
# Space Rocks

## Outreach ToolKit Manual

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***Created by the Astronomical Society of the Pacific***

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Distributed to members of the NASA NIGHT SKY NETWORK

nightskynetwork.org

**Night Sky Network**

Astronomy Clubs bringing the wonders of the universe to the public

**The Night Sky Network was founded and is supported by:**

**JPL's EXOPLANET EXPLORATION PROGRAM**

## Contacts

**The Night Sky Network is managed by the non-profit Astronomical Society of the Pacific (ASP), one of the nation's leading organizations devoted to astronomy and space science education, in cooperation with NASA and JPL. Learn more about the ASP at http://www.astrosociety.org**

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## *Introduction: Space Rocks*

Our smallest Solar System neighbors are often overlooked when we think of objects in our solar neighborhood. But in fact, asteroids and comets have had dramatic effects on Solar System bodies, including Earth. Impacts are not just a part of history. The Earth is hit all the time with literally tons of space rocks. This ToolKit explores some of our smallest neighbors, asteroids, and their significance for us here on Earth.

We see effects of past impacts on the planets, moons and even other asteroids in our Solar System. The material orbiting the Sun between Mars and Jupiter has a dynamic past. It never came together to form a planet. Instead, Jupiter's gravity sent early proto-planets flying together, knocking each other out of their orbits. Today, what remains is much less chaotic with very little of the original mass remaining. The Asteroid Belt is not the densely packed place that you see in the movies, but a sparse region that presents no obstacles for spacecraft passing through.

Even in such an empty place, occasionally asteroids do collide and send pieces of rock out of the Asteroid Belt. Some of their orbits cross Earth's path. Most of the pieces are small enough that they explode or vaporize in our atmosphere, never making it to the ground. Small asteroid pieces that *do* survive to make it to the ground are called meteorites. These space rocks give us clues to the composition of asteroids and to the history of our Solar System.

Wayward pieces of asteroids larger than a house can penetrate our atmosphere, impacting the ground with enough energy to create craters and destroy the surroundings. The largest collisions can cause worldwide devastation. Over 170 craters around the globe show evidence of past large impacts on Earth.

Astronomers are taking steps to identify asteroids that pose a potential hazard to Earth. This effort includes work by professional and amateur astronomers. NASA's **Wide-field Infrared Survey Explorer (WISE)** is finding hundreds of near Earth asteroids and *hundreds of thousands* more in the main Asteroid Belt. Finding all of the asteroids and comets that come close to the Earth is the first step in protecting the planet from a devastating impact.

Scientists are also sending missions to explore the Asteroid Belt. NASA's Dawn mission will orbit two of the largest asteroids. The Rosetta mission will image two more on its way to a comet. These spacecraft will contribute much to our understanding of the Asteroid Belt and our own planet's history.

## Summary of activities and resources:

The Space Rocks ToolKit concentrates on asteroids and phenomena stemming from the dynamic nature of the Asteroid Belt, such as impacts and meteorites. Comets also play a part in the history of Earth impacts and are referenced in the handout and card game.

1. **Media and Resources**
   a. *Manual & Resources CD* contains the ToolKit Manual and a variety of other resources
   b. *Training DVD* is for training your club members on the ToolKit
   c. *PowerPoint: Space Rocks* (on the Manual & Resources CD)
   *d. DVD: Cosmic Collisions*
   e. *Background Materials* on NASA Missions for sharing with club members



2. **Our Rocky Neighbors**
   a. *Sorting the Solar System* cards introduce your visitors to the variety of objects found in our Solar System.
   b. *Scaling the Asteroid Belt* uses a 1-meter Earth banner with Moon and asteroid models to talk about sizes and distances in the Asteroid Belt.
   c. *Asteroid Hunters* shows one of the ways we search for asteroids and explains how infrared technology makes the search easier.

3. **Earth Impacts**
   a. *Meteorite or MeteorWrong* includes real meteorites to let your visitors act like scientists. They try to pick out space rocks from among a pile of normal rocks.
   b. *Craters on the Earth and Moon* explores why the Earth isn't covered in craters like the Moon is. Make craters and simulate processes on our dynamic planet.
   c. *Heads Up! It's a Meteor Shower* Handout is a great way to give visitors more information about upcoming meteor showers and their sources. Be sure to include your club information on the back.

# Media & Resources


The “Media and Resources” bag includes:

- Manual & Resources CD
- Space Rocks Training DVD
- DVD: Cosmic Collisions
- Background Materials on NASA Missions

The **Training Video DVD** should be viewed as soon as you receive the ToolKit. This will provide an introduction to the activities and materials.

**<u>Explore this “Manual and Resources CD”</u>**

○ For the **Space Rocks ToolKit Manual**, open the file: “SRocksManual.pdf”
You need the free Adobe Acrobat Reader to view the manual:
**<u>http://www.adobe.com/products/acrobat/readstep2.html</u>**

○ **The “PowerPoint” folder contains**:

- The Space Rocks PowerPoint "*SpaceRocks.ppt" and its suggested script. The script is called “*SRocksPPTScript.pdf” and is included also as a Word document “SRocksPPTScript.doc”. This PowerPoint provides an overview of the topics covered in the ToolKit and can be used as an introduction to any of the activities. The PowerPoint is recommended for ages 12 to adult.
- A document named "MissionPowerPoints.doc" which gives links to the latest PowerPoint presentations about NASA missions related to asteroids and comets.

○ **The “Additional Resources” folder contains:**

- A document named "AdditionalResources.doc" with links to exciting mission programs and information.
- Fact Sheets on the WISE, Dawn, and Rosetta missions. These can be used as background for you and your club members.
- A document about the history of asteroid discovery.
- *"DawnJourney.mov"* a 12-minute movie about the Dawn Mission's investigation of the Asteroid Belt. You can find this and many other animations here:
<u>http://dawn.jpl.nasa.gov/multimedia/videos.asp</u>

## *WHERE COULD I USE THE RESOURCES INCLUDED HERE?*

| MEDIA / RESOURCE | Pre-Star Party – Indoors | Girl Scouts / Youth Group Meeting | Classroom | | | Club Meeting | Gen Public Presentation (Seated) |
|---|---|---|---|---|---|---|---|
| | | | K-4 | 5-8 | 9-12 | | |
| Training DVD | | | | | | √ | |
| Manual & Resources CD | | | | | | √ | |
| PowerPoint: Space Rocks | √ | √ | | √ | √ | √ | √ |
| DVD: Cosmic Collisions | √ | √ | | √ | √ | √ | √ |
| Background Materials on NASA Missions | | | | | | √ | |

**Feel free to make additional copies of the Training Video and Manual & Resources CD to distribute to other club members.**

# Sorting the Solar System

## *What's this activity about?*

**Big Questions:**
- What types of objects are in our Solar System?
- Why do the definitions of the objects change?

**Big Activities:**
- Using images of Solar System objects, start discussions of the characteristics of asteroids, comets, planets, and moons.
- Practice scientific thinking by sorting objects into categories according to their common qualities.

**Participants:**

**From the club**: A minimum of one person.
With larger groups, up to four presenters can participate.

**Visitors:** This activity is appropriate for families, the general public, and school groups ages 10 and up.  With small groups, one set of cards can be used. Four sets are included for use in classrooms or larger groups.

Also, a large set of objects is included in this manual. You may print them yourself, but it is recommended that you do this at a print shop. Printing them requires a lot of ink.

**Duration:**

Ten minutes, up to a half hour, depending on the depth of questions and conversation.

**Topics Covered:**
- Review of the diversity of objects in our Solar System
- How scientists use common characteristics to classify the world around us

## *Where could I use this activity?*

| ACTIVITY | Star Party | Pre-Star Party – Outdoors | Pre-Star Party – Indoors | Girl Scouts / Youth Group Meeting | Classroom | | | Club Mtg | Gen Public Presentation (Seated) | Gen Public Presentation (Interactive) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | K-4 | 5-8 | 9-12 | | | |
| **Sorting the Solar System** | | √ | √ | √ | | √ | √ | √ | √ | √ |

## *What do I need to do before I use this activity?*

| What materials from the ToolKit are needed for this activity? | What do I need to supply to run this activity that is not included in the kit? | Preparation and Set Up |
|---|---|---|
| At least one set of Sorting the Solar System Cards. Four sets are included for use with larger groups. | A table or flat surface is preferred. | Remove the Ceres card from the deck(s). These will be used later. |

## *Helpful Hints*

**Common *misconceptions* addressed by these resources:**

- The Solar System contains more than one star
- The planets are the only things in our Solar System
- Science is a rigid set of facts to be memorized

**Other Games:**

**Sort It:**
With a group of 20+, give each person a card and ask them to sort themselves by size, distance from the Sun, common materials, alphabetically, or shape. There may be more than one way to sort. All reasonable attempts should be accepted.

With smaller groups, each person (or group of up to 3 people) gets their own deck to answer the same questions. The first group to sort them correctly wins. Allow each group to finish and hold their hand up when they're done. Once they raise their hand, they can't change their order. If the first group has anything out of order, go to the second, and so forth.

**20 Questions:**
Have the presenter pick an object but don't tell the visitors. Let the visitors take turns asking yes/no questions until they guess the object. The person who guesses correctly gets to pick the next object. Give time during games and between rounds for visitors to look at the backs of the cards.

## *Background Information*

This activity was adapted from a classroom activity originally developed by Anna Hurst Schmitt for the Teacher's Newsletter Universe in the Classroom:
http://www.astrosociety.org/education/publications/tnl/70/pluto.html - 10

For a history of the definition of a planet, see these websites:
http://www2.ess.ucla.edu/~jlm/epo/planet/planet.html

http://www.astrosociety.org/education/publications/tnl/70/pluto.html

http://www6.cet.edu/dawn/multimedia/makeplanet.asp

## *Detailed Activity Description*

### Sorting Our Solar System

| |
|---|
| **Misconception Tip:**<br>Many people don't understand the difference between Solar System, Galaxy and Universe. Here is a chance to talk at length about the smallest of these scales. |
| **Presentation Tips:**<br>These cards can be used to illustrate many points. The activity described here is one example, but you may find others that work in different situations. You can also find other ideas in the "Helpful Hints" section.<br><br>Using more than one deck and breaking visitors into small groups can be interesting because they see that there are different ways to categorize the same objects.<br><br>If you would like to use more than one set of cards, it is recommended that you print them on various color card stock. The individual sets get easily combined into a single pile if they are all one color. |
| **Before you get started:**<br>Remove the Ceres card from the deck and put in your pocket. You will bring this out later. |

| **Leader's Role** | **Participants' Role (Anticipated)** |
|---|---|
| *<u>To say:</u>*<br>What kinds of things do we find in our Solar System? | Planets, stars, people, airplanes |
| Ahh! How many stars are there in our Solar System? | Billions and billions |
| There is actually only one star in our Solar System. The term "Solar System" refers just to our own star, the Sun and everything orbiting it.<br>That includes planets, like you said. What else is in the Solar System that's not here on Earth? | Comets, moons, asteroids |
| *<u>To do:</u>*<br>Bring out all of the Solar System Cards, except for Ceres. | |
| *<u>To say:</u>*<br>Great! Take a look at this. I've got pictures here that represent a sample of the different kinds of objects found in our Solar System. Now, you can't tell how big each object is just from the picture. Some pictures are taken close up and others from far away. You'll want to check the backs of the cards to see how big each object is. What else does the back of the card tell us? | Where it is, what it's made of, how big it is |
| To do:<br>Pick up one of the cards (in the following example, we are using Gaspra) | |
| *<u>To say:</u>*<br>Scientists sort things by their physical characteristics. What are some characteristics of this object? Can you describe what it looks like?<br> | It's lumpy. And brown, and has craters |

| **Leader's Role** | **Participants' Role (Anticipated)** |
| --- | --- |
| *<u>To say:</u>*<br>Great! We also know from the information on the back that it's as big as a city and that it orbits the Sun between Mars and Jupiter. These are characteristics too. | |
| Now it's your turn to be the scientist. Work together to sort these objects into some categories using their characteristics. Get creative! You get to choose the categories. | Participants sort the cards into various groups. |
| **<u>Presentation Tip:</u>**<br>If you are working with a large group, give each person a card and have them sort themselves into categories. This can be very fun and collaborative! | |
| *<u>To say:</u>*<br>There are no limits to the number of categories you can have. But think about the characteristics that objects in each of your categories have. | |
| Tell me about the categories you picked. | Describe groups |
| Did any of the objects fit into more than one category? Tell me why you decided on the category you put them in. | Usually they do |
| Okay, now where would this object fit? | |
| *<u>To do:</u>*<br>Hand the group the Ceres card. | Put it in one of the categories |
| *<u>To say:</u>*<br>What characteristics does it share with that group? Could it fit in more than one group? | |
| *(Extension)* Could you refine your category definitions so that nothing fits in more than one category? | Sometimes the groups are flexible enough |

| Leader's Role | Participants' Role (Anticipated) |
|---|---|
| *To say:*<br>This is great! You are being real scientists. This is exactly what biologists, chemists, geologists, and astronomers do. And as new bacteria or birds or fossils are found, they use their knowledge of what has already been discovered to help them think about this new object.<br><br>That's exactly what happened when Eris was discovered. Eris is another Pluto-sized object that's also orbiting way out past Neptune. And many more objects are being found out there all the time.<br><br>Sometimes new discoveries even cause the definitions to change! The definition of a planet changed in 2006 and a whole new category was created: dwarf planet. That category includes both Ceres and Pluto. | |
| (If before an observing evening) Can you see any of these categories in the sky right now?<br><br>Actually, do you see that bright star-like light over there? Well, it's not a star at all. That's Jupiter! Which category does that fit onto? | Sun or Moon or none |

## *Materials*

### What materials from the ToolKit do I need?

In the activity bag:
At least one set of Solar System Cards (4 sets included in 2 decks)

### What must I supply?

- Table or flat surface for organizing the cards, unless you have a big group that can hold one card each

## Where do I get additional materials?

You can order additional sets, while supplies last, from the Night Sky Network. For more information, send an email to: nightskyinfo@astrosociety.org

To make additional copies of the cards, just print the following five pages in color, *one-sided* on card stock (or other thick paper).

Cut each page into 3 strips so that the image and description stay together.

Fold each strip in half to make two-sided cards. You can paste them with glue or tape around the edges.

For large groups where each person will hold a single card, you may want to print the large size cards. In that case, simply fold them in half and glue them together, as shown.


This activity can be done with any set of images in any size. The Hubble Site and the NASA Image archive have a wealth of pictures of Solar System objects.

- http://hubblesite.org/newscenter/
- http://www.nasa.gov/multimedia/imagegallery/

# Key to Sorting the Solar System Cards

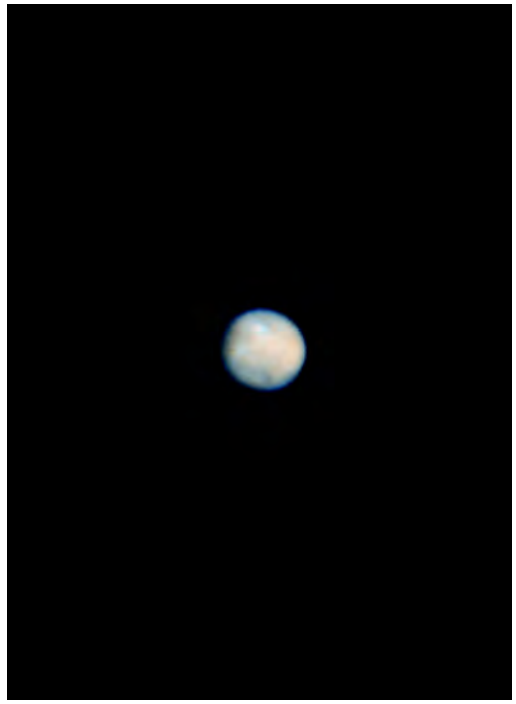
| Object | Description | Size (km) | Picture Credits |
|---|---|---|---|
| **Barringer Crater** | Also known as Meteor Crater, it is located in Arizona, USA. Created by the impact of a meteorite about 50,000 years ago, this crater was formed before humans inhabited the Americas. | 1.2 | B.P. Snowder |
| **Ceres** | Ceres is the largest object in the Asteroid Belt. The International Astronomical Union classifies Ceres as a Dwarf Planet. It is the target of the Dawn spacecraft in 2015. | 950 | NASA, ESA, J. Parker (SwRI) et al. |
| **Earth** | Earth is the third planet from the Sun and is the fifth largest planet in the Solar System. About 71% of Earth's surface is water, the remainder consists of land. | 12,650 | Taken from Apollo 17 in 1972, credit NASA |
| **Earth's moon** | The moon is the fifth largest satellite in the Solar System. It is the only celestial body on which humans have landed. Although it appears bright in the sky, it is actually as dark as coal. | 3,500 | NASA/JPL/USGS |
| **Eris** | Eris is a Dwarf Planet with a moon called Dysnomia. It is more massive than Pluto and orbits the Sun three times farther. It was discovered in 2005 and caused a stir after initially being described as the 10th planet. | 2,600 | NASA/ESA/M. Brown |
| **Eros** | Eros was the first near-Earth asteroid discovered. It is also one of the largest. The probe NEAR Shoemaker landed on this asteroid in 2001. Eros orbits between Earth and Jupiter, crossing Mars's orbit. | 34 | NASA/JPL/JHUAPL |
| **Gaspra** | Gaspra is an asteroid that orbits the inner edge of the main Asteroid Belt. The Galileo spacecraft flew by Gaspra on its way to Jupiter. | 18 | NASA/JPL/USGS |
| **Hale-Bopp** | Hale-Bopp was one of the brightest and most widely viewed comets of the 20th century. It came into the inner Solar System in 1997 and has an orbital period of over 4,000 years. | 1,000,000 | E. Kolmhofer, H. Raab; Johannes-Kepler-Observatory |
| **Hoba** | The Hoba meteorite is the largest known meteorite on Earth. It landed here about 80,000 years ago in what is now Namibia. Hoba weighs over 60 tons and is the most massive piece of naturally-occurring iron on Earth's surface. | 0.003 | Patrick Giraud |
| **Iapetus** | Iapetus is the third largest moon of Saturn. It has an equatorial ridge that makes it look a bit like a walnut, as well as a light and a dark side. Astronomers think that the dark side is covered with a thin layer of residue from the icy surface sublimating. | 1,500 | NASA/JPL/Space Science Institute |
| **Ida and Dactyl** | Ida is a main belt asteroid and the first asteroid found to have a moon, Dactyl. It was imaged by the Galileo spacecraft on its way to Jupiter. | 15 | NASA/JPL |
| **Itokawa** | Asteroid Itokawa crosses the orbits of both Mars and Earth. It is a rubble pile of rocks. In 2005, the Hayabusa probe landed on Itokawa to collect samples. | 0.5 | ISAS, JAXA |
| **Jupiter** | Jupiter is the largest planet in the Solar System, more massive than all the other planets combined. This gas giant has been explored by many spacecraft, notably the Galileo orbiter. It has four large moons and dozens of smaller moons. | 70,000 | NASA/JPL/University of Arizona |

Night Sky Network Resources
You can print your own cards here:
http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=459

# Key to Sorting the Solar System Cards

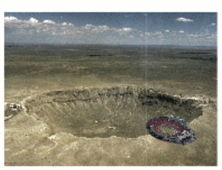
| Object | Description | Size (km) | Picture Credits |
|---|---|---|---|
| **Mars** | Mars is the fourth planet from the Sun. Iron oxide gives it a reddish appearance. It has polar ice caps and a very thin atmosphere. Two tiny moons might be captured asteroids. | 6,800 | NASA |
| **Meteor** | Small pieces of asteroids or comets collide with Earth's atmosphere to create meteors. The compressed air in front of the rock heats up, causing it to glow and leave a trail of ionized gas. | 0.00001 | Chuck Hunt |
| **Meteorite** | Most meteorites are pieces of the Asteroid Belt that land on Earth's surface. Over 90% of meteorites are considered stony meteorites. About 5% are iron meteorites. Both types contain a significant about of iron. | 0.001 | Dr. Svend Buhl www.meteorite-recon.com |
| **Phobos** | Phobos is the largest moon of Mars, but still quite small. It is likely a captured asteroid and will break up and crash into Mars in the next 40 million years. | 11 | NASA/JPL-Caltech/University of Arizona |
| **Pluto and Charon** | Pluto is the 2nd largest dwarf planet in the Solar System (after Eris). It has a large moon Charon and two smaller moons, Nix and Hydra. Pluto and Charon are sometimes treated as a binary system since their center of gravity is between the two. | 2,300 | ESA/ESO/NASA |
| **Saturn** | Saturn is the second largest planet in the Solar System. It is made of gas and has very thin icy rings. It also has dozens of moons. The Cassini-Huygens spacecraft has been orbiting Saturn since 2004. | 120,000 | NASA/JPL/Space Science Institute |
| **Shoemaker-Levy 9** | Comet Shoemaker-Levy 9 provided the first direct observation of the collision of extraterrestrial solar system objects. It broke into many fragments, called the "String of Pearls," and impacted Jupiter in 1994. | 1 | NASA/HST |
| **Sun** | The Sun is the star at the center of our Solar System, about 150 million km from Earth. It contains 99.9% of all the mass in our Solar System. It travels once around the Milky Way Galaxy in about 250 million years. | 1,400,000 | ESA/NASA/SOHO |
| **Titan** | Titan is the largest moon of Saturn, comprising 96% of the mass of all Saturn's moons combined. It is a cold world with a thick nitrogen atmosphere and liquid methane lakes on its surface. The Huygens probe landed on its surface in 2005 and took pictures of icy conditions. | 5,150 | NASA/JPL/Space Science Institute |
| **Victoria Crater** | This impact crater near the equator of Mars was visited by the Mars Exploration Rover *Opportunity*. The scalloped edges of the crater are caused by erosion. Although Mars has very little atmosphere, it does have dust storms. | 0.75 | NASA/JPL-Caltech/University of Arizona/Cornell/Ohio State University |
| **Wild 2** | Comet Wild 2 is officially named 81P/Wild. It once orbited beyond Jupiter but got too close to the giant planet in 1974 and was tugged into a smaller orbit between Jupiter and Mars. The Stardust sample return mission took pictures and captured some of the comet's coma in 2004. | 4 | NASA/JPL-Caltech |

Night Sky Network Resources
You can print your own cards here:
http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=459



## Barringer Crater

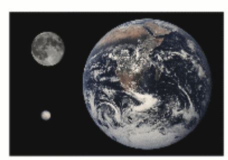
- This crater is located in Arizona, USA
- It was created 50,000 years ago by a chunk of **METAL** from space
- It measures about **1.2 km** in diameter



Size of crater compared to a stadium

## Ceres

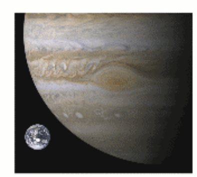
- Ceres is the largest object between the orbits of Mars and Jupiter
- It is made mostly of **ROCK** and **ICE**
- Ceres is about **950 km** in diameter



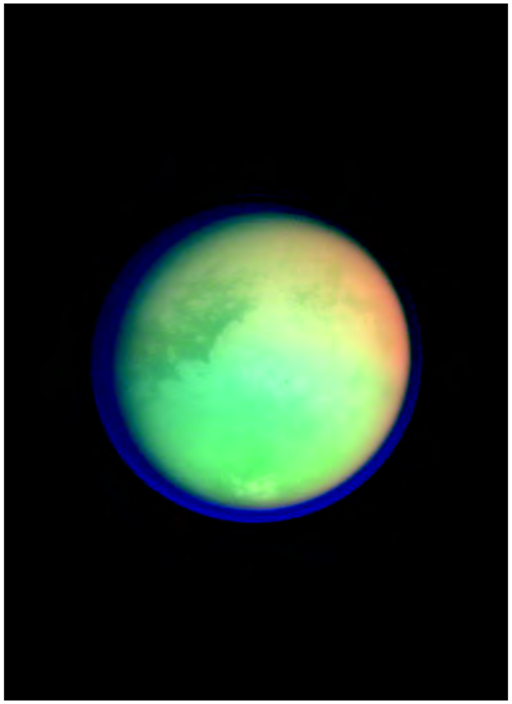
Ceres (bottom left) compared to the Earth and Moon

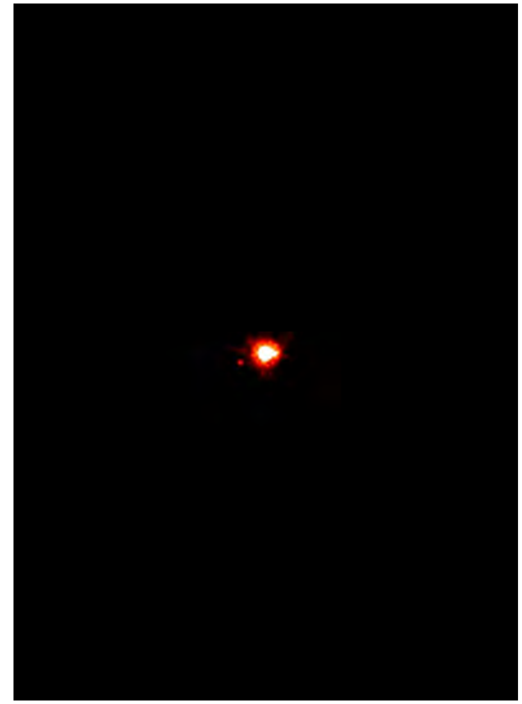
## Earth

- It orbits the Sun between Venus and Mars
- Earth is made of **ROCK**, a **METAL** core and both solid and liquid **ICE** (water, that is) on its surface
- Its diameter is **12,650 km**



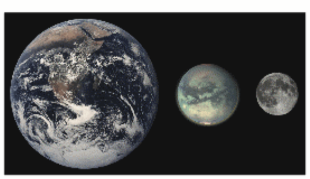
Size of Earth compared to Jupiter





## Titan

- Titan orbits Saturn
- It is made of **ROCK** and **ICE** and has a thick atmosphere
- It is **5,150 km** in diameter, between the size of the Earth and Moon



Size of Titan (center) compared to the Earth and Moon

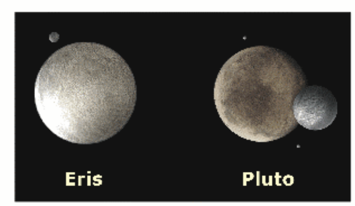
## Wild 2

- Wild 2 orbits the Sun between Mars and Jupiter, though its orbit used to be much more distant
- It is made of **ICE** and **DUST**
- It is about **4 km** across

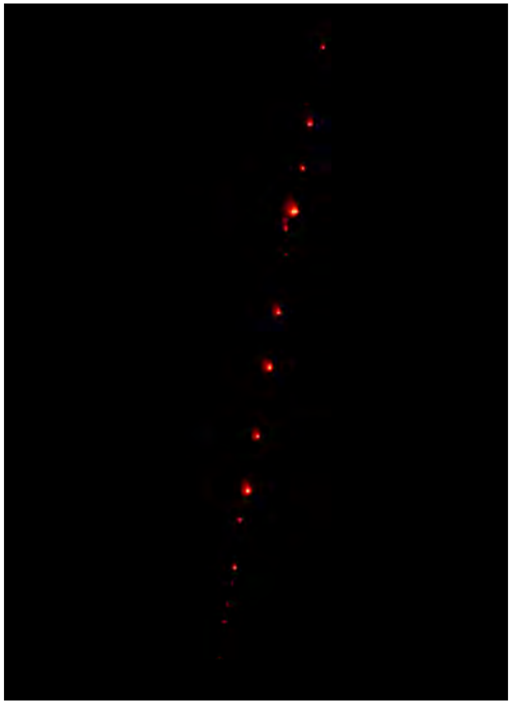
Size of Wild 2 compared to Manhattan

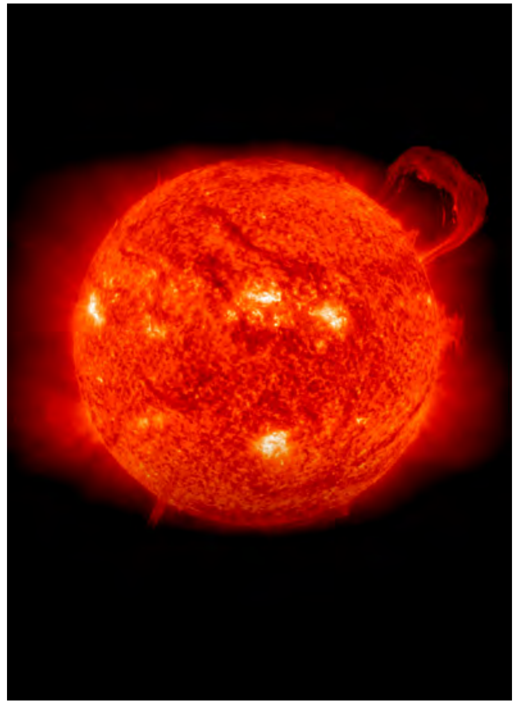
## Eris

- The orbit of Eris is very distant, mostly beyond Pluto's orbit.
- It is made of **ICE** and **ROCK**
- The diameter of Eris is about **2,600 km**



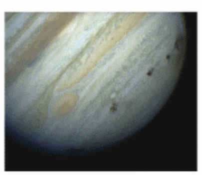

Size of Eris compared to Pluto





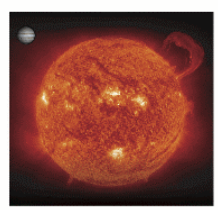
## Shoemaker-Levy 9

- Its orbit originally took it beyond Pluto. After it was captured by Jupiter's gravity, it was torn apart and eventually smashed into Jupiter.
- Made of ICE and **ROCK**
- Largest pieces were **1km** and left huge marks on Jupiter



## Sun

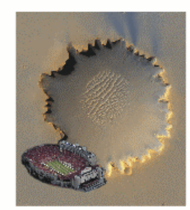
- The Sun is located in the center of our Solar System
- It is made mostly of hydrogen and helium **GAS**
- The Sun is **1.4 million km** in diameter



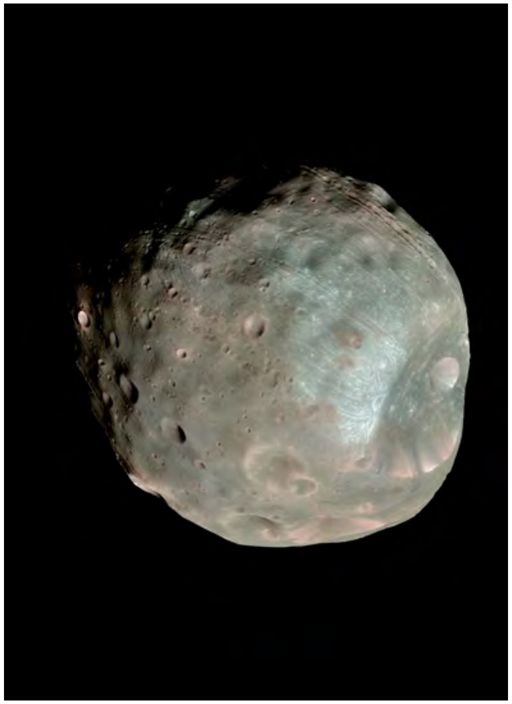
Size of Sun compared to Jupiter

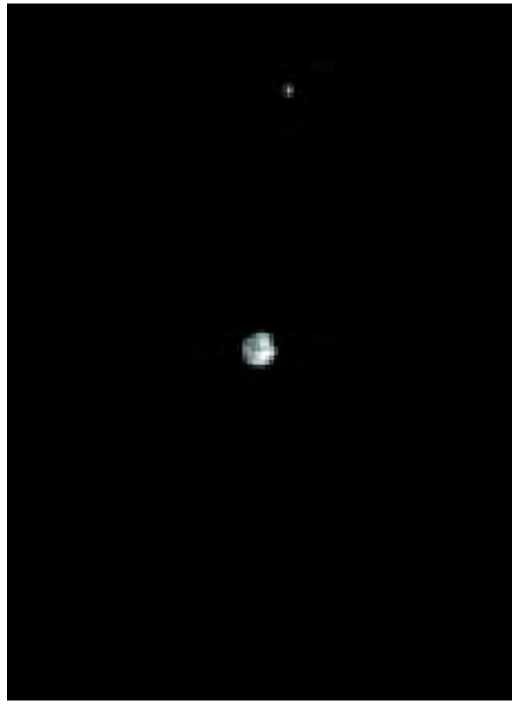
## Victoria Crater

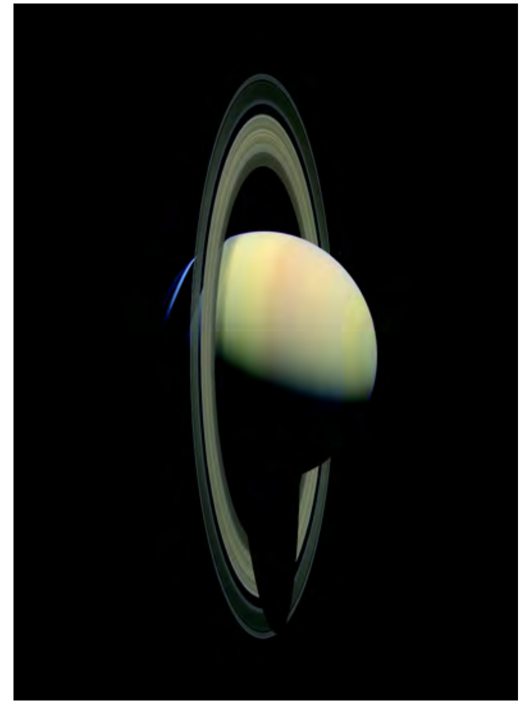
- This crater is one of the smaller craters on Mars
- The rim's jagged edges are due to erosion caused by **ROCK** and **DUST**
- It is **750 meters** across



Size of crater compared to a stadium

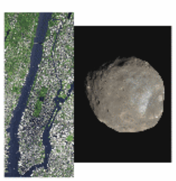






## Phobos

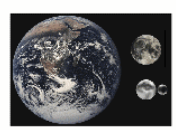
- Phobos closely orbits Mars and will eventually collide with it
- It is mostly made of **ROCK** but may have **ICE** inside
- Phobos is about **11 km** across



Size of Phobos compared to Manhattan

## Pluto & Charon

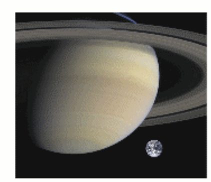
- Pluto and Charon orbit orbit each other, together are mostly outside Neptune's orbit
- These round objects are made of **ICE** and **ROCK**
- Pluto is about **2,300 km** across



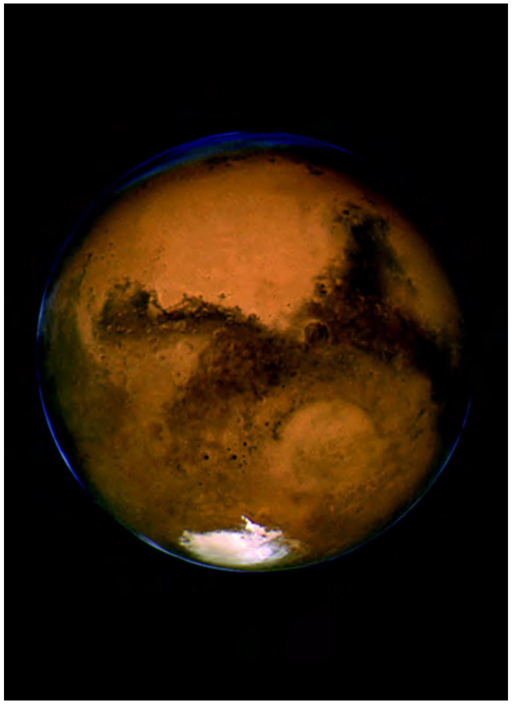
Size of Pluto & Charon compared to Earth and Moon

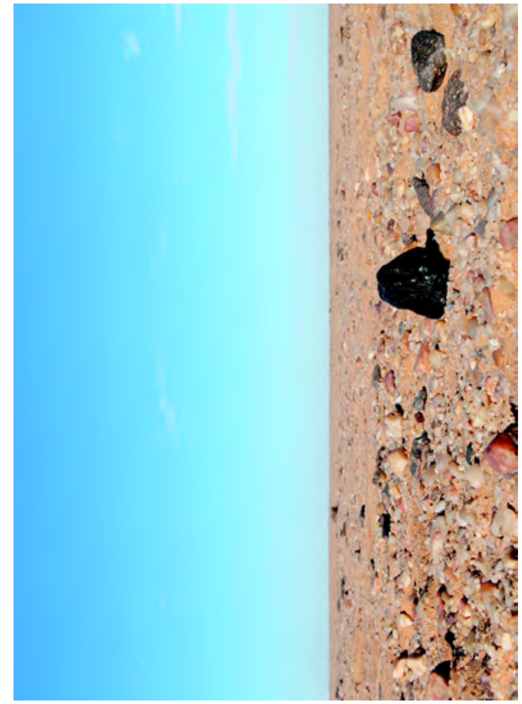
## Saturn

- Saturn orbits the Sun between Jupiter and Uranus
- Saturn is mostly made of **GAS**
- The main body is **120,000 km** across



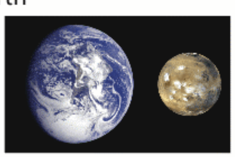
Size of Saturn compared to Earth





## Mars

- The orbit of Mars is between Earth and the Asteroid Belt
- Mars is made of **ROCK** with a **METAL** core and some solid **ICE** on its surface
- It is **6,800 km** in diameter, about half as wide as the Earth



Size of Mars compared to Earth

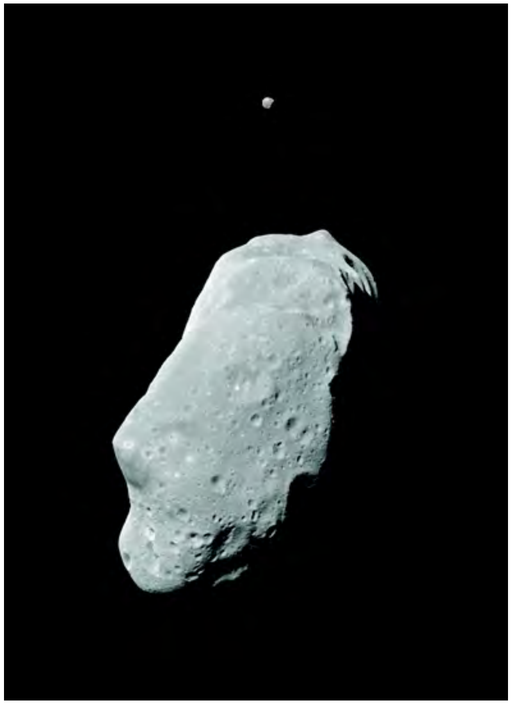
## Meteor

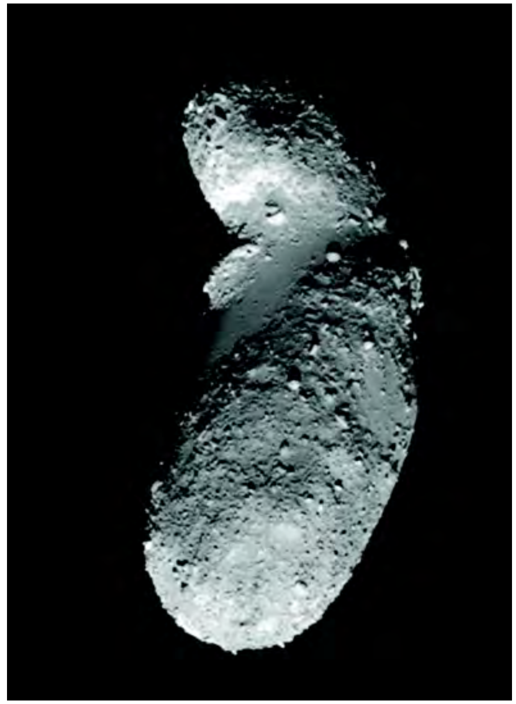
- Meteors occur in Earth's atmosphere, about 75km above the surface
- We see the glowing pieces of **ROCK**
- The pieces of rock are mostly less than **1cm**, or the size of a coin


Size of rock compared to a coin

## Meteorite

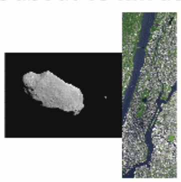
- Meteorites are pieces of asteroids that land on other worlds
- They are made of **METAL** and **ROCK**
- Almost all meteorites on Earth are smaller than **1 meter**





## Ida and Dactyl

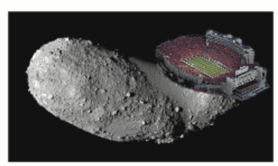
- Together they orbit the Sun between the orbits of Mars and Jupiter. Dactyl (the smaller object) orbits Ida.
- They are mixtures of **ROCK** and **METAL**
- Ida is about **15 km** across



Size of Ida compared to Manhattan

## Itokawa

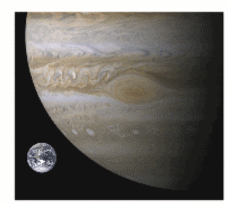
- Itokawa's orbit crosses the orbits of Earth and Mars but is not a threat to either
- It is made of a loose pile of boulders made of **ROCK** and **METAL**
- Its longest side is **535 meters**



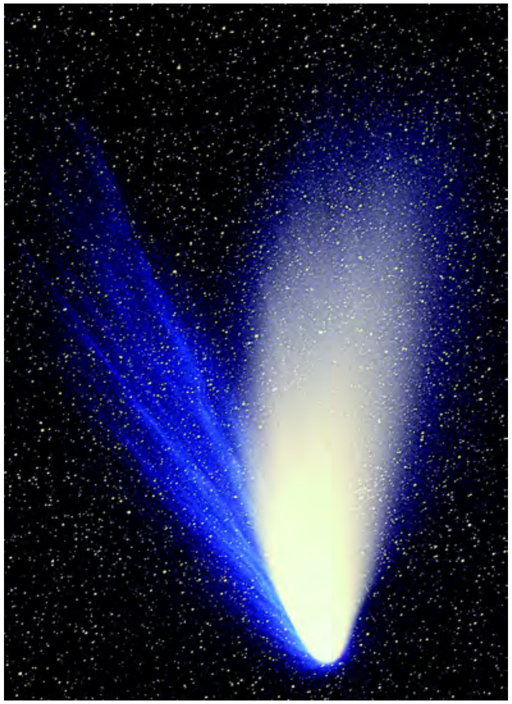
Size of Itokawa compared to a stadium

## Jupiter

- Jupiter orbits the Sun between the Asteroid Belt and Saturn
- It is made of **GAS**
- Its diameter is about **70,000 km**

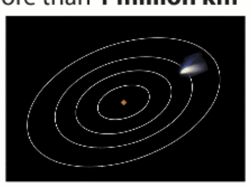


Size of Jupiter's Red Spot compared to Earth



## Hale-Bopp

- Hale-Bopp orbits between Earth's orbit and the distant Solar System — far beyond the orbit of Pluto
- Hale-Bopp is made of ICE and DUST
- The tail shown here extends more than **1 million km**



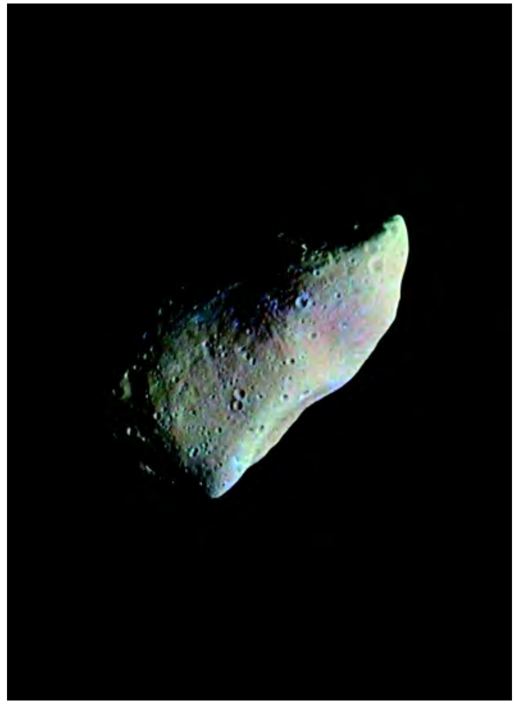
## Hoba

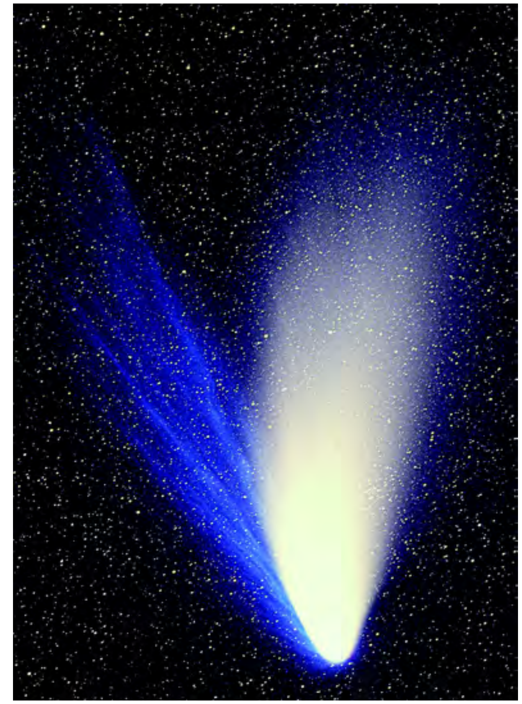
- This object landed on Earth 80,000 years ago in what is now the country of Namibia
- Hoba is made of METAL
- It measures about **3 meters** across

## Iapetus

- Iapetus orbits Saturn
- This walnut-shaped object is made of ICE with some ROCK
- It is **1,500 km** across, or about half as wide as the Earth's Moon

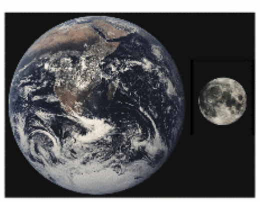
Size of Iapetus compared to Moon





## Earth's Moon

- The Moon orbits Earth
- It is made of **ROCK** with a small **METAL** core
- The Moon is **3,500 km** in diameter or about ¼ the width of Earth



Size of Moon compared to Earth

## Gaspra

- This object orbits the Sun between Mars and Jupiter
- It is made of a mixture of **ROCK** and **METAL**
- It is **18 km** on the longest side

Size of Gaspra compared to Manhanttan

## Hale-Bopp

- Hale-Bopp orbits between Earth's orbit and the distant Solar System — far beyond the orbit of Pluto
- Hale-Bopp is made of **ICE** and **DUST**
- The tail shown here extends more than **1 million km**


# Barringer Crater

- This crater is located in Arizona, USA
- It was created 50,000 years ago by a chunk of **METAL** from space
- It measures about **1.2 km** in diameter

Size of crater compared to a stadium

# Ceres

- Ceres is the largest object between the orbits of Mars and Jupiter
- It is made mostly of **ROCK** and **ICE**
- Ceres is about **950 km** in diameter

Ceres (bottom left) compared to the Earth and Moon

# Earth

- It orbits the Sun between Venus and Mars
- Earth is made of **ROCK**, a **METAL** core and both solid and liquid **ICE** (water, that is) on its surface
- Its diameter is **12,650 km**

Size of Earth compared to Jupiter

# Earth's Moon

- The Moon orbits Earth
- It is made of **ROCK** with a small **METAL** core
- The Moon is **3,500 km** in diameter or about ¼ the width of Earth

Size of Moon compared to Earth

# Eros

- The orbit of Eros ranges between Earth and Jupiter, crossing Mars's orbit
- It is a mixture of **ROCK** and **METAL**
- This object is **34 km** on its longest side

Size of Eros compared with Manhattan

# Gaspra

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Size of Gaspra compared to Manhanttan

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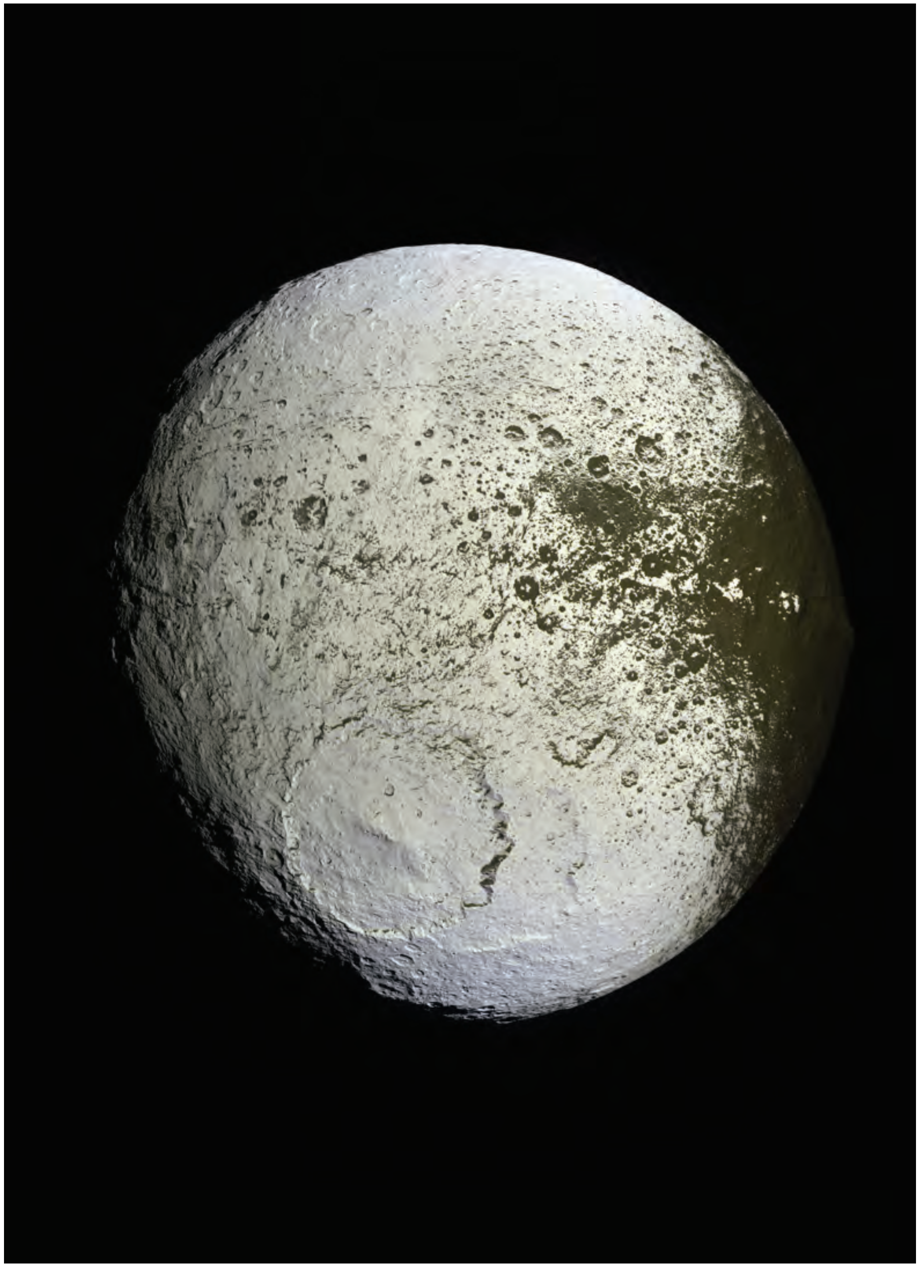
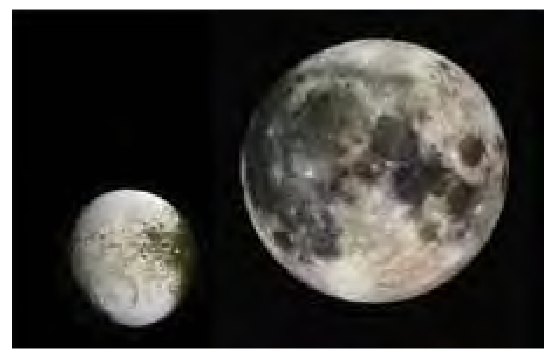
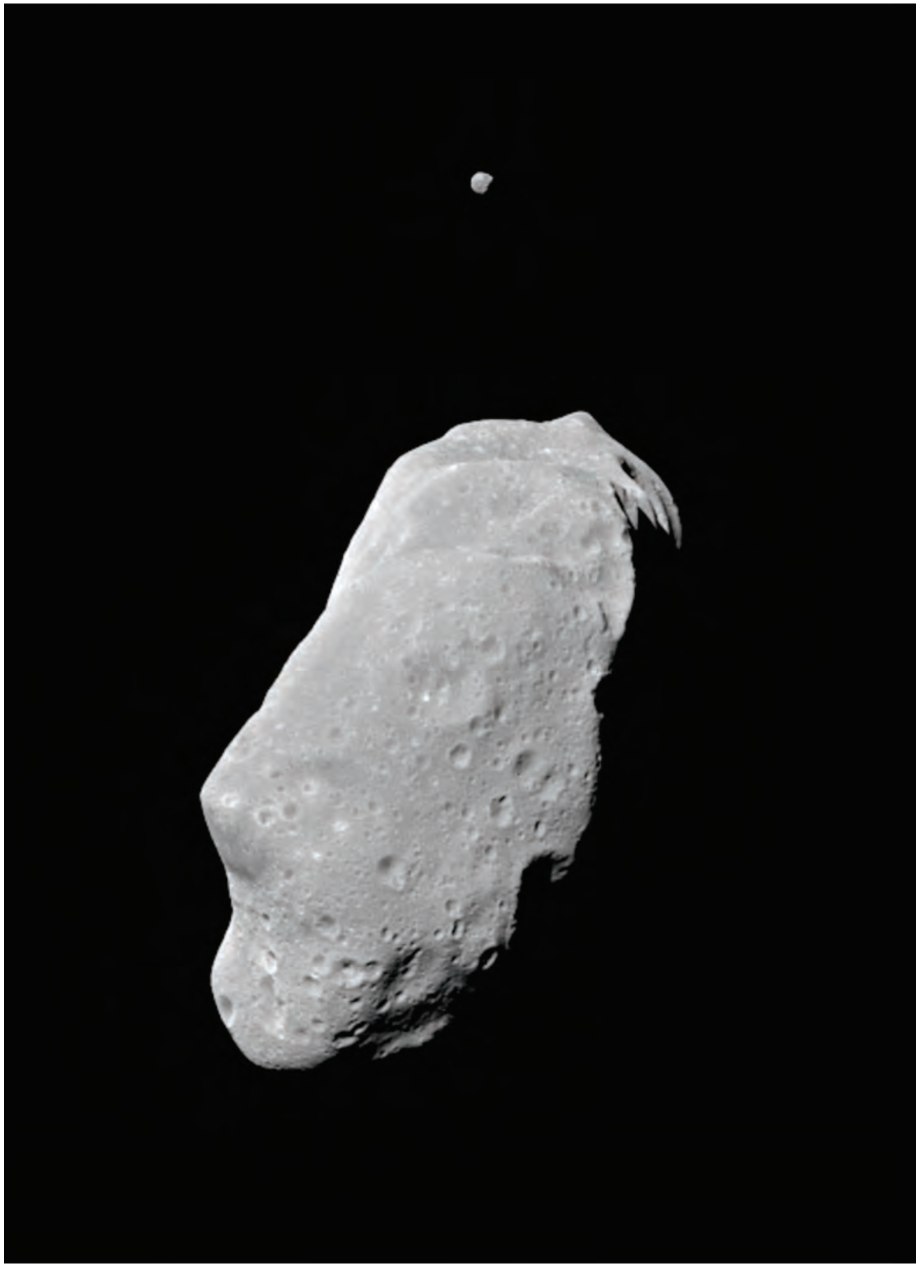


# Iapetus

- Iapetus orbits Saturn
- This walnut-shaped object is made of **ICE** with some **ROCK**
- It is **1,500 km** across, or about half as wide as the Earth's Moon



Size of Iapetus compared to Moon



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Size of Ida compared to Manhattan

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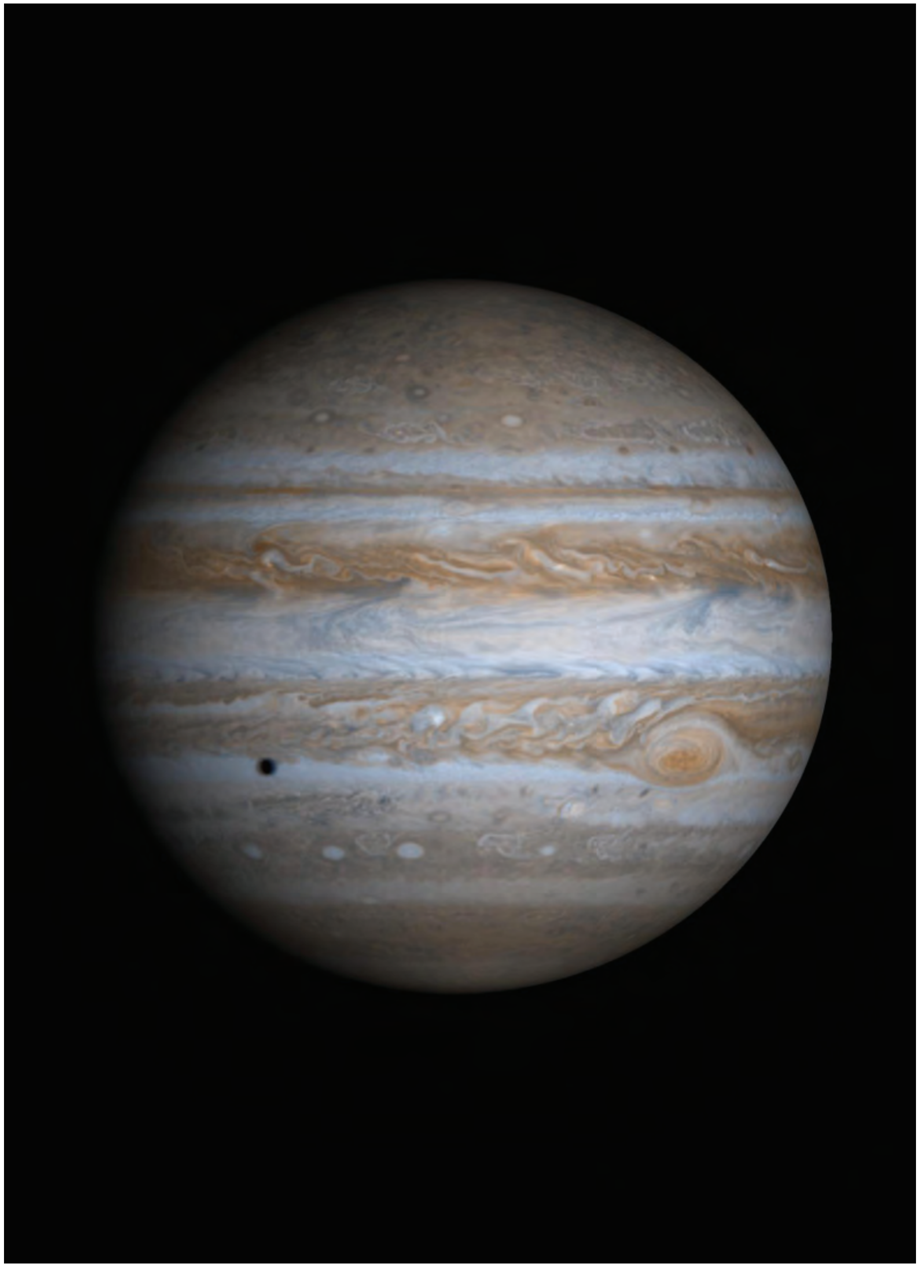
- It is made of a loose pile of boulders made of **ROCK** and **METAL**
- Its longest side is **535 meters**

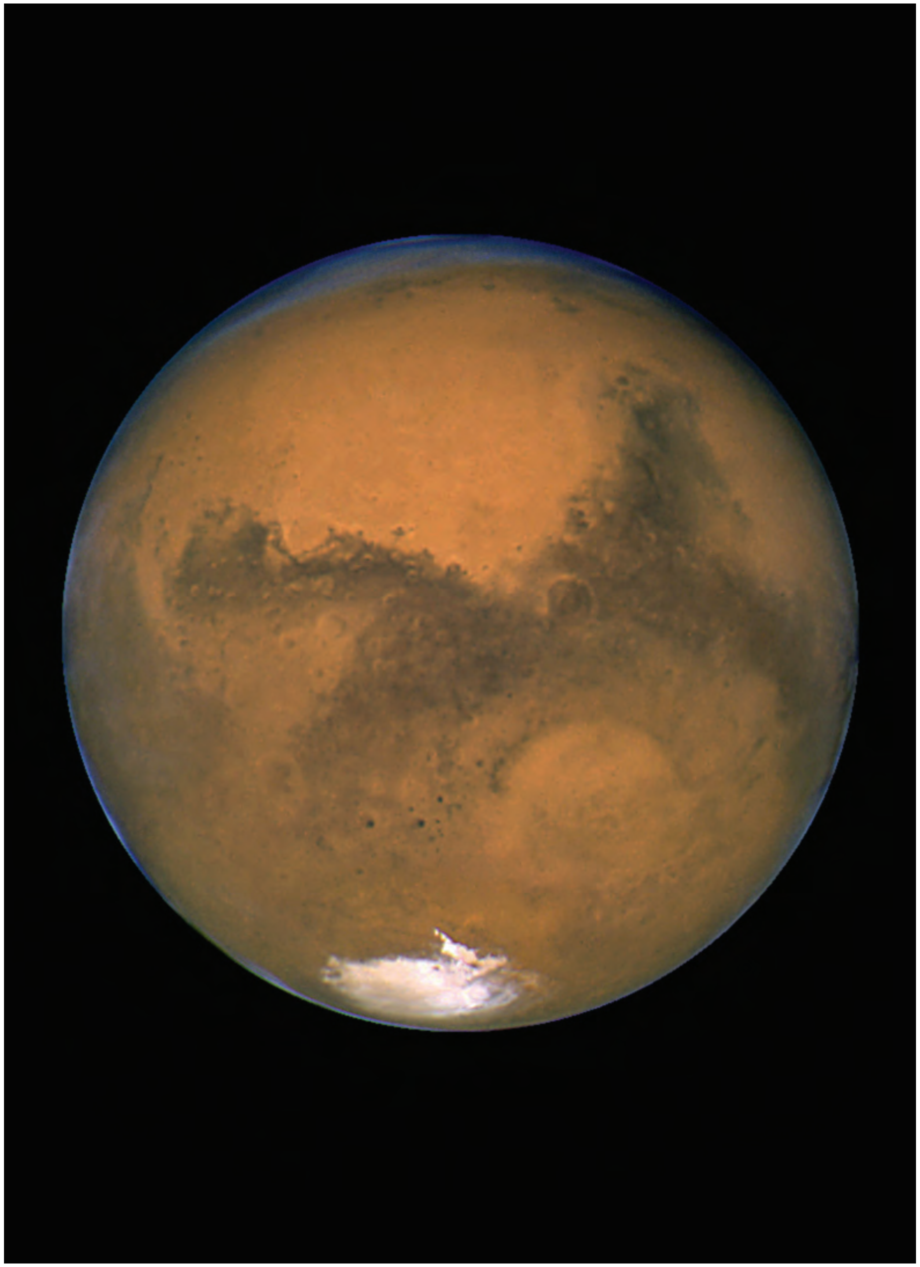
Size of Itokawa compared to a stadium



# Jupiter

- Jupiter orbits the Sun between the Asteroid Belt and Saturn
- It is made of **GAS**
- Its diameter is about **70,000 km**

Size of Jupiter's Red Spot compared to Earth



# Mars

- The orbit of Mars is between Earth and the Asteroid Belt
- Mars is made of **ROCK** with a **METAL** core and some solid **ICE** on its surface
- It is **6,800 km** in diameter, about half as wide as the Earth

Size of Mars compared to Earth

# Meteor

- Meteors occur in Earth's atmosphere, about 75km above the surface
- We see the glowing pieces of **ROCK**
- The pieces of rock are mostly less than **1cm**, or the size of a coin

Size of rock compared to a coin

# Meteorite

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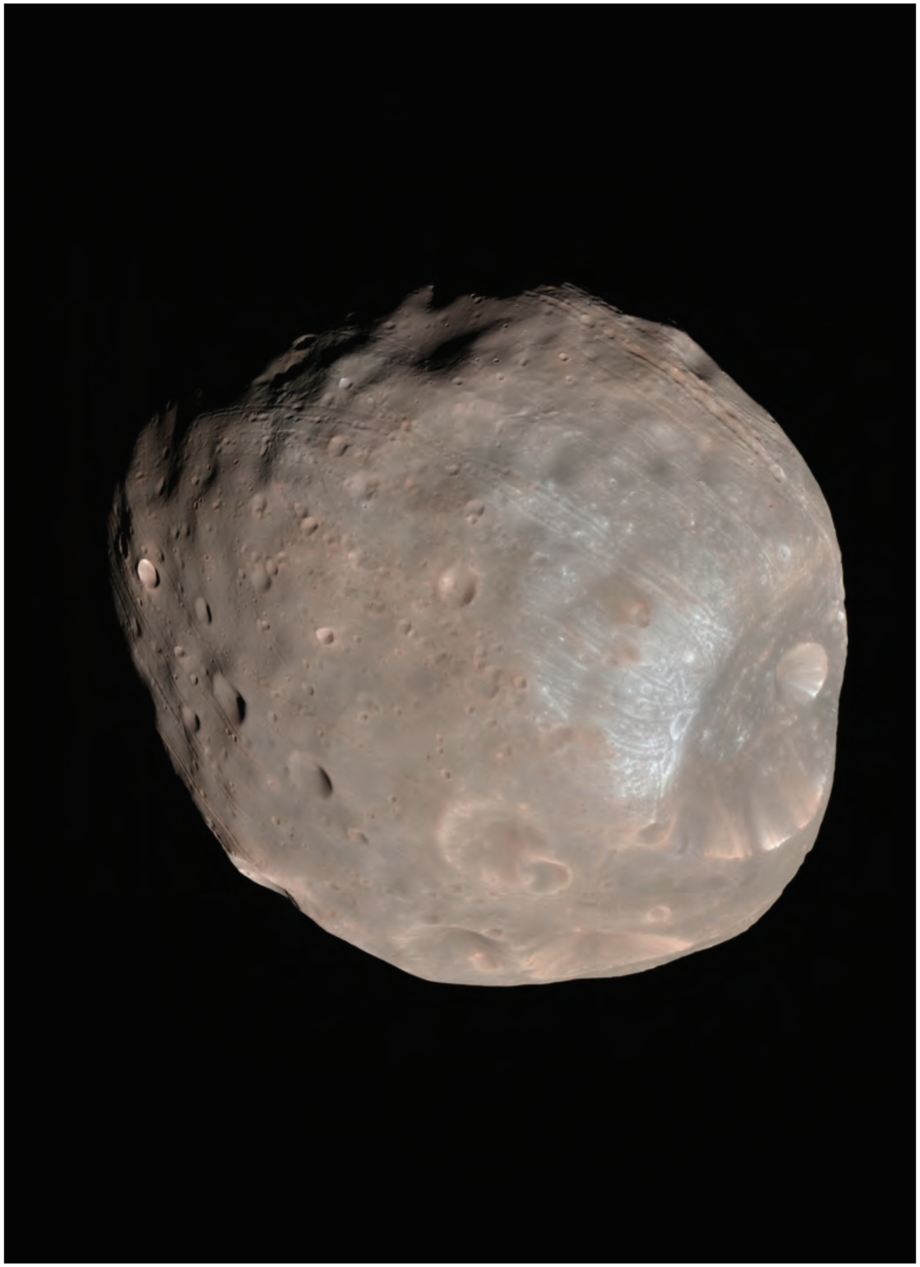
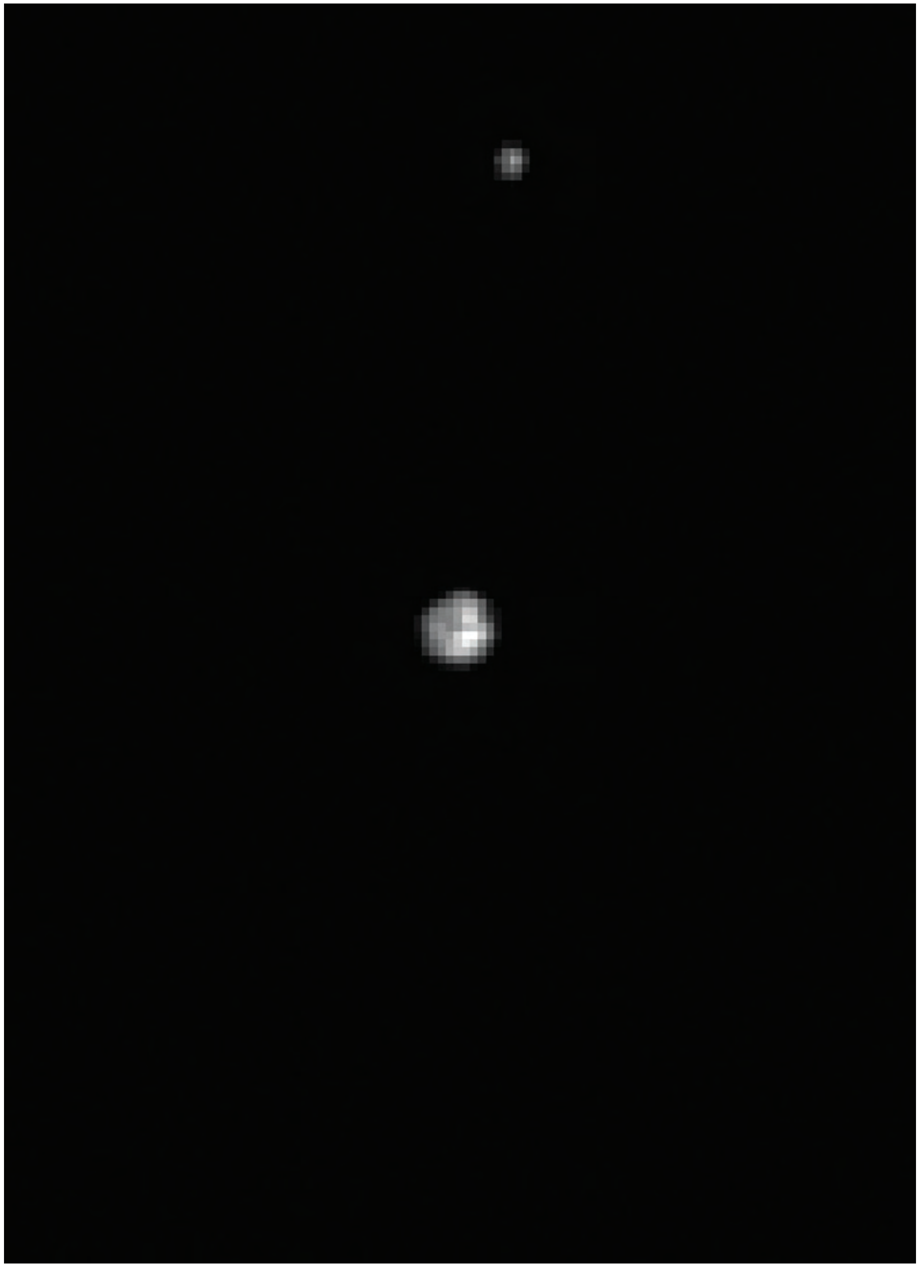


# Phobos

- Phobos closely orbits Mars and will eventually collide with it
- It is mostly made of **ROCK** but may have **ICE** inside
- Phobos is about **11 km** across

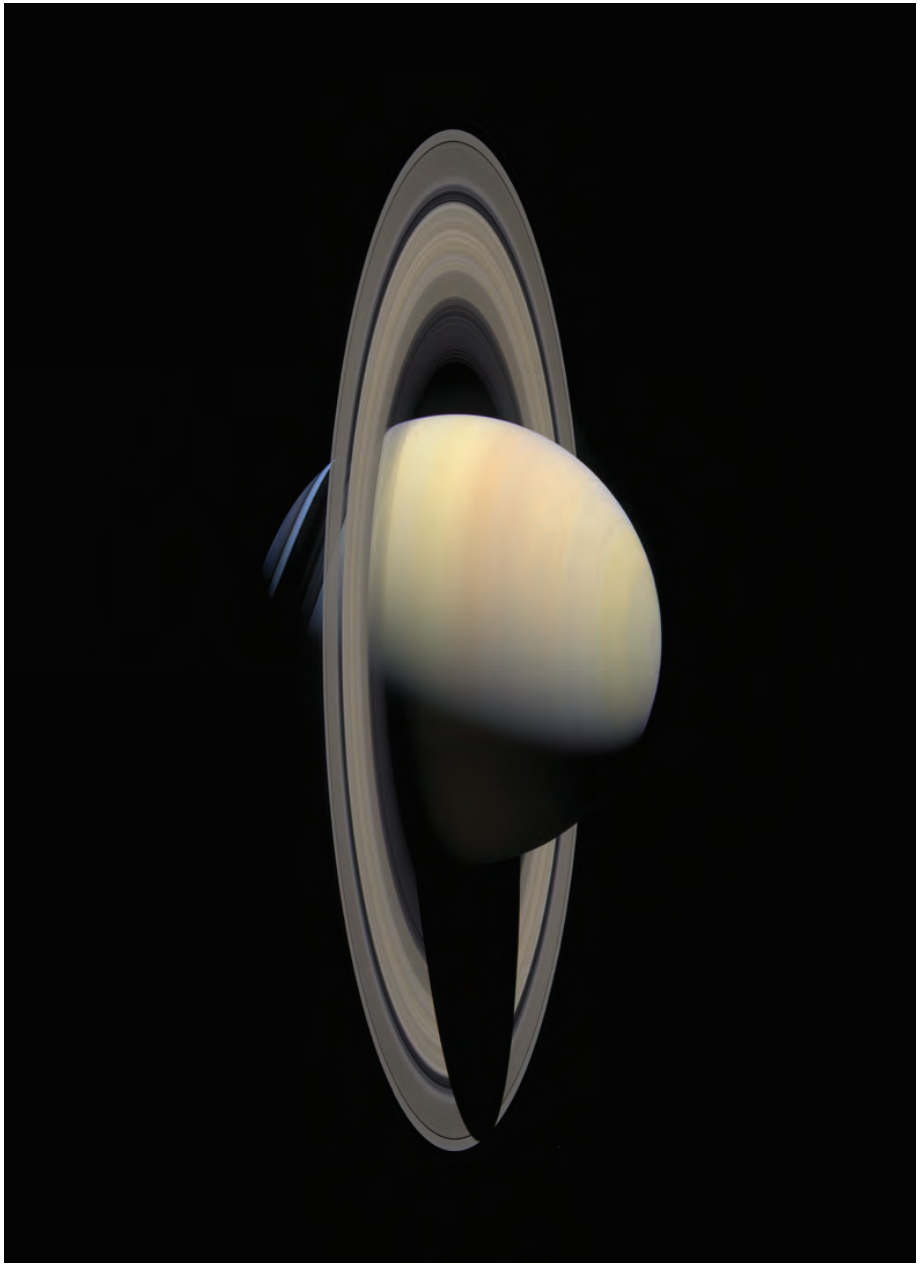
Size of Phobos compared to Manhattan



# Pluto & Charon

- Pluto and Charon orbit orbit each other, together are mostly outside Neptune's orbit
- These round objects are made of **ICE** and **ROCK**
- Pluto is about **2,300 km** across

Size of Pluto & Charon compared to Earth and Moon



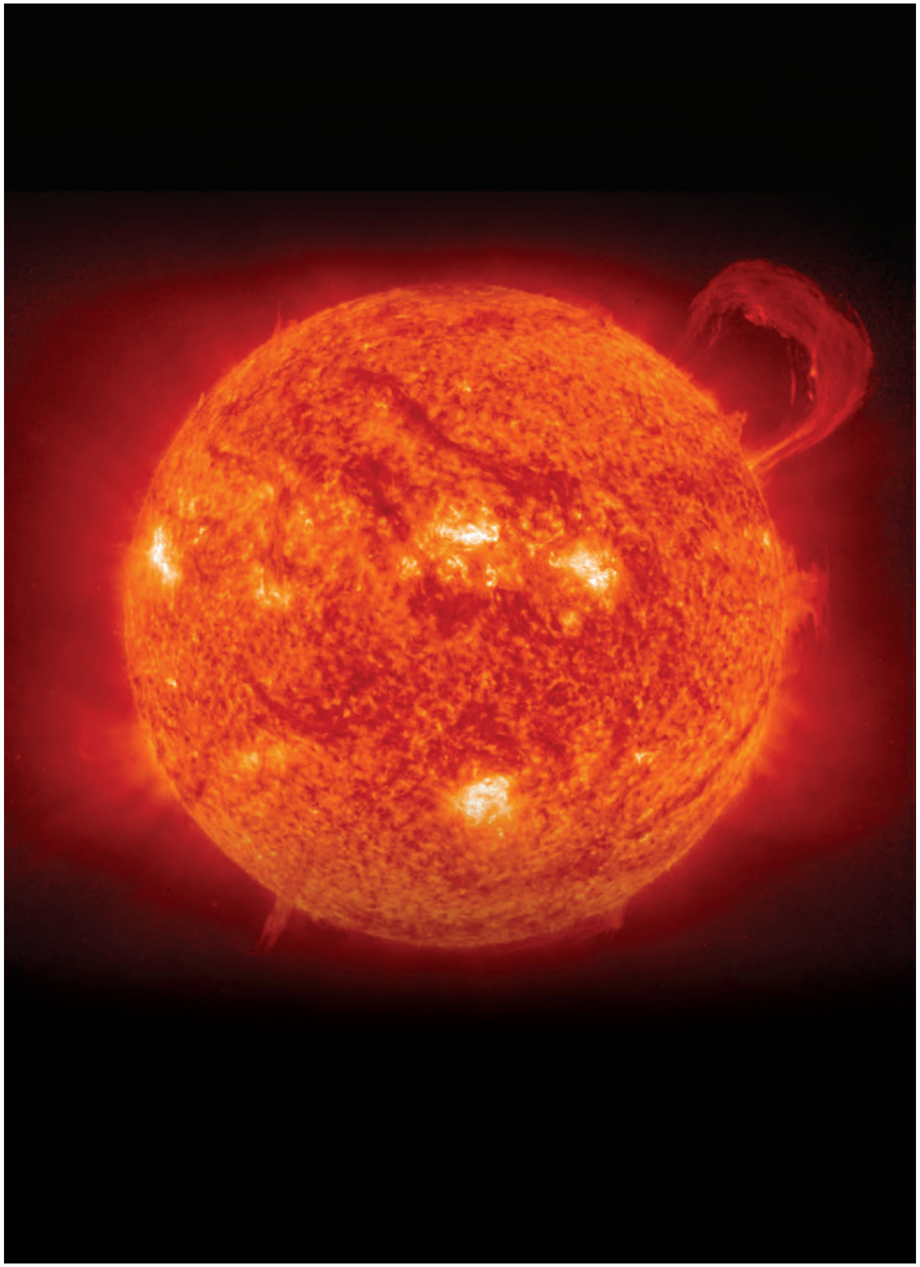
# Saturn

- Saturn orbits the Sun between Jupiter and Uranus
- Saturn is mostly made of **GAS**
- The main body is **120,000 km** across

Size of Saturn compared to Earth

## Shoemaker-Levy 9

- Its orbit originally took it beyond Pluto. After it was captured by Jupiter's gravity, it was torn apart and eventually smashed into Jupiter.
- Made of **ICE** and **ROCK**
- Largest pieces were **1km** and left huge marks on Jupiter



# Sun

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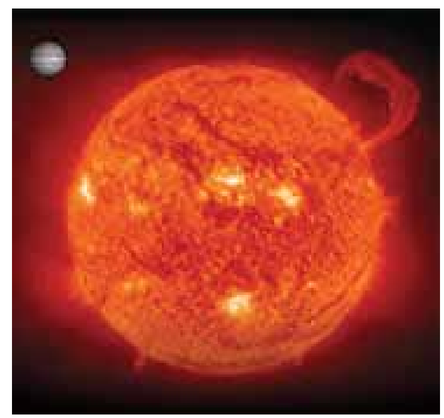
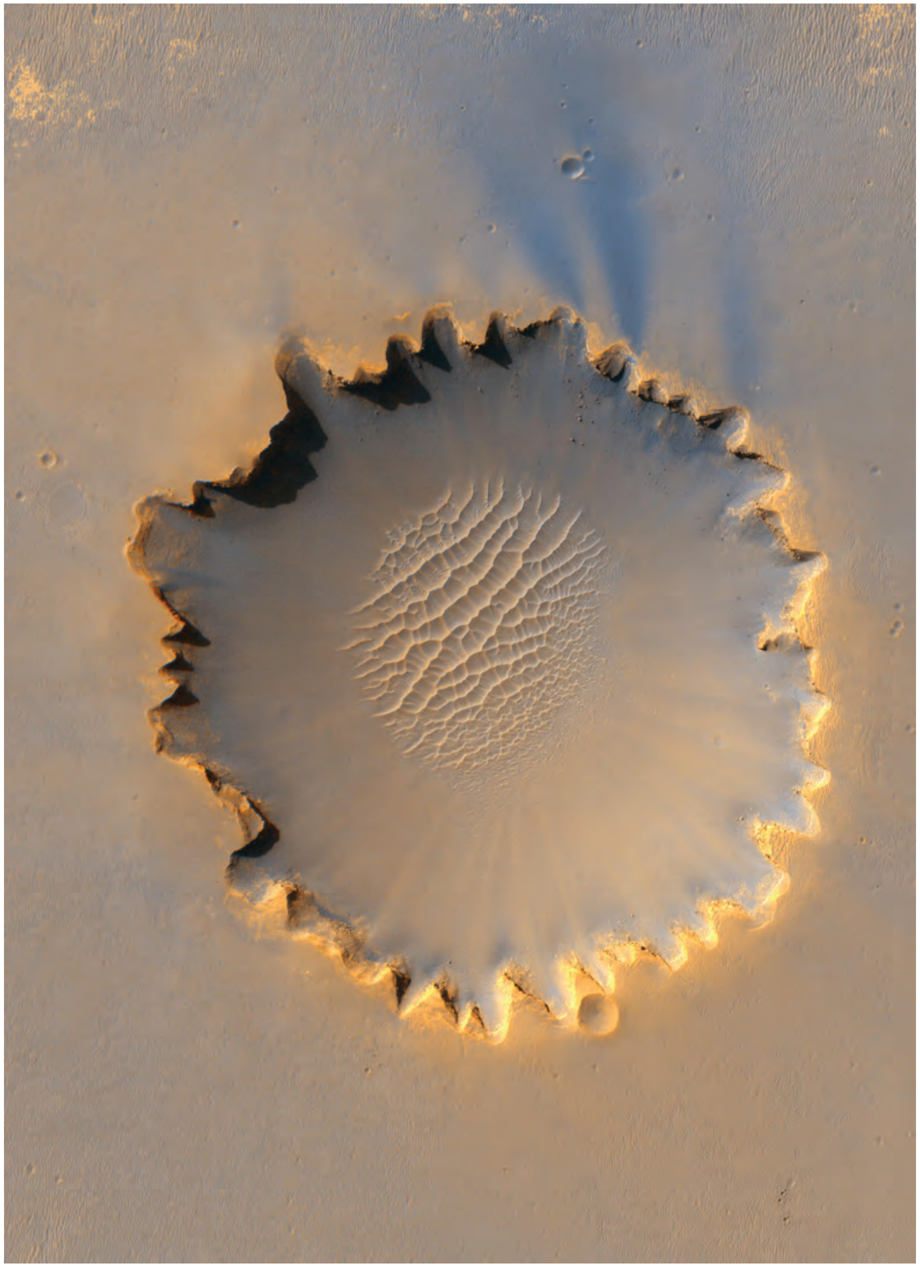
- The Sun is **1.4 million km** in diameter



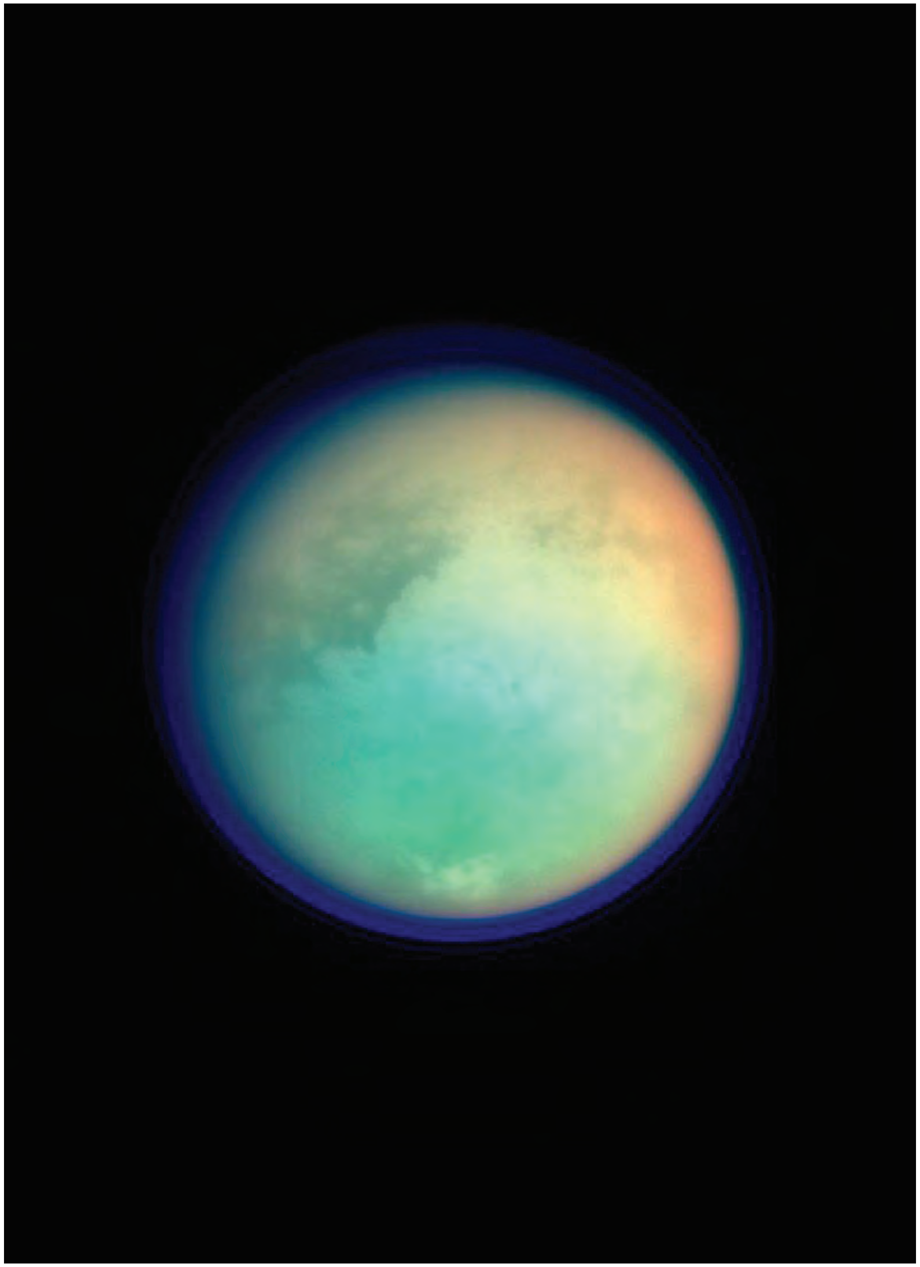
Size of Sun compared to Jupiter



# Victoria Crater

- This crater is one of the smaller craters on Mars
- The rim's jagged edges are due to erosion caused by **ROCK** and **DUST**
- It is **750 meters** across

Size of crater compared to a stadium



# Titan

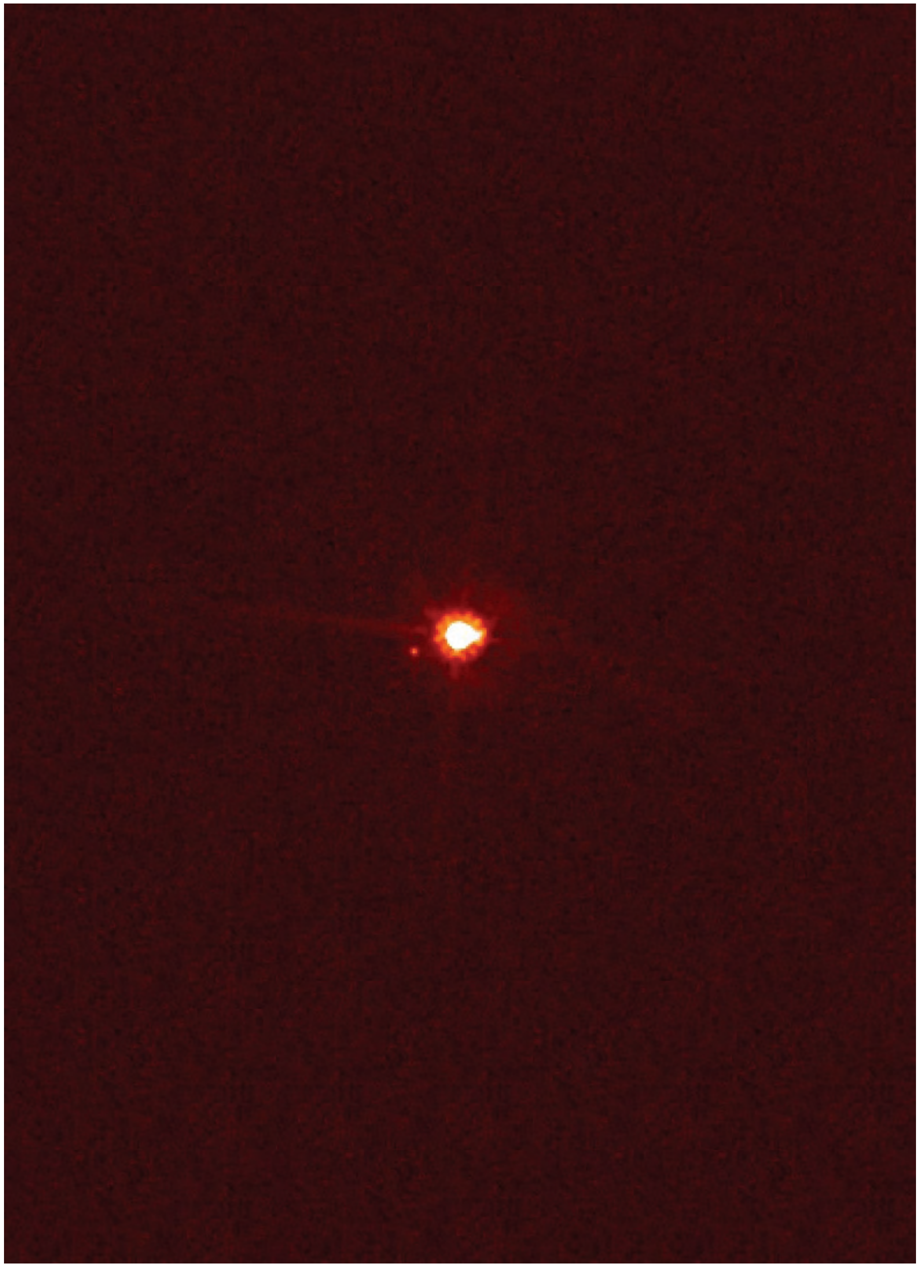
- Titan orbits Saturn
- It is made of **ROCK** and **ICE** and has a thick atmosphere
- It is **5,150 km** in diameter, between the size of the Earth and Moon

Size of Titan (center) compared to the Earth and Moon

# Wild 2

- Wild 2 orbits the Sun between Mars and Jupiter, though its orbit used to be much more distant
- It is made of **ICE** and **DUST**
- It is about **4 km** across

Size of Wild 2 compared to Manhattan



# Eris

- The orbit of Eris is very distant, mostly beyond Pluto’s orbit.
- It is made of **ICE** and **ROCK**
- The diameter of Eris is about **2,600 km**


Size of Eris compared to Pluto

# Heads Up! It's a Meteor Shower

Smaller than grains of sand, meteors vaporize in a bright streak of light as they hit Earth's atmosphere. Meteor showers come from comets, but the sporadic meteors on other nights are mostly asteroid bits.

## Observing a Meteor Shower

- ✓ You don't need a telescope, just your eyes.
- ✓ Find a dark spot away from streetlights
- ✓ Get warm — layers are good
- ✓ Lie down on a blanket or reclining chair
- ✓ Look up! Watch the whole sky.

### Tips:

- ✓ A bright Moon can wash out meteors, making them hard to see.
- ✓ Give your eyes time to adjust to the dark and you will see more faint meteors.

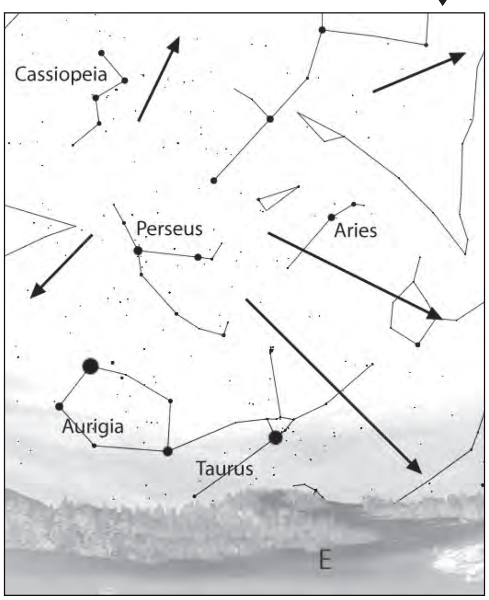
Meteors can be seen all over the sky. If you trace them back, they appear to be radiating from one constellation. That's how they get their names!

**If you get up early on August 12th and look to the east, you might see something like this**

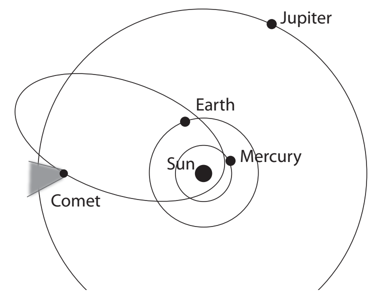
What constellation can you trace the meteors to?

Check the calendar below to see which meteor shower happens in August.

The Perseids appear to radiate from the constellation Perseus




## Meteor Showers Come From Comets

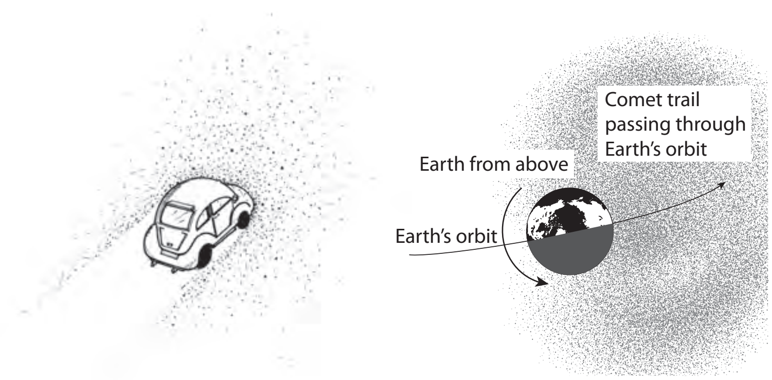



Comets come from the outer Solar System and leave behind a stream of dust as they are warmed by the Sun. Only a few comets pass through Earth's orbit.

The dust left behind by Halley's comet causes the Eta Aquarid and Orionid meteor showers (see calendar below).

Halley's comet passes Earth every 75 years. We will see it again in 2061.

How old will you be the next time it comes around?




**Here's how:** As Earth runs into these particles, it's like bugs hitting Earth's windshield (or atmosphere). But the comet bits hit Earth's atmosphere so fast, the pieces vaporize in bright streaks — making a meteor shower! We see meteor showers better after midnight because that's when we are facing the direction of Earth's orbit.

## Calendar of Major Meteor Showers

Meteor showers are best viewed **after midnight** around the dates listed below.

| | |
|---|---|
| January 2nd–3rd | Quadrantids |
| April 22nd–23rd | Lyrids |
| May 5th–6th | Eta Aquarids |
| July 29th–30th | Delta Aquarids |
| **August 11–12th** | **Perseids*** |
| October 21–22nd | Orionids |
| November 4–5th | Taurids |
| **November 16–17th** | **Leonids*** |
| **December 12–13th** | **Geminids*** |
| December 22–23rd | Ursids |

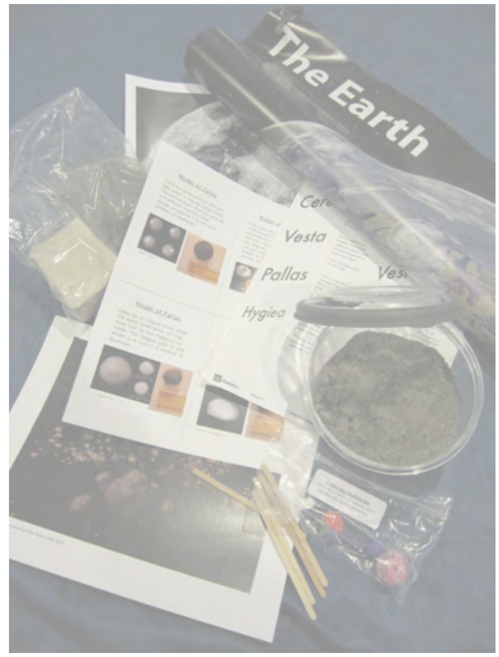
*** Don't miss these!**

Check **stardate.org/nightsky/meteors** for this year's viewing suggestions, including Moon phases

Find the most exciting astronomy clubs and events: **NightSkyNetwork.org**

Night Sky Network

# Scaling the Asteroid Belt




## *What's this model about?*

Explore the Asteroid Belt and learn some surprising truths about just how difficult it would be to navigate.

**Big Questions:**

- Is it hard to navigate a ship through all of the debris in the Asteroid Belt?
- How dense is the Asteroid Belt?
- How did the Asteroid Belt form?

**Big Activities:**

Compare a scale model of the Earth and Moon with a model of the Asteroid Belt. See how empty the Asteroid Belt actually is.

**Participants:**

**From the club**: One presenter

**Visitors:** Appropriate for families, the general public, and school groups ages 10 and up. 5 to 15 visitors at a time may comfortably participate.

**Duration:**

The whole demonstration takes about 15-20 minutes. Pieces can be used in shorter explanations.

**Topics Covered:**

- Amount of material in the Asteroid Belt
- Average distances between asteroids in the Asteroid Belt
- Names of the first asteroids discovered
- Size and distance scale of the Earth and Moon
- Size of impactor that caused the Chicxulub crater and the downfall of the dinosaurs

### *Where could I use this activity?*

| ACTIVITY | Star Party | Pre-Star Party – Outdoors | Pre-Star Party – Indoors | Girl Scouts / Youth Group Meeting | Classroom | | | Club Mtg | Gen Public Presentation (Seated) | Gen Public Presentation (Interactive) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | K-4 | 5-8 | 9-12 | | | |
| **Scaling the Asteroid Belt** | | √ | √ | √ | | √ | √ | √ | √ | √ |

### *What do I need to do before I use this activity?*

| What materials from the ToolKit are needed for this activity? | What do I need to supply to run this activity that is not included in the kit? | Preparation and Set Up |
|---|---|---|
| • 1-meter Earth Banner<br>• Scaled 29 cm Moon image<br>• Clay, a ruler, and cratering implements to make models, including the four largest asteroids:<br>  ○ Ceres, 7.3cm, black<br>  ○ Pallas, 4.1cm, black<br>  ○ Vesta, 4.1 cm, light gray<br>  ○ Hygiea, 3.4cm, black<br>• Artists' impressions of a busy Asteroid Belt | (Optional) Space for a visitor to pace off 30 meters. | • Make models of the 4 largest asteroids (or more) asteroids at least 3 days prior to activity. See "Making Model Asteroids" at the end of this activity.<br>• Hang the Earth Banner<br>• Leave the Moon image face down until you need it.<br>• Keep the asteroids out of view at first. You will use these during the presentation. |

## *Background Information*

**Missions traversing the Asteroid Belt:** When Pioneer 10 became the first spacecraft to cross the Asteroid belt in 1972, there was some concern that it would encounter an asteroid that could do damage. It did not and neither did the next 9 missions that passed through the Asteroid Belt. In fact, it is calculated that a spacecraft has less that a 1 in a billion chance of accidentally running into an asteroid. For your audience, **that means we could send a billion spaceships through the Asteroid Belt and likely never hit an asteroid!**

**Dawn Mission Timeline**

| | |
|---|---|
| Launch | September 27, 2007 |
| Mars gravity assist | February 2009 |
| Vesta arrival | July 2011 |
| Vesta departure | July 2012 |
| Ceres arrival | February 2015 |
| End of primary mission | July 2015 |

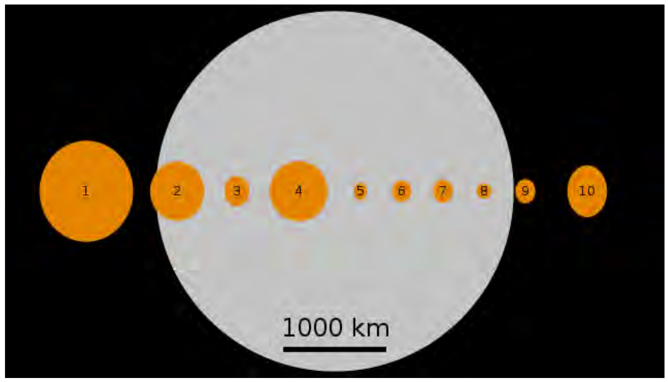
**Additional Asteroid Belt materials:**
On the Dawn website, you can find image galleries, activities, and much background information:
http://dawn.jpl.nasa.gov/mission/

Dawn Mission Solar System Ambassadors Speaker Kit
(non-public site for Solar System Ambassadors):
http://dawn.jpl.nasa.gov/DawnCommunity/speak_kit/index.asp

Interactive featuring the Visual Infrared and Imaging Spectrometer instrument aboard the Dawn spacecraft: http://dawn.jpl.nasa.gov/technology/VIR_inter.asp

A podcast giving a thorough discussion about the Asteroid Belt:
http://www.astronomycast.com/astronomy/episode-55-the-asteroid-belt/

**The First 10 Asteroids to be Discovered:**
All of these models will not be used in the activity as written. It is only necessary to make models of the 4 largest asteroids. With larger groups, you may want to have more on hand to pass around. Note that these are some of the very largest (hence some of the first to be discovered) asteroids in the Asteroid Belt. It is not a representative size distribution. Most would be the size of a grain of sand or smaller on the 1-meter Earth scale.




*Size of the first 10 asteroids discovered compared to Earth's Moon*

Learn about the history of asteroid discovery:
http://dawn.jpl.nasa.gov/DawnCommunity/flashbacks/fb_06.asp

**Far Side of the Moon Information:**
You'll notice that the far side of the Moon looks very different from the near side that we are used to seeing. There are few maria and lots of craters. The reasons for this are not well understood, but we do know a few things.

Here's the quick answer and you can find more details in the resources that follow. The Moon's crust is thinner and the core closer to the surface on the near side. Impacts during the Late Heavy Bombardment Phase (4 billion years ago) cratered the entire Moon, but the near side saw more lava flows due to the thinner crust and a core that was molten at the time. Lava flowed in to fill some of the basins with a dark basalt rock. Those are the maria we see today.

There's some basic information about the Moon's evolution here:
http://www.lpi.usra.edu/education/moonPosters/Poster1/backb.pdf

And a PowerPoint here:
http://www.lpi.usra.edu/education/powerpoints/moon_formation_processes.ppt

Science Friday Podcast about the far side of the Moon:
http://www.sciencefriday.com/program/archives/200902131

## *Detailed Activity Description*

### Scaling the Asteroid Belt

| Leader’s Role | Participants’ Role (Anticipated) |
|---|---|
| <u>*To do:*</u><br>Point to the Earth Banner | |
| <u>*To say:*</u><br>Hey, take a look at this. What does this picture show? | Earth |
| Great! Let's make a model. If I could shrink the Earth down to this size, 1-meter, how big do you think the Moon would be? Show me with your hands.<br>Those are good guesses. You're the closest. Here, I happen to have a model of the Moon here with me too. | Guess sizes |
| <u>*To do:*</u><br>Bring out the model of the Moon. Put it in front of the Earth to show size comparison. | |
| <u>*To say:*</u><br>See, you could fit almost 4 Moons across the Earth if you lined them up like this. Of course, they're not flat, they're spheres, but this is just a size comparison model.<br><br>Now, here's the big question. At this scale, how far away would they be from each other? Show me what your guess is. |  |
| <u>*To do:*</u><br>Hand the Moon to an audience member; encourage other visitors to offer suggestions. | Usually guess close |

| **Leader's Role** | **Participants' Role (Anticipated)** |
|---|---|
| *<u>To say:</u>*<br>Good guess, but it's actually a lot farther. You could line up 30 Earths in between the Earth and the Moon. | |
| *<u>If you have the room:</u>*<br>*(To the visitor holding the Moon)* Could you start here at the Earth and take 30 steps *("big steps" if Moon holder is a young child)* that way and hold up the Moon when you get there? Great. Come back when I wave at you. | Walks 30 meters away |
| *(When Moon reaches 30 meters)*<br>Wow, the neighborhood around Earth is fairly empty, huh? We're sitting here in California, planet Earth, with just the Moon going round and round, month after month. I guess there's a reason they call it "space". | |
| What would you guess is the busiest place in our Solar System? | Sun? Saturn's rings? |
| Have you ever seen pictures of the Asteroid Belt? What does it look like? | Yes!<br>Lots of rocks! |
| *<u>To do:</u>*<br>Hold up artists' impressions of the Asteroid Belt. | |
| *<u>To say:</u>*<br>Yeah, the artists' impressions I've seen look really crowded there. Take a look at these. You know, NASA's Dawn Mission is traveling to the Asteroid Belt to visit two of the biggest asteroids, Ceres and Vesta. Do you think it might have to dodge a lot of asteroids on the way to visit these two? | Yes! |
| *<u>To do:</u>*<br>Bring out the four largest asteroids and any others you have made- Ceres, Pallas, Vesta, and Hygiea. | |
| *<u>To say:</u>*<br>Let's find out. | |

| **Leader's Role** | **Participants' Role (Anticipated)** |
|---|---|
| *<u>To say:</u>*<br>I happen to have models here of the four largest asteroids in the Asteroid Belt, on the same scale as the Earth and Moon here. The biggest is Ceres. Is it bigger or smaller than our Moon?<br><br>Yes, it's about the size of Texas if you hold it up to the Earth.<br><br>*<u>To do:</u>*<br>Hand out 4 asteroids *(or more if you have a larger crowd).*<br><br>*<u>To say:</u>*<br>Of course these are nowhere near the Earth and Moon. Does anyone know where the Asteroid Belt is?<br><br>Right, after Earth's orbit, there's Mars, then the Asteroid Belt and then Jupiter.<br><br>*<u>To do:</u>*<br>If you have the "Exploring the Solar System" banner, show the Asteroid Belt area.<br><br>*<u>To say:</u>*<br>Imagine we could scoop up all those asteroids, including the ones you're holding. On the scale you're got there, how big of a ball do you think they would make?<br>Show me with your hands.<br><br>It turns out, there's not that much material in the Asteroid Belt. Those four biggest asteroids make up half of all the mass in the Asteroid Belt!<br><br>At this scale, we could fit all of the asteroids in the Solar System -- including the biggest ones that you're holding -- in my hands. That's a lot smaller than the planet Earth, even than our Moon.<br><br>*<u>To do:</u>*<br>Compare your open hands to the size of the Moon. | Smaller<br><br>Between Mars and Jupiter<br><br>Make predictions, usually large |

| Leader's Role | Participants' Role (Anticipated) |
|---|---|
| *To say:*<br>I'm sorry to say; those pictures and the asteroid belts you see in the movies aren't even close to what it's really like.<br>In fact, the average distance between asteroids is over three times the distance from the Earth to the Moon! At this scale, that's a whole football field between asteroids. If you were at one asteroid, chances are you wouldn't even see another asteroid in any direction!<br><br>What do you think about these drawings then?<br><br>Yes, contrary to what those artists' impressions show, the Asteroid Belt is actually very sparse. None of the space missions that have gone through the Asteroid Belt have ever accidentally hit anything.<br>(See "Background Information" for further details.)<br><br>**So why is it so sparse?** Well, there used to be a lot more material in that region when the Solar System first formed. But instead of slowly coming together like the other rocky planets, this region of space had a huge neighbor that couldn't keep its gravity to itself. Does anyone remember what big planet is close to the Asteroid Belt?<br><br>Right, Jupiter's gravity tugged on the small bits, sending them colliding with each other instead of slowly coming together. These fast collisions sprayed so many pieces of asteroids out of the belt that eventually it became fairly empty.<br><br>This all happened billions of years ago, not long after the Solar System formed. But we can still see evidence of all of the asteroids being scattered out of the Asteroid Belt. Take a look at these craters on the Moon. Almost all of these were created during that period! | They're wrong?<br><br>Jupiter |

**Presentation Tips:**
On this scale, it would only take an asteroid about the size one of a grain of sand to make a crater the size of the Chicxulub crater. It was caused by a 15 km asteroid -- less than 1mm on this scale and spelled disaster for the dinosaurs that were roaming the planet then.

Included in the ToolKit are fact sheets on NASA's Dawn Mission to the Asteroid Belt. These will give you more information and allow you to answer visitors' questions. Also, see their website for background, current mission status, and activities you can do in a classroom:
http://dawn.jpl.nasa.gov/mission/

If you have the Solar System banner, be sure to check on dawn's progress. You can place the Mission sticker in its correct location:
http://dawn.jpl.nasa.gov/mission/live_shots.asp

## *Materials*

## Where do I get additional materials?

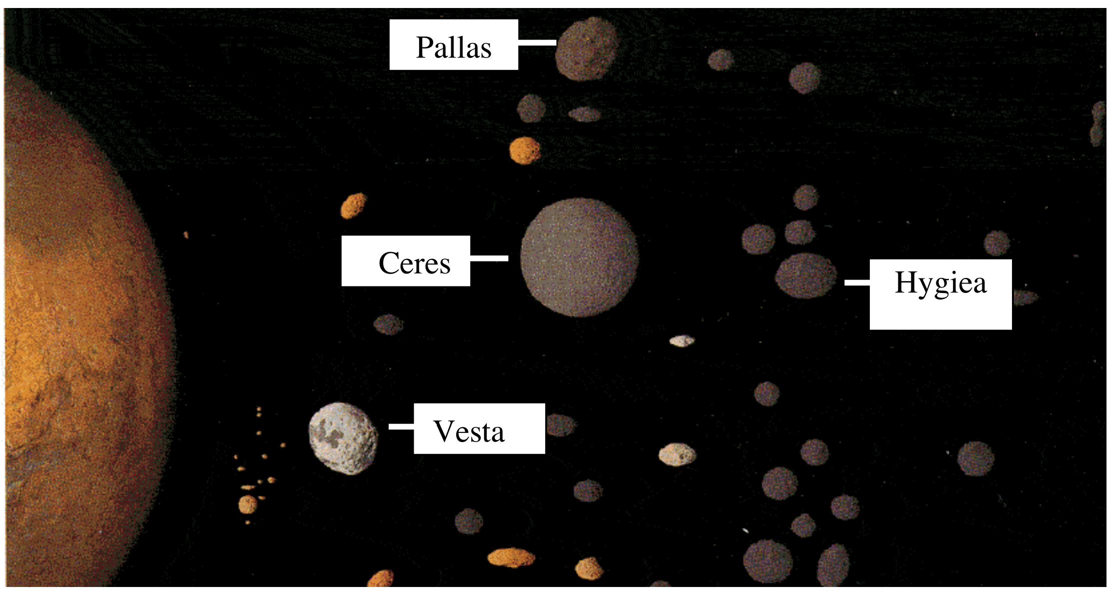
1. Find air-dry clay in art stores or toy-stores. Das Modeling Clay does well without cracking. Dried models can be painted with non-toxic paints or markers
2. Ruler: hardware store or many grocery stores
3. Artists' impressions of the Asteroid Belt can be found online by searching images of "Asteroid Belt"
4. Earth Banner: Print your own from the files found here:
    - http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=460

## Making Model Asteroids

***Important note:***
**Until Dawn arrives, none of the four biggest asteroids have ever been seen up-close. For now we have to make models using what we do know.**

Make a clay model of each asteroid using the dark and light clay supplied in the ToolKit. The light clay will be used to make Vesta only. **Images on the following page** give you tips to make each asteroid the correct size and approximate shape.
Use tools such as erasers, pens, and other small, round implements to make the craters that likely cover all of the asteroids.

Allow it to dry for 2-5 days or until hard. **It may require a few coats of paint or black marker to get a true black color.**




This image shows the scale size and variations in color of the largest asteroids, with Mars on the left for comparison. © Andrew Chaiken

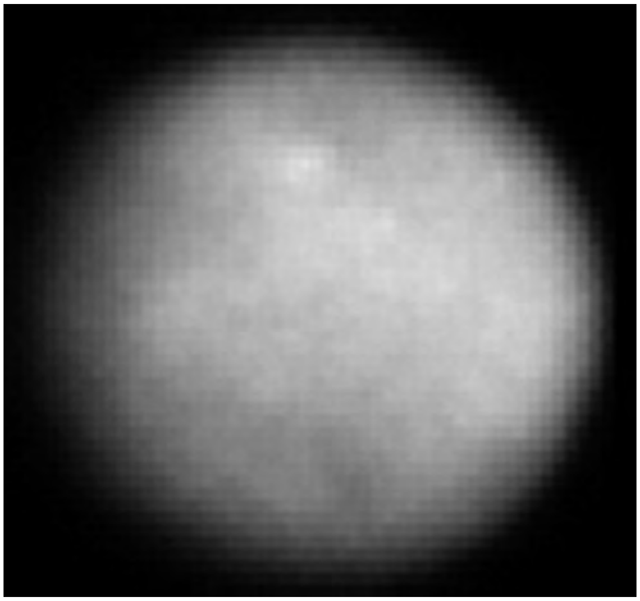
Use the images on the bottom left corner of the Earth Banner as a guide, but remember to use the ruler to measure the longest sides.

# Making Models of Asteroids 1–10

## To scale with a 1-meter Earth

### 1 Ceres (Dwarf Planet)

- 7.3 cm (3 in)
- Spherical with a bright spot, possibly a crater?
- Black



Model from Hubble data/NASA

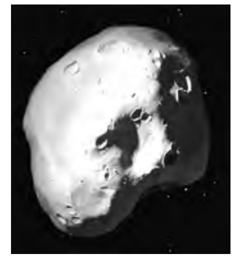
### 2 Pallas

- 4.1 cm (1½ in) on the longest side
- Egg-shaped
- Dark Gray

Model from photometric data: Torppa, 2003

### 3 Juno

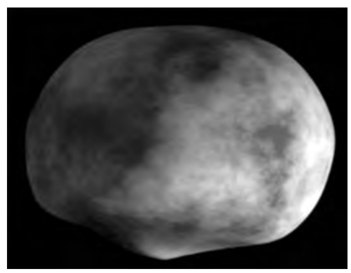
- 2.5 cm (1 in)
- Large crater in one side, as seen with Hubble
- Dark Gray



Artist's conception of the large craters on Juno (David A. Aguilar, Harvard-Smithsonian Center for Astrophysics)

### 4 Vesta

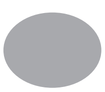
- 4.1 cm (1½ in) on the long side
- Large crater with central bump seen on one side
- Light gray



Model from Hubble data/NASA

### 5 Astraea

- 1.3 cm (½ in)
- No images available
- Dark Gray



### 6 Hebe

- 1.6 cm (2/3 in)
- Dark Gray

Model from photometric data: Torppa, 2003

### 7 Iris

- 1.6 cm (2/3 in)
- Dark Gray

Model from photometric data: Kaasalainen, 2002

### 8 Flora

- 1.1 cm (½ in)
- Dark Gray

Model from photometric data: Torppa, 2003

### 9 Metis

- 1.8 cm (¾ in)
- Dark Gray

Model from photometric data: Torppa, 2003

### 10 Hygiea

- 3.4 cm (1⅓ in)
- Black

Model from photometric data: Kaasalainen, 2002

### A Note About Asteroids

These models give the general shape of the first 10 asteroids ever discovered, to scale with a 1 meter Earth. These include the 4 largest asteroids in the Asteroid Belt. Most asteroids are much smaller.

We haven't visited these asteroids yet, so we don't know about their surfaces in detail. But all of the asteroids are likely covered in craters, like on this one that we have visited.

**Be sure to add craters of different sizes to your asteroid models.**

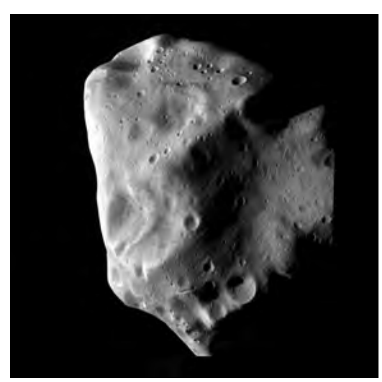
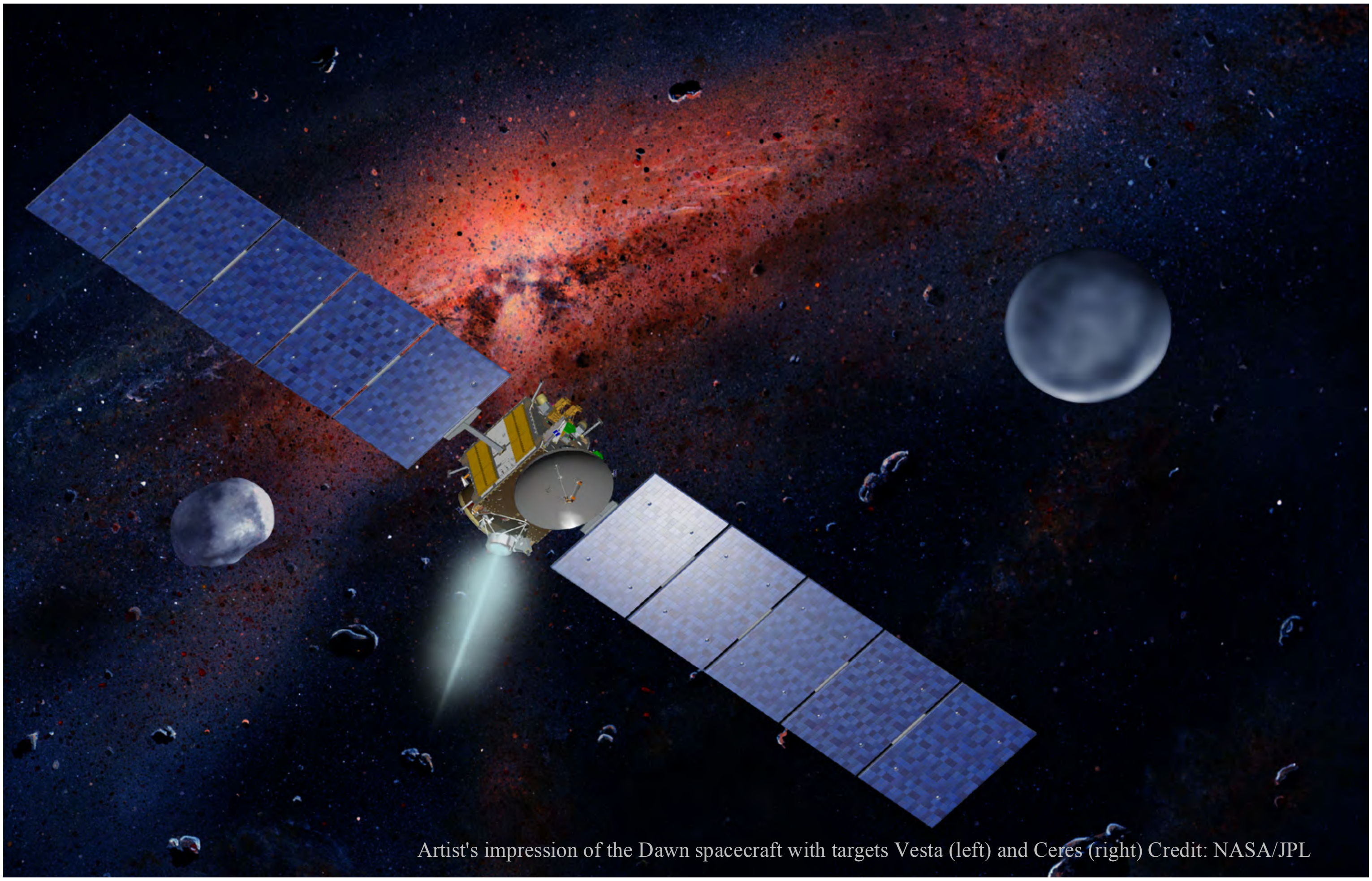
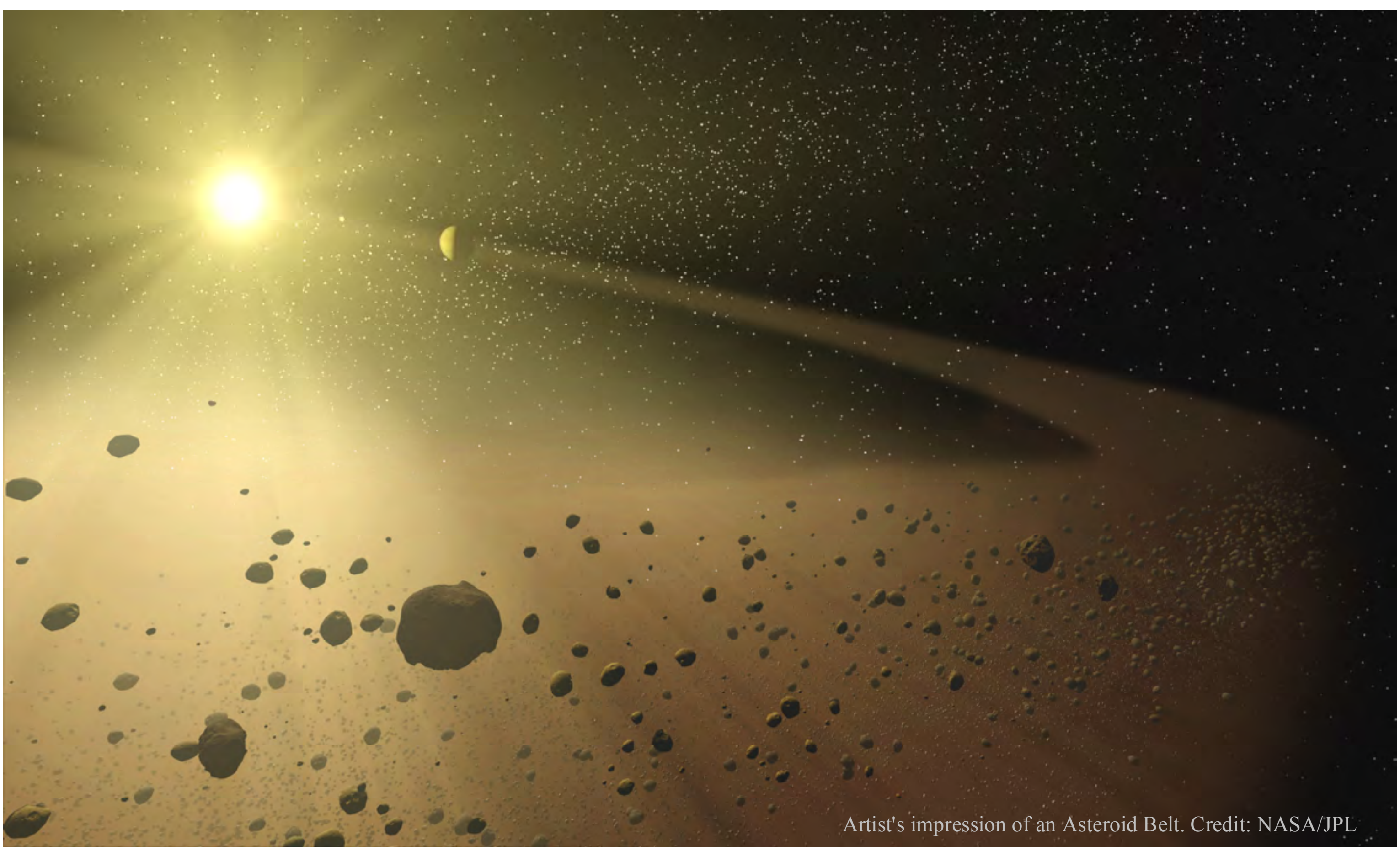


Photo of asteroid 21 Lutetia by the Rosetta Mission/ESA (Not to scale with a 1-meter earth)


Artist's impression of the Dawn spacecraft with targets Vesta (left) and Ceres (right) Credit: NASA/JPL


Artist's impression of an Asteroid Belt. Credit: NASA/JPL

# Craters on the Earth and Moon

## *What's this activity about?*

**Big Questions:**

- Why do the Moon and the Earth look so different?
- What processes on Earth erase the evidence of past impacts?
- How old are the craters on the Moon?

**Big Activities:**

Make craters on models of the Moon and Earth. Investigate the properties of Earth that hide past cratering events -- movement of the crust, erosion, water, and a protective atmosphere.

**Participants:**

**From the club**: A minimum of one person. With large groups, it is good to have at least two presenters.

**Visitors:** Cratering is appropriate for families, the general public, and school groups ages 8 and up. Up to 10 visitors at a time may comfortably participate.

**Duration:**

10 to 20 minutes

**Topics Covered:**

- How craters are formed
- How atmosphere protects Earth from small impacts
- Why natural processes erase the evidence of impact craters on Earth
- When most of the Moon craters were created

## *Where could I use this activity?*

| ACTIVITY | Star Party | Pre-Star Party – Outdoors | Pre-Star Party – Indoors | Girl Scouts / Youth Group Meeting | Classroom | | | Club Mtg | Public Presentation (Seated) | Gen Public Presentation (Interactive) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | K-4 | 5-8 | 9-12 | | | |
| **Craters on the Earth and Moon** | √ | √ | √ | √ | √ | √ | √ | √ | | √ |

## *What do I need to do before I use this activity?*

| What materials from the ToolKit are needed for this activity? | What do I need to supply to run this activity that is not included in the kit? | Preparation and Set Up |
|---|---|---|
| Two plastic containers with tops<br>Cocoa in a shaker jar<br>Meteor image card<br>Blue plastic circle<br>Picture of the Moon<br>Earth Banner | Flour<br>Handful of regular rocks<br>Newspapers if running activity inside | • Put the newspaper down on the ground.<br>• Place one pan on newspaper.<br>• Fill the pan at least 1 inch deep with flour.<br>• Sprinkle lightly with cocoa mix.<br>• Create a second pan of flour in the same way, cover it and place it on the blue circle. |

## *Background Information*

### **Impacts**

The Planetary and Space Science Center at the University of New Brunswick maintains the Earth Impact Database, a list of all known impact craters on Earth: http://www.unb.ca/passc/ImpactDatabase/

Meteors don't actually "burn up" in the atmosphere. See an explanation by Phil Plait in Bad Astronomy here: http://www.space.com/scienceastronomy/top5_myths_020903-5.html

### **Scales Represented by this Model**

The Moon and Earth models are not to size scale. The Earth model shows the relative proportions of water (71%) to land area (29%) in order to illustrate the likelihood of impacts occurring in the water. The Earth has about four times the land area as the Moon. (150 million $km^2$ of land on Earth vs. the Moon's entire surface of 38 million $km^2$)

If you would like to make an approximate scale model comparing the land area of the Earth and Moon, place the 1-meter Earth Banner on the ground and compare it to one of the containers (Moon). Have visitors observe which rocks hit the land area or place the equivalent of 4 pans, (2,300 $cm^2$ or 350 $in^2$) of flour on the banner. You can use cake and pie pans or sturdy, clean take-out containers. There is about 4 times more land area on the Earth than on the entire Moon.

## *Detailed Activity Description*

### Craters on Earth and the Moon

| **Leader's Role** | **Participants' Role (Anticipated)** |
|---|---|
| *To Do:*<br>Point to the pan full of flour on the newspaper. Have regular rocks ready.<br><br>*To Say:*<br>This represents a small area of the surface of the Moon, our closest neighbor. We have some mountains here, but what's missing from our Moonscape?<br>Right – let's make some!<br><br>*To Say:*<br>Small asteroids sometimes stray from the Asteroid Belt, but they weren't headed for the Moon on purpose -- they're rocks and don't have eyes!<br><br>Let's take these rocks, representing the asteroids that bombarded the Moon early on, and drop them behind you to create craters, like this.<br><br><br>*To do:*<br>Stand with your back to the pan and drop the rock behind you.<br><br>*To say:*<br>Okay, now you try.<br><br>*To do:*<br>Ask **all visitors to stand on one side of the pan** so no one gets hit by misfired rocks. Pass out a rock or two to each participant and let them try to drop one at a time. | Craters!<br><br>Drop rocks into flour. |
| ***Presentation Tip:***<br>Do not let participants throw the rocks up in the air. Dropping them reduces the chance of injury. | |

| Leader's Role | Participants' Role (Anticipated) |
| --- | --- |
| **Misconception Tip:**<br>One thing this model doesn't show is that you won't find the rock that made the crater sitting there at the bottom. They hit so hard that the energy blows them to bits! | |
| *<u>To Say:</u>*<br>Now it looks more like the Moon. Look, many rocks didn't hit the pan. That's all right. Most of the asteroids don't hit the Moon either, but go whizzing right by. | |
| The Moon is our closest neighbor. If all of those things are hitting the Moon, don't you think some would be hitting the Earth too? | Sure |
| Is the Earth covered in craters like the Moon? | No |
| Why do you think that is? | Erosion? |
| Let's go to Earth and find out! | |
| *<u>To do:</u>*<br>Go to the second model with blue plastic under the flour container. | |
| *<u>To say:</u>*<br>This is a model of the Earth. It was hit with lots of space rocks long ago too. Let's make some craters! (Repeat same as before)<br>Look at where those rocks hit. Where did most of your rocks end up? | On the blue sheet |
| This represents the **ocean** that covers 70% of the Earth. If something hits deep water, it won't leave a permanent crater.  | |

| **Leader's Role** | **Participants' Role (Anticipated)** |
|---|---|
| *To say:*<br>Does the Moon have oceans?<br><br>What about the big meteorites that did hit on land? Why don't we see the craters left by those?<br><br>That's right. Almost all of those craters we see on the Moon happened a long time ago, when the Solar System was a much wilder and more dangerous, place. So they've been around a while.<br><br>Thanks to the water and air here on Earth, we have **erosion**. This slowly wears down and fills up craters over time. Something like this.<br><br>*To do:*<br>Blow on the flour to fill in some of the craters. Be sure to blow away from people and telescopes.<br><br>*To say:*<br>There's another big reason we don't see them, and that's because of what a dynamic place our Earth is. The **crust is moving** all the time. We have earthquakes, volcanoes, and mountains forming.<br><br>Here, do you want to make an earthquake? Shake the pan gently.<br><br>What else? The Earth has an **atmosphere**. We're lucky because anything smaller than a house will explode in the atmosphere. Let's see how that works. | <br>No!<br><br><br>Erosion!<br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br><br>Visitor shakes pan |

| **Leader's Role** | **Participants' Role (Anticipated)** |
| --- | --- |
| *<u>To do:</u>*<br>Put the meteor illustration on top of the pan.<br><br>*<u>To say:</u>*<br>When asteroids collide with Earth, they hit the atmosphere first. The small ones are going faster than a bullet, around 25 *miles per second!* The atmosphere slows them down really fast. Has anyone ever done a belly flop in a pool? When you hit the water, it feels really hard, almost like it's solid. Believe it or not, when a space rock hits our atmosphere, it's like it is slamming into a solid too.  Most small rocks simply explode. Do you know what we see when that happens?<br><br><br><br>*<u>To do:</u>*<br>Flip the sheet over to show meteors.<br><br>*<u>To say:</u>*<br>When the atmosphere puts the breaks on these rocks so fast, they heat up and leave a trail of gas and vaporized rock. We see that streak as a meteor! Anything up to the size of a house will explode or vaporize in our atmosphere.<br><br>So small rocks don't make impact craters at all.<br><br>But of course really large asteroids aren't stopped by the atmosphere and do hit dry land sometimes. Did you know that there are over 170 impact craters on Earth that haven't been erased- yet?<br>You can see the ones found in North America here.<br><br>*<u>To do:</u>*<br>Show red dots on the Earth Banner | Meteors! |
| **Presentation Tip:**<br>You might want to familiarize yourself with the impact craters nearest to you. You can find a list here:<br>http://www.unb.ca/passc/ImpactDatabase/ | |

***Materials***

## What do I need to prepare?

- Put the newspaper down on the ground.
- Place one pan on newspaper.
- Fill the pan at least 1 inch deep with flour.
- Sprinkle lightly with cocoa mix.
- Create a second pan of flour in the same way, cover it and place it on the blue circle.

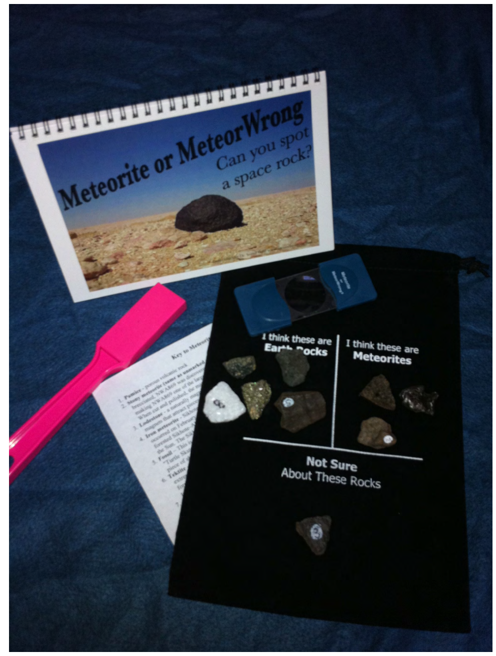
## Where do I get additional materials?

1. Container: Use a 9" pie tin.
2. Blue fabric circle: plastic tablecloths can be found at dollar stores or party supply stores. Cut to a diameter of 18".
3. Flour and cocoa can be found at any grocery store.
4. Earth Banner: print your own 42" square banner. Find the original artwork here:
   http://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=460


Credit: Chuck Hunt


Credit: NASA Earth Observatory

# Meteorite or MeteorWrong




## *What's this activity about?*

Learn all about meteorites with this hands-on activity: where they come from, how they got here, and what they are made of. Compare the characteristics of meteorites and Earth rocks.

**Big Questions:**

- What are the physical characteristics of meteorites?
- How can they be distinguished among a group of Earth rocks?

**Big Activities:**

Use various tests to pick meteorites from among a group of Earth rocks.

**Participants:**

**From the club**: One presenter

**Visitors:** Appropriate for families, the general public, and school groups in grade 5 and up. Up to 5 visitors at a time may comfortably participate.

**Duration:**

About 15 minutes. Additional time can be used for discussion and extensions.

**Topics Covered:**

- Where meteorites originate and how they end up on Earth
- Types of meteorites and what they are made of
- Characteristics of meteorites

## *Where could I use this activity?*

| ACTIVITY | Star Party | Pre-Star Party – Outdoors | Pre-Star Party – Indoors | Girl Scouts / Youth Group Meeting | Classroom | | | Club Mtg | Gen Public Presentation (Seated) | Gen Public Presentation (Interactive) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | K-4 | 5-8 | 9-12 | | | |
| **Meteorite/MeteorWrong** | | √ | √ | √ | | √ | √ | √ | | √ |

## *What do I need to do before I use this activity?*

| What materials from the ToolKit are needed for this activity? | What do I need to supply to run this activity that is not included in the kit? | Preparation and Set Up |
|---|---|---|
| • Set of rocks and meteorites<br>• Flipbook<br>• Magnet<br>• Magnifying Glass<br>• Bag that is used for sorting | It is helpful to have a table or flat surface to spread the rocks on. | • Remove the sliced meteorite (with no dot) from the set of rocks.<br>• Place the rest on a flat surface or on the bag for your visitors to see.<br>• Keep the sliced specimen and the magnet out of view until needed.<br>• Begin the flipbook with the title page facing your audience and the words "Start Here" facing the presenter (page 1). |

## *Helpful Hints*

**Common misconceptions addressed by these resources:**

- Meteors are thought to be actual falling stars
- Many people think that meteorites are easy to find
- Meteorites are assumed to be very valuable and expensive.
- Meteorites are hot when they land on the Earth.
- Contrary to what most people have learned, meteors are not caused by friction.

## *Background Information*

A well-annotated and timeless article about meteorites by Dr. David Kring: http://www.lpi.usra.edu/science/kring/epo_web/meteorites/toc.html

For a good animation of the difference between a meteoroid, meteor, and meteorite, try here:
http://upload.wikimedia.org/wikipedia/commons/6/63/Meteoroid_meteor_meteorite.gif

**Many metals are mistaken as meteorites, including:**
**Lodestone**, or magnetite, is a naturally occurring iron-rich stone found here on Earth in veins like gold. It responds strongly to a magnet. However, it does not have the high nickel content of an iron meteorite.
**Slag** refers to impure pieces of metal left over from the ore refining process or other melting of metal. These pieces may look like meteorites at first glance and may also respond to a magnet.

In order to determine whether or not a piece of metal is a meteorite, it is necessary to do further testing. This includes testing for nickel, a metal that is present in high concentration in meteorites. This test is not recommended for use with a general audience or with children because of the chemicals involved. More information is found here:
http://meteorites.wustl.edu/id/metal.htm

**Meteorite Treatment**

*Thanks to Dr. Mike Reynolds for preparing the meteorites and providing us with this description of the process:*

Most meteorites – about 99% -- contain iron and nickel. Depending on the iron to nickel ratio, these can oxidize or rust. To prevent or inhibit rusting, several steps are taken with the meteorites in this set.

- Meteorites and slices are thoroughly cleaned with Ethyl Alcohol (EtOH) and a nylon brush. This does two things: loosens/removes surface rust and dehydrates the meteorite samples. The meteorites are left to “soak” in EtOH for about 30 minutes and then set to the side to dry. Meteorites that are found to be extremely oxidized are further treated to remove rust and hopefully prevent future oxidation.

- The meteorite samples are next baked in an oven to dry and further dehydrate the samples. One does not want too high a temperature; around 175$^{o}$F is about right. The baking process takes between 30 and 60 minutes depending on the size of the meteorite(s).
- Finally, each sample is lightly coated with a spray that was specifically formulated for meteorites.
- There is no need to treat tektites in this manner since they are dry, glassy materials. However, each tektite was cleaned and rinsed in EtOH.

## Key to Meteorite or MeteorWrong Rocks

1. **Pumice** - porous volcanic rock
2. **Stony meteorite (same as unmarked slice)** - Northwest Africa 869 Ordinary Chondrite (L5); brecciated, NWA869 was discovered in 1999. It is estimated that 1,500 kg have been recovered, making NWA869 one of the largest total known weight meteorites to come out of Northwest Africa. When cut and polished, the matrix is full of color and chondrules.
3. **Lodestone** - a naturally magnetized piece of the mineral magnetite. They are naturally occurring magnets that attract pieces of iron. They are often mistaken for meteorites.
4. **Iron meteorite** - Sikhote-Alin Found in Russia. Coarsest Octahedrite (IIAB) This well–observed fall occurred on February 12, 1947 over the Maritime Territory. A shower of fireballs fell in the thick-forested Sikhote–Alin Mountains. According to eyewitnesses, the fireball's brightness exceeded that of the Sun. The Sikhote–Alin fall produced 106 impact holes and over 27,000 kilograms of meteorites.
5. **Fossil** – This is a piece of a turtle shell that has been fossilized in the creeks of Florida. They are called "Turtle Skutes" and naturally fall off of turtles as they grow. On most fossils, you can see where the piece of shell was once fused to the vertebrae.  They are between 10,000 and 4 million years old.
6. **Tektite** - Chinese Tektite Found in the Australasian Strewn Field, Composition-wise, tektites are extremely dry fused glasses–that is, they contain very little water. They are silica-rich ($SiO_2$) with a form that indicates aerodynamic flight, including spheres, ellipsoids and spheroids, dumbbells, and teardrops, with spheres being the most-common form.
7. **Pyrite** – a naturally occurring Earth mineral. It is an iron sulfide with the formula $FeS_2$. It is also called "fool's gold" because of its appearance.
8. **Marble** – a metamorphic rock (made from calcite or dolomite) commonly used in sculpture and building materials.

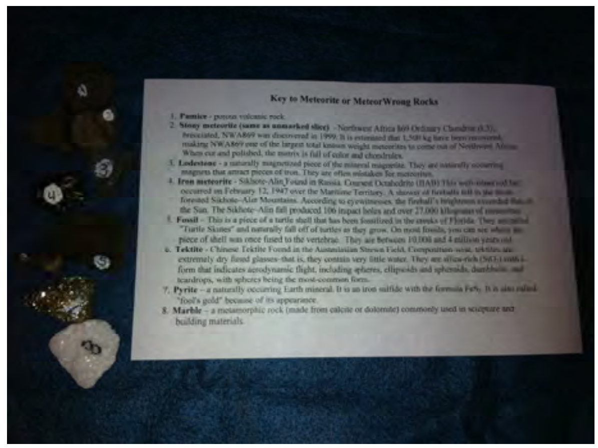
## *Detailed Activity Description*

### Meteorite or MeteorWrong

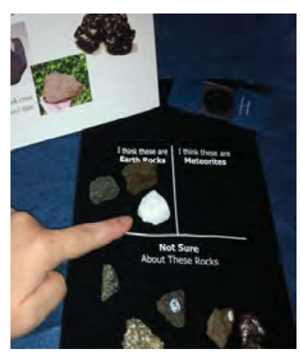
**Presentation Tips:**
The flipbook is a useful tool to use with this activity. It gives the audience visual reinforcement of the concepts. And it doubles as a reminder of points to cover in the activity for the presenter. In the "Activity Description" below, the column on the left indicates when to turn to the next page in the flipbook and what image the visitors will be seeing. (Only the presenter pages are numbered.)

Included in the black bag is a key to the rocks and meteorites. To help you remember what you are looking for, the meteorites and tektite are labeled 2, 4, and 6.

The rocks and meteorites are numbered to ensure you pick the correct meteorites. You will also find the key to the numbers on page 13 of the flipbook.




| Page | Leader's Role | Participants' Role (Anticipated) |
|---|---|---|
| 1<br>Intro/<br>Start Here | <u>*To say:*</u><br>Hey, I have some cool rocks from outer space here. Can you figure out which of these rocks are meteorites?<br><br>It's impossible to tell just by looking. Would you like to become a meteorite detective and see if you can find one? Are you ready for some clues?<br><br>Our first clue comes from how they got here. Between outer space and the ground here on Earth, what do they have to travel through? | <br><br>Yes!<br><br><br><br>Yeah<br><br><br><br>Atmosphere |

| Page | Leader's Role | Participants' Role (Anticipated) |
|---|---|---|
| 2<br>Rocks | *To say:*<br>Right. And they're traveling really fast when they slam into Earth's atmosphere.<br><br>To make it through our atmosphere and onto the ground, a space rock has to be strong and solid. If they're not strong, the only thing we'll see is a streak of light as the small rocks vaporize in our atmosphere. What do we call that streak of light? | Shooting stars/ falling stars |
| 3<br>Meteors<br>Porous<br>Rocks | Right. Or **meteors**! Space rocks that are porous or with lots of holes wouldn't have made it through the atmosphere. That means that any of the rocks that are full of holes are probably Earth rocks, not meteorites. Do any of these rocks have holes? If so, you can be pretty sure they're not meteorites. Put those in the Earth Rocks category. | Put porous rocks in the Earth Rocks pile |
| 4<br>Fusion<br>Crust | Another thing their trip through the atmosphere does is to heat the outside layer of the rock until it melts. This gives some meteorites what we call a dark fusion crust, like in this picture.<br><br>*To do:*<br>Point to pictures of stony meteorite with fusion crust, then to iron meteorite next.<br><br>*To say:*<br>Other types of meteorites look like a splash of dark metal instead. You may be able to see tiny dents that look almost like thumbprints. These are called regmaglypts.<br>(Pronounced *reg* mag lips)<br><br>No matter what type they are, the outsides will be dark in color. So light colored rocks are not meteorites, unless you can see that thin, dark fusion crust on them somewhere. Put any light colored rocks into the Earth Rocks section too. Those aren't likely to be meteorites. | <br><br>Put rocks light in color in the Earth Rocks pile |

<table>
<tr><th>Page</th><th>Leader’s Role</th><th>Participants’ Role (Anticipated)</th></tr>
<tr><td colspan="3">Misconception Tips:<br><br>Many people think that meteorites are hot when they land on the Earth. For small meteorites, that is not the case. Only the very outer layer of the rock has time to heat up. Most of the mass of a meteorite is lost as the outside layer vaporizes in the atmosphere, leaving only a thin fusion crust by the time it hits the ground.<br><br>Heating of the surface of the rock (the meteor phase) only lasts a few seconds upon entering the atmosphere and normally stops between 15 to 20 km (9-12 miles) altitudes. After this point, they are moving at only about 0.2 km/sec and there is minimal heating from friction. They are free falling through the atmosphere for a minute or two and it is very cold that far up.<br><br>So meteorites are most likely to arrive on the ground about room temperature. Imagine holding a piece of metal over a flame for a few seconds then putting it in the freezer for a minute. The interior never heats up and the heat on the top layer dissipates quickly.<br><br>Contrary to what most people have learned, the glow of meteors is not caused by friction. The great speed of a meteoroid entering the atmosphere (average 30 km/sec or 20 miles/sec) compresses the air in front of it, causing the outer layer of the rock to heat so that it glows and vaporizes.</td></tr>
<tr><td>5<br>Asteroid Belt</td><td><u>To say:</u><br>Okay, so now we're down to strong, dark rocks without holes. We'll get the next clue when we figure out where space rocks come from. Does anyone know where meteorites come from originally?<br><br>Right. More specifically, almost all meteorites found on Earth originally come from the Asteroid Belt. They are pieces of an asteroid. Way out past the orbit of Mars, asteroids collided and pieces of them were scattered. Just a few end up here on Earth as meteorites.<br><br>So when you hold a meteorite, you're actually holding a piece of an asteroid.</td><td>Space.</td></tr>
</table>

<table>
<tr><th>Page</th><th>Leader’s Role</th><th>Participants’ Role (Anticipated)</th></tr>
<tr><td>6<br>Planets<br>Asteroids</td><td><u>To say:</u><br>All of the rocky planets and asteroids formed from the same space stuff- mostly dust, rock, and metal. But here's the thing that makes asteroids different from planets like Earth. Most never got very big. And this gives us a clue.<br><br>Let me explain. When Earth and the other rocky planets formed from space dust, they got big enough and hot enough that most of the metal liquefied and sank to the core. Does anyone know what the Earth's core is made of?<br><br>Right, well, most asteroids never got very big so all of these little bits of material are still stuck together just the way they arrived. And the metal never heated up or sank to the core. So in most asteroids, there's metal all mixed in with the rock. Meteorites from these asteroids are called stony meteorites.<br><br>Now, there are some exceptions. Some asteroids did get big enough to have a core. And these also get smashed apart sometimes. When they do, the bits of metal from the core can land on Earth too. We call these iron meteorites.</td><td>Iron</td></tr>
<tr><td colspan="3">Tip: An astute audience member may ask why we don't see many meteorites from the crust/mantle part of these large asteroids. This question is as yet unanswered by scientists as well.</td></tr>
<tr><td>7<br>Scale</td><td><u>To say:</u><br>But either way, it turns out that 99% of meteorites found on Earth have a good amount of iron in them. And iron is heavy. That makes a meteorite heavier than an average Earth rock of the same size.<br><br>Go ahead; pick up some of the rocks. If any of them weigh considerably less than another of the same size, it's probably not a meteorite. Make sure to compare rocks of about the same size for this test.</td><td>
</td></tr>
</table>

| Page | Leader's Role | Participants' Role (Anticipated) |
|---|---|---|
| 8<br>Stony<br>vs. Iron | *To say:*<br>Now we can put aside not just the rocks that are light in color but also those that are light by weight.<br><br>Now there's one last test that's a really important one. Can you think of another way to test for iron?<br><br>Good guess. How about a magnet? Rocks with iron in them should stick to a strong magnet. I just happen to have this one here.<br><br>*To do:*<br>Bring out the magnet.<br><br>*To say:*<br>Remember that some meteorites come from the cores of asteroids. These are called **iron meteorites** and they will stick to a magnet very strongly. When you find rocks that stick to the magnet, let's put those in the Meteorite pile.<br><br>The other type of meteorite we talked about is a mixture of metal and stone. These are called **stony meteorites** and you have to watch carefully for these. Try dragging the magnet slowly across the surface of the rocks to see if any stick even just a little bit.<br><br>Great. Let's see what you found.<br><br>*To do:*<br>Pick up the lodestone (#3).<br><br>*To say:*<br>Now, a few types of Earth rocks also have iron in them, so this isn't definitive. If we did more extensive tests, we'd find that this rock doesn't have nickel in it, like meteorites do. That's because it's a lodestone- an Earth rock with lots of iron in it that is often mistaken for a meteorite! It's hard to tell unless you slice it or do more thorough tests. | Put rocks that are not heavy for their size in the Earth Rocks section.<br><br>Metal detector!<br><br>Make a pile of rocks that stick to the magnet<br><br><br>Visitors usually identify the lodestone and the iron meteorite (#4). Some careful observers find the stony meteorite (#2). |

<table>
<tr><th>Page</th><th>Leader’s Role</th><th>Participants’ Role (Anticipated)</th></tr>
<tr><td colspan="3">See Background Information for more details on slag and lodestone.</td></tr>
<tr><td>9<br>Iron<br>Meteorite<br><br>10<br>Chondrules<br><br>11<br>Tektites</td><td><u>To say:</u><br>Now this is an iron meteorite! The largest meteorites on Earth are iron meteorites. Can you guess why?<br><br>They are really strong and more often make it to the ground in one piece.<br><br><u>To do:</u><br>Pick up iron meteorite (#4) and pass to a visitor.<br><br><u>To say:</u><br>Only the most careful meteorite detectives pick out this one. This is the stony meteorite (#2).<br><br><u>To do:</u><br>Also pick up the stony if you they haven't already picked it out. Now bring out the sliced chondrite to show the interior- the chondrules and metal flakes<br><br><u>To say:</u><br>Here you go. I have a stony meteorite that has been sliced open. With that magnifying glass, you can easily see the metal flakes and pieces of rock or chondrules. (Pronounced: con-drools)<br><br>Congratulations! You are now holding pieces of the Asteroid Belt. These also happen to be older than any Earth rock. They are glimpses into what our Solar System looked like when it was first forming.<br><br>Now there's one other thing in here that's not a meteorite but that is related to Earth impacts.<br><br><u>To do:</u><br>Pick up the tektite (#6) and point out features before passing it around.</td><td>They are bigger to start with?</td></tr>
</table>

| Page | Leader's Role | Participants' Role (Anticipated) |
|---|---|---|
| | *To say:*<br>When very large asteroids or comets impact the Earth, they explode with so much energy that they heat up the rock or sand they hit and can leave a big crater. The energy from that impact heats the rock and sand up to such high temperatures that they can melt. | |
| | (For older visitors) Does anyone know what happens when sand gets super-heated? | Older students and adults may know it becomes glass. |
| | That's right, melted sand becomes a kind of glass. This is a piece of glass that splashed out of an impact site. It's called a **tektite**! | |
| 12<br>Other Kinds | There are also types of rare meteorites, from the Moon, Mars, and very specific parts of an asteroids, like the boundary between the core and the mantle. | |
| | It's hard to come up with characteristics that fit every meteorite, but the tests we just did will help identify over 90% of meteorites out there. | |
| 13<br>Looking for Meteorites | Does anyone want to see if you can pick out the two meteorites in this picture? | Sure! (Try it) |
| | It's still not easy. Here are some tips if you want to be a meteorite hunter:<br>• Look in a place without lots of other rocks to fool you. What kind of place might that be?<br>    o Right, or even a freshly plowed field.<br>• Get a good book about meteorite hunting from the library or a bookstore. | Desert? |
| | Good luck! | |

**Misconception Tips:**
Many people think that meteorites are easy to find. Be careful to let them know that finding meteorites is not a simple exercise. It can take experts days, weeks, or longer between finds.

Also, most people think meteorites are very valuable and expensive. Indeed some are! Point out that the meteorites you are passing around are small, common and worth less than ten dollars each.

### *Materials*

## Where do I get additional materials?

1. Powerful magnets can be purchased at a toy store, hardware store, or online. The wand magnets are simple to use for all ages:
    - http://www.discountschoolsupply.com search for "mag wand"
2. Magnifying glasses can be found at a drugstore or dollar store.
3. To make a copy of the Flipbook, follow these instructions:
    - Print the flipbook pages double sided on cardstock (best left to a professional printer).
    - Cut the pages in half.
    - Stack them with the presenter-side in numerical order, with *page 1 on top*. If you have access to the tools, spiral-bind the top edge.
    - If you leave them loose, as you flip the pages, place them on the table in front of you.
4. Limited numbers of bags with the 3 meteorites, one tektite, and Earth rocks that match the flipbook are available, while supplies last.
    - Contact Dr. Mike Reynolds: fallingstars1@comcast.net
5. Small rocks can be collected from your neighborhood or purchased from landscape supply centers.
6. Lodestone can be found through many online suppliers, including here:
    - http://www.buylodestones.com/
7. Meteorites and tektites: The largest supplier is EBay. Most of the sellers are honest and a pleasure to deal with. However, use caution when buying meteorites on EBay. Although most ads for meteorites are real, sometimes less reputable sellers try to list tektites as meteorites. Read this very informative site for more information:
    - http://reviews.ebay.com/Buying-Meteorites-on-eBay-a-Beginner-apos-s-Guide_W0QQugidZ10000000004437563
    - You can also go to gem and mineral shows in your area. A current list is here: http://www.rockngem.com/showdates.asp
    - Members of your astronomy club may have small meteorites they are willing to share for this activity.

# Start Here

With this page facing you, the presenter,
set out your rocks and meteorites for the visitors to handle.
Remove the sliced stony meteorite (no number)
and the magnet for use later.

Hook them with an introduction like…
***"Have you ever seen a rock from outer space?***
***At least one of these rocks is a meteorite.***
***Can you figure out which ones are space rocks?"***

Flip this page towards
the visitors to get started



# Our First Clue:

## The space rock made it through Earth's Atmosphere

As space rocks come through the atmosphere,
they are traveling *really* fast (>20 miles/sec).

Most small porous rocks explode or vaporize when they hit the atmosphere and never make it to the ground.

***Does anyone know what we call***
***a space rock vaporizing in our atmosphere?***

# A Meteor!

Rocks with lots of holes **vaporize** or **explode** in the atmosphere (they don't "burn up")

Only **strong** space rocks **without lots of holes** make it to the ground to become meteorites

***Audience:***
***Rocks with lots of holes are likely Earth rocks.***
***These likely aren't meteorites.***



# The Atmosphere Also…

## Melts the Outer Layer of Space Rocks

Some meteorites get a dark crust
Other meteorites can look like
a splash of metal.
They're all **dark** (at least on the outside).

***Audience:***
***Light colored rocks are probably Earth rocks.***
***These probably aren't meteorites.***

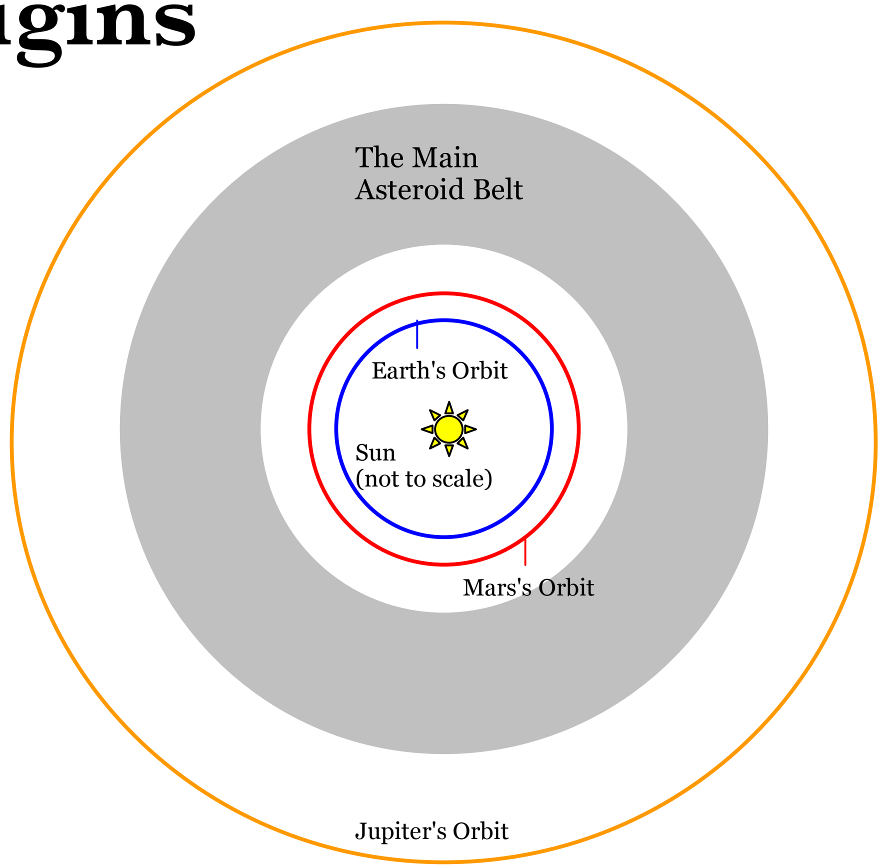
# Examples of Meteorites

The dark crust
can rust over time

# Meteorite Origins

Collisions in the
Asteroid Belt

Art by Don Davis © SwRI 2007



# The Next Clue
## Comes from meteorites' origin

Almost all meteorites on Earth
come from the Asteroid Belt.

How are asteroids different from
rocky planets like Mars and Earth?



# Asteroids are Small

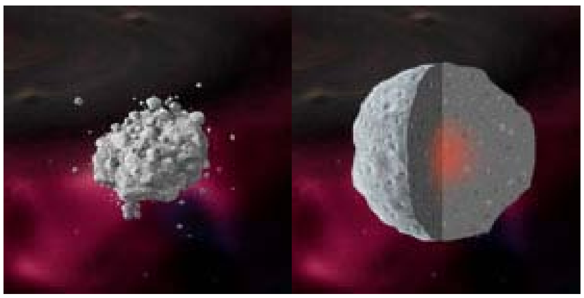
Most never got big enough or hot enough for the metal to liquefy and sink to the core, like on Earth.
Metal is still mixed in with rock and dust.
These are **stony meteorites**.

A few did get big and hot and formed metal cores.
Sometimes these collided too, sending pieces of the iron core to Earth. We call these pieces **iron meteorites**

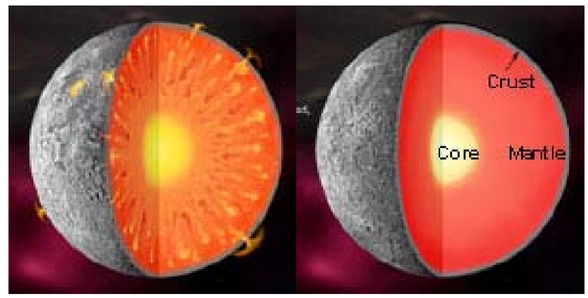
# Meteorites come from Asteroids

Most asteroids are small and never got very hot inside. They are still a mixture of **stone** and **metals** from the formation of our Solar Sytem

Only a few asteroids got bigger. Iron meteorites come from the cores of big asteroids. They are made mostly of **metals (iron)**



**Stony Meteorites**




Pictures courtesy Smithsonian National Museum of Natural History

**Iron Meteorites**

# Metal is Heavy

Both types of meteorites **contain a lot of iron**.

So meteorites are usually heavier than Earth rocks of the same size.

# Meteorites are Heavy

Iron is heavy and meteorites contain a lot of iron.

So a meteorite is usually heavier than
an Earth Rock of the same size.

(Of course we know that we are talking about the rock's density,
but many people do not understand this concept. )

***Audience:***
***<u>Remove any lightweight rocks</u>-***
***Lightweight rocks are not likely to be meteorites***



# Iron is Attracted to a Magnet

Since almost all meteorites have lots of iron in them,
they should be attracted to a magnet.

***Audience:***
***<u>Remove any rocks that are not attracted to the magnet</u>-***
***Rocks without iron are not likely to be meteorites***

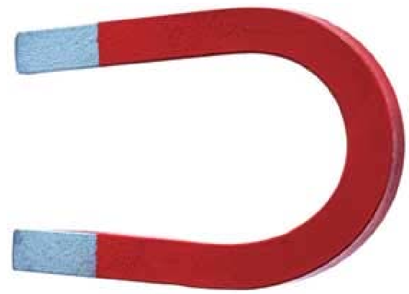
**But this is not a definitive test!**
There is also a piece of **lodestone** in the set. **(Marked # 3)**
This is an Earth Rock that contains a lot of iron.
More detailed tests will show that this rock
does not have nickel in it like meteorites do.

**Which do you think will be more strongly attracted?**

An Iron Meteorite

or

A Stony Meteorite?



# Iron Meteorites

The biggest meteorites on Earth are iron meteorites.

This is the largest meteorite ever found- the Hoba meteorite in Namibia.

# Iron Meteorite

**Marked # 4**

<u>Background Information:</u>

- Only about 5% of the meteorites that hit the Earth are iron meteorites. But because they are stronger, more of them survive the trip through the atmosphere. Also, iron meteorites are more resistant to weather effects and easier to find. Over half of the meteorite finds are of this type.
- Iron meteorites were once part of the core of a long-vanished large asteroid and originated within the Asteroid Belt between Mars and Jupiter.
- They are among the densest materials on Earth and will stick very strongly to a powerful magnet. Iron meteorites are far heavier than most earth rocks-if you've ever lifted up a cannon ball or a slab or iron or steel, you'll get the idea.
- The largest space rock ever found on Earth is an iron meteorite. The Hoba meteorite in Namibia weighs 60,000 kg (about 50 tons).



# Common Stony Meteorite

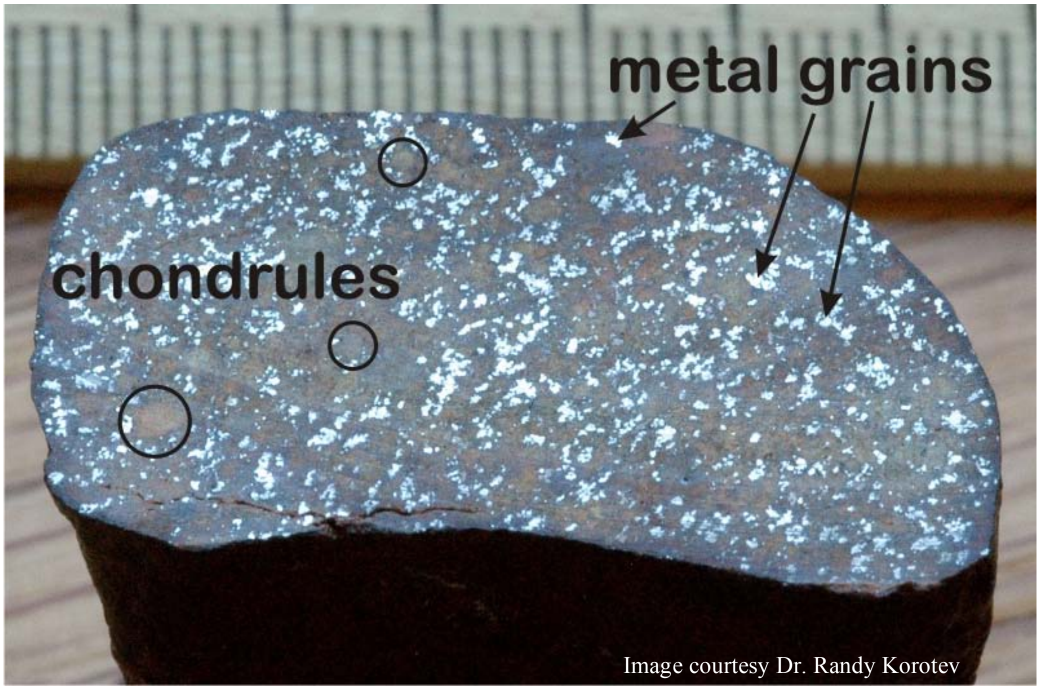
**Marked # 2**

Take a look at this sliced specimen.
You can see the mixed metal and stone.

<u>Background Information:</u>

- 94% of the meteorites that fall to Earth are Stony meteorites.
- Of these, most are *chondrites*, which are named for the small, round particles composed mostly of silicate minerals or stone (shown opposite).
- Even though these are the most abundant type of meteorite, only about 40% of all meteorites that have been found are stony. This is partly because they weather quickly and also they look a lot like earth rocks.
- At 4.5 billion years old chondrites are are some of the oldest and most primitive materials in the solar system. Chondrites are often considered to be "the building blocks of the planets."

# Common Stony Meteorites




# Not Meteorites, but <u>Tektites</u>

Melted sand from large impacts gets thrown from the crater and out of our atmosphere

# Tektite **Marked # 6**

Do any of your visitors know what the result is when sand gets so hot that it melts? *Glass!*

- Tektites are not meteorites, but they do have something to do with large Earth impacts. These are natural glass objects up to a few centimeters in size that were formed--according to most scientists--by the impacts of large meteorites on Earth's surface.
- In a cratering event, soil and rock are liquefied, or vaporized. This liquid rock formed a type of glass as it was ejected from the impact site. Tektites are typically black or olive-green.
- The tektite included here was ejected out of our atmosphere and landed back on Earth as glass.



# Other Types of Meteorites

**Other types of rare meteorites** are not included in this kit. Some of these are:

- Achondrites are stony meteorites without the small round specks called chondrules. Most of these are from the crust of the asteroid Vesta.
- Stony-irons, some which probably come from the boundary of the core and mantle in large asteroids.
- Lunar and Martian meteorites come from our Moon or Mars, not from the Asteroid Belt. These are the most rare types of meteorites and do not look like the meteorites we discussed here.

# Other Types of Meteorites

Stony-iron meteorites can be very beautiful

Lunar meteorites are very rare and not like others

There are even a few meteorites from Mars!

# Can you find the meteorites?

These two in the red circles are meteorites. But it's nearly impossible to find meteorites surrounded by other rocks. **Good places to look**: a glacier, a newly plowed field, or a desert.

**Key to rocks:**

**1) Pumice** from a volcano
**2) Stony chondrite meteorite** NWA 869
**3) Lodestone** a magnetic Earth Rock (tricky…)
**4) Iron meteorite** Sikhote-Alin from Russia
**5) Fossilized turtle shell** about 1 million years old
**6) Tektite** glass formed from sand during a huge impact
**7) Pyrite** "fool's gold" or more accurately iron sulfide
**8) Marble** the same kind that statues are made from



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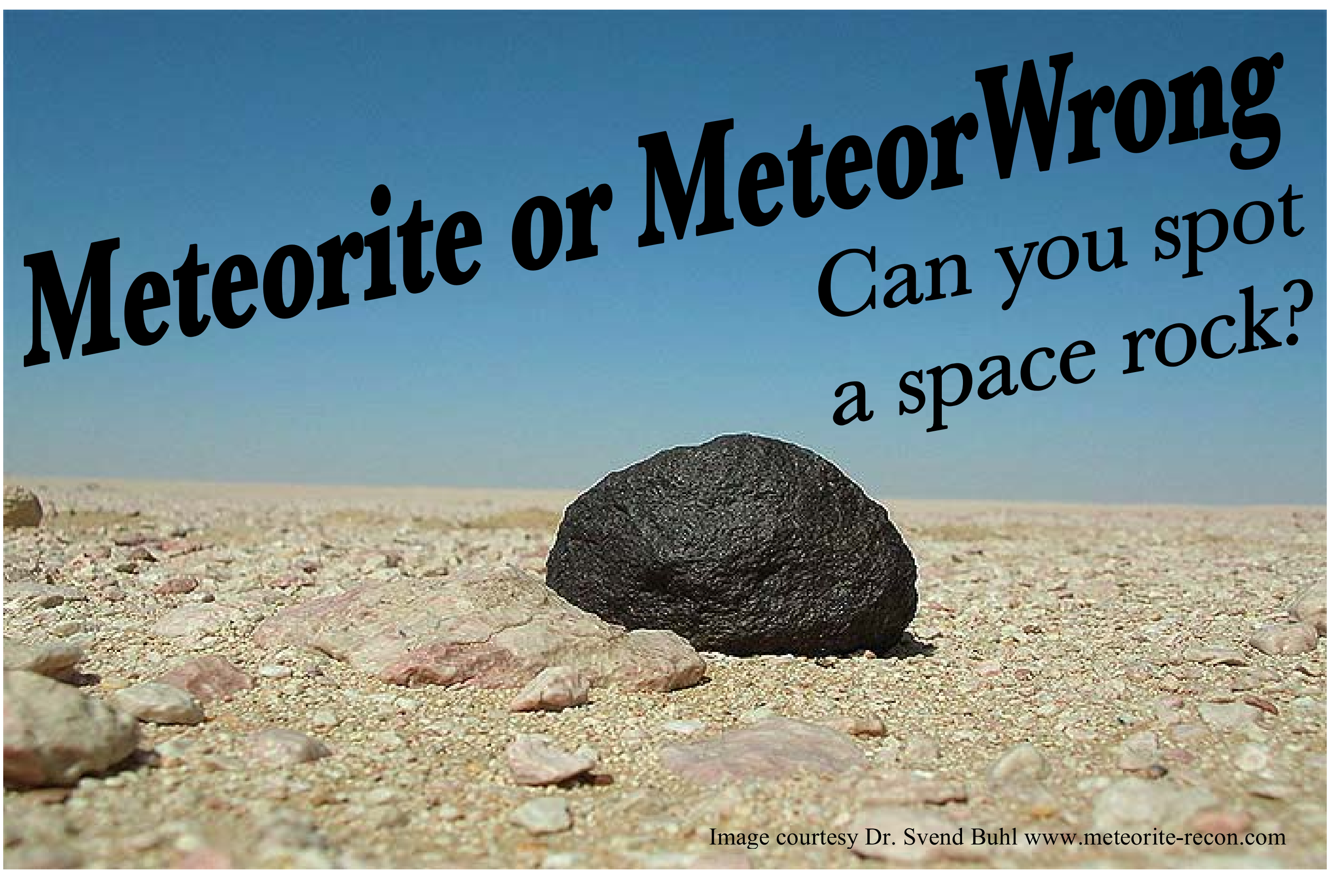


# Asteroid Hunters

## *What's this activity about?*

**Big Questions:**

- How are asteroids discovered?
- How fast do asteroids appear to move in the sky?
- How are infrared detectors used to locate more asteroids?
- How does the WISE Mission detect asteroids?

**Big Activities:**

Find asteroids in a starfield and discover why astronomers are locating even more asteroids using infrared detectors.

**Participants:**

**From the club**: One or two presenters can lead this activity.

**Visitors:** Appropriate for families, the general public, and school groups ages 10 and up. Up to 3 visitors at a time may comfortably share a set of starfields. For larger groups, there are 4 copies of each starfield included.

**Duration:**

10-15 minutes

**Topics Covered:**

- How scientists search for asteroids in starfields
- How an infrared camera sees temperature

## *Where could I use this activity?*

| ACTIVITY | Star Party | Pre-Star Party – Outdoors | Pre-Star Party – Indoors | Girl Scouts / Youth Group Meeting | Classroom | | | Club Mtg | Gen Public Presentation (Seated) | Gen Public Presentation (Interactive) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | K-4 | 5-8 | 9-12 | | | |
| **Asteroid Hunters** | | √ | √ | √ | | √ | √ | √ | √ | √ |

## *What do I need to do before I use this activity?*

| What materials from the ToolKit are needed for this activity? | What do I need to supply to run this activity that is not included in the kit? | Preparation and Set Up |
|---|---|---|
| • 2 sets of starfields -- one taken in visible light and one in infrared<br>• Pictures of warm rocks in visible and infrared<br>• Clay, a ruler, and cratering implements to make models of the asteroids:<br>○ Ceres, 7.3cm, black<br>○ Pallas, 4.1cm, black<br>○ Vesta, 4.1 cm, light gray | <br>For large groups, use all four copies of the starfields. | • Make models of the asteroids at least 3 days prior to activity. See "Making Model Asteroids" at the end of this activity<br>• Punch holes in the top left corner of the starfields and attach them with binder rings. Each transparency should be placed on top of a corresponding card. Make sure to keep the Visible and Infrared sets separate. |

## *Background Information*

NASA's Wide-field Infrared Survey Explorer (WISE) is an unmanned satellite carrying an infrared-sensitive telescope that will image the entire sky. Among the objects WISE will study are asteroids, the coolest and dimmest stars, and the most luminous galaxies.

Take a look at the NASA WISE Mission PowerPoints on the Manual & Resources CD. These will give an excellent overview of the mission and the science. They can also be found online here:
http://wise.ssl.berkeley.edu/gallery_slideshows.html
Also, the website is full of information and images:
http://wise.ssl.berkeley.edu/mission.html

### Difference between Heat and Temperature (excerpt from Cool Cosmos)

When talking about warm asteroids, it's good to be reminded of the fundamental difference between heat and temperature. In casual conversation, we often refer to heat and temperature interchangeably. However, to be precise, heat and temperature are different concepts, related to each other.

Heat is the total energy of molecular motion in a substance while temperature is a measure of the average energy of molecular motion in a substance.

For example, the temperature of a small cup of water might be the same as the temperature of a large tub of water, but the tub of water has more heat because it has more water and thus more total thermal energy. Temperature does not depend on the size or type of object.

It is heat that will increase or decrease the temperature. If we add heat, the temperature will become higher. If we remove heat the temperature will become lower. Higher temperatures mean that the molecules are moving, vibrating and rotating with more energy.

Heat is energy; temperature is a measure of it.
http://coolcosmos.ipac.caltech.edu

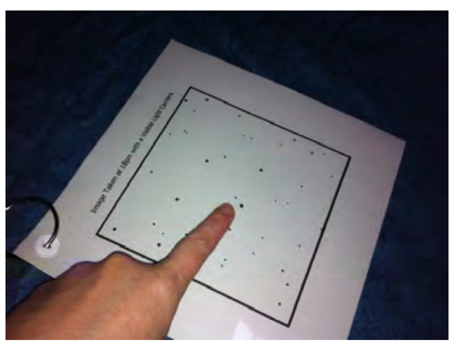
### Additional Asteroid Belt materials from the Dawn Mission

On the Dawn website, you can find image galleries, activities, and much background information:
http://dawn.jpl.nasa.gov/

## *Detailed Activity Description*

### Asteroid Hunters

| Leader's Role | Participants' Role (Anticipated) |
|---|---|
| *<u>To say:</u>*<br>Is anyone concerned about asteroids hitting the Earth?<br><br>Well, we are keeping our eyes out for potentially hazardous asteroids and nothing we've found so far is headed our way. But it is pretty much guaranteed that an asteroid will eventually hit Earth and we want to be prepared. Don't worry too much; the chance of that happening in our lifetimes is very small.<br><br>Scientists are taking the first step towards being able to avoid an asteroid impact now. Can you guess what that is?<br><br>Well, before we decide what to do about it, we have to find out if any of them are headed our way. Astronomers want to find the potentially hazardous asteroids with enough warning to do something about it. Do you want to see if you can spot an asteroid?<br><br>Let me show you how it's done. When we look through our telescopes, and even with large space telescopes, most asteroids just look like any other point of light. They're too small and far away to see their shape. So essentially they look just like dots, just like stars except for an important difference. Can anyone guess what that is?<br><br>Well, you're close -- they do move. They don't shoot across the sky like a meteor. They are moving fast but they are far away so it looks slow to us. But over an hour or so, you can see a difference. | Yes!<br><br>Blow it up! Shoot it!<br><br>Sure.<br><br>They shoot across the sky! |
| **Misconception Tip:**<br>The sizes of dots in the starfields do not represent the *size* of the object, but its *brightness*. | |

| **Leader's Role** | **Participants' Role (Anticipated)** |
| --- | --- |
| <u>*To say:*</u><br>Here's one way we find asteroids. An astronomer takes a picture of one piece of the sky. It looks something like this. Can you tell which of these dots is an asteroid? | No |
| <u>*To do:*</u><br>Hold up one visible light card. | |
| <u>*To say:*</u><br>Then she waits, and an hour later takes another picture. It looks a lot like the first. | |
| <u>*To do:*</u><br>Hold up the visible light transparency. | |
| <u>*To say:*</u><br>Astronomers simply line up the dots and see if any of the points moved over that hour. We've made the second image a different color so it's easier to see. If any dot has moved compared to the rest of the field, you know that point of light isn't a star. Would anyone like to try to find the asteroid in these pictures? | Sure! |
| <u>*To do:*</u><br>Pass out Visible starfields to the group. Up to 3 people can comfortably use a starfield.  | *Finding the asteroid (in the center)* |
| <u>*To say:*</u><br>Great! That's exactly how scientists have been finding asteroids for over 100 years. But recently we've been able to use even better tools. Can anyone guess what those are? | Computers |

| Leader's Role | Participants' Role (Anticipated) |
|---|---|
| *To say:*<br>Absolutely! Using computers means that humans don't have to look over and over at countless frames like this. But asteroids are still hard to find. That's because they are small and very dark. Most of them are blacker even than asphalt, like this model.<br><br>*To do:*<br>Hold up small dark asteroid model.<br><br>*To say:*<br>But because asteroids are so dark in color, they are hard to see.<br><br><br><br>*To do:*<br>Find someone wearing black or a black car. Ask them to be your "background".<br><br>Make a circle with your hand and hold it to your eye to simulate a telescope, as in the picture on the right.<br><br>*To say:*<br>Everybody else get out your telescopes. Which one of these asteroids would appear brighter to you on Earth? Remember, all we see is a point of light.<br><br>*To do:*<br>Hold the two small asteroids in front of the dark background. | The light gray one is brighter than the black one. |
| *To say:*<br>Right, to our eyes, the one that reflects more sunlight appears brighter. The lighter gray appears brighter. In fact, in a telescope you might even be able to see this small bright one better than a large asteroid that's very dark.<br><br><br><br>*To do:*<br>Hold up the large dark asteroid next to the small light one. | |

| Leader's Role | Participants' Role (Anticipated) |
|---|---|
| *To say:*<br>Remember, they just look like points against the black of space. We see the sunlight they reflect, but can't tell their shapes or how big they are.<br><br>So we have come up with a different way of looking. I'll tell you how it works. Have you ever been out in the sun in a dark t-shirt? | Yes |
| What happens? | It gets hot |
| Right. The same thing happens to asteroids! They get warm. Hmmm… So if we could just measure the temperature of the asteroids, we could see them a lot better. And that's exactly what scientists do.<br>*(See Background Information for more on the difference between heat and temperature.)*<br><br>There are special cameras called infrared detectors that basically "see" the temperatures of objects. Here, take a look at this picture.<br><br>*To do:*<br>Hand one card with warm rocks to an audience member and hold the other for the rest to see. Start on the visible light side. (looks like one white rock)<br><br>*To say:*<br>This is a picture of two warm rocks on a cool black background. Really, there are two rocks there. One is hard to see, isn't it? | Yes |
| Well, on the other side is a picture of those same rocks taken with an infrared camera. An infrared camera detects temperature. Look at how bright the large one is compared to the background! | |
| But, is this what the rock looks like to our eyes?<br>No, this picture of the rock taken with an infrared detector shows how warm the rock is. We do the same thing with asteroids. | No |

| **Leader's Role** | **Participants' Role (Anticipated)** |
|---|---|
| Misconception Tip:<br>While asteroids are warmer than the surrounding space, they are still very cold in comparison to temperatures on Earth. The average surface temperature of a typical asteroid is -100 degrees F (-73 degrees C). The surrounding space is much, much colder. | |
| *To do:*<br>Hold up the infrared card next to the visible light card.<br><br>*To say:*<br>Does anyone want to see that same starfield taken with an infrared camera? Compared to the cold, cold background of space, both asteroids and stars shine brightly in the infrared. Can you see more dots? | Yes |
| Can you tell which are stars and which are asteroids?<br>What should we do? | No<br>Take another picture! |
| Right, here you go. This picture was taken an hour later. Go ahead and see if you can line up the dots.<br><br>*To do:*<br>Flip the transparency over and hand out the two infrared starfields to visitors. | It's hard to find |
| *To say:*<br>That's because so many of the dots you see here are actually asteroids! Wow! Look at all the asteroids that infrared detectors can find.<br><br>NASA's WISE Mission took pictures of the sky with infrared cameras every hour. Do you think that might be a good way to find asteroids? | Yes |
| Absolutely. It found hundreds of thousands of asteroids in less than a year. That gives us a better idea of the asteroids in the Asteroid Belt. And it can warn us of any potentially hazardous asteroids that might be coming close to us too. This is the first step in eventually protecting Earth from dangerous asteroids. | |

***Common questions:***

**Can we see infrared from ground-based telescopes?**
Some parts of the near infrared spectrum make it through the atmosphere. And a few windows of longer wavelengths make it to the ground as well. But the atmospheric greenhouse gases, especially water vapor, absorb most infrared. So WISE orbited Earth taking pictures out in space where it's cold and clear.

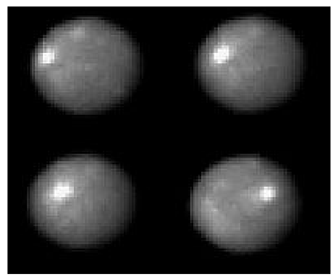
**Are dark asteroids brighter in infrared?**
Yes, and the difference between what we can see in the infrared and what we see in visible light tells us about the surface of the asteroid.

**Misconception Tip:**
There are many wavelengths of infrared. Only the longest can be detected as temperature. Near infrared is used in remote controls and wireless hardware, and we do not detect this as temperature with our skin.

## What do I need to prepare?

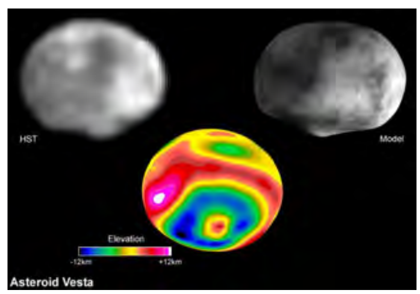
__Asteroid models:__
To make clay scale models of the three largest asteroids in our Solar System, here are some guidelines and examples, scaled to a 1-meter Earth. (Note that these are simply approximations of their appearance because the asteroids have not been seen in fine detail.) Use air-dry clay and non-toxic black and gray paint. Use pens and beads to make craters all over the surface:

__Ceres__ is the largest asteroid and also a dwarf planet. It is spherical and likely very cratered. On this scale, it is 7.3 cm (3 in) in diameter and blacker than asphalt.




Top two images: Hubble

__Vesta__ (middle) and __Pallas__ (lower) are the next largest. They are similar in size but with different shapes and colors. **Vesta** looks like a sphere with an enormous crater smashed out of one side (flattened). Vesta is a light gray color and 4.1 cm (1.6 in) across. **Pallas** probably looks more like a lemon with dents and is the same black as Ceres. It is 4.1 cm on its long side like Vesta.



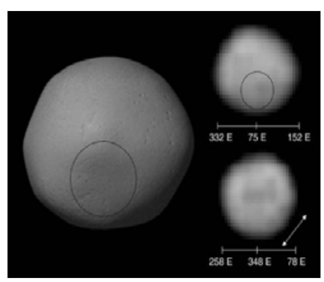



Image: Science / AAAS

## Where do I get additional materials?

1. Air-dry clay can be found at art stores or toy stores. If you can't find black clay, you can paint dried models with non-toxic paints.
2. **Transparency sheets** can be found at office supply stores or copy centers. Be sure to get the type that works with your printer.

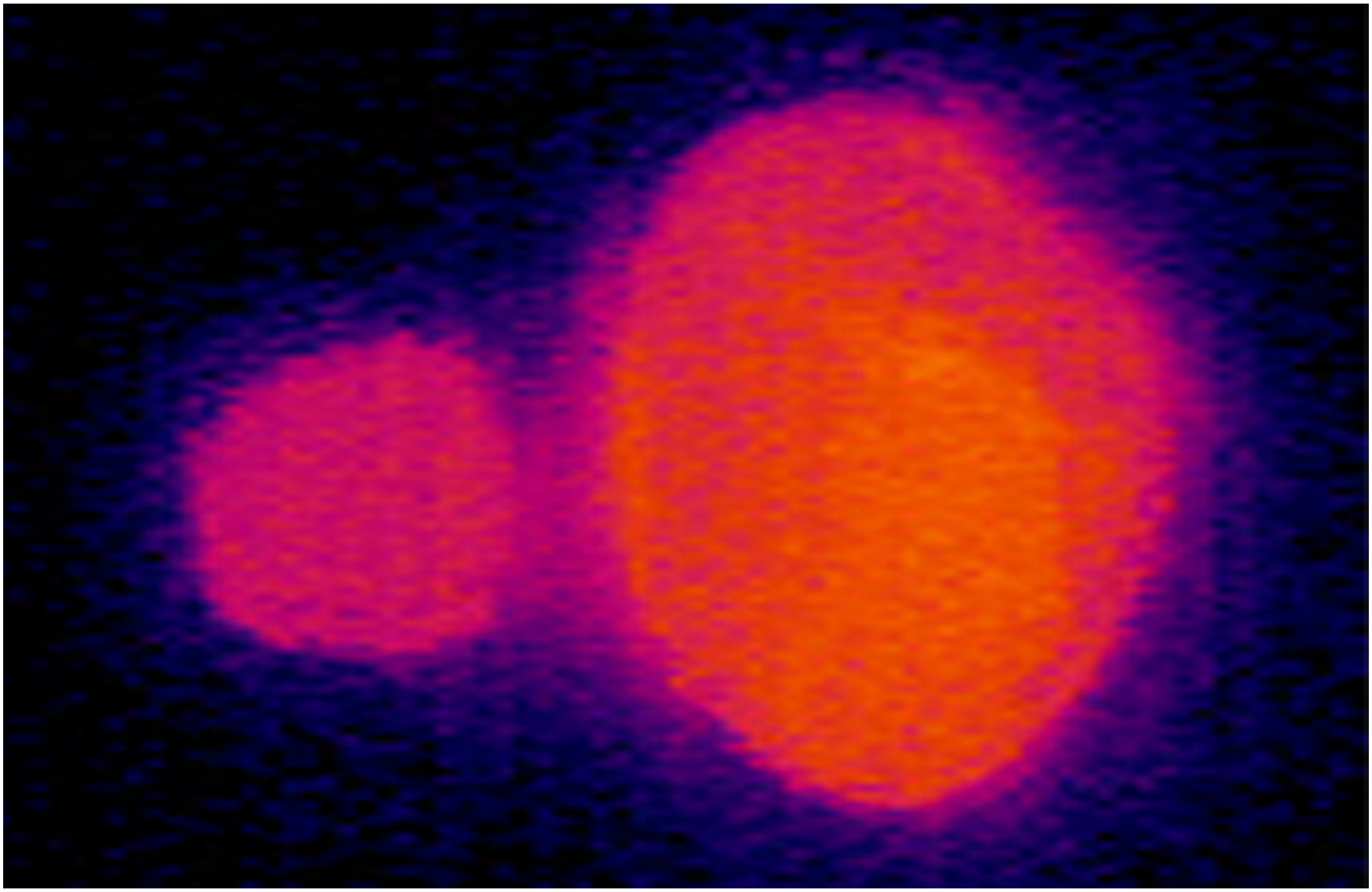


Image Taken at 10pm with an Infrared Camera

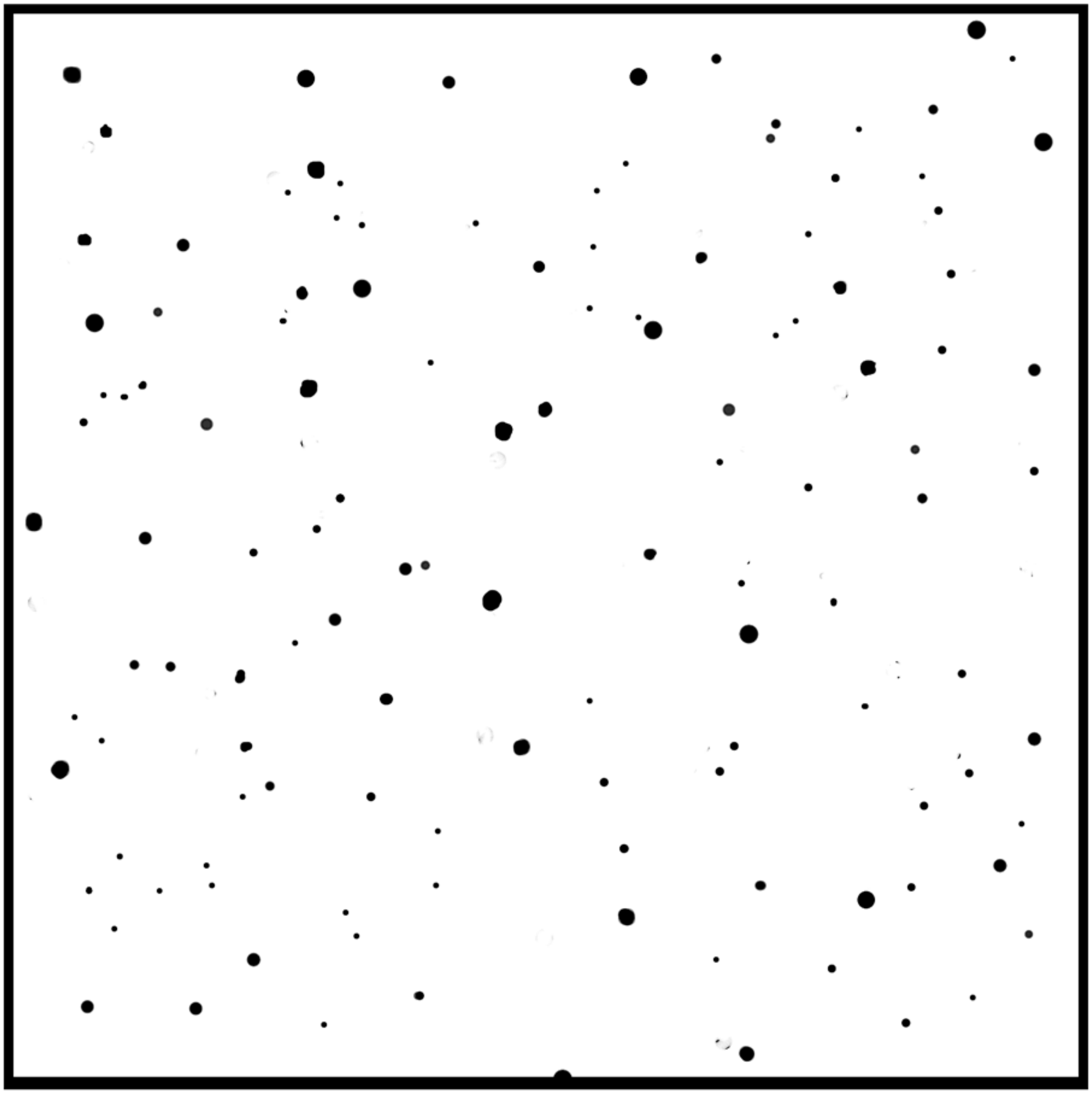


Image Taken at 10pm with a Visible Light Camera

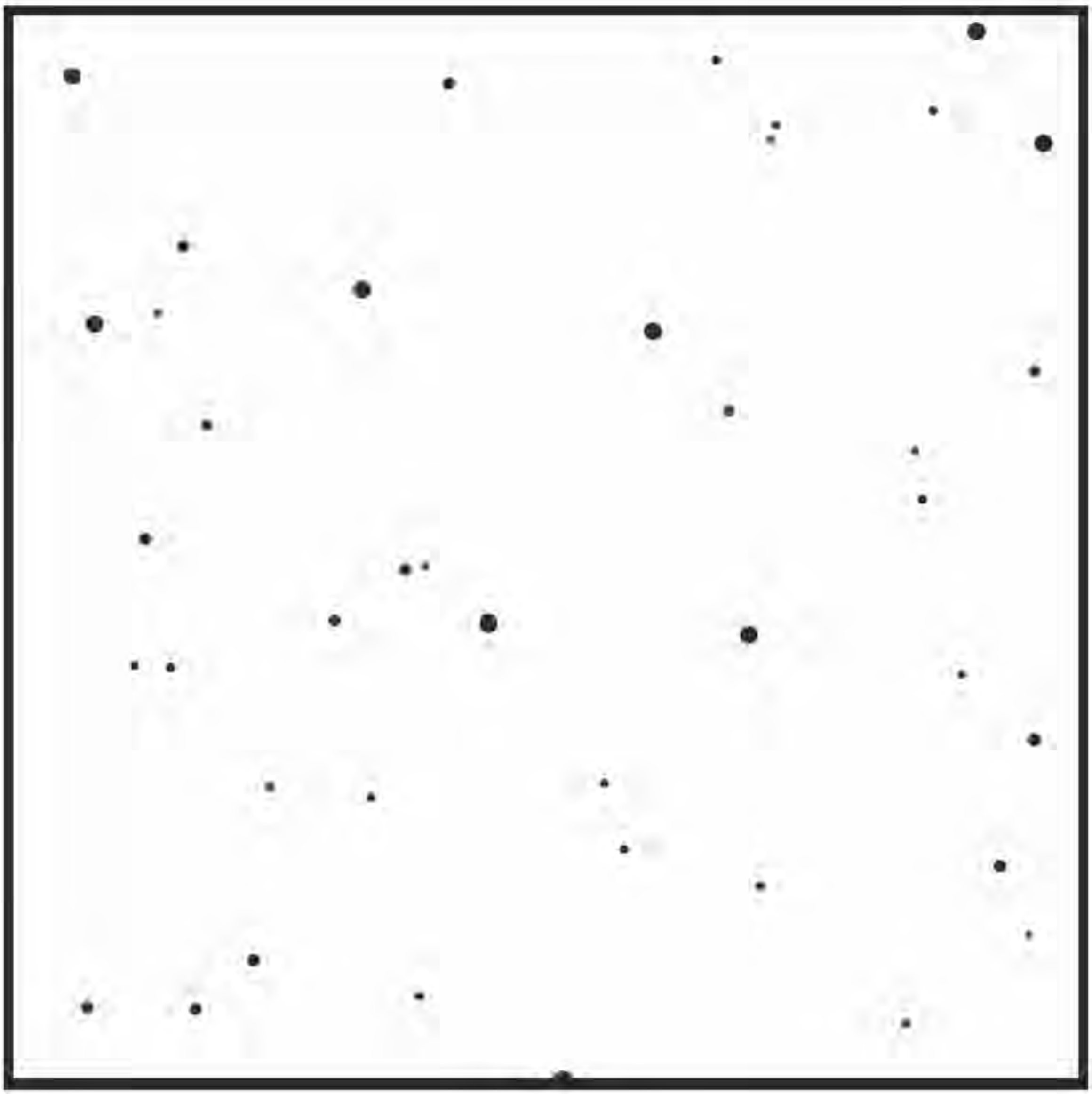


Image Taken at 11pm with an Infrared Camera

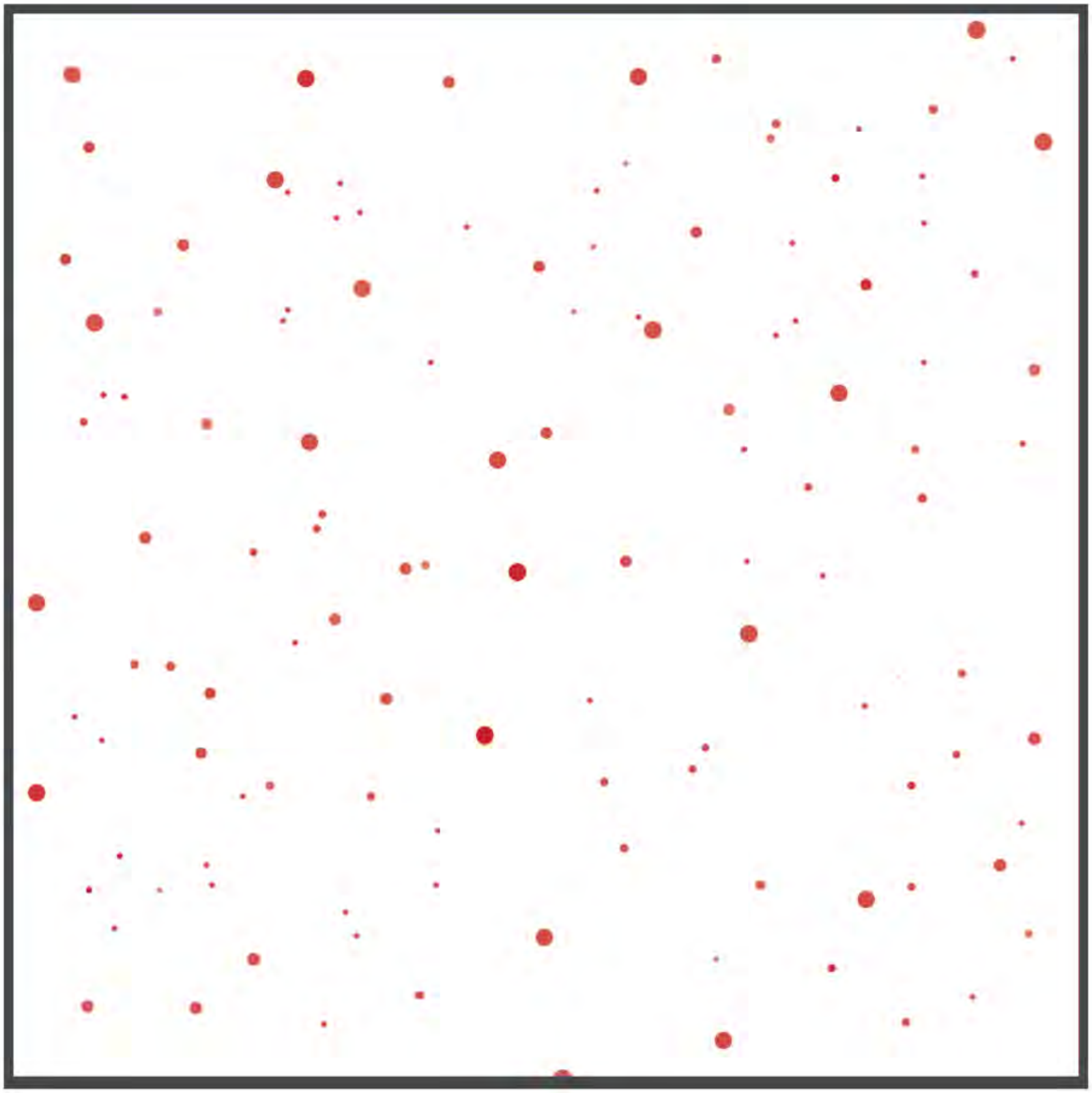


Image Taken at 11pm with a Visible Light Camera