

Moon

The **Moon** is an astronomical body that orbits planet Earth, being Earth's only permanent natural satellite. It is the fifth-largest natural satellite in the Solar System, and the largest among planetary satellites relative to the size of the planet that it orbits (its primary). Following Jupiter's satellite Io, the Moon is the second-densest satellite in the Solar System among those whose densities are known.

The Moon is thought to have formed about 4.51 billion years ago, not long after Earth. The most widely accepted explanation is that the Moon formed from the debris left over after a giant impact between Earth and a Mars-sized body called Theia.

The Moon is in synchronous rotation with Earth, always showing the same face, with its near side marked by dark volcanic maria that fill the spaces between the bright ancient crustal highlands and the prominent impact craters. As seen from the Earth, it is the second-brightest regularly visible celestial object in Earth's sky, after the Sun. Its surface is actually dark, although compared to the night sky it appears very bright, with a reflectance just slightly higher than that of worn asphalt. Its gravitational influence produces the ocean tides, body tides, and the slight lengthening of the day.

The Moon's average orbital distance at the present time is 384,402 km (238,856 mi),^{[10][11]} or 1.28 light-seconds. This is about thirty times the diameter of Earth, with its apparent size in the sky almost the same as that of the Sun (due to it being 400x farther and larger), resulting in the Moon covering the Sun nearly precisely in total solar eclipse. This matching of apparent visual size will not continue in the far future, because the Moon's distance from Earth is slowly increasing.

The Soviet Union's Luna program was the first to reach the Moon with unmanned spacecraft in 1959; the United States' NASA Apollo program achieved the only manned missions to date, beginning with the first manned lunar orbiting mission by Apollo 8 in 1968, and six manned lunar landings between 1969 and 1972, with the first being Apollo 11. These missions returned lunar rocks which have been used to develop a geological

Moon ☾



Full moon as seen from North America in Earth's Northern Hemisphere

Designations	
Adjectives	Lunar · selenic
Orbital characteristics	
Perigee	362 600 km (356 400–370 400 km)
Apogee	405 400 km (404 000–406 700 km)
Semi-major axis	384 399 km (0.002 57 AU) ^[1]
Eccentricity	0.0549 ^[1]
Orbital period	27.321 661 d (27 d 7 h 43 min 11.5 s^[1])
Synodic period	29.530 589 d (29 d 12 h 44 min 2.9 s)
Average orbital speed	1.022 km/s
Inclination	5.145° to the ecliptic ^{[2][a]}
Longitude of ascending node	Regressing by one revolution in 18.61 years
Argument of perigee	Progressing by one revolution in 8.85 years
Satellite of	Earth ^{[b][3]}
Physical characteristics	
Mean radius	1 737.1 km (0.273 of Earth's) ^{[1][4][5]}
Equatorial radius	1 738.1 km (0.273 of Earth's) ^[4]
Polar radius	1 736.0 km (0.273 of Earth's) ^[4]
Flattening	0.0012 ^[4]
Circumference	10 921 km (equatorial)

understanding of the Moon's origin, internal structure, and later history. Since the Apollo 17 mission in 1972, the Moon has been visited only by unmanned spacecraft.

Within human culture, both the Moon's natural prominence in the earthy sky, and its regular cycle of phases as seen from the Earth have provided cultural references and influences for human societies and cultures since time immemorial. Such cultural influences can be found in language, lunar based calendar systems, art, and mythology.

Contents

Name and etymology

Formation

Physical characteristics

- Internal structure
- Surface geology
 - Volcanic features
 - Impact craters
 - Lunar swirls
 - Presence of water
- Gravitational field
- Magnetic field
- Atmosphere
 - Dust
 - Past thicker atmosphere
- Seasons

Relationship to Earth

- Orbit
- Relative size
- Appearance from Earth
- Tidal effects
- Eclipses

Observation and exploration

- Ancient and medieval studies
- By spacecraft
 - 20th century
 - Soviet missions
 - United States missions
 - 1980s–2000
 - 21st century
 - Planned commercial missions

Astronomy from the Moon

Legal status

In culture

- Mythology
- Calendar
- Lunacy

Surface area	3.793 × 10 ⁷ km ² (0.074 of Earth's)		
Volume	2.1958 × 10 ¹⁰ km ³ (0.020 of Earth's) ^[4]		
Mass	7.342 × 10 ²² kg (0.012 300 of Earth's) ^{[1][4]}		
Mean density	3.344 g/cm ³ ^{[1][4]} 0.606 × Earth		
Surface gravity	1.62 m/s ² (0.1654 g) ^[4]		
Moment of inertia factor	0.3929 ± 0.0009 ^[6]		
Escape velocity	2.38 km/s		
Sidereal rotation period	27.321 661 d (synchronous)		
Equatorial rotation velocity	4.627 m/s		
Axial tilt	1.5424° to ecliptic 6.687° to orbit plane^[2]		
Albedo	0.136 ^[7]		
Surface temp.	min	mean	max
Equator	100 K	220 K	390 K
85°N		150 K	230 K ^[8]
Apparent magnitude	−2.5 to −12.9 ^[c] −12.74 (mean full moon)^[4]		
Angular diameter	29.3 to 34.1 arcminutes ^{[4][d]}		
Atmosphere ^[9]			
Surface pressure	10 ^{−7} Pa (1 picobar) (day) 10^{−10} Pa (1 femtobar) (night)^[e]		
Composition by volume	He · Ar · Ne · Na · K · H · Rn		

See also

References

Notes

Citations

Bibliography

Further reading

External links

Cartographic resources

Observation tools

General

Name and etymology

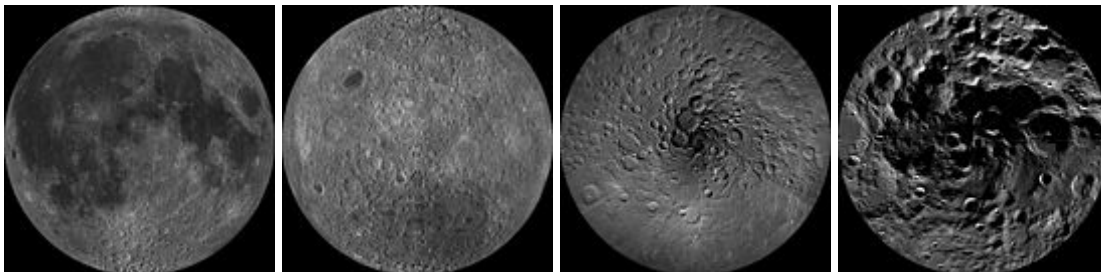
The usual English proper name for Earth's natural satellite is "the Moon", which in nonscientific texts is usually not capitalized.^{[12][13][14][15][16]} The noun *moon* is derived from Old English *mōna*, which (like all Germanic language cognates) stems from Proto-Germanic **mēnō*, which comes from Proto-Indo-European **mēh₁ns* "moon", "month", which comes from the Proto-Indo-European root **meh₁-* "to measure", the month being the ancient unit of time measured by the Moon.^{[17][18]} Occasionally, the name "Luna" is used. In literature, especially science fiction, "Luna" is used to distinguish it from other moons, while in poetry, the name has been used to denote personification of our moon.^[19]

The modern English adjective pertaining to the Moon is *lunar*, derived from the Latin word for the Moon, *luna*. The adjective *selenic* (usually only used to refer to the chemical element selenium) is so rarely used to refer to the moon that this meaning is not recorded in most major dictionaries.^{[20][21][22]} It is derived from the Ancient Greek word for the Moon, *σελήνη* (*selḗnē*), from which is however also derived the prefix "seleno-", as in *selenography*, the study of the physical features of the Moon, as well as the element name *selenium*.^{[23][24]} Both the Greek goddess Selene and the Roman goddess Diana were alternatively called Cynthia.^[25] The names Luna, Cynthia, and Selene are reflected in terminology for lunar orbits in words such as *apolune*, *pericynthion*, and *selenocentric*. The name Diana comes from the Proto-Indo-European **diw-yo*, "heavenly", which comes from the PIE root **dyeu-* "to shine," which in many derivatives means "sky/heaven, and god" and is also the origin of Latin *dies*, "day".



The Moon, tinted reddish, during a lunar eclipse

The Moon



Near side of the Moon

Far side of the Moon

Lunar north pole

Lunar south pole

Formation

Several mechanisms have been proposed for the Moon's formation 4.51 billion years ago^[8], and some 60 million years after the origin of the Solar System.^[26] These mechanisms included the fission of the Moon from Earth's crust through centrifugal force^[27] (which would require too great an initial spin of Earth),^[28] the gravitational capture of a pre-formed Moon^[29] (which would require an

unfeasibly extended atmosphere of Earth to dissipate the energy of the passing Moon),^[28] and the co-formation of Earth and the Moon together in the primordial accretion disk (which does not explain the depletion of metals in the Moon).^[28] These hypotheses also cannot account for the high angular momentum of the Earth–Moon system!^[30]

The prevailing hypothesis is that the Earth–Moon system formed as a result of the impact of a Mars-sized body (named *Theia*) with the proto-Earth (giant impact), that blasted material into orbit about the Earth that then accreted to form the present Earth-Moon system.^{[31][32]}

The far side of the Moon has a crust that is 30 mi (48 km) thicker than the near side of the Moon. This is thought to be due to the Moon having been amalgamated from two different bodies.

This hypothesis, although not perfect, perhaps best explains the evidence. Eighteen months prior to an October 1984 conference on lunar origins, Bill Hartmann, Roger Phillips, and Jeff Taylor challenged fellow lunar scientists: "You have eighteen months. Go back to your Apollo data, go back to your computer, do whatever you have to, but make up your mind. Don't come to our conference unless you have something to say about the Moon's birth." At the 1984 conference at Kona, Hawaii, the giant impact hypothesis emerged as the most popular



[Play media](#)

The evolution of the Moon and a tour of the Moon

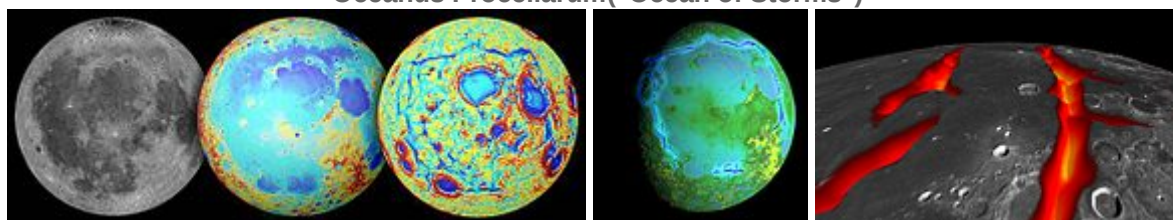
Before the conference, there were partisans of the three "traditional" theories, plus a few people who were starting to take the giant impact seriously, and there was a huge apathetic middle who didn't think the debate would ever be resolved. Afterward there were essentially only two groups: the giant impact camp and the agnostics.^[33]

Giant impacts are thought to have been common in the early Solar System. Computer simulations of a giant impact have produced results that are consistent with the mass of the lunar core and the present angular momentum of the Earth–Moon system. These simulations also show that most of the Moon derived from the impactor, rather than the proto-Earth.^[34] More recent simulations suggest a larger fraction of the Moon derived from the original Earth mass.^{[35][36][37][38]} Studies of meteorites originating from inner Solar System bodies such as Mars and Vesta show that they have very different oxygen and tungsten isotopic compositions as compared to Earth, whereas Earth and the Moon have nearly identical isotopic compositions. The isotopic equalization of the Earth-Moon system might be explained by the post-impact mixing of the vaporized material that formed the two,^[39] although this is debated.^[40]

The great amount of energy released in the impact event and the subsequent re-accretion of that material into the Earth-Moon system would have melted the outer shell of Earth, forming a magma ocean.^{[41][42]} Similarly, the newly formed Moon would also have been affected and had its own lunar magma ocean; estimates for its depth range from about 500 km (300 miles) to its entire depth (1,737 km (1,079 miles)).^[41]

While the giant impact hypothesis might explain many lines of evidence, there are still some unresolved questions, most of which involve the Moon's composition.^[43]

Oceanus Procellarum("Ocean of Storms")



Ancient rift valleys – rectangular structure (visible – topography – GRAIL gravity gradients)

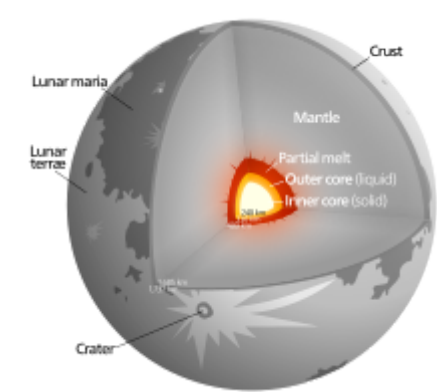
Ancient rift valleys – context.

Ancient rift valleys – closeup (artist's concept).

In 2001, a team at the Carnegie Institute of Washington reported the most precise measurement of the isotopic signatures of lunar rocks.^[44] To their surprise, the team found that the rocks from the Apollo program carried an isotopic signature that was identical with rocks from Earth, and were different from almost all other bodies in the Solar System. Because most of the material that went into orbit to form the Moon was thought to come from Theia, this observation was unexpected. In 2007, researchers from the California Institute of Technology announced that there was less than a 1% chance that Theia and Earth had identical isotopic signatures.^[45] Published in 2012, an analysis of titanium isotopes in Apollo lunar samples showed that the Moon has the same composition as Earth,^[46] which conflicts with what is expected if the Moon formed far from Earth's orbit or from Theia. Variations on the giant impact hypothesis may explain this data.

Physical characteristics

Internal structure



Structure of the Moon

The Moon is a differentiated body: it has a geochemically distinct crust, mantle, and core. The Moon has a solid iron-rich inner core with a radius possibly as small as 240 km (150 mi) and a fluid outer core primarily made of liquid iron with a radius of roughly 300 km (190 mi). Around the core is a partially molten boundary layer with a radius of about 500 km (310 mi).^{[48][49]} This structure is thought to have developed through the fractional crystallization of a global magma ocean shortly after the Moon's formation 4.5 billion years ago.^[50] Crystallization of this magma ocean would have created a mafic mantle from the precipitation and sinking of the minerals olivine, clinopyroxene, and orthopyroxene; after about three-quarters of the magma ocean had crystallised, lower-density plagioclase minerals could form and float into a crust atop.^[51] The final liquids to crystallise would have been initially sandwiched between the crust and mantle, with a high abundance of incompatible and heat-producing elements.^[1] Consistent with this perspective, geochemical mapping made from orbit suggests the crust of mostly anorthosite.^[9] The Moon rock samples of the flood lavas that erupted onto the surface from partial melting in the mantle confirm the mafic mantle composition, which is more iron-rich than that of Earth.^[1] The crust is on average about 50 km (31 mi) thick.^[1]

The Moon is the second-densest satellite in the Solar System, after Io.^[52] However, the inner core of the Moon is small, with a radius of about 350 km (220 mi) or less,^[1] around 20% of the radius of the Moon. Its composition is not well defined, but is probably metallic iron alloyed with a small amount of sulfur and nickel; analyses of the Moon's time-variable rotation suggest that it is at least partly molten.^[53]

Surface geology

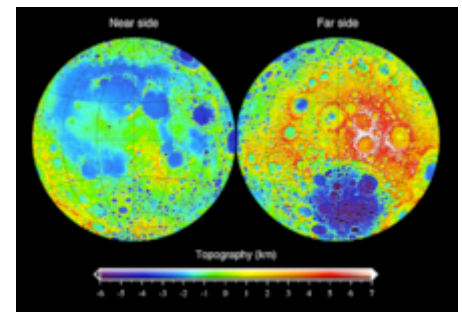
The topography of the Moon has been measured with laser altimetry and stereo image analysis.^[54] Its most visible topographic feature is the giant far-side South Pole–Aitken basin, some 2,240 km (1,390 mi) in diameter, the largest crater on the Moon and the second-largest confirmed impactcrater in the Solar System^{[55][56]} At 13 km (8.1 mi) deep, its floor is the lowest point on the surface

Chemical composition of the lunar surface regolith (derived from crustal rocks)^[47]

Compound	Formula	Composition (wt %)	
		Maria	Highlands
<u>silica</u>	SiO ₂	45.4%	45.5%
<u>alumina</u>	Al ₂ O ₃	14.9%	24.0%
<u>lime</u>	CaO	11.8%	15.9%
<u>iron(II) oxide</u>	FeO	14.1%	5.9%
<u>magnesia</u>	MgO	9.2%	7.5%
<u>titanium dioxide</u>	TiO ₂	3.9%	0.6%
<u>sodium oxide</u>	Na ₂ O	0.6%	0.6%
Total		99.9%	100.0%

of the Moon.^{[55][57]} The highest elevations of the Moon's surface are located directly to the northeast, and it has been suggested might have been thickened by the oblique formation impact of the South Pole–Aitken basin.^[58] Other large impact basins, such as Imbrium, Serenitatis, Crisium, Smythii, and Oriente, also possess regionally low elevations and elevated rims.^[55] The far side of the lunar surface is on average about 1.9 km (1.2 mi) higher than that of the near side.^[1]

The discovery of fault scarp cliffs by the Lunar Reconnaissance Orbiter suggest that the Moon has shrunk within the past billion years, by about 90 metres (300 ft).^[59] Similar shrinkage features exist on Mercury.



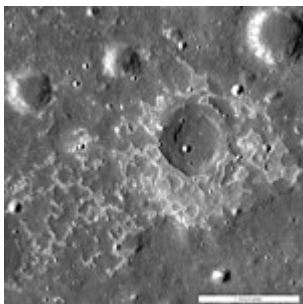
Topography of the Moon

Volcanic features

The dark and relatively featureless lunar plains, clearly seen with the naked eye, are called *maria* (Latin for "seas"; singular *mare*), as they were once believed to be filled with water;^[60] they are now known to be vast solidified pools of ancient basaltic lava. Although similar to terrestrial basalts, lunar basalts have more iron and no minerals altered by water.^[61] The majority of these lavas erupted or flowed into the depressions associated with impact basins. Several geologic provinces containing shield volcanoes and volcanic domes are found within the near side "maria".^[62]



Lunar nearside with major maria and craters labeled



Evidence of young lunar volcanism

Almost all maria are on the near side of the Moon, and cover 31% of the surface of the near side,^[63] compared with 2% of the far side.^[64]

This is thought to be due to a concentration of heat-producing elements under the crust on the near side, seen on geochemical maps obtained by Lunar Prospector's gamma-ray spectrometer, which would have caused the underlying mantle to heat up, partially melt, rise to the surface and erupt.^{[51][65][66]} Most of the Moon's mare basalts erupted during the Imbrian period, 3.0–3.5 billion years ago, although some radiometrically dated samples are as old as 4.2 billion years.^[67] Until recently, the youngest eruptions, dated by crater counting appeared to have been only 1.2 billion years ago.^[68] In 2006, a study of Ina, a tiny depression in Lacus Felicitatis found jagged, relatively dust-free features that, due to the lack of erosion by infalling debris, appeared to

be only 2 million years old.^[69] Moonquakes and releases of gas also indicate some continued lunar activity.^[69] In 2014 NASA announced "widespread evidence of young lunar volcanism" at 70 irregular mare patches identified by the Lunar Reconnaissance Orbiter, some less than 50 million years old. This raises the possibility of a much warmer lunar mantle than previously believed, at least on the near side where the deep crust is substantially warmer due to the greater concentration of radioactive elements.^{[70][71][72][73]} Just prior to this, evidence has been presented for 2–10 million years younger basaltic volcanism inside Lowell crater,^{[74][75]} Orientale basin, located in the transition zone between the near and far sides of the Moon. An initially hotter mantle and/or local enrichment of heat-producing elements in the mantle could be responsible for prolonged activities also on the far side in the Orientale basin!^{[76][77]}

The lighter-coloured regions of the Moon are called *terrae*, or more commonly *highlands*, because they are higher than most maria. They have been radiometrically dated to having formed 4.4 billion years ago, and may represent plagioclase cumulates of the lunar magma ocean.^{[67][68]} In contrast to Earth, no major lunar mountains are believed to have formed as a result of tectonic events.^[78]

The concentration of maria on the Near Side likely reflects the substantially thicker crust of the highlands of the Far Side, which may have formed in a slow-velocity impact of a second moon of Earth a few tens of millions of years after their formation.^{[79][80]}

Impact craters

The other major geologic process that has affected the Moon's surface is impact cratering^[81] with craters formed when asteroids and comets collide with the lunar surface. There are estimated to be roughly 300,000 craters wider than 1 km (0.6 mi) on the Moon's near side alone.^[82] The lunar geologic timescale is based on the most prominent impact events, including Nectaris, Imbrium, and Oriente, structures characterized by multiple rings of uplifted material, between hundreds and thousands of kilometres in diameter and associated with a broad apron of ejecta deposits that form a regional stratigraphic horizon.^[83] The lack of an atmosphere, weather and recent geological processes mean that many of these craters are well-preserved. Although only a few multi-ring basins have been definitively dated, they are useful for assigning relative ages. Because impact craters accumulate at a nearly constant rate, counting the number of craters per unit area can be used to estimate the age of the surface.^[83] The radiometric ages of impact-melted rocks collected during the Apollo missions cluster between 3.8 and 4.1 billion years old: this has been used to propose a Late Heavy Bombardment of impacts.^[84]



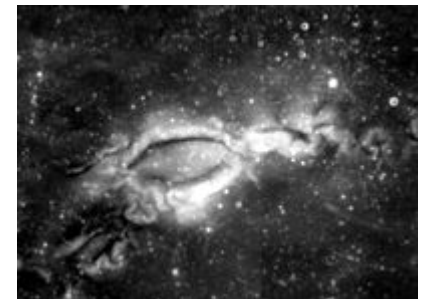
Lunar crater Daedalus on the Moon's far side

Blanketed on top of the Moon's crust is a highly comminuted (broken into ever smaller particles) and impact gardened surface layer called regolith, formed by impact processes. The finer regolith, the lunar soil of silicon dioxide glass, has a texture resembling snow and a scent resembling spent gunpowder.^[85] The regolith of older surfaces is generally thicker than for younger surfaces: it varies in thickness from 10–20 km (6.2–12.4 mi) in the highlands and 3–5 km (1.9–3.1 mi) in the maria.^[86] Beneath the finely comminuted regolith layer is the megaregolith, a layer of highly fractured bedrock many kilometres thick.^[87]

Comparison of high-resolution images obtained by the Lunar Reconnaissance Orbiter has shown a contemporary crater-production rate significantly higher than previously estimated. A secondary cratering process caused by distal ejecta is thought to churn the top two centimetres of regolith a hundred times more quickly than previous models suggested—on a timescale of 81,000 years.^{[88][89]}

Lunar swirls

Lunar swirls are enigmatic features found across the Moon's surface, which are characterized by a high albedo, appearing optically immature (i.e. the optical characteristics of a relatively young regolith), and often displaying a sinuous shape. Their curvilinear shape is often accentuated by low albedo regions that wind between the bright swirls.



Lunar swirls at Reiner Gamma

Presence of water

Liquid water cannot persist on the lunar surface. When exposed to solar radiation, water quickly decomposes through a process known as photodissociation and is lost to space. However, since the 1960s, scientists have hypothesized that water ice may be deposited by impacting comets or possibly produced by the reaction of oxygen-rich lunar rocks, and hydrogen from solar wind, leaving traces of water which could possibly persist in cold, permanently shadowed craters at either pole on the Moon.^{[90][91]} Computer simulations suggest that up to 14,000 km² (5,400 sq mi) of the surface may be in permanent shadow.^[92] The presence of usable quantities of water on the Moon is an important factor in rendering lunar habitation as a cost-effective plan; the alternative of transporting water from Earth would be prohibitively expensive.^[93]

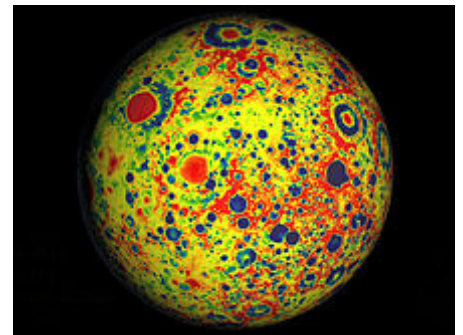
In years since, signatures of water have been found to exist on the lunar surface.^[94] In 1994, the bistatic radar experiment located on the Clementine spacecraft, indicated the existence of small, frozen pockets of water close to the surface. However, later radar observations by Arecibo, suggest these findings may rather be rocks ejected from young impact craters.^[95] In 1998, the neutron spectrometer on the Lunar Prospector spacecraft showed that high concentrations of hydrogen are present in the first meter of depth in the regolith near the polar regions.^[96] Volcanic lava beads, brought back to Earth aboard Apollo 15, showed small amounts of water in their interior.^[97]

The 2008 *Chandrayaan-1* spacecraft has since confirmed the existence of surface water ice, using the on-board *Moon Mineralogy Mapper*. The spectrometer observed absorption lines common to *hydroxyl*, in reflected sunlight, providing evidence of large quantities of water ice, on the lunar surface. The spacecraft showed that concentrations may possibly be as high as 1,000 ppm.^[98] In 2009, *LCROSS* sent a 2,300 kg (5,100 lb) impactor into a permanently shadowed polar crater, and detected at least 100 kg (220 lb) of water in a plume of ejected material.^{[99][100]} Another examination of the LCROSS data showed the amount of detected water to be closer to 155 ± 12 kg (342 ± 26 lb).^[101]

In May 2011, 615–1410 ppm water in *melt inclusions* in lunar sample 74220 was reported,^[102] the famous high-titanium "orange glass soil" of volcanic origin collected during the *Apollo 17* mission in 1972. The inclusions were formed during explosive eruptions on the Moon approximately 3.7 billion years ago. This concentration is comparable with that of magma in Earth's *upper mantle*. Although of considerable selenological interest, this announcement affords little comfort to would-be lunar colonists—the sample originated many kilometers below the surface, and the inclusions are so difficult to access that it took 39 years to find them with a state-of-the-art ion microprobe instrument.

Gravitational field

The gravitational field of the Moon has been measured through tracking the *Doppler shift* of radio signals emitted by orbiting spacecraft. The main lunar gravity features are *mascons*, large positive gravitational anomalies associated with some of the giant *impact basins*, partly caused by the dense mare basaltic lava flows that fill those basins.^{[103][104]} The anomalies greatly influence the orbit of spacecraft about the Moon. There are some puzzles: lava flows by themselves cannot explain all of the gravitational signature, and some mascons exist that are not linked to mare volcanism.^[105]



GRAIL's gravity map of the Moon

Magnetic field

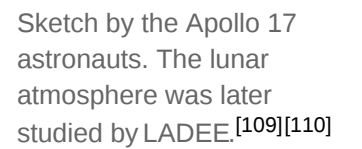
The Moon has an external *magnetic field* of about 1–100 *nanoteslas*, less than one-hundredth that of *Earth*. It does not currently have a global *dipolar* magnetic field and only has crustal magnetization, probably acquired early in lunar history when a dynamo was still operating.^{[106][107]} Alternatively, some of the remnant magnetization may be from transient magnetic fields generated during large impact events through the expansion of an impact-generated plasma cloud in the presence of an ambient magnetic field. This is supported by the apparent location of the largest crustal magnetizations near the *antipodes* of the giant impact basins.^[108]

Atmosphere

The Moon has an atmosphere so tenuous as to be nearly *vacuum*, with a total mass of less than 10 metric tons (9.8 long tons; 11 short tons).^[111] The surface pressure of this small mass is around 3×10^{-15} *atm* (0.3 *nPa*); it varies with the lunar day. Its sources include *outgassing* and *sputtering*, a product of the bombardment of lunar soil by *solar wind* ions.^{[9][112]} Elements that have been detected include *sodium* and *potassium*, produced by sputtering (also found in the atmospheres of *Mercury* and *Io*); *helium-4* and *neon*^[113] from the solar wind; and *argon-40*, *radon-222*, and *polonium-210*, outgassed after their creation by *radioactive decay* within the crust and mantle.^{[114][115]} The absence of such neutral species (atoms or molecules) as *oxygen*, *nitrogen*, *carbon*, *hydrogen* and *magnesium*, which are present in the *regolith*, is not understood.^[114] Water vapour has been detected by *Chandrayaan-1* and found to vary with latitude, with a maximum at ~60–70 degrees; it is possibly generated from the *sublimation* of water ice in the regolith.^[116] These gases either return into the regolith due to the Moon's gravity or are lost to space, either through solar radiation pressure or, if they are ionized, by being swept away by the solar wind's magnetic field.^[114]

Dust

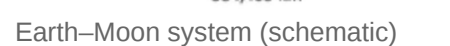
near the boundary between the Moon's dayside and nightside.^{[117][118]}



In October 2017, NASA scientists at the Marshall Space Flight Center and the Lunar and Planetary Institute in Houston announced their finding, based on studies of Moon magma samples retrieved by the Apollo missions, that the Moon had once possessed a relatively thick atmosphere for a period of 70 million years between 3 and 4 billion years ago. This atmosphere, sourced from gases ejected from lunar volcanic eruptions, was twice the thickness of that of present-day Mars. The ancient lunar atmosphere was eventually stripped away by solar winds and dissipated into space.^[119]

The Moon's axial tilt with respect to the ecliptic is only 1.5424° ,^[120] much less than the 23.44° of Earth. Because of this, the Moon's solar illumination varies much less with season, and topographical details play a crucial role in seasonal effects.^[121] From images taken by *Clementine* in 1994, it appears that four mountainous regions on the rim of Peary Crater at the Moon's north pole may remain illuminated for the entire lunar day, creating peaks of eternal light. No such regions exist at the south pole. Similarly, there are places that remain in permanent shadow at the bottoms of many polar craters,^[92] and these "craters of eternal darkness" are extremely cold: *Lunar Reconnaissance Orbiter* measured the lowest summer temperatures in craters at the southern pole at 35 K (-238°C ; -397°F)^[122] and just 26 K (-247°C ; -413°F) close to the winter solstice in north polar Hermite Crater. This is the coldest temperature in the Solar System ever measured by a spacecraft, colder even than the surface of Pluto.^[121] Average temperatures of the Moon's surface are reported, but temperatures of different areas will vary greatly depending upon whether they are in sunlight or shadow.^[123]

The Moon makes a complete orbit around Earth with respect to the fixed stars about once every 27.3 days^[9] (its sidereal period). However, because Earth is moving in its orbit around the Sun at the same time, it takes slightly longer for the Moon to show the same phase to Earth, which is about 29.5 days^[h] (its synodic period).^[63] Unlike most satellites of other planets, the Moon orbits closer to the ecliptic plane than to the planet's equatorial plane. The Moon's orbit is subtly perturbed by the Sun and Earth in many small, complex and interacting ways. For example, the plane of the Moon's orbit gradually rotates once every 18.61^[124] years, which affects other aspects of lunar motion. These follow-on effects are mathematically described by Cassini's laws^[125]



Relative size

The Moon is exceptionally large relative to Earth: a quarter its diameter and 1/81 its mass.^[63] It is the largest moon in the Solar System relative to the size of its planet,^[i] though Charon is larger relative to the dwarf planet Pluto, at 1/9 Pluto's mass.^{[j][126]} The Earth and the Moon's barycentre, their common centre of mass, is located 1,700 km (1,100 mi) (about a quarter of Earth's radius) beneath Earth's surface.

The Earth revolves around the Earth-Moon barycentre once a sidereal month, moving at 1/81 the speed of the Moon, or about 12.5 metres (41 ft) per second. This motion is superimposed on the much larger revolution of the Earth around the Sun at a speed of about 30 kilometres (19 mi) per second.

Appearance from Earth



Moon setting in western sky over the High Desert in California

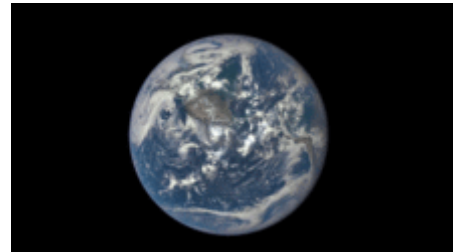
The Moon is in synchronous rotation as it orbits Earth; it rotates about its axis in about the same time it takes to orbit Earth. This results in it always keeping nearly the same face turned towards Earth. However, due to the effect of libration, about 59% of the Moon's surface can actually be seen from Earth. The side of the Moon that

faces Earth is called the near side, and the opposite the far side. The far side is often inaccurately called the "dark side", but it is in fact illuminated as often as the near side: once every 29.5 Earth days. During new moon, the near side is dark!^[127]

The Moon had once rotated at a faster rate, but early in its history, its rotation slowed and became tidally locked in this orientation as a result of frictional effects associated with tidal deformations caused by Earth.^[128] With time, the energy of rotation of the Moon on its axis was dissipated as heat, until there was no rotation of the Moon relative to Earth. In 2016, planetary scientists, using data collected on the much earlier NASA Lunar Prospector mission, found two hydrogen-rich areas on opposite sides of the Moon, probably in the form of water ice. It is speculated that these patches were the poles of the Moon billions of years ago, before it was tidally locked to Earth.^[129]

The Moon has an exceptionally low albedo, giving it a reflectance that is slightly brighter than that of worn asphalt. Despite this, it is the brightest object in the sky after the Sun.^{[63][k]} This is partly due to the brightness enhancement of the opposition surge; the Moon at quarter phase is only one-tenth as bright, rather than half as bright, as at full moon.^[130] Additionally, color constancy in the visual system recalibrates the relations between the colors of an object and its surroundings, and because the surrounding sky is comparatively dark, the sunlit Moon is perceived as a bright object. The edges of the full moon seem as bright as the centre, without limb darkening due to the reflective properties of lunar soil, which retroreflects light more towards the Sun than in other directions. The Moon does appear larger when close to the horizon, but this is a purely psychological effect, known as the moon illusion, first described in the 7th century BC.^[131] The full Moon's angular diameter is about 0.52° (on average) in the sky, roughly the same apparent size as the Sun (see Eclipses).

The Moon's highest altitude at culmination varies by its phase and time of year. The full moon is currently northernmost during winter. The 18.61-year nodal cycle has an influence on lunar standstill. When the ascending node of the lunar orbit is in the vernal equinox, the lunar declination can reach up to plus or minus 28° each month. This means the Moon can pass overhead if viewed from



DSCOVR satellite sees the Moon passing in front of Earth



Moon above Makarska, Croatia

latitudes up to 28° north or south (of the Equator), instead of only 18°. The orientation of the Moon's crescent also depends on the latitude of the viewing location; an observer in the tropics can see a smile-shaped crescent Moon.^[132] The Moon is visible for two weeks every 27.3 days at the North and South Poles. Zooplankton in the Arctic use moonlight when the Sun is below the horizon for months on end.^[133]

The distance between the Moon and Earth varies from around 356,400 km (221,500 mi) to 406,700 km (252,700 mi) at perigee (closest) and apogee (farthest), respectively. On 14 November 2016, it was closer to Earth when at full phase than it has been since 1948, 14% closer than its farthest position in apogee.^[136] Reported as a "supermoon", this closest point coincides within an hour of a full moon, and it was 30% more luminous than when at its greatest distance due to its angular diameter being 14% greater, because $1.14^2 \approx 1.30$.^{[137][138][139]} At lower levels, the human perception of reduced brightness as a percentage is provided by the following formula:^{[140][141]}

$$\text{perceived reduction}\% = 100 \times \sqrt{\frac{\text{actual reduction}\%}{100}}$$

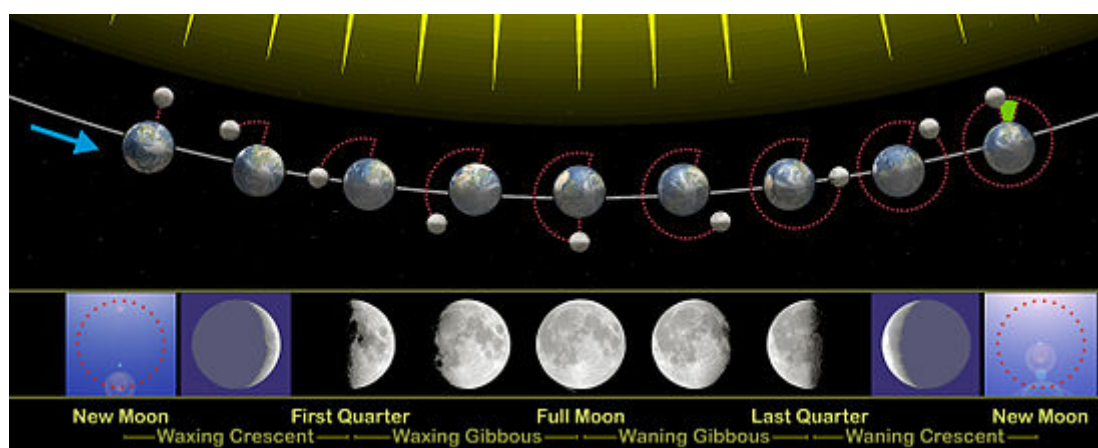
When the actual reduction is 1.00 / 1.30, or about 0.770, the perceived reduction is about 0.877, or 1.00 / 1.14. This gives a maximum perceived increase of 14% between apogee and perigee moons of the same phase.^[142]

There has been historical controversy over whether features on the Moon's surface change over time. Today, many of these claims are thought to be illusory, resulting from observation under different lighting conditions, poor astronomical seeing, or inadequate drawings. However, outgassing does occasionally occur and could be responsible for a minor percentage of the reported lunar transient phenomena. Recently, it has been suggested that a roughly 3 km (1.9 mi) diameter region of the lunar surface was modified by a gas release event about a million years ago.^{[143][144]}

The Moon's appearance, like the Sun's, can be affected by Earth's atmosphere. Common optical effects are the 22° halo ring, formed when the Moon's light is refracted through the ice crystals of high cirrostratus clouds, and smaller coronal rings when the Moon is seen through thin clouds.^[145]



14 November 2016 supermoon was 356,511 kilometres (221,526 mi) away^[134] from the center of Earth, the closest occurrence since 26 January 1948. It will not be closer until 25 November 2034!^[135]



The monthly changes in the angle between the direction of sunlight and view from Earth, and the phases of the Moon that result, as viewed from the Northern Hemisphere. The Earth–Moon distance is not to scale.

The illuminated area of the visible sphere (degree of illumination) is given by $(1 - \cos e)/2 = \sin^2(e/2)$, where e is the elongation (i.e., the angle between Moon, the observer (on Earth) and the Sun).

Tidal effects

The gravitational attraction that masses have for one another decreases inversely with the square of the distance of those masses from each other. As a result, the slightly greater attraction that the Moon has for the side of Earth closest to the Moon, as compared to the part of the Earth opposite the Moon, results in tidal forces. Tidal forces affect both the Earth's crust and oceans.

The most obvious effect of tidal forces is to cause two bulges in the Earth's oceans, one on the side facing the Moon and the other on the side opposite. This results in elevated sea levels called ocean tides.^[146] As the Earth spins on its axis, one of the ocean bulges (high tide) is held in place "under" the Moon, while another such tide is opposite. As a result, there are two high tides, and two low tides in about 24 hours.^[146] Since the Moon is orbiting the Earth in the same direction of the Earth's rotation, the high tides occur about every 12 hours and 25 minutes; the 25 minutes is due to the Moon's time to orbit the Earth. The Sun has the same tidal effect on the Earth, but its forces of attraction are only 40% that of the Moon's; the Sun's and Moon's interplay is responsible for spring and neap tides.^[146] If the Earth were a water world (one with no continents) it would produce a tide of only one meter, and that tide would be very predictable, but the ocean tides are greatly modified by other effects: the frictional coupling of water to Earth's rotation through the ocean floors, the inertia of water's movement, ocean basins that grow shallower near land, the sloshing of water between different ocean basins.^[147] As a result, the timing of the tides at most points on the Earth is a product of observations that are explained, incidentally by theory.



The libration of the Moon over a single lunar month. Also visible is the slight variation in the Moon's visual size from Earth.

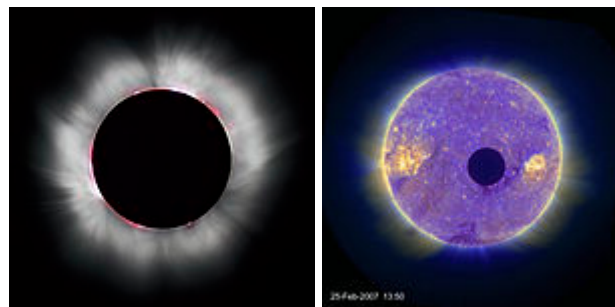
While gravitation causes acceleration and movement of the Earth's fluid oceans, gravitational coupling between the Moon and Earth's solid body is mostly elastic and plastic. The result is a further tidal effect of the Moon on the Earth that causes a bulge of the solid portion of the Earth nearest the Moon that acts as a torque in opposition to the Earth's rotation. This "drains" angular momentum and rotational kinetic energy from Earth's spin, slowing the Earth's rotation.^{[146][148]} That angular momentum, lost from the Earth, is transferred to the Moon in a process (confusingly known as tidal acceleration), which lifts the Moon into a higher orbit and results in its lower orbital speed about the Earth. Thus the distance between Earth and Moon is increasing, and the Earth's spin is slowing in reaction.^[148] Measurements from laser reflectors left during the Apollo missions (lunar ranging experiments) have found that the Moon's distance increases by 38 mm (1.5 in) per year^[149] (roughly the rate at which human fingernails grow).^[150] Atomic clocks also show that Earth's day lengthens by about 15 microseconds every year,^[151] slowly increasing the rate at which UTC is adjusted by leap seconds. Left to run its course, this tidal drag would continue until the spin of Earth and the orbital period of the Moon matched, creating mutual tidal locking between the two. As a result, the Moon would be suspended in the sky over one meridian, as is already currently the case with Pluto and its moon Charon. However, the Sun will become a red giant engulfing the Earth-Moon system long before this occurrence.^{[152][153]}

In a like manner, the lunar surface experiences tides of around 10 cm (4 in) amplitude over 27 days, with two components: a fixed one due to Earth, because they are in synchronous rotation, and a varying component from the Sun.^[148] The Earth-induced component arises from libration, a result of the Moon's orbital eccentricity (if the Moon's orbit were perfectly circular, there would only be solar tides).^[148] Libration also changes the angle from which the Moon is seen, allowing a total of about 59% of its surface to be seen from Earth over time.^[63] The cumulative effects of stress built up by these tidal forces produces moonquakes. Moonquakes are much less common and weaker than are earthquakes, although moon quakes can last for up to an hour—a significantly longer time than terrestrial quakes—because of the absence of water to damp out the seismic vibrations. The existence of moonquakes was an unexpected discovery from seismometers placed on the Moon by Apollo astronauts from 1969 through 1972.^[154]

Eclipses

Eclipses can only occur when the Sun, Earth, and Moon are all in a straight line (termed syzygy). Solar eclipses occur at new moon, when the Moon is between the Sun and Earth. In contrast, lunar eclipses occur at full moon, when Earth is between the Sun and Moon. The apparent size of the Moon is roughly the same as that of the Sun, with both being viewed at close to one-half a degree

wide. The Sun is much larger than the Moon but it is the vastly greater distance that gives it the same apparent size as the much closer and much smaller Moon from the perspective of Earth. The variations in apparent size, due to the non-circular orbits, are nearly the same as well, though occurring in different cycles. This makes possible both total (with the Moon appearing larger than the Sun) and annular (with the Moon appearing smaller than the Sun) solar eclipses.^[156] In a total eclipse, the Moon completely covers the disc of the Sun and the solar corona becomes visible to the naked eye. Because the distance between the Moon and Earth is very slowly increasing over time,^[146] the angular diameter of the Moon is decreasing. Also, as it evolves toward becoming a red giant, the size of the Sun, and its apparent diameter in the sky, are slowly increasing.^[1] The combination of these two changes means that hundreds of millions of years ago, the Moon would always completely cover the Sun on solar eclipses, and no annular eclipses were possible. Likewise, hundreds of millions of years in the future, the Moon will no longer cover the Sun completely, and total solar eclipses will not occur^[157]



From Earth, the Moon and the Sun appear the same size, as seen in the 1999 solar eclipse (left), whereas from the *STEREO-B* spacecraft in an Earth-trailing orbit, the Moon appears much smaller than the Sun (right)!^[155]

Because the Moon's orbit around Earth is inclined by about 5.145° ($5^\circ 9'$) to the orbit of Earth around the Sun, eclipses do not occur at every full and new moon. For an eclipse to occur, the Moon must be near the intersection of the two orbital planes.^[158] The periodicity and recurrence of eclipses of the Sun by the Moon, and of the Moon by Earth, is described by the saros, which has a period of approximately 18 years.^[159]

Because the Moon is continuously blocking our view of a half-degree-wide circular area of the sky,^{[m][160]} the related phenomenon of occultation occurs when a bright star or planet passes behind the Moon and is occulted: hidden from view. In this way, a solar eclipse is an occultation of the Sun. Because the Moon is comparatively close to Earth, occultations of individual stars are not visible everywhere on the planet, nor at the same time. Because of the precession of the lunar orbit, each year different stars are occulted.^[161]

Observation and exploration

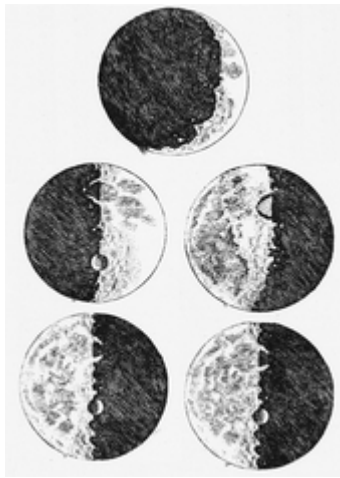
Ancient and medieval studies

Understanding of the Moon's cycles was an early development of astronomy: by the 5th century BC, Babylonian astronomers had recorded the 18-year Saros cycle of lunar eclipses,^[162] and Indian astronomers had described the Moon's monthly elongation.^[163] The Chinese astronomer Shi Shen (fl. 4th century BC) gave instructions for predicting solar and lunar eclipses.^[164] Later, the physical form of the Moon and the cause of moonlight became understood. The ancient Greek philosopher Anaxagoras (d. 428 BC) reasoned that the Sun and Moon were both giant spherical rocks, and that the latter reflected the light of the former.^{[165][166]} Although the Chinese of the Han Dynasty believed the Moon to be energy equated to qi, their 'radiating influence' theory also recognized that the light of the Moon was merely a reflection of the Sun, and Jing Fang (78–37 BC) noted the sphericity of the Moon.^[167] In the 2nd century AD, Lucian wrote the novel *A True Story*, in which the heroes travel to the Moon and meet its inhabitants. In 499 AD, the Indian astronomer Aryabhata mentioned in his *Aryabhatiya* that reflected sunlight is the cause of the shining of the Moon.^[168] The astronomer and physicist Alhazen (965–1039) found that sunlight was not reflected from the Moon like a mirror, but that light was emitted from every part of the Moon's



Map of the Moon by Johannes Hevelius from his *Selenographia* (1647), the first map to include the libration zones

sunlit surface in all directions.^[169] Shen Kuo (1031–1095) of the Song dynasty created an allegory equating the waxing and waning of the Moon to a round ball of reflective silver that, when doused with white powder and viewed from the side, would appear to be a crescent.^[170]



Galileo's sketches of the Moon from *Sidereus Nuncius*

In Aristotle's (384–322 BC) description of the universe, the Moon marked the boundary between the spheres of the mutable elements (earth, water, air and fire), and the imperishable stars of aether, an influential philosophy that would dominate for centuries.^[171] However, in the 2nd century BC, Seleucus of Seleucia correctly theorized that tides were due to the attraction of the Moon, and that their height depends on the Moon's position relative to the Sun.^[172] In the same century Aristarchus computed the size and distance of the Moon from Earth, obtaining a value of about twenty times the radius of Earth for the distance.

These figures were greatly improved by Ptolemy (90–168 AD): his values of a mean distance of 59 times Earth's radius and a diameter of 0.292 Earth diameters were close to the correct values of about 60 and 0.273 respectively.^[173] Archimedes (287–212 BC) designed a planetarium that could calculate the motions of the Moon and other objects in the Solar System.^[174]

During the Middle Ages, before the invention of the telescope, the Moon was increasingly recognised as a sphere, though many believed that it was "perfectly smooth".^[175]

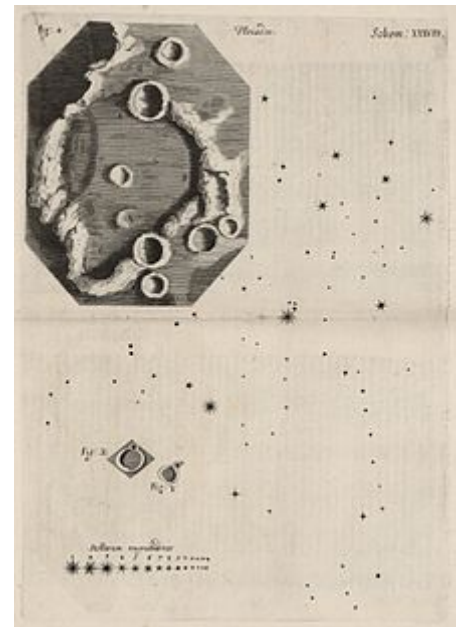
In 1609, Galileo Galilei drew one of the first telescopic drawings of the Moon in his book *Sidereus Nuncius* and noted that it was not smooth but had mountains and craters. Telescopic mapping of the Moon followed: later in the 17th century, the efforts of Giovanni Battista Riccioli and Francesco Maria Grimaldi led to the system of naming of lunar features in use today. The more exact 1834–36 *Mappa Selenographica* of Wilhelm Beer and Johann Heinrich Mädler, and their associated 1837 book *Der Mond*, the first trigonometrically accurate study of lunar features, included the heights of more than a thousand mountains, and introduced the study of the Moon at accuracies possible in earthly geography.^[176] Lunar craters, first noted by Galileo, were thought to be volcanic until the 1870s proposal of Richard Proctor that they were formed by collisions.^[63] This view gained support in 1892 from the experimentation of geologist Grove Karl Gilbert, and from comparative studies from 1920 to the 1940s,^[177] leading to the development of lunar stratigraphy, which by the 1950s was becoming a new and growing branch of astrogeology.^[63]

By spacecraft

20th century

Soviet missions

The Cold War-inspired Space Race between the Soviet Union and the U.S. led to an acceleration of interest in exploration of the Moon. Once launchers had the necessary capabilities, these nations sent unmanned probes on both flyby and impact/lander missions. Spacecraft from the Soviet Union's Luna program were the first to accomplish a number of goals: following three unnamed, failed missions in 1958,^[178] the first human-made object to escape Earth's gravity and pass near the Moon was Luna 1; the first human-made object to impact the lunar surface was Luna 2, and the first photographs of the normally occluded far side of the Moon were made by Luna 3, all in 1959.



A study of the Moon in Robert Hooke's *Micrographia*, 1665

The first spacecraft to perform a successful lunar soft landing was Luna 9 and the first unmanned vehicle to orbit the Moon was Luna 10, both in 1966.^[63] Rock and soil samples were brought back to Earth by three Luna sample return missions (Luna 16 in 1970, Luna 20 in 1972, and Luna 24 in 1976), which returned 0.3 kg total.^[179] Two pioneering robotic rovers landed on the Moon in 1970 and 1973 as a part of Soviet Lunokhod programme

Luna 24 was the last Soviet/Russian mission to the Moon.

United States missions



Earthrise (Apollo 8, 1968)



Moon rock (Apollo 17, 1972)

During the late 1950s at the height of the Cold War, the United States Army conducted a classified feasibility study that proposed the construction of a manned military outpost on the Moon called Project Horizon with the potential to conduct a wide range of missions from scientific research to nuclear Earth bombardment. The study included the possibility of conducting a lunar-based nuclear test.^{[180][181]} The Air Force, which at the time was in competition with the Army for a leading role in the space program, developed its own similar plan called Lunex.^{[182][183][180]} However, both these proposals were ultimately passed over as the space program was largely transferred from the military to the civilian agency NASA.^[183]

Following President John F. Kennedy's 1961 commitment to a manned moon landing before the end of the decade, the United States, under NASA leadership, launched a series of unmanned probes to develop an understanding of the lunar surface in preparation for manned missions: the Jet Propulsion Laboratory's Ranger program produced the first close-up pictures; the Lunar Orbiter program produced maps of the entire Moon; the Surveyor program landed its first spacecraft four months after Luna 9. The manned Apollo program was developed in parallel; after a series of unmanned and manned tests of the Apollo spacecraft in Earth orbit, and spurred on by a potential Soviet lunar flight, in 1968 Apollo 8 made the first manned mission to lunar orbit. The subsequent landing of the first humans on

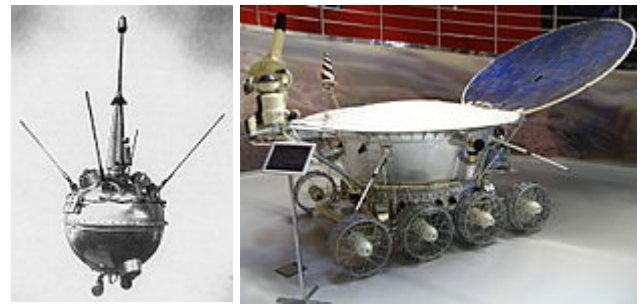
the Moon in 1969 is seen by many as the culmination of the Space Race.^[184]

Neil Armstrong became the first person to walk on the Moon as the commander of the American mission Apollo 11 by first setting foot on the Moon at 02:56 UTC on 21 July 1969.^[185] An estimated 500 million people worldwide watched the transmission by the Apollo TV camera, the largest television audience for a live broadcast at that time.^{[186][187]} The Apollo missions 11 to 17 (except Apollo 13, which aborted its planned lunar landing) returned 380.05 kilograms (837.87 lb) of lunar rock and soil in 2,196 separate samples.^[188] The American Moon landing and return was enabled by considerable technological advances in the early 1960s, in domains such as ablation chemistry, software engineering and atmospheric re-entry technology, and by highly competent management of the enormous technical undertaking.^{[189][190]}



Neil Armstrong working at the lunar module

Scientific instrument packages were installed on the lunar surface during all the Apollo landings. Long-lived instrument stations, including heat flow probes, seismometers, and magnetometers, were installed at the Apollo 12, 14, 15, 16, and 17 landing sites. Direct transmission of data to Earth concluded in late 1977 due to budgetary considerations,^{[191][192]} but as the stations' lunar laser ranging corner-cube retroreflector arrays are



Luna 2, the first human-made object to reach the surface of the Moon (left) and Soviet Moon rover Lunokhod 1



"That's one small step ..."



Problems playing this file? See [media help](#).

passive instruments, they are still being used. Ranging to the stations is routinely performed from Earth-based stations with an accuracy of a few centimetres, and data from this experiment are being used to place constraints on the size of the lunar core.^[193]

1980s–2000

After the first Moon race there were years of near quietude but starting in the 1990s, many more countries have become involved in direct exploration of the Moon. In 1990, Japan became the third country to place a spacecraft into lunar orbit with its *Hiten* spacecraft. The spacecraft released a smaller probe, *Hagoromo*, in lunar orbit, but the transmitter failed, preventing further scientific use of the mission.^[194] In 1994, the U.S. sent the joint Defense Department/NASA spacecraft *Clementine* to lunar orbit. This mission obtained the first near-global topographic map of the Moon, and the first global multispectral images of the lunar surface.^[195] This was followed in 1998 by the *Lunar Prospector* mission, whose instruments indicated the presence of excess hydrogen at the lunar poles, which is likely to have been caused by the presence of water ice in the upper few meters of the regolith within permanently shadowed craters.^[196]

India, Japan, China, the United States, and the European Space Agency each sent lunar orbiters, and especially *ISRO's Chandrayaan-1* has contributed to confirming the discovery of lunar water ice in permanently shadowed craters at the poles and bound into the lunar regolith. The post-Apollo era has also seen two rover missions: the final Soviet *Lunokhod* mission in 1973, and China's ongoing *Chang'e 3* mission, which deployed its *Yutu rover* on 14 December 2013. The Moon remains, under the Outer Space Treaty, free to all nations to explore for peaceful purposes.

21st century

The European spacecraft *SMART-1*, the second ion-propelled spacecraft, was in lunar orbit from 15 November 2004 until its lunar impact on 3 September 2006, and made the first detailed survey of chemical elements on the lunar surface.^[197]

The ambitious Chinese Lunar Exploration Program began with *Chang'e 1*, which successfully orbited the Moon from 5 November 2007 until its controlled lunar impact on 1 March 2009.^[198] It obtained a full image map of the Moon. *Chang'e 2*, beginning in October 2010, reached the Moon more quickly, mapped the Moon at a higher resolution over an eight-month period, then left lunar orbit for an extended stay at the Earth–Sun L2 Lagrangian point, before finally performing a flyby of asteroid 4179 Toutatis on 13 December 2012, and then heading off into deep space.

On 14 December 2013, *Chang'e 3* landed a lunar lander onto the Moon's surface, which in turn deployed a lunar rover, named *Yutu* (Chinese: 玉兔; literally "Jade Rabbit"). This was the first lunar soft landing since *Luna 24* in 1976, and the first lunar rover mission since *Lunokhod 2* in 1973. China intends to launch another rover mission (*Chang'e 4*) before 2020, followed by a sample return mission (*Chang'e 5*) soon after.^[199]

Between 4 October 2007 and 10 June 2009, the Japan Aerospace Exploration Agency's Kaguya (Selene) mission, a lunar orbiter fitted with a high-definition videocamera, and two small radio-transmitter satellites, obtained lunar geophysics data and took the first high-definition movies from beyond Earth orbit.^{[200][201]} India's first lunar mission, *Chandrayaan I*, orbited from 8 November 2008 until loss of contact on 27 August 2009, creating a high resolution chemical, mineralogical and photo-geological map of the lunar surface, and confirming the presence of water molecules in lunar soil.^[202] The Indian Space Research Organisation planned to launch *Chandrayaan II* in 2013, which would have included a Russian robotic lunar rover.^{[203][204]} However, the failure of Russia's *Fobos-Grunt* mission has delayed this project.



An artificially coloured mosaic constructed from a series of 53 images taken through three spectral filters by *Galileo's* imaging system as the spacecraft flew over the northern regions of the Moon on 7 December 1992.



Artistic representation of a future Moon colony

The U.S. co-launched the Lunar Reconnaissance Orbiter (LRO) and the LCROSS impactor and follow-up observation orbiter on 18 June 2009; LCROSS completed its mission by making a planned and widely observed impact in the crater Cabeus on 9 October 2009,^[205] whereas LRO is currently in operation, obtaining precise lunar altimetry and high-resolution imagery. In November 2011, the LRO passed over the large and bright Aristarchus crater. NASA released photos of the crater on 25 December 2011.^[206]

Two NASA GRAIL spacecraft began orbiting the Moon around 1 January 2012,^[207] on a mission to learn more about the Moon's internal structure. NASA's LADEE probe, designed to study the lunarexosphere, achieved orbit on 6 October 2013.

Upcoming lunar missions include Russia's Luna-Glob, an unmanned lander with a set of seismometers, and an orbiter based on its failed Martian Fobos-Grunt mission.^{[208][209]} Privately funded lunar exploration has been promoted by the Google Lunar X Prize, announced 13 September 2007, which offers US\$20 million to anyone who can land a robotic rover on the Moon and meet other specified criteria.^[210] Shackleton Energy Company is building a program to establish operations on the south pole of the Moon to harvest water and supply their Propellant Depots.^[211]

NASA began to plan to resume manned missions following the call by U.S. President George W. Bush on 14 January 2004 for a manned mission to the Moon by 2019 and the construction of a lunar base by 2024.^[212] The Constellation program was funded and construction and testing begun on a manned spacecraft and launch vehicle,^[213] and design studies for a lunar base.^[214] However, that program has been cancelled in favor of a manned asteroid landing by 2025 and a manned Mars orbit by 2035.^[215] India has also expressed its hope to send a manned mission to the Moon by 2026.^[216]

On February 28, 2018, SpaceX, Vodafone, Nokia and Audi announced a collaboration to install a 4G wireless communication network on the Moon, with the aim of streaming live footage on the surface to Earth.^[217]

Planned commercial missions

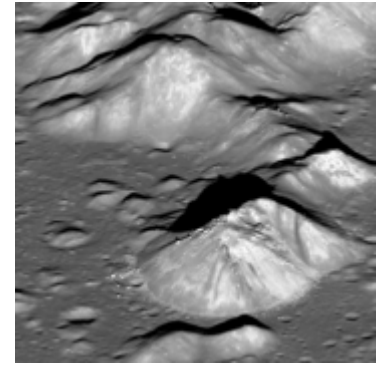
In 2007, the X Prize Foundation together with Google launched the Google Lunar X Prize to encourage commercial endeavors to the Moon. A prize of \$20 million will be awarded to the first private venture to get to the moon with a robotic lander by the end of March 2018, with additional prizes worth \$10 million for further milestones.^{[218][219]} As of August 2016, 16 teams are participating in the competition.^[220]

In August 2016, the US government granted permission to US-based start-up Moon Express to land on the Moon.^[221] This marked the first time that a private enterprise was given the right to do so. The decision is regarded as a precedent helping to define regulatory standards for deep-space commercial activity in the future, as thus far companies' operation had been restricted to being on or around Earth.^[221]

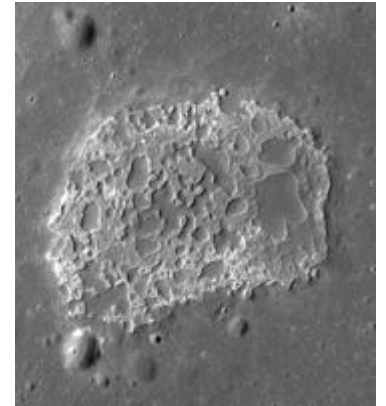
Astronomy from the Moon

For many years, the Moon has been recognized as an excellent site for telescopes.^[223] It is relatively nearby; astronomical seeing is not a concern; certain craters near the poles are permanently dark and cold, and thus especially useful for infrared telescopes; and radio telescopes on the far side would be shielded from the radio chatter of Earth.^[224] The lunar soil, although it poses a problem for any moving parts of telescopes, can be mixed with carbon nanotubes and epoxies and employed in the construction of mirrors up to 50 meters in diameter.^[225] A lunar zenith telescope can be made cheaply with anionic liquid.^[226]

In April 1972, the Apollo 16 mission recorded various astronomical photos and spectra in ultraviolet with the Far Ultraviolet Camera/Spectrograph.^[227]



Copernicus's central peaks as observed by the LRO, 2012



The Ina formation, 2009

Legal status

Although Luna landers scattered pennants of the Soviet Union on the Moon, and U.S. flags were symbolically planted at their landing sites by the Apollo astronauts, no nation claims ownership of any part of the Moon's surface.^[228] Russia and the U.S. are party to the 1967 Outer Space Treaty,^[229] which defines the Moon and all outer space as the 'province of all mankind'.^[228] This treaty also restricts the use of the Moon to peaceful purposes, explicitly banning military installations and weapons of mass destruction.^[230] The 1979 Moon Agreement was created to restrict the exploitation of the Moon's resources by any single nation, but as of November 2016, it has been signed and ratified by only 18 nations, none of which engages in self-launched human space exploration or has plans to do so.^[231] Although several individuals have made claims to the Moon in whole or in part, none of these are considered credible.^{[232][233][234]}

In culture

Mythology

A 5,000-year-old rock carving at Knowth, Ireland, may represent the Moon, which would be the earliest depiction discovered.^[235] The contrast between the brighter highlands and the darker maria creates the patterns seen by different cultures as the Man in the Moon, the rabbit and the buffalo, among others. In many prehistoric and ancient cultures, the Moon was personified as a deity or other supernatural phenomenon, and astrological views of the Moon continue to be propagated today

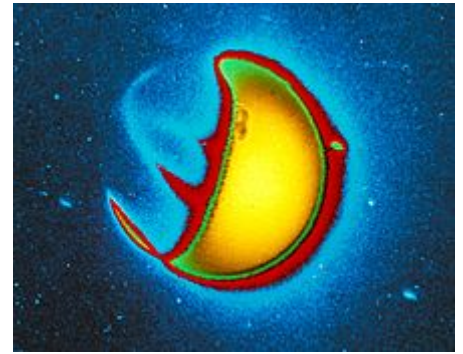
In Proto-Indo-European religion, the moon was personified as the male god **Meh₁not*.^[236] The ancient Sumerians believed that the moon was the god Nanna,^{[237][238]} who was the father of Inanna, the goddess of the planet Venus,^{[237][238]} and Utu, the god of the sun.^{[237][238]} Nanna was later known as Sîn,^{[238][237]} and was particularly associated with magic and sorcery.^[237] In Greco-Roman mythology, the Sun and the Moon are represented as male and female, respectively (Helios/Sol and Selene/Luna).^[236] this is a development unique to the eastern Mediterranean^[236] and traces of an earlier male moon god in the Greek tradition are preserved in the figure of Menelaus.^[236]

In Mesopotamian iconography, the crescent was the primary symbol of Nanna-Sîn.^[238] In ancient Greek art, the Moon goddess Selene was represented wearing a crescent on her headgear in an arrangement reminiscent of horns.^{[239][240]} The star and crescent arrangement also goes back to the Bronze Age, representing either the Sun and Moon, or the Moon and planet Venus, in combination. It came to represent the goddess Artemis or Hecate, and via the patronage of Hecate came to be used as a symbol of Byzantium.

An iconographic tradition of representing Sun and Moon with faces developed in the late medieval period.

The splitting of the moon (Arabic: انشقاق القمر) is a miracle attributed to Muhammad.^[241]

Calendar



A false-color image of Earth in ultraviolet light taken from the surface of the Moon on the Apollo 16 mission. The day-side reflects a lot of UV light from the Sun, but the night-side shows faint bands of UV emission from the aurora caused by charged particles.^[222]



Luna, the Moon, from a 1550 edition of Guido Bonatti's *Liber astronomiae*



Sun and Moon with faces (1493 woodcut)

The Moon's regular phases make it a very convenient timepiece, and the periods of its waxing and waning form the basis of many of the oldest calendars. Tally sticks, notched bones dating as far back as 20–30,000 years ago, are believed by some to mark the phases of the Moon.^{[242][243][244]} The ~30-day month is an approximation of the lunar cycle. The English noun *month* and its cognates in other Germanic languages stem from Proto-Germanic **mǣnōth-*, which is connected to the above-mentioned Proto-Germanic **mǣnōn*, indicating the usage of a lunar calendar among the Germanic peoples (Germanic calendar) prior to the adoption of a solar calendar.^[245] The PIE root of *moon*, **méh₁nōt*, derives from the PIE verbal root **meh₁-*, "to measure", "indicat[ing] a functional conception of the moon, i.e. marker of the month" (cf. the English words *measure* and *menstrual*),^{[246][247][248]} and echoing the Moon's importance to many ancient cultures in measuring time (see Latin mensis and Ancient Greek μέις (*meis*) or μήν (*mēn*), meaning "month").^{[249][250][251][252]} Most historical calendars are lunisolar. The 7th-century Islamic calendar is an exceptional example of a purely lunar calendar. Months are traditionally determined by the visual sighting of the hila, or earliest crescent moon, over the horizon.^[253]

Lunacy

The Moon has long been associated with insanity and irrationality; the words *lunacy* and *lunatic* (popular shortening *loony*) are derived from the Latin name for the Moon, *Luna*. Philosophers Aristotle and Pliny the Elder argued that the full moon induced insanity in susceptible individuals, believing that the brain, which is mostly water, must be affected by the Moon and its power over the tides, but the Moon's gravity is too slight to affect any single person.^[254] Even today, people who believe in a lunar effect claim that admissions to psychiatric hospitals, traffic accidents, homicides or suicides increase during a full moon, but dozens of studies invalidate these claims.^{[254][255][256][257][258]}



"Moonrise", 1884, picture by Stanisław Masłowski (National Museum, Kraków, Gallery of Sukiennice Museum)

See also

- List of lunar features
- Former classification of planets
- Other moons of Earth
- 2006 RH₁₂₀
- List of natural satellites
- Tourism on the Moon
- Timeline of the far future

References

Notes

- Between 18.29° and 28.58° to Earth's equator.^[1]
- There are a number of near-Earth asteroids, including 3753 Cruithne, that are co-orbital with Earth: their orbits bring them close to Earth for periods of time but then alter in the long term (Morais et al, 2002). These are quasi-satellites – they are not moons as they do not orbit Earth. For more information, see Other moons of Earth
- The *maximum value* is given based on scaling of the brightness from the value of −12.74 given for an equator to Moon-centre distance of 378 000 km in the NASA factsheet reference to the minimum Earth–Moon distance given there, after the latter is corrected for Earth's equatorial radius of 6 378 km, giving 350 600 km. The *minimum value* (for a distant new moon) is based on a similar scaling using the maximum Earth–Moon distance of 407 000 km (given in the factsheet) and by calculating the brightness of the earthshine onto such a new moon. The brightness of the earthshine is [Earth albedo × (Earth radius / Radius of Moon's orbit)²] relative to the direct solar illumination that occurs for a full moon. (Earth albedo = 0.367, Earth radius = (polarradius × equatorialradius)^{1/2} = 6 367 km.)

- d. The range of angular size values given are based on simple scaling of the following values given in the fact sheet reference: at an Earth-equator to Moon-centre distance of 378 000 km, the angular size is 1896 arcseconds. The same fact sheet gives extreme Earth–Moon distances of 407 000 km and 357 000 km. For the maximum angular size, the minimum distance has to be corrected for Earth's equatorial radius of 6 378 km, giving 350 600 km.
- e. Lucey et al. (2006) give 10^7 particles cm^{-3} by day and 10^5 particles cm^{-3} by night. Along with equatorial surface temperatures of 390 K by day and 100 K by night, the ideal gas law yields the pressures given in the infobox (rounded to the nearest order of magnitude): 10^{-7} Pa by day and 10^{-10} Pa by night.
- f. This age is calculated from isotope dating of lunar zircons.
- g. More accurately, the Moon's mean sidereal ~~period~~ (fixed star to fixed star) is 27.321661 days (27 d 07 h 43 min 11.5 s) and its mean tropical orbital period (from equinox to equinox) is 27.321582 days (27 d 07 h 43 min 04.7 s) (*Explanatory Supplement to the Astronomical Ephemeris* 1961, at p.107).
- h. More accurately, the Moon's mean synodic ~~period~~ (between mean solar conjunctions) is 29.530589 days (29 d 12 h 44 min 02.9 s) (*Explanatory Supplement to the Astronomical Ephemeris* 1961, at p.107).
- i. There is no strong correlation between the sizes of planets and the sizes of their satellites. Larger planets tend to have more satellites, both large and small, than smaller planets.
- j. With 27% the diameter and 60% the density of Earth, the Moon has 1.23% of the mass of Earth. The moon Charon is larger relative to its primary Pluto, but Pluto is now considered to be a dwarf planet.
- k. The Sun's apparent magnitude is -26.7 , while the full moon's apparent magnitude is -12.7 .
- l. See graph in Sun#Life phases. At present, the diameter of the Sun is increasing at a rate of about five percent per billion years. This is very similar to the rate at which the apparent angular diameter of the Moon is decreasing as it recedes from Earth.
- m. On average, the Moon covers an area of 0.21078 square degrees on the night sky.

Citations

1. Wieczorek, Mark A.; et al. (2006). "The constitution and structure of the lunar interior" *Reviews in Mineralogy and Geochemistry*. **60** (1): 221–364. Bibcode:2006RvMG...60..221W (<http://adsabs.harvard.edu/abs/2006RvMG...60..221W>). doi:10.2138/rmg.2006.60.3 (<https://doi.org/10.2138/rmg.2006.60.3>)
2. Lang, Kenneth R. (2011), *The Cambridge Guide to the Solar System* (<https://books.google.com/books?id=S4xDhVCxAQIC&pg=PA184>) Archived (<https://web.archive.org/web/20160101071141/https://books.google.com/books?id=S4xDhVCxAQIC&pg=PA184>) 1 January 2016 at the Wayback Machine, 2nd ed., Cambridge University Press.
3. Morais, M.H.M.; Morbidelli, A. (2002). "The Population of Near-Earth Asteroids in Coorbital Motion with the Earth". *Icarus*. **160** (1): 1–9. Bibcode:2002Icar.160....1M (<http://adsabs.harvard.edu/abs/2002Icar.160....1M>). doi:10.1006/icar.2002.6937 (<https://doi.org/10.1006/icar.2002.6937>).
4. Williams, Dr. David R. (2 February 2006). "Moon Fact Sheet" (<http://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html>). NASA/National Space Science Data Center Archived (<https://web.archive.org/web/20100323165650/http://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html>) from the original on 23 March 2010 Retrieved 31 December 2008.
5. Smith, David E.; Zuber, Maria T.; Neumann, Gregory A.; Lemoine, Frank G. (1 January 197). "Topography of the Moon from the Clementine lidar". *Journal of Geophysical Research* **102** (E1): 1601. Bibcode:1997JGR...102.1591S (<http://adsabs.harvard.edu/abs/1997JGR...102.1591S>) doi:10.1029/96JE02940 (<https://doi.org/10.1029/96JE02940>).
6. Williams, James G.; Newhall, XX; Dickey, Jean O. (1996). "Lunar moments, tides, orientation, and coordinate frames". *Planetary and Space Science* **44** (10): 1077–1080. Bibcode:1996P&SS...44.1077W (<http://adsabs.harvard.edu/abs/1996P&SS...44.1077W>) doi:10.1016/0032-0633(95)00154-9 ([https://doi.org/10.1016/0032-0633\(95\)00154-9](https://doi.org/10.1016/0032-0633(95)00154-9))
7. Matthews, Grant (2008). "Celestial body irradiance determination from an underfilled satellite radiometer: application to albedo and thermal emission measurements of the Moon using CERES" *Applied Optics*. **47** (27): 4981–93. Bibcode:2008ApOpt..47.4981M (<http://adsabs.harvard.edu/abs/2008ApOpt..47.4981M>) doi:10.1364/AO.47.004981 (<https://doi.org/10.1364/AO.47.004981>) PMID 18806861 (<https://www.ncbi.nlm.nih.gov/pubmed/18806861>).
8. A.R. Vasavada; D.A. Paige & S.E. Wood (1999). "Near-Surface Temperatures on Mercury and the Moon and the Stability of Polar Ice Deposits" *Icarus*. **141** (2): 179–193. Bibcode:1999Icar.141..179V (<http://adsabs.harvard.edu/abs/1999Icar.141..179V>) doi:10.1006/icar.1999.6175 (<https://doi.org/10.1006/icar.1999.6175>).

9. Lucey, Paul; Korotev, Randy L.; et al. (2006). "Understanding the lunar surface and space-Moon interactions". *Reviews in Mineralogy and Geochemistry* **60** (1): 83–219. Bibcode:2006RvMG...60...83L (<http://adsabs.harvard.edu/abs/2006RvMG...60...83L>) doi:10.2138/rmg.2006.60.2 (<https://doi.org/10.2138%2Frmg.2006.60.2>)
10. "How far away is the moon? :: NASA Space Place" (<http://spaceplace.nasa.gov/moon-distance/en/>) Archived (<http://web.archive.org/web/20161006220531/http://spaceplace.nasa.gov/moon-distance/en/>) from the original on 6 October 2016.
11. Scott, Elaine. *Our Moon: New Discoveries About Earth's Closest Companion* Houghton Mifflin Harcourt (2016) ISBN 9780544750586 page 7.
12. Collins English Dictionary (<https://www.collinsdictionary.com/dictionary/english/moon>)
13. Oxford Living Dictionaries (<https://en.oxforddictionaries.com/definition/us/moon#moon>)
14. Meaning of "moon" in the English Dictionary (<https://dictionarycambridge.org/dictionary/english/moon>) Cambridge Learner's Dictionary
15. "Naming Astronomical Objects: Spelling of Names" (http://www.iau.org/public_press/themes/naming/#spelling). International Astronomical Union Archived (https://web.archive.org/web/20081216024716/http://www.iau.org/public_press/themes/naming/#spelling) from the original on 16 December 2008 Retrieved 29 March 2010.
16. "Gazetteer of Planetary Nomenclature: Planetary Nomenclature FAQ" (<http://planetarynames.wr.usgs.gov/nomenFAQ.html>). USGS Astrogeology Research Program Archived (<https://web.archive.org/web/20100527120646/http://planetarynames.wr.usgs.gov/nomenFAQ.html>) from the original on 27 May 2010 Retrieved 29 March 2010.
17. The American Heritage Dictionary Indo-European Roots Appendix (<https://www.ahdictionary.com/word/indoeurop.html>)
18. Barnhart, Robert K. (1995). *The Barnhart Concise Dictionary of Etymology* USA: Harper Collins p. 487. ISBN 978-0-06-270084-1
19. *Oxford English Dictionary* 2nd ed. "luna", Oxford University Press (Oxford), 2009.
20. American Heritage Dictionary (<https://www.ahdictionary.com/word/search.html?q=selenic>)
21. Collins English Dictionary (<https://www.collinsdictionary.com/dictionary/english/selenic>)
22. Oxford Living Dictionaries (<https://en.oxforddictionaries.com/definition/selenic>)
23. "Oxford English Dictionary: lunar a. and n" (http://dictionary.oed.com/cgi/entry/50136796?single=1&query_type=word&queryword=lunar&first=&max_to_show=10) *Oxford English Dictionary: Second Edition 1989* Oxford University Press. Retrieved 23 March 2010.
24. σελήνη (<http://www.perseus.tufts.edu/hopper/text?d=Perseus:text:1999.04.0057:entry=selh/nh>) Liddell, Henry George; Scott, Robert, *A Greek-English Lexicon* at the Perseus Project
25. Imke Pannen (2010). *When the Bad Bleeds: Mantic Elements in English Renaissance Revenge Tragedy* (<https://books.google.com/books?id=37CPbHwqPjwC&pg=PA96>). V&R unipress GmbH pp. 96–. ISBN 978-3-89971-640-5 Archived (<https://web.archive.org/web/20160904223627/https://books.google.com/books?id=37CPbHwqPjwC&pg=PA96>) from the original on 4 September 2016.
26. Barboni, M.; Boehnke, P; Keller, C.B.; Kohl, I.E.; Schoene, B.; Young, E.D.; McKeegan, K.D. (2017). "Early formation of the Moon 4.51 billion years ago" *Science Advances* **3** (1): e1602365. Bibcode:2017SciA....3E2365B (<http://adsabs.harvard.edu/abs/2017SciA....3E2365B>) doi:10.1126/sciadv.1602365 (<https://doi.org/10.1126%2Fsciadv.1602365>).
27. Binder, A.B. (1974). "On the origin of the Moon by rotational fission". *The Moon*. **11** (2): 53–76. Bibcode:1974Moon...11...53B (<http://adsabs.harvard.edu/abs/1974Moon...11...53B>) doi:10.1007/BF01877794 (<https://doi.org/10.1007%2FBF01877794>)
28. Stroud, Rick (2009). *The Book of the Moon* Walken and Company pp. 24–27. ISBN 978-0-8027-1734-4
29. Mitler, H.E. (1975). "Formation of an iron-poor moon by partial capture, or: Yet another exotic theory of lunar origin". *Icarus*. **24** (2): 256–268. Bibcode:1975Icar...24..256M (<http://adsabs.harvard.edu/abs/1975Icar...24..256M>). doi:10.1016/0019-1035(75)90102-5 (<https://doi.org/10.1016%2F0019-1035%2875%2990102-5>)
30. Stevenson, D.J. (1987). "Origin of the moon—The collision hypothesis" *Annual Review of Earth and Planetary Sciences*. **15** (1): 271–315. Bibcode:1987AREPS..15..271S (<http://adsabs.harvard.edu/abs/1987AREPS..15..271S>) doi:10.1146/annurevea.15.050187.001415 (<https://doi.org/10.1146%2Fannurevea.15.050187.001415>)
31. Taylor, G. Jeffrey (31 December 1998). "Origin of the Earth and Moon" (<http://www.psrcd.hawaii.edu/Dec98/OriginEarthMoon.html>). *Planetary Science Research Discoveries* Hawai'i Institute of Geophysics and Planetology Archived (<https://web.archive.org/web/20100610011142/http://www.psrcd.hawaii.edu/Dec98/OriginEarthMoon.html>) from the original on 10 June 2010 Retrieved 7 April 2010.

32. "Asteroids Bear Scars of Moon's Violent Formation" (<http://news.nationalgeographic.com/2015/04/150416-asteroids-scars-moon-formation-space/>) 16 April 2015. Archived (<https://web.archive.org/web/20161008160812/http://news.nationalgeographic.com/2015/04/150416-asteroids-scars-moon-formation-space/>) from the original on 8 October 2016.
33. Dana Mackenzie (21 July 2003). *The Big Splat, or How Our Moon Came to Be* (<https://books.google.com/books?id=omVaG7u4qG8C&pg=PA166>). John Wiley & Sons pp. 166–168. ISBN 978-0-471-48073-0 Archived (<https://web.archive.org/web/20160101071141/https://books.google.com/books?id=omVaG7u4qG8C&pg=PA166>) from the original on 1 January 2016.
34. Canup, R.; Asphaug, E. (2001). "Origin of the Moon in a giant impact near the end of Earth's formation" *Nature*. **412** (6848): 708–712. Bibcode:2001Natur.412..708C (<http://adsabs.harvard.edu/abs/2001Natur.412..708C>). doi:10.1038/35089010 (<https://doi.org/10.1038/35089010>) PMID 11507633 (<https://www.ncbi.nlm.nih.gov/pubmed/11507633>)
35. "Earth-Asteroid Collision Formed Moon Later Than Thought" (<http://news.nationalgeographic.com/news/2007/12/071219-moon-collision.html>) National Geographic 28 October 2010. Archived (<https://web.archive.org/web/20090418171528/http://news.nationalgeographic.com/news/2007/12/071219-moon-collision.html>) from the original on 18 April 2009. Retrieved 7 May 2012.
36. "2008 Pellas-Ryder Award for Mathieu Touboul" (http://digitalcommons.arizona.edu/objectviewer?o=uadc://azu_map_s/Volume43/NumberSupplement/Touboul.pdf) (PDF). Meteoritical Society. 2008.
37. Touboul, M.; Kleine, T.; Bourdon, B.; Palme, H.; Wieler, R. (2007). "Late formation and prolonged differentiation of the Moon inferred from W isotopes in lunar metals" *Nature*. **450** (7173): 1206–9. Bibcode:2007Natur.450.1206T (<http://adsabs.harvard.edu/abs/2007Natur.450.1206T>). doi:10.1038/nature06428 (<https://doi.org/10.1038/nature06428>). PMID 18097403 (<https://www.ncbi.nlm.nih.gov/pubmed/18097403>).
38. "Flying Oceans of Magma Help Demystify the Moon's Creation" (<http://news.nationalgeographic.com/2015/04/150408-moon-form-giant-impact-earth>) National Geographic 8 April 2015. Archived (<https://web.archive.org/web/20150409220422/http://news.nationalgeographic.com/2015/04/150408-moon-form-giant-impact-earth/>) from the original on 9 April 2015.
39. Pahlevan, Kaveh; Stevenson, David J. (2007). "Equilibration in the aftermath of the lunar-forming giant impact". *Earth and Planetary Science Letters* **262** (3–4): 438–449. arXiv:1012.5323 (<https://arxiv.org/abs/1012.5323>). Bibcode:2007E&PSL.262..438P (<http://adsabs.harvard.edu/abs/2007E&PSL.262..438P>) doi:10.1016/j.epsl.2007.07.055 (<https://doi.org/10.1016/j.epsl.2007.07.055>)
40. Nield, Ted (2009). "Moonwalk (summary of meeting at Meteoritical Society's 72nd Annual Meeting, Nancy France)" (<https://web.archive.org/web/20120927034348/http://www.geolsoc.org.uk/gsl/geoscientist/geonews/page6072.html>) *Geoscientist*. Vol. 19. p. 8. Archived from the original (<http://www.geolsoc.org.uk/gsl/geoscientist/geonews/page6072.html>) on 27 September 2012.
41. Warren, P. H. (1985). "The magma ocean concept and lunar evolution". *Annual Review of Earth and Planetary Sciences*. **13** (1): 201–240. Bibcode:1985AREPS..13..201W (<http://adsabs.harvard.edu/abs/1985AREPS..13..201W>) doi:10.1146/annurevea.13.050185.001221 (<https://doi.org/10.1146/annurevea.13.050185.001221>)
42. Tonks, W. Brian; Melosh, H. Jay (1993). "Magma ocean formation due to giant impacts" *Journal of Geophysical Research*. **98** (E3): 5319–5333. Bibcode:1993JGR....98.5319T (<http://adsabs.harvard.edu/abs/1993JGR....98.5319T>). doi:10.1029/92JE02726 (<https://doi.org/10.1029/92JE02726>)
43. Daniel Clery (11 October 2013). "Impact Theory Gets Whacked" *Science*. **342** (6155): 183–185. Bibcode:2013Sci...342..183C (<http://adsabs.harvard.edu/abs/2013Sci...342..183C>) doi:10.1126/science.342.6155.183 (<https://doi.org/10.1126/science.342.6155.183>) PMID 24115419 (<https://www.ncbi.nlm.nih.gov/pubmed/24115419>)
44. Wiechert, U.; et al. (October 2001). "Oxygen Isotopes and the Moon-Forming Giant Impact" (<http://www.sciencemag.org/cgi/content/abstract/294/5541/345>) *Science*. **294** (12): 345–348. Bibcode:2001Sci...294..345W (<http://adsabs.harvard.edu/abs/2001Sci...294..345W>) doi:10.1126/science.1063037 (<https://doi.org/10.1126/science.1063037>) PMID 11598294 (<https://www.ncbi.nlm.nih.gov/pubmed/11598294>). Archived (<https://web.archive.org/web/20090420154721/http://www.sciencemag.org/cgi/content/abstract/294/5541/345>) from the original on 20 April 2009 Retrieved 5 July 2009.
45. Pahlevan, Kaveh; Stevenson, David (October 2007). "Equilibration in the Aftermath of the Lunar-forming Giant Impact". *EPSL*. **262** (3–4): 438–449. arXiv:1012.5323 (<https://arxiv.org/abs/1012.5323>). Bibcode:2007E&PSL.262..438P (<http://adsabs.harvard.edu/abs/2007E&PSL.262..438P>) doi:10.1016/j.epsl.2007.07.055 (<https://doi.org/10.1016/j.epsl.2007.07.055>)

46. "Titanium Paternity Test Says Earth is the Moon's Only Parent (University of Chicago)"(<http://www.astrobio.net/press-release/4673/titanium-paternity-test-says-earth-is-the-moons-only-parent>)Astrobio.net Retrieved 3 October 2013.
47. Taylor, Stuart Ross (1975). *Lunar science: A post-Apollo view* Pergamon Press p. 64. Bibcode:1975Ispa.book.....T (<http://adsabs.harvard.edu/abs/1975Ispa.book.....T>)
48. Brown, D.; Anderson, J. (6 January 2011). "NASA Research Team Reveals Moon Has Earth-Like Core" (http://www.nasa.gov/topics/moonmars/features/lunar_core.html)NASA. NASA. Archived (https://www.webcitation.org/66BdXGozx?url=http://www.nasa.gov/topics/moonmars/features/lunar_core.html)from the original on 15 March 2012.
49. Weber, R. C.; Lin, P.-Y.; Garner, E. J.; Williams, Q.; Lognonne, P.(21 January 2011). "Seismic Detection of the Lunar Core" (<http://www.earth.northwestern.edu/people/seth/351/lunarcore.2011.pdf>) (PDF). *Science*. **331** (6015): 309–312. Bibcode:2011Sci...331..309W (<http://adsabs.harvard.edu/abs/2011Sci...331..309W>) doi:10.1126/science.1199375 (<https://doi.org/10.1126%2Fscience.1199375>) PMID 21212323 (<https://www.ncbi.nlm.nih.gov/pubmed/21212323>) Archived (<https://web.archive.org/web/20151015035756/http://www.earth.northwestern.edu/people/seth/351/lunarcore.2011.pdf>) (PDF) from the original on 15 October 2015.
50. Nemchin, A.; Timms, N.; Pidgeon, R.; Geisler, T.; Reddy, S.; Meyer, C. (2009). "Timing of crystallization of the lunar magma ocean constrained by the oldest zircon" *Nature Geoscience* **2** (2): 133–136. Bibcode:2009NatGe...2..133N (<http://adsabs.harvard.edu/abs/2009NatGe...2..133N>) doi:10.1038/ngeo417 (<https://doi.org/10.1038%2Fng417>)
51. Shearer, Charles K.; et al. (2006). "Thermal and magmatic evolution of the Moon" *Reviews in Mineralogy and Geochemistry*. **60** (1): 365–518. Bibcode:2006RvMG...60..365S (<http://adsabs.harvard.edu/abs/2006RvMG...60..365S>). doi:10.2138/rmg.2006.60.4 (<https://doi.org/10.2138%2Frmg.2006.60.4>)
52. Schubert, J. (2004). "Interior composition, structure, and dynamics of the Galilean satellites.". In Bagenal; et al. *Jupiter: The Planet, Satellites, and Magnetosphere* Cambridge University Press pp. 281–306. ISBN 978-0-521-81808-7.
53. Williams, J. G.; Turyshev, S. G.; Boggs, D. H.; Ratcliff, J. T. (2006). "Lunar laser ranging science: Gravitational physics and lunar interior and geodesy" *Advances in Space Research* **37** (1): 67–71. arXiv:gr-qc/0412049 (<https://arxiv.org/abs/gr-qc/0412049>). Bibcode:2006AdSpR...37...67W (<http://adsabs.harvard.edu/abs/2006AdSpR...37...67W>). doi:10.1016/j.asr.2005.05.013 (<https://doi.org/10.1016%2Fj.asr.2005.05.013>).
54. Spudis, Paul D.; Cook, A.; Robinson, M.; Bussey, B.; Fessler, B. (January 1998). "Topography of the South Polar Region from Clementine Stereo Imaging". *Workshop on New Views of the Moon: Integrated Remotely Sensed, Geophysical, and Sample Datasets* 69. Bibcode:1998nvmi.conf...69S (<http://adsabs.harvard.edu/abs/1998nvmi.conf...69S>).
55. Spudis, Paul D.; Reisse, Robert A.; Gillis, Jeffrey J. (1994). "Ancient Multiring Basins on the Moon Revealed by Clementine Laser Altimetry". *Science*. **266** (5192): 1848–1851. Bibcode:1994Sci...266.1848S (<http://adsabs.harvard.edu/abs/1994Sci...266.1848S>) doi:10.1126/science.266.5192.1848 (<https://doi.org/10.1126%2Fscience.266.5192.1848>). PMID 17737079 (<https://www.ncbi.nlm.nih.gov/pubmed/17737079>).
56. Pieters, C.M.; Tompkins, S.; Head, J.W.; Hess, P.C. (1997). "Mineralogy of the Mafic Anomaly in the South Pole-Aitken Basin: Implications for excavation of the lunar mantle" *Geophysical Research Letters* **24** (15): 1903–1906. Bibcode:1997GeoRL..24.1903P (<http://adsabs.harvard.edu/abs/1997GeoRL..24.1903P>) doi:10.1029/97GL01718 (<https://doi.org/10.1029%2F97GL01718>)
57. Taylor, G.J. (17 July 1998). "The Biggest Hole in the Solar System" (<http://www.psrcd.hawaii.edu/July98/spa.html>). *Planetary Science Research Discoveries* Hawai'i Institute of Geophysics and Planetology Archived (<https://web.archive.org/web/20070820042129/http://www.psrcd.hawaii.edu/July98/spa.html>)from the original on 20 August 2007 Retrieved 12 April 2007.
58. Schultz, P. H. (March 1997). "Forming the south-pole Aitken basin – The extreme games" *Conference Paper, 28th Annual Lunar and Planetary Science Conference* 28: 1259. Bibcode:1997LPI....28.1259S (<http://adsabs.harvard.edu/abs/1997LPI....28.1259S>)
59. "NASA's LRO Reveals 'Incredible Shrinking Moon'" (http://www.nasa.gov/mission_pages/LRO/news/shrinking-moon.html). NASA. 19 August 2010. Archived (https://web.archive.org/web/20100821124252/http://www.nasa.gov/mission_pages/LRO/news/shrinking-moon.html)from the original on 21 August 2010.
60. Wlasuk, Peter (2000). *Observing the Moon* (<https://books.google.com/?id=TWtLIOIPwS4C>) Springer. p. 19. ISBN 978-1-85233-193-1
61. Norman, M. (21 April 2004). "The Oldest Moon Rocks" (<http://www.psrcd.hawaii.edu/April04/lunarAnorthosites.html>). *Planetary Science Research Discoveries* Hawai'i Institute of Geophysics and Planetology Archived (<https://web.archive.org/web/20070418152325/http://www.psrcd.hawaii.edu/April04/lunarAnorthosites.html>)from the original on 18 April 2007. Retrieved 12 April 2007.

62. Head, L.W.J.W. (2003). "Lunar Gruithuisen and Mairan domes: Rheology and mode of emplacement"(<http://www.agu.org/pubs/crossref/2003/2002JE001909.shtml>) *Journal of Geophysical Research* **108** (E2): 5012. Bibcode:2003JGRE..108.5012W(<http://adsabs.harvard.edu/abs/2003JGRE..108.5012W>) doi:10.1029/2002JE001909(<https://doi.org/10.1029%2F2002JE001909>) Archived (<https://web.archive.org/web/20070312071105/http://www.agu.org/pubs/crossref/2003/2002JE001909.shtml>) from the original on 12 March 2007 Retrieved 12 April 2007.
63. Spudis, P.D. (2004). "Moon" (https://web.archive.org/web/20130703162844/http://www.nasa.gov/worldbook/moon_worldbook.html) World Book Online Reference Center NASA. Archived from the original (http://www.nasa.gov/worldbook/moon_worldbook.html) on 3 July 2013 Retrieved 12 April 2007.
64. Gillis, J.J.; Spudis, P.D. (1996). "The Composition and Geologic Setting of Lunar Far Side Maria" *Lunar and Planetary Science* **27**: 413. Bibcode:1996LPI....27..413G(<http://adsabs.harvard.edu/abs/1996LPI....27..413G>)
65. Lawrence, D. J., et al. (11 August 1998). "Global Elemental Maps of the Moon: The Lunar Prospector Gamma-Ray Spectrometer" (<http://www.sciencemag.org/cgi/content/full/281/5382/1484>) *Science*. **281** (5382): 1484–1489. Bibcode:1998Sci...281.1484L(<http://adsabs.harvard.edu/abs/1998Sci...281.1484L>) doi:10.1126/science.281.5382.1484(<https://doi.org/10.1126%2Fscience.281.5382.1484>) PMID 9727970 (<https://www.ncbi.nlm.nih.gov/pubmed/9727970>) Archived (<https://web.archive.org/web/20090516065007/http://www.sciencemag.org/cgi/content/full/281/5382/1484>) from the original on 16 May 2009 Retrieved 29 August 2009.
66. Taylor, G.J. (31 August 2000). "A New Moon for the Twenty-First Century" (<http://www.psrcd.hawaii.edu/Aug00/newMoon.html>). *Planetary Science Research Discoveries* Hawai'i Institute of Geophysics and Planetology Archived (<http://www.webcitation.org/66BdZ4zPb?url=http://www.psrcd.hawaii.edu/Aug00/newMoon.html>) from the original on 15 March 2012 Retrieved 12 April 2007.
67. Papike, J.; Ryder, G.; Shearer, C. (1998). "Lunar Samples". *Reviews in Mineralogy and Geochemistry* **36**: 5.1–5.234.
68. Hiesinger, H.; Head, J.W.; Wolf, U.; Jaumann, R.; Neukum, G. (2003). "Ages and stratigraphy of mare basalts in Oceanus Procellarum, Mare Nubium, Mare Cognitum, and Mare Insularum" *Journal of Geophysical Research* **108** (E7): 1029. Bibcode:2003JGRE..108.5065H(<http://adsabs.harvard.edu/abs/2003JGRE..108.5065H>) doi:10.1029/2002JE001985(<https://doi.org/10.1029%2F2002JE001985>)
69. Phil Berardelli (9 November 2006). "Long Live the Moon!" (<http://news.sciencemag.org/2006/11/long-live-moon>) *Science*. Archived (<https://web.archive.org/web/20141018153016/http://news.sciencemag.org/2006/11/long-live-moon>) from the original on 18 October 2014.
70. Jason Major (14 October 2014). "Volcanoes Erupted 'Recently' on the Moon" (<http://news.discovery.com/space/imps-reveal-volcanoes-erupted-recently-on-the-moon-141014.htm>) Discovery News Archived (<https://web.archive.org/web/20141016190653/http://news.discovery.com/space/imps-reveal-volcanoes-erupted-recently-on-the-moon-141014.htm>) from the original on 16 October 2014.
71. "NASA Mission Finds Widespread Evidence of Young Lunar Volcanism" (<http://www.nasa.gov/press/2014/october/nasa-mission-finds-widespread-evidence-of-young-lunar-volcanism/#.VDxNwOt3uxo>) NASA. 12 October 2014. Archived (<https://web.archive.org/web/20150103095208/http://www.nasa.gov/press/2014/october/nasa-mission-finds-widespread-evidence-of-young-lunar-volcanism/#.VDxNwOt3uxo>) from the original on 3 January 2015.
72. Eric Hand (12 October 2014). "Recent volcanic eruptions on the moon" (<http://news.sciencemag.org/space/2014/10/recent-volcanic-eruptions-moon>) *Science*. Archived (<https://web.archive.org/web/20141014092239/http://news.sciencemag.org/space/2014/10/recent-volcanic-eruptions-moon>) from the original on 14 October 2014.
73. Braden, S. E.; Stopar, J. D.; Robinson, M. S.; Lawrence, S. J.; van der Bogert, C. H.; Hiesinger, H. doi:10.1038/ngeo2252 (2014). "Evidence for basaltic volcanism on the Moon within the past 100 million years" (<http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo2252.html>) *Nature Geoscience* **7** (11): 787–791. Bibcode:2014NatGe...7..787B(<http://adsabs.harvard.edu/abs/2014NatGe...7..787B>) doi:10.1038/ngeo2252(<https://doi.org/10.1038%2Fngeo2252>)
74. Srivastava, N.; Gupta, R.P. (2013). "Young viscous flows in the Lowell crater of Orientale basin, Moon: Impact melts or volcanic eruptions?" *Planetary and Space Science* **87**: 37–45. Bibcode:2013P&SS...87...37S(<http://adsabs.harvard.edu/abs/2013P&SS...87...37S>) doi:10.1016/j.pss.2013.09.001(<https://doi.org/10.1016%2Fj.pss.2013.09.001>)
75. Gupta, R.P.; Srivastava, N.; Tiwari, R.K. (2014). "Evidences of relatively new volcanic flows on the Moon" *Current Science*. **107** (3): 454–460.

76. Whitten, J.; et al. (2011). "Lunar mare deposits associated with the Orientale impact basin: New insights into mineralogy, history, mode of emplacement, and relation to Orientale Basin evolution from Moon Mineralogy Mapper (M3) data from Chandrayaan-1". *Journal of Geophysical Research* **116**: E00G09. Bibcode:2011JGRE...116.0G09W (<http://adsabs.harvard.edu/abs/2011JGRE...116.0G09W>) doi:10.1029/2010JE003736 (<https://doi.org/10.1029/2010JE003736>).
77. Cho, Y.; et al. (2012). "Young mare volcanism in the Orientale region contemporary with the Procellarum KREEP Terrane (PKT) volcanism peak period 2 b. yago". *Geophysical Research Letters* **39** (11): L11203. Bibcode:2012GeoRL..3911203C (<http://adsabs.harvard.edu/abs/2012GeoRL..3911203C>) doi:10.1029/2012GL051838 (<https://doi.org/10.1029/2012GL051838>)
78. Munsell, K. (4 December 2006). "Majestic Mountains" (<https://web.archive.org/web/20080917055643/http://sse.jpl.nasa.gov/educ/themes/displaycfm?Item=mountains>). *Solar System Exploration NASA*. Archived from the original (<http://sse.jpl.nasa.gov/educ/themes/displaycfm?Item=mountains>) on 17 September 2008 Retrieved 12 April 2007.
79. Richard Lovett. "Early Earth may have had two moons : Nature News" (<http://www.nature.com/news/2011/110803/full/news.2011.456.html#B1>) Nature. Archived (<https://web.archive.org/web/20121103145236/http://www.nature.com/news/2011/110803/full/news.2011.456.html#B1>) from the original on 3 November 2012 Retrieved 1 November 2012.
80. "Was our two-faced moon in a small collision?" (<http://theconversation.edu.au/was-our-two-faced-moon-in-a-small-collision-2659>). Theconversation.edu.au. Archived (<https://web.archive.org/web/20130130004522/http://theconversation.edu.au/was-our-two-faced-moon-in-a-small-collision-2659>) from the original on 30 January 2013 Retrieved 1 November 2012.
81. Melosh, H. J. (1989). *Impact cratering: A geologic process* Oxford University Press ISBN 978-0-19-504284-9
82. "Moon Facts" (<http://planck.esa.int/science-e/www/object/index.cfm?fobjectid=31412>) SMART-1. European Space Agency. 2010. Retrieved 12 May 2010.
83. Wilhelms, Don (1987). "Relative Ages" *Geologic History of the Moon* (http://ser.sese.asu.edu/GHM/ghm_07txt.pdf) (PDF). U.S. Geological Survey Archived (https://web.archive.org/web/20100611054723/http://ser.sese.asu.edu/GHM/ghm_07txt.pdf) (PDF) from the original on 11 June 2010.
84. Hartmann, William K.; Quantin, Cathy; Mangold, Nicolas (2007). "Possible long-term decline in impact rates: 2. Lunar impact-melt data regarding impact history" *Icarus*. **186** (1): 11–23. Bibcode:2007Icar.186...11H (<http://adsabs.harvard.edu/abs/2007Icar.186...11H>) doi:10.1016/j.icarus.2006.09.009 (<https://doi.org/10.1016/j.icarus.2006.09.009>).
85. "The Smell of Moondust" (https://web.archive.org/web/20100308112332/http://science.nasa.gov/headlines/y2006/30jan_smellofmoondust.htm) NASA. 30 January 2006. Archived from the original (https://science.nasa.gov/headlines/y2006/30jan_smellofmoondust.htm) on 8 March 2010 Retrieved 15 March 2010.
86. Heiken, G. (1991). Vaniman, D.; French, B., eds. *Lunar Sourcebook, a user's guide to the Moon* New York: Cambridge University Press p. 736. ISBN 978-0-521-33444-0
87. Rasmussen, K.L.; Warren, P.H. (1985). "Megaregolith thickness, heat flow and the bulk composition of the Moon". *Nature*. **313** (5998): 121–124. Bibcode:1985Natur.313..121R (<http://adsabs.harvard.edu/abs/1985Natur.313..121R>) doi:10.1038/313121a0 (<https://doi.org/10.1038/313121a0>)
88. Boyle, Rebecca. "The moon has hundreds more craters than we thought" (<https://www.newscientist.com/article/2108929-the-moon-has-hundreds-more-craters-than-we-thought/>) Archived (<https://web.archive.org/web/20161013143743/https://www.newscientist.com/article/2108929-the-moon-has-hundreds-more-craters-than-we-thought/>) from the original on 13 October 2016.
89. Speyerer, Emerson J.; Povilaitis, Reinhold Z; Robinson, Mark S.; Thomas, Peter C.; Wagner, Robert V. (13 October 2016). "Quantifying crater production and regolith overturn on the Moon with temporal imaging" (<http://www.nature.com/nature/journal/v538/n7624/full/nature19829.html>) *Nature*. **538** (7624): 215–218. Bibcode:2016Natur.538..215S (<http://adsabs.harvard.edu/abs/2016Natur.538..215S>) doi:10.1038/nature19829 (<https://doi.org/10.1038/nature19829>). PMID 27734864 (<https://www.ncbi.nlm.nih.gov/pubmed/27734864>) – via www.nature.com.
90. Margot, J. L.; Campbell, D. B.; Jurgens, R. F; Slade, M. A. (4 June 1999). "Topography of the Lunar Poles from Radar Interferometry: A Survey of Cold Trap Locations" (<http://www.astro.cornell.edu/~jlm/publications/Margot00.science284.lunarice.pdf>) (PDF). *Science*. **284** (5420): 1658–1660. Bibcode:1999Sci...284.1658M (<http://adsabs.harvard.edu/abs/1999Sci...284.1658M>) doi:10.1126/science.284.5420.1658 (<https://doi.org/10.1126/science.284.5420.1658>). PMID 10356393 (<https://www.ncbi.nlm.nih.gov/pubmed/10356393>).

91. Ward, William R. (1 August 1975). "Past Orientation of the Lunar Spin Axis". *Science*. **189** (4200): 377–379. Bibcode:1975Sci...189..377W(<http://adsabs.harvard.edu/abs/1975Sci...189..377W>) doi:10.1126/science.189.4200.377(<https://doi.org/10.1126%2Fscience.189.4200.377>) PMID 17840827 (<https://www.ncbi.nlm.nih.gov/pubmed/17840827>)
92. Martel, L. M. V. (4 June 2003). "The Moon's Dark, Icy Poles"(<http://www.psrhawaii.edu/June03/lunarShadows.html>). *Planetary Science Research Discoveries* Hawai'i Institute of Geophysics and Planetology Archived (<https://www.webcitation.org/66BdcgHlw?url=http://www.psrhawaii.edu/June03/lunarShadows.html>) from the original on 15 March 2012 Retrieved 12 April 2007.
93. Seedhouse, Erik (2009). *Lunar Outpost: The Challenges of Establishing a Human Settlement on the Moon*(https://books.google.com/?id=ZJm_i3GS4r4C&pg=PA136). Springer-Praxis Books in Space Exploration. Germany Springer Praxis. p. 136. ISBN 978-0-387-09746-6
94. Coulter, Dauna (18 March 2010). "The Multiplying Mystery of Moonwater"(http://arquivo.pt/wayback/20160516155030/http://science.nasa.gov/headlines/y2010/18mar_moonwater.htm?list940097) NASA Archived from the original (https://science.nasa.gov/headlines/y2010/18mar_moonwater.htm?list940097) on 16 May 2016 Retrieved 28 March 2010.
95. Spudis, P. (6 November 2006). "Ice on the Moon"(<http://www.thespacereview.com/article/740/1>) The Space Review Archived (<https://web.archive.org/web/20070222083000/http://www.thespacereview.com/article/740/1>) from the original on 22 February 2007 Retrieved 12 April 2007.
96. Feldman, W. C.; S. Maurice; A. B. Binder; B.L. Barraclough; R. C. Elphic; D. J. Lawrence (1998). "Fluxes of Fast and Epithermal Neutrons from Lunar Prospector: Evidence for Water Ice at the Lunar Poles". *Science*. **281** (5382): 1496–1500. Bibcode:1998Sci...281.1496F(<http://adsabs.harvard.edu/abs/1998Sci...281.1496F>) doi:10.1126/science.281.5382.1496(<https://doi.org/10.1126%2Fscience.281.5382.1496>) PMID 9727973 (<https://www.ncbi.nlm.nih.gov/pubmed/9727973>)
97. Saal, Alberto E.; Hauri, Erik H.; Cascio, Mauro L.; van Orman, James A.; Rutherford, Malcolm C.; Cooper, Reid F. (2008). "Volatile content of lunar volcanic glasses and the presence of water in the Moon's interior" *Nature*. **454** (7201): 192–195. Bibcode:2008Natur.454..192S (<http://adsabs.harvard.edu/abs/2008Natur.454..192S>) doi:10.1038/nature07047(<https://doi.org/10.1038%2Fnature07047>) PMID 18615079 (<https://www.ncbi.nlm.nih.gov/pubmed/18615079>)
98. Pieters, C. M.; Goswami, J. N.; Clark, R. N.; Annadurai, M.; Boardman, J.; Buratti, B.; Combe, J.; Dyar, M. D.; Green, R.; Head, J. W.; Hibbitts, C.; Hicks, M.; Isaacson, P.; Klima, R.; Kramer, G.; Kumar, S.; Livo, E.; Lundeen, S.; Malaret, E.; McCord, T.; Mustard, J.; Nettles, J.; Petro, N.; Runyon, C.; Staid, M.; Sunshine, J.; Taylor, L. A.; Tompkins, S.; Varanasi, P. (2009). "Character and Spatial Distribution of OH/H₂O on the Surface of the Moon Seen by M3 on Chandrayaan-1". *Science*. **326** (5952): 568–72. Bibcode:2009Sci...326..568P(<http://adsabs.harvard.edu/abs/2009Sci...326..568P>) doi:10.1126/science.1178658(<https://doi.org/10.1126%2Fscience.1178658>) PMID 19779151 (<https://www.ncbi.nlm.nih.gov/pubmed/19779151>)
99. Lakdawalla, Emily (13 November 2009). "LCROSS Lunar Impactor Mission: "Yes, We Found Water!" (https://web.archive.org/web/20100122233405/http://www.planetary.org/news/2009/1113_LCROSS_Lunar_Impactor_Mission_Yes_We.html). The Planetary Society Archived from the original (http://planetary.org/news/2009/1113_LCROSS_Lunar_Impactor_Mission_Yes_We.html) on 22 January 2010 Retrieved 13 April 2010.
100. Colaprete, A.; Ennico, K.; Wooden, D.; Shirley, M.; Heldmann, J.; Marshall, W.; Sollitt, L.; Asphaug, E.; Korycansky, D.; Schultz, P.; Hermalyn, B.; Galal, K.; Bart, G. D.; Goldstein, D.; Summy, D. (1–5 March 2010). "Water and More: An Overview of LCROSS Impact Results" *41st Lunar and Planetary Science Conference* **41** (1533): 2335. Bibcode:2010LPI....41.2335C(<http://adsabs.harvard.edu/abs/2010LPI....41.2335C>)
101. Colaprete, Anthony; Schultz, Peter; Heldmann, Jennifer; Wooden, Diane; Shirley, Mark; Ennico, Kimberly; Hermalyn, Brendan; Marshall, William; Ricco, Antonio; Elphic, Richard C.; Goldstein, David; Summy, Dustin; Bart, Gwendolyn D.; Asphaug, Erik; Korycansky, Don; Landis, David; Sollitt, Luke (22 October 2010). "Detection of Water in the LCROSS Ejecta Plume". *Science*. **330** (6003): 463–468. Bibcode:2010Sci...330..463C(<http://adsabs.harvard.edu/abs/2010Sci...330..463C>) doi:10.1126/science.1186986(<https://doi.org/10.1126%2Fscience.1186986>) PMID 20966242 (<https://www.ncbi.nlm.nih.gov/pubmed/20966242>)
102. Hauri, Erik; Thomas Weinreich; Albert E. Sad; Malcolm C. Rutherford; James A. Van Orman (26 May 2011). "High Pre-Eruptive Water Contents Preserved in Lunar Melt Inclusions". *Science Express* **10** (1126): 213–215. Bibcode:2011Sci...333..213H(<http://adsabs.harvard.edu/abs/2011Sci...333..213H>) doi:10.1126/science.1204626(<https://doi.org/10.1126%2Fscience.1204626>)

103. Muller, P.; Sjogren, W. (1968). "Mascons: lunar mass concentrations" *Science*. **161** (3842): 680–684.
Bibcode:1968Sci...161..680M(<http://adsabs.harvard.edu/abs/1968Sci...161..680M>)
doi:10.1126/science.161.3842.680(<https://doi.org/10.1126%2Fscience.161.3842.680>) PMID 17801458 (<https://www.ncbi.nlm.nih.gov/pubmed/17801458>)
104. Richard A. Kerr (12 April 2013). "The Mystery of Our Moon's Gravitational Bumps Solved?" *Science*. **340** (6129): 138–139. doi:10.1126/science.340.6129.138-a(<https://doi.org/10.1126%2Fscience.340.6129.138-a>) PMID 23580504 (<https://www.ncbi.nlm.nih.gov/pubmed/23580504>).
105. Konopliv, A.; Asmar, S.; Carranza, E.; Sjogren, W.; Yuan, D. (2001). "Recent gravity models as a result of the Lunar Prospector mission" (<https://web.archive.org/web/20041113045200/http://techreports.jpl.nasa.gov/2000/00-1301.pdf>) (PDF). *Icarus*. **50** (1): 1–18. Bibcode:2001Icar..150....1K (<http://adsabs.harvard.edu/abs/2001Icar..150....1K>). doi:10.1006/icar.2000.6573 (<https://doi.org/10.1006%2Ficar.2000.6573>). Archived from the original (<http://techreports.jpl.nasa.gov/2000/00-1301.pdf>) (PDF) on 13 November 2004.
106. Garrick-Bethell, Ian; Weiss, iBenjamin P.; Shuster, David L.; Buz, Jennifer (2009). "Early Lunar Magnetism" *Science*. **323** (5912): 356–359. Bibcode:2009Sci...323..356G (<http://adsabs.harvard.edu/abs/2009Sci...323..356G>) doi:10.1126/science.1166804(<https://doi.org/10.1126%2Fscience.1166804>) PMID 19150839 (<https://www.ncbi.nlm.nih.gov/pubmed/19150839>)
107. "Magnetometer / Electron Reflectometer Results"(<https://web.archive.org/web/20100527121330/http://lunaarc.nasa.gov/results/magelres.htm>) Lunar Prospector (NASA). 2001. Archived from the original (<http://lunar.arc.nasa.gov/results/magelres.htm>) on 27 May 2010 Retrieved 17 March 2010.
108. Hood, L.L.; Huang, Z. (1991). "Formation of magnetic anomalies antipodal to lunar impact basins with 3-dimensional model calculations". *Journal of Geophysical Research* **96** (B6): 9837–9846. Bibcode:1991JGR....96.9837H(<http://adsabs.harvard.edu/abs/1991JGR....96.9837H>) doi:10.1029/91JB00308(<https://doi.org/10.1029%2F91JB00308>)
109. "Moon Storms" (https://science.nasa.gov/science-news/science-at-nasa/2005/07dec_moonstorms/) NASA. 27 September 2013. Archived (https://web.archive.org/web/20130912092057/http://science.nasa.gov/science-news/science-at-nasa/2005/07dec_moonstorms/) from the original on 12 September 2013 Retrieved 3 October 2013.
110. Culler, Jessica (16 June 2015). "LADEE - Lunar Atmosphere Dust and Environment Explorer" (http://www.nasa.gov/mission_pages/ladee/main/#.VXCc0vBdiM8) Archived (https://web.archive.org/web/20150408015242/http://www.nasa.gov/mission_pages/ladee/main/#.VXCc0vBdiM8) from the original on 8 April 2015.
111. Globus, Ruth (1977). "Chapter 5, Appendix J: Impact Upon Lunar Atmosphere". In Richard D. Johnson & Charles Holbrow. *Space Settlements: A Design Study* (<http://settlement.arc.nasa.gov/75SummerStudy/5appendJ.html>) NASA. Archived (<https://web.archive.org/web/20100531205037/http://settlement.arc.nasa.gov/75SummerStudy/5appendJ.html>) from the original on 31 May 2010 Retrieved 17 March 2010.
112. Crotts, Arlin P.S. (2008). "Lunar Outgassing, Transient Phenomena and The Return to The Moon, I: Existing Data" (<http://www.astro.columbia.edu/~arlin/TLP/paper1.pdf>) (PDF). *The Astrophysical Journal* **687**: 692–705. arXiv:0706.3949 (<https://arxiv.org/abs/0706.3949>). Bibcode:2008ApJ...687..692C (<http://adsabs.harvard.edu/abs/2008ApJ...687..692C>) doi:10.1086/591634 (<https://doi.org/10.1086%2F591634>) Archived (<https://web.archive.org/web/20090220081142/http://www.astro.columbia.edu/~arlin/TLP/paper1.pdf>) (PDF) from the original on 20 February 2009.
113. Steigerwald, William (17 August 2015). "NASA's LADEE Spacecraft Finds Neon in Lunar Atmosphere" (<http://www.nasa.gov/content/goddard/ladee-lunar-neon>) NASA. Retrieved 18 August 2015.
114. Stern, S.A. (1999). "The Lunar atmosphere: History, status, current problems, and context" *Reviews in Geophysics* **37** (4): 453–491. Bibcode:1999RvGeo..37..453S (<http://adsabs.harvard.edu/abs/1999RvGeo..37..453S>) doi:10.1029/1999RG900005 (<https://doi.org/10.1029%2F1999RG900005>)
115. Lawson, S.; Feldman, W.; Lawrence, D.; Moore, K.; Elphic, R.; Belian, R. (2005). "Recent outgassing from the lunar surface: the Lunar Prospector alpha particle spectrometer" *Journal of Geophysical Research* **110** (E9): 1029. Bibcode:2005JGRE..11009009L (<http://adsabs.harvard.edu/abs/2005JGRE..11009009L>) doi:10.1029/2005JE002433 (<https://doi.org/10.1029%2F2005JE002433>)
116. R. Sridharan; S. M. Ahmed; Tritha Pratim Dasa; P. Sreelatha; P. Pradeepkumara; Neha Naika; Gogulapati Supriya (2010). "'Direct' evidence for water (H₂O) in the sunlit lunar ambience from CHACE on MIP of Chandrayaan I". *Planetary and Space Science* **58** (6): 947–950. Bibcode:2010P&SS...58..947S (<http://adsabs.harvard.edu/abs/2010P&SS...58..947S>) doi:10.1016/j.pss.2010.02.013 (<https://doi.org/10.1016%2Fj.pss.2010.02.013>)

117. Drake, Nadia; 17, National Geographic PUBLISHED June:"Lopsided Cloud of Dust Discovered Around the Moon"(<http://news.nationalgeographic.com/2015/06/150617-moon-dust-cloud-comet-space>)*National Geographic News* Archived (<https://web.archive.org/web/20150619052915/http://news.nationalgeographic.com/2015/06/150617-moon-dust-cloud-comet-space/>)from the original on 19 June 2015 Retrieved 20 June 2015.
118. Horányi, M.; Szalay J. R.; Kempf, S.; Schmid, J.; Grün, E.; Srama, R.; Sternovsky Z. (18 June 2015). "A permanent, asymmetric dust cloud around the Moon"(<http://www.nature.com/nature/journal/v522/i7556/full/nature14479.html>). *Nature*. **522** (7556): 324–326. Bibcode:2015Natur.522..324H (<http://adsabs.harvard.edu/abs/2015Natur.522..324H>). doi:10.1038/nature14479(<https://doi.org/10.1038%2Fnature14479>) PMID 26085272 (<https://www.ncbi.nlm.nih.gov/pubmed/26085272>)
119. NASA: The Moon Once Had an Atmosphere That Faded ~~Way~~ | Time (<http://time.com/4974580/nasa-moon-had-atmosphere-volcanoes>)
120. Hamilton, Calvin J.; Hamilton, Rosanna L.,*The Moon, Views of the Solar System*(<http://www.solarviews.com/eng/moon.htm>) Archived (<https://web.archive.org/web/20160204134527/http://solarviews.com/eng/moon.htm>) February 2016 at the Wayback Machine, 1995–2011.
121. Amos, Jonathan (16 December 2009). "'Coldest place' found on the Moon" (<http://news.bbc.co.uk/1/hi/8416749.stm>) BBC News. Retrieved 20 March 2010.
122. "Diviner News" (<https://web.archive.org/web/20100307031354/http://www.diviner.ucla.edu/blog/?p=123>) UCLA. 17 September 2009. Archived from the original (<http://www.diviner.ucla.edu/blog/?p=123>) on 7 March 2010 Retrieved 17 March 2010.
123. Rocheleau, Jake. "Temperature on the Moon – Surface Temperature of the Moon – PlanetFacts.org"(<http://planetfacts.org/temperature-on-the-moon/>) Archived (<https://web.archive.org/web/20150527194737/http://planetfacts.org/temperature-on-the-moon/>)from the original on 27 May 2015.
124. Global influences of the 18.61 year nodal cycle and 8.85 year cycle of lunar perigee on high tidal levels, U. of Western Australia ([http://research-repository.uwa.edu.au/en/publications/global-influences-of-the-1861-year-nodal-cycle-and-885-year-cycle-of-lunar-perigee-on-high-tidal-levels\(54ec1689-b2b0-472f-a717-2019f2c6f2b9\)/export.html](http://research-repository.uwa.edu.au/en/publications/global-influences-of-the-1861-year-nodal-cycle-and-885-year-cycle-of-lunar-perigee-on-high-tidal-levels(54ec1689-b2b0-472f-a717-2019f2c6f2b9)/export.html))
125. V V Belet'skiĭ (2001). *Essays on the Motion of Celestial Bodies*(<https://books.google.com/?id=byWZusmVSecC>) Birkhäuser. p. 183. ISBN 978-3-7643-5866-2
126. "Space Topics: Pluto and Charon"(<https://www.webcitation.org/66BdV5X0c?url=http://www.planetary.org/explore/topics/pluto/>). The Planetary Society. Archived from the original (<http://www.planetary.org/explore/topics/pluto/>) on 15 March 2012 Retrieved 6 April 2010.
127. Phil Plait. "Dark Side of the Moon"(http://www.badastronomy.com/bad/misc/dark_side.html) Bad Astronomy Misconceptions. Archived (https://web.archive.org/web/20100412192834/http://www.badastronomy.com/bad/misc/dark_side.html) from the original on 12 April 2010 Retrieved 15 February 2010.
128. Alexander, M. E. (1973). "The Weak Friction Approximation and Tidal Evolution in Close Binary Systems". *Astrophysics and Space Science* **23** (2): 459–508. Bibcode:1973Ap&SS..23..459A (<http://adsabs.harvard.edu/abs/1973Ap&SS..23..459A>) doi:10.1007/BF00645172(<https://doi.org/10.1007%2FBF00645172>)
129. "Moon used to spin 'on different axis'" (<http://www.bbc.com/news/science-environment-35883576>). BBC. Archived (<https://web.archive.org/web/20160323203442/http://www.bbc.com/news/science-environment-35883576>)from the original on 23 March 2016 Retrieved 23 March 2016.
130. Luciuk, Mike. "How Bright is the Moon?"(<http://www.asterism.org/tutorials/tut26-1.htm>). Amateur Astronomers Archived (<https://web.archive.org/web/20100312092655/http://www.asterism.org/tutorials/tut26-1.htm>)from the original on 12 March 2010 Retrieved 16 March 2010.
131. Hershenson, Maurice (1989).*The Moon illusion* Routledge. p. 5. ISBN 978-0-8058-0121-7.
132. Spekkens, K. (18 October 2002). "Is the Moon seen as a crescent (and not a "boat") all over the world?"(<http://curious.astro.cornell.edu/our-solar-system/46-our-solar-system/the-moon/observing-the-moon/124-is-the-moon-seen-as-a-crescent-and-not-a-boat-all-over-the-world-is-the-same-phase-of-the-moon-visible-from-the-northern-and-southern-hemispheres-advanced>) Curious About Astronomy Archived (<https://web.archive.org/web/20151016011356/http://curious.astro.cornell.edu/our-solar-system/46-our-solar-system/the-moon/observing-the-moon/124-is-the-moon-seen-as-a-crescent-and-not-a-boat-all-over-the-world-is-the-same-phase-of-the-moon-visible-from-the-northern-and-southern-hemispheres-advanced>)from the original on 16 October 2015 Retrieved 28 September 2015.
133. "Moonlight helps plankton escape predators during Arctic winters"(<https://www.newscientist.com/article/mg2290562-500-moonlight-helps-plankton-escape-predators-during-arctic-winters/>)*New Scientist*. 16 January 2016. Archived (<https://web.archive.org/web/20160130112225/https://www.newscientist.com/article/mg2290562-500-moonlight-helps-plankton-escape-predators-during-arctic-winters/>)from the original on 30 January 2016.

134. "'Super Moon' exceptional. Brightest moon in the sky of Normandy Monday, November 14 - The Siver Times" (<http://sivertimes.com/super-moon-exceptional-brightest-moon-in-the-sky-of-normandy-Monday-November-14/1872>) Archived (<https://web.archive.org/web/20161114232404/http://sivertimes.com/super-moon-exceptional-brightest-moon-in-the-sky-of-normandy-monday-november-14/1872>) from the original on 14 November 2016.
135. "Moongazers Delight — Biggest Supermoon in Decades Looms Large Sunday Night" (<http://astrobob.areavoices.com/2016/11/10/moongazers-delight-biggest-supermoon-in-decades-looms-large-sunday-night/>) 10 November 2016. Archived (<https://web.archive.org/web/20161114170208/http://astrobob.areavoices.com/2016/11/10/moongazers-delight-biggest-supermoon-in-decades-looms-large-sunday-night/>) from the original on 14 November 2016.
136. "Supermoon November 2016" (<http://www.space.com/34515-supermoon-guide.html>). Space.com. 13 November 2016. Archived (<https://web.archive.org/web/20161114220725/http://www.space.com/34515-supermoon-guide.html>) from the original on 14 November 2016 Retrieved 14 November 2016.
137. Tony Phillips (16 March 2011). "Super Full Moon" (https://web.archive.org/web/20120507035348/https://science.nasa.gov/science-news/science-at-nasa/2011/16mar_supermoon/) NASA. Archived from the original (https://science.nasa.gov/science-news/science-at-nasa/2011/16mar_supermoon/) on 7 May 2012 Retrieved 19 March 2011.
138. Richard K. De Atley (18 March 2011). "Full moon tonight is as close as it gets" (https://web.archive.org/web/20110322161600/http://www.pe.com/localnews/stories/PE_News_Local_D_moon19.23a6364.html) The Press-Enterprise Archived from the original (http://www.pe.com/localnews/stories/PE_News_Local_D_moon19.23a6364.html) on 22 March 2011 Retrieved 19 March 2011.
139. "'Super moon' to reach closest point for almost 20 years" (<https://www.theguardian.com/science/2011/mar/19/super-moon-closest-point-years>) *The Guardian*. 19 March 2011. Archived (<https://web.archive.org/web/20131225175506/http://www.theguardian.com/science/2011/mar/19/super-moon-closest-point-years>) from the original on 25 December 2013. Retrieved 19 March 2011.
140. Georgia State University Dept. of Physics (Astronomy). "Perceived Brightness" (<http://hyperphysics.phy-astr.gsu.edu/hbase/vision/bright.html>) *Brightness and Night/Day Sensitivity* Georgia State University Archived (<https://web.archive.org/web/20140221094605/http://hyperphysics.phy-astr.gsu.edu/hbase/vision/bright.html>) from the original on 21 February 2014 Retrieved 25 January 2014.
141. Lutron. "Measured light vs. perceived light" (http://www.lutron.com/TechnicalDocumentLibrary/Measured_vs_Perceived.pdf) (PDF). *From IES Lighting Handbook 2000, 27-4* Lutron. Archived (https://web.archive.org/web/20130205204351/http://www.lutron.com/TechnicalDocumentLibrary/Measured_vs_Perceived.pdf) (PDF) from the original on 5 February 2013 Retrieved 25 January 2014.
142. Walker, John (May 1997). "Inconstant Moon" (http://www.fourmilab.ch/earthview/moon_ap_per.html). *Earth and Moon Viewer*. Fourth paragraph of "How Bright the Moonlight" Fourmilab. Archived (https://web.archive.org/web/20131214123836/https://www.fourmilab.ch/earthview/moon_ap_per.html) from the original on 14 December 2013 Retrieved 23 January 2014. "14% [...] due to the logarithmic response of the human eye".
143. Taylor, G.J. (8 November 2006). "Recent Gas Escape from the Moon" (<http://www.psrcd.hawaii.edu/Nov06/MoonGas.html>). *Planetary Science Research Discoveries* Hawai'i Institute of Geophysics and Planetology Archived (<https://web.archive.org/web/20070304055515/http://www.psrcd.hawaii.edu/Nov06/MoonGas.html>) from the original on 4 March 2007. Retrieved 4 April 2007.
144. Schultz, P. H.; Staid, M. I.; Pieters, C. M. (2006). "Lunar activity from recent gas release" *Nature*. **444** (7116): 184–186. Bibcode:2006Natur.444..184S (<http://adsabs.harvard.edu/abs/2006Natur.444..184S>). doi:10.1038/nature05303 (<https://doi.org/10.1038/nature05303>) PMID 17093445 (<https://www.ncbi.nlm.nih.gov/pubmed/17093445>).
145. "22 Degree Halo: a ring of light 22 degrees from the sun or moon" (<http://www2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/opt/ice/halo/22.xml>) Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign Retrieved 13 April 2010.
146. Lambeck, K. (1977). "Tidal Dissipation in the Oceans: Astronomical, Geophysical and Oceanographic Consequences". *Philosophical Transactions of the Royal Society A*. **287** (1347): 545–594. Bibcode:1977RSPTA.287..545L (<http://adsabs.harvard.edu/abs/1977RSPTA.287..545L>). doi:10.1098/rsta.1977.0159 (<https://doi.org/10.1098/rsta.1977.0159>)
147. Le Provost, C.; Bennett, A. F.; Cartwright, D. E. (1995). "Ocean Tides for and from TOPEX/POSEIDON". *Science*. **267** (5198): 639–42. Bibcode:1995Sci...267..639L (<http://adsabs.harvard.edu/abs/1995Sci...267..639L>) doi:10.1126/science.267.5198.639 (<https://doi.org/10.1126/science.267.5198.639>) PMID 17745840 (<https://www.ncbi.nlm.nih.gov/pubmed/17745840>)

148. Touma, Jihad; Wisdom, Jack (1994). "Evolution of the Earth-Moon system". *The Astronomical Journal* **108** (5): 1943–1961. Bibcode:1994AJ....108.1943T (<http://adsabs.harvard.edu/abs/1994AJ....108.1943T>) doi:10.1086/117209 (<https://doi.org/10.1086%2F117209>)
149. Chapront, J.; Chapront-Tuzy, M.; Francou, G (2002). "A new determination of lunar orbital parameters, precession constant and tidal acceleration from LLR measurements" *Astronomy and Astrophysics* **387** (2): 700–709. Bibcode:2002A&A...387..700C (<http://adsabs.harvard.edu/abs/2002A&A...387..700C>) doi:10.1051/0004-6361:20020420 (<https://doi.org/10.1051%2F0004-6361%3A20020420>)
150. "Why the Moon is getting further away from Earth" (<http://www.bbc.co.uk/news/science-environment-12311119>) *BBC News*. 1 February 2011. Archived (<https://web.archive.org/web/20150925185706/http://www.bbc.co.uk/news/science-environment-12311119>) from the original on 25 September 2015 Retrieved 18 September 2015.
151. Ray, R. (15 May 2001). "Ocean Tides and the Earth's Rotation" (<http://bowie.gsfc.nasa.gov/ggfc/tides/intro.html>) IERS Special Bureau for Tides. Archived (<https://web.archive.org/web/20100327084125/http://bowie.gsfc.nasa.gov/ggfc/tides/intro.html>) from the original on 27 March 2010 Retrieved 17 March 2010.
152. Murray, C.D.; Dermott, Stanley F (1999). *Solar System Dynamics* Cambridge University Press p. 184. ISBN 978-0-521-57295-8
153. Dickinson, Terence (1993). *From the Big Bang to Planet X* Camden East, Ontario: Camden House pp. 79–81. ISBN 978-0-921820-71-0
154. Latham, Gary; Ewing, Maurice; Dorman, James; Lammlein, David; Press, Frank; Ksöz, Naft; Sutton, George; Duennebier, Fred; Nakamura, Yosio (1972). "Moonquakes and lunar tectonism" *Earth, Moon, and Planets* **4** (3–4): 373–382. Bibcode:1972Moon....4..373L (<http://adsabs.harvard.edu/abs/1972Moon....4..373L>) doi:10.1007/BF00562004 (<https://doi.org/10.1007%2FBF00562004>)
155. Phillips, Tony (12 March 2007). "Stereo Eclipse" (https://web.archive.org/web/20080610082213/https://science.nasa.gov/headlines/y2007/12mar_stereoclipse.htm) *Science@NASA* Archived from the original (https://science.nasa.gov/headlines/y2007/12mar_stereoclipse.htm) on 10 June 2008 Retrieved 17 March 2010.
156. Espenak, F. (2000). "Solar Eclipses for Beginners" (<http://www.mreclipse.com/Special/SEprime.html>). MrEclip]]. Retrieved 17 March 2010.
157. Walker, John (10 July 2004). "Moon near Perigee, Earth near Aphelion" (http://www.fourmilab.ch/images/peri_apo/) Fourmilab. Archived (https://web.archive.org/web/20131208153430/http://www.fourmilab.ch/images/peri_apo/) from the original on 8 December 2013 Retrieved 25 December 2013.
158. Thieman, J.; Keating, S. (2 May 2006). "Eclipse 99, Frequently Asked Questions" (<https://web.archive.org/web/20070211120127/http://eclipse99.nasa.gov/pages/faq.html>) NASA. Archived from the original (<http://eclipse99.nasa.gov/pages/faq.html>) on 11 February 2007. Retrieved 12 April 2007.
159. Espenak, F. "Saros Cycle" (<https://archive.is/20120524183445/sunearth.gsfc.nasa.gov/eclipse/SEsaros/SEsaros.html>) NASA. Archived from the original (<http://sunearth.gsfc.nasa.gov/eclipse/SEsaros/SEsaros.html>) on 24 May 2012 Retrieved 17 March 2010.
160. Guthrie, D.V. (1947). "The Square Degree as a Unit of Celestial Area" (<http://adsabs.harvard.edu/abs/1947PA.....55..200G>) *Popular Astronomy*. Vol. 55. pp. 200–203. Bibcode:1947PA.....55..200G (<http://adsabs.harvard.edu/abs/1947PA.....55..200G>)
161. "Total Lunar Occultations" (<https://web.archive.org/web/20100223022627/http://occsec.wellington.net.nz/total/totocc.htm>). Royal Astronomical Society of New Zealand Archived from the original (<http://occsec.wellington.net.nz/total/totocc.htm>) on 23 February 2010 Retrieved 17 March 2010.
162. Aaboe, A.; Britton, J. P.; Henderson, J. A.; Neugebauer, Otto; Sachs, A. J. (1991). "Saros Cycle Dates and Related Babylonian Astronomical Texts". *Transactions of the American Philosophical Society. American Philosophical Society*. **81** (6): 1–75. doi:10.2307/1006543 (<https://doi.org/10.2307%2F1006543>) JSTOR 1006543 (<https://www.jstor.org/stable/1006543>) "One comprises what we have called "Saros Cycle Texts", which give the months of eclipse possibilities arranged in consistent cycles of 223 months (or 18 years)".
163. Sarma, K. V. (2008). "Astronomy in India". In Helaine Selin. *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures* (2 ed.). Springer. pp. 317–321. ISBN 978-1-4020-4559-2
164. Needham 1986 p. 411.
165. O'Connor, J.J.; Robertson, E.F. (February 1999). "Anaxagoras of Clazomenae" (<http://www.historymcs.st-andrews.ac.uk/Biographies/Anaxagoras.html>) University of St Andrews Archived (<https://www.webcitation.org/66BhcrUqG?url=http://www-historymcs.st-andrews.ac.uk/Biographies/Anaxagoras.html>) from the original on 15 March 2012 Retrieved 12 April 2007.

166. Needham 1986 p. 227.
167. Needham 1986 p. 413–414.
168. Robertson, E. F. (November 2000). "Aryabhata the Elder" (http://www-historymcs.st-andrews.ac.uk/Biographies/Aryabhata_I.html) Scotland: School of Mathematics and Statistics University of St Andrews Archived (https://web.archive.org/web/20150711055702/http://www-historymcs.st-andrews.ac.uk/Biographies/Aryabhata_I.html) from the original on 11 July 2015 Retrieved 15 April 2010.
169. A. I. Sabra (2008). "Ibn Al-Haytham, Abū Alī Al-Ḥasan Ibn Al-Ḥasan". *Dictionary of Scientific Biography* Detroit: Charles Scribner's Sons pp. 189–210, at 195.
170. Needham 1986 p. 415–416.
171. Lewis, C. S. (1964). *The Discarded Image* Cambridge: Cambridge University Press p. 108. ISBN 978-0-521-47735-2.
172. van der Waerden, Bartel Leendert (1987). "The Heliocentric System in Greek, Persian and Hindu Astronomy". *Annals of the New York Academy of Sciences*. **500**: 1–569. Bibcode:1987NYASA.500....1A (<http://adsabs.harvard.edu/abs/1987NYASA.500....1A>). doi:10.1111/j.1749-6632.1987.tb37193.x (<https://doi.org/10.1111%2Fj.1749-6632.1987.tb37193.x>). PMID 3296915 (<https://www.ncbi.nlm.nih.gov/pubmed/3296915>).
173. Evans, James (1998). *The History and Practice of Ancient Astronomy* Oxford & New York: Oxford University Press pp. 71, 386. ISBN 978-0-19-509539-5
174. "Discovering How Greeks Computed in 100 B.C." (<https://www.nytimes.com/2008/07/31/science/31computer.html?hp>) *The New York Times*. 31 July 2008. Archived (<https://web.archive.org/web/20131204053238/http://www.nytimes.com/2008/07/31/science/31computer.html?hp>) from the original on 4 December 2013 Retrieved 9 March 2014.
175. Van Helden, A. (1995). "The Moon" (<https://web.archive.org/web/20040623085326/http://galileo.rice.edu/sci/observations/Moon.html>) Galileo Project Archived from the original (<http://galileo.rice.edu/sci/observations/moon.html>) on 23 June 2004. Retrieved 12 April 2007.
176. Consolmagno, Guy J. (1996). "Astronomy Science Fiction and Popular Culture: 1277 to 2001 (And beyond)". *Leonardo*. The MIT Press **29** (2): 128. doi:10.2307/1576348 (<https://doi.org/10.2307%2F1576348>) JSTOR 1576348 (<https://www.jstor.org/stable/1576348>)
177. Hall, R. Cargill (1977). "Appendix A: LUNAR THEORY BEFORE 1964" (https://history.nasa.gov/SP-4210/pages/App_A.htm). *NASA History Series. LUNAR IMPACT: A History of Project Ranger* Washington, D.C.: Scientific and Technical Information Office, NASA. Archived (https://web.archive.org/web/20100410085526/http://history.nasa.gov/SP-4210/pages/App_A.htm) from the original on 10 April 2010 Retrieved 13 April 2010.
178. Zak, Anatoly (2009). "Russia's unmanned missions toward the Moon" (http://www.russianspaceweb.com/spacecraft_planetary_lunar.html). Archived (https://web.archive.org/web/20100414115710/http://www.russianspaceweb.com/spacecraft_planetary_lunar.html) from the original on 14 April 2010 Retrieved 20 April 2010.
179. "Rocks and Soils from the Moon" (<http://curator.jsc.nasa.gov/lunar/index.cfm>) NASA. Archived (<https://web.archive.org/web/20100527085532/http://curator.jsc.nasa.gov/lunar/index.cfm>) from the original on 27 May 2010 Retrieved 6 April 2010.
180. "Soldiers, Spies and the Moon: Secret U.S. and Soviet Plans from the 1950s and 1960s" (<http://nsarchive.gwu.edu/NSAEBB/NSAEBB479/>) *The National Security Archive* National Security Archive. Archived (<https://web.archive.org/web/20161219060341/http://nsarchive.gwu.edu/NSAEBB/NSAEBB479/>) from the original on 19 December 2016 Retrieved 1 May 2017.
181. Brumfield, Ben (25 July 2014). "U.S. reveals secret plans for '60s moon base" (<http://www.cnn.com/2014/07/24/us/1960s-moon-military-base/>) *CNN*. Archived (<https://web.archive.org/web/20140727212259/http://www.cnn.com/2014/07/24/us/1960s-moon-military-base/>) from the original on 27 July 2014 Retrieved 26 July 2014.
182. Teitel, Amy (11 November 2013). "LUNEX: Another way to the Moon" (<http://www.popsci.com/blog-network/vintagespace/lunex-another-way-moon>) Popular Science Archived (<https://web.archive.org/web/20151016011356/http://www.popsci.com/blog-network/vintage-space/lunex-another-way-moon>) from the original on 16 October 2015.
183. Logsdon, John (2010). *John F. Kennedy and the Race to the Moon* Palgrave Macmillan ISBN 978-0-230-11010-6
184. Coren, M. (26 July 2004). "'Giant leap' opens world of possibility" (<http://edition.cnn.com/2004/TECH/space/07/16/moon.landing/index.html>) *CNN*. Archived (<https://www.webcitation.org/66CTOLNBW?url=http://edition.cnn.com/2004/TECH/space/07/16/moon.landing/index.html>) from the original on 16 March 2012 Retrieved 16 March 2010.
185. "Record of Lunar Events, 24 July 1969" (<https://history.nasa.gov/ap11ann/ap11events.html>). *Apollo 11 30th anniversary*. NASA. Archived (<https://web.archive.org/web/20100408213454/http://history.nasa.gov/ap11ann/ap11events.html>) from the original on 8 April 2010 Retrieved 13 April 2010.

186. "Manned Space Chronology: Apollo 11"(<http://www.spaceline.org/flightchron/apollo11.html>). Spaceline.org. Archived (<https://web.archive.org/web/20080214213826/http://www.spaceline.org/flightchron/apollo11.html>) from the original on 14 February 2008 Retrieved 6 February 2008.
187. "Apollo Anniversary: Moon Landing "Inspired World"" (http://news.nationalgeographic.com/news/2004/07/0714_040714_moonlanding.html) *National Geographic* Archived (https://web.archive.org/web/20080209140059/http://news.nationalgeographic.com/news/2004/07/0714_040714_moonlanding.html) from the original on 9 February 2008 Retrieved 6 February 2008.
188. Orloff, Richard W. (September 2004) [First published 2000]. "Extravehicular Activity"(https://history.nasa.gov/SP-4029/Apollo_18-30_Extravehicular_Activity.htm). *Apollo by the Numbers: A Statistical Reference*(<https://history.nasa.gov/SP-4029/SP-4029.htm>) NASA History Division, Office of Policy and Plans The NASA History Series. Washington, D.C.: NASA. ISBN 0-16-050631-X LCCN 00061677 (<https://lccn.loc.gov/00061677>) NASA SP-2000-4029. Archived (<https://web.archive.org/web/20130606114042/http://history.nasa.gov/SP-4029/SP-4029.htm>) from the original on 6 June 2013. Retrieved 1 August 2013.
189. Launius, Roger D. (July 1999). "The Legacy of Project Apollo"(<https://history.nasa.gov/ap11ann/legacy.htm>). NASA History Office]]. Archived (<https://web.archive.org/web/20100408213555/http://history.nasa.gov/ap11ann/legacy.htm>) from the original on 8 April 2010 Retrieved 13 April 2010.
190. *SP-287 What Made Apollo a Success? A series of eight articles reprinted by permission from the March 1970 issue of Astronautics & Aeronautics, a publication of the American Institute of Aeronautics and Astronautics* Washington, D.C.: Scientific and Technical Information Office, National Aeronautics and Space Administration 1971.
191. "NASA news release 77-47 page 242"(http://www.nasa.gov/centers/johnson/pdf/83129main_1977.pdf) (PDF) (Press release). 1 September 1977. Archived (https://www.webcitation.org/5ziulRAv2?url=http://www.nasa.gov/centers/johnson/pdf/83129main_1977.pdf) (PDF) from the original on 26 June 2011 Retrieved 16 March 2010.
192. Appleton, James; Radley Charles; Deans, John; Harvey, Simon; Burt, Paul; Haxell, Michael; Adams, Roy; Spooner N.; Brieske, Wayne (1977). "OASI Newsletters Archive"(https://web.archive.org/web/20071210143103/http://www.ast.cam.ac.uk/~ipswich/Miscellaneous/Archived_spaceflight_news.htm) NASA Turns A Deaf Ear To The Moon. Archived from the original (http://www.ast.cam.ac.uk/~ipswich/Miscellaneous/Archived_spaceflight_news.htm) on 10 December 2007. Retrieved 29 August 2007.
193. Dickey, J.; et al. (1994). "Lunar laser ranging: a continuing legacy of the Apollo program" *Science*. **265** (5171): 482–490. Bibcode:1994Sci...265..482D (<http://adsabs.harvard.edu/abs/1994Sci...265..482D>) doi:10.1126/science.265.5171.482(<https://doi.org/10.1126/science.265.5171.482>) PMID 17781305 (<https://www.ncbi.nlm.nih.gov/pubmed/17781305>)
194. "Hiten-Hagomoro"(<https://web.archive.org/web/20110614115823/http://solarsystem.nasa.gov/missions/profile.cfm?MCode=Hiten&Display=ReadMore>) NASA. Archived from the original (<http://solarsystem.nasa.gov/missions/profile.cfm?MCode=Hiten&Display=ReadMore>) on 14 June 2011 Retrieved 29 March 2010.
195. "Clementine information"(<http://nssdc.gsfc.nasa.gov/planetary/cleminfo.html>) NASA. 1994. Archived (<https://web.archive.org/web/20100925095846/http://nssdc.gsfc.nasa.gov/planetary/cleminfo.html>) from the original on 25 September 2010 Retrieved 29 March 2010.
196. "Lunar Prospector: Neutron Spectrometer"(<https://web.archive.org/web/20100527105801/http://lunar.arc.nasa.gov/results/neutron.htm>) NASA. 2001. Archived from the original (<http://lunar.arc.nasa.gov/results/neutron.htm>) on 27 May 2010. Retrieved 29 March 2010.
197. "SMART-1 factsheet" (http://www.esa.int/SPECIALS/SMART-1/SEMSDE1A6BD_0.html) European Space Agency 26 February 2007. Archived (https://web.archive.org/web/20100323044139/http://www.esa.int/SPECIALS/SMART-1/SEMSDE1A6BD_0.html) from the original on 23 March 2010 Retrieved 29 March 2010.
198. "China's first lunar probe ends mission"(http://www.chinadaily.com.cn/china/2009-03/01/content_7523687.htm) Xinhua. 1 March 2009. Archived (https://web.archive.org/web/20090304124614/http://www.chinadaily.com.cn/china/2009-03/01/content_7523687.htm) from the original on 4 March 2009 Retrieved 29 March 2010.
199. Leonard David (17 March 2015). "China Outlines New Rockets, Space Station and Moon Plans"(<http://www.space.com/28809-china-rocket-family-moon-plans.html>) Space.com. Archived (<https://web.archive.org/web/20160701055507/http://www.space.com/28809-china-rocketfamily-moon-plans.html>) from the original on 1 July 2016 Retrieved 29 June 2016.
200. "KAGUYA Mission Profile"(<http://www.selene.jaxa.jp/en/profile/index.htm>). JAXA. Archived (<https://web.archive.org/web/20100328223338/http://www.selene.jaxa.jp/en/profile/index.htm>) from the original on 28 March 2010 Retrieved 13 April 2010.

201. "KAGUYA (SELENE) World's First Image Taking of the Moon by HDTV"(http://www.jaxa.jp/press/2007/11/20071107_kaguya_e.html) Japan Aerospace Exploration Agency(JAXA) and Japan Broadcasting Corporation(NHK). 7 November 2007. Archived (https://web.archive.org/web/20100316190341/http://www.jaxa.jp/press/2007/11/20071107_kaguya_e.html) from the original on 16 March 2010 Retrieved 13 April 2010.
202. "Mission Sequence"(http://www.isro.org/Chandrayaan/htmls/mission_sequence.htm) Indian Space Research Organisation. 17 November 2008. Archived (https://web.archive.org/web/20100706225136/http://www.isro.org/chandrayaan/htmls/mission_sequence.htm) from the original on 6 July 2010 Retrieved 13 April 2010.
203. "Indian Space Research Organisation: Future Program"(<http://www.isro.org/scripts/futureprogramme.aspx#Space>). Indian Space Research Organisation Archived (<https://web.archive.org/web/20101125163045/http://isro.org/scripts/futureprogramme.aspx#Space>) from the original on 25 November 2010 Retrieved 13 April 2010.
204. "India and Russia Sign an Agreement on Chandrayaan-2"(https://web.archive.org/web/20071217203828/http://isro.org/pressrelease/Nov14_2007.htm) Indian Space Research Organisation 14 November 2007. Archived from the original (http://isro.org/pressrelease/Nov14_2007.htm) on 17 December 2007. Retrieved 13 April 2010.
205. "Lunar CRater Observation and Sensing Satellite (LCROSS): Strategy & Astronomer Observation Campaign"(<http://www.webcitation.org/66BhosrQk?url=http://lcross.arc.nasa.gov/observation.htm>) NASA. October 2009. Archived from the original (<http://lcross.arc.nasa.gov/observation.htm>) on 15 March 2012 Retrieved 13 April 2010.
206. "Giant moon crater revealed in spectacular up-close photos"(http://www.msnbc.msn.com/id/45901428#.Twe_flbWxvY). MSNBC. Space.com. 6 January 2012. Archived (https://web.archive.org/web/20120107072136/http://www.msnbc.msn.com/id/45901428#.Twe_flbWxvY) from the original on 7 January 2012.
207. Chang, Alicia (26 December 2011). "Twin probes to circle moon to study gravity field" (<http://www.cnsnews.com/new/s/article/twin-probes-circle-moon-study-gravity-field>) CNS News. Associated Press Retrieved 18 June 2017.
208. Covault, C. (4 June 2006). "Russia Plans Ambitious Robotic Lunar Mission"(http://www.aviationnow.com/avnow/news/channel_awst_storyjsp?id=news/aw060506p2.xml). Aviation Week. Archived (https://web.archive.org/web/20060612215659/http://www.aviationnow.com/avnow/news/channel_awst_storyjsp?id=news%2Faw060506p2.xml) from the original on 12 June 2006 Retrieved 12 April 2007.
209. "Russia to send mission to Mars this year Moon in three years" (https://web.archive.org/web/20100913073553/http://rt.com/Top_News/2009-02-25/Russia_to_send_mission_to_Mars_this_year_Moon_in_three_years_.html) TV-Novosti. 25 February 2009. Archived from the original (http://rt.com/Top_News/2009-02-25/Russia_to_send_mission_to_Mars_this_year_Moon_in_three_years_.html) on 13 September 2010 Retrieved 13 April 2010.
210. "About the Google Lunar X Prize"(<https://web.archive.org/web/20100228024532/http://www.googlelunarxprize.org/lunar/about-the-prize>) X-Prize Foundation 2010. Archived from the original (<http://www.googlelunarxprize.org/lunar/about-the-prize>) on 28 February 2010 Retrieved 24 March 2010.
211. Wall, Mike (14 January 2011). "Mining the Moon's Water: Q&A with Shackleton Energy's Bill Stone"(<http://www.spacenews.com/10619-mining-moon-water-bill-stone-110114.html>) Space News
212. "President Bush Offers New Vision For NASA"(http://www.nasa.gov/missions/solarsystem/bush_vision.html) (Press release). NASA. 14 December 2004. Archived (https://web.archive.org/web/20070510062228/http://www.nasa.gov/missions/solarsystem/bush_vision.html) from the original on 10 May 2007 Retrieved 12 April 2007.
213. "Constellation" (http://www.nasa.gov/mission_pages/constellation/main/index.html) NASA. Archived (https://web.archive.org/web/20100412052653/http://www.nasa.gov/mission_pages/constellation/main/index.html) from the original on 12 April 2010. Retrieved 13 April 2010.
214. "NASA Unveils Global Exploration Strategy and Lunar Architecture"(http://www.nasa.gov/home/hqnews/2006/dec/HQ_06361_ESMD_Lunar_Architecture.html) (Press release). NASA. 4 December 2006. Archived (https://web.archive.org/web/20070823131906/http://www.nasa.gov/home/hqnews/2006/dec/HQ_06361_ESMD_Lunar_Architecture.html) from the original on 23 August 2007 Retrieved 12 April 2007.
215. NASAtelevision (15 April 2010). "President Obama Pledges Total Commitment to NASA" (https://www.youtube.com/watch?v=3rNn_cUrImE) YouTube. Archived (https://web.archive.org/web/20120428205122/http://www.youtube.com/watch?v=3rNn_cUrImE) from the original on 28 April 2012 Retrieved 7 May 2012.
216. "India's Space Agency Proposes Manned Spaceflight Program"(http://www.space.com/news/061110_india_manned_space.html) Space.com. 10 November 2006. Archived (<https://www.webcitation.org/66Bhn0GD7?url=http://www.space.com/3098-indias-space-agency-proposes-manned-spaceflight-program.html>) from the original on 15 March 2012 Retrieved 23 October 2008.
217. SpaceX to help Vodafone and Nokia install first 4G signal on the Moon | The Week UK (<http://www.theweek.co.uk/91979/spacex-to-help-vodafone-and-nokia-install-first-4g-signal-on-the-moon>)

218. Chang, Kenneth (24 January 2017). "For 5 Contest Finalists, a \$20 Million Dash to the Moon" (<https://www.nytimes.com/2017/01/24/science/google-lunar-xprize-finalists.html>) *The New York Times*. ISSN 0362-4331 (<https://www.worldcat.org/issn/0362-4331>) Archived (<https://web.archive.org/web/20170715065721/https://www.nytimes.com/2017/01/24/science/google-lunar-xprize-finalists.html>) from the original on 15 July 2017 Retrieved 13 July 2017.
219. Mike Wall (16 August 2017), "Deadline for Google Lunar X Prize Moon Race Extended Through March 2018" (<http://www.space.com/37813-google-lunar-x-prize-deadline-extended-march-2018.html>) *space.com*, retrieved 25 September 2017
220. McCarthy, Ciara (3 August 2016). "US startup Moon Express approved to make 2017 lunar mission" (<https://www.theguardian.com/science/2016/aug/03/us-startup-moon-express-2017-lunar-mission>) *The Guardian*. ISSN 0261-3077 (<https://www.worldcat.org/issn/0261-3077>) Archived (<https://web.archive.org/web/20170730225106/https://www.theguardian.com/science/2016/aug/03/us-startup-moon-express-2017-lunar-mission>) from the original on 30 July 2017 Retrieved 13 July 2017.
221. "Moon Express Approved for Private Lunar Landing in 2017, a Space First" (<https://www.space.com/33632-moon-express-private-lunar-landing-approval.html>) *Space.com*. Archived (<https://web.archive.org/web/20170712211615/http://www.space.com/33632-moon-express-private-lunar-landing-approval.html>) from the original on 12 July 2017 Retrieved 13 July 2017.
222. "NASA - Ultraviolet Waves" (<https://web.archive.org/web/20131017235057/http://science.hq.nasa.gov/kids/imagers/ems/uv.html>). Science.hq.nasa.gov 27 September 2013. Archived from the original (<http://science.hq.nasa.gov/kids/imagers/ems/uv.html>) on 17 October 2013 Retrieved 3 October 2013.
223. Takahashi, Yuki (September 1999). "Mission Design for Setting up an Optical Telescope on the Moon" (<https://web.archive.org/web/20151106142659/http://www.ugcs.caltech.edu/~yukimoon/MoonTelescope/>) California Institute of Technology. Archived from the original (<http://www.ugcs.caltech.edu/~yukimoon/MoonTelescope/>) on 6 November 2015. Retrieved 27 March 2011.
224. Chandler, David (15 February 2008). "MIT to lead development of new telescopes on moon" (<http://web.mit.edu/newsoffice/2008/moonscope-0215.html>) *MIT News*. Archived (<https://web.archive.org/web/20090304062601/http://web.mit.edu/newsoffice/2008/moonscope-0215.html>) from the original on 4 March 2009 Retrieved 27 March 2011.
225. Naeye, Robert (6 April 2008). "NASA Scientists Pioneer Method for Making Giant Lunar Telescopes" (http://www.nasa.gov/centers/goddard/news/topstory/2008/lunar_telescopes.html) Goddard Space Flight Center Archived (https://web.archive.org/web/20101222142443/http://www.nasa.gov/centers/goddard/news/topstory/2008/lunar_telescopes.html) from the original on 22 December 2010 Retrieved 27 March 2011.
226. Bell, Trudy (9 October 2008). "Liquid Mirror Telescopes on the Moon" (https://science.nasa.gov/science-news/science-at-nasa/2008/09oct_liquidmirror/) *Science News*. NASA. Archived (https://web.archive.org/web/20110323081215/http://science.nasa.gov/science-news/science-at-nasa/2008/09oct_liquidmirror/) from the original on 23 March 2011 Retrieved 27 March 2011.
227. "Far Ultraviolet Camera/Spectrograph" (http://www.lpi.usra.edu/lunar/missions/apollo/apollo_16/experiments/f_ultra/) Lpi.usra.edu. Archived (https://web.archive.org/web/20131203010615/http://www.lpi.usra.edu/lunar/missions/apollo/apollo_16/experiments/f_ultra/) from the original on 3 December 2013 Retrieved 3 October 2013.
228. "Can any State claim a part of outer space as its own?" (<http://www.unoosa.org/oosa/en/FAQ/splawfaq.html#Q6>) United Nations Office for Outer Space Affairs. Archived (<https://web.archive.org/web/20100421232450/http://www.unoosa.org/oosa/en/FAQ/splawfaq.html#Q6>) from the original on 21 April 2010 Retrieved 28 March 2010.
229. "How many States have signed and ratified the five international treaties governing outer space?" (<http://www.unoosa.org/oosa/en/FAQ/splawfaq.html#Q4>) United Nations Office for Outer Space Affairs. 1 January 2006. Archived (<https://web.archive.org/web/20100421232450/http://www.unoosa.org/oosa/en/FAQ/splawfaq.html#Q4>) from the original on 21 April 2010 Retrieved 28 March 2010.
230. "Do the five international treaties regulate military activities in outer space?" (<http://www.unoosa.org/oosa/en/FAQ/splawfaq.html#Q5>) United Nations Office for Outer Space Affairs. Archived (<https://web.archive.org/web/20100421232450/http://www.unoosa.org/oosa/en/FAQ/splawfaq.html#Q5>) from the original on 21 April 2010 Retrieved 28 March 2010.
231. "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies" (<http://www.unoosa.org/oosa/en/SpaceLaw/moon.html>) United Nations Office for Outer Space Affairs. Archived (<https://web.archive.org/web/20100809072447/http://www.unoosa.org/oosa/en/SpaceLaw/moon.html>) from the original on 9 August 2010 Retrieved 28 March 2010.

232. "The treaties control space-related activities of States. What about non-governmental entities active in outer space, like companies and even individuals?"(<http://www.unoosa.org/oosa/en/FAQ/splawfaq.html#Q7>) United Nations Office for Outer Space Affairs. Archived (<https://web.archive.org/web/20100421232450/http://www.unoosa.org/oosa/en/FAQ/splawfaq.html#Q7>) from the original on 21 April 2010 Retrieved 28 March 2010.
233. "Statement by the Board of Directors of the IISL On Claims to Property Rights Regarding The Moon and Other Celestial Bodies (2004)"(http://www.iislweb.org/docs/IISL_Outer_Space_Treaty_Statement.pdf)(PDF). International Institute of Space Law 2004. Archived (https://web.archive.org/web/20091222021426/http://www.iislweb.org/docs/IISL_Outer_Space_Treaty_Statement.pdf)(PDF) from the original on 22 December 2009 Retrieved 28 March 2010.
234. "Further Statement by the Board of Directors of the IISL On Claims to Lunar Property Rights (2009)"(<http://www.iislweb.org/docs/Statement%20BoD.pdf>)(PDF). International Institute of Space Law 22 March 2009. Archived (<https://web.archive.org/web/20091222022107/http://www.iislweb.org/docs/Statement%20BoD.pdf>)(PDF) from the original on 22 December 2009 Retrieved 28 March 2010.
235. "Carved and Drawn Prehistoric Maps of the Cosmos"(<http://www.spacetoday.org/SolSys/Earth/OldStarCharts.html>) Space Today. 2006. Archived (<https://www.webcitation.org/66Bhc1WIC?url=http://www.spacetoday.org/SolSys/Earth/OldStarCharts.html>) from the original on 15 March 2012 Retrieved 12 April 2007.
236. Dexter, Miriam Robbins (1984). "Proto-Indo-European Sun Maidens and Gods of the Moon"*Mankind Quarterly*. **25** (1 & 2): 137–144.
237. Nemet-Nejat, Karen Rhea(1998), *Daily Life in Ancient Mesopotamia* Daily Life, Greenwood, p. 203, ISBN 978-0313294976
238. Black, Jeremy; Green, Anthony (1992) *Gods, Demons and Symbols of Ancient Mesopotamia: An Illustrated Dictionary* (<https://books.google.com/?id=05LXAAAAMAAJ&q=Inana>) The British Museum Press. p. 135. ISBN 0-7141-1705-6
239. Zschietzschmann, W (2006). *Hellas and Rome: The Classical World in Pictures* Whitefish, Montana: Kessinger Publishing. p. 23. ISBN 9781428655447.
240. Cohen, Beth (2006). "Outline as a Special Technique in Black- and Red-figure Vase-painting". *The Colors of Clay: Special Techniques in Athenian Vases* (https://books.google.com/books?id=YyufPUA_S74C&pg=PR178). Los Angeles, California: Getty Publications. pp. 178–179 ISBN 9780892369423
241. "Muhammad." *Encyclopædia Britannica* 2007. Encyclopædia Britannica Online, p.13
242. Marshack, Alexander (1991), *The Roots of Civilization*, Colonial Hill, Mount Kisco, NY
243. Brooks, A. S. and Smith, C. C. (1987): "Ishango revisited: new age determinations and cultural interpretations" *The African Archaeological Review* 5 : 65–78.
244. Duncan, David Ewing (1998). *The Calendar*. Fourth Estate Ltd. pp. 10–11. ISBN 978-1-85702-721-1
245. For etymology, see Barnhart, Robert K. (1995). *The Barnhart Concise Dictionary of Etymology* Harper Collins p. 487. ISBN 978-0-06-270084-1. For the lunar calendar of the Germanic peoples, see Birley, A. R. (Trans.) (1999). *Agricola and Germany*. Oxford World's Classics. USA: Oxford University Press p. 108. ISBN 978-0-19-283300-6
246. Mallory, J. P.; Adams, D. Q. (2006). *The Oxford Introduction to Proto-Indo-European and the Proto-Indo-European World*. Oxford Linguistics. Oxford University Press pp. 98, 128, 317. ISBN 978-0-19-928791-8
247. Harper, Douglas. "measure" (<http://www.etymonline.com/?term=measure>). *Online Etymology Dictionary*
248. Harper, Douglas. "menstrual" (<http://www.etymonline.com/?term=menstrual>). *Online Etymology Dictionary*
249. Smith, William George (1849). *Dictionary of Greek and Roman Biography and Mythology: Oarses-Zygi* (<https://books.google.com/?id=PJ0YAAAIAAJ>). 3. J. Walton. p. 768. Retrieved 29 March 2010.
250. Estienne, Henri (1846). *Thesaurus graecae linguae* (https://books.google.com/?id=0qQ_AAAAcAAJ) 5. Didot. p. 1001. Retrieved 29 March 2010.
251. mensis (<http://www.perseus.tufts.edu/hopper/text?d=Perseus:text:1999.04.0059:entry=mensis>) Charlton T. Lewis and Charles Short. *A Latin Dictionary* on Perseus Project
252. μείς (<http://www.perseus.tufts.edu/hopper/text?d=Perseus:text:1999.04.0057:entry=mei/s>) Liddell and Scott.
253. "Islamic Calendars based on the Calculated First Visibility of the Lunar Crescent"(http://www.staff.science.uu.nl/~gent0113/islam/islam_tabcal_hilal.htm) University of Utrecht Archived (https://web.archive.org/web/20140111112349/http://www.staff.science.uu.nl/~gent0113/islam/islam_tabcal_hilal.htm) from the original on 11 January 2014 Retrieved 11 January 2014.

254. Lilienfeld, Scott O.; Arkowitz, Hal (2009). "Lunacy and the Full Moon" (<http://www.scientificamerican.com/article.cfm?id=lunacy-and-the-full-moon>) *Scientific American*. Archived (<https://web.archive.org/web/20091016163312/http://www.scientificamerican.com/article.cfm?id=lunacy-and-the-full-moon>) from the original on 16 October 2009 Retrieved 13 April 2010.
255. Rotton, James; Kelly I. W. (1985). "Much ado about the full moon: A meta-analysis of lunacy research". *Psychological Bulletin* **97** (2): 286–306. doi:10.1037/0033-2909.97.2.286(<https://doi.org/10.1037/0033-2909.97.2.286>).
256. Martens, R.; Kelly I. W.; Saklofske, D. H. (1988). "Lunar Phase and Birthrate: A 50-year Critical Review". *Psychological Reports* **63** (3): 923–934. doi:10.2466/pr0.1988.63.3.923(<https://doi.org/10.2466/pr0.1988.63.3.923>).
257. Kelly, Ivan; Rotton, James; Culver Roger (1986), "The Moon Was Full and Nothing Happened: A Review of Studies on the Moon and Human Behavior", *Skeptical Inquirer*, **10** (2): 129–43. Reprinted in *The Hundredth Monkey - and other paradigms of the paranormal* edited by Kendrick Frazier, Prometheus Books. Revised and updated in *The Outer Edge: Classic Investigations of the Paranormal* edited by Joe Nickell, Barry Karr, and Tom Genoni, 1996, CSICOP.
258. Foster, Russell G.; Roenneberg, Till (2008). "Human Responses to the Geophysical Daily Annual and Lunar Cycles". *Current Biology*. **18** (17): R784–R794. doi:10.1016/j.cub.2008.07.003(<https://doi.org/10.1016/j.cub.2008.07.003>). PMID 18786384 (<https://www.ncbi.nlm.nih.gov/pubmed/18786384>).

Bibliography

- Needham, Joseph (1986). *Science and Civilization in China, Volume III: Mathematics and the Sciences of the Heavens and Earth* Taipei: Caves Books ISBN 978-0-521-05801-8

Further reading

- "Revisiting the Moon". *New York Times*. Retrieved 8 September 2014.
- The Moon. *Discovery 2008* BBC World Service.
- Bussey, B.; Spudis, P.D. (2004). *The Clementine Atlas of the Moon* Cambridge University Press ISBN 0-521-81528-2.
- Cain, Fraser. "Where does the Moon Come From?" *Universe Today*. Retrieved 1 April 2008. (podcast and transcript)
- Jolliff, B. (2006). Wieczorek, M.; Shearer C.; Neal, C., eds. "New views of the Moon" *Reviews in Mineralogy and Geochemistry*. Chantilly, Virginia: Mineralogy Society of America **60** (1): 721. Bibcode:2006RvMG...60D...5J doi:10.2138/rmg.2006.60.0 ISBN 0-939950-72-3 Retrieved 12 April 2007.
- Jones, E.M. (2006). "Apollo Lunar Surface Journal". NASA. Retrieved 12 April 2007.
- "Exploring the Moon" Lunar and Planetary Institute Retrieved 12 April 2007.
- Mackenzie, Dana (2003). *The Big Splat, or How Our Moon Came to Be* Hoboken, New Jersey: John Wiley & Sons ISBN 0-471-15057-6
- Moore, P. (2001). *On the Moon*. Tucson, Arizona: Sterling Publishing Co. ISBN 0-304-35469-4
- "Moon Articles". *Planetary Science Research Discoveries* Hawai'i Institute of Geophysics and Planetology
- Spudis, P. D. (1996). *The Once and Future Moon* Smithsonian Institution Press ISBN 1-56098-634-4
- Taylor, S.R. (1992). *Solar system evolution* Cambridge University Press p. 307. ISBN 0-521-37212-7.
- Teague, K. (2006). "The Project Apollo Archive" Retrieved 12 April 2007.
- Wilhelms, D.E. (1987). "Geologic History of the Moon". *U.S. Geological Survey Professional paper* **1348**. Retrieved 12 April 2007.
- Wilhelms, D.E. (1993). *To a Rocky Moon: A Geologist's History of Lunar Exploration*. Tucson, Arizona: University of Arizona Press ISBN 0-8165-1065-2 Retrieved 10 March 2009.

External links

- [NASA images and videos about the Moon](#)

- [Album of images and high-resolution overflight videos by Seán Doran, based on LRO data](#)

Cartographic resources

- [The Moon on Google Maps](#) a 3-D rendition of the moon akin to Google Earth
- ["Consolidated Lunar Atlas"](#). Lunar and Planetary Institute Retrieved 26 February 2012.
- [Gazetteer of Planetary Nomenclature \(USGS\)](#) List of feature names.
- ["Clementine Lunar Image Browser"](#). U.S. Navy. 15 October 2003 Retrieved 12 April 2007.
- 3D zoomable globes:
 - ["Google Moon"](#). Google. 2007. Retrieved 12 April 2007.
 - ["Moon"](#). *World Wind Central*. NASA. 2007. Retrieved 12 April 2007.
- Aeschliman, R. ["Lunar Maps"](#). *Planetary Cartography and Graphics* Retrieved 12 April 2007. Maps and panoramas at Apollo landing sites
- [Japan Aerospace Exploration Agency \(JAXA\) Kaguya \(Selene\) images](#)
- [Large image of the Moon's north pole area](#)

Observation tools

- ["NASA's SKYCAL—Sky Events Calendar"](#). NASA. Archived from [the original](#) on 20 August 2007. Retrieved 27 August 2007.
- ["Find moonrise, moonset and moonphase for a location"](#) 2008. Retrieved 18 February 2008.
- ["HMNAO's Moon Watch"](#). 2005. Retrieved 24 May 2009. See when the next new crescent moon is visible for any location.

General

- [Lunar shelter \(building a lunar base with 3D printing\)](#)

Retrieved from ["https://en.wikipedia.org/w/index.php?title=Moon&oldid=831996213"](https://en.wikipedia.org/w/index.php?title=Moon&oldid=831996213)

This page was last edited on 23 March 2018, at 05:36.

Text is available under the [Creative Commons Attribution-ShareAlike License](#); additional terms may apply. By using this site, you agree to the [Terms of Use](#) and [Privacy Policy](#). Wikipedia® is a registered trademark of the [Wikimedia Foundation, Inc.](#), a non-profit organization.