GORE JOHN ELLARD

ASTRONOMICAL CURIOSITIES: FACTS AND FALLACIES

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Содержание

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PREFACE

The curious facts, fallacies, and paradoxes contained in the following pages have been collected from various sources. Most of the information given will not, I think, be found in popular works on astronomy, and will, it is hoped, prove of interest to the general reader.
J. E. G.

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CHAPTER I
The Sun

Some observations recently made by Prof. W. H. Pickering in Jamaica, make the value of sunlight 540,000 times that of moonlight. This makes the sun's "stellar magnitude" minus 26·83, and that of moonlight minus 12·5. Prof. Pickering finds that the light of the full moon is equal to 100,000 stars of zero magnitude. He finds that the moon's "albedo" is about 0·0909; or in other words, the moon reflects about one-tenth of the light which falls on it from the sun. He also finds that the light of the full moon is about twelve times the light of the half moon: a curious and rather unexpected result.

M. C. Fabry found that during the total eclipse of the sun on August 30, 1905, the light of the corona at a distance of five minutes of arc from the sun's limit, and in the vicinity of the sun's equator, was about 720 candle-power. Comparing this with the intrinsic light of the full moon (2600 candle-power) we have the ratio of 0·28 to 1. He finds that the light of the sun in the zenith, and at its mean distance from the earth, is 100,000 times greater than the light of a "decimal candle" placed at a distance of one metre from the eye.[1] He also finds that sunlight is equal to 60,000 million times the light of Vega. This would make the sun's "stellar magnitude" minus 26·7, which does not differ much from Prof. Pickering's result, given above, and is probably not far from the truth.

From experiments made in 1906 at Moscow, Prof. Ceraski found that the light of the sun's limb is only 31·4 to 38·4 times brighter than the illumination of the earth's atmosphere very near the limb. This is a very unexpected result; and considering the comparative faintness of the sun's corona during a total eclipse, it is not surprising that all attempts to photograph it without an eclipse have hitherto failed.[2]

From Paschen's investigations on the heat of the sun's surface, he finds a result of 5961° (absolute), "assuming that the sun is a perfectly black body."[3] Schuster finds that "There is a stratum near the sun's surface having an average temperature of approximately 5500 °C., to which about 0·3 of the sun's radiation is due. The remaining portion of the radiation has an intensity equal to that due to a black body having a temperature of about 6700 °C." The above results agree fairly well with those found by the late Dr. W. E. Wilson.[4] The assumption of the sun being "a black body" seems a curious paradox; but the simple meaning of the statement is that the sun is assumed to act as a radiator as *if it were a perfectly black body heated to the high temperature given above.*

According to Prof. Langley, the sun's photosphere is 5000 times brighter than the molten metal in a "Bessemer convertor."[5]

Observations of the sun even with small telescopes and protected by dark glasses are very dangerous to the eyesight. Galileo blinded himself in this way; Sir William Herschel lost one of his eyes; and some modern observers have also suffered. The present writer had a narrow escape from permanent injury while observing the transit of Venus, in 1874, in India, the dark screen before the eyepiece of a 3-inch telescope having blistered – that is, partially fused during the observation. Mr. Cooper, Markree Castle, Ireland, in observing the sun, used a "drum" of alum water and dark spectacles, and found this sufficient protection against the glare in using his large refracting telescope of 13·3-inches aperture.

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[1] *Comptes Rendus*, 1903, December 7.

[2] *Nature*, April 11, 1907.

[3] *Astrophysical Journal*, vol. 19 (1904), p. 39.

[4] *Astrophysical Journal*, vol. 21 (1905), p. 260.

[5] *Knowledge*, July, 1902, p. 132.

Prof. Mitchell, of Columbia University (U.S.A.), finds that lines due to the recently discovered atmospherical gases argon and neon are present in the spectrum of the sun's chromosphere. The evidence for the existence of krypton and xenon is, however, inconclusive. Prof. Mitchell suggests that these gases may possibly have reached the earth's atmosphere from the sun. This would agree with the theory advanced by Arrhenius that "ionised particles are constantly being repulsed by the pressure of light, and thus journey from one sun to another."[6]

Prof. Young in 1870, and Dr. Kreusler in June, 1904, observed the helium line D3 as a *dark* line "in the spectrum of the region about a sun-spot."[7] This famous line, from which helium was originally discovered in the sun, and by which it was long afterwards detected in terrestrial minerals, usually appears as a *bright* line in the spectrum of the solar chromosphere and "prominences." It has also been seen *dark* by Mr. Buss in sun-spot regions.[8]

The discovery of sun-spots was claimed by Hariotte, in 1610, and by Galileo, Fabricius, and Scheiner, in 1611. The latter wrote 800 pages on them, and thought they were small planets revolving round the sun! This idea was also held by Tardè, who called them *Astra Borbonia*, and by C. Malapert, who termed them *Sydera Austricea*. But they seem to have been noticed by the ancients.

Although in modern times there has been no extraordinary development of sun-spots at the epoch of maximum, it is not altogether impossible that in former times these spots may have occasionally increased to such an extent, both in number and size, as to have perceptibly darkened the sun's light. A more probable explanation of recorded sun-darkenings seems, however, to be the passing of a meteoric or nebulous cloud between the sun and the earth. A remarkable instance of sun-darkening recorded in Europe occurred on May 22, 1870, when the sun's light was observed to be considerably reduced in a cloudless sky in the west of Ireland, by the late John Birmingham; at Greenwich on the 23rd; and on the same date, but at a later hour, in North-Eastern France – "a progressive manifestation," Mr. Birmingham says, "that seems to accord well with the hypothesis of moving nebulous matter." A similar phenomenon was observed in New England (U.S.A.), on September 6, 1881.

One of the largest spots ever seen on the sun was observed in June, 1843. It remained visible for seven or eight days. According to Schwabe – the discoverer of the sun-spot period – its diameter was 74,000 miles, so that its area was many times that of the earth's surface. The most curious thing about this spot was that it appeared near a *minimum* of the sun-spot cycle! and was therefore rather an anomalous phenomenon. It was suggested by the late Daniel Kirkwood that this great spot was caused by the fall of meteoric matter into the sun; and that it had possibly some connection with the great comet of 1843, which approached the sun nearer than any other recorded comet, its distance from the sun at perihelion being about 65,000 miles, or less than one-third of the moon's distance from the earth. This near approach of the comet to the sun occurred about three months before the appearance of the great sun-spot; and it seems probable that the spot was caused by the downfall of a large meteorite travelling in the wake of the comet.[9] The connection between comets and meteors is well known.

The so-called blackness of sun-spots is merely relative. They are really very bright. The most brilliant light which can be produced artificially looks like a black spot when projected on the sun's disc.

According to Sir Robert Ball a pound of coal striking a body with a velocity of five miles a second would develop as much heat as it would produce by its combustion. A body falling into the sun from infinity would have a velocity of 450 miles a second when it reached the sun's surface. Now

[6] *Nature*, April 30, 1903.

[7] *Ibid.*, May 18, 1905.

[8] *Ibid.*, May 18, 1905.

[9] *Nature*, June 29, 1871.

as the momentum varies as the square of the velocity we have a pound of coal developing 902 (= 450⁄5)2, or 8,100 times as much heat as would be produced by its combustion. If the sun were formed of coal it would be consumed in about 3000 years. Hence it follows that the contraction of the sun's substance from infinity would produce a supply of heat for 3000 × 8100, or 24,300,000 years.

The late Mr. Proctor and Prof. Young believed "that the contraction theory of the sun's heat is the true and only available theory." The theory is, of course, a sound one; but it may now be supplemented by supposing the sun to contain a certain small amount of radium. This would bring physics and geology into harmony. Proctor thought the "sun's real globe is very much smaller than the globe we see. In other words the process of contraction has gone on further than, judging from the sun's apparent size, we should suppose it to have done, and therefore represents more sun work" done in past ages.

With reference to the suggestion, recently made, that a portion, at least, of the sun's heat may be due to radium, and the experiments which have been made with negative results, Mr. R. T. Strutt – the eminent physicist – has made some calculations on the subject and says, "even if all the sun's heat were due to radium, there does not appear to be the smallest possibility that the Becquerel radiation from it could ever be detected at the earth's surface."[10]

The eminent Swedish physicist Arrhenius, while admitting that a large proportion of the sun's heat is due to contraction, considers that it is probably the chemical processes going on in the sun, and not the contraction which constitute the *chief* source of the solar heat.[11]

As the centre of gravity of the sun and Jupiter lies at a distance of about 460,000 miles from the sun's centre, and the sun's radius is only 433,000 miles, it follows that the centre of gravity of the sun and planet is about 27,000 miles *outside* the sun's surface. The attractions of the other planets perpetually change the position of the centre of gravity of the solar system; but in some books on astronomy it is erroneously stated that the centre of gravity of the system is *always* within the sun's surface. If *all* the planets lay on the same side of the sun at the same time (as might possibly happen), then the centre of gravity of the whole system would lie considerably more than 27,000 miles outside the sun's surface.

With reference to the sun's great size, Carl Snyder has well said, "It was as if in Vulcan's smithy the gods had moulded one giant ball, and the planets were but bits and small shot which had spattered off as the glowing ingot was cast and set in space. Little man on a little part of a little earth – a minor planet, a million of which might be tumbled into the shell of the central sun – was growing very small; his wars, the convulsions of a state, were losing consequence. Human endeavour, human ambitions could now scarce possess the significance they had when men could regard the earth as the central fact of the universe."[12]

With reference to the late Prof. C. A. Young (U.S.A.) – a great authority on the sun – an American writer has written the following lines: —

"The destined course of whirling worlds to trace,
To plot the highways of the universe,
And hear the morning stars their song rehearse,
And find the wandering comet in his place;
This is the triumph written in his face,
And in the gleaming eye that read the sun
Like open book, and from the spectrum won

[10] *Nature*, October 15, 1903.

[11] *The Life of the Universe* (1909), vol. ii. p. 209.

[12] *The World Machine*, p. 234.

The secrets of immeasurable space."[13]

[13] Quoted in *The Observatory*, March 1908, p. 125.

CHAPTER II
Mercury

As the elongation of Mercury from the sun seldom exceeds 18°, it is a difficult object, at least in this country, to see without a telescope. As the poet says, the planet —

> "Can scarce be caught by philosophic eye
> Lost in the near effulgence of its blaze."

Tycho Brahé, however, records several observations of Mercury with the unaided vision in Denmark.

It can be occasionally caught with the naked eye in this country after sunset, when it is favourably placed for observation, and I have so seen it several times in Ireland. On February 19, 1888, I found it very visible in strong twilight near the western horizon, and apparently brighter than an average star of the first magnitude would be in the same position. In the clear air of the Punjab sky I observed Mercury on November 24-29, 1872, near the western horizon after sunset. Its appearance was that of a reddish star of the first magnitude. On November 29 I compared its brilliancy with that of Saturn, which was some distance above it, and making allowance for the glare near the horizon in which Mercury was immersed, its brightness appeared to me to be quite equal to that of Saturn. In June, 1874, I found it equal to Aldebaran, and of very much the same colour. Mr. W. F. Denning, the famous observer of meteors, states that he observed Mercury with the naked eye about 150 times during the years 1868 to 1905.[14]

He found that the duration of visibility after sunset is about 1h 40m when seen in March, 1h 30m in April, and 1h 20m in May. He thinks that the planet is, at its brightest, "certainly much brighter than a first magnitude star."[15] In February, 1868, he found that its brightness rivalled that of Jupiter, then only 2° or 3° distant. In November, 1882, it seemed brighter than Sirius. In 1876 it was more striking than Mars, but the latter was then "faint and at a considerable distance from the earth."

In 1878, when Mercury and Venus were in the same field of view of a telescope, Nasmyth found that the surface brightness (or "intrinsic brightness," as it is called) of Venus was at least twice as great as that of Mercury; and Zöllner found that from a photometric point of view the surface of Mercury is comparable with that of the moon.

With reference to the difficulty of seeing Mercury, owing to its proximity to the sun, Admiral Smyth says, "Although Mercury is never in *opposition* to the earth, he was, when in the house of Mars, always viewed by astrologers as a most malignant planet, and one full of evil influences. The sages stigmatized him as a false deceitful star (*sidus dolosum*), the eternal torment of astronomers, eluding them as much as terrestrial mercury did the alchemists; and Goad, who in 1686 published a whole folio volume full of astro-meteorological aphorisms, unveiling the choicest secrets of nature, contemptuously calls Mercury a 'squinting lacquey of the sun, who seldom shows his head in these parts, as if he was in debt.' His extreme mobility is so striking that chemists adopted his symbol to denote quicksilver."[16]

Prof. W. H. Pickering thinks that the shortness of the cusps (or "horns") of Mercury's disc indicates that the planet's atmosphere is of small density – even rarer than that of Mars.

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[14] *The Observatory*, September, 1906.

[15] *Nature*, March 1, 1900.

[16] *Cycle of Celestial Objects*, p. 96.

The diameter of Mercury is usually stated at about 3000 miles; but a long series of measures made by Prof. See in the year 1901 make the real diameter about 2702 miles. This would make the planet smaller than some of the satellites of the large planets, probably smaller than satellites III. and IV. of Jupiter, less than Saturn's satellite Titan, and possibly inferior in size to the satellite of Neptune. Prof. Pickering thinks that the density of Mercury is about 3 (water = 1). Dr. See's observations show "no noticeable falling off in the brightness of Mercury near the limb." There is therefore no evidence of any kind of atmospheric absorption in Mercury, and the observer "gets the impression that the physical condition of the planet is very similar to that of our moon."[17]

Schröter (1780-1815) observed markings on Mercury, from which he inferred that the planet's surface was mountainous, and one of these mountains he estimated at about 11 miles in height![18] But this seems very doubtful.

To account for the observed irregularities in the motion of Mercury in its orbit, Prof. Newcomb thinks it possible that there may exist a ring or zone of "asteroids" a little "outside the orbit of Mercury" and having a combined mass of "one-fiftieth to one-three-hundredth of the mass of Venus, according to its distance from Mercury." Prof. Newcomb, however, considers that the existence of such a ring is extremely improbable, and regards it "more as a curiosity than a reality."[19]

M. Léo Brenner thinks that he has seen the dark side of Mercury, in the same way that the dark side of Venus has been seen by many observers. In the case of Mercury the dark side appeared *darker* than the background of the sky. Perhaps this may be due to its being projected on the zodiacal light, or outer envelope of the sun.[20]

Mercury is said to have been occulted by Venus in the year 1737.[21] But whether this was an actual occultation, or merely a near approach does not seem to be certain.

The first transit of Mercury across the sun's disc was observed by Gassendi on November 6, 1631, and Halley observed one on November 7, 1677, when in the island of St. Helena.

Seen from Mercury, Venus would appear brighter than even we see it, and as it would be at its brightest when in opposition to the sun, and seen on a dark sky with a full face, it must present a magnificent appearance in the midnight sky of Mercury. The earth will also form a brilliant object, and the moon would be distinctly visible. The other planets would appear very much as they do to us, but with somewhat less brilliancy owing to their greater distance.

As the existence of an intra-Mercurial planet (that is a planet revolving round the sun within the orbit of Mercury) seems now to be very improbable, Prof. Perrine suggests that possibly "the finely divided matter which produces the zodiacal light when considered in the aggregate may be sufficient to cause the perturbations in the orbit of Mercury."[22] Prof. Newcomb, however, questions the exact accuracy of Newton's law, and seems to adopt Hall's hypothesis that gravity does not act *exactly* as the inverse square of the distance, and that the exponent of the distance is not 2, but 2·0000001574.[23]

Voltaire said, "If Newton had been in Portugal, and any Dominican had discovered a heresy in his inverse ratio of the squares of the distances, he would without hesitation have been clothed in a *san benito*, and burnt as a sacrifice to God at an *auto da fé*."[24]

An occultation of Mercury by Venus was observed with a telescope on May 17, 1737.[25]

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[17] *Ast. Nach.* No. 3737.

[18] *Observatory*, September, 1906.

[19] *Nature*, November 29 and December 20, 1894.

[20] *Bulletin, Ast. Soc. de France*, July, 1898.

[21] *Observatory*, vol. 8 (1885), pp. 306-7.

[22] *Nature*, October 30, 1902.

[23] Charles Lane Poor, *The Solar System*, p. 170.

[24] Smyth, *Celestial Cycle*, p. 60.

[25] Denning, *Telescopic Work for Starlight Evenings*, p. 225.

May transits of Mercury across the sun's disc will occur in the years 1924, 1957, and 1970; and November transits in the years 1914, 1927, and 1940.[26]

From measurements of the disc of Mercury during the last transit, M. R. Jonckheere concludes that the *polar* diameter of the planet is greater than the *equatorial*! His result, which is very curious, if true, seems to be supported by the observations of other observers.[27]

The rotation period of Mercury, or the length of its day, seems to be still in doubt. From a series of observations made in the years 1896 to 1909, Mr. John McHarg finds a period of 1·0121162 day, or 1d 0h 17m 26s·8. He thinks that "the planet possesses a considerable atmosphere not so clear as that of Mars"; that "its axis is very considerably tilted"; and that it "has fairly large sheets of water."[28]

[26] *The Observatory*, 1894, p. 395.

[27] *Ast. Nach.* 4333, quoted in *Nature*, July 1, 1909, p. 20.

[28] *English Mechanic*, July 23, 1909.

CHAPTER III
Venus

Venus was naturally – owing to its brightness – the first of the planets known to the ancients. It is mentioned by Hesiod, Homer, Virgil, Martial, and Pliny; and Isaiah's remark about "Lucifer, son of the morning" (Isaiah xiv. 12) probably refers to Venus as a "morning star." An observation of Venus is found on the Nineveh tablets of date B.C. 684. It was observed in daylight by Halley in July, 1716.

In *very* ancient times Venus, when a morning star, was called Phosphorus or Lucifer, and when an evening star Hesperus; but, according to Sir G. C. Lewis, the identity of the two objects was known so far back as 540 B.C.

When Venus is at its greatest brilliancy, and appears as a morning star about Christmas time (which occurred in 1887, and again in 1889), it has been mistaken by the public for a return of the "Star of Bethlehem."[29] But whatever "the star of the Magi" was it certainly was *not* Venus. It, seems, indeed absurd to suppose that "the wise men" of the East should have mistaken a familiar object like Venus for a strange apparition. There seems to be nothing whatever in the Bible to lead us to expect that the star of Bethlehem will reappear.

Mr. J. H. Stockwell has suggested that the "Star of Bethlehem" may perhaps be explained by a conjunction of the planets Venus and Jupiter which occurred on May 8, B.C. 6, which was two years before the death of Herod. From this it would follow that the Crucifixion took place on April 3, A.D. 33. But it seems very doubtful that the phenomenon recorded in the Bible refers to any conjunction of planets.

Chacornac found the intrinsic brightness of Venus to be ten times greater than the most luminous parts of the moon.[30] But this estimate is probably too high.

When at its brightest, the planet is visible in broad daylight to good eyesight, if its exact position in the sky is known. In the clear air of Cambridge (U.S.A.) it is said to be possible to see it in this way in all parts of its orbit, except when the planet is within 10° of the sun.[31] Mr. A. Cameron, of Yarmouth, Nova Scotia, has, however, seen Venus with the naked eye three days before conjunction when the planet was only 6¼° from the sun.[32] This seems a remarkable observation, and shows that the observer's eyesight must have been very keen. In a private letter dated October 22, 1888, the late Rev. S. J. Johnson informed the present writer that he saw Venus with the naked eye only four days before conjunction with the sun in February, 1878, and February, 1886.

The crescent shape of Venus is said to have been seen with the naked eye by Theodore Parker in America when he was only 12 years old. Other observers have stated the same thing; but the possibility of such an observation has been much disputed in recent years.

In the Chinese Annals some records are given of Venus having been seen in the Pleiades. On March 16, A.D. 845, it is said that "Venus eclipsed the Pleiades." This means, of course, that the cluster was apparently effaced by the brilliant light of the planet. Computing backwards for the above date, Hind found that on the evening of March 16, 845, Venus was situated near the star Electra; and on the following evening the planet passed close to Maia; thus showing the accuracy of the Chinese record. Another "eclipse" of the Pleiades by Venus is recorded in the same annals as having occurred on March 10, A.D. 1002.[33]

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[29] *Nature*, December 22, 1892.

[30] *Celestial Objects*, vol. i. p. 52, footnote.

[31] *Ibid.*, p. 54.

[32] *Astronomy and Astrophysics*, 1892, p. 618.

[33] *Nature*, August 7, 1879.

When Venus is in the crescent phase, that is near "Inferior conjunction" with the sun, it will be noticed, even by a casual observer, that the crescent is not of the same shape as that of the crescent moon. The horns or "cusps" of the planetary crescent are more prolonged than in the case of the moon, and extend beyond the hemisphere. This appearance is caused by refraction of the sun's light through the planetary atmosphere, and is, in fact, a certain proof that Venus has an atmosphere similar to that of the earth. Observations further show that this atmosphere is denser than ours.

Seen from Venus, the earth and moon, when in opposition, must present a splendid spectacle. I find that the earth would shine as a star about half as bright again as Venus at her brightest appears to us, and the moon about equal in brightness to Sirius! the two forming a superb "naked eye double star" – perhaps the finest sight of its kind in the solar system.[34]

Some of the earlier observers, such as La Hire, Fontana, Cassini, and Schröter, thought they saw evidence of mountains on Venus. Schröter estimated some of these to be 27 or 28 miles in height! but this seems very doubtful. Sir William Herschel severely attacked these supposed discoveries. Schröter defended himself, and was supported by Beer and Mädler, the famous lunar observers. Several modern observers seem to confirm Schröter's conclusions; but very little is really known about the topography of Venus.

The well-known French astronomer Trouvelot – a most excellent observer – saw white spots on Venus similar to those on Mars. These were well seen and quite brilliant in July and August, 1876, and in February and November, 1877. The observations seem to show that these spots do not (unlike Mars) increase and decrease with the planet's seasons. These white spots had been previously noticed by former observers, including Bianchini, Derham, Gruithuisen, and La Hire; but these early observers do not seem to have considered them as snow caps, like those of Mars. Trouvelot was led by his own observations to conclude that the period of rotation of Venus is short, and the best result he obtained was 23h 49m 28s. This does not differ much from the results previously found by De Vico, Fritsch, and Schröter.[35]

A white spot near the planet's south pole was seen on several occasions by H. C. Russell in May and June, 1876.[36]

Photographs of Venus taken on March 18 and April 29, 1908, by M. Quénisset at the Observatory of Juvissy, France, show a white polar spot. The spot was also seen at the same observatory by M. A. Benoit on May 20, 1903.

The controversy on the period of rotation of Venus, or the length of its day, is a very curious one and has not yet been decided. Many good observers assert confidently that it is short (about 24 hours); while others affirm with equal confidence that it is long (about 225 days, the period of the planet's revolution round the sun). Among the observers who favour the short period of rotation are: D. Cassini (1667), J. Cassini (1730), Schröter (1788-93), Mädler (1836), De Vico (1840?) Trouvelot (1871-79), Flammarion, Léo Brenner, Stanley Williams, and J. McHarg; and among those who support the long period are: Bianchini (1727), Schiaparelli, Cerulli, Tacchini, Mascari, and Lowell. Some recent spectroscopic observations seem to favour the short period.

Flammarion thinks that "nothing certain can be descried upon the surface of Venus, and that whatever has hitherto been written regarding its period of rotation must be considered null and void"; and again he says, "Nothing can be affirmed regarding the rotation of Venus, inasmuch as the absorption of its immense atmosphere certainly prevents any detail on its surface from being perceived."[37]

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[34] *The World of Space*, p. 56.

[35] *Nature*, September 15, 1892.

[36] *Observatory*, 1880, p. 574.

[37] *Knowledge*, November 1, 1897, pp. 260, 261.

The eminent Swedish physicist Arrhenius thinks, however, that the dense atmosphere and clouds of Venus are in favour of a rapid rotation on its axis.[38] He thinks that the mean temperature of Venus may "not differ much from the calculated temperature 104° F." "Under these circumstances the assumption would appear plausible that a very considerable portion of the surface of Venus, and particularly the districts about the poles, would be favourable to organic life."[39]

The "secondary light of Venus," or the visibility of the dark side, seems to have been first mentioned by Derham in his *Astro Theology* published in 1715. He speaks of the visibility of the dark part of the planet's disc "by the aid of a light of a somewhat dull and ruddy colour." The date of Derham's observation is not given, but it seems to have been previous to the year 1714. The light seems to have been also seen by a friend of Derham. We next find observations by Christfried Kirch, assistant astronomer to the Berlin Academy of Sciences, on June 7, 1721, and March 8, 1726. These observations are found in his original papers, and were printed in the *Astronomische Nachrichten*, No. 1586. On the first date the telescopic image of the planet was "rather tremulous," but in 1726 he noticed that the dark part of the circle seemed to belong to a smaller circle than the illuminated portion of the disc.[40] The same effect was also noted by Webb.[41] A similar illusion is seen in the case of the crescent moon, and this has given rise to the saying, "the old moon in the new moon's arms."

We next come, in order of date, to an observation made by Andreas Mayer, Professor of Mathematics at Griefswald in Prussia. The observation was made on October 20, 1759, and the dark part of Venus was seen distinctly by Mayer. As the planet's altitude at the time was not more than 14° above the horizon, and its apparent distance from the sun only 10°, the phenomenon – as Professor Safarik has pointed out – "must have had a most unusual intensity."

Sir William Herschel makes no mention of having ever seen the "secondary light" of Venus, although he noticed the extension of the horns beyond a semicircle.

In the spring and summer of the year 1793, Von Hahn of Remplin in Mecklenburg, using excellent telescopes made by Dollond and Herschel, saw the dark part of Venus on several occasions, and describes the light as "grey verging upon brown."

Schröter of Lilienthal – the famous observer of the moon – saw the horns of the crescent of Venus extended many degrees beyond the semicircle on several occasions in 1784 and 1795, and the border of the dark part faintly lit up by a dusky grey light. On February 14, 1806, at 7 P.M. he saw the whole of the dark part visible with an ash-coloured light, and he was satisfied that there was no illusion. On January 24 of the same year, 1806, Harding at Göttingen, using a reflector of 9 inches aperture and power 84, saw the dark side of Venus "shining with a pale ash-coloured light," and very visible against the dark background of the sky. The appearance was seen with various magnifying powers, and he thought that there could be no illusion. In fact the phenomenon was as evident as in the case of the moon. Harding again saw it on February 28 of the same year, the illumination being of a reddish grey colour, "like that of the moon in a total eclipse."

The "secondary light" was also seen by Pastorff in 1822, and by Gruithuisen in 1825. Since 1824 observations of the "light" were made by Berry, Browning, Guthrie, Langdon, Noble, Prince, Webb, and others. Webb saw it with powers of 90 and 212 on a 9·38-inch mirror, and found it "equally visible when the bright crescent was hidden by a field bar."[42]

Captain Noble's observation was rather unique. He found that the dark side was "always distinctly and positively *darker* than the background upon which it is projected."

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[38] *Worlds in the Making*, p. 61.

[39] *Ibid.*, p. 48.

[40] *Nature*, June 1, 1876.

[41] *Cel. Objects*, vol. i. p. 66 (5th Edition).

[42] *Celestial Objects*, vol. i. p. 65 (5th Edition).

The "light" was also seen by Lyman in America in 1867, and by Safarik at Prague. In 1871 the whole disc of Venus was seen by Professor Winnecke.[43] On the other hand, Winnecke stated that he only saw it twice in 24 years; and the great observers Dawes and Mädler never saw it at all![44]

Various attempts have been made to explain the visibility – at times – of the "dark side" of Venus. The following may be mentioned[45]: – (1) Reflected earth-light, analogous to the dark side of the crescent moon. This explanation was advocated by Harding, Schröter, and others. But, although the earth is undoubtedly a bright object in the sky of Venus, the explanation is evidently quite inadequate. (2) Phosphorescence of the planet's atmosphere. This has been suggested by some observers. (3) Visibility by contrast, a theory advanced by the great French astronomer Arago. (4) Illumination of the planet's surface by an aurora borealis. This also seems rather inadequate, but would account for the light being sometimes visible and sometimes not. (5) Luminosity of the oceans – if there be any – on Venus. But this also seems inadequate. (6) A planetary surface glowing with intense heat. But this seems improbable. (7) The Kunstliche Feuer (artificial fire) of Gruithuisen, a very fanciful theory. Flammarion thinks that the visibility of the dark side may perhaps be explained by its projection on a somewhat lighter background, such as the zodiacal light, or an extended solar envelope.[46]

It will be seen that none of these explanations are entirely satisfactory, and the phenomenon, if real, remains a sort of astronomical enigma. The fact that the "light" is visible on some occasions and not on others would render some of the explanations improbable or even inadmissible. But the condition of the earth's atmosphere at times might account for its invisibility on many occasions.

A curious suggestion was made by Zöllner, namely, that if the secondary light of Venus could be observed with the spectroscope it would show bright lines! But such an observation would be one of extreme difficulty.

M. Hansky finds that the visibility of the "light" is greater during periods of maximum solar activity – that is, at the maxima of sun spots. This he explains by the theory of Arrhenius, in which electrified "ions emitted by the sun cause the phenomena of terrestrial magnetic storms and auroras." "In the same way the dense atmosphere of Venus is rendered more phosphorescent, and therefore more easily visible by the increased solar activity."[47] This seems a very plausible hypothesis.

On the whole the occasional illumination of the night side of Venus by a very brilliant aurora (explanation (4) above) seems to the present writer to be the most probable explanation. Gruithuisen's hypothesis (7) seems utterly improbable.

There is a curious apparent anomaly about the motion of Venus in the sky. Although the planet's period of revolution round the sun is 224·7 days, it remains on the same side of the sun, as seen from the earth, for 290 days. The reason of this is that the earth is going at the same time round the sun in the same direction, though at a slower pace; and Venus must continue to appear on the same side of the sun until the excess of her daily motion above that of the earth amounts to 179°, and this at the daily rate of 37′ will be about 290 days.

Several observations have been recorded of a supposed satellite of Venus. But the existence of such a body has never been verified. In the year 1887, M. Stroobant investigated the various accounts, and came to the conclusion that in several at least of the recorded observations the object seen was certainly a star. Thus, in the observation made by Rœdickœr and Boserup on August 4, 1761, a satellite and star are recorded as having been seen near the planet. M. Stroobant finds that the supposed "satellite" was the star χ4 Orionis, and the "star" χ3 Orionis. A supposed observation of

[43] *Ast. Nach.* No. 1863.

[44] *Nature*, June 1, 1876.

[45] *Ibid.*, June 8, 1876.

[46] *Nature*, October 17, 1895.

[47] *Ibid.*, July 27, 1905.

a satellite made by Horrebow on January 3, 1768, was undoubtedly θ Libræ. M. Stroobant found that the supposed motion of the "satellite" as seen by Horrebow is accurately represented by the motion of Venus itself during the time of observation. In most of the other supposed observations of a satellite a satisfactory identification has also been found. M. Stroobant finds that with a telescope of 6 inches aperture, a star of the 8th or even the 9th magnitude can be well seen when close to Venus.[48]

On the night of August 13, 1892, Professor Barnard, while examining Venus with the great 36-inch telescope of the Lick Observatory, saw a star of the 7th magnitude in the same field with the planet. He carefully determined the exact position of this star, and found that it is not in Argelander's great catalogue, the *Durchmusterung*. Prof. Barnard finds that owing to elongation of Venus from the sun at the time of observation the star could not possibly be an intra-Mercurial planet (that is, a planet revolving round the sun inside the orbit of Mercury); but that possibly it might be a planet revolving between the orbits of Venus and Mercury. As the brightest of the minor planets – Ceres, Pallas, Juno, and Vesta – were not at the time near the position of the observed object, the observation remains unexplained. It might possibly have been a *nova*, or temporary star.[49]

Scheuten is said to have seen a supposed satellite of Venus following the planet across the sun at the end of the transit of June 6, 1761.[50]

Humboldt speaks of the supposed satellite of Venus as among "the astronomical myths of an uncritical age."[51]

An occultation of Venus by the moon is mentioned in the Chinese Annals as having occurred on March 19, 361 A.D., and Tycho Brahé observed another on May 23, 1587.[52]

A close conjunction of Venus and Regulus (α Leonis) is recorded by the Arabian astronomer, Ibn Yunis, as having occurred on September 9, 885 A.D. Calculations by Hind show that the planet and star were within 2′ of arc on that night, and consequently would have appeared as a single star to the naked eye. The telescope had not then been invented.[53]

Seen from Venus, the maximum apparent distance between the earth and moon would vary from about 5′ to 31′.[54]

It is related by Arago that Buonaparte, when going to the Luxembourg in Paris, where the Directory were giving a fête in his honour, was very much surprised to find the crowd assembled in the Rue de Touracour "pay more attention to a region of the heavens situated above the palace than to his person or the brilliant staff that accompanied him. He inquired the cause and learned that these curious persons were observing with astonishment, although it was noon, a star, which they supposed to be that of the conqueror of Italy – an allusion to which the illustrious general did not seem indifferent, when he himself, with his piercing eyes, remarked the radiant body." The "star" in question was Venus.[55]

[48] *Nature*, October 6, 1887.

[49] *Ast. Nach.*, No. 4106.

[50] *Copernicus*, vol. ii. p. 168.

[51] *Cosmos*, vol. iv. p. 476, footnote.

[52] Denning, *Telescopic Work for Starlight Evenings*, p. 153.

[53] *Ibid.*, p. 154.

[54] *Nature*, July 13, 1876.

[55] P. M. Ryves in *Knowledge*, June 1, 1897, p. 144.

CHAPTER IV
The Earth

The earth being our place of abode is, of course, to us the most important planet in the solar system. It is a curious paradox that the moon's surface (at least the visible portion) is better known to us than the surface of the earth. Every spot on the moon's visible surface equal in size to say Liverpool or Glasgow is well known to lunar observers, whereas there are thousands of square miles on the earth's surface – for example, near the poles and in the centre of Australia – which are wholly unknown to the earth's inhabitants; and are perhaps likely to remain so.

Many attempts have been made by "paradoxers" to show that the earth is a flat plane and not a sphere. But M. Ricco has found by actual experiment that the reflected image of the setting sun from a smooth sea is an elongated ellipse. This proves mathematically beyond all doubt that the surface of the sea is spherical; for the reflection from a plane surface would be necessarily *circular*. The theory of a "flat earth" is therefore proved to be quite untenable, and all the arguments (?) of the "earth flatteners" have now been – like the French Revolution – "blown into space."

The pole of minimum temperature in the northern hemisphere, or "the pole of cold," as it has been termed, is supposed to lie near Werchojansk in Siberia, where a temperature of nearly -70° has been observed.

From a series of observations made at Annapolis (U.S.A.) on the gradual disappearance of the blue of the sky after sunset, Dr. See finds that the extreme height of the earth's atmosphere is about 130 miles. Prof. Newcomb finds that meteors first appear at a mean height of about 74 miles.[56]

An aurora seen in Canada on July 15, 1893, was observed from stations 110 miles apart, and from these observations the aurora was found to lie at a height of 166 miles above the earth's surface. It was computed that if the auroral "arch maintained an equal height above the earth its ends were 1150 miles away, so that the magnificent sight was presented of an auroral belt in the sky with 2300 miles between its two extremities."[57]

"Luminous clouds" are bright clouds sometimes seen at night near the end of June and beginning of July. They appear above the northern horizon over the sun's place about midnight, and evidently lie at a great height above the earth's surface. Observations made in Germany by Dr. Jesse, and in England by Mr. Backhouse, in the years 1885-91, show that the height of these clouds is nearly constant at about 51 miles.[58] The present writer has seen these remarkable clouds on one or two occasions in County Sligo, Ireland, during the period above mentioned.

M. Montigny has shown that "the approach of violent cyclones or other storms is heralded by an increase of scintillation" (or twinkling of the stars). The effect is also very evident when such storms pass at a considerable distance. He has also made some interesting observations (especially on the star Capella), which show that, not only does scintillation increase in rainy weather, but that "it is very evident, at such times, in stars situated at an altitude at which on other occasions it would not be perceptible at all; thus confirming the remark of Humboldt's with regard to the advent of the wet season in tropical countries."[59]

In a paper on the subject of "Optical Illusions" in *Popular Astronomy*, February, 1906, Mr. Arthur K. Bartlett, of Batter Creek, Michigan (U.S.A.), makes the following interesting remarks: —

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[56] *Bulletin, Ast. Soc. de France*, August, 1905.

[57] *Nature*, April 5, 1894.

[58] *Nature*, May 14, 1896. Some have attributed these "luminous clouds" to light reflected from the dust of the Krakatoa eruption (1883).

[59] *The Observatory*, 1877, p. 90.

> "The lunar halo which by many persons is regarded as a remarkable and unexplained luminosity associated with the moon, is to meteorological students neither a mysterious nor an anomalous occurrence. It has been frequently observed and for many years thoroughly understood, and at the present time admits of an easy scientific explanation. It is an atmospheric exhibition due to the refraction and dispersion of the moon's light through very minute ice crystals floating at great elevations above the earth, and it is explained by the science of meteorology, to which it properly belongs; for it is not of cosmical origin, and in no way pertains to astronomy, as most persons suppose, except as it depends on the moon, whose light passing through the atmosphere, produces the luminous halo, which as will be seen, is simply an optical illusion, originating, not in the vicinity of the moon – two hundred and forty thousand miles away – but just above the earth's surface, and within the aqueous envelope that surrounds it on all sides… A halo may form round the sun as well as the moon … but a halo is more frequently noticed round the moon for the reason that we are too much dazzled by the sun's light to distinguish faint colours surrounding its disc, and to see them it is necessary to look through smoked glass, or view the sun by reflection from the surface of still water, by which its brilliancy is very much reduced."…

"A 'corona' is an appearance of faintly coloured rings often seen around the sun and moon when a light fleecy cloud passes over them, and should not be mistaken for a halo, which is much larger and more complicated in its structure. These two phenomena are frequently confounded by inexperienced observers." With these remarks the present writer fully concurs.

Mr. Bartlett adds —

> "As a halo is never seen except when the sky is hazy, it indicates that moisture is accumulating in the atmosphere which will form clouds, and usually result in a storm. But the popular notion that the number of bright stars visible within the circle indicates the number of days before the storm will occur, is without any foundation whatever, and the belief is almost too absurd to be refuted. In whatever part of the sky a lunar halo is seen, one or more bright stars are always sure to be noticed inside the luminous ring, and the number visible depends entirely upon the position of the moon. Moreover, when the sky within the circle is examined with even a small telescope, hundreds of stars are visible where only one, or perhaps two or three, are perceived with the naked eye."

It is possible to have five Sundays in February (the year must of course be a "leap year"). This occurred in the year 1880, Sunday falling on February 1, 8, 15, 22, and 29. But this will not happen again till the year 1920. No century year (such as 1900, 2000, etc.) could possibly have five Sundays in February, and the Rev. Richard Campbell, who investigated this matter, finds the following sequence of years in which five Sundays occur in February: 1604, 1632, 1660, 1688, 1728, 1756, 1784, 1824, 1852, 1880, 1920, 1948, 1976.[60]

In an article on "The Last Day and Year of the Century: Remarks on Time Reckoning," in *Nature*, September 10, 1896, Mr. W. T. Lynn, the eminent astronomer, says, "The late Astronomer Royal, Sir George Airy, once received a letter requesting him to settle a dispute which had arisen in some local debating society, as to which would be the first day of the next century. His reply was, 'A very little consideration will suffice to show that the first day of the twentieth century will be January 1, 1901.' Simple as the matter seems, the fact that it is occasionally brought into question shows that there is some little difficulty connected with it. Probably, however, this is in a great measure

[60] *Popular Astronomy*, vol. 11 (1903), p. 293.

due to the circumstance that the actual figures are changed on January 1, 1900, the day preceding being December 31, 1899. A century is a very definite word for an interval respecting which there is no possible room for mistake or difference of opinion. But the date of its ending depends upon that of its beginning. Our double system of backward and forward reckoning leads to a good deal of inconvenience. Our reckoning supposes (what we know was not the case, but as an era the date does equally well) that Christ was born at the end of B.C. 1. At the end of A.D. 1, therefore, one year had elapsed from the event, at the end of A.D. 100, one century, and at the end of 1900, nineteen centuries… It is clear, then, that the year, as we call it, is an ordinal number, and that 1900 years from the birth of Christ (reckoning as we do from B.C. 1) will not be completed until the end of December 31 in that year, the twentieth century beginning with January 1, 1901, that is (to be exact) at the previous midnight, when the day commences by civil reckoning." With these remarks of Mr. Lynn I fully concur, and, so far as I know, all astronomers agree with him. As the discussion will probably again arise at the end of the twentieth century, I would like to put on record here what the scientific opinion was at the close of the nineteenth century.

Prof. E. Rutherford, the well-known authority on radium, suggests that possibly radium is a source of heat from within the earth. Traces of radium have been detected in many rocks and soils, and even in sea water. Calculation shows that the total amount distributed through the earth's crust is enormously large, although relatively small "compared with the annual output of coal for the world." The amount of radium necessary to compensate for the present loss of heat from the earth "corresponds to only five parts in one hundred million millions per unit mass," and the "observations of Elster and Gertel show that the radio-activity observed in soils corresponds to the presence of about this proportion of radium."[61]

The earth has 12 different motions. These are as follows: —

1. Rotation on its axis, having a period of 24 hours.
2. Revolution round the sun; period 365¼ days.
3. Precession; period of about 25,765 years.
4. Semi-lunar gravitation; period 28 days.
5. Nutation; period 18½ years.
6. Variation in obliquity of the ecliptic; about 47″ in 100 years.
7. Variation of eccentricity of orbit.
8. Change of line of apsides; period about 21,000 years.
9. Planetary perturbations.
10. Change of centre of gravity of whole solar system.
11. General motion of solar system in space.
12. Variation of latitude with several degrees of periodicity.[62]

> "An amusing story has been told which affords a good illustration of the ignorance and popular notions regarding the tides prevailing even among persons of average intelligence. 'Tell me,' said a man to an eminent living English astronomer not long ago, 'is it still considered probable that the tides are caused by the moon?' The man of science replied that to the best of his belief it was, and then asked in turn whether the inquirer had any serious reason for questioning the relationship. 'Well, I don't know,' was the answer; 'sometimes when there is no moon there seems to be a tide all the same.'"![63]

With reference to the force of gravitation, on the earth and other bodies in the universe, Mr. William B. Taylor has well said, "With each revolving year new demonstrations of its absolute

[61] *Popular Astronomy*, vol. 13 (1905), p. 226.

[62] *Nature*, July 25, 1901 (from Flammarion).

[63] *Popular Astronomy*, vol. 11 (1903), p. 496.

precision and of its universal domination serves only to fill the mind with added wonder and with added confidence in the stability and the supremacy of the power in which has been found no variableness neither shadow of turning, but which – the same yesterday, to-day and for ever —

> "Lives through all life, extends through all extent,
> Spreads undivided, operates unspent."[64]

With reference to the habitability of other planets, Tennyson has beautifully said —

> "Venus near her! smiling downwards at this earthlier earth of ours,
> Closer on the sun, perhaps a world of never fading flowers.
> Hesper, whom the poets call'd the Bringer home of all good things;
> All good things may move in Hesper; perfect people, perfect kings.
> Hesper – Venus – were we native to that splendour, or in Mars,
> We should see the globe we groan in fairest of their evening stars.
> Could we dream of war and carnage, craft and madness, lust and spite,
> Roaring London, raving Paris, in that spot of peaceful light?
> Might we not in glancing heavenward on a star so silver fair,
> Yearn and clasp the hands, and murmur, 'Would to God that we were there!'"

The ancient Greek writer, Diogenes Laertius, states that Anaximander (610-547 B.C.) believed that the earth was a sphere. The Greek words are: μίσην τε τὴν γήν κεῖσθαι, κέντρυ τάξιν ἐπεχοῦσαν οὐσαν σφαιροειδῆ.[65]

With reference to the Aurora Borealis, the exact nature of which is not accurately known, "a good story used to be told some years ago of a candidate who, undergoing the torture of a *vivâ voce* examination, was unable to reply satisfactorily to any of the questions asked. 'Come, sir,' said the examiner, with the air of a man asking the simplest question, 'explain to me the cause of the aurora borealis.' 'Sir,' said the unhappy aspirant for physical honours, 'I could have explained it perfectly yesterday, but nervousness has, I think, made me lose my memory.' 'This is very unfortunate,' said the examiner; 'you are the only man who could have explained this mystery, and you have forgotten it.'"[66] This was written in the year 1899, and probably the phenomenon of the aurora remains nearly as great a mystery to-day. In 1839, MM. Bravais and Lottin made observations on the aurora in Norway in about N. latitude 70°. Bravais found the height to be between 62 and 93 miles above the earth's surface.

The cause of the so-called Glacial Epoch in the earth's history has been much discussed. The Russian physicist, Rogovsky, has advanced the following theory —

> "If we suppose that the temperature of the sun at the present time is still increasing, or at least has been increasing until now, the glacial epoch can be easily accounted for. Formerly the earth had a high temperature of its own, but received a lesser quantity of heat from the sun than now; on cooling gradually, the earth's surface attained such a temperature as caused a great part of the surface of the northern and southern hemispheres to be covered with ice; but the sun's radiation increasing, the glaciers melted, and the climatic conditions became as they are now. In a word, the temperature of the earth's surface is a function of two quantities: one

[64] *Kinetic Theories of Gravitation*, Washington, 1877.

[65] *The Observatory*, June, 1894, p. 208.

[66] *Nature*, June 8, 1899.

> decreasing (the earth's own heat), and the other increasing (the sun's radiation), and consequently there may be a minimum, and this minimum was the glacial epoch, which, as shown by recent investigations, those of Luigi de Marchi (Report of *G. Schiaparelli, Meteorolog. Zeitschr.*, 30, 130-136, 1895), are not local, but general for the whole earth" (see also M. Neumahr, *Erdegeschicht*).[67]

Prof. Percival Lowell thinks that the life of geological palæozoic times was supported by the earth's internal heat, which maintained the ocean at a comparatively warm temperature.[68]

The following passage in the Book of the Maccabees may possibly refer to an aurora —

> "Now about this time Antiochus made his second inroad into Egypt. And it *so* befell that throughout all the city, for the space of almost forty days, there appeared in the midst of the sky horsemen in swift motion, wearing robes inwrought with gold and *carrying* spears, equipped in troops for battle; and drawing of swords; and *on the other side* squadrons of horse in array; and encounters and pursuits of both armies; and shaking of shields, and multitudes of lances, and casting of darts, and flashing of golden trappings, and girding on of all sorts of armour. Wherefore all men besought that the vision might have been given for food."[69]

According to Laplace "the decrease of the mean heat of the earth during a period of 2000 years has not, taking the extremist limits, diminished as much as 1⁄300th of a degree Fahrenheit."[70]

From his researches on the cause of the Precession of the Equinoxes, Laplace concluded that "the motion of the earth's axis is the same as if the whole sea formed a solid mass adhering to its surface."[71]

Laplace found that the major (or longer) axis of the earth's orbit coincided with the line of Equinoxes in the year 4107 B.C. The earth's perigee then coincided with the autumnal equinox. The epoch at which the major axis was perpendicular to the line of equinoxes fell in the year 1250 A.D.[72]

Leverrier has found the minimum eccentricity of the earth's orbit round the sun to be 0·0047; so that the orbit will never become absolutely circular, as some have imagined.

Laplace says —

> "Astronomy considered in its entirety is the finest monument of the human mind, the noblest essay of its intelligence. Seduced by the illusions of the senses and of self-pride, for a long time man considered himself as the centre of the movement of the stars; his vain-glory has been punished by the terrors which his own ideas have inspired. At last the efforts of several centuries brushed aside the veil which concealed the system of the world. We discover ourselves upon a planet, itself almost imperceptible in the vast extent of the solar system, which in its turn is only an insensible point in the immensity of space. The sublime results to which this discovery has led should suffice to console us for our extreme littleness, and the rank which it assigns to the earth. Let us treasure with solicitude, let us add to as we may, this store of higher knowledge, the most exquisite treasure of thinking beings."[73]

With reference to probable future changes in climate, the great physicist, Arrhenius, says —

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[67] *Astrophysical Journal*, vol. 14 (1901), p. 238, footnote.

[68] *Mars as the Abode of Life*, p. 52.

[69] Second Book of the Maccabees v. 1-4 (Revised Edition).

[70] Humboldt's *Cosmos*, vol. i. p. 169 (Otté's translation).

[71] Quoted by Grant in *History of Physical Astronomy*, p. 71.

[72] *Ibid.*, pp. 100, 101.

[73] *Exposition du Système du Monde*, quoted by Carl Snyder in *The World Machine*, p. 226.

> "We often hear lamentation that the coal stored up in the earth is wasted by the present generation without any thought of the future, and we are terrified by the awful destruction of life and property which has followed the volcanic eruptions of our days. We may find a kind of consolation in the consideration that here, as in every other case, there is good mixed with evil. By the influence of the increasing percentage of carbonic acid in the atmosphere, we may hope to enjoy ages with more equable and better climates, especially as regards the colder regions of the earth, ages when the earth will bring forth much more abundant crops than at present, for the benefit of rapidly propagating mankind."[74]

The night of July 1, 1908, was unusually bright. This was noticed in various parts of England and Ireland, and by the present writer in Dublin. Humboldt states that "at the time of the new moon at midnight in 1743, the phosphorescence was so intense that objects could be distinctly recognized at a distance of more than 600 feet."[75]

An interesting proof of the earth's rotation on its axis has recently been found.

> "In a paper in the *Proceedings* of the Vienna Academy (June, 1908) by Herr Tumlirz, it is shown mathematically that if a liquid is flowing outwards between two horizontal discs, the lines of flow will be strictly straight only if the discs and vessel be at rest, and will assume certain curves if that vessel and the discs are in rotation, as, for example, due to the earth's rotation. An experimental arrangement was set up with all precautions, and the stream lines were marked with coloured liquids and photographed. These were in general accord with the predictions of theory and the supposition that the earth is rotating about an axis."[76]

In a book published in 1905 entitled *The Rational Almanac*, by Moses B. Cotsworth, of York, the author states that (p. 397), "The explanation is apparent from the Great Pyramid's Slope, which conclusively proves that when it was built the latitude of that region was 7°·1 more than at present. Egyptian Memphis now near Cairo was then in latitude 37°·1, where Asia Minor now ranges, whilst Syria would then be where the Caucasus regions now experience those rigorous winters formerly experienced in Syria." But the reality of this comparatively great change of latitude in the position of the Great Pyramid can be easily disproved. Pytheas of Marseilles – who lived in the time of Alexander the Great, about 330 B.C. – measured the latitude of Marseilles by means of a gnomon, and found it to be about 42° 56′½. As the present latitude of Marseilles is 43° 17′ 50″, no great change in the latitude could have taken place in over 2000 years.[77] From this we may conclude that the latitude of the Great Pyramid has *not* changed by 7°·1 since its construction. There is, it is true, a slow diminution going on in the obliquity of the ecliptic (or inclination of the earth's axis), but modern observations show that this would not amount to as much as one degree in 6000 years. Eudemus of Rhodes – a disciple of Aristotle (who died in 322 B.C.) – found the obliquity of the ecliptic to be 24°, which differs but little from its present value, 23° 27′. Al-Sufi in the tenth century measured the latitude of Schiraz in Persia, and found it 29° 36′. Its present latitude is 29° 36′ 30″,[78] so that evidently there has been no change in the latitude in 900 years.

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[74] *Worlds in the Making*, p. 63.

[75] *Cosmos*, vol. i. p. 131.

[76] *The Observatory*, June, 1909, p. 261.

[77] *Astronomical Essays*, pp. 61, 62.

[78] *Encyclopædia Britannica* (*Schiraz*).

CHAPTER V
The Moon

The total area of the moon's surface is about equal to that of North and South America. The actual surface visible at any one time is about equal to North America.

The famous lunar observer, Schröter, thought that the moon had an atmosphere, but estimated its height at only a little over a mile. Its density he supposed to be less than that of the vacuum in an air-pump. Recent investigations, however, seem to show that owing to its small mass and attractive force the moon could not retain an atmosphere like that of the earth.

Prof. N. S. Shaler, of Harvard (U.S.A.), finds from a study of the moon (from a geological point of view) with the 15-inch refractor of the Harvard Observatory, that our satellite has no atmosphere nor any form of organic life, and he believes that its surface "was brought to its present condition before the earth had even a solid crust."[79]

There is a curious illusion with reference to the moon's apparent diameter referred to by Proctor.[80] If, when the moon is absent in the winter months, we ask a person whether the moon's diameter is greater or less than the distance between the stars δ and ε, and ε and ζ Orionis, the three well-known stars in the "belt of Orion," the answer will probably be that the moon's apparent diameter is about equal to each of these distances. But in reality the apparent distance between δ and ε Orionis (or between ε and ζ, which is about the same) is more than double the moon's apparent diameter. This seems at first sight a startling statement; but its truth is, of course, beyond all doubt and is not open to argument. Proctor points out that if a person estimates the moon as a foot in diameter, as its apparent diameter is about half a degree, this would imply that the observer estimates the circumference of the star sphere as about 720 feet (360° × 2), and hence the radius (or the moon's distance from the earth) about 115 feet. But in reality all such estimates have no scientific (that is, accurate) meaning. Some of the ancients, such as Aristotle, Cicero, and Heraclitus, seem to have estimated the moon's apparent diameter at about a foot.[81] This shows that even great minds may make serious mistakes.

It has been stated by some writer that the moon as seen with the highest powers of the great Yerkes telescope (40 inches aperture) appears "just as it would be seen with the naked eye if it were suspended 60 miles over our heads." But this statement is quite erroneous. The moon as seen with the naked eye or with a telescope shows us nearly a whole hemisphere of its surface. But if the eye were placed only 60 miles from the moon's surface, we should see only a small portion of its surface. In fact, it is a curious paradox that the nearer the eye is to a sphere the less we see of its surface! The truth of this will be evident from the fact that on a level plain an eye placed at a height, say 5 feet, sees a very small portion indeed of the earth's surface, and the higher we ascend the more of the surface we see. I find that at a distance of 60 miles from the moon's surface we should only see a small portion of its visible hemisphere (about 1⁄90th). The lunar features would also appear under a different aspect. The view would be more of a landscape than that seen in any telescope. This view of the matter is not new. It has been previously pointed out, especially by M. Flammarion and Mr. Whitmell, but its truth is not, I think, generally recognized. Prof. Newcomb doubts whether with any telescope the moon has ever been seen so well as it would be if brought within 500 miles of the earth.

A relief map of the moon 19 feet in diameter was added, in 1898, to the Field Columbian Museum (U.S.A.). It was prepared with great care from the lunar charts of Beer and Mädler, and Dr.

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[79] *Monthly Notices*, R.A.S., February, 1905.

[80] *Nature*, March 3, 1870.

[81] *Ibid.*, March 31, 1870, p. 557.

Schmidt of the Athens Observatory, and it shows the lunar features very accurately. Its construction took five years.

On a photograph of a part of the moon's surface near the crater Eratosthenes, Prof. William H. Pickering finds markings which very much resemble the so-called "canals" of Mars. The photograph was taken in Jamaica, and a copy of it is given in Prof. Pickering's book on the Moon, and in *Popular Astronomy*, February, 1904.

Experiments made in America by Messrs. Stebbins and F. C. Brown, by means of selenium cells, show that the light of the full moon is about nine times that of the half moon;[82] and that "the moon is brighter between the first quarter and full than in the corresponding phase after full moon." They also find that the light of the full moon is equal to "0·23 candle power,"[83] that is, according to the method of measurement used in America, its light is equal to 0·23 of a standard candle placed at a distance of one metre (39·37 inches) from the eye.[83]

Mr. H. H. Kimball finds that no less than 52 per cent. of the observed changes in intensity of the "earth-shine" visible on the moon when at or near the crescent phase is due to the eccentricity of the lunar orbit, and "this is probably much greater than could be expected from any increase or diminution in the average cloudiness over the hemisphere of the earth reflecting light to the moon."[84]

> The "moon maiden" is a term applied to a fancied resemblance of a portion of the Sinus Iridum to a female head. It forms the "promontory" known as Cape Heraclides, and may be looked for when the moon's "age" is about 11 days. Mr. C. J. Caswell, who observed it on September 29, 1895, describes it as resembling "a beautiful silver statuette of a graceful female figure with flowing hair."

M. Landerer finds that the angle of polarization of the moon's surface – about 33° – agrees well with the polarizing angle for many specimens of igneous rocks (30° 51′ to 33° 46′). The polarizing angle for ice is more than 37°, and this fact is opposed to the theories of lunar glaciation advanced by some observers.[85]

Kepler states in his *Somnium* that he saw the moon in the crescent phase on the morning and evening of the *same* day (that is, before and after conjunction with the sun). Kepler could see 14 stars in the Pleiades with the naked eye, so his eyesight must have been exceptionally keen.

Investigations on ancient eclipses of the moon show that the eclipse mentioned by Josephus as having occurred before the death of Herod is probably that which took place on September 15, B.C. 5. This occurred about 9.45 p.m.; and probably about six months before the death of Herod (St. Matthew ii. 15).

The total lunar eclipse which occurred on October 4, 1884, was remarkable for the almost total disappearance of the moon during totality. One observer says that "in the open air, if one had not known exactly where to look for it, one might have searched for some time without discovering it. I speak of course of the naked eye appearance."[86] On the other hand the same observer, speaking of the total eclipse of the moon on August 23, 1877, which was a bright one, says —

"The moon even in the middle of the total phase was a conspicuous object in the sky, and the ruddy colour was well marked. In the very middle of the eclipse the degree of illumination was as nearly as possible equal all round the edge of the moon, the central parts being darker than those near the edge."

In Roger de Hovedin's *Chronicle* (A.D. 756) an account is given of the occultation of "a bright star," by the moon during a total eclipse. This is confirmed by Simeon of Durham, who also dates

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[82] Prof. W. H. Pickering found 12 times (see p. 1).

[83] *Nature*, January 30, 1908.

[84] *Nature*, September 5, 1901.

[85] *Ibid.*, July 31, 1890.

[86] *Nature*, October 16, 1884.

the eclipse A.D. 756. This is, however, a mistake, the eclipse having occurred on the evening of November 23, A.D. 755. Calvisius supposed that the occulted "star" might have been Aldebaran. Pingré, however, showed that this was impossible, and Struyck, in 1740, showed that the planet Jupiter was the "star" referred to by the early observer. Further calculations by Hind (1885) show conclusively that Struyck was quite correct, and that the phenomenon described in the old chronicles was the occultation of Jupiter by a totally eclipsed moon – a rather unique phenomenon.[87]

An occultation of Mars by the moon is recorded by the Chinese, on February 14, B.C. 69, and one of Venus, on March 30, A.D. 361. These have also been verified by Hind, and his calculations show the accuracy of these old Chinese records.

It has been suggested that the moon may possibly have a satellite revolving round it, as the moon itself revolves round the earth. This would, of course, form an object of great interest. During the total lunar eclipses of March 10 and September 3, 1895, a careful photographic search was made by Prof. Barnard for a possible lunar satellite. The eclipse of March 10 was not very suitable for the purpose owing to a hazy sky, but that of September 3 was "entirely satisfactory," as the sky was very clear, and the duration of totality was very long. On the latter occasion "six splendid" photographs were obtained of the total phase with a 6-inch Willard lens. The result was that none of these photographs "show anything which might be taken for a lunar satellite," at least any satellite as bright as the 10th or 12th magnitude. It is, of course, just possible that the supposed satellite might have been behind the moon during the totality.

With reference to the attraction between the earth and moon, Sir Oliver Lodge says —

> "The force with which the moon is held in its orbit would be great enough to tear asunder a steel rod 400 miles thick, with a tenacity of 30 tons to the square inch, so that if the moon and earth were connected by steel instead of gravity, a forest of pillars would be necessary to whirl the system once a month round their common centre of gravity. Such a force necessarily implies enormous tensure or pressure in the medium. Maxwell calculates that the gravitational stress near the earth, which we must suppose to exist in the invisible medium, is 3000 times greater than what the strongest steel can stand, and near the sun it should be 2500 times as great as that."[88]

With reference to the names given to "craters" on the moon, Prof. W. H. Pickering says,[89] "The system of nomenclature is, I think, unfortunate. The names of the chief craters are generally those of men who have done little or nothing for selenography, or even for astronomy, while the men who should be really commemorated are represented in general by small and unimportant craters," and again —

> "A serious objection to the whole system of nomenclature lies in the fact that it has apparently been used by some selenographers, from the earliest times up to the present, as a means of satisfying their spite against some of their contemporaries. Under the guise of pretending to honour them by placing their names in perpetuity upon the moon, they have used their names merely to designate the smallest objects that their telescopes were capable of showing. An interesting illustration of this point is found in the craters of Galileo and Riccioli, which lie close together on the moon. It will be remembered that Galileo was the discoverer of the craters on the moon. Both names were given by Riccioli, and the relative size and importance of the craters [Riccioli large, and Galileo very small] probably indicates to us the relative importance that he assigned to the two men themselves. Other examples might be

[87] *Nature*, February 19, 1885.

[88] *Nature*, January 14, 1909, p. 323.

[89] *Photographic Atlas of the Moon, Annals of Harvard Observatory*, vol. li. pp. 14, 15.

> quoted of craters named in the same spirit after men still living… With the exception of Maedler, one might almost say, the more prominent the selenographer the more insignificant the crater."

The mathematical treatment of the lunar theory is a problem of great difficulty. The famous mathematician, Euler, described it as *incredibile stadium atque indefessus labor*.[90]

With reference to the "earth-shine" on the moon when in the crescent phase, Humboldt says, "Lambert made the remarkable observation (14th of February, 1774) of a change of the ash-coloured moonlight into an olive-green colour, bordering upon yellow. The moon, which then stood vertically over the Atlantic Ocean, received upon its night side the green terrestrial light, which is reflected towards her when the sky is clear by the forest districts of South America."[91] Arago said, "Il n'est donc pas impossible, malgré tout ce qu'un pareil résultat exciterait de surprise au premier coup d'œil qu'un jour les météorologistes aillent puiser dans l'aspect de la Lune des notions précieuses sur *l'etat moyen* de diaphanité de l'atmosphère terrestre, dans les hemisphères qui successivement concurrent à la production de la lumière cendrée."[92]

The "earth-shine" on the new moon was successfully photographed in February, 1895, by Prof. Barnard at the Lick Observatory, with a 6-inch Willard portrait lens. He says —

> "The earth-lit globe stands out beautifully round, encircled by the slender crescent. All the 'seas' are conspicuously visible, as are also the other prominent features, especially the region about *Tycho*. *Aristarchus* and *Copernicus* appear as bright specks, and the light streams from *Tycho* are very distinct."[93]

Kepler found that the moon completely disappeared during the total eclipse of December 9, 1601, and Hevelius observed the same phenomenon during the eclipse of April 25, 1642, when "not a vestige of the moon could be seen."[94] In the total lunar eclipse of June 10, 1816, the moon during totality was not visible in London, even with a telescope![95]

The lunar mountains are *relatively* much higher than those on the earth. Beer and Mädler found the following heights: Dörfel, 23,174 feet; Newton, 22,141; Casatus, 21,102; Curtius, 20,632; Callippus, 18,946; and Tycho, 18,748 feet.[95]

Taking the earth's diameter at 7912 miles, the moon's diameter, 2163 miles, and the height of Mount Everest as 29,000 feet, I find that

Everest	=	1	, and	Dörfel	=	1
Earth's diameter		1440		moon's diameter		492

From which it follows that the lunar mountains are *proportionately* about three times higher than those on the earth.

According to an hypothesis recently advanced by Dr. See, all the satellites of the solar system, including our moon, were "captured" by their primaries. He thinks, therefore, that the "moon came to earth from heavenly space."[96]

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[90] *Nature*, January 18, 1906.

[91] Humboldt's *Cosmos*, vol. iv. p. 481.

[92] *Ibid.*, p. 482.

[93] *Monthly Notices*, R.A.S., June, 1895.

[94] Humboldt's *Cosmos*, vol. iv. p. 483 (Otté's translation).

[95] Grant, *History of Physical Astronomy*, p. 229.

[96] *Popular Astronomy*, vol. xvii. No. 6, p. 387 (June-July, 1909).

CHAPTER VI
Mars

Mars was called by the ancients "the vanishing star," owing to the long periods during which it is practically invisible from the earth.[97] It was also called πυρόεις and Hercules.

I have seen it stated in a book on the "Solar System" by a well-known astronomer that the *axis* of Mars "is inclined to the plane of the orbit" at an angle of 24° 50′! But this is quite erroneous. The angle given is the angle between *the plane of the planet's equator* and the plane of its orbit, which is quite a different thing. This angle, which may be called the obliquity of Mars' ecliptic, does not differ much from that of the earth. Lowell finds it 23° 13′ from observations in 1907.[98]

The late Mr. Proctor thought that Mars is "far the reddest star in the heavens; Aldebaran and Antares are pale beside him."[99] But this does not agree with my experience. Antares is to my eye quite as red as Mars. Its name is derived from two Greek words implying "redder than Mars." The colour of Aldebaran is, I think, quite comparable with that of the "ruddy planet." In the telescope the colour of Mars is, I believe, more yellow than red, but I have not seen the planet very often in a telescope. Sir John Herschel suggested that the reddish colour of Mars may possibly be due to red rocks, like those of the Old Red Sandstone, and the red soil often associated with such rocks, as I have myself noticed near Torquay and other places in Devonshire.

The ruddy colour of Mars was formerly thought to be due to the great density of its atmosphere. But modern observations seem to show that the planet's atmosphere is, on the contrary, much rarer than that of the earth. The persistent visibility of the markings on its surface shows that its atmosphere cannot be cloud-laden like ours; and the spectroscope shows that the water vapour present is – although perceptible – less than that of our terrestrial envelope.

The existence of water vapour is clearly shown by photographs of the planet's spectrum taken by Mr. Slipher at the Lowell Observatory in 1908. These show that the water vapour bands *a* and near D are stronger in the spectrum of Mars than in that of the moon at the same altitude.[100]

The dark markings on Mars were formerly supposed to represent water and the light parts land. But this idea has now been abandoned. Light reflected from a water surface is polarized at certain angles. Prof. W. H. Pickering, in his observations on Mars, finds no trace of polarization in the light reflected from the dark parts of the planet. But under the same conditions he finds that the bluish-black ring surrounding the white polar cap shows a well-marked polarization of light, thus indicating that this dark ring is probably water.[101]

Projections on the limb of the planet have frequently been observed in America. These are known *not* to be mountains, as they do not reappear under similar conditions. They are supposed to be clouds, and one seen in December, 1900, has been explained as a cloud lying at a height of some 13 miles above the planet's surface and drifting at the rate of about 27 miles an hour. If there are any mountains on Mars they have not yet been discovered.

The existence of the so-called "canals" of Mars is supposed to be confirmed by Lowell's photographs of the planet. But what these "canals" really represent, that is the question. They have certainly an artificial look about them, and they form one of the most curious and interesting problems in the heavens. Prof. Lowell says —

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[97] *Nature*, October 7, 1875.

[98] *Mars as an Abode of Life* (1908), p. 281.

[99] *Knowledge*, May 2, 1886.

[100] *Nature*, March 12, 1908.

[101] *Bulletin, Ast. Soc. de France*, April, 1899.

> "Most suggestive of all Martian phenomena are the canals. Were they more generally observable the world would have been spared much scepticism and more theory. They may of course not be artificial, but observations here [Flagstaff] indicate that they are; as will, I think, appear from the drawings. For it is one thing to see two or three canals and quite another to have the planet's disc mapped with them on a most elaborate system of triangulation. In the first place they are this season (August, 1894) bluish-green, of the same colour as the seas into which the longer ones all eventually debouch. In the next place they are almost without exception geodetically straight, supernaturally so, and this in spite of their leading in every possible direction. Then they are of apparently nearly uniform width throughout their length. What they are is another matter. Their mere aspect, however, is enough to cause all theories about glaciation fissures or surface cracks to die an instant and natural death."[102]

Some of the observed colour-changes on Mars are very curious. In April, 1905, Mr. Lowell observed that the marking known as Mare Erythræum, just above Syrtis, had "changed from a blue-green to a chocolate-brown colour." The season on Mars corresponded with our February.

Signor V. Cerulli says that, having observed Mars regularly for ten years, he has come to the conclusion that the actual existence of the "canals" is as much a subject for physiological as for astronomical investigation. He states that "the phenomena observed are so near the limit of the range of the human eye that in observing them one really experiences an effect accompanying the 'birth of vision.' That is to say, the eye sees more and more as it becomes accustomed, or strained, to the delicate markings, and thus the joining up of spots to form 'canals' and the gemination of the latter follow as a physiological effect, and need not necessarily be subjective phenomena seen by the unaccustomed eye."[103]

The possibility of life on Mars has been recently much discussed; some denying, others asserting. M. E. Rogovsky says —

> "As free oxygen and carbonic dioxide may exist in the atmosphere of *Mars*, vegetable and animal life is quite possible. If the temperature which prevails upon *Mars* is nearer to -36 °C. than to -73 °C., the existence of living beings like ourselves is possible. In fact, the ice of some Greenland and Alpine glaciers is covered by red algæ (*Sphærella nivalis*); we find there also different species of rotaloria, variegated spiders, and other animals on the snow fields illuminated by the sun; at the edges of glacier snows in the Tyrol we see violet bells of *Soldanella pusilla*, the stalks of which make their way through the snow by producing heat which melts it round about them. Finally the Siberian town Verkhociansk, near Yakutsk, exists, though the temperature there falls to -69°·8 C. and the mean temperature of January to -51°·2, and the mean pressure of the vapour of water is less than 0·05mm. It is possible, therefore, that living beings have become adapted to the conditions now prevailing upon *Mars* after the lapse of many ages, and live at an even lower temperature than upon the earth, developing the necessary heat themselves."

M. Rogovsky adds, "Water in organisms is mainly a liquid or solvent, and many other liquids may be the same. We have no reason to believe that life is possible only under the same conditions and with the same chemical composition of organisms as upon the earth, although indeed we cannot affirm that they actually exist on Mars."[104] With the above views the present writer fully concurs.

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[102] *Astronomy and Astrophysics* (1894), p. 649.

[103] *Nature*, April 20, 1905.

[104] *Astrophysical Journal*, vol. 14 (1901), p. 258.

Prof. Lowell thinks that the polar regions of Mars, both north and south, are actually warmer than the corresponding regions of the earth, although the mean temperature of the planet is probably twelve degrees lower than the earth's mean temperature.[105]

A writer in *Astronomy and Astrophysics* (1892, p. 748) says —

> "Whether the planet Mars is inhabited or not seems to be the all-absorbing question with the ordinary reader. With the astronomer this query is almost the last thing about the planet that he would think of when he has an opportunity to study its surface markings … no astronomer claims to know whether the planet is inhabited or not."

Several suggestions have been made with reference to the possibility of signalling to Mars. But, as Mr. Larkin of Mount Lowe (U.S.A.) points out, all writers on this subject seem to forget the fact that the night side of two planets are never turned towards each other. "When the sun is between them it is day on the side of Mars which is towards us, and also day on the side of the earth which is towards Mars. When they are on the same side of the sun, it is day on Mars when night on the earth, and for this reason they could never see our signals. This should make it apparent that the task of signalling to Mars is a more difficult one than the most hopeful theorist has probably considered. All this is under the supposition that the Martians (if there are such) are beings like ourselves. If they are not like us, we cannot guess what they are like."[106] These views seem to me to be undoubtedly correct, and show the futility of visual signals. Electricity might, however, be conceivably used for the purpose; but even this seems highly improbable.

Prof. Newcomb, in his work *Astronomy for Everybody*, says with reference to this question, "The reader will excuse me from saying nothing in this chapter about the possible inhabitants of Mars. He knows just as much about the subject as I do, and that is nothing at all."

It is, however, quite possible that life *in some form* may exist on Mars. As Lowell well says, "Life but waits in the wings of existence for its cue to enter the scene the moment the stage is set."[107] With reference to the "canals" he says —

> "It is certainly no exaggeration to say that they are the most astonishing objects to be viewed in the heavens. There are celestial sights more dazzling, spectacles that inspire more awe, but to the thoughtful observer who is privileged to see them well, there is nothing in the sky so profoundly impressive as these canals of Mars."[108]

The eminent Swedish physicist Arrhenius thinks that the mean annual temperature on Mars may possibly be as high as 50° F. He says, "Sometimes the snow-caps on the poles of Mars disappear entirely during the Mars summer; this never happens on our terrestrial poles. The mean temperature of Mars must therefore be above zero, probably about +10° [Centigrade = 50° Fahrenheit]. Organic life may very probably thrive, therefore, on Mars."[109] He thinks that this excess of mean temperature above the calculated temperature may be due to an increased amount of carbonic acid in the planet's atmosphere, and says "any doubling of the percentage of carbon dioxide in the air would raise the temperature of the earth's surface by 4°; and if the carbon dioxide were increased fourfold, the temperature would rise by 8°."[110]

Denning says, —[111]

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[105] *Nature*, August 22, 1907.

[106] *Popular Astronomy*, vol. 12 (1904), p. 679.

[107] *Mars as an Abode of Life*, p. 69.

[108] *Ibid.*, p. 146.

[109] *Worlds in the Making*, p. 49.

[110] *Worlds in the Making*, p. 53.

[111] Denning, *Telescopic Work for Starlight Evenings*, p. 158.

> "A few years ago, when christening celestial formations was more in fashion than it is now, a man simply had to use a telescope for an evening or two on Mars or the moon, and spice the relation of his seeings with something in the way of novelty, when his name would be pretty certainly attached to an object and hung in the heavens for all time! A writer in the *Astronomical Register* for January, 1879, humorously suggested that 'the matter should be put into the hands of an advertising agent,' and 'made the means of raising a revenue for astronomical purposes.' Some men would not object to pay handsomely for the distinction of having their names applied to the seas and continents of Mars or the craters of the moon."

An occultation of Mars by the moon is recorded by Aristotle as having occurred on April 4, 357 B.C.[112]

Seen from Mars the maximum apparent distance between the earth and moon would vary from 3½′ to nearly 17′.[113]

[112] *Ibid.*, p. 166.

[113] *Nature*, July 13, 1876.

CHAPTER VII
The Minor Planets

Up to 1908 the number of minor planets (or asteroids) certainly known amounted to over 650.

From an examination of the distribution of the first 512 of these small bodies, Dr. P. Stroobant finds that a decided maximum in number occurs between the limits of distance of 2·55 and 2·85 (earth's mean distance from sun = 1), "199 of the asteroids considered revolving in this annulus." He finds that nearly all the asteroidal matter is concentrated near to the middle of the ring in the neighbourhood of the mean distance of 2·7, and the smallest asteroids are relatively less numerous in the richest zones.[114]

There are some "striking similarities" in the orbits of some of the asteroids. Thus, in the small planets Sophia (No. 251 in order of discovery) and Magdalena (No. 318) we have the mean distance of Sophia 3·10, and that of Magdalena 3·19 (earth's mean distance = 1). The eccentricities of the orbits are 0·09 and 0·07; and the inclinations of the orbits to the plane of the ecliptic 10° 29′ and 10° 33′ respectively.[115] This similarity may be – and probably is – merely accidental, but it is none the less curious and interesting.

Some very interesting discoveries have recently been made among the minor planets. The orbit of Eros intersects the orbit of Mars; and the following have nearly the same mean distance from the sun as Jupiter: —

Achilles (1906 TG), No. 588,
Patrocles (1906 XY), No. 617,
Hector (1907 XM), No. 624,

and another (No. 659) has been recently found. Each of these small planets "moves approximately in a vertex of an equilateral triangle that it forms with Jupiter and the sun."[116] The minor planet known provisionally as HN is remarkable for the large eccentricity of its orbit (0·38), and its small perihelion distance (1·6). When discovered it had a very high South Declination (61½ °), showing that the inclination of the plane of its orbit to the plane of the ecliptic is considerable.[117]

Dr. Bauschinger has made a study of the minor planets discovered up to the end of 1900. He finds that the ascending nodes of the orbits show a marked tendency to cluster near the ascending node of Jupiter's orbit, a fact which agrees well with Prof. Newcomb's theoretical results. There seems to be a slight tendency for large inclinations and great eccentricities to go together; but there appears to be no connection between the eccentricity and the mean distance from the sun. The longitudes of the perihelia of these small planets "show a well-marked maximum near the longitude of *Jupiter's* perihelion, and equally well-marked minimum near the longitude of his aphelion," which is again in good agreement with Newcomb's calculations.[118] Dr. Bauschinger's diameter for Eros is 20 miles. He finds that the whole group, including those remaining to be discovered, would probably form a sphere of about 830 miles in diameter.

The total mass of the minor planets has been frequently estimated, but generally much too high. Mr. B. M. Roszel of the John Hopkins University (U.S.A.) has made a calculation of the probable mass from the known diameter of Vesta (319 miles, Pickering), and finds the volume of the first 216 asteroids discovered. From this calculation it appears that it would take 310 asteroids of the 6th

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[114] *Nature*, May 2, 1907.

[115] *Nature*, May 30, 1907.

[116] *Publications of the Astronomical Society of the Pacific*, August, 1908.

[117] *Monthly Notices*, R.A.S., 1902, p. 291.

[118] *Monthly Notices*, R.A.S., February, 1902, p. 291.

magnitude, or 1200 of the 7th to equal the moon in volume. Mr. Roszel concludes that the probable mass of the whole asteroidal belt is between 1⁄50th and 1⁄100th of that of the moon.[119] Subsequently Mr. Roszel extended his study to the mass of 311 asteroids,[120] and found a combined mass of about 1⁄40th of the moon's mass.

Dr. Palisa finds that the recently discovered minor planet (1905 QY) varies in light to a considerable extent.[121] This planet was discovered by Dr. Max Wolf on August 23, 1905; but it was subsequently found that it is identical with one previously known, (167) Urda.[122] The light variation is said to be from the 11th to the 13th magnitude.[123] Variation in some of the other minor planets has also been suspected. Prof. Wendell found a variation of about half a magnitude in the planet Eunomia (No. 15). He also found that Iris (No. 7) varies about a quarter of a magnitude in a period of about 6h 12m.[124] But these variations are small, and perhaps doubtful. The variability of Eros is well known.

The planet Eros is a very interesting one. The perihelion portion of its orbit lies between the orbits of Mars and the earth, and the aphelion part is outside the orbit of Mars. Owing to the great variation in its distance from the earth the brightness of Eros varies from the 6th to the 12th magnitude. That is, when brightest, it is 250 times brighter than when it is faintest.[125] This variation of light, is of course, merely due to the variation of distance; but some actual variation in the brightness of the planet has been observed.

It has been shown by Oeltzen and Valz that Cacciatore's supposed distant comet, mentioned by Admiral Smyth in his *Bedford Catalogue*, must have been a minor planet.[126]

Dr. Max Wolf discovered 36 new minor planets by photography in the years 1892-95. Up to the latter year he had never seen one of these through a telescope! His words are, "Ich selsbt habe noch nie einen meinen kleinen Planeten am Himmel gesehen."[127]

These small bodies have now become so numerous that it is a matter of much difficulty to follow them. At the meeting of the Royal Astronomical Society on January 8, 1909, Mr. G. F. Chambers made the following facetious remarks —

> "I would like to make a suggestion that has been in my mind for several years past – that it should be made an offence punishable by fine or imprisonment to discover any more minor planets. They seem to be an intolerable nuisance, and are a great burden upon the literary gentlemen who have to keep pace with them and record them. I have never seen, during the last few years at any rate, any good come from them, or likely to come, and I should like to see the supply stopped, and the energies of the German gentlemen who find so many turned into more promising channels."

Among the minor planets numbered 1 to 500, about 40 "have not been seen since the year of their discovery, and must be regarded as lost."[128]

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[119] *Nature*, May 24, 1894.

[120] *Ibid.*, February 14, 1895.

[121] *Ibid.*, September 14, 1905.

[122] *Ibid.*, September 21, 1905.

[123] *Ibid.*, September 28, 1905.

[124] *Ibid.*, July 13, 1905.

[125] *Nature*, November 3, 1898.

[126] *Ibid.*, July 14, 1881, p. 235.

[127] Quoted in *The Observatory*, February, 1896, p. 104, from *Ast. Nach.*, No. 3319.

[128] *Monthly Notices*, R.A.S., February, 1909.

CHAPTER VIII
Jupiter

This brilliant planet – only inferior to Venus in brightness – was often seen by Bond (Jun.) with the naked eye in "high and clear sunshine"; also by Denning, who has very keen eyesight. Its brightness on such occasions is so great, that – like Venus – it casts a distinct shadow in a dark room.[129]

The great "red spot" on Jupiter seems to have been originally discovered by Robert Hooke on May 9, 1664, with a telescope of 2 inches aperture and 12 feet focus. It seems to have existed ever since; at least the evidence is, according to Denning, in favour of the identity of Hooke's spot with the red spot visible in recent years. The spot was also observed by Cassini in the years 1665-72, and is sometimes called "Cassini's spot." But the real discoverer was Hooke.[130]

The orbit of Jupiter is so far outside the earth's orbit that there can be little visible in the way of "phase" – as in the case of Mars, where the "gibbous" phase is sometimes very perceptible. Some books on astronomy state that Jupiter shows no phase. But this is incorrect. A distinct, although very slight, gibbous appearance is visible when the planet is near quadrature. Webb thought it more conspicuous in twilight than in a dark sky. With large telescopes, Jupiter's satellites II. and III. have been seen – in consequence of Jupiter's phase – to emerge from occultation "at a sensible distance from the limb."[131]

According to M. E. Rogovsky, the high "albedo of Jupiter, the appearance of the clear (red) and dark spots on its surface and their continual variation, the different velocity of rotation of the equatorial and other zones of its surface, and particularly its small density (1·33, water as unity), all these facts afford irrefragable proofs of the high temperature of this planet. The dense and opaque atmosphere hides its glowing surface from our view, and we see therefore only the external surface of its clouds. The objective existence of this atmosphere is proved by the bands and lines of absorption in its spectrum. The interesting photograph obtained by Draper, September 27, 1879, in which the blue and green parts are more brilliant for the equatorial zone than for the adjacent parts of the surface, appears to show that *Jupiter* emits its proper light. It is possible that the constant red spot noticed on its surface by several observers, as Gledhill, Lord Rosse, and Copeland (1873), Russel and Bredikhin (1876), is the summit of a high glowing mountain. G. W. Hough considers Jupiter to be gaseous, and A. Ritter inferred from his formulæ that in this case the temperature at the centre would be 600,000 °C."[132]

The four brighter satellites of Jupiter are usually known by numbers I., II., III., and IV.; I. being the nearest to the planet, and IV. the farthest. III. is usually the brightest, and IV. the faintest, but exceptions to this rule have been noticed.

With reference to the recently discovered sixth and seventh satellites of Jupiter, Prof. Perrine has suggested that the large inclination of their orbits to the plane of the planet's equator seems to indicate that neither of these bodies was originally a member of Jupiter's family, but has been "captured by the planet." This seems possible as the orbits of some of the minor planets lie near the orbit of Jupiter (see "Minor Planets"). A similar suggestion has been made by Prof. del Marmol.[133]

Many curious observations have been recorded with reference to Jupiter's satellites; some very difficult of explanation. In 1711 Bianchini saw satellite IV. so faint for more than an hour that it was

[129] *Celestial Objects*, vol. i. p. 163.
[130] *Nature*, December 29, 1898.
[131] *Celestial Objects*, vol. i. p. 166.
[132] *Astrophysical Journal*, vol. 14 (1901), pp. 248-9.
[133] *Nature*, August 27, 1908.

hardly visible! A similar observation was made by Lassell with a more powerful telescope on June 13, 1849. Key, T. T. Smyth, and Denning have also recorded unusual faintness.[134] A very remarkable phenomenon was seen by Admiral Smyth, Maclear, and Pearson on June 26, 1828. Satellite II., "having fairly entered on Jupiter, was found 12 or 13 minutes afterwards *outside the limb*, where it remained visible for at least 4 minutes, and then suddenly vanished." As Webb says, "Explanation is here set at defiance; demonstrably neither in the atmosphere of the earth, nor Jupiter, where and what could have been the cause? At present we can get no answer."[135] When Jupiter is in opposition to the sun – that is, on the meridian at midnight – satellite I. has been seen projected on its own shadow, the shadow appearing as a dark ring round the satellite.

On January 28, 1848, at Cambridge (U.S.A.) satellite III. was seen in transit lying between the shadows of I. and II. and so black that it could not be distinguished from the shadows, "except by the place it occupied." This seems to suggest inherent light in the planet's surface, as the satellite was at the time illuminated by full sunshine; its apparent blackness being due to the effect of contrast. Cassini on one occasion failed to find the shadow of satellite I. when it should have been on the planet's disc,[136] an observation which again points to the glowing light of Jupiter's surface. Sadler and Trouvelot saw the shadow of satellite I. double! an observation difficult to explain – but the same phenomenon was again seen on the evening of September 19, 1891, by Mr. H. S. Halbert of Detroit, Michigan (U.S.A.). He says that the satellite "was in transit nearing egress, and it appeared as a white disc against the dark southern equatorial belt; following it was the usual shadow, and at an equal distance from this was a second shadow, smaller and not so dark as the true one, and surrounded by a faint penumbra."[137]

A dark transit of satellite III. was again seen on the evening of December 19, 1891, by two observers in America. One observer noted that the satellite, when on the disc of the planet, was intensely black. To the other observer (Willis L. Barnes) it appeared as an ill-defined *dark* image.[138] A similar observation was made on October 9 of the same year by Messrs. Gale and Innes.[139]

A "black transit" of satellite IV. was seen by several observers in 1873, and by Prof. Barnard on May 4, 1886. The same phenomenon was observed on October 30, 1903, in America, by Miss Anne S. Young and Willis S. Barnes. Miss Young says —

> "The ingress of the satellite took place at 8h 50m (E. standard time) when it became invisible upon the background of the planet. An hour later it was plainly visible as a dark round spot upon the planet. It was decidedly darker than the equatorial belt."[140]

The rather rare phenomenon of an occultation of one of Jupiter's satellites by another was observed by Mr. Apple, director of the Daniel Scholl Observatory, Franklin and Marshall College, Lancaster, Pa. (U.S.A.), on the evening of March 16, 1908. The satellites in question were I. and II., and they were so close that they could not be separated with the 11·5-inch telescope of the Observatory.[141] One of the present writer's first observations with a telescope is dated May 17, 1873, and is as follows: "Observed one of Jupiter's satellites occulted (or very nearly so) by another. Appeared as one with power 133" (on 3-inch refractor in the Punjab). These satellites were probably I. and II.

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[134] Webb's *Celestial Objects*, vol. i. p. 177.

[135] *Ibid.*, vol. i. p. 187.

[136] *Celestial Objects*, vol. i. p. 186.

[137] *Astronomy and Astrophysics*, 1892, p. 87.

[138] *Ibid.*, 1892, pp. 94-5.

[139] *Observatory*, December, 1891.

[140] *Popular Astronomy*, vol. 11 (1903), p. 574.

[141] *Ibid.*, October, 1908.

Jupiter has been seen on several occasions apparently without his satellites; some being behind the disc, some eclipsed in his shadow, and some in transit across the disc. This phenomenon was seen by Galileo, March 15, 1611; by Molyneux, on November 12, 1681; by Sir William Herschel, May 23, 1802; by Wallis, April 15, 1826; by Greisbach, September 27, 1843; and by several observers on four occasions in the years 1867-1895.[142] The phenomenon again occurred on October 3, 1907, No. 1 being eclipsed and occulted, No. 2 in transit, No. 3 eclipsed, and No. 4 occulted.[143] It was not, however, visible in Europe, but could have been seen in Asia and Oceania.[144] The phenomenon will occur again on October 22, 1913.[144]

On the night of September 19, 1903, a star of magnitude 6½ was occulted by the disc of Jupiter. This curious and rare phenomenon was photographed by M. Lucien Rudaux at the Observatory of Donville, France.[145] The star was Lalande 45698 (= BAC 8129).[146]

Prof. Barnard, using telescopes with apertures from 5 inches up to 36 inches (Lick), has failed to see a satellite through the planet's limb (an observation which has been claimed by other astronomers). He says, "To my mind this has been due to either poor seeing, a poor telescope, or an excited observer."[147] He adds —

> "I think it is high time that the astronomers reject the idea that the satellites of Jupiter can be seen through his limb at occultation. When the seeing is bad there is a spurious limb to Jupiter that well might give the appearance of transparency at the occultation of a satellite. But under first-class conditions the limb of Jupiter is perfectly opaque. It is quibbling and begging the question altogether to say the phenomenon of transparency may be a rare one and so have escaped my observations. Has any one said that the moon was transparent when a star has been seen projected on it when it ought to have been behind it?"

Prof. Barnard and Mr. Douglass have seen white polar caps on the third and fourth satellites of Jupiter. The former says they are "exactly like those on Mars." "Both caps of the fourth satellite have been clearly distinguished, that at the north being sometimes exceptionally large, covering a surface equal to one-quarter or one-third of the diameter of the satellite."[148] This was confirmed on November 23, 1906, when Signor J. Comas Sola observed a brilliant white spot surrounded by a dark marking in the north polar region of the third satellite. There were other dark markings visible, and the satellite presented the appearance of a miniature of Mars.[149]

An eighth satellite of Jupiter has recently been discovered by Mr. Melotte at the Greenwich Observatory by means of photography. It moves in a retrograde direction round Jupiter in an orbit inclined about 30° to that of the planet. The period of revolution is about two years. The orbit is very eccentric, the eccentricity being about one-third, or greater than that of any other satellite of the solar system. When nearest to Jupiter it is about 9 millions of miles from the planet, and when farthest about 20 millions.[150] It has been suggested by Mr. George Forbes that this satellite may possibly be identical with the lost comet of Lexell which at its return in the year 1779 became entangled in Jupiter's system, and has not been seen since. If this be the case, we should have the curious phenomenon of a comet revolving round a planet!

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[142] *Bulletin, Ast. Soc. de France*, August, 1907.

[143] *Nature*, August, 29 1907.

[144] *Ibid.*, March 7, 1907.

[145] *Bulletin, Ast. Soc. de France*, June, 1904.

[146] *The Observatory*, October, 1903, p. 392.

[147] *Astronomy and Astrophysics*, 1894, p. 277.

[148] *Nature*, November 18, 1897.

[149] *Journal*, B.A.A., January, 1907.

[150] *Journal*, B.A.A., February, 1909, p. 161.

According to Humboldt the four bright satellites of Jupiter were seen almost simultaneously and quite independently by Simon Marius at Ausbach on December 29, 1609, and by Galileo at Padua on January 7, 1610.[151] The actual priority, therefore, seems to rest with Simon Marius, but the publication of the discovery was first made by Galileo in his *Nuncius Siderius* (1610).[152] Grant, however, in his *History of Physical Astronomy*, calls Simon Marius an "impudent pretender"! (p. 79).

M. Dupret at Algiers saw Jupiter with the naked eye on September 26, 1890, twenty minutes before sunset.[153]

Humboldt states that he saw Jupiter with the naked eye when the sun was from 18° to 20° above the horizon.[154] This was in the plains of South America near the sea-level.

[151] *Cosmos*, vol. ii. p. 703.

[152] *Ibid.*

[153] Denning, *Telescopic Work for Starlight Evenings*, p. 349.

[154] *Cosmos*, vol. iii. p. 75.

CHAPTER IX
Saturn

To show the advantages of large telescopes over small ones, Mr. C. Roberts says that "with the 25-inch refractor of the Cambridge Observatory the view of the planet Saturn is indescribably glorious; everything I had ever seen before was visible at a glance, and an enormous amount of detail that I had never even glimpsed before, after a few minutes' observation."[155]

Chacornac found that the illumination of Saturn's disc is the reverse of that of Jupiter, the edges of Saturn being brighter than the centre of the disc, while in the case of Jupiter – as in that of the sun – the edges are fainter than the centre.[156] According to Mr. Denning, Saturn bears satisfactorily "greater magnifying power than either Mars or Jupiter."[157]

At an occultation of Saturn by the moon, which occurred on June 13, 1900, M. M. Honorat noticed the great contrast between the slightly yellowish colour of the moon and the greenish tint of the planet.[158]

In the year 1892, when the rings of Saturn had nearly disappeared, Prof. L. W. Underwood, of the Underwood Observatory, Appleton, Wisconsin (U.S.A.), saw one of Saturn's satellites (Titan) apparently moving along the needlelike appendage to the planet presented by the rings. "The apparent diameter of the satellite so far exceeded the apparent thickness of the ring that it gave the appearance of a beautiful golden bead moving very slowly along a fine golden thread."[159]

In 1907, when the rings of Saturn became invisible in ordinary telescopes, Professor Campbell, observing with the great Lick telescope, noticed "prominent bright knots, visible … in Saturn's rings. The knots were symmetrically placed, two being to the east and two to the west." This was confirmed by Mr. Lowell, who says, "Condensations in Saturn's rings confirmed here and measured repeatedly. Symmetric and permanent." This phenomenon was previously seen by Bond in the years 1847-56. Measures of these light spots made by Prof. Barnard with the 40-inch Yerkes telescope show that the outer one corresponded in position with the outer edge of the middle ring close to the Cassini division, and the inner condensation, curious to say, seemed to coincide in position with the "crape ring." Prof. Barnard thinks that the thickness of the rings "must be greatly under 100 miles, and probably less than 50 miles," and he says —

"The important fact clearly brought out at this apparition of *Saturn* is that the bright rings are not opaque to the light of the sun – and this is really what we should expect from the nature of their constitution as shown by the theory of Clerk Maxwell, and the spectroscopic results of Keeler."[160]

Under certain conditions it would be theoretically possible, according to Mr. Whitmell, to see the globe of Saturn through the Cassini division in the ring. But the observation would be one of great difficulty and delicacy. The effect would be that, of the arc of the division which crosses the planet's disc, "a small portion will appear bright instead of dark, and may almost disappear."[161]

A remarkable white spot was seen on Saturn on June 23, 1903, by Prof. Barnard, and afterwards by Mr. Denning.[162] Another white spot was seen by Denning on July 9 of the same year.[163] From

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[155] *Journal*, B.A.A., June, 1896.

[156] *Celestial Objects*, vol. i. p. 191.

[157] *Nature*, May 30, 1901.

[158] *Bulletin, Ast. Soc. de France*, August, 1900.

[159] *Astronomy and Astrophysics*, 1892.

[160] *Astrophysical Journal*, January, 1908, p. 35.

[161] *Nature*, May 22, 1902.

[162] *Ibid.*, July 9, 1903.

[163] *Ibid.*, July 16, 1903.

numerous observations of these spots, Denning found a rotation period for the planet of about 10h 39m 21s.[164] From observations of the same spots Signor Comas Sola found a period 10h 38m·4, a close agreement with Denning's result. For Saturn's equator, Prof. Hill found a rotation period of 10h 14m 23s·8, so that – as in the case of Jupiter – the rotation is faster at the equator than in the northern latitudes of the planet. A similar phenomenon is observed in the sun. Mr. Denning's results were fully confirmed by Herr Leo Brenner, and other German astronomers.[165]

Photographs taken by Prof. V. M. Slipher in America show that the spectrum of Saturn is similar to that of Jupiter. None of the bands observed in the planet's spectrum are visible in the spectrum of the rings. This shows that if the rings possess an atmosphere at all, it must be much rarer than that surrounding the ball of the planet. Prof. Slipher says that "none of the absorption bands in the spectrum of *Saturn* can be identified with those bands due to absorption in the earth's atmosphere," and there is no trace of aqueous vapour.[166]

In September, 1907, M. G. Fournier suspected the existence of a "faint transparent and luminous ring" outside the principal rings of Saturn. He thinks that it may possibly be subject to periodical fluctuations of brightness, sometimes being visible and sometimes not.[167] This dusky ring was again suspected at the Geneva Observatory in October, 1908.[168] M. Schaer found it a difficult object with a 16-inch Cassegrain reflector. Prof. Stromgen at Copenhagen, and Prof. Hartwig at Bamberg, however, failed to see any trace of the supposed ring.[169] It was seen at Greenwich in October, 1908.

A "dark transit" of Saturn's satellite Titan across the disc of the planet has been observed on several occasions. It was seen by Mr. Isaac W. Ward, of Belfast, on March 27, 1892, with a 4·3-inch Wray refractor. The satellite appeared smaller than its shadow. The phenomenon was also seen on March 12 of the same year by the Rev. A. Freeman, Mr. Mee, and M. F. Terby; and again on November 6, 1907, by Mr. Paul Chauleur and Mr. A. B. Cobham.[170]

> The recently discovered tenth satellite of Saturn, Themis, was discovered by photography, and has never been seen by the eye even with the largest telescopes! But its existence is beyond all doubt, and its orbit round the planet has been calculated.

Prof. Hussey of the Lick Observatory finds that Saturn's satellite Mimas is probably larger than Hyperion. He also finds from careful measurements that the diameter of Titan is certainly overestimated, and that its probable diameter is about 2500 miles.[171]

The French astronomer, M. Lucien Rudaux, finds the following variation in the light of the satellites of Saturn: —

Japetus	from	9th	magnitude to	12th
Rhea	"	9	"	10·6
Dione	"	9·5	"	10·5
Tethys	"	9·8	"	10·5
Titan	"	8	"	8·6

[164] *Nature*, September 24, 1903.

[165] *Ibid.*, October 8, 1903.

[166] *Astrophysical Journal*, vol. 26 (1907), p. 60.

[167] *Nature*, January 30, 1908.

[168] *Ibid.*, October 15, 1908.

[169] *Ibid.*, October 29, 1908.

[170] *Journal*, B.A.A., March, 1908, and June 22, 1908.

[171] *Nature*, June 25, 1903.

The variation of light is, he thinks, due to the fact that the period of rotation of each satellite is equal to that of their revolution round the planet; as in the case of our moon.[172]

The names of the satellites of Saturn are derived from the ancient heathen mythology. They are given in order of distance from the planet, the nearest being Mimas and the farthest Themis.

1. Mimas was a Trojan born at the same time as Paris.

2. Enceladus was son of Tartarus and Ge.

3. Tethys was wife of Oceanus, god of ocean currents. She became mother of all the chief rivers in the universe, as also the Oceanides or sea nymphs.

4. Dione was one of the wives of Zeus.

5. Rhea was a daughter of Uranus. She married Saturn, and became the mother of Vesta, Ceres, Juno, and Pluto.

6. Titan was the eldest son of Uranus.

7. Hyperion was the god of day, and the father of sun and moon.

8. Japetus was the fifth son of Uranus, and father of Atlas and Prometheus.[173]

9. Phœbe was daughter of Uranus and Ge.

10. Themis was daughter of Uranus and Ge, and, therefore, sister of Phœbe.

In a review of Prof. Comstock's *Text Book of Astronomy* in *The Observatory*, November, 1901, the remark occurs, "We are astonished to see that Mr. Comstock alludes with apparent seriousness to the *nine* satellites of Saturn. As regards the ninth satellite, we thought that all astronomers held with Mrs. Betsy Prig on the subject of this astronomical Mrs. Harris." This reads curiously now (1909) when the existence of the ninth satellite (Phœbe) has been fully confirmed, and a tenth satellite discovered.

[172] *Bulletin, Ast. Soc. de France*, June, 1904.

[173] *Pop. Ast.*, vol. 12, pp. 408-9.

CHAPTER X
Uranus and Neptune

From observations of Uranus made in 1896, M. Leo Brenner concluded that the planet rotates on its axis in about 8½ hours (probably 8h 27m). This is a short period, but considering the short periods of Jupiter and Saturn there seems to be nothing improbable about it.

Prof. Barnard finds that the two inner satellites of Uranus are difficult objects even with the great 36-inch telescope of the Lick Observatory! They have, however, been photographed at Cambridge (U.S.A.) with a 13-inch lens, although they are "among the most difficult objects known."[174]

Sir William Huggins in 1871 found strong absorption lines (six strong lines) in the spectrum of Uranus. One of these lines indicated the presence of hydrogen, a gas which does not exist in our atmosphere. Three of the other lines seen were situated near lines in the spectrum of atmospheric air. Neither carbonic acid nor sodium showed any indications of their presence in the planet's spectrum. A photograph by Prof. Slipher of Neptune's spectrum "shows the spectrum of this planet to contain many strong absorption bands. These bands are so pronounced in the part of the spectrum between the Fraunhofer lines F and D, as to leave the solar spectrum unrecognizable… Neptune's spectrum is strikingly different from that of *Uranus*, the bands in the latter planet all being reinforced in *Neptune*. In this planet there are also new bands which have not been observed in any of the other planets. The F line of hydrogen is remarkably dark … this band is of more than solar strength in the spectrum of Uranus also. Thus free hydrogen seems to be present in the atmosphere of both these planets. This and the other dark bands in these planets bear evidence of an enveloping atmosphere of gases which is quite unlike that which surrounds the earth."[175]

With the 18-inch equatorial telescope of the Strasburgh Observatory, M. Wirtz measured the diameter of Neptune, and found from forty-nine measures made between December 9, 1902, and March 28, 1903, a value of 2″·303 at a distance of 30·1093 (earth's distance from sun = 1). This gives a diameter of 50,251 kilometres, or about 31,225 miles,[176] and a mean density of 1·54 (water = 1; earth's mean density = 5·53). Prof. Barnard's measures gave a diameter of 32,900 miles, a fairly close agreement, considering the difficulty of measuring so small a disc as that shown by Neptune.

The satellite of Neptune was photographed at the Pulkown Observatory in the year 1899. The name Triton has been suggested for it. In the old Greek mythology Triton was a son of Neptune, so the name would be an appropriate one.

The existence of a second satellite of Neptune is suspected by Prof. Schaeberle, who thinks he once saw it with the 36-inch telescope of the Lick Observatory "on an exceptionally fine night" in 1895.[177] But this supposed discovery has not yet been confirmed. Lassell also thought he had discovered a second satellite, but this supposed discovery was never confirmed.[178]

The ancient Burmese mention eight planets, the sun, the moon, Mercury, Venus, Mars, Jupiter, Saturn, and another named Râhu, which is invisible. It has been surmised that "Râhu" is Uranus, which is just visible to the naked eye, and may possibly have been discovered by keen eyesight in ancient times. The present writer has seen it several times without optical aid in the West of Ireland, and with a binocular field-glass of 2 inches aperture he found it quite a conspicuous object.

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[174] *Nature*, August 29, 1889.

[175] *Astrophysical Journal*, vol. 26 (1907), p. 62.

[176] *Bulletin, Ast. Soc. de France*, January, 1904.

[177] Humboldt's *Cosmos*, vol. iv. p. 532.

When Neptune was *visually* discovered by Galle, at Berlin, he was assisted in his observation by Prof. d'Arrest. The incident is thus described by Dr. Dreyer, "On the night of June 14, 1874, while observing Coggia's comet together, I reminded Prof. d'Arrest how he had once said in the course of a lecture, that he had been present at the finding of Neptune, and that 'he might say it would not have been found without him.' He then told me (and I wrote it down the next day), how he had suggested the use of Bremiker's map (as first mentioned by Dr. Galle in 1877) and continued, 'We then went back to the dome, where there was a kind of desk, at which I placed myself with the map, while Galle, looking through the refractor, described the configurations of the stars he saw. I followed them on the map one by one, until he said: "And then there is a star of the 8th magnitude, in such and such a position," whereupon I immediately exclaimed: "That star is not on the map."'"[178] This was the planet. But it seems to the present writer that if Galle or d'Arrest had access to Harding's Atlas (as they probably had) they might easily have found the planet with a good binocular field-glass. As a matter of fact Neptune is shown in Harding's Atlas (1822) as a star of the 8th magnitude, having been mistaken for a star by Lalande on May 8 and 10, 1795; and the present writer has found Harding's 8th magnitude stars quite easy objects with a binocular field-glass having object-glasses of two inches diameter, and a power of about six diameters.

Supposed Planet beyond Neptune. – The possible existence of a planet beyond Neptune has been frequently suggested. From considerations on the aphelia of certain comets, Prof. Forbes in 1880 computed the probable position of such a body. He thought this hypothetical planet would be considerably larger than Jupiter, and probably revolve round the sun at a distance of about 100 times the earth's mean distance from the sun. The place indicated was between R.A. 11h 24m and 12h 12m, and declination 0° 0′ to 6° 0′ north. With a view to its discovery, the late Dr. Roberts took a series of eighteen photographs covering the region indicated. The result of an examination of these photographs showed, Dr. Roberts says, that "no planet of greater brightness than a star of the 15th magnitude exists on the sky area herein indicated." Prof. W. H. Pickering has recently revived the question, and has arrived at the following results: Mean distance of the planet from the sun, 51·9 (earth's mean distance = 1); period of revolution, 373½ years; mass about twice the earth's mass; probable position for 1909 about R.A. 7h 47m, north declination 21°, or about 5° south-east of the star κ Geminorum. The supposed planet would be faint, its brightness being from 11½ to 13½, according to the "albedo" (or reflecting power) it may have.[179]

[178] *Copernicus*, vol. ii. p. 64.

[179] *Knowledge*, May, 1909.

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