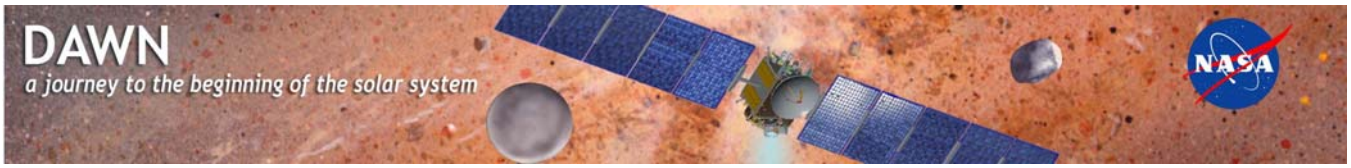


Modern Era of Asteroid Study

In recent years, the study of asteroids has skyrocketed to new heights! Literally. Asteroid studies, dating back to the discovery of asteriod 1 Ceres in 1801, were conducted from the ground using such technology as **telescopes** and **spectroscopes.** These ground-based observations have provided a wealth of information, but by their nature revealed only so much data. Astronomers could see what was on the surface of an asteroid; however, they could not determine the internal composition. Closer observations were needed to confirm ground-based observations and increase our knowledge of asteroids. The development of rocket and spacecraft technologies provided an opportunity to send unmanned or robotic spacecraft to collect this data. Six space missions have planned encounters with asteroids. In three of those missions—Galileo, Deep Space 1 and Stardust—gathering information on asteroids was a secondary mission. The other three missions—NEAR, MUSES-C and Dawn—were designed with the expressed goal of studying asteroids.


NASA

Galileo

Although its primary mission was to explore Jupiter, Galileo was the first NASA mission to observe asteroids close up. In 1991, the Galileo spacecraft crossed paths with the asteroid 951 Gaspra at a distance of 1600 kilometers. Based on images sent back from the spacecraft, scientists have been able to calculate Gaspra's size and age.

Almost two years later in 1993, the Galileo spacecraft sent back images of asteroid 243 Ida taken from a distance of 2,400 kilometers. Scientists learned that Ida is more than twice as big as Gaspra and discovered the first known asteroidal moon, Dactyl. Both Gaspra and Ida are **S-type asteroids**, meaning that that they are comprised of metallic nickel-iron mixed with iron- and magnesium-silicates.


NASA

Deep Space 1

On July 29, 1999, the Deep Space 1 spacecraft encountered asteroid 9969 Braille. In a flyby that came within 26 kilometers of the asteroid, readings from infrared sensors confirmed that the asteroid is similar in composition to the much larger asteroid 4 Vesta. Based on images, scientists confirmed that Braille is an elongated asteroid and irregular in shape. Braille is a **V-type asteroid**, which is similar to the more common S-type but contains more pyroxene. The primary objective of the Deep Space 1 mission was to test advanced technologies that had not been flown in space before, one of which was the ion propulsion system. Ion propulsion allows Dawn to undertake a bold and important mission that would be unaffordable—or perhaps even impossible—with a more conventional propulsion system.

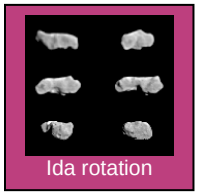
Asteroid Facts by Mission

Galileo

951 Gaspra
- Discovered 1916
- S-type asteroid
- 19 kilometers long
- 12 kilometers wide
- 11 kilometers thick
- 200-500 years old

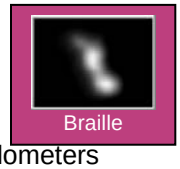

Gaspra

243 Ida
- Discovered 1884
- S-type asteroid
- 58 kilometers long
- 23 kilometers wide
- Moon: Dactyl


Ida rotation

Deep Space 1

9969 Braille
- Discovered 1992
- V-type asteroid
- Irregular shape
- Longest side: 2.2 kilometers


Braille

NEAR Shoemaker

433 Eros
- Discovered 1898
- S-type asteroid
- 33 kilometers long
- 8 kilometers wide
- 8 kilometers thick

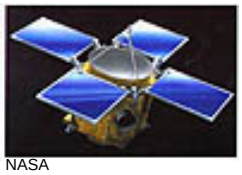

Close-up of Eros

253 Mathilde
- Discovered 1885
- C-type asteroid
- 70 kilometers long
- 50 kilometers wide


Mathilde

NASA/JPL

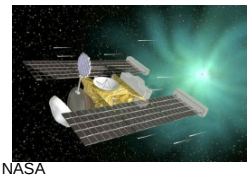
NEAR


NASA

The first NASA mission dedicated to study an asteroid was the Near-Earth Asteroid Rendezvous (NEAR) mission. Launched in 1996, the NEAR Shoemaker spacecraft became the first to orbit and touchdown on an asteroid. The primary objective of the mission was to answer fundamental questions about **S-types asteroids**. On February 14, 2000, the spacecraft began a year-long orbit around asteroid 433 Eros returning the highest resolution images ever made of an asteroid. The spacecraft was renamed NEAR Shoemaker after **Eugene M. Shoemaker**, a geologist who influenced decades of research on the role of asteroids and comments in shaping the planets.

On its way to Eros, the NEAR Shoemaker spacecraft conducted a flyby of asteroid 253 Mathilde. Prior to the encounter, little was known about the asteroid. During the 25-minute flyby, the spacecraft came within 1200 kilometers (745 miles), sending back 500 images of the asteroid. The encounter gave scientists the first close-up look at a **C-type asteroid**, a type of carbon-rich asteroid that is very dark reflecting only 3% - 9% of sunlight. Mathilde is one of the blackest objects in the solar system.

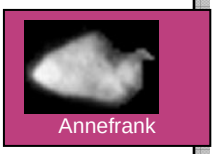
Stardust


NASA

Like Galileo and Deep Space 1, the primary objective of the Stardust mission was not to study asteroids. On its way to rendezvous with its primary target Comet Wild 2, the Stardust spacecraft came within 3,300 kilometers (2,050 miles) of asteroid 5535 Annefrank in November 2002. Mission scientists used this opportunity to test systems and procedures for the comet sample collection and return mission. As a result, they learned that the asteroid was about twice as big and much darker than previously thought.

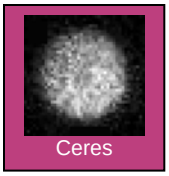
Asteroid Facts by Mission

Stardust
5535 Annefrank


Annefrank

- Discovered 1942
- Irregularly shaped
- 8 kilometers long
- 4 kilometer in diameter

MUSES- C
25413 1998SF36


Ceres

- Discovered 1999

Dawn
1 Ceres

- Discovered 1801
- C-type asteroid
- 960 kilometers long
- 932 kilometers wide

4 Vesta


Vesta

- Discovered 1807
- V-type asteroid
- 530 kilometers in diameter
- Only asteroid ever visible to the unaided eye

NASA/JPL

MUSES-C


JAXA/ISAS

The MUSES-C mission was undertaken by the Japanese Institute of Space and Aeronautical Science. Launched on May 9, 2003, the MUSES-C spacecraft traveled to the asteroid, Itokawa. The main mission objective was to collect asteroid surface samples and return them to Earth for analysis. However, the spacecraft experienced anomalies during its attempts to acquire samples, and mission controllers do not know whether or not it was successful in acquiring a few grains of sample material. The spacecraft was scheduled to return to Earth in 2007, but complications with the MUSES-C spacecraft have delayed its return.

Dawn


NASA

The Dawn mission is scheduled for launch in 2007. The mission objective is to understand the conditions and processes during the earliest era of the solar system. To accomplish this goal, the Dawn spacecraft will visit asteroids 1 Ceres and 4 Vesta. The asteroids are two of the largest **protoplanets** remaining intact since their formation, yet they differ in important ways. Ceres is very primitive and wet, while Vesta is evolved and dry. By observing both **minor**

planets with the same set of instruments, Dawn will provide new answers to questions about the formation and evolution of the early solar system. After launching, the Dawn mission will study Vesta beginning in the fall of 2011, and Ceres beginning in early 2015.

While several hundred thousand asteroids have been identified so far, scientists estimate that there are between 1.1 million and 1.9 million asteroids larger than 1 kilometer in diameter in the main asteroid belt. In many ways asteroids are much harder to study than distant galaxies. Their small size, varying brightness and relatively swift movement make them difficult to track and study. Although there have been relatively few space missions that have provided up-close observations of asteroids, they have yielded important information about their size and composition. The Dawn mission will build upon that science and provide even more data to help scientists unlock the mysteries of the beginning of the solar system.

Additional Resources

http://dawn.jpl.nasa.gov/
Missions to Asteroids: Dawn

http://galileo.jpl.nasa.gov/
Missions to Asteroids: Galileo

http://neo.jpl.nasa.gov/images/vesta.html
Hubble Space Telescope and Keck images of Vesta

http://nmp.jpl.nasa.gov/ds1/
Missions to Asteroids: Deep Space 1

http://nssdc.gsfc.nasa.gov/planetary/factsheet/asteroidfact.html
Asteroid Fact Sheet

http://nssdc.gsfc.nasa.gov/planetary/near.html
Missions to Asteroids: NEAR

http://www.muses-c.isas.ac.jp/
Missions to Asteroids: MUSES-C

http://stardust.jpl.nasa.gov/
Missions to Comets: Stardust

http://www.solarviews.com/cap/ast/vesta.htm
Animation of Vesta rotation

Print Resources

McSween, H.Y. (1999). *Meteorites and their parent planets***.** Cambridge; NY: Cambridge University Press.

Peebles, C. (2000). *Asteroids: A history*. Washington, DC: Smithsonian Institution Press.

Roth, G.D., (1962). *The system of minor planet*. Princeton, NJ: Company Inc.