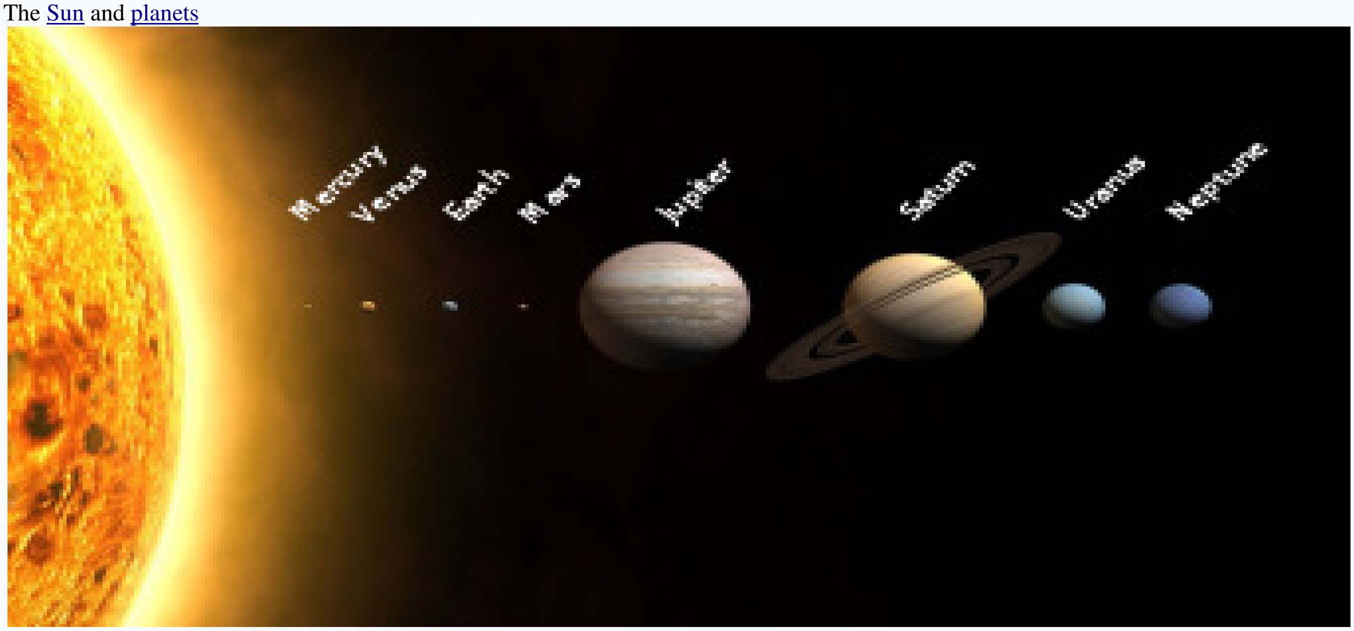
Class XI Geography

Solar System

This article is about the Sun and its planetary system. For other similar systems, see Planetary system.

Solar System

The Sun and planets



(distances not to scale)

Age	4.568 billion years
Location	Local Interstellar Cloud, Local Bubble, Orion–Cygnus Arm, Milky Way
System mass	1.0014 Solar masses
Nearest star	Proxima Centauri (4.25 ly) Alpha Centauri (4.37 ly)
Nearest known planetary system	Proxima Centauri system (4.25 ly)
Planetary system	

Semi-major axis of outer known planet (Neptune)	30.10 AU (4.503 billion km)
Distance to Kuiper cliff	50 AU
Populations	
Stars	1 (Sun)
Known planets	8 (Mercury Venus Earth Mars Jupiter Saturn Uranus Neptune)
Known dwarf planets	Possibly several hundred;[1] five currently recognized by the IAU (Ceres Pluto Haumea Makemake Eris)
Known natural satellites	525 (185 planetary[2] 347 minor planetary[3])
Known minor planets	778,897 (as of 2018-06-21)[4]
Known comets	4,017 (as of 2018-06-21)[4]
Identified rounded satellites	19
Orbit about Galactic Center	
Invariable-to-galactic plane inclination	60.19° (ecliptic)
Distance to Galactic Center	27,000 ± 1,000 ly
Orbital speed	220 km/s
Orbital period	225–250 Myr
Star-related properties	
Spectral type	G2V

Frost line	≈5 AU[5]
Distance to heliopause	≈120 AU
Hill sphere radius	≈1–3 ly

Solar System

The **Solar System**[a] is the gravitationally bound planetary system of the Sun and the objects that orbit it, either directly or indirectly.[b] Of the objects that orbit the Sun directly, the largest are the eight planets,[c]with the remainder being smaller objects, such as the five dwarf planets and small Solar System bodies. Of the objects that orbit the Sun indirectly—the moons—two are larger than the smallest planet, Mercury.[d]

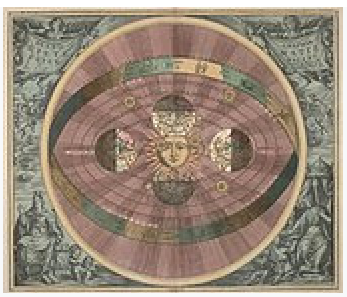
The Solar System formed 4.6 billion years ago from the gravitational collapse of a giant interstellar molecular cloud. The vast majority of the system's mass is in the Sun, with the majority of the remaining mass contained in Jupiter. The four smaller inner planets, Mercury, Venus, Earth and Mars, are terrestrial planets, being primarily composed of rock and metal. The four outer planets are giant planets, being substantially more massive than the terrestrials. The two largest, Jupiter and Saturn, are gas giants, being composed mainly of hydrogen and helium; the two outermost planets, Uranus and Neptune, are ice giants, being composed mostly of substances with relatively high melting points compared with hydrogen and helium, called volatiles, such as water, ammonia and methane. All eight planets have almost circular orbits that lie within a nearly flat disc called the ecliptic.

The Solar System also contains smaller objects.[e] The asteroid belt, which lies between the orbits of Mars and Jupiter, mostly contains objects composed, like the terrestrial planets, of rock and metal. Beyond Neptune's orbit lie the Kuiper belt and scattered disc, which are populations of trans-Neptunian objectscomposed mostly of ices, and beyond them a newly discovered population of sednoids. Within these populations are several dozen to possibly tens of thousands of objects large enough that they have been rounded by their own gravity.[10] Such objects are categorized as dwarf planets. Identified dwarf planets include the asteroid Ceres and the trans-Neptunian objects Pluto and Eris.[e] In addition to these two regions, various other small-body populations, including comets, centaurs and interplanetary dust clouds, freely travel between regions. Six of the planets, at least four of the dwarf planets, and many of the smaller bodies are orbited by natural satellites,[f] usually termed "moons" after the Moon. Each of the outer planets is encircled by planetary rings of dust and other small objects.

The solar wind, a stream of charged particles flowing outwards from the Sun, creates a bubble-like region in the interstellar medium known as the heliosphere. The heliopause is the point at which pressure from the solar wind is equal to the opposing pressure of the interstellar medium; it extends out to the edge of the scattered disc. The Oort cloud, which is thought to be the source for long-period comets, may also exist at a distance roughly a thousand times further than the heliosphere. The Solar System is located in the Orion Arm, 26,000 light-years from the center of the Milky Way galaxy.

Discovery and exploration

Main article: Discovery and exploration of the Solar System

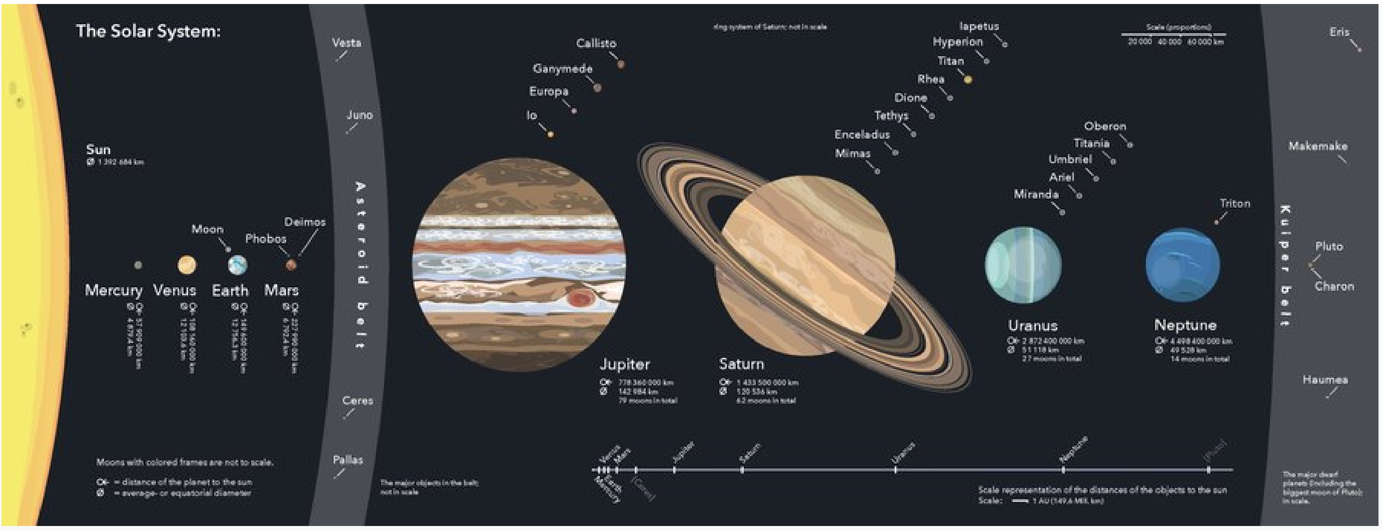


Andreas Cellarius's illustration of the Copernican system, from the *Harmonia Macrocosmica* (1660)

For most of history, humanity did not recognize or understand the concept of the Solar System. Most people up to the Late Middle Ages–Renaissance believed Earth to be stationary at the centre of the universe and categorically different from the divine or ethereal objects that moved through the sky. Although the Greek philosopher Aristarchus of Samos had speculated on a heliocentric reordering of the cosmos, Nicolaus Copernicus was the first to develop a mathematically predictive heliocentric system.[11][12]

In the 17th century, Galileo discovered that the Sun was marked with sunspots, and that Jupiter had four satellites in orbit around it.[13]Christiaan Huygens followed on from Galileo's discoveries by discovering Saturn's moon Titan and the shape of the rings of Saturn.[14]Edmond Halley realised in 1705 that repeated sightings of a comet were recording the same object, returning regularly once every 75–76 years. This was the first evidence that anything other than the planets orbited the Sun.[15] Around this time (1704), the term "Solar System" first appeared in English.[16] In 1838, Friedrich Bessel successfully measured a stellar parallax, an apparent shift in the position of a star created by Earth's motion around the Sun, providing the first direct, experimental proof of heliocentrism.[17]Improvements in observational astronomy and the use of unmanned spacecraft have since enabled the detailed investigation of other bodies orbiting the Sun.

Structure and composition



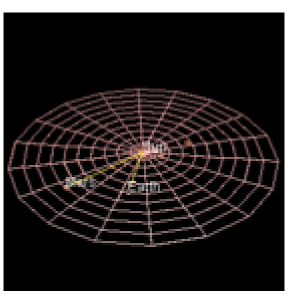
Comprehensive overview of the Solar System. The Sun, planets, dwarf planets and moons are at scale for their relative sizes, not for distances. A separate distance scale is at the bottom. Moons are listed near their planets by proximity of their orbits; only the largest moons are shown.

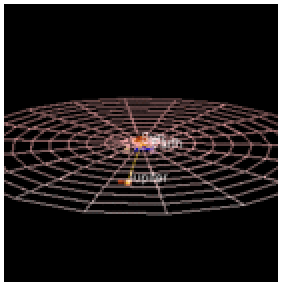
The principal component of the Solar System is the Sun, a G2 main-sequence star that contains 99.86% of the system's known mass and dominates it gravitationally.[18] The Sun's four largest orbiting bodies, the giant planets, account for 99% of the remaining mass, with Jupiter and Saturn together comprising more than 90%. The remaining objects of the Solar System (including the four terrestrial planets, the dwarf planets, moons, asteroids, and comets) together comprise less than 0.002% of the Solar System's total mass.[g]

Most large objects in orbit around the Sun lie near the plane of Earth's orbit, known as the ecliptic. The planets are very close to the ecliptic, whereas comets and Kuiper belt objects are frequently at significantly greater angles to it.[22][23] All the planets, and most other objects, orbit the Sun in the same direction that the Sun is rotating (counter-clockwise, as viewed from above Earth's north pole).[24] There are exceptions, such as Halley's Comet.

The overall structure of the charted regions of the Solar System consists of the Sun, four relatively small inner planets surrounded by a belt of mostly rocky asteroids, and four giant planets surrounded by the Kuiper belt of mostly icy objects. Astronomers sometimes informally divide this structure into separate regions. The inner Solar System includes the four terrestrial planets and the asteroid belt. The outer Solar System is beyond the asteroids, including the four giant planets.[25] Since the discovery of the Kuiper belt, the outermost parts of the Solar System are considered a distinct region consisting of the objects beyond Neptune.[26]

Most of the planets in the Solar System have secondary systems of their own, being orbited by planetary objects called natural satellites, or moons (two of which, Titanand Ganymede, are larger than the planet Mercury), and, in the case of the four giant planets, by planetary rings, thin bands of tiny particles that orbit them in unison. Most of the largest natural satellites are in synchronous rotation, with one face permanently turned toward their parent.





All planets of the Solar System lie very close to the ecliptic. The closer they are to the Sun, the faster they travel *(inner planets on the left, all planets except Neptune on the right)*.

Kepler's laws of planetary motion describe the orbits of objects about the Sun. Following Kepler's laws, each object travels along an ellipse with the Sun at one focus. Objects closer to the Sun (with smaller semi-major axes) travel more quickly because they are more affected by the Sun's gravity. On an elliptical orbit, a body's distance from the Sun varies over the course of its year. A body's closest approach to the Sun is called its *perihelion*, whereas its most distant point from the Sun is called its *aphelion*. The orbits of the planets are nearly circular, but many comets, asteroids, and Kuiper belt objects follow highly elliptical orbits. The positions of the bodies in the Solar System can be predicted using numerical models.

Although the Sun dominates the system by mass, it accounts for only about 2% of the angular momentum.[27][28] The planets, dominated by Jupiter, account for most of the rest of the angular momentum due to the combination of their mass, orbit, and distance from the Sun, with a possibly significant contribution from comets.[27]

The Sun, which comprises nearly all the matter in the Solar System, is composed of roughly 98% hydrogen and helium.[29] Jupiter and Saturn, which comprise nearly all the remaining matter, are also primarily composed of hydrogen and helium.[30][31] A composition gradient exists in the Solar System, created by heat and light pressure from the Sun; those objects closer to the Sun, which are more affected by heat and light pressure, are composed of elements with high melting points. Objects farther from the Sun are composed largely of materials with lower melting points.[32] The boundary in the Solar System beyond which those volatile substances could condense is known as the frost line, and it lies at roughly 5 AU from the Sun.[5]

The objects of the inner Solar System are composed mostly of rock,[33] the collective name for compounds with high melting points, such as silicates, iron or nickel, that remained solid under almost all conditions in the protoplanetary nebula.[34] Jupiter and Saturn are composed mainly of gases, the astronomical term for materials with extremely low melting points and high vapour pressure, such as hydrogen, helium, and neon, which were always in the gaseous phase in the nebula.[34] Ices, like water, methane, ammonia, hydrogen sulfide, and carbon dioxide,[33] have melting points up to a few hundred kelvins.[34] They can be found as ices, liquids, or gases in various places in the Solar System, whereas in the nebula they were either in the solid or gaseous phase.[34] Icy substances comprise the majority of the satellites of the giant planets, as well as most of Uranus and Neptune (the so-called "ice giants") and the numerous small objects that lie beyond Neptune's orbit.[33][35] Together, gases and ices are referred to as *volatiles*.[36]

Distances and scales

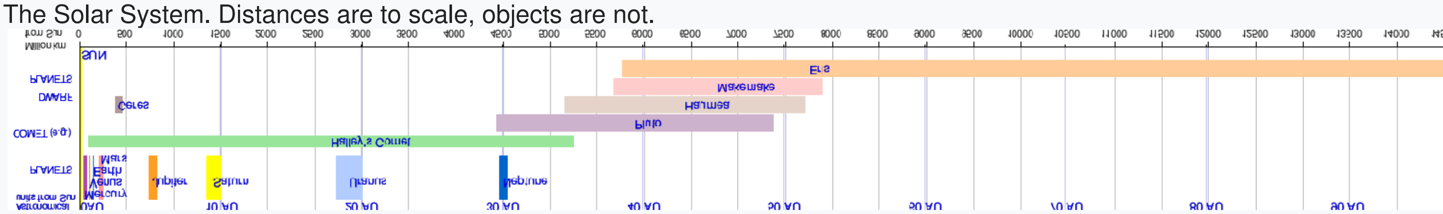
The distance from Earth to the Sun is 1 astronomical unit [AU] (150,000,000 km; 93,000,000 mi). For comparison, the radius of the Sun is 0.0047 AU (700,000 km). Thus, the Sun occupies 0.00001% (10^{-5} %) of the volume of a sphere with a radius the size of Earth's orbit, whereas Earth's volume is roughly one millionth (10^{-6}) that of the Sun. Jupiter, the largest planet, is 5.2 astronomical units (780,000,000 km) from the Sun and has a radius of 71,000 km (0.00047 AU), whereas the most distant planet, Neptune, is 30 AU (4.5×10^{9} km) from the Sun.

With a few exceptions, the farther a planet or belt is from the Sun, the larger the distance between its orbit and the orbit of the next nearer object to the Sun. For example, Venus is approximately 0.33 AU farther out from the Sun than Mercury, whereas Saturn is 4.3 AU out from Jupiter, and Neptune lies 10.5 AU out from Uranus. Attempts have been made to determine a relationship between these orbital distances (for example, the Titius–Bode law),[37] but no such theory has been accepted. The images at the beginning of this section show the orbits of the various constituents of the Solar System on different scales.

Some Solar System models attempt to convey the relative scales involved in the Solar System on human terms. Some are small in scale (and may be mechanical—called orreries)—whereas others extend across cities or regional areas.[38] The largest such scale model, the Sweden Solar System, uses the 110-metre (361 ft) Ericsson Globe in Stockholm as its substitute Sun, and, following the scale, Jupiter is a 7.5-metre (25-foot) sphere at Arlanda International Airport, 40 km (25 mi) away, whereas the farthest current object, Sedna, is a 10 cm (4 in) sphere in Luleå, 912 km (567 mi) away.[39][40]

If the Sun–Neptune distance is scaled to 100 metres, then the Sun would be about 3 cm in diameter (roughly two-thirds the diameter of a golf ball), the giant planets would be all smaller than about 3 mm, and Earth's diameter along with that of the other terrestrial planets would be smaller than a flea (0.3 mm) at this scale.[41]

The Solar System. Distances are to scale, objects are not.



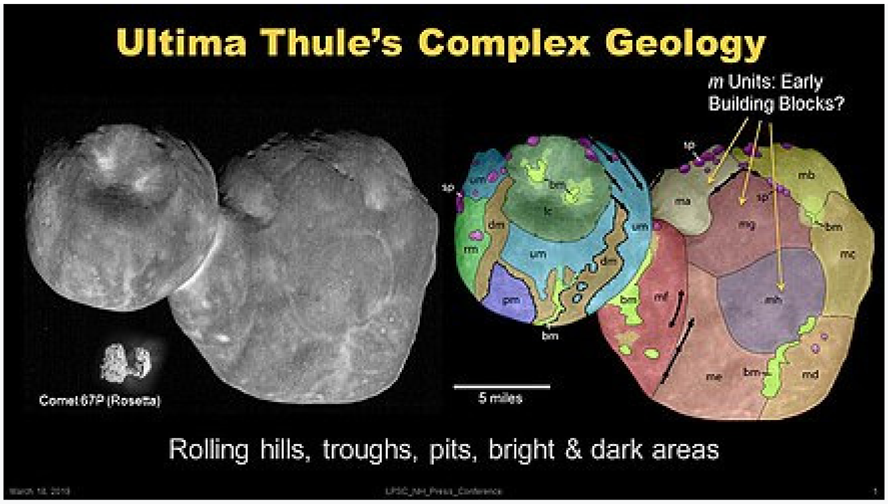
Distances of selected bodies of the Solar System from the Sun. The left and right edges of each bar correspond to the perihelion and aphelion of the body, respectively, hence long bars denote high orbital eccentricity. The radius of the Sun is 0.7 million km, and the radius of Jupiter (the largest planet) is 0.07 million km, both too small to resolve on this image.

Formation and evolution

Artist's conception of a protoplanetary disk

Main article: Formation and evolution of the Solar System

The Solar System formed 4.568 billion years ago from the gravitational collapse of a region within a large molecular cloud.[h] This initial cloud was likely several light-years across and probably birthed several stars.[43] As is typical of molecular clouds, this one consisted mostly of hydrogen, with some helium, and small amounts of heavier elements fused by previous generations of stars. As the region that would become the Solar System, known as the pre-solar nebula,[44] collapsed, conservation of angular momentum caused it to rotate faster. The centre, where most of the mass collected, became increasingly hotter than the surrounding disc.[43] As the contracting nebula rotated faster, it began to flatten into a protoplanetary disc with a diameter of roughly 200 AU[43] and a hot, dense protostar at the centre.[45][46] The planets formed by accretion from this disc,[47] in which dust and gas gravitationally attracted each other, coalescing to form ever larger bodies. Hundreds of protoplanets may have existed in the early Solar System, but they either merged or were destroyed, leaving the planets, dwarf planets, and leftover minor bodies.



The geology of 2014 MU_{69} ("Ultima Thule"), the first undisturbed planetesimal visited by a spacecraft, with comet 67P to scale. Notable surface features are highlighted at right. The eight subunits of the larger lobe, labeled *ma* to *mh*, are thought to have been its building blocks. The two lobes came together later, forming a contact binary. Objects such as MU_{69} are believed in turn to have formed protoplanets.[48]

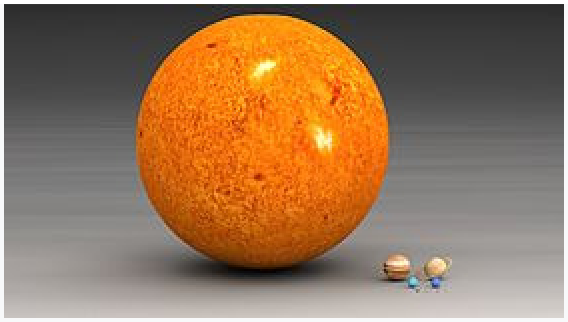
Due to their higher boiling points, only metals and silicates could exist in solid form in the warm inner Solar System close to the Sun, and these would eventually form the rocky planets of Mercury, Venus, Earth, and Mars. Because metallic elements only comprised a very small fraction of the solar nebula, the terrestrial planets could not grow very large. The giant planets (Jupiter, Saturn, Uranus, and Neptune) formed further out, beyond the frost line, the point between the orbits of Mars and Jupiter where material is cool enough for volatile icy compounds to remain solid. The ices that formed these planets were more plentiful than the metals and silicates that formed the terrestrial inner planets, allowing them to grow massive enough to capture large atmospheres of hydrogen and helium, the lightest and most abundant elements. Leftover debris that never became planets congregated in regions such as the asteroid belt, Kuiper belt, and Oort cloud. The Nice model is an explanation for the creation of these regions and how the outer planets could have formed in different positions and migrated to their current orbits through various gravitational interactions.

Within 50 million years, the pressure and density of hydrogen in the centre of the protostar became great enough for it to begin thermonuclear fusion.[49] The temperature, reaction rate, pressure, and density increased until hydrostatic equilibrium was achieved: the thermal pressure equalled the force of gravity. At this point, the Sun became a main-sequence star.[50] The main-sequence phase, from beginning to end, will last about 10 billion years for the Sun compared to around two billion years for all other phases of the Sun's pre-remnant life combined.[51] Solar wind from the Sun created the heliosphere and swept away the remaining gas and dust from the protoplanetary disc into interstellar space, ending the planetary formation process. The Sun is growing brighter; early in its main-sequence life its brightness was 70% that of what it is today.[52]

The Solar System will remain roughly as we know it today until the hydrogen in the core of the Sun has been entirely converted to helium, which will occur roughly 5 billion years from now. This will mark the end of the Sun's main-sequence life. At this time, the core of the Sun will contract with hydrogen fusion occurring along a shell surrounding the inert helium, and the energy output will be much greater than at present. The outer layers of the Sun will expand to roughly 260 times its current diameter, and the Sun will become a red giant. Because of its vastly increased surface area, the surface of the Sun will be considerably cooler (2,600 K at its coolest) than it is on the main sequence.[51] The expanding Sun is expected to vaporize Mercury and render Earth uninhabitable. Eventually, the core will be hot enough for helium fusion; the Sun will burn helium for a fraction of the time it burned hydrogen in the core. The Sun is not massive enough to commence the fusion of heavier elements, and nuclear reactions in the core will dwindle. Its outer layers will move away into space, leaving a white dwarf, an extraordinarily dense object, half the original mass of the Sun but only the size of Earth.[53] The ejected outer layers will form what is known as a planetary nebula, returning some of the material that formed the Sun—but now enriched with heavier elements like carbon—to the interstellar medium.

Sun

Main article: Sun



Size comparison of the Sun and the planets

The Sun is the Solar System's star and by far its most massive component. Its large mass (332,900 Earth masses),[54] which comprises 99.86% of all the mass in the Solar System,[55] produces temperatures and densities in its core high enough to sustain nuclear fusion of hydrogen into helium, making it a main-sequence star.[56] This releases an enormous amount of energy, mostly radiated into space as electromagnetic radiation peaking in visible light.[57]

The Sun is a G2-type main-sequence star. Hotter main-sequence stars are more luminous. The Sun's temperature is intermediate between that of the hottest stars and that of the coolest stars. Stars brighter and hotter than the Sun are rare, whereas substantially dimmer and cooler stars, known as red dwarfs, make up 85% of the stars in the Milky Way.[58][59]

The Sun is a population I star; it has a higher abundance of elements heavier than hydrogen and helium ("metals" in astronomical parlance) than the older population II stars.[60] Elements heavier than hydrogen and helium were formed in the cores of ancient and exploding stars, so the first generation of stars had to die before the Universe could be enriched with these atoms. The oldest stars contain few metals, whereas stars born later have more. This high metallicity is thought to have been crucial to the Sun's development of a planetary system because the planets form from the accretion of "metals".[61]

Interplanetary medium

Main articles: Interplanetary medium and Solar wind

The heliospheric current sheet

The vast majority of the Solar System consists of a near-vacuum known as the interplanetary medium. Along with light, the Sun radiates a continuous stream of charged particles (a plasma) known as the solar wind. This stream of particles spreads outwards at roughly 1.5 million kilometres per hour,[62] creating a tenuous atmosphere that permeates the interplanetary medium out to at least 100 AU *(see § Heliosphere)*.[63] Activity on the Sun's surface, such as solar flares and coronal mass ejections, disturbs the heliosphere, creating space weather and causing geomagnetic storms.[64] The largest structure within the heliosphere is the heliospheric current sheet, a spiral form created by the actions of the Sun's rotating magnetic field on the interplanetary medium.[65][66]

Earth's magnetic field stops its atmosphere from being stripped away by the solar wind.[67] Venus and Mars do not have magnetic fields, and as a result the solar wind is causing their atmospheres to gradually bleed away into space.[68] Coronal mass ejections and similar events blow a magnetic field and huge quantities of material from the surface of the Sun. The interaction of this magnetic field and material with Earth's magnetic field funnels charged particles into Earth's upper atmosphere, where its interactions create aurorae seen near the magnetic poles.

The heliosphere and planetary magnetic fields (for those planets that have them) partially shield the Solar System from high-energy interstellar particles called cosmic rays. The density of cosmic rays in the interstellar medium and the strength of the Sun's magnetic field change on very long timescales, so the level of cosmic-ray penetration in the Solar System varies, though by how much is unknown.[69]

The interplanetary medium is home to at least two disc-like regions of cosmic dust. The first, the zodiacal dust cloud, lies in the inner Solar System and causes the zodiacal light. It was likely formed by collisions within the asteroid belt brought on by gravitational interactions with the planets.[70] The second dust cloud extends from about 10 AU to about 40 AU, and was probably created by similar collisions within the Kuiper belt.[71][72]

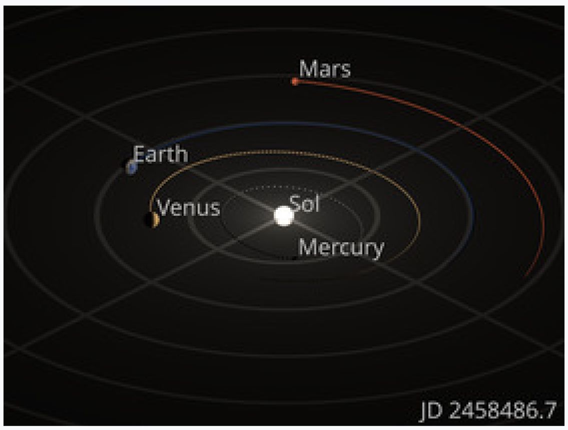
Inner Solar System

The **inner Solar System** is the region comprising the terrestrial planets and the asteroid belt.[73] Composed mainly of silicates and metals, the objects of the inner Solar System are relatively close to the Sun; the radius of this entire region is less than the distance between the orbits of Jupiter and Saturn. This region is also within the frost line, which is a little less than 5 AU (about 700 million km) from the Sun.[74]

Inner planets

Main article: Terrestrial planet

The inner planets. From left to right: Earth, Mars, Venus, and Mercury (sizes to scale).



Orrery showing the motions of the inner four planets. The small spheres represent the position of each planet on every Julian day, beginning July 6 2018 (aphelion) and ending January 3 2019 (perihelion).

The four terrestrial or **inner planets** have dense, rocky compositions, few or no moons, and no ring systems. They are composed largely of refractory minerals, such as the silicates—which form their crusts and mantles—and metals, such as iron and nickel, which form their cores. Three of the four inner planets (Venus, Earth and Mars) have atmospheres substantial enough to generate weather; all have impact craters and tectonic surface features, such as rift valleys and volcanoes. The term *inner planet* should not be confused with *inferior planet*, which designates those planets that are closer to the Sun than Earth is (i.e. Mercury and Venus).

Mercury

Main article: Mercury (planet)

Mercury (0.4 AU from the Sun) is the closest planet to the Sun and on average, all seven other planets.[75][76] The smallest planet in the Solar System (0.055 $M_{\oplus}$), Mercury has no natural satellites. Besides impact craters, its only known geological features are lobed ridges or rupes that were probably produced by a period of contraction early in its history.[77] Mercury's very tenuous atmosphere consists of atoms blasted off its surface by the solar wind.[78]Its relatively large iron core and thin mantle have not yet been adequately explained. Hypotheses include that its outer layers were stripped off by a giant impact, or that it was prevented from fully accreting by the young Sun's energy.[79][80]

Venus

Main article: Venus

Venus (0.7 AU from the Sun) is close in size to Earth (0.815 $M_{\oplus}$) and, like Earth, has a thick silicate mantle around an iron core, a substantial atmosphere, and evidence of internal geological activity. It is much drier than Earth, and its atmosphere is ninety times as dense. Venus has no natural satellites. It is the hottest planet, with surface temperatures over 400 °C (752 °F), most likely due to the amount of greenhouse gases in the atmosphere.[81] No definitive evidence of current geological activity has been detected on Venus, but it has no magnetic field that would prevent depletion of its substantial atmosphere, which suggests that its atmosphere is being replenished by volcanic eruptions.[82]

Earth

Main article: Earth

Earth (1 AU from the Sun) is the largest and densest of the inner planets, the only one known to have current geological activity, and the only place where life is known to exist.[83] Its liquid hydrosphere is unique among the terrestrial planets, and it is the only planet where plate tectonics has been observed. Earth's atmosphere is radically different from those of the other planets, having been altered by the presence of life to contain 21% free oxygen.[84] It has one natural satellite, the Moon, the only large satellite of a terrestrial planet in the Solar System.

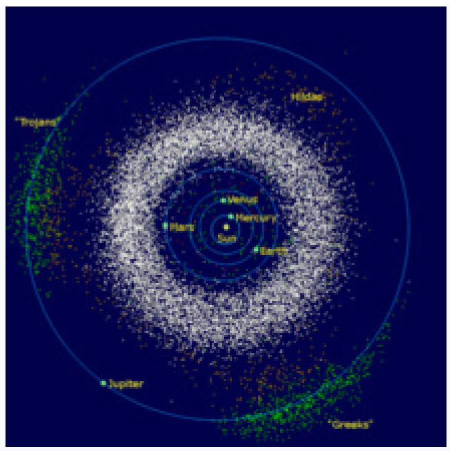
Mars

Main article: Mars

Mars (1.5 AU from the Sun) is smaller than Earth and Venus (0.107 $M_\oplus$). It has an atmosphere of mostly carbon dioxide with a surface pressure of 6.1 millibars (roughly 0.6% of that of Earth).[85] Its surface, peppered with vast volcanoes, such as Olympus Mons, and rift valleys, such as Valles Marineris, shows geological activity that may have persisted until as recently as 2 million years ago.[86] Its red colour comes from iron oxide (rust) in its soil.[87] Mars has two tiny natural satellites (Deimos and Phobos) thought to be either captured asteroids,[88] or ejected debris from a massive impact early in Mars's history.[89]

Asteroid belt

Main article: Asteroid belt



The donut-shaped asteroid belt is located between the orbits of Mars and Jupiter.

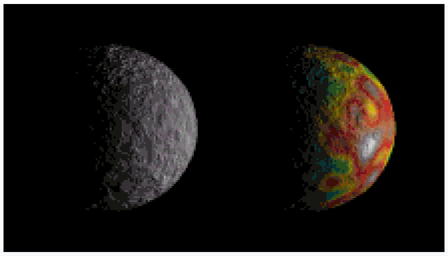
Sun	Asteroid belt
Jupiter trojans	Hilda asteroids
Planetary orbit	NEOs (selection)

Asteroids except for the largest, Ceres, are classified as small Solar System bodies[e] and are composed mainly of refractory rocky and metallic minerals, with some ice.[90][91] They range from a few metres to hundreds of kilometres in size. Asteroids smaller than one meter are usually called meteoroids and micrometeoroids (grain-sized), depending on different, somewhat arbitrary definitions.

The asteroid belt occupies the orbit between Mars and Jupiter, between 2.3 and 3.3 AU from the Sun. It is thought to be remnants from the Solar System's formation that failed to coalesce because of the gravitational interference of Jupiter.[92] The asteroid belt contains tens of thousands, possibly millions, of objects over one kilometre in diameter.[93] Despite this, the total mass of the asteroid belt is unlikely to be more than a thousandth of that of Earth.[21] The asteroid belt is very sparsely populated; spacecraft routinely pass through without incident.

Ceres

*Main article: **Ceres (dwarf planet)***



Ceres – map of gravity fields: red is high; blue, low.

Ceres (2.77 AU) is the largest asteroid, a protoplanet, and a dwarf planet.[e] It has a diameter of slightly under 1000 km, and a mass large enough for its own gravity to pull it into a spherical shape. Ceres was considered a planet when it was discovered in 1801, and was reclassified to asteroid in the 1850s as further observations revealed additional asteroids.[94] It was classified as a dwarf planet in 2006 when the definition of a planet was created.

Asteroid groups

Asteroids in the asteroid belt are divided into asteroid groups and families based on their orbital characteristics. Asteroid moons are asteroids that orbit larger asteroids. They are not as clearly distinguished as planetary moons, sometimes being almost as large as their partners. The asteroid belt also contains main-belt comets, which may have been the source of Earth's water.[95]

Jupiter trojans are located in either of Jupiter's L_4 or L_5 points (gravitationally stable regions leading and trailing a planet in its orbit); the term *trojan* is also used for small bodies in any other planetary or satellite Lagrange point. Hilda asteroids are in a 2:3 resonance with Jupiter; that is, they go around the Sun three times for every two Jupiter orbits.[96]

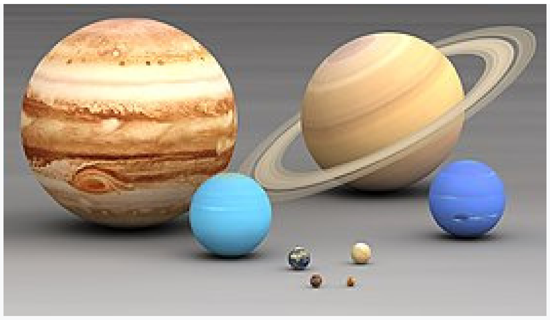
The inner Solar System also contains near-Earth asteroids, many of which cross the orbits of the inner planets.[97] Some of them are potentially hazardous objects.

Outer Solar System

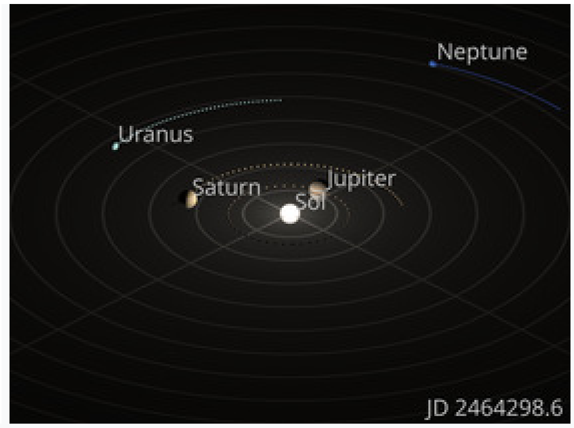
The outer region of the Solar System is home to the giant planets and their large moons. The centaurs and many short-period comets also orbit in this region. Due to their greater distance from the Sun, the solid objects in the outer Solar System contain a higher proportion of volatiles, such as water, ammonia, and methane than those of the inner Solar System because the lower temperatures allow these compounds to remain solid.

Outer planets

Main article: Giant planet



The outer planets (in the background) Jupiter, Saturn, Uranus and Neptune, compared to the inner planets Earth, Venus, Mars and Mercury (in the foreground).



Orrery showing the motions of the outer four planets. The small spheres represent the position of each planet on every 100 Julian days, beginning January 21 2023 (Jovian perihelion) and ending December 2 2034 (Jovian perihelion).

The four outer planets, or giant planets (sometimes called Jovian planets), collectively make up 99% of the mass known to orbit the Sun.[g] Jupiter and Saturn are together more than 400 times the mass of Earth and consist overwhelmingly of hydrogen and helium. Uranus and Neptune are far less massive—less than 20 Earth masses ($M_\oplus$) each—and are composed primarily of ices. For these reasons, some astronomers suggest they belong in their own category, ice giants.[98] All four giant planets have rings, although only Saturn's ring system is easily observed from Earth. The term *superior planet* designates planets outside Earth's orbit and thus includes both the outer planets and Mars.

Jupiter

Main article: Jupiter

Jupiter (5.2 AU), at 318 $M_\oplus$, is 2.5 times the mass of all the other planets put together. It is composed largely of hydrogen and helium. Jupiter's strong internal heat creates semi-permanent features in its atmosphere, such as cloud bands and the Great Red Spot. Jupiter has 79 known satellites. The four largest, Ganymede, Callisto, Io, and Europa, show similarities to the terrestrial planets, such as volcanism and internal heating.[99] Ganymede, the largest satellite in the Solar System, is larger than Mercury.

Saturn

Main article: Saturn

Saturn (9.5 AU), distinguished by its extensive ring system, has several similarities to Jupiter, such as its atmospheric composition and magnetosphere. Although Saturn has 60% of Jupiter's volume, it is less than a third as massive, at 95 $M_\oplus$. Saturn is the only planet of the Solar System that is less dense than water.[100] The rings of Saturn are made up of small ice and rock particles. Saturn has 62 confirmed satellites composed largely of ice. Two of these, Titan and Enceladus, show signs of geological activity.[101] Titan, the second-largest moon in the Solar System, is larger than Mercury and the only satellite in the Solar System with a substantial atmosphere.

Uranus

Main article: Uranus

Uranus (19.2 AU), at 14 $M_\oplus$, is the lightest of the outer planets. Uniquely among the planets, it orbits the Sun on its side; its axial tilt is over ninety degrees to the ecliptic. It has a much colder core than the other giant planets and radiates very little heat into space.[102] Uranus has 27 known satellites, the largest ones being Titania, Oberon, Umbriel, Ariel, and Miranda.

Neptune

Main article: Neptune

Neptune (30.1 AU), though slightly smaller than Uranus, is more massive (17 $M_\oplus$) and hence more dense. It radiates more internal heat, but not as much as Jupiter or Saturn.[103] Neptune has 14 known satellites. The largest, Triton, is geologically active, with geysers of liquid nitrogen.[104] Triton is the only large satellite with a retrograde orbit. Neptune is accompanied in its orbit by several minor planets, termed Neptune trojans, that are in 1:1 resonance with it.

Centaurs

Main article: Centaur (minor planet)

The centaurs are icy comet-like bodies whose orbits have semi-major axes greater than Jupiter's (5.5 AU) and less than Neptune's (30 AU). The largest known centaur, 10199 Chariklo, has a diameter of about 250 km.[105] The first centaur discovered, 2060 Chiron, has also been classified as comet (95P) because it develops a coma just as comets do when they approach the Sun.[106]

Comets

Hale–Bopp seen in 1997

Main *article: Comet*

Comets are small Solar System bodies,[e] typically only a few kilometres across, composed largely of volatile ices. They have highly eccentric orbits, generally a perihelion within the orbits of the inner planets and an aphelion far beyond Pluto. When a comet enters the inner Solar System, its proximity to the Sun causes its icy surface to sublimate and ionise, creating a coma: a long tail of gas and dust often visible to the naked eye.

Short-period comets have orbits lasting less than two hundred years. Long-period comets have orbits lasting thousands of years. Short-period comets are thought to originate in the Kuiper belt, whereas long-period comets, such as Hale–Bopp, are thought to originate in the Oort cloud. Many comet groups, such as the Kreutz Sungrazers, formed from the breakup of a single parent.[107] Some comets with hyperbolic orbits may originate outside the Solar System, but determining their precise orbits is difficult.[108] Old comets that have had most of their volatiles driven out by solar warming are often categorised as asteroids.[109]

Trans-Neptunian region

Beyond the orbit of Neptune lies the area of the "trans-Neptunian region", with the doughnut-shaped Kuiper belt, home of Pluto and several other dwarf planets, and an overlapping disc of scattered objects, which is tilted toward the plane of the Solar System and reaches much further out than the Kuiper belt. The entire region is still largely unexplored. It appears to consist overwhelmingly of many thousands of small worlds—the largest having a diameter only a fifth that of Earth and a mass far smaller than that of the Moon—composed mainly of rock and ice. This region is sometimes described as the "third zone of the Solar System", enclosing the inner and the outer Solar System.[110]

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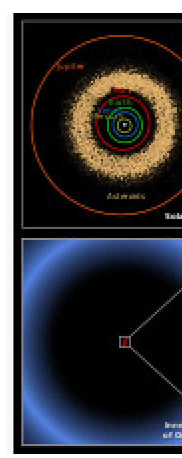

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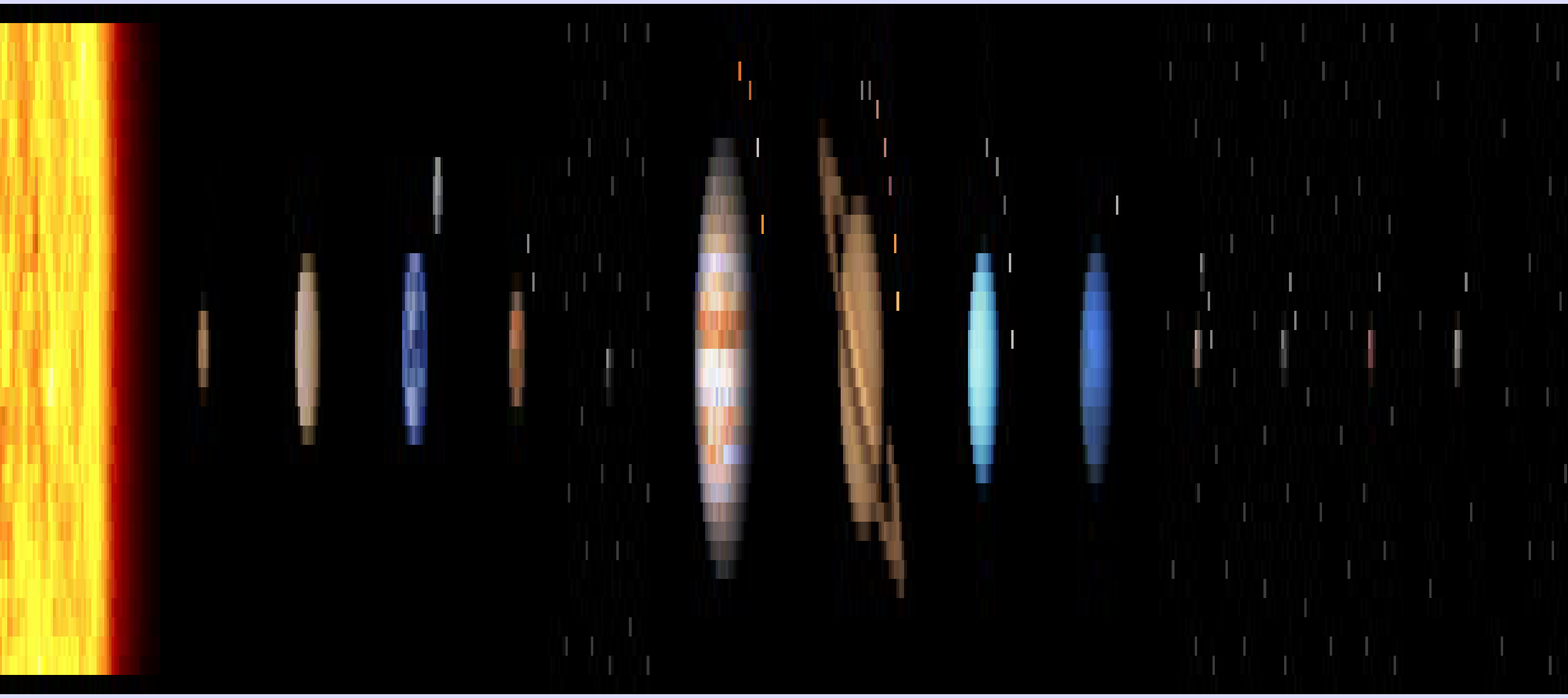

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Earth

Mars

Giant planets

Jupiter

Saturn

Uranus

Neptune

Dwarf planets

Ceres

Pluto

Haumea

Makemake

Eris

Jovian

Saturnian (Rhean)

Charikloan

Chironean

Uranian

Neptunian

Haumean

Terrestrial

Moon

other near-Earth objects

Martian

Phobos

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Jovian

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Callisto

Io

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moons

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Damocloids

Mercury-crossers

Venus-crossers

Venus trojans

Near-Earth objects

Earth-crossers

Earth trojans

Mars-crossers

Mars trojans

Asteroid belt

Asteroids

Ceres

Pallas

Juno

Vesta

first 1000

families

exceptional

Kirkwood gap

Main-belt comets

Jupiter trojans

Jupiter-crossers

Centaurs

Saturn-crossers

Uranus trojans

Uranus-crossers

Neptune trojans

Cis-Neptunian objects

Trans-Neptunian objects

Neptune-crossers

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Kuiper belt

Plutinos

Rhea
Iapetus
Dione
Tethys
Enceladus
Mimas
Hyperion
Phoebe
all 62
Uranian
Titania
Oberon
Umbriel
Ariel
Miranda
all 27
Neptunian
Triton
Proteus
Nereid
all 14
Plutonian
Charon
Nix
Hydra
Kerberos
Styx
Haumean
Hiʻiaka
Namaka
Makemakean
S/2015 (136472) 1
Eridian
Dysnomia

	Cubewanos Scattered disc Detached objects Sednoids Hills cloud Oort cloud
Hypothetical objects	Vulcan Vulcanoids Theia Phaeton Planet V Fifth giant Planet X Planet Nine Tyche Nemesis Subsatellites
Lists	Solar System models Solar System objects by size by discovery date Minor planets names Gravitationally rounded objects Possible dwarf planets Natural satellites Comets

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