COSMIC COLLISIONS

EDUCATOR'S GUIDE

www.amnh.org/education/resources/exhibitions/collisions

INSIDE:

- Background Information to Help You Prepare
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American Museum of Natural History

KEY CONCEPTS

The universe is dynamic. Everything in the universe changes. All **stars**, including our Sun, are born, shine for millions to billions of years, run out of fuel, and die. **Galaxies** can grow by cannibalizing their neighbors. Even the universe itself is evolving: it grew from a tiny, dense fireball over 13 billion years ago and continues to expand.

Collisions in space release enormous amounts of energy. Massive impacts — some as violent as the explosion of 10 thousand billion, billion, billion, billion (10^{40}) atomic bombs — are the natural outcome of the motion of celestial objects. Collisions smash **asteroids** apart, created our Moon, power the stars, and build giant galaxies. For us, the most important impacts occur when particles smaller than atoms collide and rearrange matter, releasing **energy** as light and heat. That's what's happening by the trillions, every second, inside our Sun — and in other stars as well.

Collisions transform. Everywhere in the universe, collisions smash things apart, bring them together, and generally leave **planets**, stars, and galaxies very different than they were before. Earth is no exception: life has been transformed — maybe even made possible — by collisions. Notably, sixty-five million years ago an Everest-sized asteroid smashed through Earth's atmosphere, contributing to the extinction of 85% of Earth's species, including most dinosaurs. Yet this catastrophe gave rise to new ecological niches — including the one humans now occupy.

This simulation shows the asteroid collision that changed life on Earth 65 million years ago. © AMNH

The Aurora Borealis © NASA

The cosmic scale of time and space is huge. There's a reason it's called space. Our Solar System is billions of miles across: to us a vast and largely empty expanse, but tiny compared to the typical distance between stars. Light from the most distant galaxies can travel for billions of light-years before it reaches us, and a light-year (the distance that light can travel in a year's time) is nearly six trillion miles! Time scales are also huge. The universe is 13.7 billion years old. Our Solar System, the Sun and the Earth, came into existence 4.5 billion years ago. The ancestors of humans may have walked on Earth 6 million years ago — an immense stretch of time, but less than 0.2% of the age of the universe. And, like the collisions that power the Sun, cosmic events can occur in the blink of an eye.

The laws of physics are the same throughout space and time. Fundamental physical forces, such as **gravity** and **electro-magnetism**, operate everywhere to keep the universe in constant motion. The same laws that pull a fly ball down towards the field also pull giant galaxies towards each other. The processes we can observe from our perch on Earth — like the **Aurora Borealis**, planetary impacts, and galaxies colliding — are happening throughout the universe, just as they have since the Big Bang and always will. The universality of nature's laws makes it possible to understand things that happened far away and very long ago, and to predict how celestial bodies will move and change in the future.

The Earth system has natural defenses. Produced by the rotation of the planet's liquid outer core, the Earth's magnetic field shields us from energetic particles in the **solar wind** that streams off the surface of the Sun at more than a million miles an hour — and which can damage DNA in living organisms. The atmosphere also protects us: most of the tons of rock and dust from space that collide with Earth every day burn up through friction before they hit the ground.

We can use knowledge and technology to protect us. Collisions with bigger objects, like **comets** and asteroids, are extremely rare, but they do happen. However, unlike the dinosaurs, we know why collisions happen and can see what's coming. Scientists have been mapping the sky in ever-greater detail to track any possible threat while it's still many years away. Our knowledge — and perhaps our ability to navigate the solar system — could help us protect our planet in the future.

BEFORE YOUR VISIT

The following activities are designed to help you and your students make the most of your visit to the Space Show.

Elementary and Middle school:

Compete in the Moon Olympics: Have students "play sports on the Moon" at http://teacher.scholastic.com/activities/explorations/space/ (go to Level One) to learn about the effects of gravity on different worlds.

Your place in space: Ask your students where they live. Then ask what they would add to that address if they traveled outside of your city or town, your state, and your country. How about if they traveled into space? Visit http://ology.amnh.org/astronomy/inspace/index.htm to hear a song about our cosmic address.

Make your own sundial: Track the motions of the Sun across the sky the way people did in ancient civilizations. Plant a straight stick in the ground and, every hour, place a stone at the top of its shadow. Ask students to find true north (the shortest shadow). Try again in three months and see what's changed.

Two faces of the same force: Demonstrate the interrelationship between electricity and magnetism for your students. They'll see how to create a magnet using the flow of electricity through a wire, and, conversely, how a magnet driven through a coil can drive a current. Download the instructions at http://image.gsfc.nasa.gov/poetry/activity/l14.pdf.

Middle and High school:

Cosmic Calendar: Ask students to create a one-year calendar, and to fit milestones of cosmic evolution onto it, so they can understand the scale of cosmic time. (For example, if the Big Bang occurs at midnight on January 1st, the Sun is born on June 6th, and humans don't arrive until 11:58PM on December 31st.) A timeline of cosmic events can be found at http://www.lpi.usra.edu/education/timeline/activity/.

Activate an asteroid! Have students visit the Science Explorations: Journey into Space website at http://teacher.scholastic.com/activities/explorations/space/ (go to Level Two) to learn how the speed and angle at which an object approaches the Sun determines its fate.

How much fuel does the Sun need? Ask students to calculate how many nuclear fusion reactions must occur per second to keep the Sun burning as brightly as it does. How much hydrogen is consumed in the process?
http://www.amnh.org/education/resources/rfl/web/einsteinguide/activities/sun.html

What if there were no Moon? Ask students to break up into teams and research how the Moon affects the Earth. (As an option, they could form three groups, one focusing on the geosphere, one on the atmosphere, and one on the hydrosphere.) After each group has presented its findings to the class, brainstorm about what Earth would be like if there were no Moon. Then, have students compare their theories to what the experts think at http://www.newscientist.com/article.ns?id=dn4786.

Explore the link between collisions and extinctions: There have been five major extinctions on Earth: the End Cretaceous (K-T), the End Triassic, the Permian-Triassic, the Late Devonian, and the Ordovician-Silurian. Break your class into five corresponding groups. Ask them to examine the evidence that experts use to determine which extinctions were related to impacts.

This program can help you teach the National Science Education Content Standards listed below. Viewing the *Cosmic Collisions* Space Show will help students gain an understanding of:

Elementary School
S1b: motions of objects and materials;
S1c: light, heat, electricity, and magnetism;
S2c: change over time, such as evolution and fossil evidence depicting the great diversity of organisms over geologic history;
S3b: objects in the sky;
S3c: changes in Earth and sky;

Middle School
S1b: motions and forces, inertia;
S1c: transfer of energy such as transformation of energy as heat; light, mechanical motion;
S2e: the evolution and adaptation of living organisms;
S3a: the structure of the Earth system;
S3c: Earth in the Solar System;

High School
S1a: the structure of atoms;
S1d: motions and forces, gravitational and electrical; magnetism;
S1f: interactions of energy and matter;
S3a: energy in the Earth system;
S3c: origin and evolution of the Earth system; geologic time; evolution of the Solar System;
S3d: the origin and evolution of the universe; nuclear reactions.

Use this guide and online resources [http://www.amnh.org/resources/exhibitions/collisions] to plan your visit ahead of time. Give students directions before you arrive, since it can be hard to find space or quiet to communicate with the group. Information about school visits is available at http://www.amnh.org/education/schools/.

BACKGROUND

Why do things collide?

When two things collide, the energy of the objects' motions is released — sometimes with destructive outcomes. Think of what happens when you drop a watermelon off the roof of a ten-story building, or when two cars collide! The energy of motion goes into rearranging the matter of the objects. And sometimes the outcome is a mess! But as *Cosmic Collisions* illustrates, the forces of nature can also transform that mess into new and beautiful forms: galaxies re-shape themselves, new stars are born from old ones, and even life on Earth has been made possible by collisions. Cosmic collisions drive change on cosmic scales, and thus the evolution of the universe.

Stars in a globular cluster collide. © AMNH

The universe is constantly in motion, and things in motion will maintain that same motion...unless acted upon by an outside force. This is Isaac Newton's 1st law of motion, the law of inertia. Newton's 2nd law of motion, F=ma, conversely states that a force is something that changes an object's motion. When a driver steps on the brakes, the car slows; when a comet passes by the Sun, its orbit is deflected by the Sun's gravitational pull. If this sounds rather circular, it is! Scientists use the concept of force to describe how things behave, not what a force is. Investigating what a force is remains a fundamental goal of science.

Gravity — the force of attraction between any two bodies with mass — is by far the most important force in setting the objects in the universe in motion. The more mass an object has, the greater the gravitational pull it exerts. And the closer the two objects are, the stronger the pull of gravity they exert on each other. That's why we feel more gravity on Earth than on the Moon.

Gravity is responsible for the fall of that proverbial apple onto Newton's head, as well as the inexorable attraction between the Milky Way and our nearest neighbor, the Andromeda Galaxy. Although it is much weaker than the other forces of nature, gravity acts over enormous distances.

Things are also in motion because they are attracted or repelled by **electromagnetism**. Like gravity, this is a fundamental force at work in the universe — and it's much stronger than gravity. It's driven by the interaction of electrical charges (such as protons or electrons), causing attraction or repulsion between them. It is the repulsion between the electrons in a baseball and the electrons in a bat (helped by the momentum of the swing) that sends the ball flying when the two collide. Another manifestation of electromagnetism is the magnetic field generated by the movement of electrical charges in the outer core of the Earth as it rotates, which protects us from collisions with solar particles.

Since everything is in motion in our dynamic universe, and the forces of gravity and electromagnetism operate throughout, collisions are inevitable.

Suggested activity: Ask students to name things in motion on Earth and what put them in motion. (For example, things fall because of gravity, cars move because of the friction of their wheels, and electromagnetic repulsion between shoes and sidewalk keep a jump-roper from falling through the concrete.) Ask students to distinguish between the different kinds of forces at work, both natural and mediated by humans. What is the source of the energy?

HOW DO WE KNOW?

Learning from Light

Most objects in the universe emit light (**electromagnetic radiation**), which contains all kinds of information. Almost everything we know about objects in the universe — from their chemical composition and temperature to how old they are and how fast they're moving — comes from studying this light, only a fraction of which is visible to the human eye. Sophisticated telescopes capture different wavelengths of light, like X-rays and microwaves, enabling astronomers to learn about celestial objects they'll never be able to visit or touch. On Earth and in orbit, these telescopes are our eyes to the universe.

The Sun as seen from space.
© NASA, ESA, SOHO

What's the evidence?

How do we know the Moon formed from a collision with Earth?

Rocks gathered during the Apollo missions suggest that the Moon formed from the same reservoir of materials as the early Earth. In particular, rocks from both bodies share the same oxygen-**isotope** ratio, pointing to a common origin. Another clue is the relative size of the Moon's iron core. Since the Moon is less dense than the Earth, it is thought to have a very small iron core. In order to explain these phenomena, scientists theorize that an object the size of Mars smashed into the early Earth (after most of the Earth's iron had settled into its core), ripping off only our planet's outer layer. Some of this churned-up material fell back to Earth, and some moved away to form the Moon. Strong support for this theory has come from scientists' ability to successfully model the Moon-forming collision; if the physics of the collision could not be correctly modeled, the theory would have been discarded.

Molten rocks collide, fuse together, and become our Moon. © AMNH

How do we know the K-T meteorite impact occurred?

Wherever scientists have studied the geological record from 65 million years ago, they've encountered a layer rich in iridium and full of shocked quartz. Iridium is a chemical element abundant in meteorites, and the crystalline structure observed in shocked quartz only forms when the quartz crystals are super-heated and squeezed by a tremendous impact. Found all over the Earth, this quartz-iridium layer also marks a clear change in the fossil record. Below it we find the remains of many life forms, including all non-avian dinosaurs ever identified; above the layer we see fossils of an abundance of new species. The "smoking gun" was discovered in 1991: a huge impact crater in the Yucatan that's also 65 million years old — the date of the great extinction.

How do we know that stars collide in globular clusters?

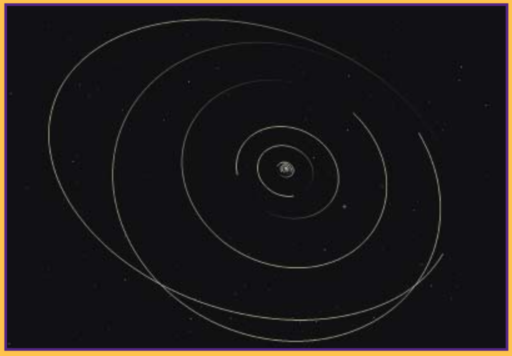
Globular clusters are groups of hundreds of thousands of stars almost as old as the universe itself. In these ancient environments the gas and dust from which new stars form were long ago used up or blown away. Yet at their very center, we see very, very young blue stars. Stars are crammed together a million times more densely in these clusters than in our Solar System — so scientists infer that they must be colliding. Numerical simulations show that this has an effect similar to tossing new logs on a fire. When two old stars collide, new hydrogen gets mixed into the core of the larger of the two, rejuvenating it.

How do we know that the Milky Way and the Andromeda Galaxies are going to collide?

Calculating the probability of an impact between two objects involves knowing how far apart they are and how they are moving relative to one another. Scientists can then apply Newton's laws of motion and gravity to predict what will happen in the future. Most scenarios indicate that the Milky Way and the Andromeda Galaxy will collide in several billion years. The details are uncertain, however, because although we know how far away Andromeda is and how fast it's moving toward us, scientists don't yet have the technology to directly measure its side-to-side motion across such a vast distance, although we can infer it from the motions of other nearby galaxies. More sophisticated instruments will provide a more precise picture in the years to come.

Observations, Models & Simulations

Telescopes can provide snapshots of the cosmos in different stages of development. However the time scales are just too long to see cosmic collisions in action. So, to help them understand these observations, astronomers create mathematical models that are based on the laws of physics to describe how nature will behave. They use powerful computers to make the vast number of complex calculations involved in computing the models. Astronomers compare the results of these models to observational data for verification. The visualizations in *Cosmic Collisions* are partly based on numerical models like these.



A model of the planetary orbits in our Solar System. © AMNH

BACK IN THE CLASSROOM

These activities will help your students to explore and extend their understanding of the dynamic forces at work in the evolving universe.

Elementary and Middle school:

Describe your journey through space: Ask students to write an article for the school newspaper about their trip to the Hayden Planetarium. How many different kinds of collisions did they observe? What was the highlight of the show, and why?

Make a solar wind sprinkler: Students use a milk carton, nails, water, and string to model the way solar wind is twisted into a spiral by the Sun's rotation. The activity is described at http://genesismission.jpl.nasa.gov/product/genesis_kids/science_activities/SpinSprinklerSA.html.

Solar burps: A coronal mass ejection stretches the Sun's magnetic field. Using a balloon, to represent the magnetic field, and glitter to represent charged plasma, students find out what happens when the field breaks free from the surface of the Sun. Find instructions at http://image.gsfc.nasa.gov/poetry/activity/l8.pdf.

Middle and High school:

Catch a shooting star! Meteor showers happen on a regular basis, and they're spectacular. Here's information on where to go and when to look:

- http://leonid.arc.nasa.gov/meteor.html
- http://liftoff.msfc.nasa.gov/academy/space/solarsystem/meteors/Showers.html
- http://science.nasa.gov/headlines/y2005/22jul_perseids2005.htm

Aurora watch: When was the last time auroras could be seen where you live? Ask students to go to http://www.spaceweather.com/ for information and predictions. (They can sign up for email alerts.)

Discuss your trip through space: Write five categories on the board: Earth, Sun, Solar System, galaxy, and universe. Have students list the collisions they observed during the Space Show, and match them to these categories based on the scale on which they occur. Follow up with a discussion about what they learned, and what new information surprised them the most. What was a highlight?

What does it take to get fusion going? Nuclear fusion is a fundamental force in the universe. Have students visit the website below to simulate conditions under which nuclear fusion occurs in the Sun. http://www.astro.ubc.ca/~scharein/a311/Sim/fusion/Fusion.html

Impacts in our lifetime: Large impacts are rare, but they do happen. On the blackboard, write out the Asteroid Impact Odds events (found on the "Near-Earth Asteroids" insert in this guide) in random order and ask students to rank them from least to most probable. Compare their results to the chart. Then ask students to research notable collisions in the Solar System that have occurred in the last century (Tunguska, Peekskill, Shoemaker-Levy 9). Did they come across any near misses?

Soda bottle magnetometer: This website show how students can use a soda bottle and bar magnet to build and operate a simple magnetometer (http://image.gsfc.nasa.gov/poetry/workbook/magnet.html). They can use it to measure changes in Earth's magnetic field and to study magnetic storms.

Mission Mitigation! Astrophysicists at NASA and around the world are busy developing strategies to avert or mitigate the effect of an asteroid colliding with Earth. Ask students to come up with plans of their own. What issues — technological, social, political, and economic — do they have to keep in mind?

Credits

Cosmic Collisions was developed by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; the Shanghai Science and Technology Museum.

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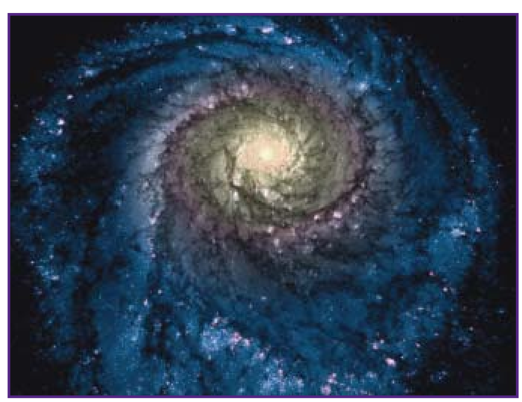
This guide was produced by the Education Department of the American Museum of Natural History.

Cover Image: A mass of molten debris swirls around an early Earth after it is struck by a planet-sized rock. This debris will fuse together to become our Moon. © AMNH



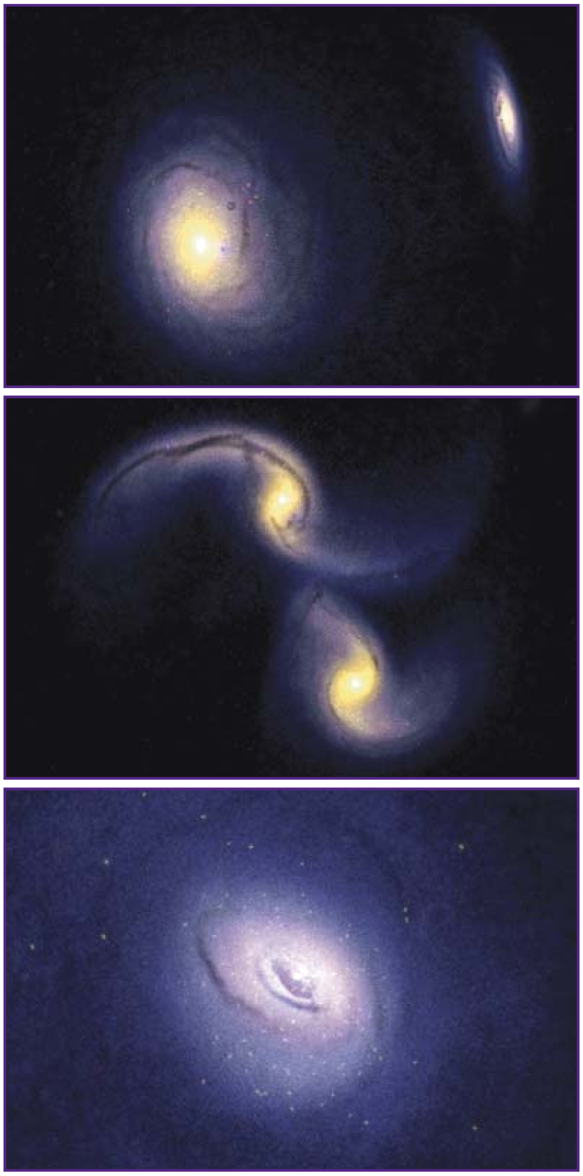
Our Milky Way Galaxy. © AMNH

SYNOPSIS

The Space Show in the Hayden Planetarium at the Rose Center for Earth and Space uses state-of-the art technology to communicate cutting-edge science. A digital video system projects across the theater's 67-foot-wide hemispheric dome, and every seat has an amazing view. It is an "immersive environment," in which you feel as if you're part of the action taking place on screen. The journey may seem like science fiction, but it is all based on authentic scientific observations, data, and models.

Synopsis

Stars, planets, and even galaxies are always in motion, and since gravity pulls them together, they collide. Dazzling and destructive, these collisions release energy that drives the growth and evolution of the universe, and shape our place within it. Using some of the world's most advanced simulation and imaging technology, the Space Show takes us far back in time, way into the future, and deep into space to witness a universe made and re-made in a story of cosmic collisions.



This sequence shows a simulation of the collision between the Milky Way and Andromeda Galaxies, creating one vast new galaxy. © AMNH

The journey begins as we follow a comet that has roamed frigid space for billions of years. This one won't collide with Earth, but as it gains speed, bits of rock from its glowing tail collide with Earth's atmosphere. As the planet plows through this debris, we see a meteor shower above North America.

The next trip is four and a half billion years back in time, when the planets were still forming and rubble littered the Solar System. Floating in space, we see a Mars-sized body smash into a young, cratered Earth. Some of the molten debris stays in orbit and is drawn together by gravity, until — in less than a month — the Moon takes shape.

A 93-million-mile journey across the Solar System brings us searingly close to the Sun, its churning surface marred by Earth-size magnetic storms called sunspots. Inside, ceaseless collisions between tiny particles called protons release incompre-hensible amounts of energy — on which life on Earth depends.

Most of this energy leaves the Sun as the light that radiates from its dramatic corona. Invisible to us, some flows off the Sun's surface in a constant stream of energized particles known as the solar wind, or in even more powerful bursts called solar storms. Riding the solar wind towards Earth, we see the planet's magnetic field shield it from this blast of charged particles. But the collision drives some particles spiraling towards the magnetic poles, causing the glowing Aurora Borealis.

Zooming past the International Space Station, we arrive in the asteroid belt between Mars and Jupiter. Every so often a large asteroid is pulled out of orbit... and we watch the giant fireball as one smashes into Earth at 40,000 miles an hour. That was 65 million years ago, and nearly three-quarters of all life went extinct on the steaming, smoke-encircled planet.

The odds of another impact like that are slim, and scientists have been figuring out ways to protect the planet. As another asteroid floats into view, we see one strategy: a rocket flies nearby, and its tiny gravitational pull is enough to change the rock's orbit, and the pair pass safely by the Earth.

Heading out again, we venture beyond the Milky Way and into a globular cluster. Densely packed stars smash together in blinding flashes of light, giving birth to new, bright blue stars. Accelerating billions of years into the future and half a million light years farther out, we see the Milky Way gently spinning towards its nearest neighbor, the galaxy Andromeda. In graceful time-lapse — 40 million years per second — they strike each other a glancing blow, retreat, and come together again in a cosmic dance. Without collisions like these, the Milky Way wouldn't exist. And probably, neither would we.

CONNECTION TO OTHER MUSEUM HALLS

Rose Center for Earth and Space

How did the universe evolve?
Walk down the **Cosmic Pathway** to gain a sense of the universe's history, from its birth over 13 billion years ago to the present day. **The Hall of the Universe** examines such questions as how the universe evolved into galaxies, stars, and planets, and how the atoms we're made of were created in the centers of stars.

How big is the universe?
In **Scales of the Universe** on the second floor of the Rose Center, compare models of various physical structures in the universe, from superclusters of galaxies to subatomic particles.

Walk past the photographs of Apollo missions to the Moon in the first floor hallways on the west and south sides of the Rose Center. With no atmosphere to protect it or water to erode it, the Moon's heavily cratered surface perfectly records our solar system's violent past.

How did the Earth form?
Visit the How has the Earth Evolved section in the **Gottesman Hall of Earth and Space,** which focuses on early events in Earth's 4.5 billion-year-history. This section focuses on the time when the planet took shape around a molten iron core through the formation of the Moon, and explores evidence for the earliest signs of life on Earth.

What is the evidence for change?
At the end of the **Cosmic Pathway**, take time to touch the bronze Moon model and feel how the Moon has been shaped by collisions. Compare the difference between the near and far side of the Moon.

Cosmic Pathway (top) and Moon model (bottom) in the Rose Center for Earth and Space. © AMNH

Arthur Ross Hall of Meteorites (top) and the Hall of Primitive Mammals (bottom). © AMNH

Arthur Ross Hall of Meteorites

What can we learn from meteorites?
Watch the short film in the Meteorite Theater, which presents the role of meteorites and their connection to the history of our Solar System. Next, visit the historic Cape York meteorite, the world's largest meteorite on display. Read about how scientists study meteorites to learn about the origin of our Solar System more than four billion years ago.

What happens when an asteroid collides with Earth?
Craters on the Earth provide an historical record of meteorite impacts. Explore craters in the Earth Impacts display, investigate the interactive computer station "Hazards: Impacts in Our Future," and see a model of the 1,200-meter-wide meteor crater, also known as Barringer Crater, located in Arizona.

Hall of Primitive Mammals

How have asteroid impacts transformed life on Earth?
In the **Hall of Mammals**, watch a video that describes what happened 65 million years ago that wiped out most dinosaurs and gave rise to mammals, including us. The Hall's fossil displays also illustrate the forces that influence the evolution of life.

OUR SUN: LIVING WITH A VARIABLE STAR

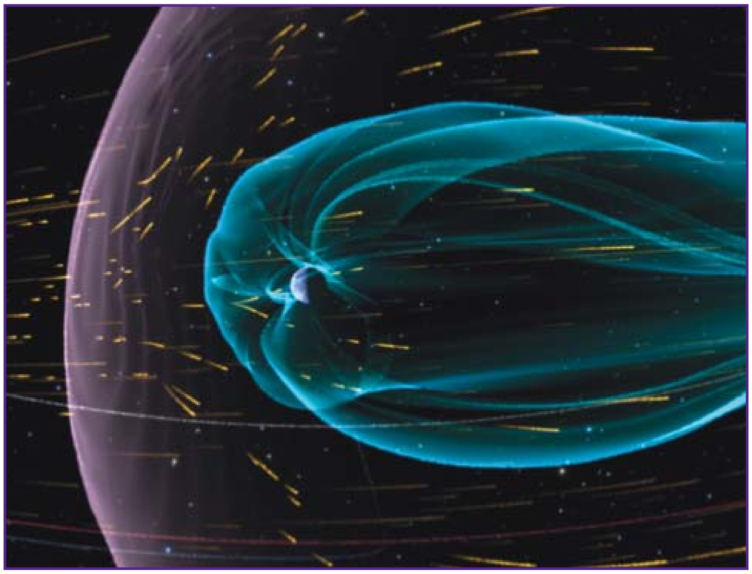
You already know that the Sun makes life possible. Its heat and light drive dynamic processes in the Earth system, from climate and ocean currents to photosynthesis. But were you aware that the Sun is a **variable star**? Or that solar winds stream off its surface and blast through space at more than a million miles per hour? Here's more about the star that's the source of it all.

Understanding the dynamic Sun is important to life on Earth – and beyond.

The Sun and everything in its environment – the heliosphere – form an immense, dynamic, and interconnected system. This system is driven by the Sun's radiation, the solar wind, and solar storms. Although the Sun appears constant, it is a variable star that emits constantly-changing energy.

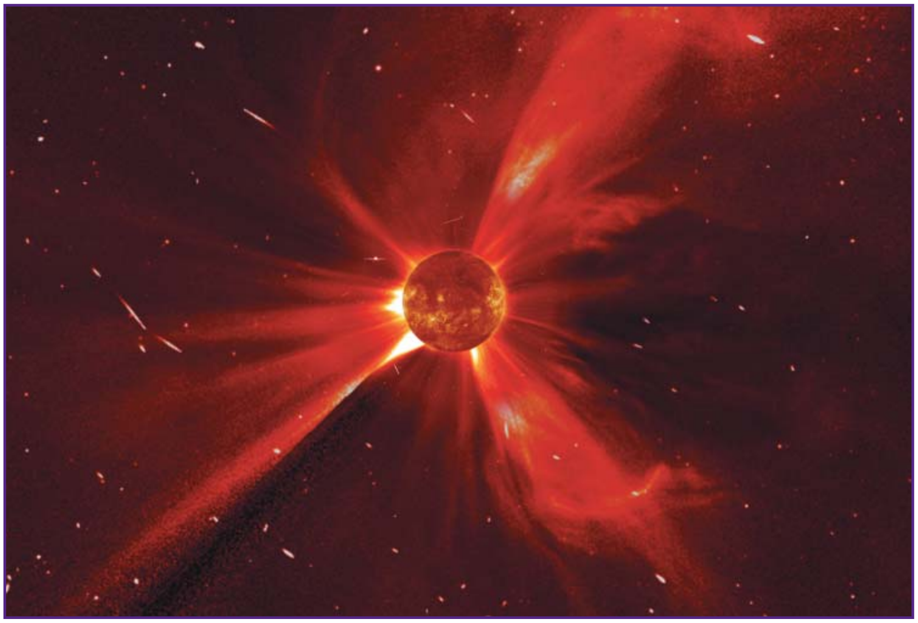
Likewise, space may appear empty, but its vast reaches are filled with streaming matter that we call solar winds. Characterized by powerful electrical currents and magnetic fields that interact with the Earth, this variable environment contains the cosmic equivalent of wind, clouds, storms, and hurricanes. In fact, it's called space weather.

Space weather affects Earth as well as the outer solar system. When these streams of particles collide with Earth's atmosphere and **magnetosphere**, they can create beautiful auroras – and they can sometimes really shake things up. In late fall, 2003, a series of Coronal Mass Ejections – huge bubbles of gas ejected from the Sun – blasted a wave of particles through the solar system. When they reached Earth, these "Halloween Storms" disrupted GPS and radio signals, caused blackouts in Sweden, and disabled satellites.



Earth is protected by an invisible magnetic field, visualized here in blue. © AMNH

The Earth has natural defenses; its magnetic field and atmosphere shield us from much of the hazardous energy the Sun sends in our direction. But we need to understand and monitor the electromagnetic processes that flow out into our solar system in order to protect Earth systems. And, as space explorers, we need to predict and mitigate the effects of solar activity so that satellites, robots, and eventually humans can venture safely beyond the shield of Earth's magnetic field.



We study the Sun from Earth and in space.

Studying the Sun is an active, ongoing research endeavor that requires special techniques and telescopes. Some telescopes, like the McMath-Pierce Solar Telescope at the Kitt Peak National Observatory, do nothing but study the Sun. Sub-orbital rockets and high-altitude balloons are an important and low-cost way to observe the Sun, as well as to test instruments for use on future space-based telescopes.

Solar wind blasts from the Sun's surface. © NASA, ESA, SOHO

The Solar and Heliospheric Observatory. © NASA, SOHO

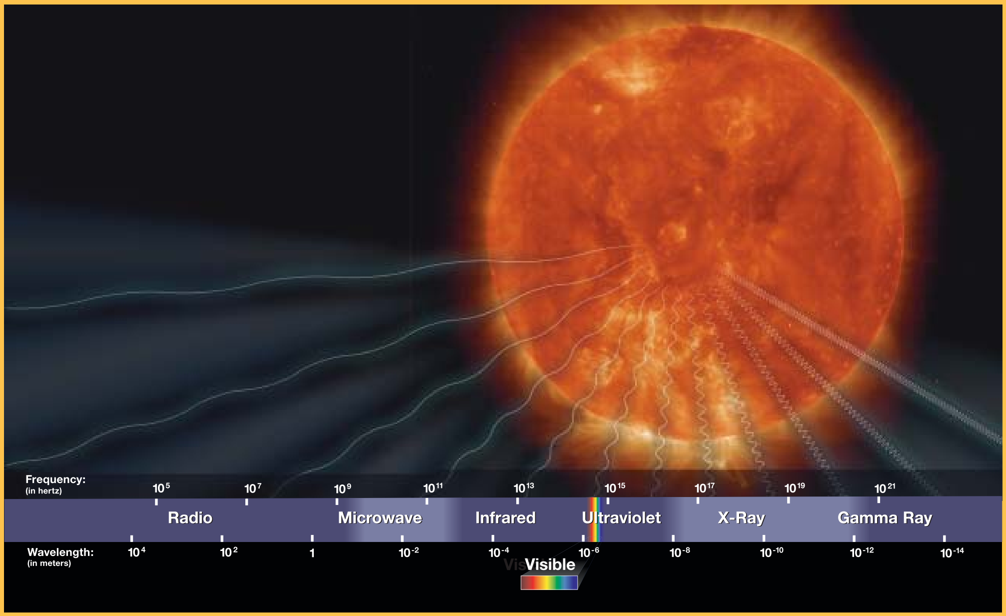
An uninterrupted view of the Sun requires going to space, and NASA's Sun-Solar System Great Observatory, a fleet of Sun, space, and Earth observing spacecraft, now patrols this space. The Great Observatory includes the Solar and Heliospheric Observatory (SOHO), and Transition Region and Coronal Explorer (TRACE). These two telescopes provide many of the dramatic close-up images of the Sun that are available today, including some shown in *Cosmic Collisions*.

As the nearest star, the Sun is our neighborhood astrophysical laboratory.

The processes that occur in our Sun also act at the center of every stellar system — and the Sun is just one of a vast number of variable stars in the universe. Since our Solar System is the one part of the universe we can investigate close up, what we learn here we can apply to the rest of the cosmos.

It's not just sunshine.

What we think of as "sunshine" is the visible light that reaches the Earth and lights our day. But the Sun gives off energy at all wavelengths of light (gamma rays, X-rays, ultraviolet, infrared, microwave, and radio) and particles called neutrinos. The source of the Sun's energy, like that of all stars, is nuclear fusion reactions. In the Sun's dense core, a complex series of interactions causes four protons (hydrogen nuclei) to come together to form helium, which has two protons and two neutrons in its nucleus. Neutrons are slightly less massive than protons. In accordance with Einstein's law ($E=mc^2$), this mass is converted to energy, which eventually reaches Earth as radiation. The enormous energies involved in nuclear reactions are what make them so powerful — far more so than chemical ones.



The Electromagnetic Spectrum. Artwork concept from NASA/Space Telescope Science Institute

Online resources from NASA:

- For more information about the structure and workings of the Sun: Solar Terrestrial Probes/Living With a Star Education & Public Outreach (http://stargazers.gsfc.nasa.gov/index.htm)
- Why We Study the Sun (http://science.msfc.nasa.gov/ssl/pad/solar/whysolar.htm)
- Each year the Sun-Earth Day program celebrates a different aspect of NASA Sun-Earth Connection science, missions, and cutting-edge research. (http://sunearthday.nasa.gov)
- The SOHO website provides nearly up to the minute images of the Sun and a full range of educational resources related to the Sun, including a very informative 'Sun 101' resource, and access to solar physicists (Dr. SOHO). (http://soho.nascom.nasa.gov)

NEAR-EARTH ASTEROIDS

What are the chances that an asteroid is headed our way?

How likely is it that something from outer space big enough to cause real trouble will smash into Earth? While we can't know for certain, we can get a sense of the odds by calculating the probability: the likelihood that such an event will take place. The statistical answer is one in a million in any given year. This figure is based on estimating the total number of asteroids and comets of a certain mass and calculating the likelihood of any of them hitting something the size and gravity of our planet.

As we inventory the asteroids and comets that could pose a threat, what really matters is the likelihood of any specific one actually hitting us. The most important variable here is how long astronomers have been watching the object. A newly discovered "Near-Earth Object" is likely to be assigned a higher probability of hitting Earth because the margin for error is huge. But as time passes — even as little as a few days — the impact probability shrinks drastically as more observations generate more accurate predictions. As Jon Giorgini, an analyst at NASA's Jet Propulsion Laboratory, points out, lots of possibilities never occur. "It's possible I will be on top of Mount Everest 60 days from now at 12:01am, but I'm not predicting it," he writes. "And there will come a point when my being on Mount Everest at some instant can be positively excluded ('That's impossible!')."

Small though it may be, there's always some chance that an asteroid or comet will strike Earth. But calculated probabilities show just how rare that is.

Calculating the probability of an asteroid impact can help protect us from these cosmic wanderers. © AMNH

Asteroid Impacts: How Do They Stack Up?

1:100,000,000	Odds of an asteroid impact causing global disaster in any given year
1:95,980,407	Odds of dying from a venomous snake or lizard bite in any given year
1:4,362,746	Odds of dying from a lightning strike in any given year
1:3,529,526	Odds of winning Lotto from a two-draw slip
1:2,598,960	Odds of drawing a royal flush in spades in a five-card poker draw
1:100,000	Odds of an asteroid impact causing regional disaster in any given year
1:91,149	Odds of dying in a fire in any given year
1:541	Odds of having triplets if you give birth
1:10	Odds that astronomers are actually aware of an asteroid larger than 1/2 mile in diameter
1:6	Odds of a sunny day in Seattle

Source: Science Bulletins (http://sciencebulletins.amnh.org/astro/f/nea.20050504/essays/56_1.php)

GLOSSARY

asteroid: A small rocky or metallic body that orbits a star. In our Solar System, most are found within the main asteroid belt, which falls roughly between the orbits of Mars and Jupiter.

asteroid impact mitigation: Plans for reducing the consequences of an asteroid impact on Earth, or preventing such an impact from occurring at all.

Aurora Borealis: An aurora that occurs in northern regions of the Earth (also called northern lights). The southern lights are called an Aurora Australis. An aurora is a glowing atmospheric phenomenon that occurs when charged particles collide with the atmosphere of the Earth near the poles. They are especially bright after solar storms.

comet: Made of ice and dust, these frozen pieces of leftover planets move in elliptical orbits around the Sun. As they approach it and begin to melt, comets may release glowing tails of dust and gas millions of miles long. In our Solar System, most are found outside the orbit of Neptune, in regions called the Kuyper Belt and the Oort Cloud.

electromagnetic spectrum: The entire range of **electromagnetic radiation** (light) that objects emit, reflect, or transmit. In order of increasing wavelength (decreasing frequency and energy), the spectrum ranges from gamma rays through X-rays, ultraviolet light, visible light, infrared radiation, and microwaves to radio waves.

energy: The power behind all phenomena, energy flows from place to place and form to form. Heat energy is the disorderly motion of molecules; chemical energy is the arrangement of atoms; mechanical energy is moving bodies or elastically distorted shapes; and gravitational energy is the separation of mutually attracting masses.

galaxy: A massive, gravitationally-bound assembly of stars, interstellar clouds, and dark matter.

gravity: The force of attraction acting between any two masses.

isotope: Every element comes in multiple varieties, called isotopes. Each isotope has the same number of protons (positively charged particles), but a different number of neutrons (electrically neutral particles).

K-T impact: The collision of an asteroid with Earth that happened 65 million years ago, contributing to a mass extinction of species (including the non-avian dinosaurs). "K-T" is the geologists term for the boundary between the Cretaceous and Tertiary periods in geological history.

magnetosphere: The volume of space around a star or a planet in which the global magnetic field influences the motion of charged particles.

meteor: If a piece of a comet or asteroid falls to Earth, as it heats up and passes through our atmosphere it is called a meteor. If it survives to land on Earth, it's called a **meteorite**.

meteor shower: A large number of meteors that appear together and that seem to come from the same area in the sky, and probably come from the same source.

moon: A natural satellite orbiting around a planet.

nuclear fusion: Energy is released when light atoms, like hydrogen and helium, combine into heavier ones. This is the reaction that powers the Sun. Nuclear fission occurs when heavier atoms like uranium and plutonium split into lighter ones, which also releases energy. Nuclear reactions are far more powerful than chemical ones.

planet: An astronomical body with enough mass for its gravity to make it spherical but not enough to generate nuclear energy. Planets have non-intersecting orbits around stars or drift freely in space.

proton: A positively-charged subatomic particle. Every atomic nucleus contains one or more protons.

solar wind: A stream of high-speed, ionized particles ejected primarily from the Sun.

star: A self-luminous body held together by its own gravity and with a central temperature and pressure sufficient to liberate energy by nuclear fusion.

variable star: A star that varies noticeably in brightness.