



## Brief Guide to Asteroids, Comets, Meteors and Meteorites

### What is an asteroid?

- Small rocky-icy or metallic non-spherical bodies that orbit the sun; most are in orbit between Mars and Jupiter.
- Most were formed within our Solar System 4.66 billion years ago.
- There are millions of asteroids; most are very small. Larger ones have sometimes been called planetoids or planetesimals.

The large asteroid Vesta is considered a protoplanet. Asteroid Ceres is now classified as a Dwarf Planet because it is spherical.

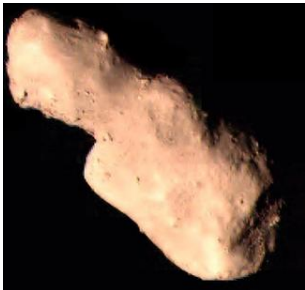
- Asteroids are characterized by their spectra (chemical composition inferred by an instrument called a spectrometer). The major composition classes are named C-type, S-type, and M-type.



(951) *Gaspra*

### How are asteroids named?

- Asteroids discovered early were named for classical mythology (Ceres, Juno, Pallas, Vesta).
- Today, they are named by their discoverers for real or fictional people, places, animals, or plants. Names are approved by the Minor Planet Center, International Astronomical Union.
- A newly discovered asteroid is first given a temporary name consisting of the year of discovery and a code for the month and sequence of discovery (Example: asteroid 1989 AC (discovered in 1989, (A) = the period January 1-15 and (C) = the third discovery during that period
- Once an asteroid's orbit has been confirmed, it is given the number of its sequence in the total



(4179) *Toutatis*

history of asteroid discovery and later may also be given a name. For example, the 4<sup>th</sup> asteroid ever to be discovered and named was Vesta, therefore its formal name is (4) Vesta. For 1989 AC (discussed above), its official name is (4179) Toutatis.

- Informally, the number is dropped and only the name is used.
- Examples of unusual names: (7758) Poulanderson (named after a science fiction author), (8749) Beatles (named after the 1960s music group) and (5460) Tsenaat'a'i ("flying rock" in the Navajo language).

### Missions to asteroids

- **Galileo** – NASA Mission to Jupiter flew past asteroids Gaspra (1991) and Ida (1993) and sent back the first close-up look at typical asteroids. It was also the first to discover a moon of an asteroid, tiny Dactyl, orbiting Ida.
- **Deep Space 1** - NASA Flyby Mission to asteroid Braille (1998).
- **NEAR Shoemaker** spacecraft (Near-Earth Asteroid Rendezvous) was the first to land on an asteroid, (433) Eros, a "near Earth asteroid," in 2001.
- **Hayabusa** and **Hayabusa 2** - JAXA (Japan) Sample Return Mission to Asteroid 25143 Itokawa (2003) and to Asteroid Ryugu (2014) both returned samples to Earth.
- **ROSETTA** - ESA Comet Mission, flew by asteroids Steins and Lutetia (2004)
- **PROCYON** – JAXA (Japan) Small Satellite Asteroid Flyby Mission (2014)

- NASA's **OSIRIS-REx** spacecraft (launched in 2016) to study a near-Earth asteroid named 101955 Bennu and in 2020, it successfully collected a sample of the asteroid that it will bring back to Earth in 2023.
- NASA's **Dawn mission** (launched in 2007 and lasted for 9 years) was the first to orbit and study the two largest asteroids in the asteroid belt, Protoplanet Vesta and Dwarf Planet Ceres.
- Dawn found evidence of an ancient ocean on Ceres. Vesta has an enormous basin, called Rheasilvia, that is twice the height of Mt. Everest, and canyons that rival the Grand Canyon in size. Dawn's instruments confirmed Vesta as the source of some meteorites found on Earth.
- **Lucy** – NASA space mission launched in 2021 to explore 7 Trojan asteroids.
- **Psyche** – NASA space mission to explore asteroid 16 Psyche, believed to be the source body of the mesosiderite class of stony-iron meteorites. Not yet launched as of 2022.



*Halley's Comet*

## What is a comet?

- Frozen “snowballs” composed of ice, dust, and rock
- Formed in the outer solar system - the Oort Cloud.
- Millions of comets orbit in very elliptical, long period orbits from the Oort Cloud into the inner Solar System.
- If they come close to the sun the surface ice is warmed and evaporated and they form a giant cloud or tail (called a coma) of gas and dust millions of miles long.

- Halley's comet, discovered by Edmund Halley in 1758, is the most well-known comet. As a periodic comet, it returns to Earth's vicinity about every 75 years and is usually easily visible. It was last here in 1986 and studied by spacecraft from Japan, ESA, and Russia. It returns in 2061.
- As of 2020, there are over 3,700 reported and known comets. Over 100 comets and over 20,000 asteroids (called NEOs for near-earth objects) have orbits that allow them to come into the inner Solar System and cross Earth's orbit.

## How are comets named?

- Comets are generally named for their discoverer; either a person or a spacecraft.
- Many comet-hunters have found multiple comets and the comet name will be the discoverer and a number for the order of discovery, for example Shoemaker-Levy 9 (collided with Jupiter in 1992) was the ninth comet discovered by Carolyn Shoemaker, Gene Shoemaker and David Levy.

## Missions to comets

- **Giotto** - ESA mission to Comets Halley and Grigg-Skjellerup (launched 1985)
- **Sakigake and Suisei** - Japan ISAS fly-by missions to Comet Halley (launched 1985)
- **ICE (ISEE-3)** - NASA Mission to Comet Giacobini-Zinner (1985).
- **Vega 1 and Vega 2** - USSR missions to Venus also close encountered Comet Halley (in 1986).
- **Galileo** – NASA's Mission to Jupiter provided the only direct observations ever seen of a comet colliding with a planet. It imaged comet Shoemaker-Levy 9 impact Jupiter (in 1989).
- **Deep Space 1** - NASA Flyby Mission to Comet Borrelly and asteroid Braille (1998).
- The **Stardust Mission** (1999) was the first to return samples from a comet (Comet Wild-2).
- **CONTOUR** - NASA Mission to fly by three comet nuclei (2002).
- **Rosetta** - ESA Mission to Comet Churyumov-Gerasimenko (2004).
- **Deep Impact/EPOXI** - NASA Flyby of Comets P/Tempel 1 and Hartley 2 (2005).



NASA – Perseid shower, 2021

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## What is a meteor?

- A bright streak of light in the sky produced by the entry through the atmosphere of an object (called a fireball or “shooting star”).
- Most small objects heat up, break up into dust, and emit light when entering the atmosphere.
- The term bolide is used to indicate the falling body.

## What is a meteor shower?

- During certain times of the year, a large number of meteors that seem to radiate from one point are observed in Earth’s night sky.
- These are produced by Earth moving in its orbit through streams of debris from a comet.

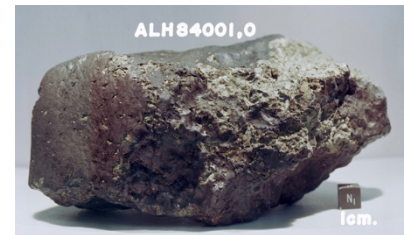
## How are meteor showers named?

- Showers are named after the nearest bright star close to the position from which they appear in the sky.
- The most visible meteor shower is the Perseids, which peaks on August 12; the most spectacular is probably the Leonids, which usually peaks in mid-November
- The Orionids meteor shower, usually peaks in October, and is believed to be created by Halley’s Comet.

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## What is a meteorite?

- A natural object originating beyond Earth’s atmosphere that survives impact with the surface.
- Millions of meteorites the size of sand grains rain down on Earth constantly; at least 100 tons of debris falls into Earth each day.
- More than 60,000 meteorites have been found on Earth so far.
- Most meteorites originate in the asteroid belt and date to 4.55 billion years of age; however, some meteorites originated on Mars or Earth’s Moon.
- Metallic Meteorites from the asteroid belt have been found on the surface of Mars. It is very possible that there are meteorites from Earth on the surface of other planets in our solar system.



## How do we classify meteorites?

- Three major types: stony, iron, and stony-iron, based on the amount of metal present.
- Stony meteorites < 20% metal, often basaltic in composition, can be divided into two sub-categories: chondrites (containing round grains called chondrules) and achondrites.
- Stony meteorites have been identified from the Moon or Mars.
- Some meteorites have been linked to individual asteroids. For example, a group of stony meteorites called the HEDs (Howardites, Eucrites, Diogenites) came from Vesta.
- Stony–iron meteorites are about 50% metal and include unusual types such as pallasites (equal amounts of olivine or peridot and nickel-iron) and mesosiderites (breccias containing equal amounts of nickel-iron and silicates).
- Iron or metallic meteorites are over 80% metal and can be divided into subtypes based on the internal crystalline structures of the nickel-iron within them.

## Where and how are meteorites found and how are they named?

- They can be found anywhere on Earth (and have also been found on Mars), but scientists specifically go on seasonal collecting trips to Antarctica or to one of the great sandy deserts of Earth to collect meteorites because they are easily found and identified on those surfaces.

- Iron meteorites are the easiest to find and identify since they are heavy and magnetic and different looking. They frequently show a dark and glassy-looking “fusion crust” and dents called thumbprints or regmaglypts on the surface; both are caused by melting as the rock came through the atmosphere.
- A higher percentage of meteorite falls on Earth are stony achondrites, but they are more difficult to find and recognize since they can look like Earth rocks.
- The study of meteorites is called meteoritics. Scientists specializing in it are meteoriticists.
- The Institute of Meteoritics at the Univ. of New Mexico and the Busek Center for Meteorite Studies at Arizona State Univ. are two of only a few centers that study meteorites nationwide.
- Meteorites are named for their landing site on Earth. Those found in Antarctica or the Sahara, where many are found, are named for the site and numbered in sequence by discovery year.

## How do we recognize meteorites from the Moon and Mars? Wasn't there one that showed evidence of life?

- Over 500 meteorites have been identified as lunar meteorites. They match the age and chemical and mineral compositions of the lunar rocks returned by the Apollo astronauts.
- Over 125 meteorites have been identified as Martian. Their age is younger than meteorites from the asteroid belt and they contain pockets of gas identical to the Mars atmosphere as analyzed by the NASA Viking Mission landers.
- As impacts occur on the Moon and Mars, rock from those bodies are ejected into space to eventually intersect with Earth.
- Cosmic ray exposure ages can be used to estimate how long ago the Lunar and Martian meteorites were ejected off their source bodies before they hit Earth.
- In 1986, scientists studying the Martian meteorite ALH84001 (found at Allen Hills, Antarctica, in 1984) suggested that some of its features had been produced by microorganisms. This was disproved by subsequent tests and other scientific analysis.



## METEORITES IN THE MUSEUM Where can you find meteorites on exhibit in the Museum?

- Large iron meteorites on display outside the *Origins Hall* and inside the *Origins Hall*
- The exhibit **Meteorites and Meteorwrongs**, shows all 3 meteorite types including a large touch specimen piece of Campo del Cielo (iron meteorite) at the entry to the *Space Science wing*.
- A cut slab of a **Mars Meteorite** (Zagami) and a section of it under a microscope mounted on the railing around the planet exhibit in the *Space Science wing*.



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