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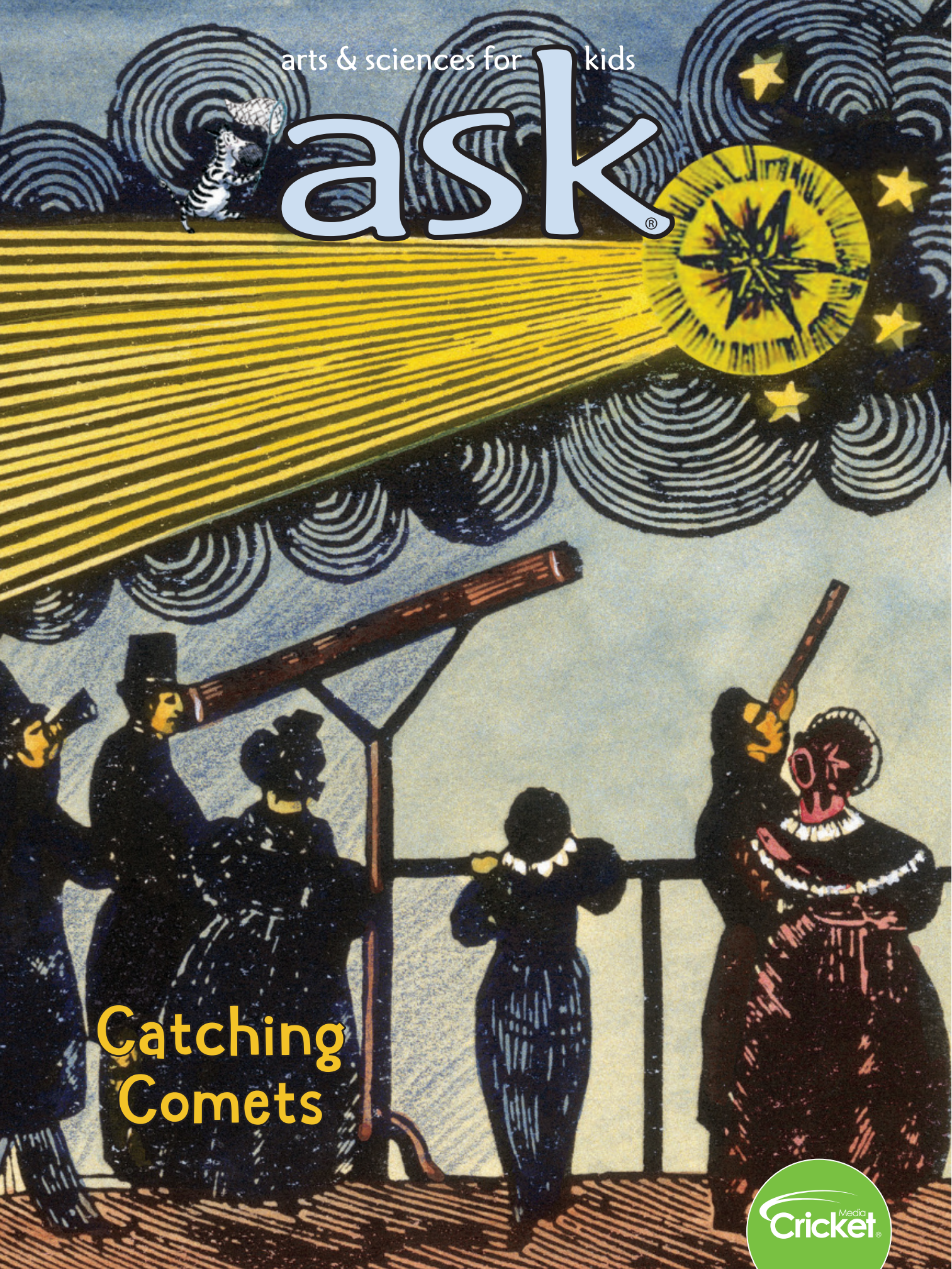

Catching Comets

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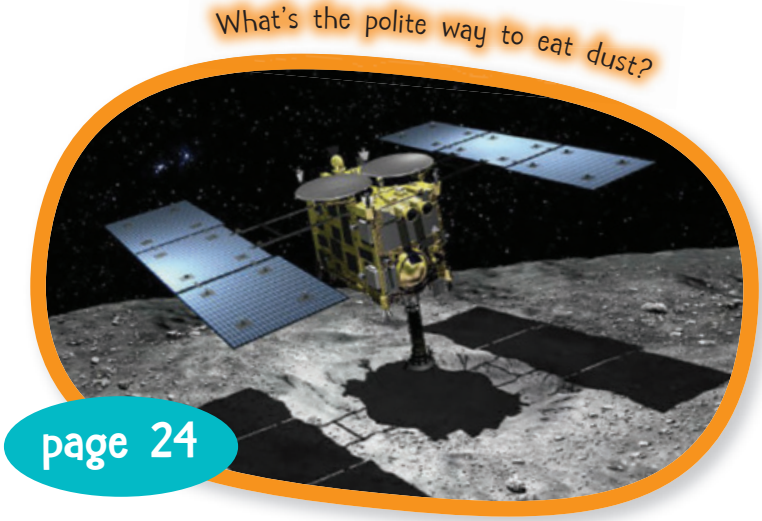

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Whose space is it, anyway?

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Did anyone order a battle comet?

Nosy News

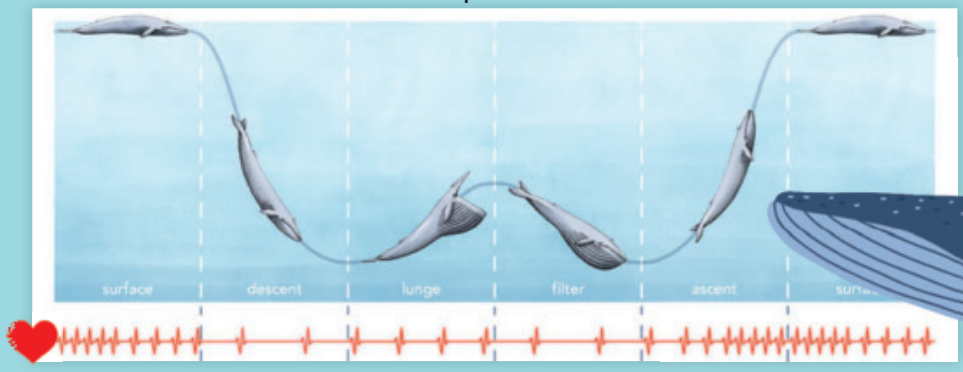
by Elizabeth Preston

A GIANT'S HEART

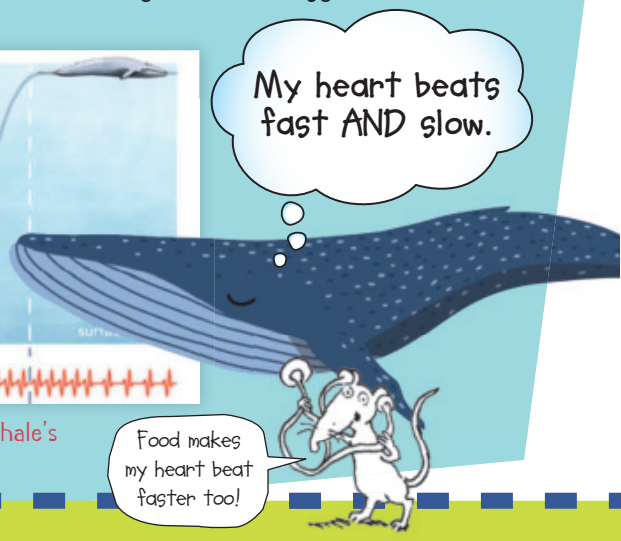
An adult human's heart beats 60 to 100 times a minute, on average. But a hamster's heart can beat 400 times a minute. Smaller animals usually have faster heartbeats than bigger animals. So what about the biggest animal on Earth—the blue whale?

Researchers decided to find out with the help of some stick-on microphones. The team used a long pole to stick tiny sensors onto whales when they came up for air at the ocean's surface. Suction cups held the sensors tight to each animal's skin. The sensors could pick up the sound of the whale's heartbeat.

The sensors showed that a blue whale's heart beats almost 40 times a minute at the surface. But when the whale dived deep, its heartbeat slowed down to just twice a minute. Slowing their heart rate helps animals like the blue whale make long dives without running out of oxygen.



The red marks at the bottom show how often a blue whale's heart beats each minute as it dives and feeds.



A New Dwarf

Snow White was friends with seven dwarves. And our solar system may now have a sixth dwarf planet.

That's what astronomers say after taking a closer look at an asteroid called Hygiea. It's part of our solar system's asteroid belt. Asteroids come in many shapes. But new telescope images showed researchers that Hygiea is nice and round. That means it might technically be a dwarf planet.

To be a dwarf planet, a space rock has to be round, orbit the sun, and not be a moon. Our solar system's most famous dwarf planet is Pluto. At about 270 miles (434 km) wide, Hygiea would be the smallest.

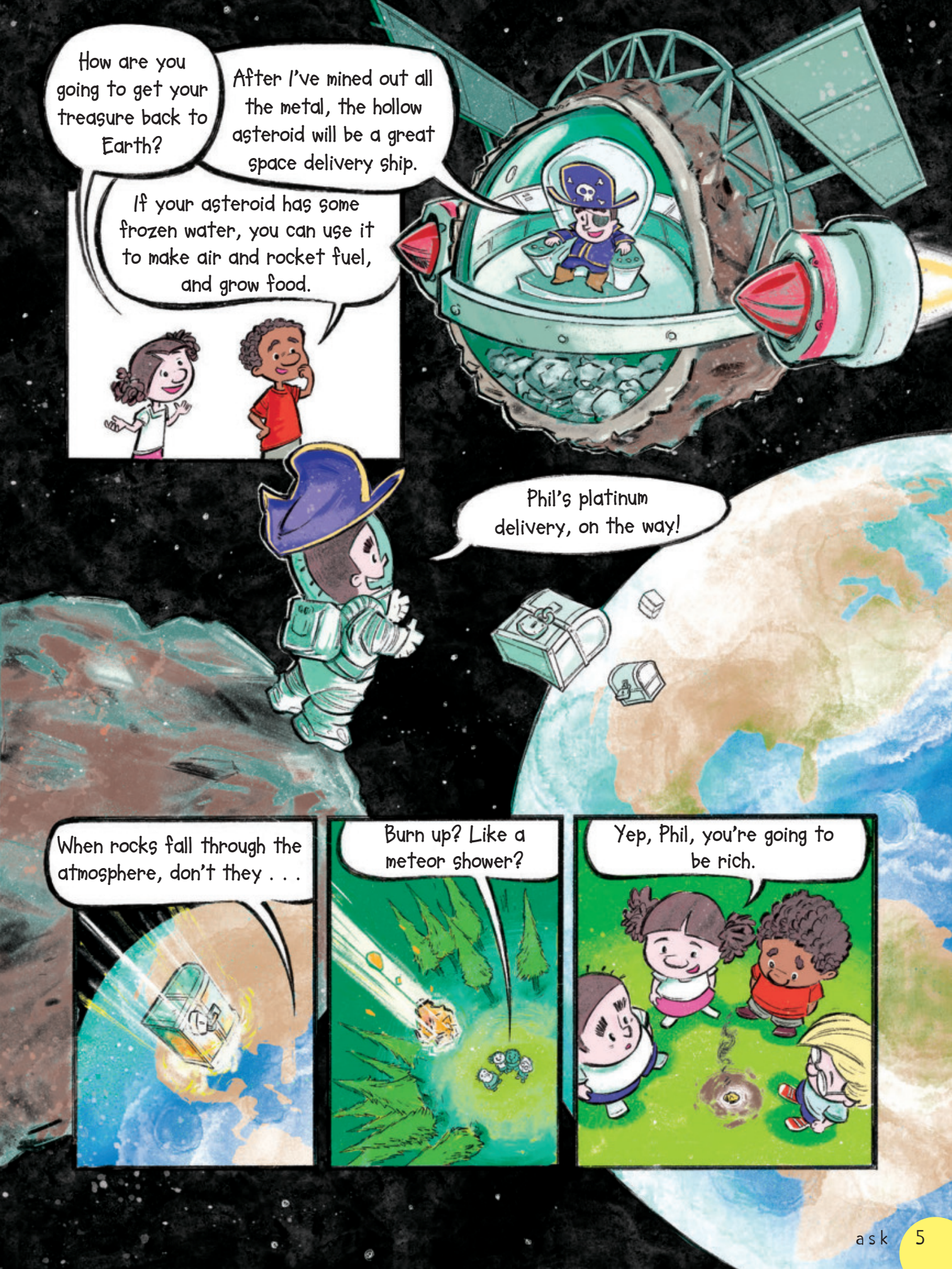
Lice Bugged Dinos, Too

Have you ever had lice? It probably seemed like the itchy bugs in your hair would never go away. Now scientists say lice have been around practically forever. Millions of years ago, the pests even nibbled dinosaur feathers.

Recently, researchers found 10 tiny bugs in pieces of amber. Amber is fossilized tree goo. These amber pieces also held feathers from dinosaurs that lived in the Cretaceous, about 100 million years ago. The fossilized bugs were clinging to feathers that were full of small chewed holes.

The scientists think these fossil bugs were long-ago lice. Like today's lice, the bugs had no wings. But they did have big jaws—perfect for pestering their hosts.


Nestor's Luck
by Jeffrey Ebbeler
Meteors are so pretty!
And interesting! Meteorites can contain all sorts of rare metals.
Free space treasure! My fortune is made!
Rare as in valuable?
Sure. Meteorites are bits of asteroids, and some asteroids are full of heavy metals like platinum.


How are you going to get your treasure back to Earth?
After I've mined out all the metal, the hollow asteroid will be a great space delivery ship.
If your asteroid has some frozen water, you can use it to make air and rocket fuel, and grow food.
Phil's platinum delivery, on the way!
When rocks fall through the atmosphere, don't they . . .
Burn up? Like a meteor shower?
Yep, Phil, you're going to be rich.

Field Guide to Space Rocks and where to find them

Space is vast, dark, and cold. And surprisingly full of rocks. Here is a short guide to some of the most common ones you may encounter on your travels.

Where do space rocks come from? Most are left over from when the solar system was born, 4.5 billion years ago. The sun and planets formed from a big spinning cloud of gas and space dust. And there are still bits of leftover rock (and gas) floating around.

Gas and dust swirl in a cloud.

Bits clump together.

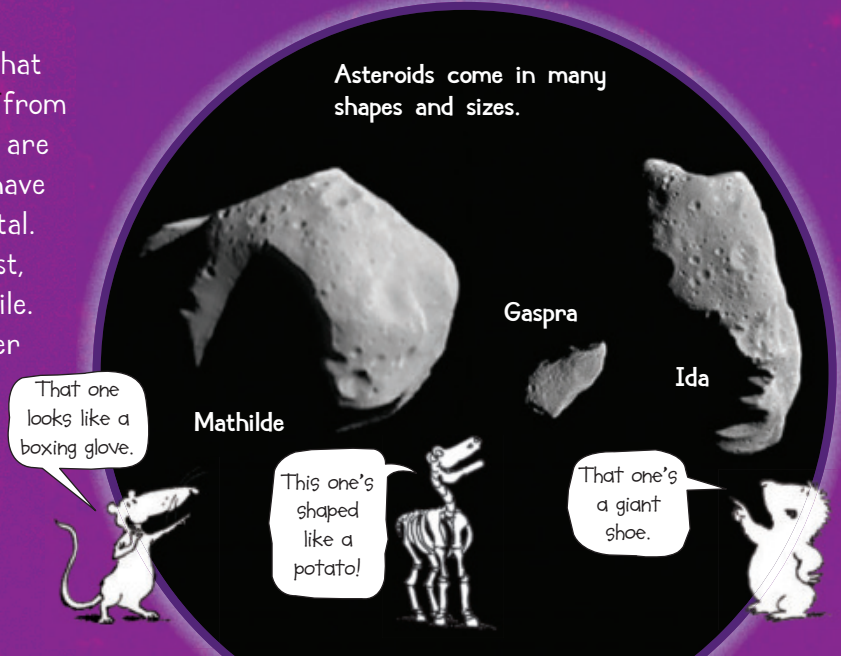
The center ignites to become the sun.

Around it spin planets and leftover rocks.

ASTEROID

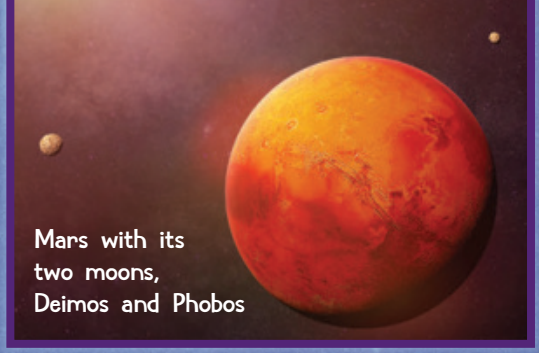
An asteroid is any small rocky object that orbits the sun. Asteroids range in size from a few feet to many miles across. They are smaller than planets or moons. Many have odd shapes. Some are solid rock or metal. Others are loose clumps of pebbles, dust, and ice, gathered together like a leaf pile. Sometimes asteroids run into each other and split up or stick together.

There are millions of asteroids in our solar system, left over from when the sun and planets formed.



MOON

A moon is a round object that orbits a planet instead of the sun. Many moons are asteroids that have been captured by a planet's gravity. Earth's moon is a bit of Earth itself that was knocked off in a collision long ago.



Mars with its two moons, Deimos and Phobos

DWARF PLANET

A dwarf planet is a big, round asteroid that is almost, but not quite, a planet.

In 2006, astronomers decided that Pluto is a dwarf planet because its orbit overlaps with other objects. Other dwarf planets in our solar system are Ceres, Eris, Makemake, and Haumea.

Dwarf planet Ceres, in the asteroid belt

SPACE DUST

Space dust is made up of tiny specks of rock and simple molecules. Space dust often coats the surfaces of moons, comets, and asteroids. Tons of space dust sifts down on Earth every year—there's probably some in your house.

A grain of space dust seen through a microscope

Scientists are very interested in space dust. They collect it as it falls to Earth by flying big airplanes with dust collectors on the wings. Some space dust comes from outside our solar system, so it could tell us about other places in the galaxy.

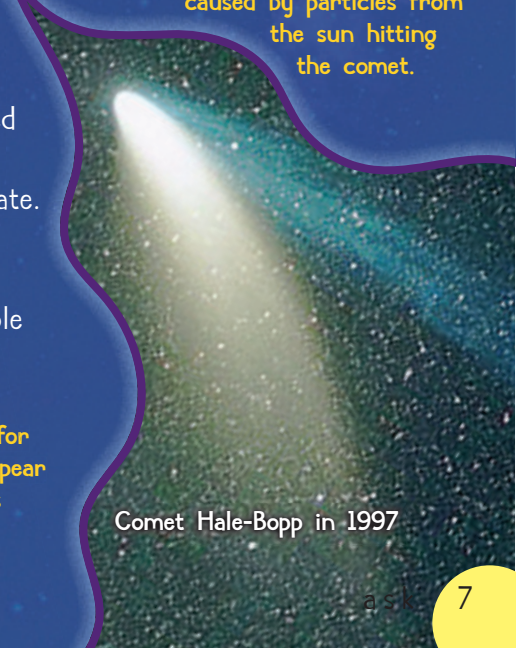
COMET

A comet is an asteroid made of ice, with a sprinkling of rock and dust. These fast-moving dirty snowballs are born in regions beyond Jupiter, where it is very cold. They orbit the sun in wide loops.

Sometimes a comet will get knocked toward the inner planets. As sunlight warms it up, the ice starts to evaporate. This makes a tail of glowing gas. The tail is the comet's most distinctive feature. Some bright comets are visible from Earth even during the day.

Comets hang in the sky in the same place for days, sometimes weeks. Some regularly reappear on their long loops around the sun. Halley's Comet passes Earth every 76 years.

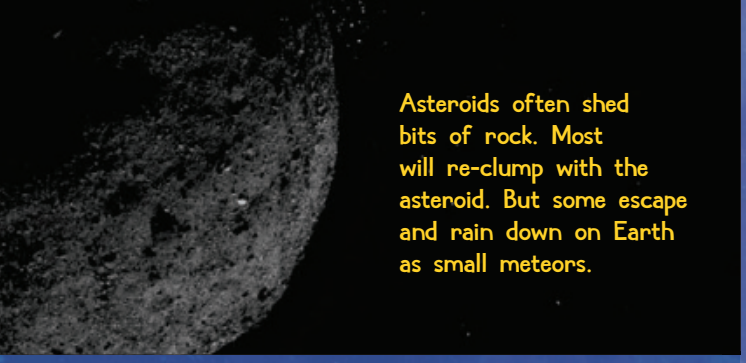
Comets have two tails, a blue tail of gas and a white tail of dust. The glow is caused by particles from the sun hitting the comet.



Comet Hale-Bopp in 1997

METEOROID *In space*

Meteoroids are small space rocks. Many are broken-off bits of comets or asteroids. There are billions of these small rocks floating around the solar system. They are called meteoroids while still in space. But if one falls to Earth, it gets a new name.



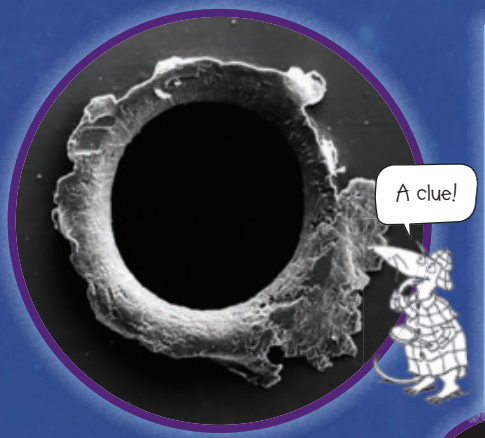
Asteroids often shed bits of rock. Most will re-clump with the asteroid. But some escape and rain down on Earth as small meteors.

METEOR *Falling*

When a meteoroid falls into Earth's atmosphere, it flashes across the sky as a bright meteor. As space rocks fall, they heat up white hot and melt. Most meteors completely vaporize before they reach the ground. Sometimes they explode with a flash and a bang.

A meteor makes a bright light trail for just a second. This looks like a star falling out of the sky, so meteors are also called shooting stars—though they are not stars, just space rocks.

Meteors move so fast that they squash up the air in front of them with a huge force. This super-heats the air enough to melt the rock and make a bright light trail.



This tiny hole in a satellite is about the size of a pencil dot. It was made by a speck of rock going very fast.

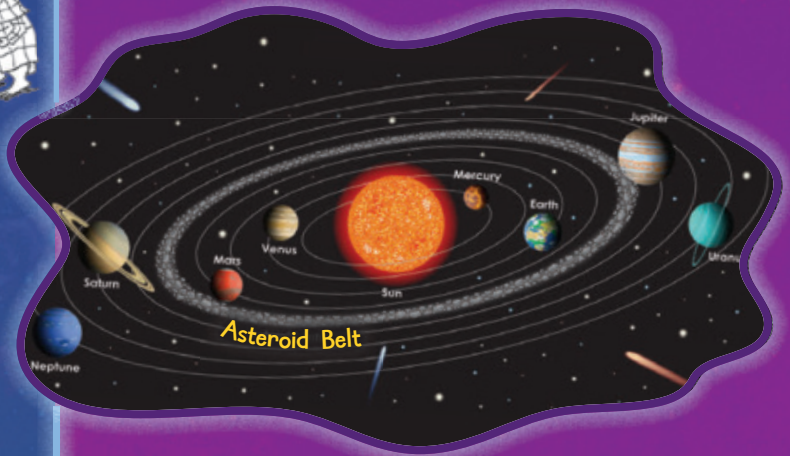
MICROMETEOROID

Very tiny space rocks are called micrometeoroids. Most are smaller than sand grains. Still, they can be a hazard to spacecraft and satellites. Even a tiny rock can punch a hole right through metal if it's traveling at high speed.

Space Rock Hang-Outs

ASTEROID BELT

Many asteroids come from the Asteroid Belt, a rocky region between Mars and Jupiter.



METEORITE

Fallen

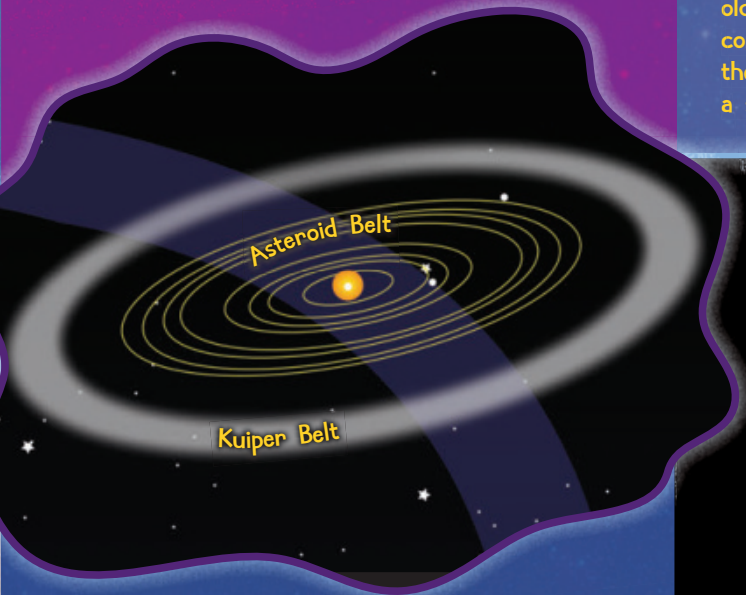
If any of the meteor makes it all the way to the ground, once it lands, it's a meteorite.

This meteorite fell in the desert in Sudan. Meteorites often have a melted black crust from their fast, hot fall.

METEOR SHOWER

A lot of meteors falling at the same time make a meteor shower. Usually these happen when Earth passes through the tail of a comet.

The Perseid meteor shower can be seen every year around August 12, as Earth passes through the old tail of comet Swift-Tuttle. Earth circles around to this showery tail at the same time every year, like running around a track that has a sprinkler turned on at one point.

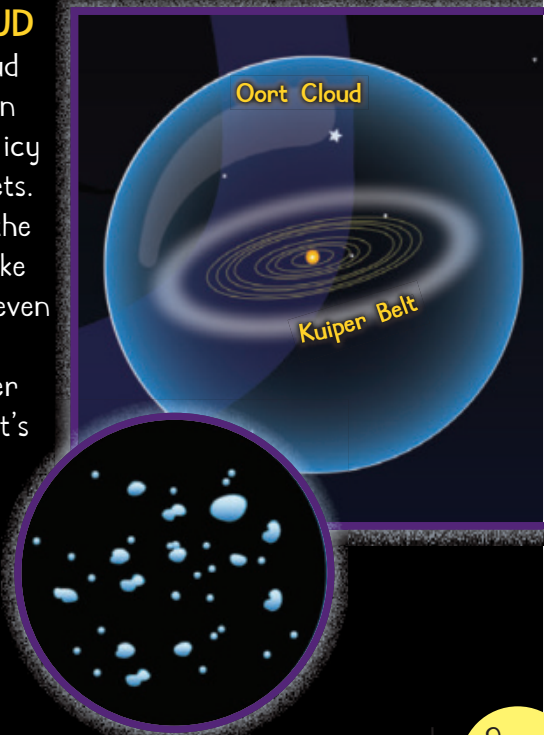


KUIPER BELT

Icy comets come from frosty regions far from the sun. The Kuiper Belt is a loose ring of rocks and comets out by Pluto. Sometimes comets get knocked out of their orbits and zoom in toward the sun.

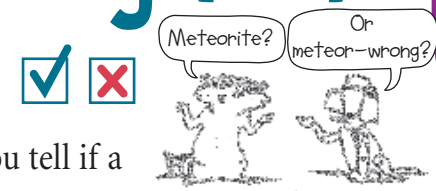
OORT CLOUD

The Oort Cloud is a vast region sprinkled with icy dust and comets. It surrounds the solar system like a bubble. It's even farther away than the Kuiper Belt. Because it's so far away, we don't know much about it.



Is There a Meteorite in Your Backyard?

Meteorites are bits of space rock that have made it all the way down to Earth's surface. They are pretty rare—but many small meteorites do fall every year.



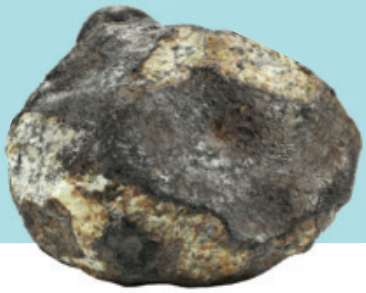
How can you tell if a rock is a meteorite or just a rock? Here are a few signs to look for.

☐ Is it a bit heavy?

Meteorites are often a bit heavier than ordinary rocks. Many contain metal. But there are also heavy Earth rocks.

☐ Does it look burnt?

Falling meteorites heat up super hot. Most vaporize entirely. Bits that survive the trip usually have a burnt crust that is darker than the rock inside. Often the crusts have melty crackle lines and flake off easily.



You can see the burnt crust on this meteorite that fell near Chelyabinsk, Russia.

☐ No holes

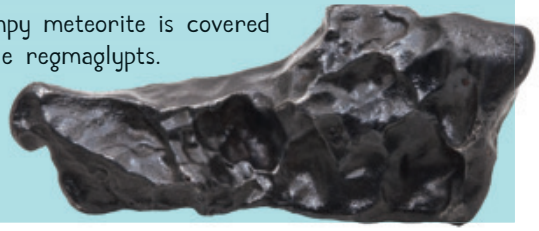
Meteorites do not have holes or air pockets in the rock. This can be an easy way to tell them apart from lava and slag, a human-made rock left over from metal-making.

Slag, or clinker, is rocky waste from metal factories.

☐ Does its surface have smoothed dents?

Often, meteorites have smooth dents that look like thumb prints. These marks are called *regmaglypts*. They are left by hot gas evaporating from the surface of the meteorite as it falls.

This lumpy meteorite is covered in telltale regmaglypts.



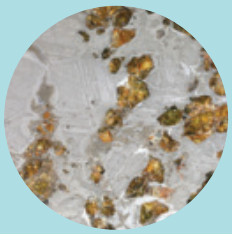
Look at the inside

To confirm a meteorite, rock experts use a special saw to slice off a bit and look inside. Meteorites come in three main types.

Stony meteorites, or chondrites, are the most common. They have a pebbly-looking inside, with round grains and silvery bits.

Iron meteorites are a mix of iron and nickel. A slice will show a special criss-cross pattern in the metal.

Stony-iron meteorites are a mix of metal and rock. These look like metal studded with rocky raisins. Often the rocks inside are olivine, a green crystal.



Will it attract a magnet?

Many meteorites have iron in them, so magnets are attracted to them. But some Earth rocks also attract magnets, so by itself this is not a sure test.

Ask an expert

Many natural history museums have "ID Days" when you can bring in rocks and bugs for experts to identify. If you think you've found a meteorite, check the museum's calendar. A geologist will be able to tell if it's a genuine meteorite.

Where the experts look

Meteorites can fall anywhere, but meteorite hunters often look for them in deserts and in the ice fields of Antarctica. Those places don't get more meteorites. It's just easier to spot small black space rocks on flat, light-colored ground.

These are two pieces of a larger meteorite that broke up over the Nubian Desert.

And there's one more place you can find space rocks—under your bed! Tiny dust grains from space constantly rain down onto Earth. Most house dust contains a few grains of dust from space. But you may need a microscope to see them.

Impostors

These Earth rocks are often mistaken for meteorites.

Lava or volcanic rock—the holes give it away.

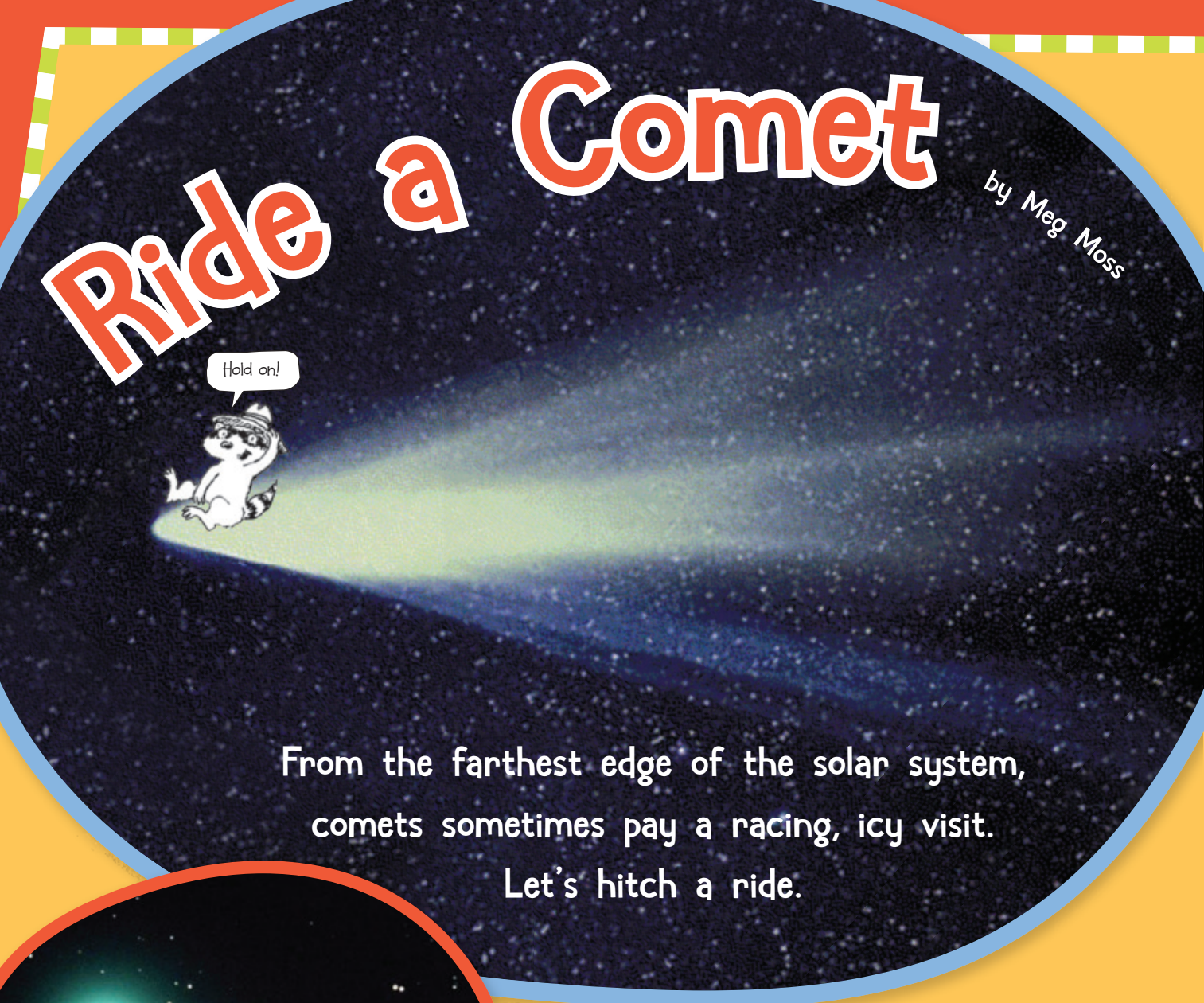
Hematite is an iron-rich rock.

Magnetite is heavy, black, and magnetic.

Manganese can look burnt.

Ride a Comet

by Meg Moss



From the farthest edge of the solar system, comets sometimes pay a racing, icy visit. Let's hitch a ride.

Comets look like fiery stars, but they're actually snowballs.

Beyond Earth, past Jupiter and Saturn, and farther than Pluto lies a cold and distant region called the Oort Cloud. Out here, trillions of dirty, icy lumps surround the solar system like a vast, loose bubble. Scientists believe that these lumps were left over when the planets formed about 4.5 billion years ago.

Now and then, a lump gets pulled out of its peaceful orbit by the gravity of a star or planet. It plunges into the inner solar system on a wild ride toward the sun. A comet is born.

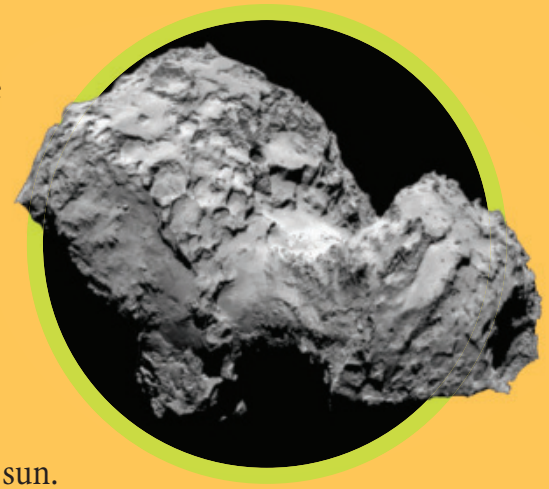
A Comet's Journey

Most pictures of comets show a bright ball of light with a long, glowing tail. That's how comets look when they pass Earth. But they don't start out that way. Our baby comet leaves the Oort Cloud as a frozen chunk of ice, dust, and frozen gas. It looks a bit like a dirty snowball. This is the comet's nucleus, its solid core.

Space probes have caught photos of comet nuclei. Many have surprisingly weird shapes, resembling hamburgers, peanuts, and bowling pins. They can be as large as 160 miles (257 km) across, or less than a mile. Some don't look icy at all. Their surfaces are rough, covered in craters, cliffs, and dust. It's hard to tell by looking whether the surface is spongy or solid. There's no air and very little gravity.

As a comet draws closer to the sun, the fun begins. The surface heats up. By the time it passes Mars, jets of gas explode from inside the nucleus. The jets make the nucleus wobble. Heat turns the comet's ice to gas. Gradually, a thin cloud of gas thousands of miles wide surrounds the nucleus. This is called the coma. It glows brightly in the sun's light.

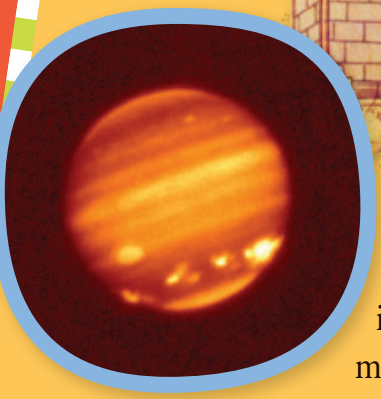
Dust escaping from the melting ice spreads out in a curving tail. The comet also grows a second, straighter tail of carbon dioxide gas. The two tails glow as they are hit by the solar wind, a stream of charged particles from the sun. These two shimmering tails of dust and gas give the comet its extraordinary appearance.



This dusty, icy lump is the core of comet Churyumov-Gerasimenko. The Rosetta spacecraft snapped this photo and landed a probe on the comet as it sped along in 2014.

When a comet is far out in space, it's just an icy lump. Its long tail appears as it heads toward the sun. Particles from the sun hit the ice, making it evaporate and glow.

The Aztec ruler Moctezuma saw a comet in the sky just before the Spanish arrived in 1519.



The bright flashes are bits of comet Shoemaker-Levy, which broke up and smacked into Jupiter in 1994.

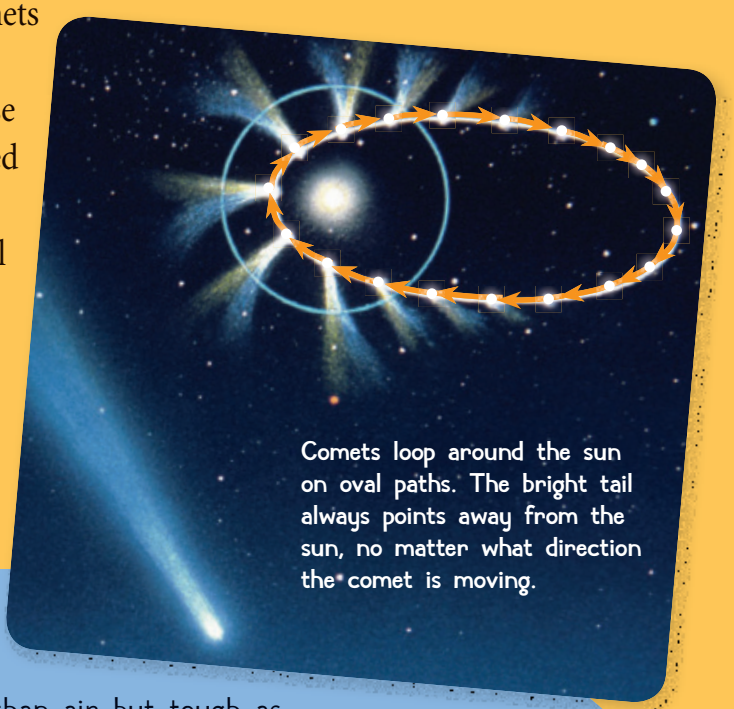
The Hairy Stars

By the time a comet passes Earth, it looks spectacular. A comet might be visible for weeks, hanging in the sky like a "hairy star." The name "comet" comes from the Greek word *kometes,* meaning "long-haired." Long ago, some people believed that comets predicted disease, warfare, or the death of a king. The ancient Chinese described 29 types of comets, sorted by the shapes of their tails. Each kind of tail was supposed to foretell the coming of a different disaster.

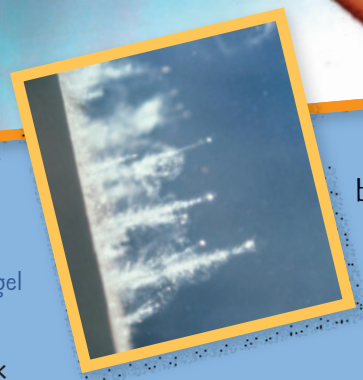
Early astronomers didn't know whether comets were close to Earth or way out in space. They wondered if weather caused comets. Or how about gases rising from the ground?

After much study, scientists realized that comets circle the sun in large, oval orbits. Some vanish into space, never to return. Some take millions of years to make each trip around. Still others zoom around in less than 200 years.

The most famous returning comet is Halley's Comet, which appears over Earth every 76 years. It will next visit in 2061.



Comets loop around the sun on oval paths. The bright tail always points away from the sun, no matter what direction the comet is moving.



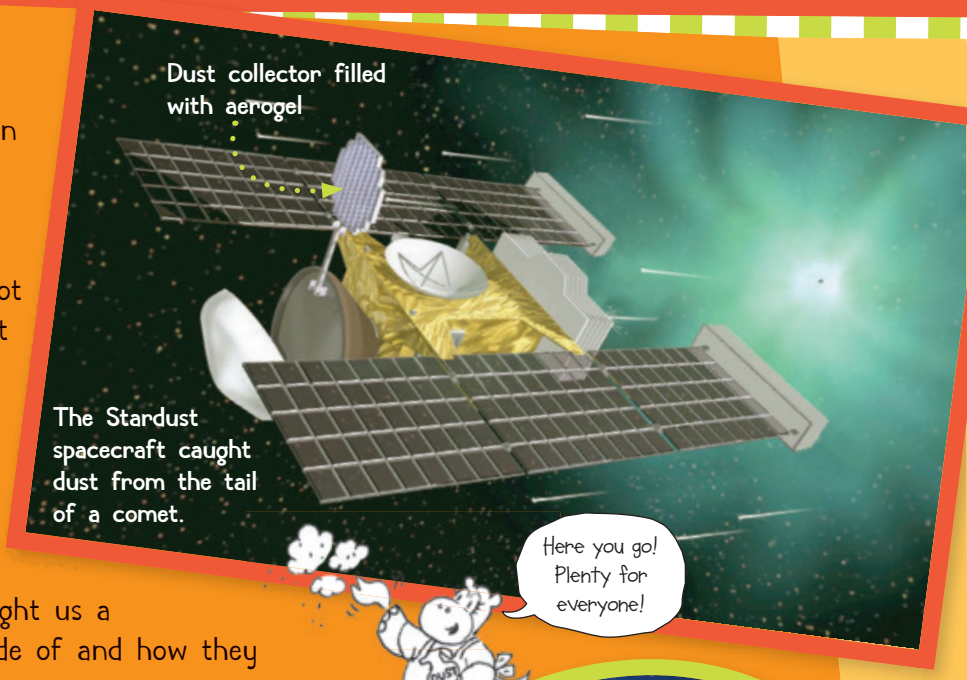
Comet grains caught in aerogel

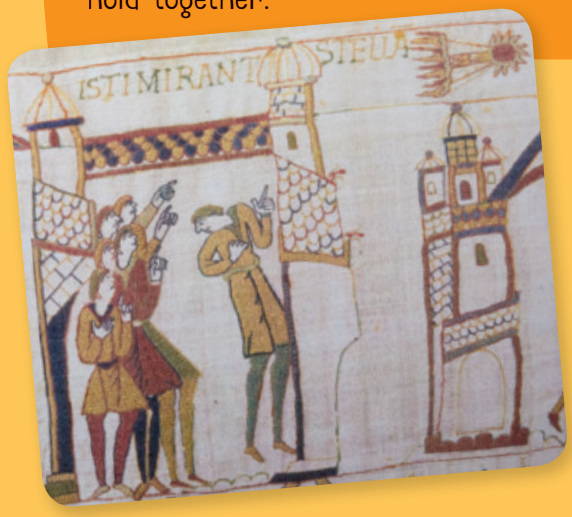
Air Gel

What's lighter than air but tough as nails? This amazing stuff is aerogel, a silicon foam invented to collect samples of dust in space—and from comet tails. Aerogel is 99.8% air. It weighs less than any other solid on Earth. Though it looks like smoke, a column of aerogel the size of a person is strong enough to hold up a car. It has to be strong to stop dust grains speeding by at hundreds of miles an hour. In 2004, the Stardust mission flew through a comet's tail holding out a tennis-racket-shaped collector filled with squares of aerogel to capture bits of comet for scientists to study.

Sampling Comets

Scientists are very interested in comets. Comets contain rock, gas, and molecules unchanged from the very early solar system. So they can reveal a lot about space history. In the last 20 years, more than 10 robot spacecraft have visited comets. In 2004, the Stardust mission caught dust grains from the tail of comet Wild-2 and returned them to Earth for study. These missions have taught us a lot about what comets are made of and how they hold together.





This tapestry shows soldiers pointing at Halley's Comet in 1066, just before the Norman invasion of England. Good luck for the Normans, bad luck for the English.

Around 30 new comets are discovered each year. Most are too faint to see without a telescope. Comets bright enough to shine in the sky are more rare.

Comets take different paths around the sun. Some make a wide circle, 20 million miles from the sun. Others scoot so close to the sun that they break up or evaporate. These are known as "sungrazers."

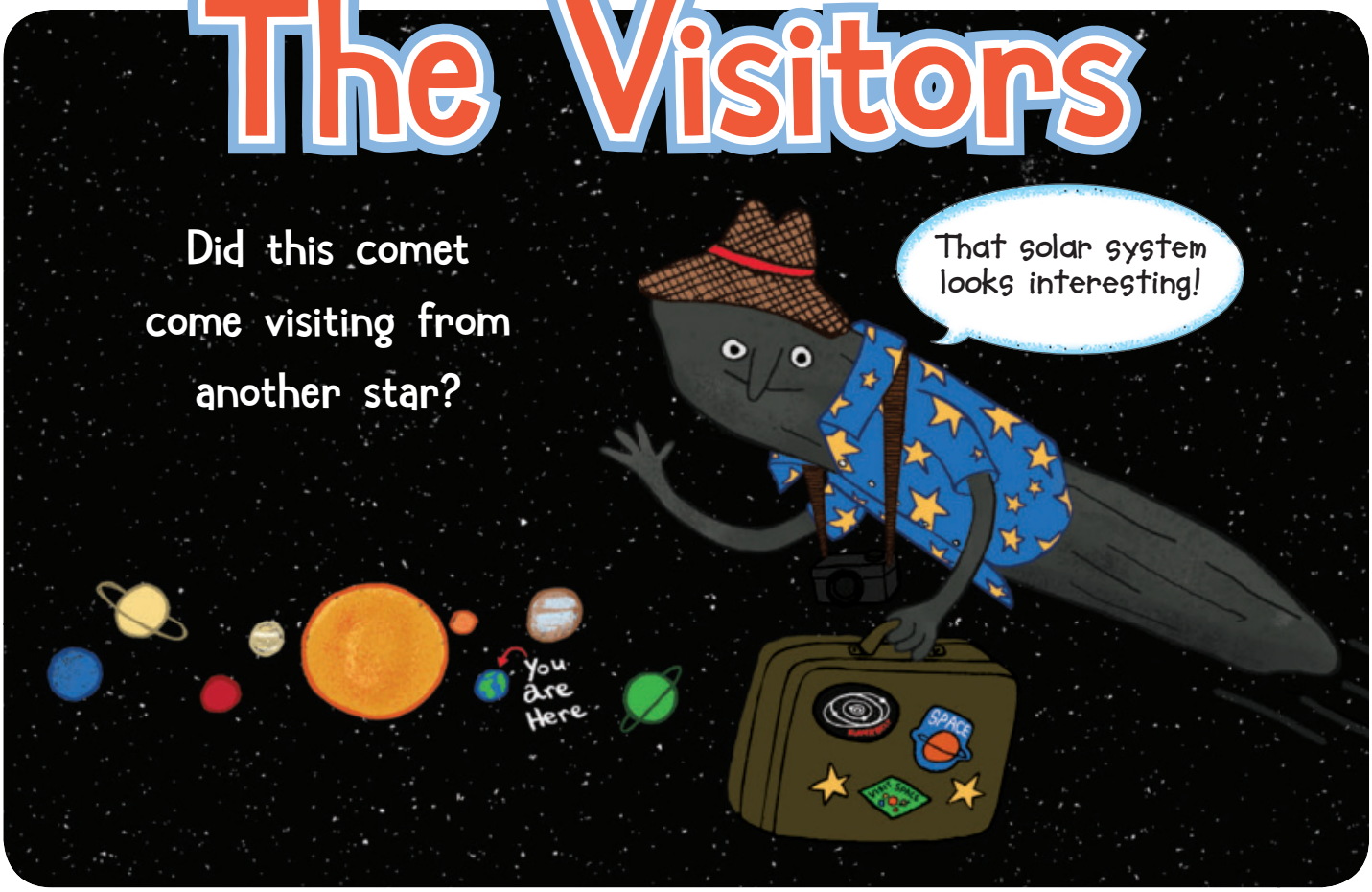
As a comet nears the sun, the solar wind pushes the comet's tail out ahead of the nucleus. Since the tail is pushed out by particles streaming from the sun, it always points away from the sun, no matter what direction the comet is going.

After looping the sun, a comet heads back out into space. As it gets farther from the sun, it quiets down and its glowing tail fades. Only when it nears the sun again will a comet grow its glowing veil of dust and gas.

Many new comets are spotted first by backyard astronomers. So, while you can't ride a comet (yet), keep an eye on the skies.

Halley's Comet passes by Earth every 76 years. This picture was snapped on its last visit, in 1986.

The Visitors



Oumuamua

On the night of October 19, 2017, the Pan-STARRS telescope in Hawaii got to work, scanning the skies for asteroids. But that night, it found something new.

It spotted a small object moving fast—five times faster than a normal comet. It was zooming away from the sun on a wide, curving path.

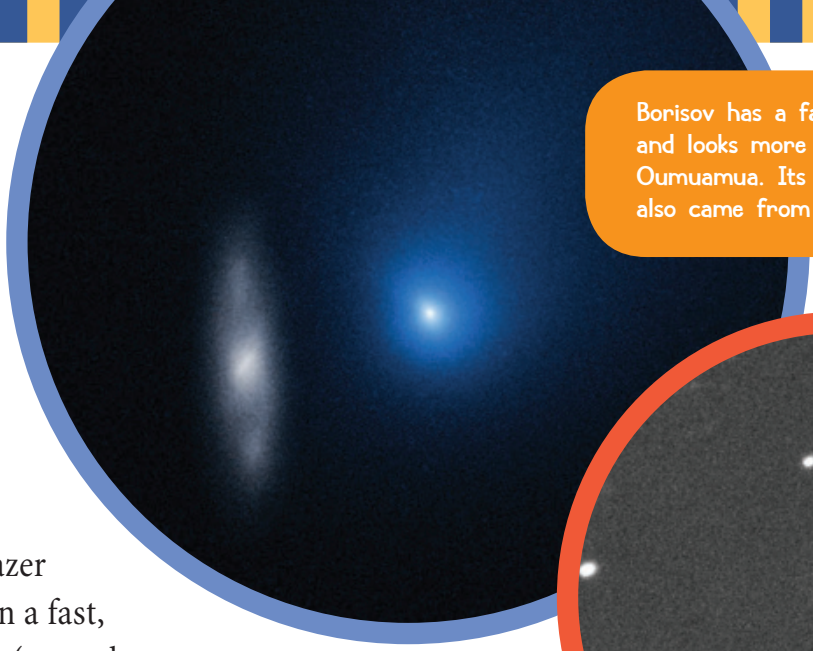
Over the next several days, telescopes around the world tracked the object. They noticed that it got brighter and darker about every seven hours. What could cause that? Maybe the object had a long shape that was tumbling over and over. When they traced the path to see where it had come from, it pointed outside our solar system entirely. The object was a visitor from another star! It was the first extrasolar space rock every spotted.

Astronomers named it Oumuamua, a Hawaiian word for "scout." When it was discovered, the speedy visitor was already leaving the solar system. Astronomers hurried to learn everything about it.

Oumuamua moved like a comet, though a strange one. It had no visible tail. But it was speeding away from the sun a bit faster than it should from just gravity. Astronomers think it was spitting out a little tail of gas, like a comet—not enough to see, but enough to give it a push.

Oumuamua passed so quickly that we didn't have much time to study it. So

we don't know for sure what it is made of, where it came from, or how long ago it left home. It may have been circling the galaxy for millions of years.



Borisov has a faint glowing tail and looks more like a comet than Oumuamua. Its path shows that it also came from far, far away.

Borisov

In 2019, a Russian star-gazer spotted a second comet on a fast, wide path. Comet Borisov (named for its discoverer) looks more like a proper comet, with a glowing head and a bushy tail. But its path and speed show that it, too, came from outside the solar system. Its route will take it on a wide circle around the sun, then back out into deep space.

Borisov is brighter than Oumuamua, and it was discovered when it was heading toward the sun, not zooming away. So astronomers have had a bit more time to watch it. By looking at the tail with special cameras, they can tell that it's made of the same stuff as comets in our own solar system—ice, pebbles, dust, and frozen gases.

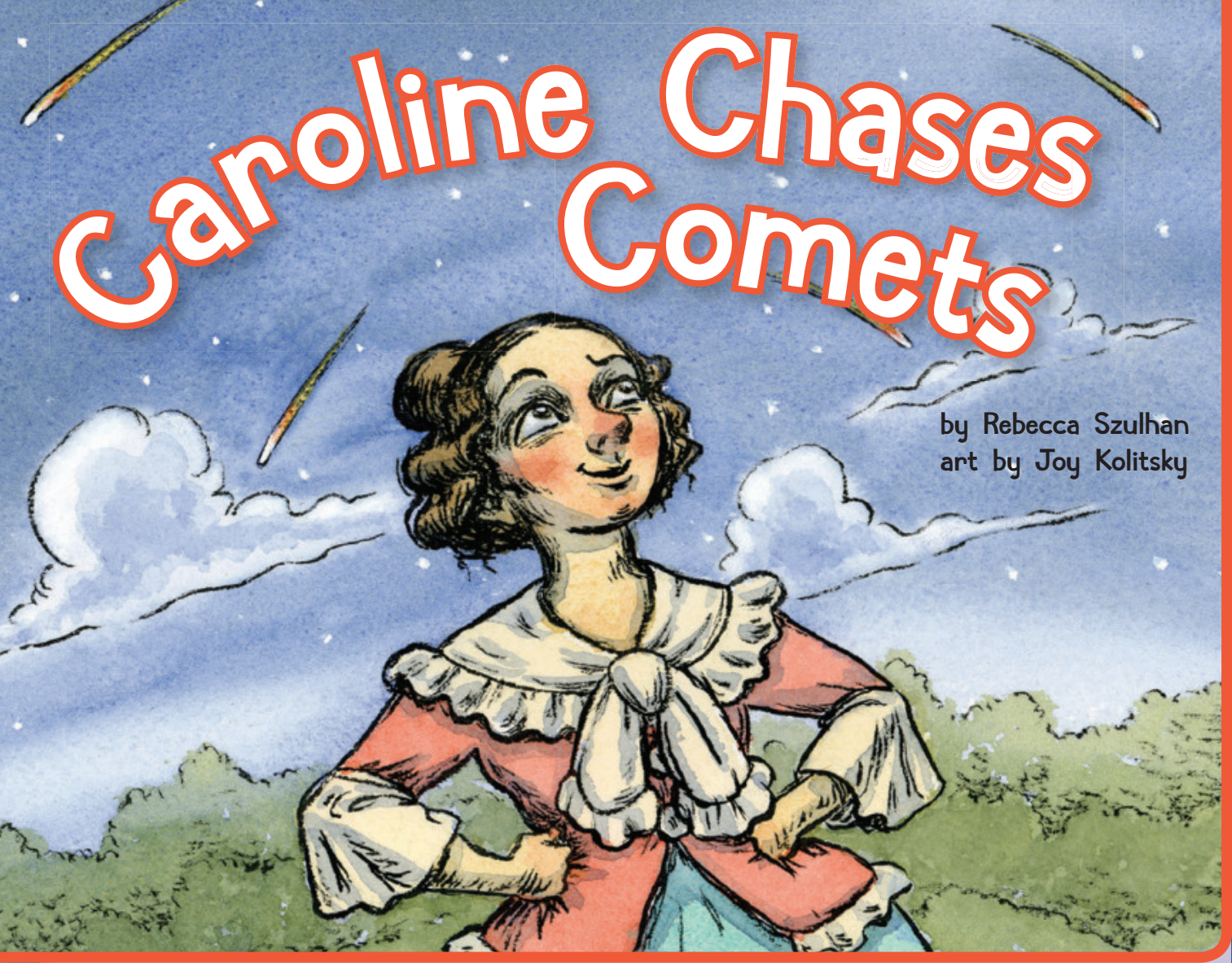
Astronomers think that there are probably lots of wandering comets and asteroids out there, tumbling around between the stars. Visitors may pass through our solar system as often as once a year. But since they are small and fast, we haven't caught any until now.

Now that we know what to look for, maybe we'll get a better look at the next one.

This is an artist's idea of what Oumuamua (say "oh-MU-ah-MU-ah") might look like. It sped by too quickly for photos. When astronomers traced its path, they realized that it must have come from outside our own solar system.

Caroline Chases Comets

by Rebecca Szulhan
art by Joy Kolitsky



When she wasn't singing or comet hunting, Caroline was also in charge of the kitchen.

One night, when I was a little girl, my father took me outside to show me the stars. As he pointed out the constellations, we spotted a visitor to our sky. A comet! I gazed at the glittering sky with wonder. That was one of the first comets I ever saw, but it wasn't the last.

My name is Caroline Herschel, and I'm a comet hunter.

Music of the Stars

I was born in Hanover, Germany in 1750. When I was 22, I moved to England to live with my older brother, William. He was a musician. At the time, I wanted to be a singer. William thought I had a pretty voice. He offered to give me singing lessons in return for doing his housekeeping. I practiced and practiced my singing. Soon, I was performing at William's concerts!

But as time went on, my brother started spending less time on music and more time on his

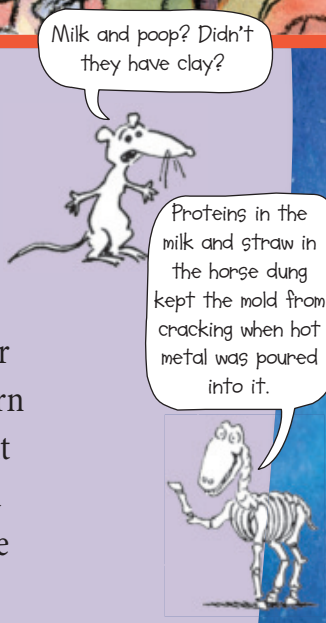
other passion—astronomy. Space fascinated William. He often fell asleep tucked under a cover of astronomy books. When he woke up in the morning, he couldn't wait to tell me what he'd learned. Breakfast in our house often turned into an astronomy lesson.

The Horse Poop Telescope

My brother loved telescopes. They showed him all the incredible things he read about in his books. He wanted to see even more. What else was out there, deep in space? William dreamed of building bigger, more powerful telescopes so that he could find out. I agreed to help him.

Telescopes use mirrors and lenses to catch light and magnify faraway things. William figured that metal mirrors would work best for the telescopes he had in mind. Even when they were very large, metal mirrors produced a clear image.

We cast the metal mirrors ourselves, using our own molds. We made the molds very carefully by hand, following a recipe that bell makers used. The ingredients included charcoal, skim milk, and dried horse dung. Lots and lots of horse dung! We kept piles of dried manure in storage rooms next to our workshop. One of my jobs was to turn the poop into powder by pounding it in a mortar, then sifting it through a sieve. It was a dirty job, but someone had to do it.



Then we melted speculum metal (copper and tin) in a furnace and poured it into the mold. After the curved metal disks were cast and cooled, they had to be polished mirror-smooth. That took a long time.

William's workbench, where he made telescope lenses.

William cast his own metal mirrors and invented this tool to polish them smooth. The mirror had to curve perfectly to give a sharp image.

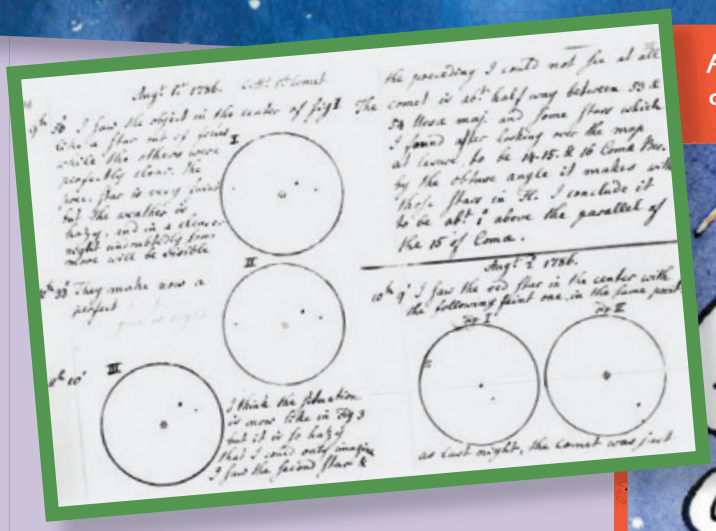
William built a special mirror-polishing machine to give the mirrors a perfect curve. But once he started polishing, he couldn't stop until it was done, or the mirror would be ruined. Once, William worked for 16 hours straight! He couldn't even stop to eat, so I had to feed him. I also read out loud to entertain him. Mirrors may be shiny, but polishing them sure is dull.

A New Planet

While looking through one of his telescopes on March 13, 1781, William noticed something unusual in the sky. Could it be a star? No, it was too blurry to be a star. The object was also moving, but a star's position seems fixed. Maybe it was a comet?

After talking with other astronomers, William realized that it wasn't a comet, either. He'd discovered a new planet! William named the planet Georgium Sidus (George's Star) in honor of King George III. But that wasn't the planet's name for very long. Other astronomers renamed it Uranus, after a Greek god who ruled the universe.

No one had discovered a new planet in centuries, and no one had ever discovered a planet using a telescope. Other people with telescopes had spotted this object before, but had dismissed it as just a faint star. It took William's keen observations



A page from Caroline's comet-spotting notebook

to show that it moved like a planet. King George was impressed. He offered William a job as a royal astronomer. William accepted, of course. And I agreed to be his assistant. William made a telescope just for me, so that I could help him search the sky for remarkable objects.

On August 1, 1786, I spied something quite remarkable indeed. In my observation notebook, I wrote that it looked "like a star out of focus." I was pretty sure that I'd found a comet. But I wanted to be certain. I decided to watch it for one more night before announcing my find.

It poured rain all the next day. I worried that I wouldn't be able to see anything through the clouds. When the sky cleared around 1 a.m., I peered eagerly into my telescope.

I found the object…

It was a comet!

Now everyone is talking about my comet. They call it the Lady's Comet.

This is the first comet I've ever discovered, but I don't think it will be the last.

Historical Note: After Caroline discovered her first comet, King George paid her £50 a year to be William's assistant. She was one of the first women astronomers to be paid for her work. She went on to find seven more comets between 1786 and 1797.

Asteroids All Around

Asteroids are space rocks, left over from when the solar system formed 4.5 billion years ago. They are some of the oldest objects in the solar system, so they are very interesting to scientists.

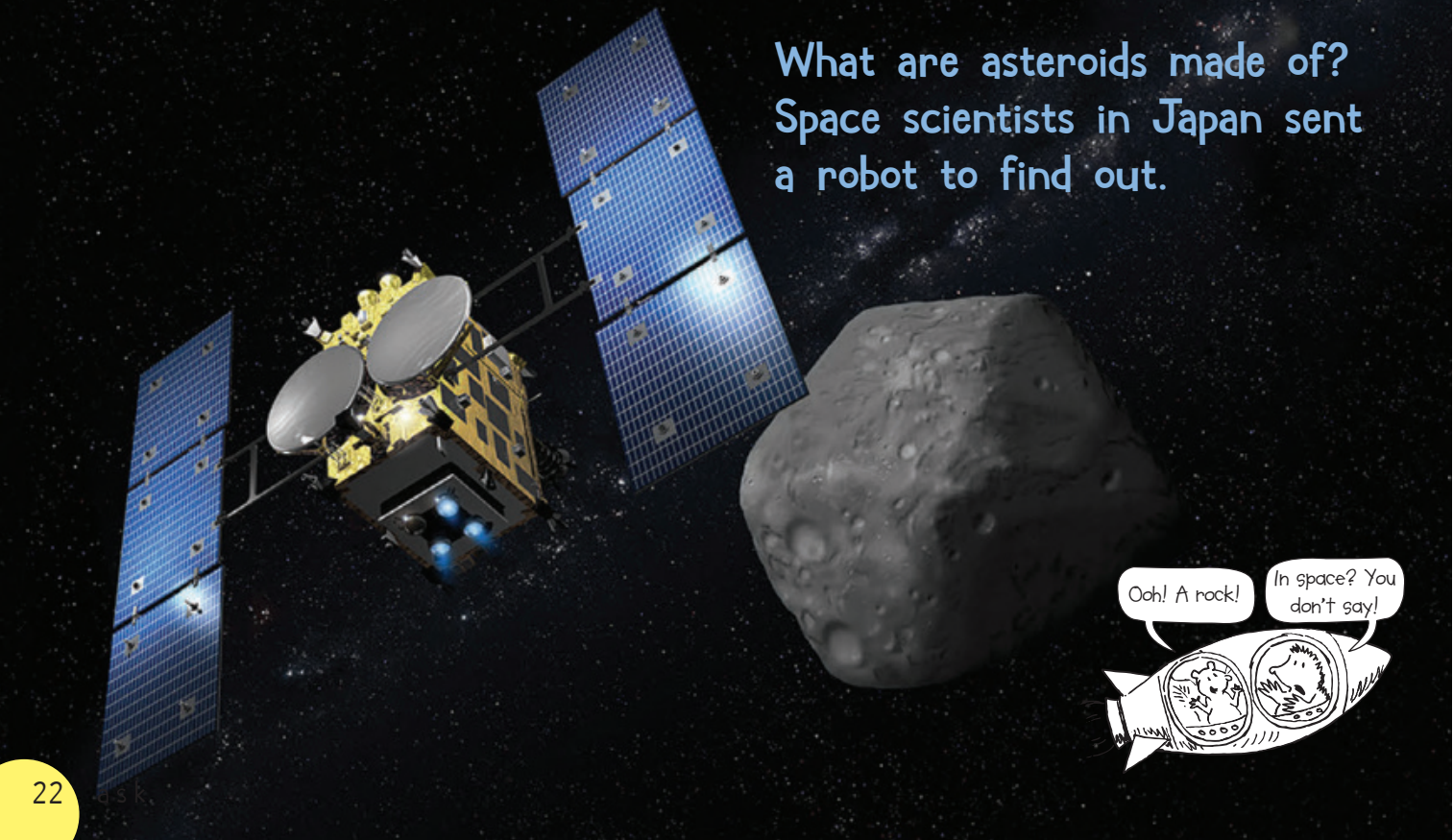
Asteroids can be a few feet (1 m) to hundreds of miles (500 km) across. They spin and travel around the sun in orbits, just like planets do. Most are found in the asteroid belt, between the orbits of Mars and Jupiter.

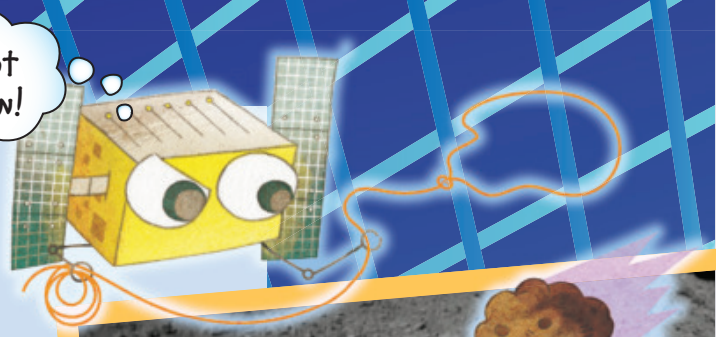
Asteroids are too small for their insides to heat up and melt. So the rocks in asteroids haven't changed much since the start of the solar system. Asteroids are like little rock museums floating in space. Scientists can look at them to see what the solar system was like long ago.

To an Asteroid and Back

by Meg Thacher
art by Merrill Rainey

What are asteroids made of? Space scientists in Japan sent a robot to find out.





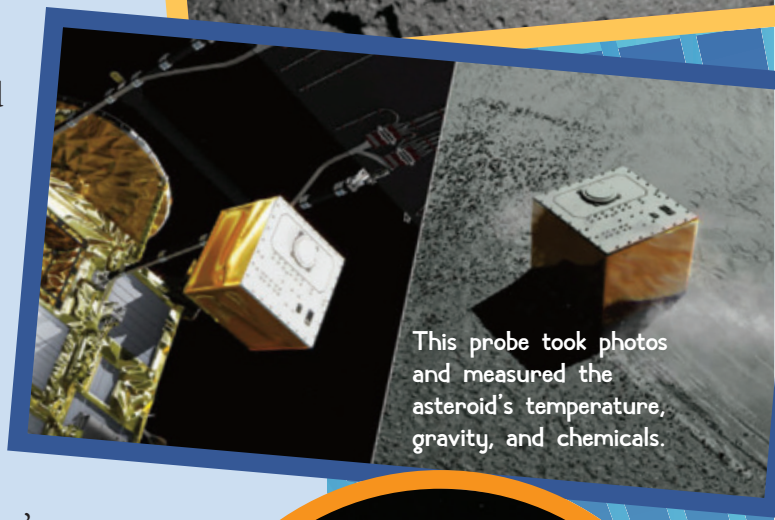
How to Catch a Space Rock

Most asteroids are very far away. They are also small and dark, which makes them difficult to see with telescopes. Most of what we know about asteroids comes from studying meteorites, small pieces of asteroids that fall to Earth.

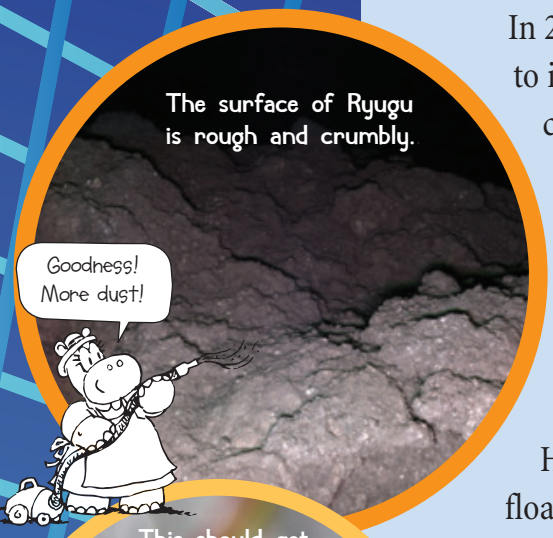
But what if we could send a spacecraft to an asteroid to see what it's like? Even bring back some asteroid rock to study? That's exactly what JAXA, the Japanese space agency, has done. In 2014, they sent a robot mission called Hayabusa2 to visit a small asteroid known as Ryugu. Its mission was to study Ryugu and bring a rock sample back to Earth. Hayabusa2 is about the size of a refrigerator. It's armed with cameras, scientific instruments, solar panels, and four tiny rovers. Its name, *Hayabusa*, means "peregrine falcon" in Japanese.

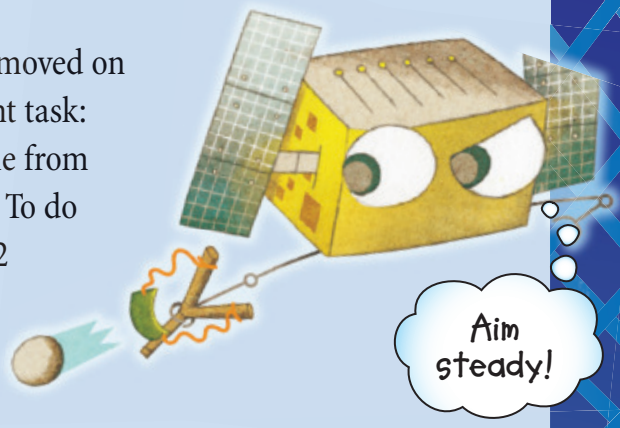

Hayabusa2 casts a shadow on asteroid Ryugu as it hovers above the surface.

After several loops around the sun to build up speed, Hayabusa2 arrived at Ryugu in 2018. First it flew around Ryugu to map it and look for safe landing spots. Special cameras analyzed the rock to see what Ryugu is made of. Hayabusa2 discovered that the asteroid is not solid. Ryugu is more like a giant rubble pile. Inside its crust, there is as much empty space as rock.


This probe took photos and measured the asteroid's temperature, gravity, and chemicals.

Hayabusa2 dropped three rovers onto Ryugu's surface. These rovers hopped from one place to another, taking photos and videos. Because Ryugu is so far away, it takes 19 minutes for a message to travel from the rover to mission control on Earth and another 19 minutes for Earth's reply. So the rovers were programmed to explore on their own, without instructions from Earth. The rovers radioed what they found to Hayabusa2, which passed the data back to JAXA.





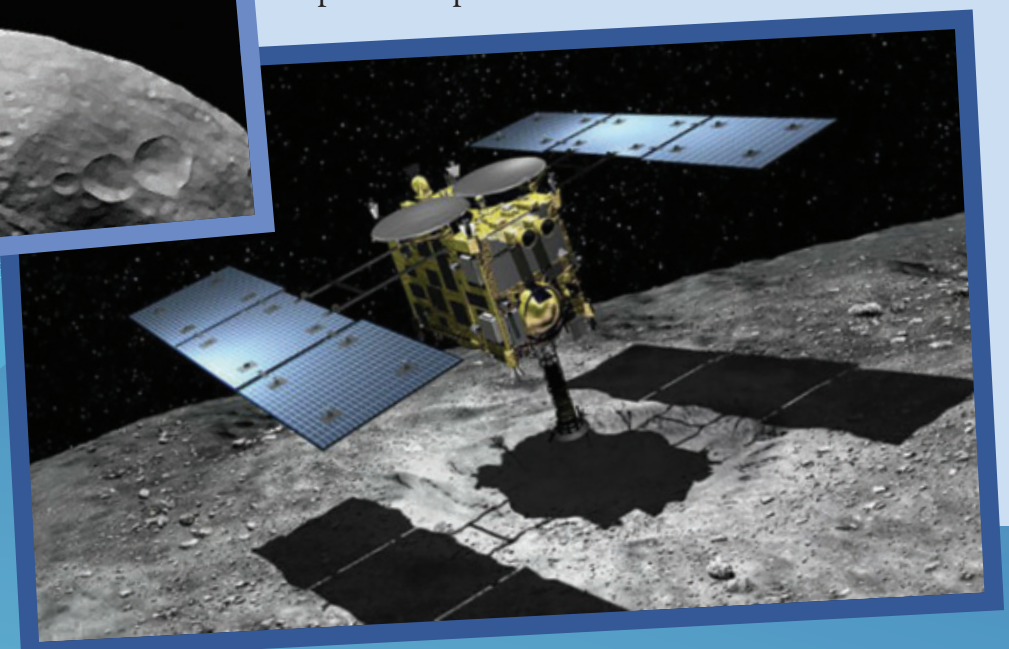
In 2019, Hayabusa2 moved on to its most important task: collecting a sample from Ryugu's surface. To do this, Hayabusa2 moved in close to Ryugu and shot a pellet, knocking pebbles and dust off the surface. Then Hayabusa2 went in close, and the pebbles and dust floated up into a storage container.

Next, Hayabusa2 shot a copper ball at Ryugu to create an artificial crater. Material from under Ryugu's surface splashed out and landed all around the crater. Hayabusa2 collected a sample of the crater material. Now Hayabusa2 has two samples of rock and dust from Ryugu, some from inside the asteroid and some from its surface.

Dust Delivery

Finally, Hayabusa2 started its trip back to Earth. In November of 2020, Hayabusa2 will drop off a capsule holding the sample containers. Then it will continue on to check out another asteroid. The capsule will parachute into the

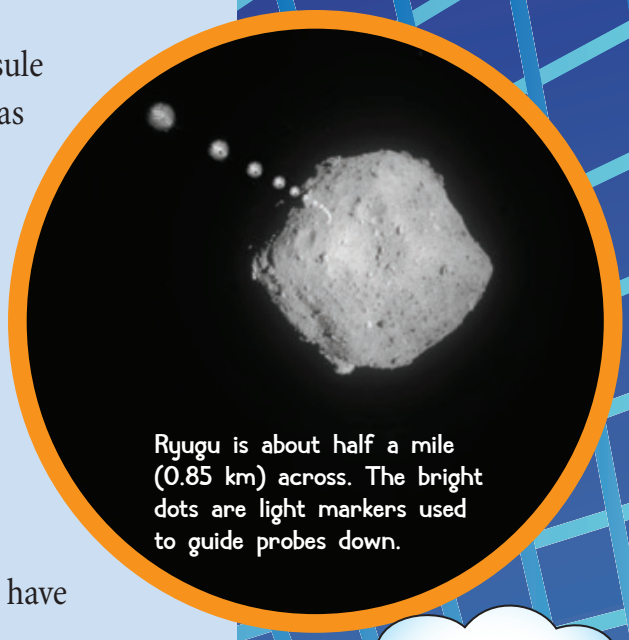
Then the probe extended a long straw to suck up the loose rock.



Australian desert. JAXA scientists will collect the capsule and take the samples to their lab to see what Ryugu has to tell us about our solar system.

The American space agency NASA is also hunting asteroids. Its robot explorer OSIRIS-REx is currently exploring asteroid Bennu. Bennu is about half the size of Ryugu. It's of special interest to scientists because its looping path may bring it close to Earth sometime in the 22nd century. OSIRIS-REx has been busy mapping Bennu and snapping photos. It will send back rock and dust samples in 2023.

What will the samples reveal? One thing scientists have already discovered is that asteroids are all different. Ryugu has surprisingly little dust. It is mostly made up of two kinds of rock. It's also quite crumbly and would break apart easily if struck by another asteroid. Bennu is also less solid than expected. It's shedding pebbles in a steady stream. We'll know more once OSIRIS-REx has done its work. And maybe we'll also have a better picture of our own Earth's early days.



Ryugu is about half a mile (0.85 km) across. The bright dots are light markers used to guide probes down.

Hayabusa 1 and 2

Was there a Hayabusa 1? Yes! In 2003, the first Hayabusa mission visited an asteroid called Itokawa. But Hayabusa had problems with its computers and steering. It lost its rover. Sample collection didn't go well, either. In 2010, it brought back a very small bit of dust from Itokawa.

But engineers learned a lot from that first mission, and they improved the new spacecraft's design. Hayabusa's problems have made Hayabusa2 a huge success!

Engineers at work on Hayabusa

How to Avoid an Asteroid

art by David Clark

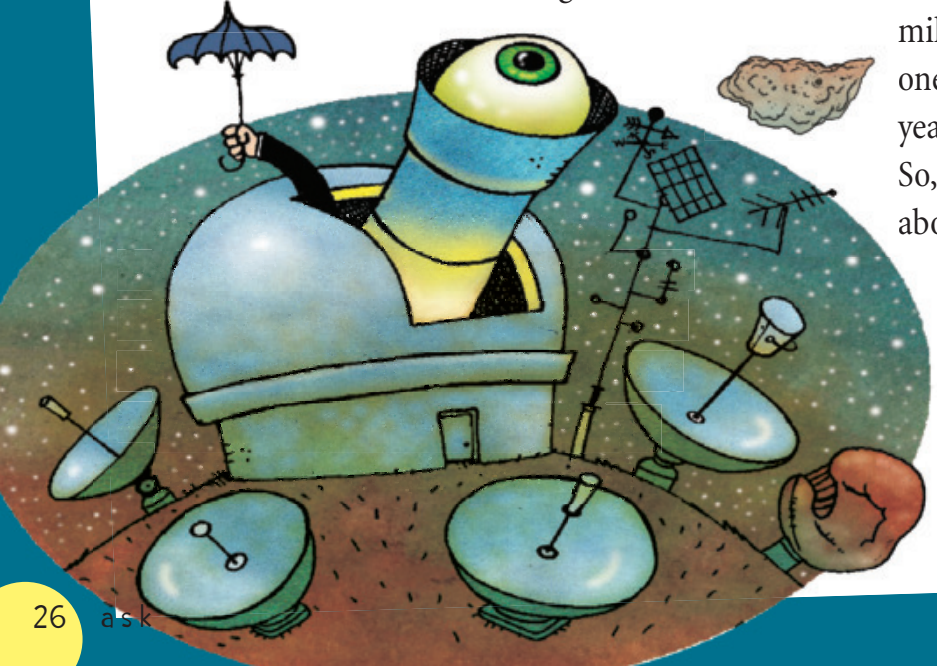
65 million years ago, a city-sized asteroid struck the Earth, wiping out the dinosaurs. Could it happen again? And what could we do to stop it?

What are the chances?

Small rocks and dust from space rain down on Earth all the time—several hundred tons fall every year. Most burn up in the atmosphere or leave pebble-sized meteorites.

The space rock that wiped out the dinosaurs was huge, about 6 miles wide. Luckily, asteroids this big are rare. And space is vast. The chances of a big wandering rock crossing Earth's path *exactly* when Earth is in the way are extremely small.

All in all, astronomers estimate that the chance of a city-sized asteroid hitting Earth is about once in 100 million years. (That doesn't mean one WILL hit Earth every 100 million years—that's just the average chance.) So, probably not something to worry about a lot.



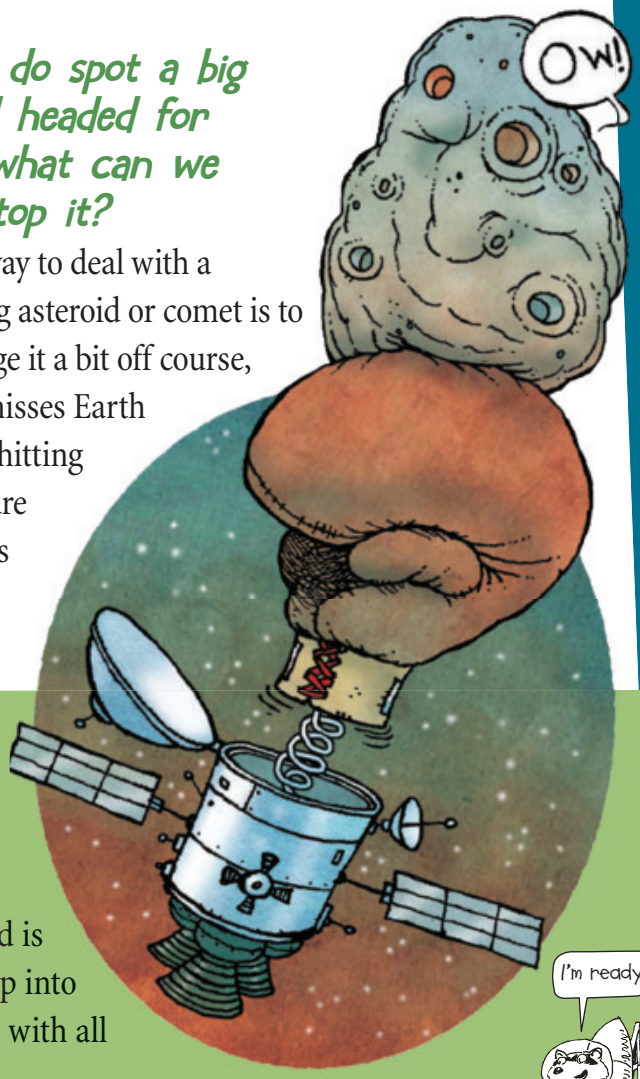
But still, it could happen, right?

It could. Though an impact is very unlikely, NASA and other space watchers keep track of large

asteroids and comets in our neighborhood, just in case. Currently, they track about 20,000 NEOs (Near-Earth Objects) larger than 460 feet (140 m) wide. They don't track smaller objects, since they're less of a danger. An object is considered "near" if its orbit brings it within 30 million miles of Earth. (That's 100 times farther away than the moon!) Satellites and computers map the objects' paths. They alert teams if it looks like any might be heading our way.

If they do spot a big asteroid headed for Earth, what can we do to stop it?

The best way to deal with a threatening asteroid or comet is to try to nudge it a bit off course, so it just misses Earth instead of hitting us. There are many ideas for how to do this.



1. Run into It

The simplest plan is to send a robot spacecraft to crash into the asteroid, to shove it off course a bit.

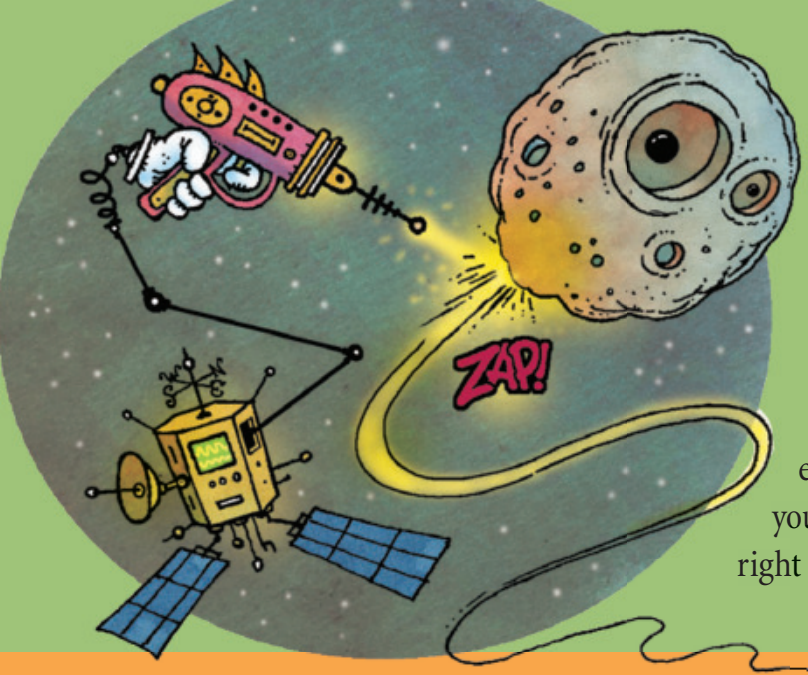
Of course, getting a spacecraft out to an asteroid can be tricky. You also want to be sure that the asteroid is solid enough to take a hit. You don't want to break it up into two or three dangerous rocks instead of one. But even with all the difficulties, this is probably our best bet.

NASA is currently building a robot spacecraft to try this out. In 2021, the DART mission will fly to a small asteroid that is orbiting a larger one. DART will crash itself into the smaller asteroid. Astronomers will measure how much it moves to see if this could nudge dangerous rocks away from Earth.

2. Gravity Tractor

Instead of ramming the asteroid, we could pull it off course—with gravity. A small robot spacecraft would fly next to the asteroid. The gravity of the spacecraft would tug the asteroid slightly off course—just enough to miss Earth.

The spacecraft would need to fly alongside for a while to have an effect. So we would have to start when the asteroid is still pretty far away.



3. Give It a Jetpack

Another idea is to use lasers or bombs to vaporize the surface on one side of the asteroid. The escaping dust and gas would act like a jet to push the asteroid in the opposite direction.

For this to work, you'd have to know exactly how the asteroid was spinning. Then you'd have to be sure to hit it in just the right place.

4. Paint It White

Sunlight reflects more off of white. If we could paint one side of an asteroid white or wrap it in shiny foil, sunlight bouncing off it might be enough to nudge it off course. You can see this idea in action if you've ever watched a photo mill spinning in a science museum. More light bounces off the white side of the paddles than the dark side, pushing the pinwheel around.

Of course, painting an asteroid might be easier said than done. Asteroids don't have much gravity, so things tend to float off them. A shiny cover might just drift away. And many asteroids are covered in loose, icy dust. So trying to paint one might be like trying to stick tape to a bowl of flour.

Couldn't we just shoot it down?

To successfully stop an asteroid in its tracks, you'd need a weapon that could match its force. An asteroid big enough to be a danger will weigh thousands of tons. And they move very, very fast—about 12 miles a second. No known weapon system, including nuclear bombs, is anywhere near powerful enough to stop a big rock moving that fast. We're much better off just nudging it a bit while it's still out in space, so it misses Earth completely.

But have no fear, the astronomers and their computers are keeping watch.

Ask Ask

WITH SAGE AND BRIAR

TEXT BY ELLEN R. BRAAF
ART BY MARNIE GALLOWAY

Hey, Sage! Ramona in Pennsylvania wants to know, why doesn't my cat have a belly button?

Cat belly buttons can be hard to see, it's true. But if you look closely, all cats do have one—tiny, flat, and covered with fur.

Because cats are mammals, and all mammals have belly buttons!

Well, almost all.

What's a mammal?

We are! Mammals are animals that have hair or fur, and are warm-blooded.

And give birth to young, and feed them with milk.

So what are belly buttons for?

It marks the spot where you were connected to your mother before you were born. She ate and breathed for you. Food and oxygen passed from her to you through a twisty tube called the umbilical cord.

What happened to it after I was born?

You didn't need it anymore. Your mother cut it with her teeth and licked you clean.

Do humans do that too?

When a human is born, a doctor cuts the umbilical cord. It doesn't hurt at all. The only thing left is a small mark—the belly button, also known as a navel.

You said *almost* all mammals have belly buttons—so some don't?

Monotremes, which lay eggs, and marsupials, like kangaroos.

When I was still tiny, I crawled into my mother's pouch to grow. I didn't need my umbilical cord for very long. When it fell off, it didn't leave any mark.

Platypuses and echidnas are odd mammals that lay eggs. So like birds, we don't have a belly button.

So...I have something you don't have!

True. But can you fly?

ASK US ANYTHING!

WRITE TO US AT:
ASK
70 EAST LAKE STREET
SUITE 800
CHICAGO, IL 60601

OR HAVE YOUR PARENT EMAIL
ASK@CRICKETMEDIA.COM

Contest and Letters

Send your letters to Ask Mail, 70 East Lake St., Suite 800, Chicago, IL 60601, or have your parent/guardian email us at ask@cricketmedia.com.

In our January issue we asked you to design a special house just for pigeons. Thanks to all you amazing avian architects for showing us your shelters!

Ayushman M., age 7, Maryland

The Grand Pigeon Hotel
Agata, age 9, by email

Pigeontown in Cactus City
Rebecca W., age 10, New Jersey

Mobile Pigeon Loft
Charlie S., age 8, New Jersey

Pigeon Tower
Jack S., age 9, New Jersey

Dear Marvin,
I have a funny prank for you: get Bot to zap a rock with his laser, so that Plush notices it. She'll think it's a meteorite. She can cool it down with a fan and add it to her specimen box. She could then draw a hippo on it.
Zachary M.

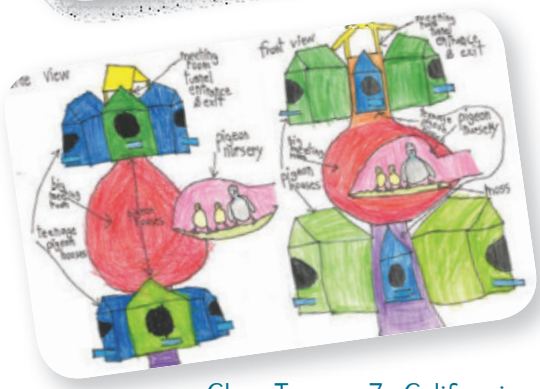
Dear Zachary,
See, I keep telling her. It's not me, it's the universe throwing rocks! It would be so cool to find a meteorite. But you're right, why not make our own? I mean, if the whole Earth formed from space rocks, all rocks are space rocks, right?
Lasers away!
Marvin

Dear Plush,
Do you like cats? I love cats. I have two cats at my house. And one bunny. A boy bunny. The girl ran away. I have a girl and boy cat, too. And you like to read rule books? I do too!
Your Friend,
Zoey S., California

A Pigeon's Dream House
Ruby K., age 8, Washington

Pigeon House 6000
Indiana G., age 7, Ohio

Tigerlily G., age 5, Ohio

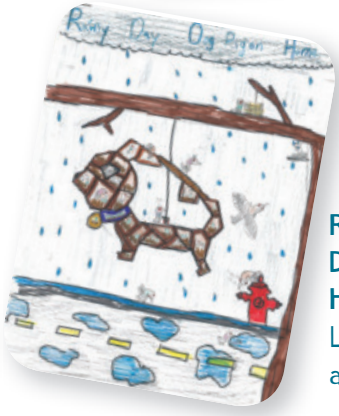


Cleo J., age 7, California

Serena Y., age 7, Massachusetts

Treetop House
Briar L., age 9, Connecticut

Nicobar Pigeon House
Isaac A., age 8, New York



Rainy Day Dog Pigeon Home
Lilliana, age 10

The Annoying Bird Party House
Lydia T., age 10, North Dakota

Dear Zoey,
I love all animals, furry or scaly. Well, maybe not the fanged ones so much. I always find it comforting to know that the universe has Rules, and that we've figured out some. Don't you agree? Plus, it keeps the peace.
In fellowship,
Plush

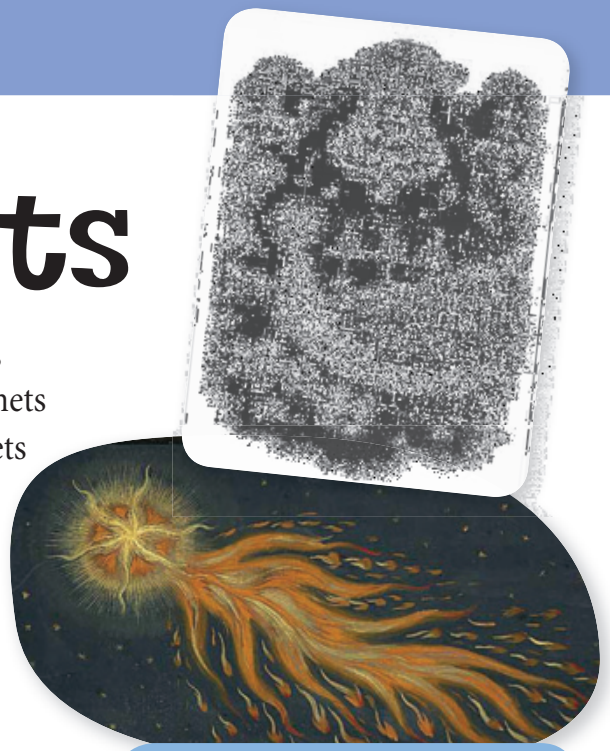
Dear *Ask,*
How much does a whale weigh? I'm guessing tons.
From Lexie R., age 9, Finland

Dear Lexie,
If you are building a swing for whales, it is important to know their weight. But what kind of whale? The smallest whale species, pygmy sperm whales, only weigh about 200 kg, a fifth of a ton. Belugas weigh a ton and a half (1,600 kg). But blue whales can grow 80 feet long and weigh 100 tons (90,000 kg). So, to make sure everyone is happy...build big.
Weightily,
Bone Pony

May/June Contest

Crazy Comets

In the days before telescopes or space robots, sky-watchers were not entirely sure what comets were. Artists had a lot of fun imagining comets as running stars, flaming ladies, horses, or phoenixes racing across the sky. And so can you! For this month's contest, let your imagination loose and draw a fanciful picture of a comet with its long tail. We'll host a constellation of the most creative in an upcoming issue of *Ask*.



Comets are made of ice, but this artist imagined a fiery one.

Contest Rules:

1. Your contest entry must be your very own work. Ideas and words should not be copied.
2. Be sure to include your name, age, and address on your entry.
3. Only one entry per person, please.
4. If you want your work returned, enclose a self-addressed, stamped envelope.
5. Your entry must be signed or emailed by a parent or legal guardian, saying it's your own work and that no one helped you, and that *Ask* has permission to publish it in print and online.
6. For information on the Children's Online Privacy Protection Act, see the Privacy Policy page at cricketmedia.com.
7. Email a photo of your artwork to: ask@cricketmedia.com, or mail to: *Ask*, 70 East Lake St., Suite 800, Chicago, IL 60601. Entries must be postmarked or emailed by June 30, 2020.
8. We will publish the winning entries in an upcoming issue of *Ask*.

by Ivars Peterson
art by Thor Wickstrom

Bot's MIGHTY MATH

Tight Fit

Can you fit a quarter through a dime-sized hole?

Trace around a dime on an index card or stiff paper. Then carefully cut out the circle to leave a hole the size of the dime. Can you get a quarter through this hole without tearing the paper?

That seems impossible. A quarter is larger than a dime.

Try this. Fold the paper so that the fold goes across the middle of the hole. With the fold pointing down, place the quarter so that it sits in the hole. Of course, the quarter just sticks out below the paper and doesn't fall through.

But if you use your fingers to gently pull the sides of the paper apart and up, the hole stretches and the quarter falls through.

The trick works because half the distance all the way around a dime (half its circumference) is more than the width of a quarter.

By pulling on the paper, you stretch the hole into an oval that is wider than the circle. But the hole can never be stretched longer than half the dime's circumference.

To find a dime's exact circumference, multiply its width (or diameter) by the special number pi, which is about 3.14. You'll find that the quarter's width is less than half that value.

With what other coins would this trick work? A half dollar would not fit through a dime-sized hole. But could it fit through a hole the size of a nickel?

text and art by Thor Wickstrom

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