SAMPLE

Worlds Beyond Earth: The Moons of Other Planets

Europa, Titan, Io, Ganymede, and Enceladus

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Of the Solar System's eight planets and its nine most likely dwarf planets, six planets and seven dwarf planets are known to be orbited by at least 468 natural satellites, or moons. At least 19 of them are large enough to be gravitationally rounded; of these, all are covered by a crust of ice except for Earth's Moon and Jupiter's Io.

Several of the largest ones are in hydrostatic equilibrium and would therefore be considered dwarf planets or planets if they were in direct orbit around the Sun and not in their current states (orbiting planets or dwarf planets).

Moons are classed into two separate categories according to their orbits:

regular moons, which have prograde orbits (they orbit in the direction of their planets' rotation) and lie close to the plane of their equators, and irregular moons, whose orbits can be pro- or retrograde (against the direction of their planets' rotation) and often lie at extreme angles to their planets' equators. Irregular moons are probably minor planets that have been captured from surrounding space.

Most irregular moons are less than 10 kilometres (6.2 mi) in diameter. The earliest published discovery of a moon other than Earth's was by Galileo Galilei, who discovered the four Galilean moons orbiting Jupiter in 1610. Over the following three centuries, only a few more moons were discovered.

Missions to other planets in the 1970s, most notably the Voyager 1 and 2 missions, saw a surge in the number of moons detected, and observations since the year 2000, using mostly large, ground-based optical telescopes, have discovered many more, all of which are irregular. Mercury, the smallest and innermost planet, has no moons, or at least none that can be detected to a diameter of 1.6 km (1.0 mi). For a very short time in 1974, Mercury was thought to have a moon.

The numbers run from Jupiter outward, thus I, II, III and IV for Io, Europa, Ganymede, and Callisto respectively.

Tidal dissipation in the Jovian system is still ongoing and Callisto will likely be captured into the resonance in about 1.5 billion years, creating a 1:2:4:8 chain. All four Galilean moons are bright enough to be viewed from Earth without a telescope, if only they could appear farther away from Jupiter.

The outer, irregular moons are thought to have originated from captured asteroids, whereas the proto-lunar disk was still massive enough to absorb much of their momentum and thus capture them into orbit. Many are believed

to have been broken up by mechanical stresses during capture, or afterward by collisions with other small bodies, producing the moons we see today.

From the start to end of these CCD-based surveys in 2000-2004, Jupiter's known moon count had grown from 17 to 63. All of these moons discovered after 2000 are faint and tiny, with apparent magnitudes between 22-23 and diameters less than 10 km (6.2 mi).

Chapter 01: The Discovery of The Moons of Other Planets

Venus also has no moons, though reports of a moon around Venus have circulated since the 17th century. Earth has one known Moon, the largest moon of any rocky planet in the Solar System and the largest body typically described as a moon that orbits anything in hydrostatic equilibrium in relation to the primary object by mass and diameter other than Charon and Pluto.

Earth also has more than 20 known co-orbitals, including the asteroids 3753 Cruithne and 469219 Kamooalewa, and the occasional temporary satellite, like 2020 CD3; however, since they do not permanently orbit Earth, they are not considered moons.

Searches for additional satellites have been unsuccessful, putting the maximum radius of any other satellites at 90 m (100 yd). Jupiter has 115 moons with known orbits announced; 73 of them have received permanent designations, and 57 have been named. Its eight regular moons are grouped into the planet-sized Galilean moons and the far smaller Amalthea group. They were named after lovers of Zeus, the Greek equivalent of Jupiter. Among them is Ganymede, the biggest and heaviest moon anywhere in the Sun's family.

The rest are irregular moons, which are organized into two categories: prograde and retrograde. The prograde satellites consist of the Himalia group and three others in groups of one. The retrograde moons are grouped into the Carme, Ananke and Pasiphae groups. Saturn has 293 moons with known orbits announced; 67 of them have received permanent designations, and 63 have been named. Most of them are quite small.

Seven moons are large enough to be in hydrostatic equilibrium, including Titan, which trails only Ganymede in size among the Sun's moons. Including these large moons, 25 of Saturn's moons are regular, and traditionally named after Titans or other figures associated with the mythological Saturn. The remaining moons are irregular, and classified by their orbital characteristics into Inuit, Norse, and Gallic groups, and their names are chosen from the corresponding mythologies the groups are named after.

The rings of Saturn are made up of icy objects ranging in size from one centimetre to hundreds of metres, each of which is on its own orbit about the planet. Thus, a precise number of Saturnian moons cannot be given, as there is no objective boundary between the countless small anonymous objects that form Saturn's ring system and the larger objects that have been named as moons.

At least 150 "moonlets" embedded in the rings have been detected by the disturbance they create in the surrounding ring material, though this is thought to be only a small sample of the total population of such objects. Uranus has 29 known moons announced, five of which are massive enough to have achieved hydrostatic equilibrium. There are 14 moons that orbit within Uranus's ring system, and another ten outer irregular moons.

Unlike most planetary moons, which are named from antiquity, every moon of Uranus takes its name from Shakespeare's plays or from Alexander Pope's The Rape of the Lock. Neptune has 16 known moons announced; the largest, Triton, accounts for more than 99.5 percent of all the mass orbiting the planet. Triton is large enough to have achieved hydrostatic equilibrium, but, uniquely for a large moon, has a retrograde orbit, suggesting it was a dwarf planet that was captured.

Neptune also has seven known inner regular satellites, and eight outer irregular satellites. Pluto, a dwarf planet, is confirmed to have five moons. Its largest moon Charon, named after the ferryman who took souls across the River Styx, is more than half as large as Pluto itself, and large enough to orbit a point outside Pluto's surface. In effect, each orbits the other, forming a binary system informally referred to as a double-dwarf-planet.

Pluto's four other moons, Nix, Hydra, Kerberos and Styx are far smaller and orbit the Pluto-Charon system. Among the other dwarf planets, Ceres has no known moons. It is 90 percent certain that Ceres has no moons larger than 1 km in size, assuming that they would have the same albedo as Ceres itself. Eris has one large known moon, Dysnomia. Accurately determining its size is difficult: one indicative estimate of its radius is 350 +/- 57.5 km.

Two objects were named as dwarf planets, under the expectation that they would prove to be so (though this remains uncertain). Haumea has two moons, Hiiaka and Namaka, of radii ~195 and ~100 km, respectively. Makemake has one moon, announced in April 2016. A number of other objects in the Kuiper belt and scattered disk may turn out to be dwarf planets. Orcus, Quaoar, Gonggong, and Sedna are generally agreed to be dwarf planets among astronomers, and all but Sedna are known to have moons.

A number of other smaller objects, such as Huya, Salacia, Uni, Varda, and Chiminigagua, also have moons, although their dwarf planethood is more doubtful. As of November 2025, 471 asteroid moons and 149 trans-Neptunian moons (including those of Pluto and the other dwarf planets) had been discovered. Due to Earth's varying distance from these planets (as well as their distance to the Sun), the limits at which we are able to detect new moons are very inconsistent.

Several different suggestions were made for names of Jupiter's outer satellites, but none were universally accepted until 1975 when the International Astronomical Union's (IAU) Task Group for Outer Solar System Nomenclature granted names to satellites V-XIII, and provided for a formal naming process for future satellites still to be discovered.

The colors also vary significantly, from red to grey, which might be the result of multiple collisions. Sinope, sometimes included in the Pasiphae group, is red and, given the difference in inclination, it could have been captured independently; Pasiphae and Sinope are also trapped in secular resonances with Jupiter.

Its most prominent features are a large (400 km diameter) impact crater named Odysseus on its leading hemisphere and a vast canyon system named Ithaca Chasma extending at least 270 degrees around Tethys. The Ithaca Chasma is concentric with Odysseus, and these two features may be related. Tethys appears to have no current geological activity. A heavily cratered hilly terrain occupies the majority of its surface, while a smaller and smoother plains region lies on the hemisphere opposite to that of Odysseus.

The plains contain fewer craters and are apparently younger. A sharp boundary separates them from the cratered terrain. There is also a system of extensional troughs radiating away from Odysseus. The density of Tethys (0.985 g/cm3) is less than that of water, indicating that it is made mainly of water ice with only a small fraction of rock.

Dione is the fourth-largest moon of Saturn. It has a higher density than the geologically dead Rhea, but lower than that of active Enceladus.

While the majority of Dione's surface is heavily cratered old terrain, this moon is also covered with an extensive network of troughs and lineaments, indicating that in the past it had global tectonic activity. The troughs and lineaments are especially prominent on the trailing hemisphere, where several intersecting sets of fractures form what is called "wispy terrain". The cratered plains have a few large impact craters reaching 250 km in diameter.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.