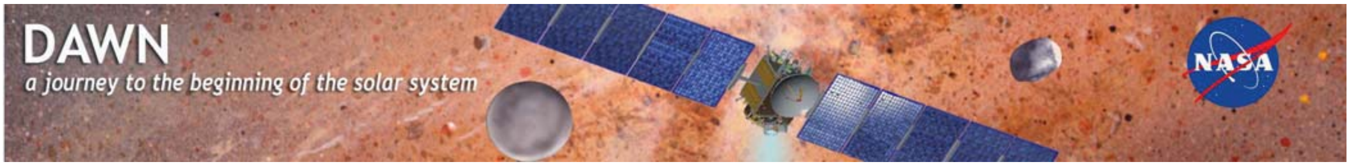
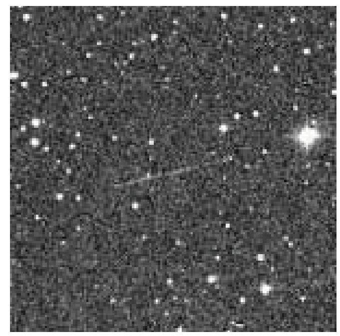


What CAN You See With a Telescope?

The four principal asteroids—Ceres, Pallas, Juno, and Vesta— were discovered between 1801 and 1807. No additional asteroids were found until 1845—almost forty years later—even though groups of amateur and professional astronomers designed special sky-mapping projects to search for them.

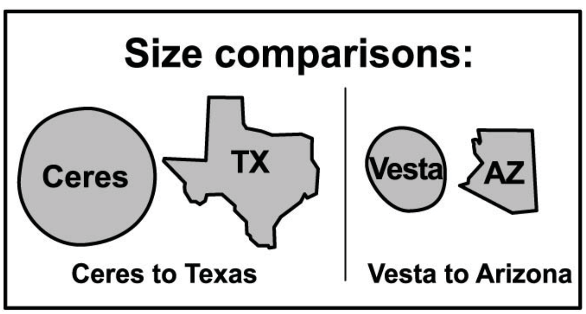
A Lull in Asteroid Discovery

Why were no new asteroids found during this period? Simply put, most of them were too small and too dim to be easily observed through the early 19th-century telescopes. Remember that many of the early asteroid discoverers were amateur astronomers using very modest equipment. Even the largest telescopes were not big enough to find asteroids that were much smaller and/or dimmer than the four principal asteroids that had already been found. Even when the four largest asteroids were seen through those telescopes, they appeared only as points of reflected sunlight. They looked very much like the countless stars around them, except that they moved. If you want to experience the difficulty of searching for a moving point of light in a sky full of stars, try out the “In Search Of…” activity.



Can you find the asteroid amidst all these stars? The faint streak in the center is the trail left by a moving asteroid. This one, captured by the Palomar Digital Sky Survey, is asteroid 1999 AN10.

Size a Factor in Asteroid Discovery



Ceres, the largest asteroid, measures about 975 km at its longest axis. Pallas’ longest axis is about 574 km. Vesta is about half the size of Ceres, with its longest axis measuring about 560 km. Juno is the smallest of the principal four; its longest axis is approximately 234 km.

In 1802, William Herschel attempted to measure the size of Ceres and Pallas by looking at the asteroids through a telescope with one eye and comparing them to a small disk of a known size at a given distance. Herschel’s estimated values of 259 km for Ceres and 236 km for Pallas were considerably smaller than the modern measurements given above.

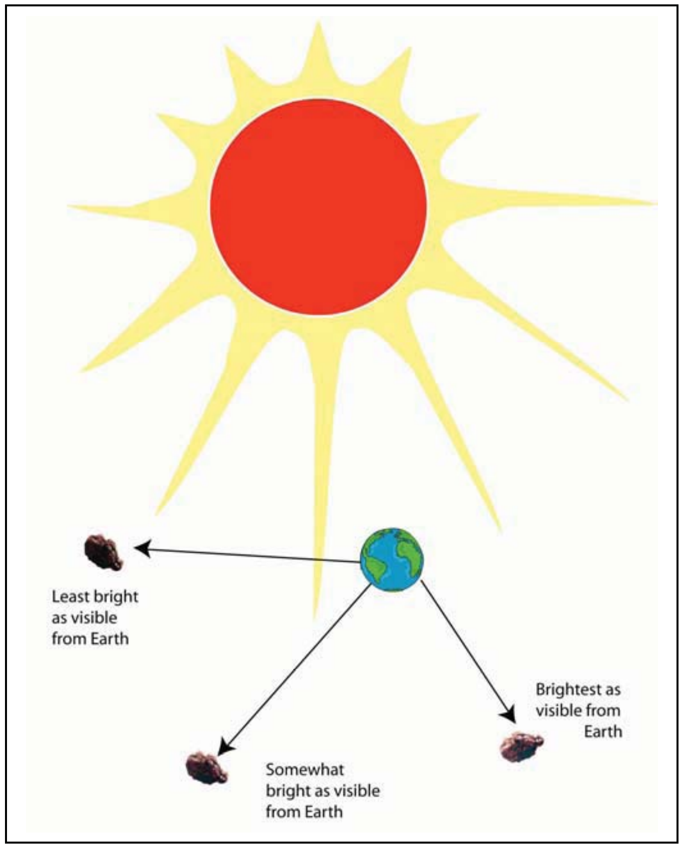
Most of the asteroids discovered between 1845 and 1890 ranged in size between 80 and 130 km, much smaller than the principal four. Hygeia, found in 1849, is an exception, with a diameter of about 410 km, but it is dimmer than any of the principal four. To date a total of only about 30 asteroids with diameters greater than 200 km have been found. It is estimated that there are 250 asteroids larger than 100 km in diameter and perhaps 1,000,000 with diameters greater than 1 km.

Asteroid Brightness—Another Factor to Consider

So, the size of the vast majority of asteroids is quite small, but that is not the whole story. An asteroid's brightness varies according to its orbital position and its *distance* from Earth. It also depends on the nature of the surface material, whether it reflects a significant portion of sunlight or absorbs most of it. The property describing this nature is called **albedo**. Another factor is the shape of the object. An asteroid with an irregular shape will have a variable brightness that depends on which part of the surface or face of the object is facing the viewer and is illuminated by the sun.

The table below shows the *brightest* attainable **magnitude** for the first ten asteroids, which is usually during "**opposition**" (see illustration to the right); that is, when the asteroid is opposite the sun as seen from Earth. Brightness is measured on a scale in which the larger the value of an asteroid's brightness, the dimmer the asteroid appears to an observer on Earth.

- Ceres is about twice the size of Vesta.
- Vesta, with a **semi-major orbital axis** (SMA) of 2.36 **AU** orbits slightly closer to the Earth than does Ceres, whose SMA is 2.77 AU.
- Vesta's surface **albedo** is 0.42, which means that it reflects four times more light than Ceres' surface with an **albedo** of 0.09.



Asteroid Number	Year of Discovery	Asteroid Name	Brightest magnitude through 2016	Asteroid Number	Year of Discovery	Asteroid Name	Brightest magnitude through 2016
1	1801	Ceres	6.8	6	1847	Hebe	7.7
2	1802	Pallas	7.0	7	1847	Iris	6.8
3	1804	Juno	7.6	8	1847	Flora	8.5
4	1807	Vesta	5.4	9	1848	Metis	8.4
5	1845	Astraea	8.7	10	1849	Hygeia	9.1

Asteroids are now numbered in the order in which they were discovered, so you can see that the relative brightness of the principal asteroids, 1 Ceres through 4 Vesta, may have been a factor in their early discovery. Even 1 Ceres, the brightest asteroid, is only a moderately bright star when seen through a telescope. The brightness of most asteroids is below the 10th magnitude, so they look like faint stars.

To put these asteroid brightness measurements into perspective, the Sun has an apparent magnitude of -27, the Moon -12, Venus -4, and the brightest stars are –1. An object of approximately the 6th magnitude, like 3 Juno, is barely visible to a person with good eyesight on a clear, moonless night. With a good set of binoculars, one can see objects down to the 10th magnitude. With an 8-inch reflecting telescope an observer can manage to see objects of 14th magnitude on very dark nights. The faintest objects detectable with the largest ground-based telescopes are about magnitude 30.

Rotation Rates Influence Asteroid Brightness

Early astronomers had used their telescopes to measure the **rotation rate** of the Sun and some of the planets. Since the asteroids were thought to be "minor planets," it was assumed that they also rotated on their own axes. In 1810, Schöeter thought he detected a 27-hour rotation rate for 3 Juno, which is about four times the current value of 7.21 hours. An asteroid's rotation rate is determined by measuring the short-period fluctuations or variations in brightness. As an asteroid rotates on its axis, its irregularly-shaped body and the different albedos of its reflecting surfaces cause changes in brightness. For asteroids, these variations are small— as small as a few hundredths to 0.4 of a magnitude—and difficult to detect except under ideal conditions.

So, the only asteroid features that early 19th-century astronomers could observe with their telescopes were dependent upon the brightness and the variations in brightness of their reflected light. And recall, these asteroids appeared only as points of light through the telescopes available during that time period. Obviously, they could not see any surface feature details of even 1 Ceres or 4 Vesta, the largest and the brightest of them all.

Additional Resources

Web Sites

For more information about the history of the brightness scale, go to:
http://www.astro-tom.com/technical_data/magnitude_scale.htm

http://www.astro.uu.se/planet/asteroid/shapes/
This interactive allows the user to rotate irregular-shaped asteroids to see how they would look in 3-D.

Print Resources

Learner, R. (1981). *Astronomy through the telescope*. Van Nostrand Reinhold.

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

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

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

Questions relating to "What Can You See with a Telescope?"

1. How long after Vesta was discovered in 1807 was the next asteroid found? What was its name? Why was there a lull in asteroid discoveries between 1807 and 1845?

2. Compare the apparent magnitude of Astraea and Ceres. Which of these asteroids is the brightest?
3. What factors affect how much sunlight asteroids reflect to observers on Earth?
4. Define albedo, in your own words.
5. In the asteroid names, 1 Ceres and 5 Astraea, what do the numbers stand for?
6. Hershel attempted to measure the size of Ceres and Pallas. Schröeter tried to measure the rotation rate of Juno. How accurate were these early measurements?
7. One person tells you that it is a long way to the next large city. Another person says that it is 150 miles to the next large city. Which gives you the most precise information?
8. Why do you think that it is important that astronomers are able to make very precise (also known as quantitative) measurements? What kept the early astronomers from making reliable measurements?
9. What asteroid features could 19th century astronomers observe through their telescopes?