzzy patch of gas and dust. Using the new telescope, he discovered that the fuzz was far more distant than anyone imagined. It contained not only gas and dust, but also stars. What was considered a small part of our galaxy, and called the Andromeda nebula, became the Andromeda galaxy. It was another island altogether, millions of light-years from ours. It is now estimated that there are more than 170 billion galaxies in the observable universe, each containing tens or hundreds of billions of stars.

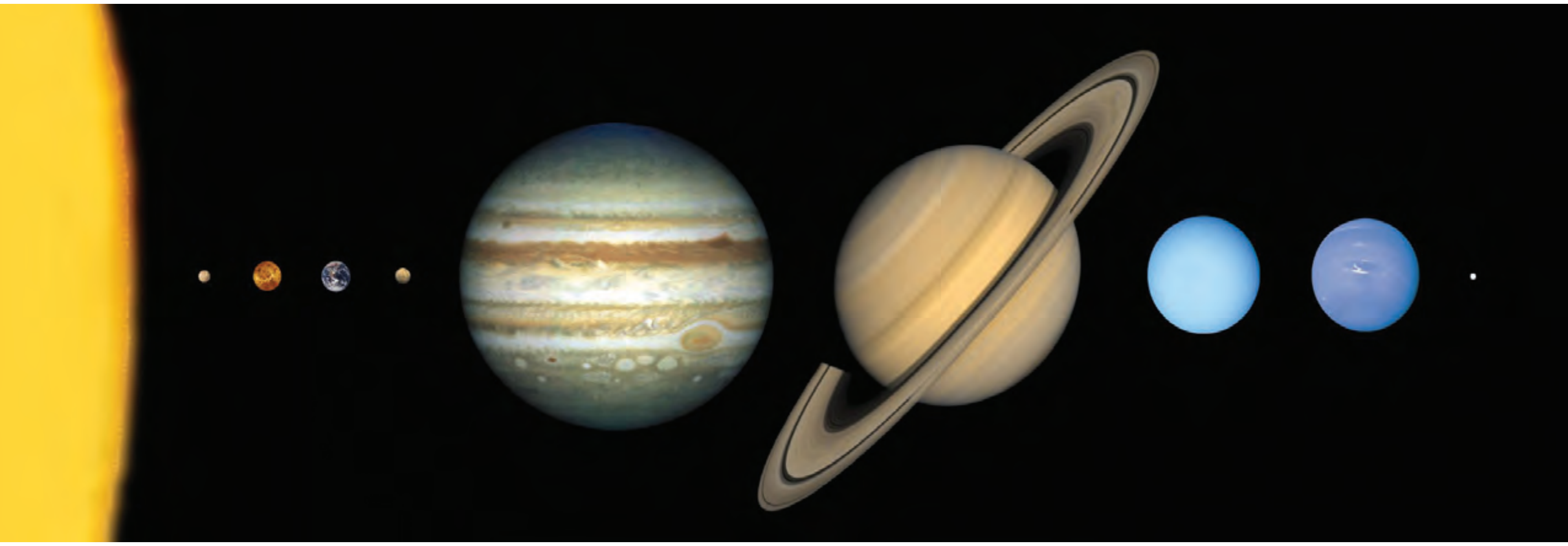
WHAT IS A STAR?

We can turn to rock and roll for a concise definition of a star. A star is a great ball of fire. It is necessarily a ball: like a planet, it forms from a spinning cloud of dust and gas that collapses under its own gravity, pulling inward equally in all directions. And it is necessarily great: unlike the smaller planets, its sheer mass exerts a pressure that sets off a nuclear fire, which in most cases burns for billions of years.

The closest star, our own star, is the Sun. As stars go, ours is quite average: middle-aged, of medium build, moderately bright. The difference between the Sun's blaze in our sky and the cool twinkle of the other stars is the difference of distance. If our galaxy is a megalopolis, our star is the core city of a metropolitan area, with its solar system as the suburbs. Earth, the third planet from its star, is in the toniest of inner suburbs, enjoying the heat and light of the star but not too much of it.

WHAT IS A PLANET?

As with *galaxy*, the meaning of *planet* has changed considerably, and even more recently. For decades, a planet could be safely defined as any of nine bodies that revolve around the Sun. Outward from the Sun, they are Mercury, Venus, Earth, and Mars (the "terrestrial," or Earth-like, planets), Jupiter, Saturn, Uranus, and Neptune (the "gas giants"), and Pluto. American astronomer Clyde Tombaugh discovered the icy misfit Pluto in 1930, and thus made possible a catchy first-letter memory aid: My Very Educated Mother Just Served Us Nine Pizzas.



SOLAR SYSTEM THIS SCALE MODEL IS FOR RELATIVE SIZE ONLY, NOT DISTANCE. AT THIS SCALE, PLUTO WOULD BE MORE THAN A MILE BEYOND THE EDGE OF THE PAGE.

In 2006, those who came to know the planets by thinking of nine pizzas were stunned to learn that Pluto was gone. That is, members of the International Astronomical Union (IAU) had voted to strip Pluto of its status as a planet. Its demotion to "dwarf planet" was the result of the IAU's effort to give *planet* its first official definition. According to the definition, a planet must be an orbiting body large enough to become round by the force of its own gravity, and large enough to dominate the neighborhood of its orbit. While certainly round, tiny Pluto is hardly dominant. If it were set down on the surface of Earth, it would barely cover India.

The loss of Pluto had been offset by the discovery of planets outside of our solar system. Since the time of Galileo, when the Sun was found to be a star, astronomers have thought it likely that other stars are orbited by planets, too. The discovery of the first "exoplanet" came in 1995, and more than four hundred have been spotted since. Most are gas giants and unlikely to support life. This does not mean that these are the most common kind of planet, only that they are the ones least difficult to find. Planet hunters are focused on the possibility that some of them have moons that are more Earth-like than the planet itself.

WHAT IS A MOON?

A moon is a natural satellite of a planet. Our own Moon is one of at least ninety in our solar system, almost all of which are beyond the realm of the terrestrial planets. Mars has two small moons. Mercury and Venus have none. Our Moon is unusually large—about one-fourth the size of Earth. While it is in thrall to our gravitational pull, it is large enough to pull back. The Moon's gravity slows our rotation and creates our ocean tides.

The surface of the Moon is, of course, the farthest out in space that we have stepped. Among the many "firsts" of the Apollo missions is that it was our first hands-on experience with the finite speed of light. The average distance to the Moon is about 240,000 miles. Light travels at 186,000 miles per second. Moonlight, then, takes a little more than one second to reach us. This slight time lag was observed in the transmission of images from the astronauts to ground control.

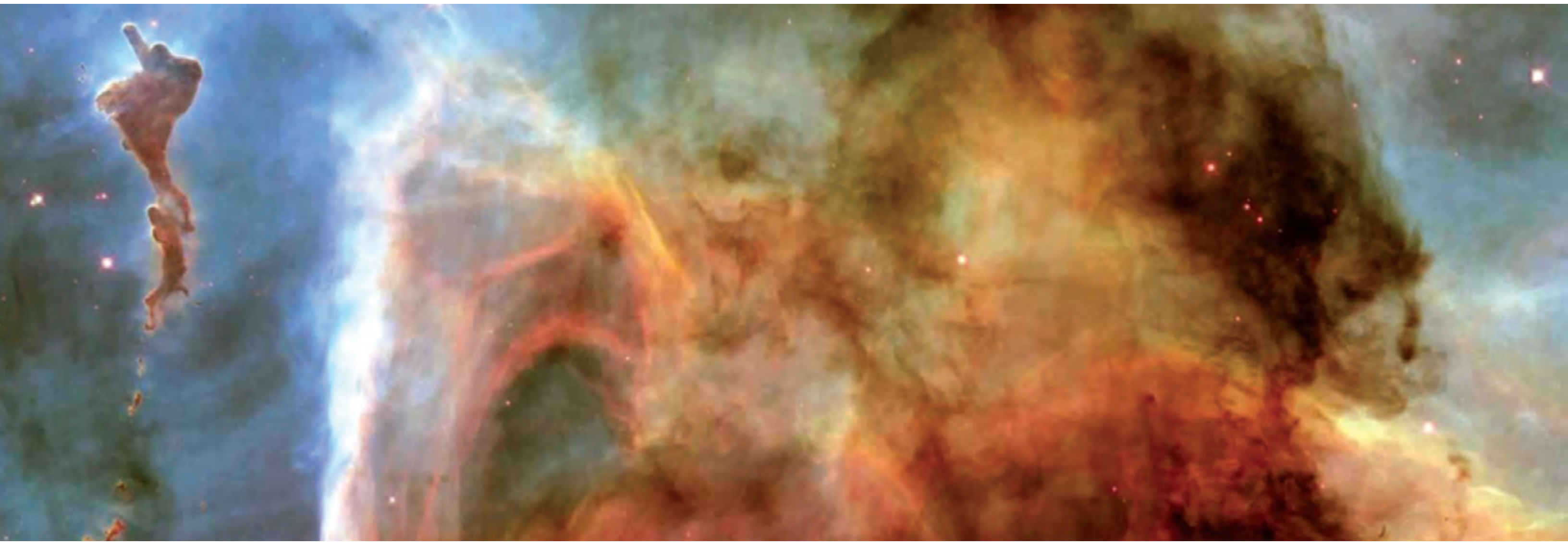
Light-year measurement allows us to pack vast numbers into manageable units. It also helps us to think in terms of age. As the Moon landings showed, nothing in space comes to us "live." When we look out into space, we look back in time. The farther we look, the farther back we see. We see the Hubble Space Telescope galaxies, 10 to 12 billion light-years away, as they were 10 to 12 billion years ago—that is how long the light has taken to reach us. We see those galaxies in an infant state, at a time near the beginning of the observable universe, which has been dated at about 14 billion years ago.

HOW CAN WE DATE THE BEGINNING OF THE UNIVERSE?

Edwin Hubble is not the only scientist to have back-to-back hits, but two of his discoveries have each done more to broaden our view of things than any others in the last century. After discovering other galaxies, he observed that they moving away.

More specifically, he observed a shift to the red end of their light's spectrum, a result of the *Doppler effect*. We all experience the Doppler effect as it applies to sound waves. A moving sound—a siren or a train whistle—rises in pitch as it nears us and lowers as it passes. As it nears us, the sound waves shorten. As it moves away, the waves lengthen. A similar principle applies to light waves. Red light has the longest wavelengths in the visible spectrum. As an object recedes, its light shifts to the red.

Measurement of the *red shift* has allowed for a measurement of the speed at which galaxies are moving away from us, and from each other. Both physics and logic dictate that if galaxies are moving apart they must have once been closer together. Dating the beginning has been a matter of running the clock backward to a first moment, known as the Big Bang, when the observable universe began its expansion.



KEYHOLE NEBULA THE GAS AND DUST OF A NEBULA SIGNIFY EITHER DEATH OR BIRTH—THE REMAINS OF OLD STARS OR THE RAW MATERIALS FOR NEW STARS.

WAS THE BIG BANG AN EXPLOSION?

If "Big Bang" seems too jokey a name for something so momentous, it is because it got the name from scientists who did not believe it. The idea was first suggested in the 1920s by Monsignor Georges Lemaître, a Belgian priest and physicist, who described the source of the universe as a "primeval atom." Adherents of the idea have had to battle the misconception that the Big Bang was an explosion of this matter *in space*. Rather, it was a sudden expansion—and, yes, a fiery explosion—*of all space*.

Expansion is often described with homey analogies of baked goods. For instance, we might imagine galaxies as blueberries and space as a muffin. As the muffin rises in the oven, the blueberries move apart and take their places on the top. The blueberries do not move of their own volition. The muffin (space itself) pushes them apart.

Expansion does not mean that individual galaxies and everything in them (including actual blueberries) are spreading apart. The force of gravity holds galaxies and star systems together.

IS THERE PHYSICAL PROOF OF THE BIG BANG?

The Big Bang theory predicted that light from the earliest universe would not be visible through a telescope. On its long journey to reach the viewer, the light would lose most of its energy and diminish into radio waves, a less energetic form of light.

These waves were discovered in 1965 in a comedy of coincidence. Two Bell Laboratories scientists, Arno Penzias and Robert Wilson, were engaged in a project that would relay telephone calls via satellite. Working with a "horn antenna" in Holmdel, New Jersey, they were vexed by a persistent background noise that seemed to be coming uniformly from every direction. To get rid of the noise they went as far as climbing into the horn with scrub brushes to clean it of pigeon droppings.

Meanwhile at Princeton University, an hour away, a team of scientists were working on ways of finding the Big Bang waves, called *cosmic microwave background*. Penzias and Wilson, unaware of this research, decided to call these very scientists for advice. When they described the situation, the Princeton scientists knew that they had been scooped.

The noise that Penzias and Wilson tried to scrub away is an echo or "afterglow" of the Big Bang, which touches every nook and cranny of the universe. It comes uniformly from all directions because the expansion occurred in all space. In 1989, NASA launched the Cosmic Background Explorer to study this primal light. The studies found that the properties of the light correspond to what could be expected from light emitted by very hot matter about 14 billion years ago, the date of the beginning of the observable universe.

WHAT CAME BEFORE THE OBSERVABLE UNIVERSE?

With this question, science comes to an end for now. Astronomers can imagine the expansion of space as if it were a movie, and then "run the movie backward" to a split second after the Big Bang. In reverse, they can visualize all space and matter shrinking to a size so small that it might as well be called nothing. But they cannot know what caused the Big Bang, or address the question of how everything can come out of nothing.

The questions beyond the observable universe are beyond what we know of physics, and so are open to anyone: *Did the observable universe displace another universe? Was the Bing Bang just one of many Big Bangs in a larger universe? If so, what is this larger universe?*

And that brings us back to where we began.

HOW BIG? HOW FAR? HOW OLD?

Students are not expected to come up with correct answers in this activity. They will be looking at pictures of celestial bodies and arranging them according to their own ideas of size, distance from Earth, and relative age. They can amend their ideas and rearrange the pictures during discussions with you and the other students. They will be learning as they go along.

And you will be learning too. If you use this as a pre-unit assessment activity, you will quickly discover the gaps in the students' understanding of outer space. If you go on to a modeling activity, such as Lesson 2 in this issue, you will be starting with the students' own "mental model" of space.

The pullout section of the issue contains all of the pictures on durable cards. You can work as a class, with everyone gathered around the cards on a desk or tabletop, or you can make copies of the pictures for the students to work in small groups before the class comes together around the cards.

STEP ONE: SIZE

Use seven of the pictures for arrangement from smallest to largest. We recommend these:

Moon	2 thousand miles diameter
Earth	8 thousand miles diameter
Saturn	75 thousand miles diameter
Sun	875 thousand miles diameter
Pleiades	60 trillion miles across
Milky Way	600 thousand trillion miles across
Hubble Deep Field	600 million trillion miles across

Display the cards randomly on the desk or tabletop, keeping them face up and not disclosing the information on the back. Before beginning a class discussion, ask that each student decide on an order—smallest to largest. If working in groups, ask that each group try to reach a consensus on the order.

Play the role of moderator in the class discussion. When students announce what they think is the correct order, ask them to arrange the cards in that way and to explain why they chose the order. When everyone has had a chance to express an opinion, offer prompts until the class reaches a consensus. The prompts might include the following:

- The Moon revolves around Earth, and Earth and Saturn are planets that revolve around the Sun. What might that tell us about the size of Earth, the Moon, and the Sun?
- In addition to its rings, Saturn has at least sixty moons. What might this tell us about its size in relation to Earth?
- The Sun is a star in our galaxy. The Pleiades is a cluster, or group, of stars in our galaxy. Hubble is a cluster of galaxies. What can that tell us?

Looking at the pictures from beyond our solar system, students might wonder if the question of size refers to individual stars or to the groups of stars. Make it clear that you will be trying to figure out the relative size of the entire "field of view" in the pictures.

The discussion of size might be an opportunity to introduce gravity and its importance to every structure in the universe. For instance: A moon cannot be larger than its planet—its orbit depends on the larger mass and stronger gravitational pull of the planet. And a planet can only get so big—an object much larger than Saturn and Jupiter would collapse under its own mass and become a star.

STEP TWO: DISTANCE

Repeat the procedure, this time for an arrangement from nearest to Earth to farthest. We recommend these pictures:

Moon	240 thousand miles on average
Sun	93 million miles on average
Saturn	120 million miles at closest
Pluto	2.6 billion miles at closest
Pleiades	2,400 trillion miles
Whirlpool Galaxy	200 million trillion miles
Hubble Deep Field	30 billion trillion miles

Possible discussion prompts:

- You now know the size of the Moon and the Sun. You know how they look in the sky. What can this tell us about their distance?
- Saturn takes 10 thousand Earth days to orbit the Sun. Pluto takes 90 thousand Earth days. What can this tell us about their distance?
- The Pleiades, or "Seven Sisters," can be seen with the naked eye. The Whirlpool Galaxy can be seen (as a little fuzzball of light) with binoculars. The Hubble cluster of galaxies was discovered by the Hubble Space Telescope in the 1990s. What can this tell us about distance?

The discussion of distance might be a good opportunity to address a question of size—the vast difference in the actual size of the Sun and the Moon and their near parity of size in our sky. In a quick modeling exercise, hold out the Sun and Moon cards for the class to see. Then pull the Sun card toward you, away from the class. *Does the Sun now seem smaller?*

STEP THREE: AGE

Repeat the procedure, this time for youngest to oldest. We recommend these pictures:

Great Pyramid of Giza	4.5 thousand years
Pleiades	100 million years
Stegosaurus	150 million years
Moon	4.5 billion years
Earth	4.5 billion years
Sun	4.5 billion years
Hubble Deep Field	12 billion years?

THE PLEIADES BELOVED BY STARGAZERS, THIS CLUSTER IS BILLIONS OF YEARS YOUNGER THAN EARTH.

Possible discussion prompts:

- Do you think everything in the sky is older than human history? Older than life on Earth?
- Three of these are pictures of objects in our solar system. Do you think they are similar in age?
- We know that the cluster of galaxies is farthest from us. Does this tell us anything about its age?

It's worth mentioning to students that Egypt, like other ancient civilizations, was quite sophisticated in astronomy. By charting the rise and fall of stars in the sky, Egyptians determined the length of a year, and so were able to predict the yearly flooding of the Nile. Astronomy also had spiritual uses. Within the Great Pyramid—the pharaoh's tomb—are upward-pointing shafts that might have pointed to specific stars. This is difficult to know because of the constant slow movement of stars in relation to Earth.

No star is an "ever-fixèd mark," as Shakespeare put it. Nor is it eternal. Stars die and are born all the time. The Pleiades, which ancient Greece associated with the seven daughters of Atlas, were born long after dinosaurs began their reign on Earth. The early dinosaurs, if they ever bothered to glance at the night sky, would not have seen the Pleiades.

Age is a tricky subject, even within our solar system. The Sun and the planets formed from the same matter at the same time. One way of looking at it, then, is that they are all the same age. On the other hand, students would be demonstrating good logic—and would in most ways be correct—to see the Sun as a kind of parent to the solar system. The characteristics of the planets as we know them—their size and composition, whether they became gas giants or relatively small balls of rock—depended on their distance from the gravity and heat of the Sun.

If students see a similar parent-child relationship between Earth and the Moon, most scientists would agree with them. The prevailing theory for the formation of the Moon is that it was a result of a collision between Earth and a stray Mars-sized object. On impact, bits of our planet and this mystery object blew off into space and clumped together in our orbit.

Trickier still is the age of the Hubble cluster of galaxies. The image on the card is from the farthest reaches of our sight. The light has taken more than 10 billion years to arrive, so we know that the galaxies are older than our solar system. On the other hand, what we see in the image are the galaxies as they were not long after their formation, when they were younger than we are. The image, then, is a bit like a baby picture of a very old man.

A telescope is a time machine. To look out into space is to look back in time. Imagine an alien space telescope that is right now cruising at the distance of the Pleiades, four hundred light-years away. Imagine that it has its sights trained on Earth. The planet it sees is the planet of four hundred years ago. Below the clouds, Shakespeare might be at work on *The Tempest* or *King Lear*. Pocahontas might have just met John Smith. And Galileo himself might be peering back at the stars.

EXTENSION: BONUS QUESTIONS

On the reverse side of each card is a math or logic problem related to the card's subject. The problems vary in difficulty. An answer key is on the back of the pullout section. As in the lesson, we use familiar English measurements. Students might try some conversions to the more scientific metric system.

ON OUR WEBSITE YOU'LL FIND A PRINT-READY SHEET FOR STUDENTS TO RECORD THEIR ARRANGEMENTS AND REARRANGEMENTS OF THE PICTURES. GO TO SMITHSONIANEDUCATION.ORG/UNIVERSE.

THE TWO-INCH UNIVERSE

Now that students have a numerical introduction to size and scale in the universe, this quick modeling activity can help them imagine things spatially. Each step calls for students to predict sizes and distances on the basis of a two-inch scale. You can also try doing the math by converting miles into feet and inches.

All the equipment you'll need is in the pullout section of the issue: a two-inch-diameter Earth (along with a half-inch Moon), a two-inch Sun, a two-inch solar system, a two-inch Milky Way, and a two-inch Andromeda galaxy. Actual distances and sizes are on the back of the page.

Just add salt!

STEP ONE: THE REALM OF EARTH AND MOON

Hold up the two-inch Earth. Read aloud the actual sizes of Earth and Moon and ask students to predict: *If the Earth is just two inches wide, how big would the Moon be at this scale?*

Hold up the half-inch Moon. Read the distance between Earth and Moon. Ask for predictions: *How far apart would they be?*

To approximate the distance, hold Earth and Moon about five feet apart. Read the Sun's size and distance from Earth. *How far away would the Sun be at this scale? Can you imagine something the size of the Sun at this scale?*

A minivan, sixteen feet across, would give an idea of the size of the Sun. The distance to this Sun would be 1,800 feet, or six football fields.

Instead of imagining six football fields end to end, you might use a street map to mark a distance of 1,800 feet from your school. Estimate the distance in feet of one block in your neighborhood, then multiply.

For instance: If the Earth is the two-inch disk in the middle of the classroom, the Sun is a minivan—a yellow one, perhaps—parked at the corner of Maple and Pine.

STEP TWO: THE REALM OF THE SUN

Now, in switching scales, the minivan-sized Sun becomes the two-inch Sun. Hold up the two-inch Sun and ask: *At this scale, how big would Earth be? How far away?*

A grain of fine table salt, held in a student's palm, would serve for the size of Earth. A speck of dust, if handy, would serve for the Moon, placed half an inch from the grain of salt. The distance between Sun and Earth would be twenty feet, which you might roughly pace off in the classroom.

STEP THREE: THE REALM OF OUR SOLAR SYSTEM

Display or pass around the two-inch solar system. The tiny dot of light in the center is the Sun. The rings represent the orbits of the planets. The planets at this scale would be invisible. The nearest star to the Sun, Proxima Centauri, would be two football fields away. (Actual distance: 25.8 trillion miles or 4.3 light-years.)

Remind students that the Sun is one of about 200 billion stars in our galaxy, the Milky Way. Ask them for their wildest predictions: *At this scale, how big is the Milky Way?*

A Milky Way made up of two-inch solar systems would be about the size of North America. If the tiny dot of light were a grain of fine salt, a teaspoon of the salt would represent about 100 thousand of the Milky Way's 200 billion stars.

STEP FOUR: THE REALM OF GALAXIES

The continent-sized Milky Way now shrinks to two inches. For this final scale model, you will need the two-inch Milky Way and the two-inch Andromeda galaxy.

Andromeda, the nearest major galaxy to ours, is sometimes visible to the naked eye as a single smeary light. Read its width and distance from the Milky Way. *At the two-inch scale, what is the distance between the galaxies?*

Here again, five feet is a good approximation. Individual stars in these two-inch galaxies would not be visible even under a microscope. The lights in the images are the combined glow of thousands and thousands of stars. At this scale, the distance to the far galaxies seen by the Hubble Space Telescope would be about four miles from your classroom.

And so: *How big is the universe?*

If students struggle with this question, they might be relieved to know that nobody knows. The universe as a whole may be infinite. The whole of our *observable* universe may be someone else's grain of salt.

EXTENSION: REFLECTION QUESTIONS

For a class discussion or an essay, ask students to consider:

- Do you think it's likely that there is life elsewhere among these incredible distances? How about intelligent life?
- What would be some of the challenges in trying to communicate with other life around other stars?
- Some people say they feel insignificant after understanding the scale of the universe. Others say it makes them feel that life on Earth is special, that the human mind has only grown more significant by understanding this vastness. What is your view?

In a profile on the next page, we pose these questions to Lisa Kaltenegger of the Harvard-Smithsonian Astrophysical Center, who spends a lot of time thinking about them.

A SMITHSONIAN PROFILE

LISA KALTENEGGER PLANET HUNTER

IN 1995, WHEN LISA KALTENEGGER WAS ABOUT TO graduate from high school, astronomers made the first discovery of a planet outside of our solar system. Fifty light years away, it was in every way a whole new world: a gas giant the size of Jupiter, but so close to its star that its orbit, its "year," takes just four days. Lisa now works as a planet hunter (the actual term) at the Harvard-Smithsonian Center for Astrophysics. In the brief time between then and now, there have been more than four hundred planet discoveries, each bringing us closer to a new view of the starry sky—from a universe of distant fires to a universe of other lands.

"All the planets so far are much heavier than Earth," says Lisa. "The lightest is about five times as massive. With bigger telescopes that we are building on the ground and launching into space in the near future, we can find smaller and smaller planets."

The next step will be to examine those planets—and any *Avatar*-like moons of the gas giants—for what she calls "weird signs," including signs of life. These places might be so interestingly different from Earth—and so weird—that "life might be the icing on the cake."

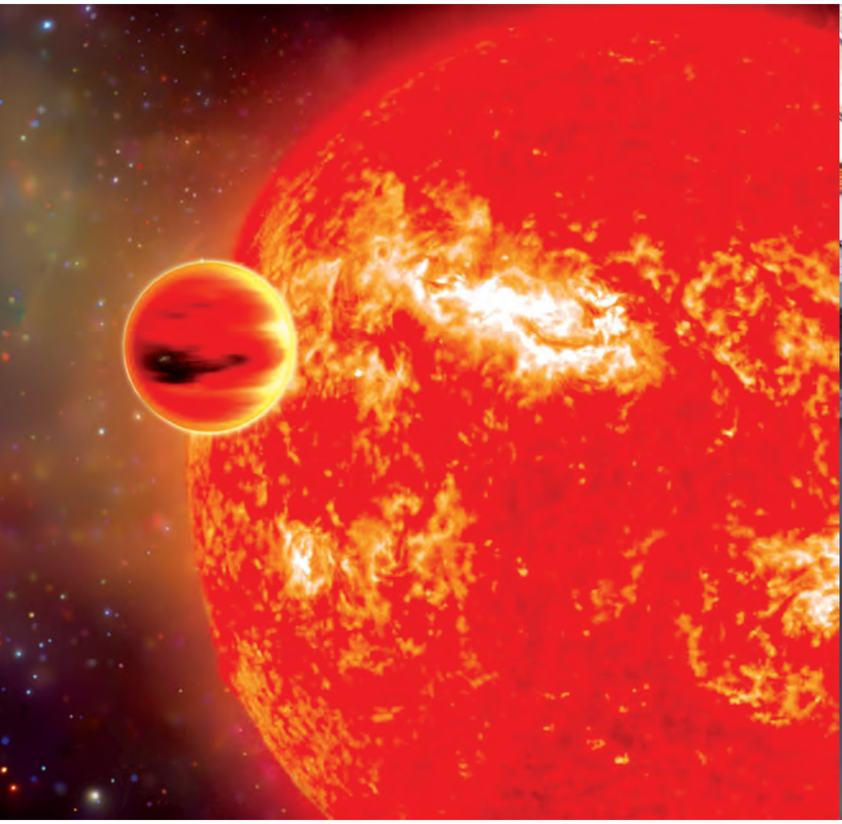
Lisa grew up in the small town of Kuchl in the Austrian Alps and attended Austria's University of Graz, earning a Ph.D. in astrophysics while working on satellite projects with the European Space Agency. When she began at the university, her curious nature left her undecided between five subjects: astronomy, chemistry, engineering, foreign languages, and film studies. She narrowed things down in graduate school, but just a bit. She wrote two master's theses, one on the use of lasers in medicine and one on the discovery of planets.

What the two have in common is light. In planet hunting, light is both the thing studied and an obstacle to study. A planet has no light of its own. It reflects the light of its star—its sun—and emits some of its heat. For a good look at the planet, this pinpoint of light and heat must be sifted from the glare of the sun. Working from the distance of trillions of miles, Lisa says, is like standing in Los Angeles and trying to find a penny in Washington, D.C.—all the while staring into a blinding spotlight.

In 2014, NASA will launch the James Webb Space Telescope, which will be equipped to detect gases in the light and heat. Lisa will be one of the scientists looking for gases like carbon dioxide, oxygen, and water vapor—indications that life is possible—and for combinations like oxygen and methane, which can only be explained, on Earth anyway, as life itself.

In preparation, she has created models of what a living planet's light might look like, some of them based on our own planet at various stages of its history. For her work, she has received a high astronomical honor: an asteroid was named for her, and so she has joined the ranks of mythological celebrities like Juno, Ceres, and Psyche. The asteroid Kaltenegger 7734 (the number is her birth date, backward) is in the belt of "minor planets" between Mars and Jupiter.

"They promised the asteroid won't hit Earth," says Kaltenegger "so I'm all good."



GAS GIANT THIS ARTIST'S INTERPRETATION SHOWS A GAS-GIANT PLANET ORBITING CLOSE TO ITS STAR.

PLANET HUNTER LISA KALTENEGGER SAYS THAT SUCH PLANETS ARE "NOT LIKE ANYTHING WE EXPECTED."

She seemed a perfect person to ask the questions that are posed in the lesson "The Two-Inch Universe."

Do you think it's likely that there is life elsewhere? What about intelligent life?

Take every pebble, every stone, and every grain of sand on Earth, and you still don't have the number of stars in the sky. So with that many stars, what are the chances of another planet like ours? Right now we are concentrating our search within about seventy-five light-years, to collect enough light to find planets that are tiny in comparison to their stars.

Intelligent life is an interesting question. The answer depends on a lot of different assumptions. How long does life need to become intelligent? How long does intelligent life survive? It is hard to know when we only have a sample of one, our own Earth. I'm assuming we want to define ourselves as intelligent!

We are just starting to find planets that are small enough to have rocky surfaces and liquid water, and thus could be habitats. But if you think of Earth's history of about 4.5 billion years and draw this time on a 24-hour clock, humans come on the scene about 38 seconds before midnight. If you want humans with technology, it is only a fraction of a second on the clock. So finding a planet that is a) nearby, b) like ours, and c) in the same evolutionary stadium? It will be tricky. But who knows, maybe we will get lucky. It is a big open question. What do *you* think?

What would be some of the challenges in trying to communicate with other life around other stars?

Many scientists are trying to puzzle this question out. How do you talk with someone whose language and culture you do not know and whose gestures you cannot see? We think that mathematics has a few rules that are universal, so some scientists try to base a communication on prime numbers, numbers that can only be divided by themselves and one. But how to transmit information using that code?

Another thing to think about: Let's assume there is a planet like ours around the star closest to our Sun, about four light-years away. So you pick up the interstellar phone and say, "Hi, who are you?" About four years later the signal gets to the other end of the phone. Another four years later the answer arrives. And you are really happy, because you had eight years to come up with a better question! What if the planet were fifty light-years away? You'd better tell your children or grandchildren about the interstellar phone call, so they can continue the conversation.

For now, this is all unknown. We've got quite a lot to discover and so much more to learn while we are doing it.

Some people say they feel insignificant after understanding the scale of the universe. Others say it makes them feel that life on Earth is special. What is your view?

I look at the stars at night and see the beautiful sparkling lights, and I wonder what worlds are out there. I think that being curious is what makes us human. We wanted to understand how the body works and we developed medicine. Curiosity brought us technology and music and literature. Musicians and poets create beautiful pieces that take us on travels we could never undertake otherwise. Who knows what we will figure out while being curious about other worlds. Maybe we'll figure out how to take care of our own.

There is an amazing universe around us and we are a part of that, embedded in it. Maybe we are very special, or maybe we are one of thousands of fantastic worlds. For me, it is a breathtaking, fun adventure to find out.

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