Modern Physics Seminer: Jupiter's Moons

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1 Introduction

Jupiter is the largest planet in the solar system, and it was named after the Roman gods' king.

The gas giant Jupiter is a turbulent enigma, shrouded in colorful clouds and swept beneath rings and moons by fierce winds. Jupiter is massive: it has more than twice the mass of all the other planets in the solar system combined. The Great Red Spot, the planet's largest and most famous storm, is twice the size of Earth.

Jupiter's massive magnetic field is the strongest of all the planets in the solar system, measuring about 20,000 times that of Earth. The planet's magnetic field traps electrons and other electrically charged particles in an intense belt that blasts the planet's moons and rings with radiation that is 1,000 times fatal to humans on a regular basis. Even extensively insulated spacecraft, such as NASA's Galileo probe, are vulnerable to the radiation. Jupiter's magnetosphere swells to a diameter of 600,000 to 2 million miles (1 million to 3 million kilometers) as it approaches the sun, then tapers to a tail of more than 600 million miles (1 billion kilometers) behind the huge planet.

Jupiter has 80 known moons, not including a handful of moonlets that are presumably shed from the inner moons. They form a satellite system known as the Jovian system when they are all combined. The four Galilean moons: Io, Europa, Ganymede, and Callisto, which were discovered independently in 1610 by Galileo Galilei and Simon Marius and were the first objects identified to orbit a body that was neither Earth nor the Sun, are the most massive of the moons. Hundreds more far smaller Jovian moons have been discovered since 1892, and have been given the names of lovers or daughters of the Roman god Jupiter or his Greek equivalent Zeus. The Galilean moons are by far the largest and most massive objects to orbit Jupiter, with the remaining 76 known moons and the rings together composing just 0.003 percent of the total orbiting mass.

Eight of Jupiter's moons are normal satellites with prograde and nearly circular orbits that are not too inclined with respect to the equatorial plane of Jupiter. Because of their planetary mass, the Galilean satellites are nearly spherical in shape and would be termed dwarf planets if they were in direct orbit around the Sun. The remaining four normal satellites are significantly smaller and closer to Jupiter, and they serve as dust supplies for Jupiter's rings.The remaining moons of Jupiter are irregular satellites with high inclinations and eccentricities and prograde and retrograde orbits that are significantly distant from Jupiter. Jupiter most likely kidnapped these moons from their solar orbits. Twenty-three of the irregular satellites have yet to be given a proper name.

Galileo's discovery of Jupiter's four giant moons, Io, Europa, Ganymede, and Callisto, in 1610, revolutionized our understanding of the universe and our role within it. This was the first time celestial bodies were seen orbiting an object other than Earth, and it was believed that the Earth was not the center of the universe, as Copernicus said.

2 Groups Classification

2.1 Regular satellites

These have prograde and nearly circular orbits of low inclination and are split into two groups:

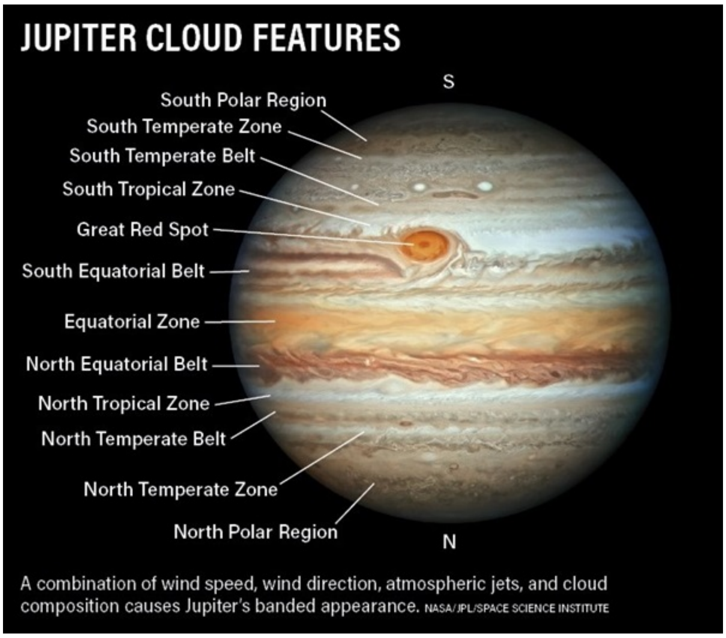

Figure 1: Jupiter's outer Appearances

- Metis, Adrastea, Amalthea, and Thebe are the inner satellites, or Amalthea group. The innermost two orbit in less than a Jovian day, and the outermost two orbit in less than a Jovian day. The latter two are the Jovian system's fifth and seventh biggest moons, respectively. Observations indicate that at least the largest member, Amalthea, formed outside of the planet's current orbit, or that it is a captured Solar System body.[1]Jupiter's weak ring system is replenished and maintained by these moons, as well as a handful of visible and as-yet-unseen inner moonlets (see Amalthea moonlets). Metis and Adrastea contribute to Jupiter's main ring's preservation, whereas Amalthea and Thebe each have their own faint outer rings.[2]

- Io, Europa, Ganymede, and Callisto make comprise the main group of Galilean moons. They are among of the largest objects in the Solar System, larger than any known dwarf planet, outside of the Sun and the eight planets in terms of mass. Even though they are less massive, Ganymede exceeds (and Callisto almost equals) the planet Mercury in diameter.

  They are the Solar System's fourth, sixth, first, and third largest natural satellites, successively containing 99.997 percent of Jupiter's total mass in orbit, despite Jupiter being over 5,000 times more massive than the Galilean moons. The orbital resonance of the inner moons is 1:2:4. Slow accretion in the low-density Jovian subnebula—a disc of gas and dust that remained around Jupiter after its formation—is thought to have generated them, with Callisto lasting up to 10 million years. Subsurface water seas are suspected on Europa, Ganymede, and Callisto, and a subsurface magma ocean is suspected on Io.[3]

2.2 Irregular satellites

The irregular satellites are much smaller and have more distant and eccentric orbits than the regular satellites. They form families with shared orbital (semi-major axis, inclination, eccentricity) and compositional similarities; it is thought that these are at least partially collisional families formed when larger (but still small) parent bodies were shattered by asteroids captured by Jupiter's gravitational field. These families are named for their most prominent members. Satellite families are tentatively identified, however the following are commonly listed:[4][5][6]

- Prograde Satellites:
  - Themisto is the innermost irregular moon and does not belong to any known family of prograde satellites.
  - The Himalia group spans only 1.4 Gm in semi-major axis, 1.6 degrees in inclination (27.5 0.8 degrees), with eccentricities ranging from 0.11 to 0.25. It's been suggested that the group is a fragment of an asteroid that broke apart in the asteroid belt.
  - Carpo is a prograde moon that belongs to no known family. It is the prograde moon with the highest inclination of all the prograde moons.
  - Valetudo is the most farthest prograde moon, with no known family. Its prograde orbit crosses paths with numerous moons on retrograde orbits, and it may collide with them in the future.
- Retrograde satellites:
  - The Carme group spans only 1.2 Gm in semi-major axis, 1.6 degrees in inclination (165.7 0.8°), with eccentricities ranging from 0.23 to 0.27. Its color is quite uniform (light red) and it is thought to have come from a D-type asteroid progenitor, maybe a Jupiter trojan.
  - The Ananke group has a broader range of eccentricities than the previous groups, with a semi-major axis of over 2.4 Gm, an inclination of 8.1° (between 145.7° and 154.8°), and eccentricities ranging from 0.02 to 0.28. The majority of the members are gray in color and are thought to have arisen from the fragmentation of a captured asteroid.
  - With a dispersion of 1.3 Gm, inclinations ranging from 144.5° to 158.3°, and eccentricities ranging from 0.25 to 0.43, the Pasiphae group is widely dispersed. The hues also differ dramatically, ranging from red to grey, maybe due to several accidents. Sinope, which is sometimes included in the Pasiphae group[20], is red and could have been captured independently because to the difference in inclination; both Pasiphae and Sinope are trapped in secular resonances with Jupiter.

3 Galilean Moons

The Galilean satellites have played an influential role in planetary science, from helping to establish the Copernican view of the solar system, to displaying a myriad of physical characteristics and intriguing dynamical and chemical histories. At Jupiter is a satellite system worthy of the term " a mini solar system," whose origin may provide us with insights into planetary formation processes, in particular those involving the growth of gas giant planets.

3.1 Io

Io, often known as Jupiter I, is Jupiter's innermost and third-largest of the four Galilean moons. Io, the fourth-largest moon in the Solar System, is slightly larger than Earth's moon and has the highest density, strongest surface gravity, and lowest proportion of water (by atomic ratio) of any known celestial object in the Solar System. It was named after the mythical heroine Io, a priestess of Hera who became one of Zeus' lovers, and was discovered in 1610 by Galileo Galilei. Io is the most geologically active object in the Solar System, with over 400 active volcanoes.[7] Tidal heating from friction generated within Io's interior as it is dragged between Jupiter and the four Galilean moons—Europa, Ganymede, and Callisto—causes this severe geologic activity. Several volcanoes spew sulfur and sulfur dioxide plumes up to 500 kilometers (300 miles) above the ground. More than 100 mountains dot Io's surface, which have been raised by severe compression near the silicate crust's base. Some of these peaks are higher than Mount Everest, the world's tallest summit. [8] Io is predominantly constructed of silicate rock surrounding a molten iron or iron sulfide core, unlike most moons in the outer Solar System, which are mostly made of water ice. The majority of Io's surface is made up of vast plains covered with a freezing layer of sulfur and sulfur dioxide. Io, along with the other Galilean satellites, was discovered in January 1610 by Galileo Galilei, and its discovery aided the adoption of the Copernican model of the Solar System, the creation of Kepler's equations of motion, and the first measurement of the speed of light. Io was only seen as a point of light from Earth until the late 19th and early 20th centuries, when large-scale surface features such as the dark red polar and brilliant equatorial regions could be resolved. Io was discovered to be a geologically active globe with various volcanic features, massive mountains, and a youthful surface with no evident impact craters by the two Voyager spacecraft in 1979. In the 1990s and early 2000s, the Galileo spacecraft made multiple close flybys of Io, gathering data on its internal structure and surface composition. These probes also discovered a link between Io and Jupiter's magnetosphere, as well as the existence of a high-energy radiation belt centered on Io's orbit. On a daily basis, Io receives roughly 3,600 rem (36 Sv) of ionizing radiation. [9]

3.1.1 Tidel Heating

Io's principal source of interior heat, unlike Earth and the Moon, is tidal dissipation rather than radioactive isotope decay, which is the outcome of Io's orbital resonance with Europa and Ganymede. [10] Io's distance from Jupiter, its orbital eccentricity, the composition of its interior, and its physical state all influence how hot it becomes. Io's eccentricity is maintained by its Laplace resonance with Europa and Ganymede, which prevents tidal dissipation within Io from circularizing its orbit. Io's distance from Jupiter is also maintained by its resonant orbit; otherwise, Jupiter's rising tides would lead Io to drift outward from its parent planet. Io's tidal forces are roughly 20,000 times higher than those experienced by Earth due to the Moon, and the vertical changes in its tidal bulge between periapsis and apoapsis in its orbit could be as much as 100 meters (330 ft). The friction or tidal dissipation created in Io's interior as a result of this variable tidal pull, which would have gone into circularizing Io's orbit if not for the resonant orbit, causes considerable tidal heating, melting a significant portion of Io's mantle and core. The quantity of energy released is up to 200 times larger than that released by radioactive decay alone. [7] Volcanic activity releases this heat, resulting in the observed high heat flow (global total: 0.6 to 1.61014 W).The quantity of tidal heating within Io appears to alter with time, according to orbital models; yet, the current level of tidal dissipation is compatible with the measured heat flux. In tidal heating and convection models, consistent planetary viscosity profiles that match tidal energy dissipation and mantle heat convection to the surface have yet to be discovered. [11] Although it is widely assumed that the source of the heat exhibited in Io's many volcanoes is tidal heating caused by Jupiter and its moon Europa's gravitational pull, the volcanoes are not in the positions expected by tidal heating. They've been pushed to the east by 30 to 60 degrees. According to Tyler et al. (2015), this eastern shift could be driven by an ocean of molten rock beneath the surface. Due to its viscosity, the movement of this magma would generate more heat through friction. The authors of the study believe the deep ocean is made up of molten and solid rock. [12]

3.1.2 Volcanism

Io is the most volcanically active world in the Solar System, with hundreds of volcanic centers and enormous lava flows due to tidal heating caused by its imposed orbital eccentricity. [12]

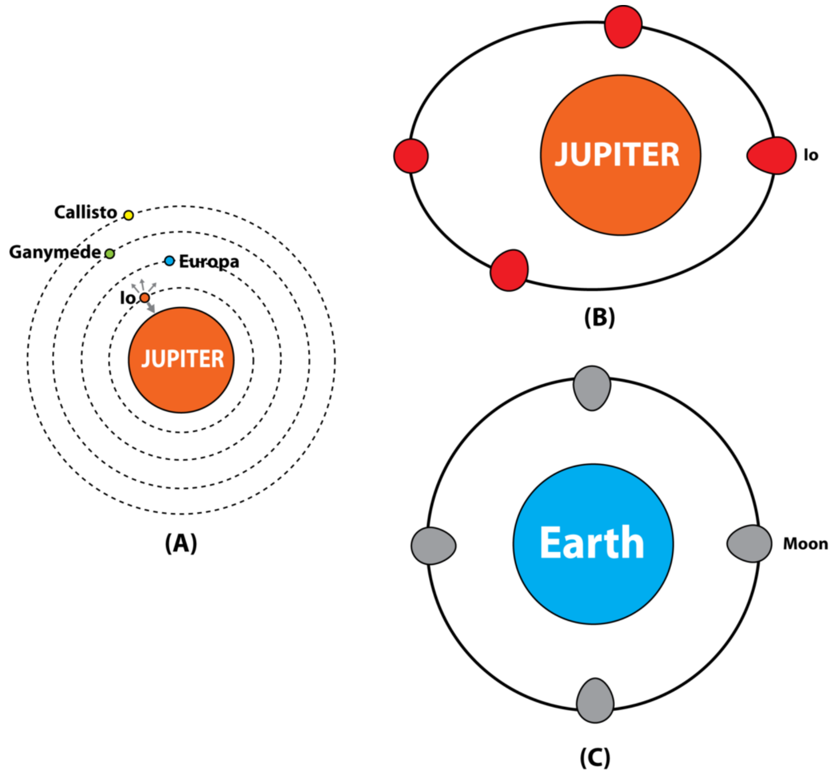

Figure 2: Tidal heating on Io. (A) Of the four major moons of Jupiter, Io is the inner-most one. Gravity from these bodies pull Io in varying directions. (B) Io's eccentric orbit. Io's shape changes as it completes its orbit. (C) Earth's moon's orbit is circular, so the moon's shape doesn't change.

Lava flows tens or even hundreds of kilometers long can be created during a big eruption, and they are mostly made up of basalt silicate lavas with mafic or ultramafic (magnesium-rich) compositions. Sulfur, sulfur dioxide gas, and silicate pyroclastic material (like ash) are blown into space as a by-product of this activity, resulting in large, umbrella-shaped plumes that paint the surrounding terrain red, black, and white and provide material for Io's patchy atmosphere and Jupiter's extensive magnetosphere. The surface of Io is littered with volcanic depressions called paterae, which have flat floors and steep walls. [13] These landforms mimic terrestrial calderas, although it's unclear if they, like their terrestrial cousins, are formed by collapse over an emptied lava chamber. According to one theory, these structures are formed when volcanic sills are exhumed and the overlaying material is either blasted away or incorporated into the sill.Using Galileo photos of the Chaac-Camaxtli region, examples of paterae in various phases of exhumation have been mapped. [105] Unlike analogous structures on Earth and Mars, these depressions are usually larger, with an average diameter of 41 km (25 mi), with Loki Patera being the largest at 202 km (126 mi).[13] Whatever the mechanism of production, the morphology and distribution of many paterae indicate that they are structurally regulated, with at least half of them being limited by faults or mountains. [13] These features are frequently the scene of volcanic eruptions, either in the form of lava flows extending across the paterae's floors, as at Gish Bar Patera in 2001, or as a lava lake. [7] On Io, lava lakes contain either a continually overturning lava crust, like Pele, or an episodically overturning lava crust, like Loki. The first clue that Io is geologically active was the discovery of plumes at the volcanoes Pele and Loki. These plumes develop when volatiles like sulfur and sulfur dioxide are propelled skyward at rates of up to 1 km/s (0.62 mi/s) from Io's volcanoes, forming umbrella-shaped clouds of gas and dust. Sodium, potassium, and chlorine are some of the other elements that could be discovered in these volcanic plumes. There appear to be two ways for these plumes to originate. Io's greatest plumes, like as Pele's, are formed when dissolved sulfur and sulfur dioxide gas are expelled from erupting magma at volcanic vents or lava lakes, trailing silicate pyroclastic material behind them. Another type of plume is produced when encroaching lava flows vaporize underlying sulfur dioxide frost, sending the sulfur skyward. This type of plume often forms bright circular deposits consisting of sulfur dioxide.

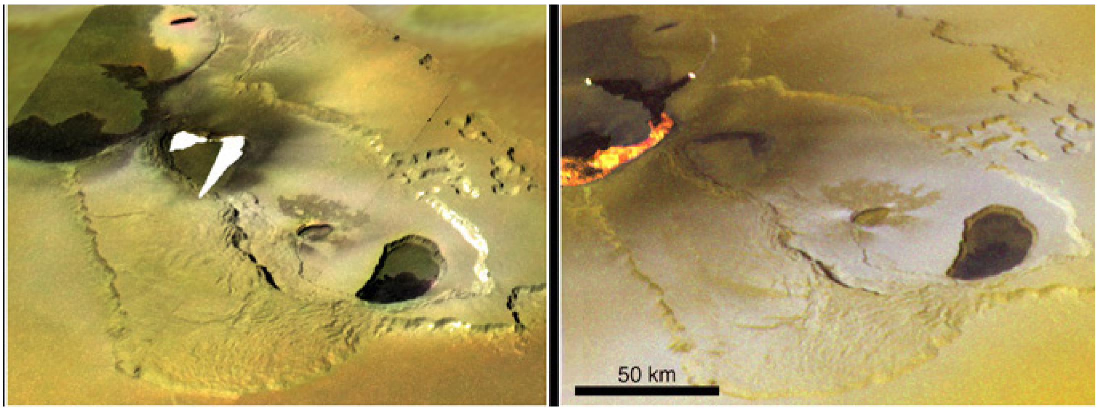

Figure 3: Active lava flows in volcanic region Tvashtar Paterae (blank region represents saturated areas in the original data). Images taken by Galileo in November 1999 and February 2000.

3.2 Europa

Europa, sometimes known as Jupiter II, is the smallest of Jupiter's four Galilean moons and the sixth-closest of the planet's 80 known moons. It is also the Solar System's sixth-largest moon. Galileo Galilei discovered Europa in 1610 and named it after Europa, the Phoenician mother of King Minos of Crete and Zeus' lover (the Greek equivalent of the Roman god Jupiter). Europa is mostly comprised of silicate rock, with a water-ice crust and a likely iron–nickel core. It is somewhat smaller than Earth's Moon. It has a relatively thin atmosphere that is mostly made up of oxygen. Cracks and lines run through its surface, but there are few craters. In addition to views from Earth-bound telescopes, Europa has been studied by a series of space probe flybys, the first of which occurred in the early 1970s. Europa's surface is the smoothest of any solid object in the Solar System. The apparent youth and smoothness of the surface has led to the speculation that there is a water ocean beneath the surface that may potentially support extraterrestrial life. According to the most widely accepted concept, heat from tidal flexing keeps the ocean liquid and drives ice migration in a similar way to plate tectonics, collecting chemicals from the surface and transporting them to the ocean below.[14] Some geological features on Europa may be coated with sea salt from a subterranean ocean, indicating that the ocean is interacting with the sea floor. This could be crucial in deciding whether or not Europa is habitable. Water vapor plumes identical to those seen on Saturn's moon Enceladus, which are assumed to be created by erupting cryogeysers, were also discovered by the Hubble Space Telescope.Based on an updated study of data received from the Galileo space mission, which orbited Jupiter from 1995 to 2003, astronomers revealed corroborating evidence of water plume activity on Europa in May 2018. Without needing to land on the moon, such plume activity could aid researchers in their quest for life in the Europan ocean's deep.[15]

3.2.1 Subsurface Ocean

Scientists agree that beneath Europa's surface there is a layer of liquid water, and that heat from tidal flexing keeps the subsurface ocean liquid.Europa's surface temperature ranges from roughly 110 K (160 °C; 260 °F) near the equator to only 50 K (220 °C; 370 °F) at the poles, ensuring that the icy crust remains as hard as granite. Theoretical calculations of tidal heating (a result of Europa's slightly eccentric orbit and orbital resonance with the other Galilean moons) provided the first signs of a subsurface ocean. Members of the Galileo imaging team use Voyager and Galileo photos to argue for the existence of a subterranean ocean. [16] The most dramatic example is "chaos terrain", a common feature on Europa's surface that some interpret as a region where the subsurface ocean has melted through the icy crust. This interpretation is controversial.

3.2.2 Tidal Heating

Tidal heating occurs through the tidal friction and tidal flexing processes caused by tidal acceleration: orbital and rotational energy are dissipated as heat in the core of the moon, the internal ocean, and the ice crust.[17]

- Tidal Friction:

  Frictional losses in the seas, as well as their interaction with the solid bottom and the top ice crust, convert ocean tides to heat. Jupiter's slight but non-zero obliquity, it was suggested in late 2008, may keep Europa's waters warm by generating massive planetary tidal waves on Europa. This produces so-called Rossby waves, which travel slowly (a few kilometers per day) but generate a lot of kinetic energy. The resonance from Rossby waves would contain 7.31018 J of kinetic energy, which is two thousand times greater than the flow excited by the major tidal forces, based on the present axial tilt estimate of 0.1 degree. The dissipation of this energy could be the ocean's primary source of heat.

- Tidal flexing:

  Europa's interior and ice shell are kneaded by tidal flexing, which creates a source of heat. The heat generated by the ocean flow might be 100 to thousands of times more than the heat generated by Europa's rocky core flexing in reaction to gravitational attraction from Jupiter and the other moons around that planet, depending on the amount of tilt. Europa's bottom could be heated by the moon's ongoing flexing, resulting in hydrothermal activity akin to that of Earth's oceans' undersea volcanoes. [17] Experiments and ice modeling conducted in 2016 show that tidal flexing dissipation generates one order of magnitude more heat in Europa's ice than previously thought. Their findings show that the majority of the heat generated by ice comes from deformation of the crystalline structure (lattice), rather than friction between the ice grains. The more the ice sheet's deformation, the more heat is created.

- Radioactivity:

  In addition to tidal heating, the interior of Europa could also be heated by the decay of radioactive material (radiogenic heating) within the rocky mantle. But the models and values observed are one hundred times higher than those that could be produced by radiogenic heating alone, thus implying that tidal heating has a leading role in Europa.

3.3 Ganymede

The largest and most massive of the Solar System's moons, Ganymede, is a satellite of Jupiter (Jupiter III). It is the Solar System's ninth-biggest object (excluding the Sun) and the largest without a strong atmosphere. It has a diameter of 5,268 kilometers (3,273 miles), making it 26 percent greater in volume than Mercury, although being just 45 percent as massive. It is the only moon known to have a magnetic field and possesses a metallic core, giving it the lowest moment of inertia of any solid body in the Solar System. It's Jupiter's seventh satellite and the third of the Galilean moons, which were the first objects identified orbiting another planet. [18] Ganymede orbits Jupiter in roughly seven days and is in a 1:2:4 orbital resonance with the moons Europa and Io, respectively. Ganymede is made up of silicate rock and water in almost equal proportions. It's a completely differentiated body with an iron-rich liquid core and an interior ocean that might hold more water than all of Earth's oceans put together. There are two basic types of terrain on its surface. About a third of it is covered by dark regions rich in impact craters and dated to four billion years ago. The remainder is covered by lighter sections, which are crosscut by large grooves and ridges and are only somewhat less ancient. The reason of the light terrain's disordered geology is unknown, but tectonic activity caused by tidal heating is possible. The magnetic field of Ganymede is most likely formed by convection within its liquid iron core, which is also influenced by Jupiter's tidal forces. The small magnetic field is buried behind Jupiter's much bigger magnetic field, so it would only show up as a local disruption of the field lines. Ganymede has a thin oxygen atmosphere of O, O2, and possibly O3 molecules (ozone). Atomic hydrogen is a tiny component of the atmosphere. It is unknown whether Ganymede has an ionosphere connected with its atmosphere. [19]

3.3.1 Subsurface oceans

Ganymede contains a thick ocean between two layers of ice, one on the surface and one beneath a liquid ocean and atop the rocky mantle, NASA scientists initially theorized in the 1970s.NASA's Galileo mission flew over Ganymede in the 1990s and discovered evidence of a subterranean ocean. According to a 2014 study that took into account actual water thermodynamics and salt effects, Ganymede might have a stack of ocean layers separated by distinct phases of ice, with the lowest liquid layer adjacent to the rocky mantle. Contact between water and rock could have played a role in the emergence of life. Temperatures at the bottom of a convective (adiabatic) ocean can be up to 40 K higher than those at the ice–water contact due to the enormous depths involved (800 km to the rocky "seafloor"). The Hubble Space Telescope measurements of how the aurora moved in March 2015 revealed that Ganymede had a subterranean ocean, according to scientists. Ganymede's magnetic field and, as a result, its aurora are affected by a vast salt-water ocean. According to research, Ganymede's oceans may be the largest in the Solar System. There has been considerable speculation about Ganymede's ocean's habitability.

3.3.2 Magnetosphere

The Galileo craft made six close flybys of Ganymede from 1995 to 2000 (G1, G2, G7, G8, G28 and G29)and discovered that Ganymede has a permanent (intrinsic) magnetic moment independent of the Jovian magnetic field. The value of the moment is about 1.3 $\times$ 1013 T·m3, which is three times larger than the magnetic moment of Mercury. The magnetic dipole is tilted with respect to the rotational axis of Ganymede by 176°, which means that it is directed against the Jovian magnetic moment. Its north pole lies below the orbital plane. The dipole magnetic field created by this permanent moment has a strength of 719 $\pm$ 2 nT at Ganymede's equator, which should be compared with the Jovian magnetic field at the distance of Ganymede—about 120 nT. The equatorial field of Ganymede is directed against the Jovian field, meaning re-connection is possible. The intrinsic field strength at the poles is two times that at the equator—1440 nT. Ganymede is the only moon in the Solar System known to have a persistent magnetic moment that carves a hole in space around it, creating a miniature magnetosphere nested within Jupiter's. [90] It is 4–5 Ganymede radii in diameter. A zone of closed field lines exists in the Ganymedian magnetosphere below 30° latitude, trapping charged particles (electrons and ions) and forming a radiation belt. Single ionized oxygen—O+is the primary ion species in the magnetosphere, which matches well with Ganymede's scant oxygen atmosphere. Magnetic field lines connect Ganymede to Jupiter's ionosphere at the polar cap areas, at latitudes greater than 30°. Electrons and ions with high energies (tens and hundreds of kiloelectronvolts) have been found in these locations. which may cause the auroras observed around the Ganymedian poles.In addition, heavy ions precipitate continuously on Ganymede's polar surface, sputtering and darkening the ice. The interaction between the Ganymedian magnetosphere and Jovian plasma is in many respects similar to that of the solar wind and Earth's magnetosphere.The plasma co-rotating with Jupiter impinges on the trailing side of the Ganymedian magnetosphere much like the solar wind impinges on the Earth's magnetosphere. The main difference is the speed of plasma flow—supersonic in the case of Earth and subsonic in the case of Ganymede. Because of the subsonic flow, there is no bow shock off the trailing hemisphere of Ganymede. Given that Ganymede is completely differentiated and has a metallic core, its intrinsic magnetic field is probably generated in a similar fashion to the Earth's: as a result of conducting material moving in the interior.[22][77] The magnetic field detected around Ganymede is likely to be caused by compositional convection in the core,if the magnetic field is the product of dynamo action, or magnetoconvection.[19]

3.4 Callisto

Callisto, often known as Jupiter IV, is Jupiter's second-largest moon after Ganymede. It is the Solar System's third-biggest moon, after Ganymede and Saturn's largest moon Titan, and the Solar System's largest object that may not be adequately distinguished. Galileo Galilei found Callisto in 1610. Callisto is nearly 99 percent the diameter of Mercury but only about a third of its mass, with a diameter of 4821 kilometers. With an orbital radius of roughly 1883000 km, it is Jupiter's fourth Galilean moon in terms of distance. It is not in an orbital resonance like the other three Galilean satellites—Io, Europa, and Ganymede—and hence is not tidally heated to a significant degree. [20] The rotation of Callisto is tidally locked to its orbit around Jupiter, ensuring that the same hemisphere faces inward at all times. As a result, Callisto's surface has a sub-Jovian point from which Jupiter appears to hang directly overhead. Because of its more distant orbit, just beyond Jupiter's main radiation belt, it is less influenced by Jupiter's magnetosphere than the other inner satellites. With a density of about 1.83 g/cm3 and the lowest density and surface gravity of Jupiter's major moons, Callisto is composed of almost equal proportions of rock and ices. Water ice, carbon dioxide, silicates, and organic molecules have all been identified spectroscopically on the surface. Callisto may have a tiny silicate core and a subterranean ocean of liquid water at depths larger than 100 kilometers, according to the Galileo mission. Callisto is surrounded by an extremely thin atmosphere composed of carbon dioxide and probably molecular oxygen, as well as by a rather intense ionosphere. Callisto is thought to have formed by slow accretion from the disk of the gas and dust that surrounded Jupiter after its formation. Callisto's gradual accretion and the lack of tidal heating meant that not enough heat was available for rapid differentiation. The slow convection in the interior of Callisto, which commenced soon after formation, led to partial differentiation and possibly to the formation of a subsurface ocean at a depth of 100–150 km and a small, rocky core. The likely presence of an ocean within Callisto leaves open the possibility that it could harbor life. However, conditions are thought to be less favorable than on nearby Europa. Various space probes from Pioneers 10 and 11 to Galileo and Cassini have studied Callisto. Because of its low radiation levels, Callisto has long been considered the most suitable place for a human base for future exploration of the Jovian system.[21]

3.4.1 Orbit and rotation

Callisto is Jupiter's most distant of the four Galilean moons. It orbits at a distance of around 1 880 000 kilometers (26.3 times the 71 492 km radius of Jupiter itself). [3] The orbital radius of the next-closest Galilean satellite, Ganymede, is 1 070 000 km, which is much greater. Callisto does not and probably never has participated in the mean-motion resonance—in which the three inner Galilean satellites are locked—due to its very distant orbit. [20] Callisto's spin, like that of most other normal planetary moons, is synchronized with its orbit. Callisto's day, as well as its orbital period, is around 16.7 Earth days long. Its orbit is slightly eccentric and inclined to the Jovian equator, with the eccentricity and inclination shifting on a timeframe of centuries due to solar and planetary gravitational perturbations. The change ranges are 0.0072–0.0076 degrees and 0.20–0.60 degrees, respectively. [20] The axial tilt (the angle between the rotational and orbital axes) varies between 0.4 and 1.6 degrees as a result of these orbital variations. Because of Callisto's dynamical isolation, it has never been significantly tidally heated, which has important implications for its internal structure and history. [44] Because of its distance from Jupiter, the charged-particle flow from Jupiter's magnetosphere is relatively modest at its surface—about 300 times lower than at Europa, for example. As a result, unlike the other Galilean moons, charged-particle irradiation on Callisto's surface has had only a minimal impact. [11] The radiation level on Callisto's surface is roughly 0.01 rem (0.1 mSv) per day, which is more than ten times higher than the typical background radiation on Earth.

4 Conclusion

Jupiter practically qualifies as a solar system unto itself, with 80 known moons, including four massive moons known as the Galilean satellites. The majority of Jupiter's moons are tiny, with around 60 of them measuring less than 6.2 miles in diameter. The 79th moon was reported in July 2018, While the recently-discovered "EJc0061 = S/2003 J 24," is the last of the known Jovian moons to be found, there could be more, even hundreds of yet undiscovered ones. The majority of the moons were discovered in the late 1970s and later as a consequence of various autonomous spacecraft explorations, including NASA's Voyager and Galileo in 1979 and 1995, respectively. Jupiter is not only the solar system's largest planet, but it's also the most massive, weighing more than 300 times the mass of Earth. Jupiter's size influences the number of moons orbiting it because there is enough gravitational stability around it to host a huge number of moons. Jupiter also has the highest magnetic field of any planet, so anything passing close by, such as an asteroid, is either destroyed or caught into its orbit by gravitational tides. Because Earth lacks the strong gravitational field and mass required to keep another satellite in orbit, it only has one moon. Jupiter's moons have orbital periods that range from seven hours to nearly three Earth years. The orbits of several of Jupiter's moons are almost circular, whereas the orbits of the moons farthest from Jupiter are more irregular. The outer moons orbit Jupiter in the opposite direction of its spin, which is rare and suggests the moons were asteroids dragged into Jupiter's orbit after the initial system formed.

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