= Galilean moons =

The Galilean moons are the four largest moons of Jupiter ? Io , Europa , Ganymede , and Callisto . They were discovered by Galileo Galilei around January 1610 and were the first group of objects found to orbit another planet . Their names derive from the lovers of Zeus . They are among the largest objects in the Solar System with the exception of the Sun and the eight planets , with radii larger than any of the dwarf planets . Ganymede is the largest moon in the Solar System , and is even bigger than the planet Mercury . The three inner moons ? Io , Europa , and Ganymede ? are in a 4 : 2 : 1 orbital resonance with each other .

The Galilean moons were discovered in either 1609 or 1610 when Galileo made improvements to his telescope , which enabled him to observe celestial bodies more distinctly than ever . Galileo 's discovery showed the importance of the telescope as a tool for astronomers by proving that there were objects in space that cannot be seen by the naked eye . More importantly , the incontrovertible discovery of celestial bodies orbiting something other than Earth dealt a serious blow to the then @-@ accepted Ptolemaic world system , or the geocentric theory in which everything orbits around Earth .

Galileo initially named his discovery the Cosmica Sidera (" Cosimo 's stars ") , but the names that eventually prevailed were chosen by Simon Marius . Marius discovered the moons independently at the same time as Galileo , and gave them their present names , which were suggested by Johannes Kepler , in his Mundus Jovialis , published in 1614 .

= = History = =

= = = Discovery = = =

As a result of improvements Galileo Galilei made to the telescope , with a magnifying capability of 20 × , he was able to see celestial bodies more distinctly than was ever possible before . This allowed Galilei to discover in either December 1609 or January 1610 what came to be known as the Galilean moons .

On January 7 , 1610 , Galileo wrote a letter containing the first mention of Jupiter 's moons . At the time , he saw only three of them , and he believed them to be fixed stars near Jupiter . He continued to observe these celestial orbs from January 8 to March 2 , 1610 . In these observations , he discovered a fourth body , and also observed that the four were not fixed stars , but rather were orbiting Jupiter .

Galileo 's discovery proved the importance of the telescope as a tool for astronomers by showing that there were objects in space to be discovered that until then had remained unseen by the naked eye . More importantly , the discovery of celestial bodies orbiting something other than Earth dealt a blow to the then @-@ accepted Ptolemaic world system , which held that Earth was at the center of the universe and all other celestial bodies revolved around it . Galileo 's Sidereus Nuncius (Starry Messenger) , which announced celestial observations through his telescope , does not explicitly mention Copernican heliocentrism , a theory that placed the Sun at the center of the universe . Nevertheless , Galileo accepted the Copernican theory .

A Chinese historian of astronomy , Xi Zezong , has claimed that a " small reddish star " observed near Jupiter in 362 BCE by Chinese astronomer Gan De may have been Ganymede , predating Galileo 's discovery by around two millennia .

= = = Dedication to the Medicis = = =

In 1605 , Galileo had been employed as a mathematics tutor for Cosimo de ' Medici . In 1609 , Cosimo became Grand Duke Cosimo II of Tuscany . Galileo , seeking patronage from his now @-@ wealthy former student and his powerful family , used the discovery of Jupiter 's moons to gain it . On February 13 , 1610 , Galileo wrote to the Grand Duke 's secretary :

" God graced me with being able , through such a singular sign , to reveal to my Lord my devotion and the desire I have that his glorious name live as equal among the stars , and since it is up to me , the first discoverer , to name these new planets , I wish , in imitation of the great sages who placed the most excellent heroes of that age among the stars , to inscribe these with the name of the Most Serene Grand Duke . "

Galileo asked whether he should name the moons the " Cosmian Stars " , after Cosimo alone , or the " Medician Stars " , which would honor all four brothers in the Medici clan . The secretary replied that the latter name would be best .

On March 12 , 1610 , Galileo wrote his dedicatory letter to the Duke of Tuscany , and the next day sent a copy to the Grand Duke , hoping to obtain the Grand Duke 's support as quickly as possible . On March 19 , he sent the telescope he had used to first view Jupiter 's moons to the Grand Duke , along with an official copy of Sidereus Nuncius (The Starry Messenger) that , following the secretary 's advice , named the four moons the Medician Stars . In his dedicatory introduction , Galileo wrote :

Scarcely have the immortal graces of your soul begun to shine forth on earth than bright stars offer themselves in the heavens which , like tongues , will speak of and celebrate your most excellent virtues for all time . Behold , therefore , four stars reserved for your illustrious name ... which ... make their journeys and orbits with a marvelous speed around the star of Jupiter ... like children of the same family ... Indeed , it appears the Maker of the Stars himself , by clear arguments , admonished me to call these new planets by the illustrious name of Your Highness before all others .

= = = Name = = =

Galileo initially called his discovery the Cosmica Sidera (" Cosimo 's stars ") , in honour of Cosimo II de ' Medici (1590 ? 1621) . At Cosimo 's suggestion , Galileo changed the name to Medicea Sidera (" the Medician stars ") , honouring all four Medici brothers (Cosimo , Francesco , Carlo , and Lorenzo) . The discovery was announced in the Sidereus Nuncius (" Starry Messenger ") , published in Venice in March 1610 , less than two months after the first observations .

Other names put forward include :

I. Principharus (for the " prince " of Tuscany) , II . Victripharus (after Vittoria della Rovere) , III . Cosmipharus (after Cosimo de ' Medici) and IV . Fernipharus (after Duke Ferdinando de ' Medici) ? by Giovanni Battista Hodierna , a disciple of Galileo and author of the first ephemerides (Medicaeorum Ephemerides , 1656) ;

Circulatores Jovis , or Jovis Comites ? by Johannes Hevelius ;

Gardes , or Satellites (from the Latin satelles , satellitis , meaning " escorts ") ? by Jacques Ozanam .

The names that eventually prevailed were chosen by Simon Marius , who discovered the moons independently at the same time as Galileo : he named them at the suggestion of Johannes Kepler after lovers of the god Zeus (the Greek equivalent of Jupiter) : Io , Europa , Ganymede and Callisto , in his Mundus Jovialis , published in 1614 .

Galileo steadfastly refused to use Marius ' names and invented as a result the numbering scheme that is still used nowadays , in parallel with proper moon names . The numbers run from Jupiter outward , thus I , II , III and IV for Io , Europa , Ganymede , and Callisto respectively . Galileo used this system in his notebooks but never actually published it . The numbered names (Jupiter x) were used until the mid @-@ 20th century when other inner moons were discovered , and Marius ' names became widely used .

= = = Determination of longitude = = =

Galileo was able to develop a method of determining longitude based on the timing of the orbits of the Galilean moons . The times of the eclipses of the moons could be precisely calculated in advance , and compared with local observations on land or on ship to determine the local time and

hence longitude . The main problem with the technique was that it was difficult to observe the Galilean moons through a telescope on a moving ship ; a problem that Galileo tried to solve with the invention of the celatone . The method was used by Cassini and Picard to re @-@ map France .

= = Members = =

Some models predict that there may have been several generations of Galilean satellites in Jupiter 's early history . Each generation of moons to have formed would have spiraled into Jupiter and been destroyed , due to tidal interactions with Jupiter 's proto @-@ satellite disk , with new moons forming from the remaining debris . By the time the present generation formed , the gas in the proto @-@ satellite disk had thinned out to the point that it no longer greatly interfered with the moons ' orbits . Other models suggest that Galilean satellites formed in a proto @-@ satellite disk , in which formation timescales were comparable to or shorter than orbital migration timescales . Io is anhydrous and likely has an interior of rock and metal . Europa is thought to contain 8 % ice and water by mass with the remainder rock . These moons are , in increasing order of distance from Jupiter :

= = = Io = = =

Io is the innermost of the four Galilean moons of Jupiter and , with a diameter of 3 @,@ 642 kilometers , the fourth @-@ largest moon in the Solar System . It was named after Io , a priestess of Hera who became one of the lovers of Zeus . Nevertheless , it was simply referred to as " Jupiter I " , or " The first satellite of Jupiter " , until the mid @-@ 20th century .

With over 400 active volcanos , Io is the most geologically active object in the Solar System . Its surface is dotted with more than 100 mountains , some of which are taller than Earth 's Mount Everest . Unlike most satellites in the outer Solar System (which have a thick coating of ice) , Io is primarily composed of silicate rock surrounding a molten iron or iron sulfide core .

Although not proven , recent data from the Galileo orbiter indicate that Io might have its own magnetic field . Io has an extremely thin atmosphere made up mostly of sulfur dioxide (SO2) . If a surface data or collection vessel were to land on Io in the future , it would have to be extremely tough (similar to the tank @-@ like bodies of the Soviet Venera landers) to survive the radiation and magnetic fields that originate from Jupiter .

= = = Europa = = =

Europa , the second of the four Galilean moons , is the second closest to Jupiter and the smallest at 3121 @.@ 6 kilometers in diameter , which is slightly smaller than the Moon . The name comes from a mythical Phoenician noblewoman , Europa , who was courted by Zeus and became the queen of Crete , though the name did not become widely used until the mid @-@ 20th century .

It is one of the smoothest objects in the Solar System , with a layer of water surrounding the mantle of the planet , thought to be 100 kilometers thick . The smooth surface includes a layer of ice , while the bottom of the ice is theorized to be liquid water . The apparent youth and smoothness of the surface have led to the hypothesis that a water ocean exists beneath it , which could conceivably serve as an abode for extraterrestrial life . Heat energy from tidal flexing ensures that the ocean remains liquid and drives geological activity . Life may exist in Europa 's under @-@ ice ocean , perhaps subsisting in an environment similar to Earth 's deep @-@ ocean hydrothermal vents or the Antarctic Lake Vostok . Life in such an ocean could possibly be similar to microbial life on Earth in the deep ocean . So far , there is no evidence that life exists on Europa , but the likely presence of liquid water has spurred calls to send a probe there .

The prominent markings that criss @-@ cross the moon seem to be mainly albedo features , which emphasize low topography . There are few craters on Europa because its surface is tectonically active and young . Some theories suggest that Jupiter 's gravity is causing these markings , as one side of Europa is constantly facing Jupiter . Also , volcanic water eruptions splitting the surface of

Europa , and even geysers have been considered as a cause . The color of the markings , reddish @-@ brown , is theorized to be caused by sulfur , but scientists cannot confirm that , because no data collection devices have been sent to Europa . Europa is primarily made of silicate rock and likely has an iron core . It has a tenuous atmosphere composed primarily of oxygen .

= = = Ganymede = = =

Ganymede , the third Galilean moon is named after the mythological Ganymede , cupbearer of the Greek gods and Zeus 's beloved . Ganymede is the largest natural satellite in the Solar System at 5262 @.@ 4 kilometers in diameter , which makes it larger than the planet Mercury ? although only at about half of its mass since Ganymede is an icy world . It is the only satellite in the Solar System known to possess a magnetosphere , likely created through convection within the liquid iron core .

Ganymede is composed primarily of silicate rock and water ice , and a salt @-@ water ocean is believed to exist nearly 200 km below Ganymede 's surface , sandwiched between layers of ice . The metallic core of Ganymede suggests a greater heat at some time in its past than had previously been proposed . The surface is a mix of two types of terrain ? highly cratered dark regions and younger , but still ancient , regions with a large array of grooves and ridges . Ganymede has a high number of craters , but many are gone or barely visible due to its icy crust forming over them . The satellite has a thin oxygen atmosphere that includes O , O2 , and possibly O3 (ozone) , and some atomic hydrogen .

= = = Callisto = = =

Callisto is the fourth and last Galilean moon , and is the second largest of the four , and at 4820 @.@ 6 kilometers in diameter , it is the third largest moon in the Solar System . Callisto was a daughter of the Arkadian King Lykaon and a hunting companion of the goddess Artemis . It does not form part of the orbital resonance that affects three inner Galilean satellites and thus does not experience appreciable tidal heating . Callisto is composed of approximately equal amounts of rock and ices , which makes it the least dense of the Galilean moons . It is one of the most heavily cratered satellites in the Solar System , and one major feature is a basin around 3000 km wide called Valhalla .

Callisto is surrounded by an extremely thin atmosphere composed of carbon dioxide and probably molecular oxygen . Investigation revealed that Callisto may possibly have a subsurface ocean of liquid water at depths greater than 100 kilometers . The likely presence of an ocean within Callisto indicates that it can or could harbor life . However , this is less likely than on nearby Europa . Callisto has long been considered the most suitable place for a human base for future exploration of the Jupiter system since it is furthest from the intense radiation of Jupiter .

= = Comparative structure = =

Fluctuations in the orbits of the moons indicate that their mean density decreases with distance from Jupiter . Callisto , the outermost and least dense of the four , has a density intermediate between ice and rock whereas Io , the innermost and densest moon , has a density intermediate between rock and iron . Callisto has an ancient , heavily @-@ cratered and unaltered ice surface and the way it rotates indicates that its density is equally distributed , suggesting that it has no rocky or metallic core but consists of a homogeneous mix of rock and ice . This may well have been the original structure of all the moons . The rotation of the three inner moons , in contrast , indicates differentiation of their interiors with denser matter at the core and lighter matter above . They also reveal significant alteration of the surface . Ganymede reveals past tectonic movement of the ice surface which required partial melting of subsurface layers . Europa reveals more dynamic and recent movement of this nature , suggesting a thinner ice crust . Finally , Io , the innermost moon , has a sulfur surface , active volcanism and no sign of ice . All this evidence suggests that the nearer a moon is to Jupiter the hotter its interior . The current model is that the moons experience tidal

heating as a result of the gravitational field of Jupiter in inverse proportion to the square of their distance from the giant planet . In all but Callisto this will have melted the interior ice , allowing rock and iron to sink to the interior and water to cover the surface . In Ganymede a thick and solid ice crust then formed . In warmer Europa a thinner more easily broken crust formed . In Io the heating is so extreme that all the rock has melted and water has long ago boiled out into space .

= = = Size = = =

= = = Latest flyby = = =

= = Origin and evolution = =

Jupiter 's regular satellites are believed to have formed from a circumplanetary disk , a ring of accreting gas and solid debris analogous to a protoplanetary disk . They may be the remnants of a score of Galilean @-@ mass satellites that formed early in Jupiter 's history .

Simulations suggest that , while the disk had a relatively high mass at any given moment , over time a substantial fraction (several tenths of a percent) of the mass of Jupiter captured from the Solar nebula was processed through it . However , the disk mass of only 2 % that of Jupiter is required to explain the existing satellites . Thus there may have been several generations of Galilean @-@ mass satellites in Jupiter 's early history . Each generation of moons would have spiraled into Jupiter , due to drag from the disk , with new moons then forming from the new debris captured from the Solar nebula . By the time the present (possibly fifth) generation formed , the disk had thinned out to the point that it no longer greatly interfered with the moons ' orbits . The current Galilean moons were still affected , falling into and being partially protected by an orbital resonance which still exists for Io , Europa , and Ganymede . Ganymede 's larger mass means that it would have migrated inward at a faster rate than Europa or Io .

= = Visibility = =

All four Galilean moons are bright enough that they could be sighted from Earth without a telescope , if they were farther away from Jupiter . (They are , however , easily visible with even low @-@ powered binoculars .) They have apparent magnitudes between 4 @.@ 6 and 5 @.@ 6 when Jupiter is in opposition with the Sun , and are about one unit of magnitude dimmer when Jupiter is in conjunction . The main difficulty in observing the moons from Earth is their proximity to Jupiter since they are obscured by its brightness . The maximum angular separations of the moons are between 2 and 10 minutes of arc from Jupiter , which is close to the limit of human visual acuity . Ganymede and Callisto , at their maximum separation , are the likeliest targets for potential naked @-@ eye observation .