Understanding of Astronomy

Foreword

Islam is a natural religion where all rituals have purposely been kept simple. Finding direction of the Qibla, sighting of the moon and timings of the prayers have been mainly based on observation rather than calculations. Where it is difficult to take decisions based on observations because of the geographical and weather constraints, it has been allowed to conjecture and make estimations based on instincts and good faith. In the juristic terminology this called “te’hri”. Details are amply covered in books of the Islamic jurisprudence. This is primarily to facilitate a person living in the distant places like an island or a mountain top to be able to comfortably perform the religious obligations.

With the Muslim conquest of the world, new subjects like logic and philosophy, arithmetic, algebra, geometry, astrology and astronomy were translated into Arabic language. These subjects were incorporated to solve the emerging needs and problems of governance and growth of Islamic society. In keeping with the cardinal principal of simplicity in Sharia, these arts and sciences were introduced to facilitate the religious practices.

Muslim scholars and researchers excelled in these fields and were recognized as the world leaders. These sciences were included as compulsory subjects in the syllabus of ‘Dars e Nizami’ many centuries back. After the independence of Pakistan, ancient Astronomy based on Ptolemaic (Claudius Ptolemaeus) System was taught in the religious schools for a long time.

Now with revolutionary progress in space research and invention of space crafts human access has reached beyond the moon. A need was therefore felt to introduce the contemporary Astronomy rather than continuing with the redundant Ptolemaician concepts.

The first stride was made by Hazrat Maulana Muhammad Musa Rohani (RA) who wrote ‘Falkiat Jadidya’ in Urdu, which was included in the syllabus of the religious schools. Later on my request he authored three more books in Arabic, ‘ Alhayat ul Sughra’, Alhayat ul Wusta’ and ‘ Alhayat ul Kubra’.

Wafaq ul Madaris Arabia, Pakistan has replaced its book ‘Falkiat e Jadida’ with ‘Alhayat ul Wusta’ in its syllabus.

Notwithstanding the above, a deficiency was still being felt especially in relation to subjects like the sighting of moon, finding of Qibla direction and scientific approach to calculation of the prayer timings as these disputations were not included in the books cited above. I had requested Hazrat Maulana Rohani (RA) to do so. The work unfortunately could not begin because of his demise. May Allah Almighty bless his soul. Ameen.

Honourable Syed Shabbir Ahmad Kakakhel has made ample strides in these realms with adequate use of computer technology. To benefit from his research, last year an Astrological Conference was held in Dar ul Aloom, Karachi. Teachers of the Institute and a large segment of Islamic scholars and jurist benefited from it. On my request, it has now been compiled in form of a book. Beside the basic concepts of astrology and astronomy subjects like Prayers timings, sighting of the moon and fixation of Qibla direction have scientifically explained.

Despite my desire to read the book, I have only been able to glance through the draft. In keeping with understanding granted to the author by Allah Almighty and his earnest approach, I am certain that the subjects have been suitably addressed. In Sha Allah, this book will be a good addition to the syllabi of the religious schools.

May Allah Almighty accept his research and scholarly service and make it rewarding for the students.

Muhammad Rafi Usmani

Rais Al Jamia Dar ul Aloom

Karachi.

26 Moham ul Haram 1421H

2nd February 2000

Preface

The holy Quran is a great blessing of Allah Almighty for the humanity. No amounts of words are sufficient to express our gratitude to Him. May Allah Almighty give us the sagacity to be grateful to Him. It is the message from our Lord, the Creator from Whom nothing is hidden, be it past or future. What happened in the past, is happening now and shall happen in future; are all in His know/knowledge. His message is therefore is for everyone and for all times to come. One only needs to understand it. Allah Almighty in holy Book points out that the Sun and the Moon are in a predestined motion based on His command. Their movement determines day and night, months and years and the climatic changes. All this happens in accordance with a well defined system. None has the grit to change its course:-

Neither it is for the sun to overtake the moon, nor can the night outpace the day. Each one is floating in an orbit. ***Ya'seen - 40***

They without fail or any laxity are perpetually in service to the mankind; as destined by Allah Almighty. Two types of duties are performed by them. One is administrative in nature i.e. light, warmth and cold. The other type is determination of prayers/fast timings and Qibla direction etc. Knowledge of the celestial bodies is therefore essential for both our religious and worldly needs. Hazrat Ali (RH) expressed liking for the understanding of Astronomy. Hazrat Abdullah bin Abbas (RH) had expressed his desire to seek knowledge of the stars. Our ancestral elders had programmed the subject to be taught along with other disciplines of the Sharia. Muslim world can lay claim to many of the prominent luminaries of this science. Undoubtedly they were the pioneers who corrected the faulty theories and concepts of Ptolemy and modernized them into contemporary sciences. Unfortunately with the passage of time; it was ignored like many other sciences becoming totally alien in our religious schools.

Ultimately it has been adopted by outsiders who taking full advantage of ignorance of the Muslims attributed major successes and discoveries to themselves. Today very few

Muslims are aware of inventions of the great Muslim scientists because they have been made to believe that way. We have drifted so away that even a reference to these sciences is considered un Islamic and averse to the tenants of the religion. This certainly is not the opinion of the learned religious scholars. There are quite a few of them who not only acquired the knowledge but penned it in their books also. Two prominent amongst them from Pakistan are Hazrat Maulana Muhammad Musa (RA) and Hazrat Mufti Rashid Ahmad Ludhianvi (RA). The former introduced astronomy in his books while the later issued many decrees based on these sciences and used it to explain the intricacies about finding the Qibla direction. Notwithstanding their effort; there is yet quite a lot to be done. Their treatises are primarily for the learned scholars and not catering for the ordinary readers who need basic expositions. In their works, simple things have been complicated. So it was difficult to make people understand rudiments of the essential aspects like sighting of the moon and matrix of the prayer timings. Had they been well conversant with modern astronomy; things could have made much simpler to understand. This situation compelled some religious scholars like Hazrat Maulana Omar Palanpuri (RA) and Hazrat Haji Farooq (RA) to jump into the foray. Hazrat Maulana Omar Palanpuri (RA) had asked the author to compile a simple book on sighting of the moon. Hazrat Haji Farooq (RA) had asked me to write a commonly understood book on astronomy. I made good use of the collection of Hazrat Maulana Musa (RA) books. May Allah Almighty accept his endeavours and also make my effort successful in achieving the aim of writing this book.

An attempt has been made in this book to explain the mathematical notions applied in astronomy in a simple form to make them easily discernable. English terminology and symbols will be introduced for their usage in computers and calculators. It is always prudent to make full use of the contemporary technologies and techniques which provide an access to the modern sciences. There is nothing wrong in adapting it. It has been explicitly stated in Hadith, “Knowledge being the lost heritage of Muslims must be found and adopted.”

In this book, basic facts about the Sun, the Moon and stars have been enunciated along with finding of Qibla direction, working out prayer timings and sighting of the Moon. Let me explain here that since this book has been written for the religious school, so useful extracts found in any book have been picked up and added with and without changes. Adequate use of books of Maulana Muhammad Musa and Mr.Sana Ullah Siddique’s book ‘Bazam e Anjum’ has been made. The envisaged change of names of stars could not be made because of lack of time. This being a major project needs lot of consultative effort. It shall Insha Allah be added in the next edition. I also intend to write another book about stars, galaxies and other celestial matters. Basic astronomical concepts have been sufficiently introduced in this book for a student.

May Allah Almighty accept this effort and make it rewarding for the students. Ameen.

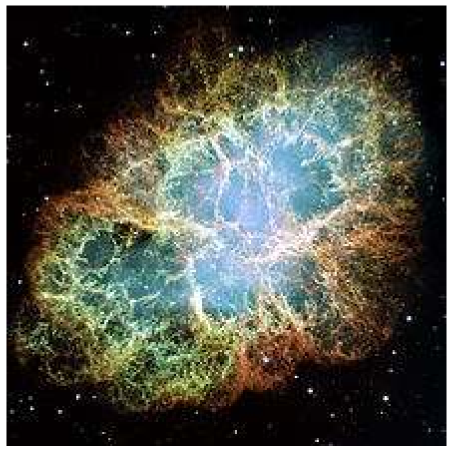
Syed Shabbir Ahmad Kakakhel

Karachi.

2nd Ze Qad 1420 H

Introduction to Astronomy

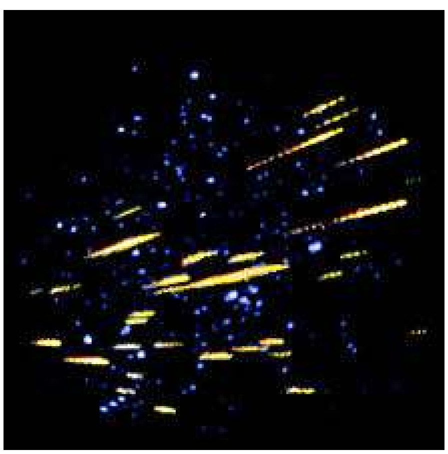
Astronomy is a natural science that deals with the study of celestial objects (such as stars, planets, comets, nebulae, star clusters and galaxies) and phenomena that originate outside the atmosphere of the Earth (such as cosmic background radiation). It is concerned with the evolution, physics, chemistry, meteorology, and motion of celestial objects, as well as the formation and development of the universe.



There are many types of celestial bodies which include the Sun, the Moon, stars, planets, comets and meteors. A star is a massive, luminous sphere of plasma held together by gravity. The nearest star to Earth is the Sun, which is the source of most of the energy on Earth. An object that does not radiate its own light but reflects the light of another star is called a planet e.g. the Moon; the Mars and the Saturn are all planets. An object revolving around a planet is called its moon. Like the earth's moon, planet Jupiter has sixteen moons of its own.

A comet is an icy small Solar System body that, when close enough to the Sun, displays a visible coma (a thin, fuzzy, temporary atmosphere) and sometimes also a tail. These rotate around a star in a half oval fashion. They comprise of a coma and a tail.

A meteoroid is those small and big objects that revolving around the Sun, sometime drift towards the earth rapidly. In the process these are destroyed because of the atmospheric friction. Some do reach the earth at times. These are called meteorites which are a portion of a meteoroid or asteroid that survives its passage through the atmosphere and impact with the ground without being destroyed. As of 2011 the International Astronomical Union officially defines a meteoroid as "a solid object moving in interplanetary space, of a size considerably smaller than an asteroid and considerably larger than an atom".



Part of the sky during a meteor shower.

Opinion of the Muslim astronomers and others vary about the capaciouness of the heavens/ sky. The non Muslim experts think that discovery of the universe leads to unveiling of secrets that can accrue worldly gains like navigation and calculation of time etc. On the other hand Muslim scholars claim that notwithstanding the worldly gains, such discoveries actually lead to cognisance of the Creator, Allah Almighty. Islamic scholars refer to the human body as a minor universe. It has been professed to ponder about it,

وفی انفسکم افلا تبصرون

and also to ponder about the universe it has been declared in the Quran,

خَلقُ السَّمٰوَاتِ وَالارَضِ اَکبَرُ مِن خَلقِ النَّاسِ وَلٰکِنَّ اَکثَرَ النَّاسِ لَا یَعلَمُونَ

Now if Allah Almighty has decreed us to ponder about the minor universe, how essentially important it is to think and meditate about the actual universe. At many places in the holy Quran references to the celestial bodies appear. Allah Almighty has said,

أَفَلَمْ يَنظُرُوا إِلَى السَّمَاءِ فَوْقَهُمْ كَيْفَ بَنَيْنَاهَا وَزَيَّنَّاهَا وَمَا لَهَا مِن فُرُوجٍ

(Did they not, then, look to the sky above them, how We have built it and beautified it, and it has no cracks? Al Qaf - 6)

The greatest need of a human being in life is correct guidance. Therefore any source can be useful for guidance which can assist us to ponder about the universe. The Quran has expressed:-

إِنَّ فِی خَلْقِ السَّمٰوَاتِ وَالْاَرْضِ وَاخْتِلاف اللَّیْلِ وَالنَّہار لَآیَاتٍ لِأُولِی الْاَلْبَابِ

(Surely, in the creation of the heavens and the earth, and in the alternation of night and day, there are signs for the people of wisdom, Ale Imran – 190)

According to Sheikh Musa (RA) this knowledge is actually the acceptance of existence of Allah Almighty, He being the only one, omnipotent and the wisest. This provides an insight into His the Divine powers and supreme wisdom. Sharia accepts learning and teaching of astronomy. Allah Almighty further adds:-

الَّذِینَ یَذْکُرُونَ اللّٰہَ قِیاماً وَقُعُوداً وَعَلی فِی جُنُوبِھِمْ وَیَتَفَکَّرُونَ

خَلْقِ السَّمٰوَاتِ وَالْاَرْضِ رَبَّنا مَا خَلَقْتَ ھَذا باطِلاً سُبْحانَکَ فَقِنا عَذَابَ النَّارِ

(Who remember Allah standing and sitting, and (lying) on their sides, and ponder on the creation of the heavens and the earth (and say) “Our Lord, You have not created all this in vain. Ale Imran – 191)

The renowned scholar Imam Ghazali (RA) said that a person not conversant with astronomy lacks the true cognizance of Allah Almighty and cannot be perfected without its knowledge.

There are approximately seven hundred ayats in the Quran that mention gene or genetic order. To interpret them, knowledge of astronomy/ astrology is needed; which means that astronomy serves as a tool to interpret and understand the holy Quran. As such anything which functions as an instrument of the Quran must be protected and preserved. If infidel poetry of the pre Islamic era can be preserved for understanding of the Quran, then why an important vessel likes astronomy be ignored? Those who consider it as a mere waste of time should reconsider their opinion. Actually it is all a matter of intentions, if the quest is genuine; the sciences can well serve as means to the identification of Allah Almighty, an effective tool for Quranic interpretation and a credible service to Islam. Otherwise with negative intention these will bear no dividends. Prayers (salat) are not even accepted if the intentions are not right. Acquisition of the knowledge helps in solving religious problem like finding of Qibla direction, recognition of prayer timings and authentication of witnesses for sighting of the moon. The science also serves the Islamic jurisprudence as an effective tool. The famous hadith cites, ‘Allah Almighty grants those with knowledge of the religion that He chooses to bless.’

Some scholars mix up astronomy with palmistry and refute it as being in contrivance to the Sharia laws. This is a fallacy just like equating alcohol with liquor. Palmistry is definitely forbidden for foretelling and predicting destiny with help of the stars. Astronomy on the other hand is study of the universe which leads to the cognition of Allah Almighty as the only being and His supreme powers. This has been accepted and appreciated in the Sharia. Even the Quran has praised it. Sahib Hadya (RA) in ‘Mukhtarat ul Nawazal’ says almost the same thing. To gauge and record movement of the stars for scientific reasons is not wrong, so long as these are not attributed to fortune telling and malice which can lead to one to becoming a non believer.

The orthodox astronomy that is being taught in the religious schools, many a time contrives with the Sharia. This has resulted in two types of misunderstandings. First are those scholars who rightly reject every other thing in comparison with the Sharia but are ignorant of the realities. The other group is the experts who reject the primitive concepts of Claudius Ptolemy with reasoning and solid arguments. How can a rejected person be the cause of aspersions for the contemporary astronomers? There can never be a clash between Divine regulations for the universe and religious orders. With growth and progress the astronomy shall keep coming closer to the teachings of Islam. Present day astronomy is confirming and authenticates the symbolic information cited in the holy Quran.

The cursory readers of astronomy who were introduced to Claddius Ptolemy in their religious school are wrongly sticking on to his primitive concepts. Lunar landing is incomprehensible for them because the moon being located in the first sky and it can not be reached. According to their understanding the Mars and the planet Venus being respectively located on the fifth and third skies cannot be reached without tearing apart the skies. This primitive knowledge has turned them against the modern sciences and they consider it as a ploy to harm Islam. Some of them went to the extent of declaring the believers of the lunar landings as infidels. Certainly this is no service to the cause of Islam. The modern astronomers are restricted to the clerestory objects below the visible sky. With the enormousity of their number and the colossal distances; they are so far bogged right there and not considering the other non visible skies (sama'wat). A Muslim on the other hand is ordained to believe in the existence of seven skies/heavens. Non Muslims only talk of the known universe. One can only believe in the unknown because of her/his religious faith. A non believer cannot be compelled to accept the unknown. Luckily a Muslim believes in the known universe based on observation and the unknown which is part of her/his faith. The discovered universe is common to all because it conforms to the Divine messages and does not contradict them.

There are some astronomers whose concepts of creation of the universe and existence of the Creator do clash with the Islamic thought. They do not represent the collective Muslim wisdom but are only expressing their individual abstractions. Which have been rejected by the Muslim astronomers and experts based on astronomical laws and logic. Guidance is Divine; for those not blessed, even an antidote turns into poison and kills them. Examples from the Muslim history amply demonstrate this fact e.g. Abu Leh'b and the wise Utaba (who was about to embrace Isalm) died as non Muslims. Talking about the medical sciences, at times Muslim scholars and saints are compelled to receive treatment from non believing doctors. Do not the medical science abound Islamic truth and logic? Yet non Muslim doctors do not accept Islam and continue to offer logic to support their contentions and beliefs. So should existence of these non believers keep us away from acquiring the knowledge? This being not so, then why single out astronomy as a taboo.

In the end, I want to make a humble request. Presence of Muslim astronomers under the circumstances is essential. They are needed to be able to convince, refute or reject the emerging concepts of the non believing astronomers. Least they can do is to save the Muslim community in general and the educated but simpleton Muslims liable to be entrapped from their misleading concepts and teachings. It is with this spirit that the author has single handedly taken on the venture. May Allah Almighty be our saviour and guide. Ameen. My endeavour is to introduce the modern astronomy and avoid its mix with the primitive concepts and teachings which more often is harmful. There is no point in following the theories of a person who is no longer accepted by the experts of the day. However anyone desirous of knowing old sciences may do so. Another misperception that needs to be corrected here is that modern astronomy cannot be understood without recourse to ancient astronomy like building a structure brick by brick. This is not so because the very bases and principles have under gone a major change.

I feel that all the celestial bodies that were mentioned in this chapter should be discussed one by one. Laws of mathematics that relate to them are being added as annexes. Prayer timings, sighting of the Moon and Qibla direction will be dealt in separate chapters. Initially this should suffice to introduce the subject of modern astronomy. Later each of the chapters can be developed into a separate book.

May Allah Almighty help and guide me and make my effort acceptable and understood. Ameen.

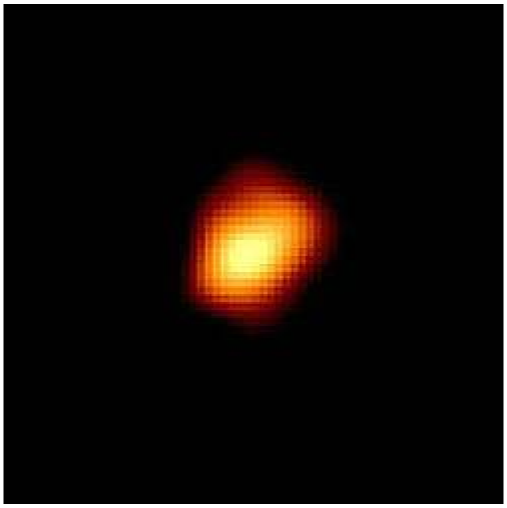
A Glance at the Universe

This universe is a masterpiece or chef d'oeuvre of the Divine creation. Everything is amazingly perfect and balanced. Human mind is spell bound like the pre dawn Arab poets who on hearing the Quranic verses could only exclaim, “This certainly is not an art work of the human mind”. Allah Almighty has repeatedly exhorted humans to dwell and ponder about the universe.

Glorious is the One in whose hand is the Kingdom (of the whole universe), and He is powerful over every thing, The One who created death and life, so that He may test you as to which of you is better in his deeds. And He is the All-Mighty, the Most-Forgiving, Who has created seven skies, one over the other. You will see nothing out of proportion in the creation of the Rahman (the All-Merciful Allah). So, cast your eye again. Do you see any rifts? Then cast your eye again and again, and the eye will come back to you abased, in a state of weariness. And We have decorated the nearest sky with lamps, and have made them devices to stone the devils, and We have prepared for them the punishment of Hell. Al Mulk, 1-5.

To ponder thoughtfully about the universe is desired by Allah Almighty. So let’s do a bit it. Our universe is comprised of numerous great galaxies. Very large stars have their own planets and moons which are continually orbiting them without any cessation. Their intervening distances are humongous with billions of meteoroids floating there ever ready to shoot out on Divine commands. A separate world of comets exists which are moving in their respective orbits in accordance with a predetermined order. The universe is spreading with stars diminishing and new ones being born; all moving toward a logical end. There was a time when nothing existed except Allah Almighty who has always been there and shall ever be there. He is subordinate to none but all are subservient to Him. A time shall come when all alone He shall call out لمن الملک الیوم and then Himself reply للہ الواحدالقہار as there will be no one else to reply. He is beyond all laws and rules. Everything shall be recreated. Looking at the universe we should be able to understand that the paradise for an ordinary soul shall be ten times bigger than our earth. He Who rules through ‘کن’ (happen) and things are created. He sees all alike at one level; no big or small. This phenomenon shall be witnessed by humans in the Heavens when desires will be granted on merely wishing them. May Allah Almighty include us amongst those lucky ones. Ameen.

The universe has billions of nebulas and galaxies with billions of stars. Some are so big that that if replaced with the Sun,it will engulf the total solar system. Diameter of the smallest star is 1/500th of the Sun's diameter. The bigger stars have a proportional ratio of their diameters with smaller one to a tune of 1400000. Mira also known as Omicron Ceti is a red giant star estimated 200-400 light years away in the constellation Cetus , has a diameter 460 times larger than the Sun.



Mira, as seen by Hubble. NASA image

Similarly star Mekbuda which is part of constellation Gemini is a super giant with a radius that is 60 times bigger, making it approximately 220,000 times the size of the Sun.

Stars in the Constellation Hercules have a diameter 600 times bigger than the Sun. We see such giants as small specks of light because of intervening distances. Celestial distances cannot be measured with the measures/scales likes kilometres and miles. Scientists have devised the scale of light year. A light-year, or light year (symbol: ly), is a unit of length equal to just under 10 trillion kilometres (or about 6 trillion miles). As defined by the International Astronomical Union (IAU), a light-year is the distance that light travels in a vacuum in one Julian year (not Gregorian year, it is of exactly 365.25 days). The star nearest to the Sun, Alpha Tauri is four and half light years away. Star شعرائے یمانی which gets visible early in the winter evenings and which is second to زہرہ in brightness is 806 light years away. The diameter of our galaxy is 120000 light years. There are an estimated number of one trillion stars in this galaxy. Our solar system is moving at a speed of eleven and half miles per second towards a star called نسرواقع which is 30000 light years away. There are trillions of galaxies in this universe. The nearest galaxy مرأة مسلسلہ is a million light years away from us. There is no imperfection as far as one can see and gauge. There are laws and balance for every object and none can defy them.

کل فی فلک یسجون

والسماء رفعهاووضع المیزان

The sun and the moon run on their fixed courses (exactly) calculated with measured out stages for each. He raised the sky high, and has placed the scale. Ar Rahman.

الشمس والقمربحسبان۔النجم والشجریسجدن

Every thing has to prostrate before Allah Almighty. Then Jinn and humans have been addressed

O assembly of jinn and men! If you have power to pass beyond the zones of the heavens and the earth, then pass beyond (them)! But you will never be able to pass them, except with authority (from Allâh)! Ar Rahman -33

No one can go astray without His desire. So certainly the best course and option is to obey the Divine Commands.

So, which of the bounties of your Lord will you deny? Ar Rahman

Allah Almighty provides us light through the lightless moon; which is so soothing to the eye. It lit our paths without disturbing the night. While rotating around the earth it changes its shapes which have provided us with a calendar. The slight tilt of the earth causes seasons to change. Ozone layer covers us from many torments from the skies. The best mankind has done is; to discover these without realizing and accepting what is desired from us. This was certainly the difference that made man superior to the other creations. Many ways have been found to satiate our physical desires but little has been done for fulfilment of the soul. The universe is well knit into a system. A laxity is immediately compensated through an elaborate a paradigm of rewards and punishment. When needs of the soul are ignored it gets constricted despite the vastness of the universe and ailments like depression emerge which often culminate into suicide. Who else can know the universe better than its creator, Allah Almighty? In the Quran it is said:-

أَلا بِذِكْرِ اللَّهِ تَطْمَئِنُّ الْقُلُوبُ

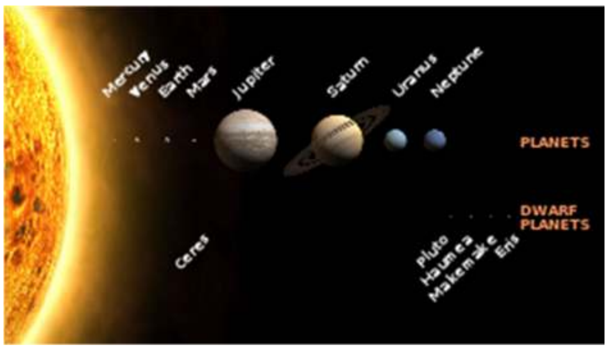
The ones who believe and their hearts are peaceful with the remembrance of Allah. Listen, the hearts find peace only in the remembrance of Allah. Al Raad - 28

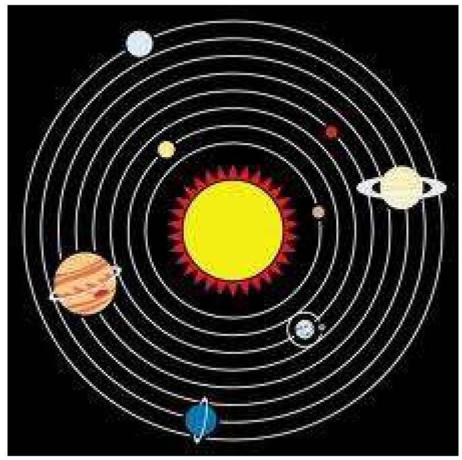
How can one find peace of mind in anything else but in remembrance of Allah Almighty? Now the world looks towards Islam for this. Let us pave the way for them through our thoughts, actions and worship. All this is only possible with strict adherence to the Sharia. We have to emulate the Prophet SAW whose one single gesture split the moon into two. The Sun turned back reversing its course to accommodate his (SAW) follower and companion. So if we follow him (SAW) then the universe will be in our service or else it doesn't need the Mars to collide with the earth; mosquitoes and swallow birds are sufficient to destroy us.

What is happening in the universe is going to be elucidated in the subsequent chapters. In the end, an attempt will be made to explain as to what is desired to be sought from study of the universe. There is a need not to discover as to how a thing happened but Who made it happen and why? Let us not return thirsty for bank of a sweet water river. Let us pray to Allah Almighty to bless us with His nearness, to know Him and do what shall please Him. Ameen.

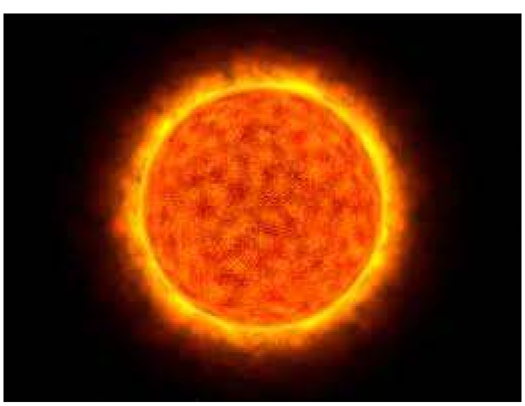
The Solar System

The Sun is a little smaller than a medium sized star. It can accommodate small sized stars in millions and there are such enormous bodies which can take millions of the Sun like stars. Our solar system basically comprises of nine planets.

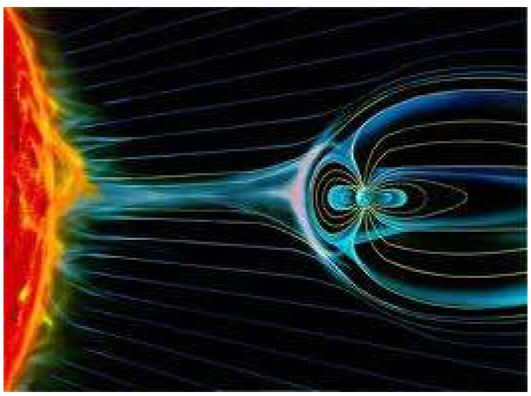




The Solar System consists of the Sun and the astronomical objects gravitationally bound in orbit around it. The vast majority of the system's mass is in the Sun. If total weight of the system is divided into a thousand parts, the other planets will have only fourteen parts while rest is the Sun (99.86% of the total mass of the Solar System). The diameter of the Sun being 864000 miles or 1,392,684 km is 109 times bigger than diameter of the earth. Its volume is 1.3 million times the earth's volume; its weight is 300000 times the earth's weight. The Sun's gravity is 32 times the gravity of the earth, its water density is four times more and its distance from the earth is 92656200 miles (called AU or astronomical unit). Of the many objects that orbit the Sun, most of the mass is contained within eight relatively solitary planets whose orbits are almost circular and lie within a nearly flat disc called the ecliptic plane.



The four smaller inner planets, Mercury, Venus, Earth and Mars, also called the terrestrial planets, are primarily composed of rock and metal. The four outer planets, the gas giants, are substantially more massive than the terrestrials. The two largest, Jupiter and Saturn, are composed mainly of hydrogen and helium; the two outermost planets, Uranus and Neptune, are composed largely of ices, such as water, ammonia and methane, and are often referred to separately as "ice giants". In addition there are the respective moons and comets that are orbiting in this space besides many smaller objects, which often collide with the planets and their moons. Those approaching the earth are destroyed with friction of its outer space and the magnetic shield around the earth, which is serving as a protective layer.



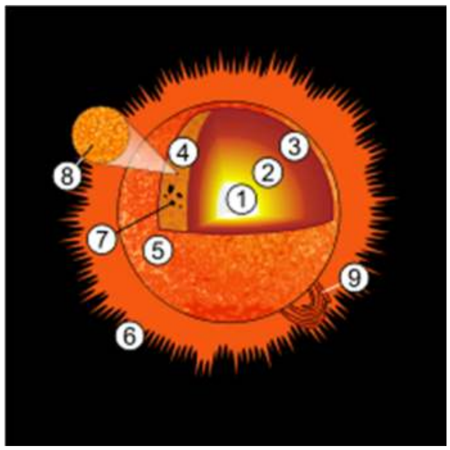
Magnetic shield around the earth

And We have made the heaven a roof, safe and well guarded. Yet they turn away from its signs. ***Al Anbya -32***

A blessing of Allah Almighty which saves the earth from damage otherwise earth’s surface would have been smashed like the moon which has no such protection.

Light of the Sun that reaches us originated 200000 years ago which it took to travel from the core to the surface of the Sun. En route it gets filtered and only hot crimson rays are left which give the Sun its whitish orange colour. Some of the rays leaving the surface of the Sun are converted into x rays and other radiological forms.

The Sun is the star at the centre of the Solar System. It is almost perfectly spherical and consists of hot plasma interwoven with magnetic fields. The outer surface of the Sun is structured into three spheres. The outer most, visible surface of the Sun, the **photosphere**, is the layer below which the Sun becomes opaque to visible light. Above the photosphere visible sunlight is free to propagate into space, and its energy escapes the Sun entirely. This sphere comprises of bubbles which can be as big as 2000 kilo meters. The change in opacity is due to the decreasing amount of H^- ions, which absorb visible light easily. Conversely, the visible light we see is produced as electrons react with hydrogen atoms to produce H^- ions. The photosphere is tens to hundreds of kilometres thick, being slightly less opaque than air on Earth. Because the upper part of the photosphere is cooler than the lower part, an image of the Sun appears brighter in the centre than on the edge or *limb* of the solar disk. Sunlight has approximately a black-body spectrum that indicates its temperature is about 6,000 K, interspersed with atomic absorption lines from the tenuous layers above the photosphere. The photosphere has a particle density of ~10^{23} m^{-3} (this is about 0.37% of the particle number per volume of Earth's atmosphere at sea level; however, photosphere particles are electrons and protons, so the average particle in air is 58 times as heavy.



An illustration of the structure of the Sun:
1. Core
2. Radioactive zone
3. Convective zone
4. Photosphere
5. Chromo sphere
6. Corona
7. Sunspot
8. Granules
9. Prominence.

The parts of the Sun above the photosphere are referred to collectively as the *solar atmosphere*. They can be viewed with telescopes operating across the electromagnetic spectrum, from radio through visible light to gamma rays, and comprise five principal zones: the *temperature minimum*, the chromo sphere, the transition region, the corona, and the helio sphere. The helio sphere, which may be considered the tenuous outer atmosphere of the Sun, extends outward past the orbit of Pluto to the helio pause, where it forms a sharp shock front boundary with the interstellar medium. The chromo sphere, transition region, and corona are much hotter than the surface of the Sun. The reason has not been conclusively proven; evidence suggests that Alfvén waves may have enough energy to heat the corona.

The coolest layer of the Sun is a temperature minimum region about 500 km above the photosphere, with a temperature of about4, 100 K. This part of the Sun is cool enough to support simple molecules such as carbon monoxide and water, which can be detected by their absorption spectra.

Above the temperature minimum layer is a layer about 2,000 km thick, dominated by a spectrum of emission and absorption lines. It is called the *chromo sphere* from the Greek root *chroma*, meaning color, because the chromo sphere is visible as a colored flash at the beginning and end of total eclipses of the Sun. The temperature in the chromo sphere increases gradually with altitude, ranging up to around 20,000 K near the top. In the upper part of chromo sphere helium becomes partially ionized.

Above the chromo sphere, in a thin (about 200 km) transition region, the temperature rises rapidly from around 20,000 K in the upper chromo sphere to coronal temperatures closer to 1,000,000 K. The temperature increase is facilitated by the full ionization of helium in the transition region, which significantly reduces radioactive cooling of the plasma. The transition region does not occur at a well-defined altitude. Rather, it forms a kind of nimbus around chromo spheric features such as spicules and filaments, and is in constant, chaotic motion. The transition region is not easily visible from Earth's surface, but is readily observable from space by instruments sensitive to the extreme ultraviolet portion of the spectrum.

The corona is the extended outer atmosphere of the Sun, which is much larger in volume than the Sun itself. The corona continuously expands into space forming the solar wind, which fills all the Solar System. The low corona, near the surface of the Sun, has a particle density around 10^{15}–10^{16} m^{-3}. The average temperature of the corona and solar wind is about 1,000,000–2,000,000 K. However, in the hottest regions it is 8,000,000–20,000,000 K. While no complete theory yet exists to account for the temperature of the corona, at least some of its heat is known to be from magnetic reconnection.

The heliosphere, which is the cavity around the Sun filled with the solar wind plasma, extends from approximately 20 solar radii (0.1 AU) to the outer fringes of the Solar System. Its inner boundary is defined as the layer in which the flow of the solar wind becomes *super alfvénic*—that is, where the flow becomes faster than the speed of Alfvén waves. Turbulence and dynamic forces outside this boundary cannot affect the shape of the solar corona within, because the information can only travel at the speed of Alfvén waves. The solar wind travels outward continuously through the helio sphere, forming the solar magnetic field into a spiral shape, until it impacts the helio pause more than 50 AU from the Sun.

The Sun serves as the nearest laboratory for the study of other stars. It is a massive ball of lights where hydrogen bombs are perpetually exploding producing enormous energy. The Sun in one second produces energy comparable to the energy produced by a trillion horses working for 16000000 years. Differently put, energy contained in one square yard of the solar surface is equal to 70000 horse power. Very little of this energy reaches the earth.

The Sun has a vast magnetic field which extends to all planets of the solar system. Solar turbulence can be seen with disturbance of the wireless systems and wavering of the magnetic needle. Floods on the earth are also caused by the solar atmosphere. It is estimated that the Sun was created five billion years before and shall remain functional for the next five billion years. Then it shall start transforming into a helium matter and swell to engulf the earth. Subsequently it will turn into a red ball and then dwarfed into white star and lie dormant as a مجہول کمیت till desired by Allah Almighty.

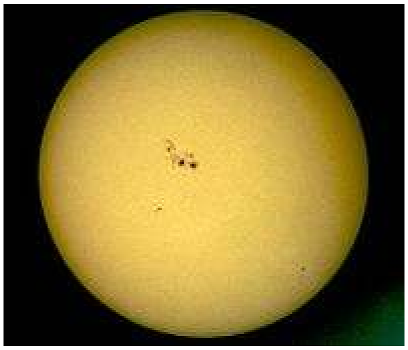
Many spacecrafts were sent for study of the Sun, but none could reach beyond thirty million miles from the solar surface. Some of them like Pyrenees 511, Venus Orbiters, Voyagers and others attempted to take samples from the atmosphere of the Sun. Spacecraft Alliance was launched on 16th October 1990. Using the gravity of the Mars it is trying to examine the solar poles. The scientists feel that the Sun presently is in its best form and shape. A little different, it could have created havoc. Allah Almighty says in the Quran:-

And the Firmament has He raised high, and He has set up the balance. In order that ye may not transgress (due) balance. ***Ar Rahman 7-8***

After this acknowledgement who can dare to refute the presence of Allah Almighty.

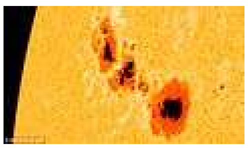
The Sun is the major source of all energy for the earth except nuclear, hot earth and oceanic energy. Be it the wind, electricity producing dams, the coal, oil and gas all owe their existence to the Sun. Source of total solar energy is the Sun.

Apparently face of the Sun looks spotless but it has many pot holes or sunspots, some as big as the size of the earth. Rotational movement of the Sun is determined through these spots. Sunspots expand and contract as they move across the surface of the Sun and can be as large as 80,000 kilo meters (50,000 miles) in diameter, making the larger ones visible from Earth without the aid of a telescope. They may also travel at relative speeds (proper motions) of a few hundred m/s when they first emerge onto the solar photosphere.



Sunspots imaged on 22 June 2004

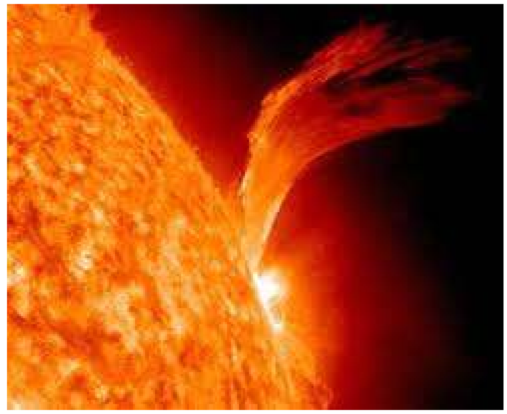
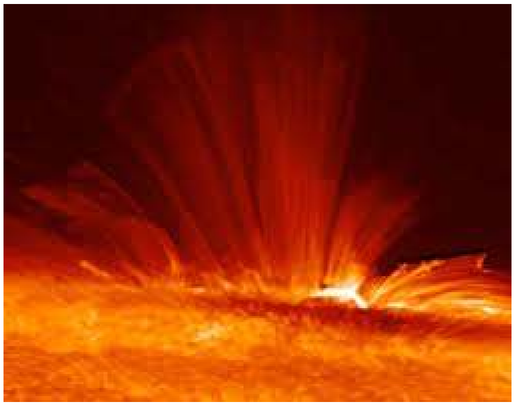
Sunspot viewed close-up in ultraviolet light, taken by the TRACE spacecraft



Sunspots. September 2011.

Galileo Galilei was the first to observe and analyse the sunspots soon after the invention of a telescope. He was tried and found "vehemently suspect of heresy", forced to recant, and spent the rest of his life under house arrest. It is a classical example of bigotry.

German Scientist Heinrich Schwabe in 1844 reported a periodic change in the number of sunspots. He declared that similar spots appear after eleven years which can be used to measure the rotational time. Unlike the earth, the Sun is totally gaseous in nature so its movement is not constant and keeps varying. Its rotation at the poles is completed in thirty three days while it takes it twenty five days to go around the equator. Vivid changes can be seen after a lapse of 30 – 31 years. The scientists ascribe it to unstable particles in the Sun which are affected by various elements causing a disruption in its homogeneity. It has been reported that number of the sunspots increase with a lapse of eleven years which result in enhanced light and temperature. These spot are mostly located in the equatorial region than at the poles. Some bright spots are also seen at the surfaces which are again used to determine the motion of the Sun. Huge storms have been seen with the help of telescopes.

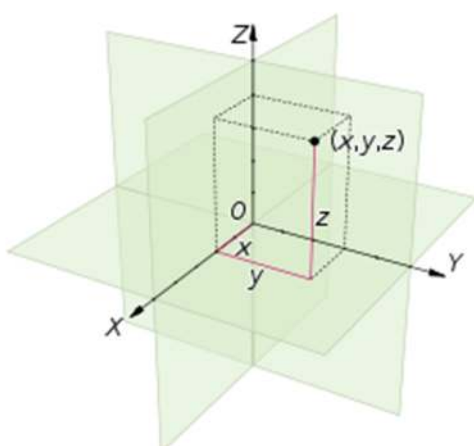

The solar storms at times rise up to millions of miles high from surface of the Sun. Their temperatures have been observed to go beyond 18 trillion Fahrenheit. A solar flare recorded in 1947 rose 250000 miles at a speed of 500000 miles/hour.

Basic Terminology

Coordinate System

To know the location of a place, a system commonly understood is essentially needed to be able to indicate directions. A lost person sitting in his vehicle fails to understand the directions to his destination being given by the bystanders. Suddenly a person appears and tells him to go west two kilometres, turn north at the cross road and travel three kilometres till reaching a water tank located on the left. The destination is approximately hundred meters away from it. Happily he is able to reach this place in ten minutes.

A Cartesian coordinate system specifies each point uniquely in a plane by a pair of numerical coordinates, which are the signed distances from the point to two fixed perpendicular directed lines, measured in the same unit of length. Each reference line is called a coordinate axis or just axis of the system, and the point where they meet is its origin, usually at ordered pair (0, 0). The coordinates can also be defined as the positions of the perpendicular projections of the point onto the two axes, expressed as signed distances from the origin.

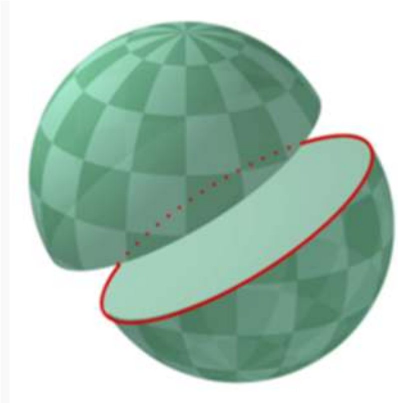


A three dimensional Cartesian coordinate system, with origin O and axis lines X, Y and Z, oriented as shown by the arrows. The tick marks on the axes are one length unit apart. The black dot shows the point with co ordinates X = 2, Y = 3, and Z = 4, or (2, 3, 4).

To locate a place on a plane, graphs are used. Two perpendicular lines pass through a centre point as shown above. Any number of parallel lines drawn is called a graph. Any point 2 cm away in direction x and line y (3 cm) can locate the point. To locate a point in the space another line z is added.

The Great Circle

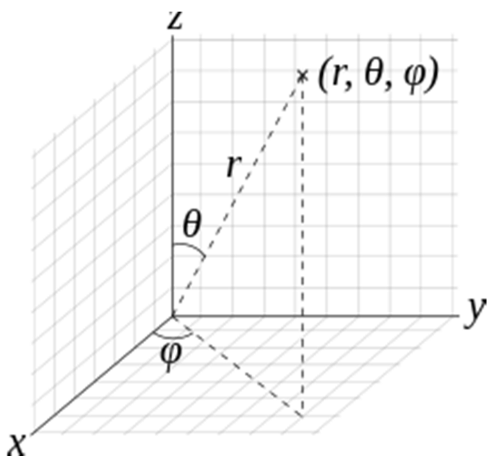
A great circle, also known as an orthodrome of a sphere is the intersection of the sphere and a plane which passes through the centre point of the sphere, as opposed to a general circle of a sphere where the plane is not required to pass through the centre.

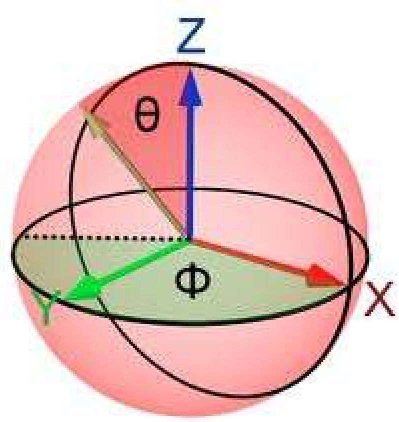


Spherical Coordinate System

A spherical coordinate system is a coordinate system for three-dimensional space where the position of a point is specified by three numbers: the radial distance of that point from a fixed origin, its polar angle measured from a fixed zenith direction, and the azimuth angle of its orthogonal projection on a reference plane that passes through the origin and is orthogonal to the zenith, measured from a fixed reference direction on that plane.

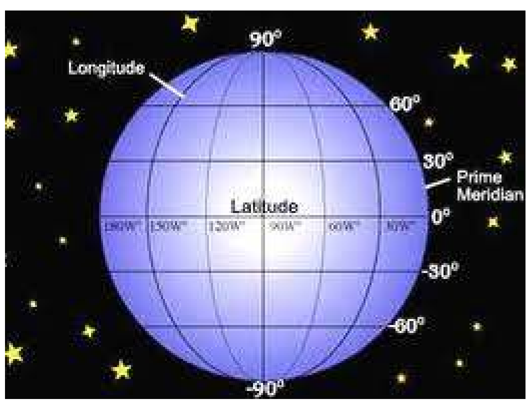
The radial distance is also called the radius or radial coordinate. The polar angle may be called co latitude, zenith angle, normal angle, or inclination angle.

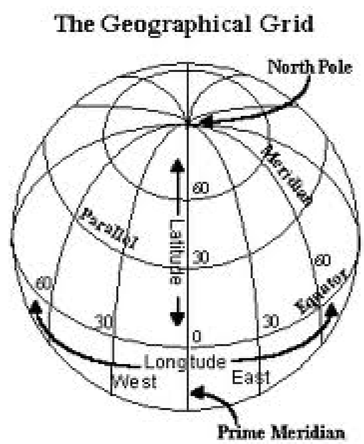




Longitude & Latitude

A geographic coordinate system is a system that enables every location on the Earth to be specified by a set of numbers and/or letters. The coordinates are often chosen such that one of the numbers represents vertical position, and two or three of the numbers represent horizontal position. A common choice of coordinates
is latitude, longitude and elevation.

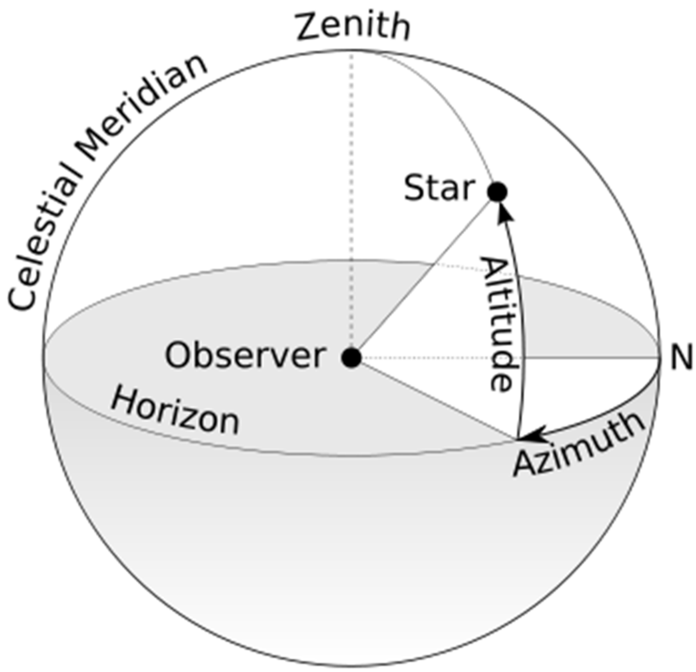




This system is a part of the Spherical Coordinate System. The only difference is that distance of a point from a centre point on the earth remains the same, so it is not mentioned. Origin of latitudes is taken from Greenwich near London. The earth being round, taken from east or west 360 degree longitude is the zero longitude. Similarly +180 or -180 longitude and +90 and -270 longitudes will be the same. Longitude of Karachi is – 67 degrees and Mansehra is – 73degress. Every longitude is a great half circle. The circle dividing the earth into halves longitudinally is called Equator.

Latitude is a geographic coordinate that specifies the north-south position of a point on the Earth's surface. Lines of constant latitude, or parallels, run east–west as circles parallel to the equator. Latitude is an angle which ranges from 0° at the Equator to 90° (North or South) at the poles.

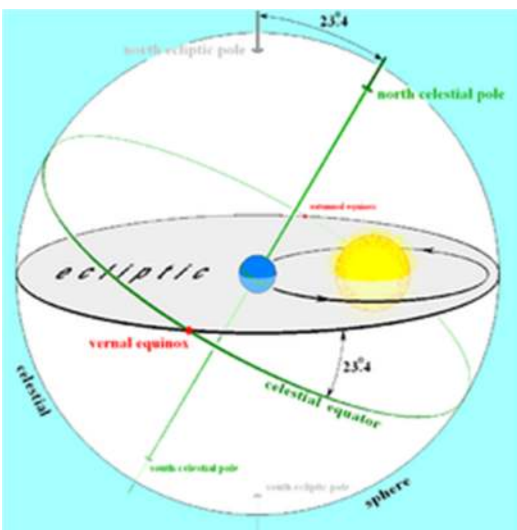
Horizontal Coordinate System

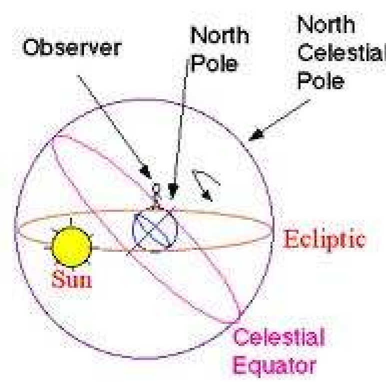


The horizontal coordinate system is a celestial coordinate system that uses the observer's local horizon as the fundamental plane. This coordinate system divides the sky into the upper hemisphere where objects are visible, and the lower hemisphere where objects cannot be seen since the earth is in the way. The great circle separating hemispheres is called celestial horizon or rational horizon. The pole of the upper hemisphere is called the zenith. The pole of the lower hemisphere is called the nadir. A star north of the horizon is at 0 degree, to the south it is considered at 180 degrees, west 270 and to the east is 90 degrees. To determine the location of an object above the horizon its altitude from the horizon has also to be considered which is called angle of inclination i.e. Inclination in general is the angle between a reference plane and another plane or axis of direction. Below the horizon angle of declination has to known e.g. at the true dawn the Sun's angle of declination is 18 degrees below the horizon. A celestial object at altitude of 70 degrees from the horizon and making a 310 degrees angle with the north is said to be at 310 degrees azimuth and its angle of inclination is 70 degrees (see picture above). So to determine the location of a celestial body its directional angle and angle of inclination have to be worked out. Same method is used to sight the Moon.

Ecliptic

The ecliptic is the apparent path of the Sun on the celestial sphere as seen from the Earth's center, and also the plane of this path, which is coplanar with the orbit of the Earth around the Sun. The path of the Sun is not normally noticeable from the Earth's surface because the Earth rotates, carrying the observer through the cycle of sunrise and sunset, obscuring the small motion of the Sun against the background stars. The Sun seems to move against the background stars as seen from the orbiting Earth. The ecliptic is the path the Sun appears to trace through the stars. The Earth completes its orbit and the Sun traces its entire path in a little over 365 days.

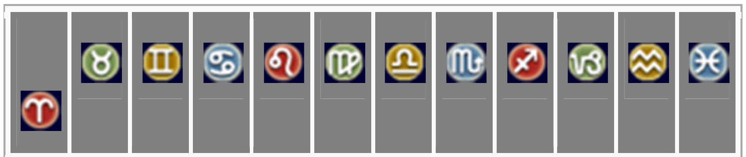




The Ecliptic poles are at 90 degrees which are 23 ½ degrees from celestial equator exactly like the tropics of Cancer and Capricorn are from the Earth’s equator.

Parallel to orbit of the earth, twelve برج had been created on the Ecliptic like Pisces, Gemini, Capricorn and Leo, Tarsus etc. A complete mythology and many myths have been associated with it especially related to prophecies and fortune telling leading on to the pseudo art of palmistry or fortune telling etc. Belief in this knowledge has been the cause irrevocable harm to many innocent people who have been lured by fortune tellers and soothsayers.

اللهم ارنا الحق حقا وارزقنا ا تباعہ و ارنا البا طل باطلا و ارزقنا اجتنابہ



Aries • Taurus • Gemini • Cancer • Leo • Virgo • Libra

Scorpio • Sagittarius • Capricorn • Aquarius • Pisces

Equinoxes

An equinox occurs twice a year (around 20 March and 22 September), when the tilt of the Earth's axis is inclined neither away from nor towards the Sun, the centre of the Sun being in the same plane as the Earth's equator. The term *equinox* can also be used in a broader sense, meaning the date when such a passage happens. The name "equinox" is derived from the Latin *aqua’s* (equal) and *nox* (night), because around the equinox, the night and day have approximately equal length.

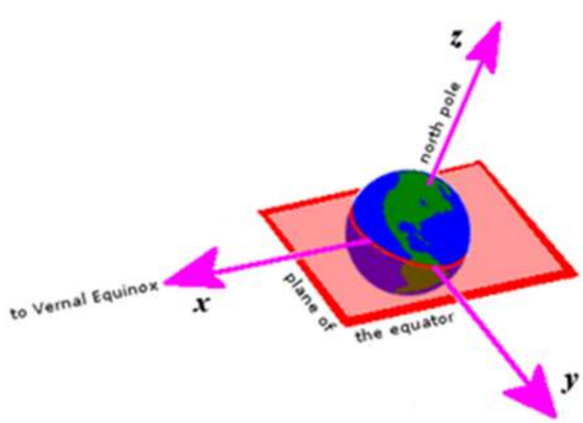
Solstice

A solstice is an astronomical event that happens twice each year as the Sun reaches its highest or lowest excursion relative to the celestial equator on the celestial sphere. As a result, on the day of the solstice the Sun appears to have reached its highest or lowest annual altitude in the sky above the horizon at local solar noon. The word *solstice* is derived from the Latin *sol* (sun) and *sistere* (to stand still), because at the solstices, the Sun stands still in declination; that is, the seasonal movement of the Sun's path (as seen from Earth) comes to a stop before reversing direction. The solstices, together with the equinoxes, are connected with the seasons. In many cultures the solstices mark either the beginning or the midpoint of winter and summer.

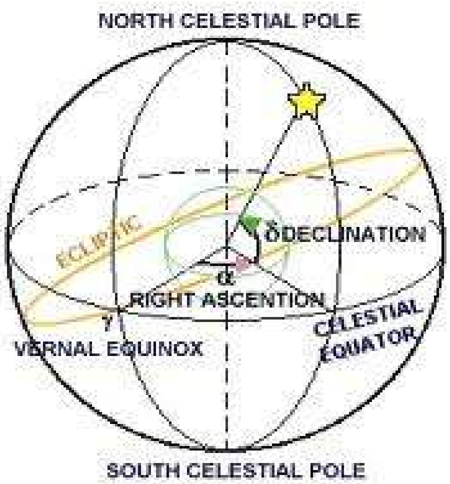
The term *solstice* can also be used in a broader sense, as the date (day) when this occurs. The day of the solstice is either the longest day of the year (in summer) or the shortest day of the year (in winter) for any place outside of the tropics.

Equatorial Coordinate System

The equatorial coordinate system is a widely-used method of specifying the positions of celestial objects. It may be implemented in spherical or rectangular coordinates, both defined by an origin at the center of the Earth, a fundamental plane consisting of the projection of the Earth's equator onto the celestial sphere (forming the celestial equator), a primary direction towards the vernal equinox, and a right-handed convention. The origin at the center of the Earth means the coordinates are *geocentric*, that is, as seen from the center of the Earth as if it was transparent and non refracting. The fundamental plane and the primary direction mean that the coordinate system, while aligned with the Earth's equator and pole, does not rotate with the Earth, but remains relatively fixed against the background stars. A right-handed convention means that coordinates are positive toward the north and toward the east in the fundamental plane.

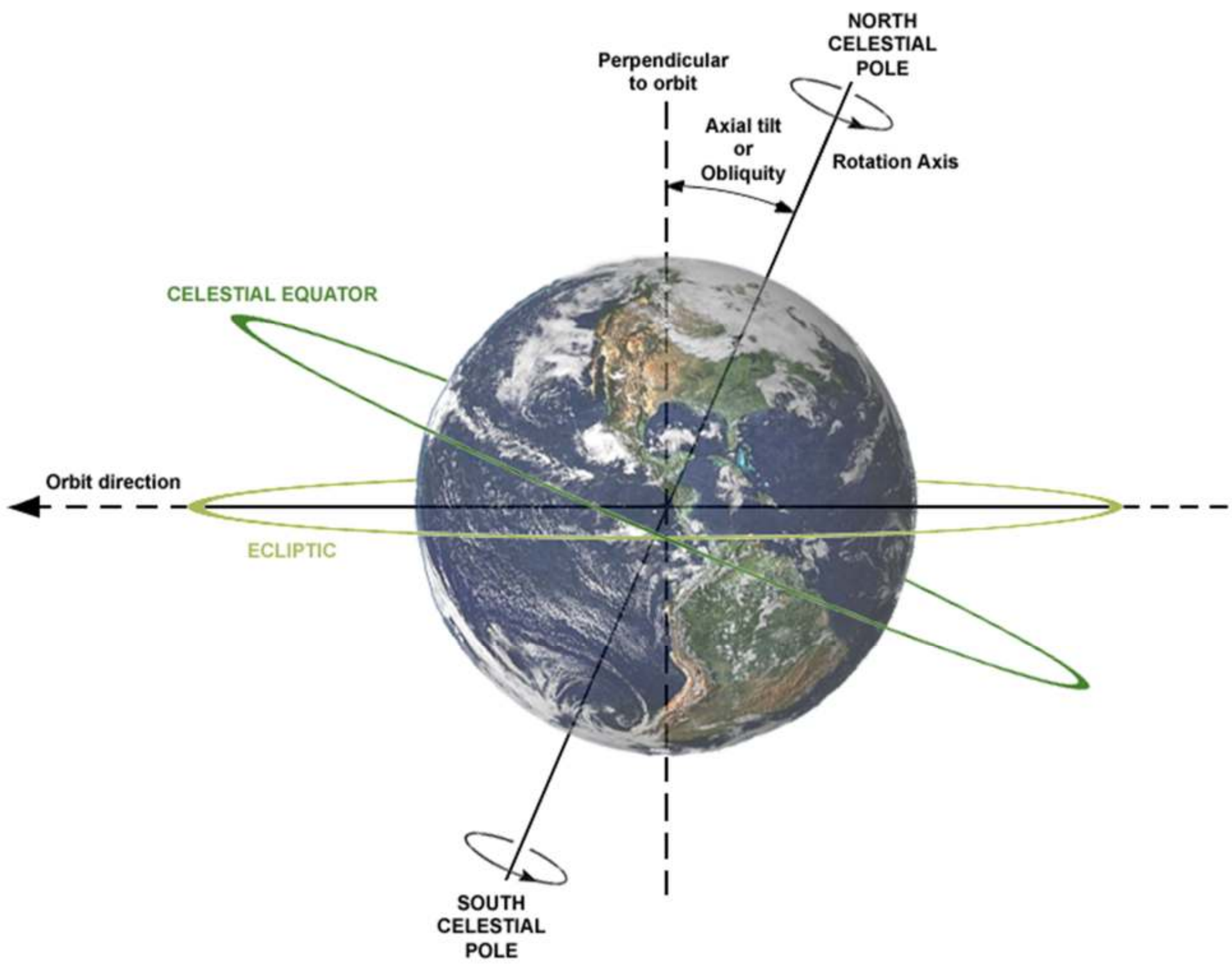


Geocentric equatorial coordinates. The origin is the centre of the Earth. The fundamental plane is the plane of the Earth's equator. The primary direction (the x axis) is the vernal equinox. A right-handed convention specifies a y axis 90° to the east in the fundamental plane; the z axis is the north polar axis. The reference frame does not rotate with the Earth; rather, the Earth rotates around the z axis.



Celestial Equator

Celestial equator is also called دابره زمانيہ. Here the northward equinox is taken as مبدا for the equatorial horizon. The number of degrees traversed by a star on the celestial equator is called its زمانی زاویہ. This angle is translated into hours and minutes in accordance with the rule of 15 degrees = 1 hour. A star can be seen to be moving in a celestial circle which may not necessarily be the great circle, called its میل. 360 degrees are traversed in twenty four hours.



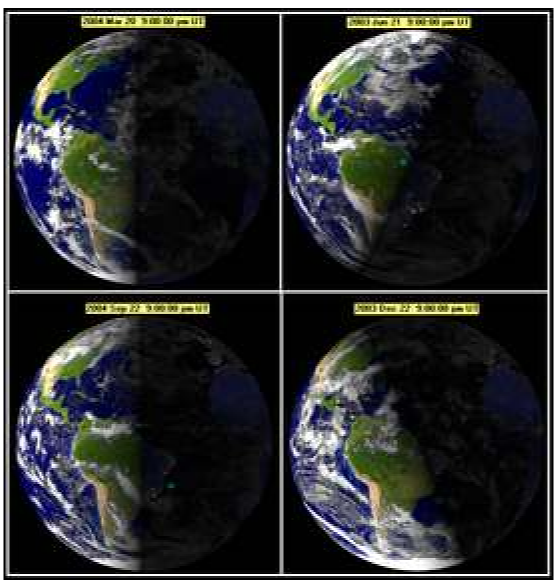
Declination of the Sun

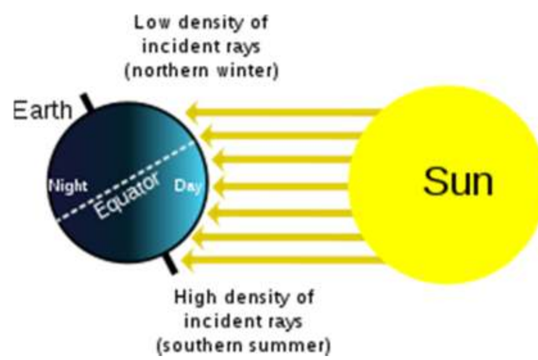
To determine position of the Sun in the Equatorial Coordinate System its declination has to known. Unlike the other stars, declination of the Sun is not fixed but keeps changing. Location of the Sun at a certain time on the celestial latitude is the declination of the Sun at that moment. On 21st March, the Sun is at the celestial equator so its declination is considered as zero. The Sun shines brightly on 21st June at the Tropic of Cancer (

23.5 degrees) and it is at the Tropic of Capricorn on 22nd December (-23.5 degrees). So the declination of the Sun on 21st June is +23.5 and -23.5 on 22nd December. However declination of the other stars is more complicated as it keeps varying on the daily basis. Whereas declination of the Sun remains the same all over the world, the noon time varies from place to place.

The Sun is daily seen to be rising from the east and setting in the west. Similarly the stars, planets and the Moon are observed rising and setting in their respective orbits. The Earth rotates around the Sun in a year. However due to its daily orbital rotation the celestial bodies are seen to be rising and setting in every day. So it is important to understand these movements in order to calculate various things.

When these celestial are observed in the context of Pakistan, it is seen that the Sun in mid spring and autumn rises from east and sets due west. During the process of rising, however, it is visible south east. At the noon it is exactly in the south. At the setting time it is due west with a 180 degree change in its azimuth.





In summers though it appears due south at noon but does not rise exactly from the east. At sun set it is North West. There is a daily more than180 degree change in azimuth of the Sun.

The Mid Night Sun

The midnight sun is a natural phenomenon occurring in summer months at places north of the Arctic Circle and south of the Antarctic Circle where the sun remains visible at the local midnight. Around the solstice (June 21 in the north and December 21 in the south) and given fair weather the sun is visible for the full 24 hours. The number of days per year with potential midnight sun increases the farther towards either pole one goes. Although approximately defined by the polar circles, in practice midnight sun can be seen as much as 90 km outside the polar circle, as described below, and the exact latitudes of the farthest reaches of midnight sun depend on topography and vary slightly year-to-year.

The mid night Sun at, Nordkapp Norway

The mid night Sun at Alta, Norway

A quarter of Finland's territory lies north of the Arctic Circle and at the country's northernmost point the sun does not set at all for 60 days during summer. In Svalbard, Norway, the northernmost inhabited region of Europe, there is no sunset from approximately 19 April to 23 August. The extreme sites are the poles where the sun can be continuously visible for a half year.

The opposite phenomenon, polar night, occurs in winter when the sun stays below the horizon throughout the day.

Since the axial tilt of the Earth is considerable (approximately 23 degrees 27 minutes) the sun does not set at high latitudes in (local) summer. The duration of sunlight increases from one day during the summer solstice at the polar circle to several weeks only a hundred kilo meters closer to the pole, to six months at the poles. At extreme latitudes, it is usually referred to as polar day.

The Time

Time is that reality of life which is encountered repeatedly in our lives, yet few know as to what it is? Looking around, one finds that there is always one thing or another happening. To record such changes a system or method of association is needed. Even in case of inactivity there is still something that changes and that is the time. A person sleeping now will wake up after a while. So it is said that he was sleeping then and is awake now. On 18th January when comparing 2 PM with 3PM it is seen that 2PM happens before 3PM. Occurrences at 2PM were before 3PM. Time is therefore succession of events from the past through the present to the future, and a measure of the durations and frequencies of events and the intervals between them. A relatively uncontroversial definition of time includes "time is what clocks measure" and "time is what keeps everything from happening at once.

“Time is not an empirical concept. For neither co-existence nor succession would be perceived by us, if the representation of time did not exist as a foundation a priori. Without this presupposition we could not represent to ourselves that things exist together at one and the same time, or at different times, that is, contemporaneously, or in succession.

Immanuel Kant, Critique of Pure Reason (1781), trans. Vasilis Politis (London: Dent., 1991), p.54.”

A comprehensive glean into the universe indicates continuity is associated with changes in time and space. Observation of these changes, led to many useful and important discoveries. In the holy Quran Allah Almighty has expressed that

We have made the night and the day two signs, then We made the sign of night marked by darkness and the sign of day bright, so that you may seek grace from your Lord, and that you may know how to number the years and how to compute, and We have expounded everything in detail. Al Isra- 12

Day and night which are the results of the rotation of the Earth; are basically the two entities for computation of the time. With the passage of a full circle of day and night the same condition returns. This basic cycle is called the solar day. Similarly with one full cyclic rotation of the year the same season returns which is due to rotation of the earth around the Sun, so this becomes another major yard stick. One rotation is normally completed in 365 solar days. Calculation of the solar day begins at the noon time. The changes in this time result in shortening and prolongation of the light hours. It suffices to say that a day/ night cycle comprises of twenty four hours despite the fact that length of day/night on 1st January is 24 hours and 29 seconds, it is 23 hours and 59 minutes on 1st April, 24 hours and 12 seconds on 1st July and it lasts for 23 hours, 59 minutes and 41seonds on 1st October. Only four times in the year the noon is exactly at 12 'O' Clock. One hour has a certain quantum and a magnitude; which is measurable. Converting days of a year into hours and seconds it is seen that an average day comprises of 86400 seconds, with 60 minutes in one hour and 60 seconds in one minute. A solar day therefore is the one which has exact 24 hours and begins at mid night. Its noon is exactly at 12 'O' Clock. As discussed earlier the noon keeps on varying in a year except only four times when it is exactly at twelve. So the positive and negative difference is indicated with help of an equation, called the time equation.

Similarly the Moon timings are worked. The full Moon gets reduced to a crescent and then disappears to reappear again.

And for the moon We have appointed measured phases, until it turned (pale, curved and fine) like an old branch of date palm. Ya'seen – 39.

The above condition of the moon reaches twelve times a year, so a lunar year has twelve months. Whereas it is sufficient for an ordinary person to know this much, the scientists have gone further into details to be able to work out the prayer timings, sighting of the Moon or rise and setting time of stars. The Quran has established working out timings with help of the Sun and the Moon.

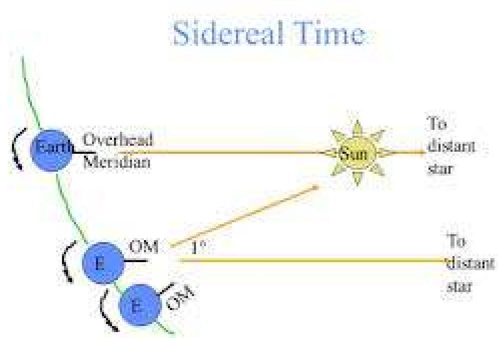
They stayed in their Cave for three hundred years and added nine.
Al Kahaf – 25.

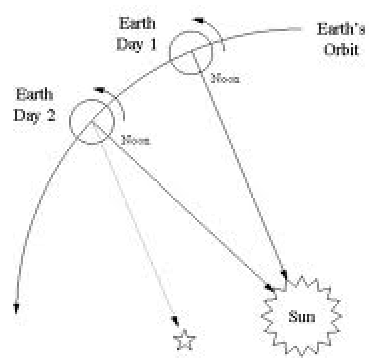
According to the solar calendar it comes to 300 years and 300 + 9 = 309 according to the lunar calendar which is a precise conversion according to the modern tables.

The lunar calendar was the first to be adopted universally because of its ease and simplicity. Islam is close to the nature, so worship have been associated with the lunar calculations to keep them simple for the masses and also to accommodate the seasonal changes which play an important role in the training of a Muslim.

Sidereal Time

Sidereal time is a time-keeping system astronomers use to keep track of the direction to point their telescopes to view a given star in the night sky. Briefly, a sidereal day is a "time scale that is based on the Earth's rate of rotation measured relative to the fixed stars." The sidereal time is deduced from the revolution of the Earth with respect to the distant stars and can therefore be determined from nightly observations of the starry sky. A sidereal day can be defined in a first approximation as the time interval between two successive passages of the same star through the meridian. Here, the meridian of an observational site is the great circle passing through the two celestial poles and the zenith of the site.





The experts believe that a cluster of stars passing at the equator sets at the same time nearly after three months. The duration of a sidereal day in units of Universal Time is 23h 56m 04.0905s which in other words is the time a distant star takes to reappear at the same spot a day later (arriving four minutes early).In ninety days it moves ahead six hours. A star seen right at the top shall be seen setting on the western horizon. This phenomena is so because of the colossal celestial distances and the relative rotation of the Earth around the Sun.

Special watches are used for keeping the sidereal time. These move four minutes slower than the conventional watches. A star is timed to reach the meridian at the same time.

GMT or Universal Time

Time is an instrument to describe universal changes and a watch is its tool. Because of the time variations in different countries a need for a standard time was felt. Greenwich Mean Time (GMT) is a time system originally referring to mean solar time at the Royal Observatory in Greenwich, London, which later became adopted as a global time standard. It is arguably the same as Coordinated Universal Time (UTC). Before the introduction of UTC on 1 January 1972 Greenwich Mean Time (also known as Zulu time) was the same as Universal Time (UT) which is a standard astronomical concept used in many technical fields. Astronomers no longer use the term "Greenwich Mean Time".

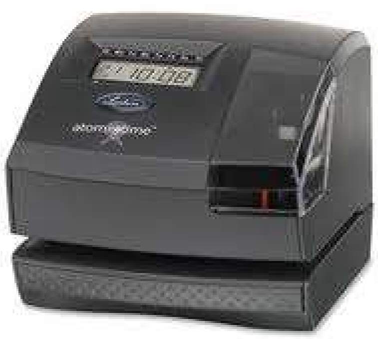
Ephemeris Time

Lack of precision in the sidereal and solar times is inadequate to record minor changes in motion of the Earth. In the last two hundred years a change of only 30 seconds was noted. Ephemeris time was therefore introduced to offset the deviations. The term ephemeris time (often abbreviated ET) can in principle refer to time in connection with any astronomical ephemeris. A former standard astronomical time scale adopted in

1952 by the IAU and superseded in the 1970s. This time scale was proposed in 1948, to overcome the drawbacks of irregularly fluctuating mean solar time. The intent was to define a uniform time (as far as was then feasible) based on Newtonian theory. Ephemeris time was a first application of the concept of a dynamical time scale, in which the time and time scale are defined implicitly, inferred from the observed position of an astronomical object via the dynamical theory of its motion.

Atomic Time

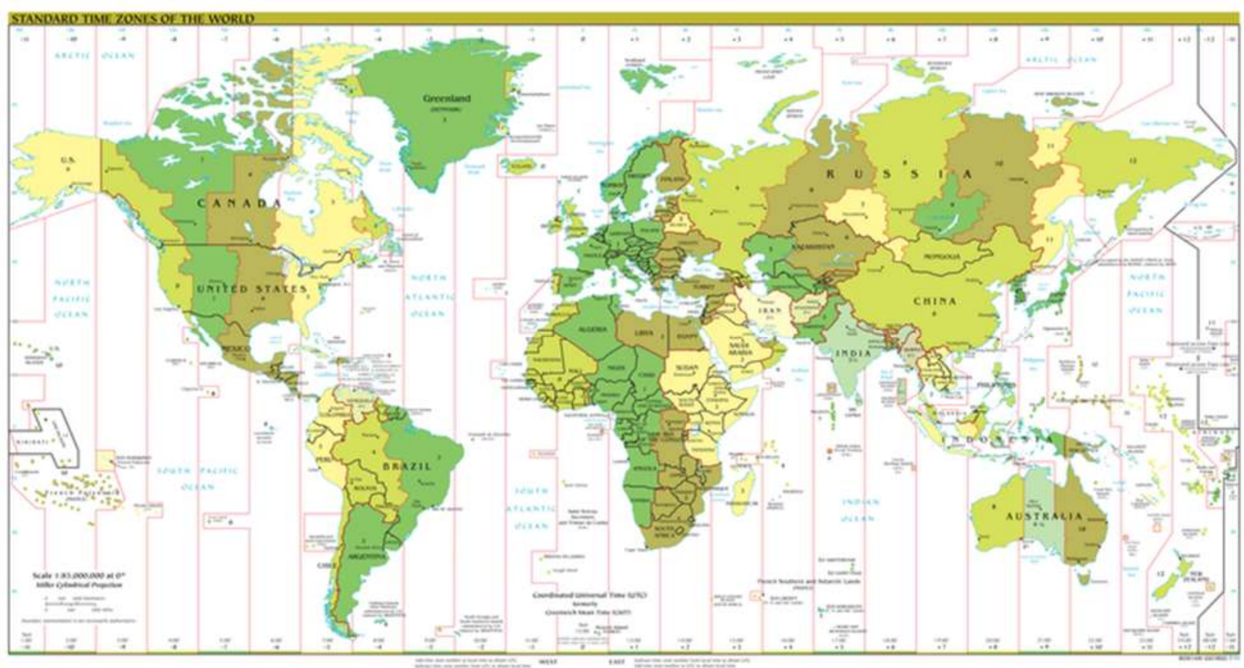
International Atomic Time is an extraordinarily precise means of time-keeping. Atomic clocks deviate only 1 second in about 20 million years. The secret to this impeccable precision is the correct measurement of the second as the base unit of modern time-keeping. The International System of Units (SI) defines one second as the time it takes a Cesium-133 atom at the ground state to oscillate exactly 9,192,631,770 times. Atomic clocks are designed to detect this frequency, most of them today using *atomic fountains*. It provides the exact speed at which our clocks tick. Universal Time (UT1), also known as astronomical time or solar time, refers to the Earth's rotation. It is used to compare the pace provided by TAI with the actual length of a day on Earth.



To achieve the highest possible level of accuracy, the International Bureau of Weights and Measures combines the output of more than 200 atomic clocks in over 50 national laboratories worldwide to determine TAI. The time scale is weighted, prioritizing the time signal provided by institutions that maintain the highest quality of primary cesium.

Standard Time

Need to standardized time for every country is a compulsion because of the earth's rotation. In the east, sun rises earlier than the west. Without standardization it would rise at 6AM at a certain place, 2PM at another so making a complete hotchpotch of things. Scientists in keeping within the natural limits have devised the standard time. Standard time is the result of synchronizing clocks in different geographical locations within a time zone to the same time rather than using the local meridian as in local mean time or solar time. Historically, this helped in the process of weather forecasting and train travel. The concept became established in the late 19th century. The time so set has come to be defined in terms of offsets from Universal Time. Where daylight saving time is used, the term standard time typically refers to the time without the offset for daylight saving time.



International Date Line

The International Date Line (IDL) is an imaginary line on the surface of the Earth that runs from the north to the South Pole and demarcates one calendar day from the next. It passes through the middle of the Pacific Ocean, roughly following the 180° longitude but it deviates to pass around some territories and island groups.

The International Date Line is on the opposite side of the Earth to the Prime Meridian. The Prime Meridian helps to define Universal Time and is the meridian from which all other time zones are calculated. Time zones to the east of the Prime Meridian are in advance of UTC (up to UTC+14); time zones to the west are behind UTC (to UTC-12).

Mostly, the International Date Line and the moving point of midnight separate the two calendar days that are current somewhere on Earth. However, during a two-hour period between 10:00 and 11:59 (UTC) each day, three different calendar days are in use. This is because of daylight saving in the UTC+12 zone and the use of additional date-shifted time zones in areas east of the 180th meridian. These additional time zones prevent the earth from observing a single date for the instant when midnight crosses the IDL. It also results in the standard time and date in some communities being 24 or 25 hours different from the standard time and date in others

A traveler crossing the International Date Line eastbound subtracts one day, or 24 hours, so that the calendar date to the west of the line is repeated. Crossing the IDL westbound results in 24 hours being added, advancing the calendar date by one day. The International Date Line is necessary to have a fixed, albeit arbitrary, boundary on the globe where the calendar date advances in the westbound direction.

Local Time

Local time is at times mixed up with the standard time which can cause errors. Local time is the one when an occurrence happens in a certain latitude. The noon in London on a specific day is at 12'o' Clock which the local and the standard time of London with zero difference between the two. On that day noon in Islamabad should be at 7.08 GMT being located in longitude 73 degrees east. To adjust it to Pakistan Standard Time (PST) five hours are added. So the noon is at 12.08 PM. The actual difference should have been of only five hours. Addition of eight minutes is because the longitude does not pass exactly through Islamabad.

Radio Time

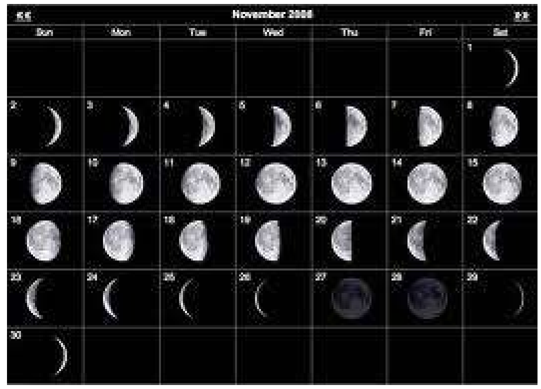
To keep the time correct, watches are synchronized with the radio. Radio Pakistan before commencing the news transmits the time signals with a beep. The last beep indicates the time being announced. Some specified radio station across the globe transmit Universal time signal. Beside the US Navy, WWV Standard Frequency Stations are transmitting the UTC signals at different frequencies round the clock. Every second is transmitted except the 59^{th}, which is stopped to indicate the minute. Two minute announcements precede every hourly transmission of the time signals.

Calendar (Taqwim)

A calendar is used to record the time. It is a system of organizing days for social, religious, commercial, or administrative purposes. This is done by giving names to periods of time, typically days, weeks, months, and years. A date is the designation of a single, specific day within such a system. Periods in a calendar (such as years and months) are usually, though not necessarily, synchronized with the cycle of the sun or the moon. Many civilizations and societies have devised a calendar, usually derived from other calendars on which they model their systems, suited to their particular needs.

Lunar Calendar

The days were first counted by man with help of the Moon. The changing configurations of this celestial body gave humans a reference to keep a tag of their activities. Most of the earlier civilization adopted the Moon for their calendars. A lunar calendar is a calendar that is based on cycles of the lunar phase. A purely lunar calendar is the Islamic calendar or Hijri Qamari calendar. Main feature of the Islamic calendar is that a year is always 12 months, so the months are not linked with the seasons and drift each solar year by 11 to 12 days. It comes back to the position it had in relation to the solar year approximately every 33 Islamic years. It is used mainly for religious purposes. It is the official calendar in Saudi Arabia . Because there are about twelve lunations in a solar year, this period (354.37 days) is sometimes referred to as a lunar year.



Although the Islamic Lunar Calendar was not formally launched during life time of the holy Prophet SAW, but its basic structure did exist. The heretic malpractice ofنسیء had waned by then as is evident from the Prophet's last sermon. The present Islamic Lunar Calendar practically became functional with the pilgrimage of the Prophet SAW. However it was officially introduced during the caliphate of Hazrat Omar (RH). The first year of the Prophet's migration to Madina was declared as the first year of its beginning and 1st Moharram was the first day falling on the auspicious day of Jummat ul Mubarik. It corresponded to 16th July 622 according to the Julian calendar and 19th July 622 according to the Gregorian date (*Common Era, also Current Era or Christian era is abbreviated as CE*). Each numbered year is designated either H for *Hijra* or AH for the Latin *anno Hegirae* (in the year of the Hijra).

Hazrat Mufti Rashid Ahmad declares its beginning from 18th July, attributing other dates to be a result of reciprocity تسامح. The present Christian Calendar underwent many changes. There are two ways to indicate a date. Firstly to correspond to the earlier calendar to obviate difficulty in comparison, taking the change to be effective from the day it was introduced. The others have accordingly matched it to the prevalent calendar at the time of introduction of the Islamic Calendar. The second way is to correspond the dates to the latest Christian calendar. Mufti Rashid Ahmad subscribes to this school of thought. Factually both are correct with only a day's difference in their research which is quite possible in the lunar calendar. The names of the Muslim months are:-

- Muḥarram — المحرّم, "forbidden" — so called because it was unlawful (*haram*) to fight during this month. Muharram is the second most sacred Muslim month and includes the Day of Ashura.
- Ṣafar — صفر, "void" — supposedly named because pagan Arabs looted during this month and left the houses empty.
- Rabīʿ I (Rabīʿ al-Awwal) — ربيع الأوّل, "the first spring".

- Rabīʿ II (Rabīʿ ath-Thānī *or* Rabīʿ al-Ākhir) — ربيع الثاني or ربيع الآخر, "the second (*or* last) spring".
- Jumādā I (Jumādā al-Ūlā) — جمادى الأولى, "the first month of parched land". Often considered the pre-Islamic "summer".
- Jumādā II (Jumādā ath-Thāniya *or* Jumādā al-Ākhira) — جمادى الثانية or جمادى الآخرة, "the second (*or* last) month of parched land".
- Rajab — رجب, "respect" or "honor". This is another sacred month in which fighting was traditionally forbidden.
- Shaʿbān — شعبان, "scattered", marking the time of year when Arab tribes dispersed to find water.
- Ramaḍān — رمضان, "scorched". Ramadan is the most venerated month of the Hijri calendar during which Muslims must fast between dawn and sunset.
- Shawwāl — شوّال, "raised", as she-camels begin to raise their tails during this time of the year, after giving birth.
- Dhū al-Qiʿda — ذو القعدة, "the one of truce". Dhu al-Qi'da was another month during which war was banned.
- Dhū al-Ḥijja — ذو الحجّة, "the one of pilgrimage", referring to the annual Muslim pilgrimage to Mecca, the Hajj.

A month commences with sighting of the Moon and a day is from the Sun set to the Sunset. There are four 29 day months while the remaining months have thirty days each.

Principal adopted in the Kingdom of Saudi Arabia for beginning of the Islamic month is linked to GMT i.e. if the Moon is born before 12 ‘O’ Clock midnight the next day is taken as the first day of the Islamic month. It has three errors

a. The day commences at 12 AM, mid night which may be correct for a solar day but not a lunar date.

b. Greenwich has been considered as the focal point whereas it should be Makkah in Saudi Arabia.

c. The Moon is considered to be sighted immediately on its birth which is not possible as the Moon cannot be sighted before 12 hours and 45 minutes have elapsed.

The above basic errors can cause a difference of six hours in the Saudi Calendar. Time differential between KSA and Greenwich being three hours and an about thirteen hours early acceptance of the Moon at it birth than actual sighting should result in a total difference of 22 hours which means a full day’s difference from the actual. Practically this difference is hardly difference because that after 29 days they start looking for the Moon. Even an Imaginary Moon is taken as actual Moon due to ignorance and lack of knowledge of the witnesses. These malpractices have caused lot of embarrassment to the Muslim community and also resulted in social problems.

In the Islamic Lunar Calendar a year is 354.367054 days on an average and a month is 29.530588 days. A lunar year is 10.87514478 days shorter than a solar year thus shifting in seasons. The holy month of Ramdhan in 1984 was in the month of June and it shifted to December in 2000.

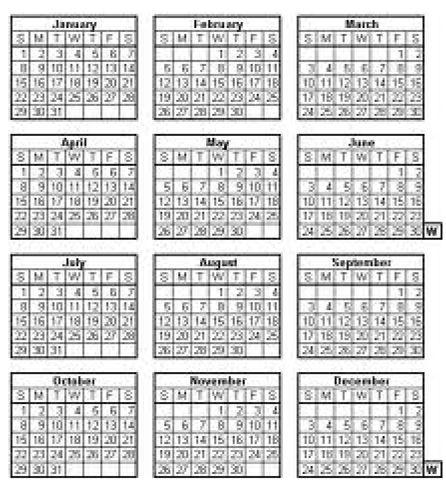
Solar – Lunar Calendar

As explained above a lunar year is shorter than a solar year, which has facilitated worship by the Muslim due change of seasons. The others however finding it difficult have added a month every three years or so to synchronized it with the seasons. Most lunar calendars are in fact luni -solar calendars. That is, months reflect the lunar cycle, but then intercalary months (e.g. "second Adar" in the Hebrew calendar) are added to bring the calendar year into synchronization with the solar year. Some examples are the Chinese and Hindu calendars, and most calendar systems used in antiquity.

All these calendars have a variable number of months in a year. The reason for this is that a year is not evenly divisible by an exact number of lunations, so without the addition of intercalary months the seasons would drift each year. This results in a thirteen-month year every two or three years.

The Solar Calendar

A solar calendar is a calendar whose dates indicate the position of the earth on its revolution around the sun or equivalently the apparent position of the sun moving on the celestial sphere. If the position of the earth in its orbit around the sun is reckoned with respect to the equinox, the point at which the orbit crosses the celestial equator, then its dates accurately indicate the seasons, that is, they are synchronized with the declination of the sun. Such a calendar is called a tropical solar calendar.



Ancient Egyptians had based their calendar on this principle. Julius Caesar changed the Roman calendar from solar-lunar to a complete solar calendar. The old calendar had ten months only, to which two new ones January and February were added and beginning of a year was changed from March to January. Beginning of the day was also shifted from the evening to midnight.   Julius Caesar completely divorced the Roman calendar from the Moon. While maintaining the number of twelve months, days were fixed to be 365 or 366 (Leap Year). He named the month of Quntlas to July (after his himself). His successor changed Sixtelux to August with 31 days. Resultantly month of February which was 29/30 days was reduced to 28/29 days. This calendar is generally misperceived to be a Christian calendar, which actually is not so. It has no connection with Hazrat Eisa AS (Jesus Christ) and names of the months also bear no semblance with Christianity. Just like some Muslims have attributed the calendar of the astrologers as a Solar Hijra Calendar.

The errors have not been corrected so far because of the diversity of opinion. Many suggestions have been made but none has been adopted e.g. number of months be increased to 13 with 28 days each with a yearly increase of a day (two days in a leap year). The other suggestion was to divide the year into four permanent quarters, beginning each quarter on a Saturday and ending on a Sunday. Add a day (two in a leap year) at the end of four quarters.

The following are some of tropical solar calendars being practiced in the world:

- Gregorian calendar
- Julian calendar
- Bahá'í calendar
- Coptic calendar
- Iranian calendar (Jalāli Calendar)

Every one of these calendars has a year of 365 days, which is occasionally extended by adding an extra day to form a year. The Zoroastrian calendar is a religious calendar used by adherents of the Zoroastrian faith, and is an approximation of the tropical solar calendar.

Solar Hijri Calendar

In order to facilitate the Muslims in matters which need use of a solar calendar e.g. for prayer timings, Sehr- Iftar and Qibla directions etc, a Solar Hijri calendar had been proposed. Its details have been covered in the Author’s book “Kashf e Hilal”. Another option was to continue to follow the existing solar calendars with their illogical base and pagan names. In view of the following Divine command there is no need to experiment with any other idea/s except to remove the existing anomalies.

Surely, the number of months according to Allah is twelve (as written) in the Book of Allah on the day He created the heavens and the Earth, of which there are Four Sacred Months. That is the right faith. So, do not wrong yourself therein.

Al Tauba- 36.

In the proposed calendar, the first six months will be of thirty days each and the remaining of thirty one days each. The last month of thirty days, in a leap year shall be of thirty one. This calendar shall begin with the arrival of the holy Prophet SAW in Qubb’a during migration to Madina Munawara. The months will be named as Hira, Meraj, Su’r, Qubb’a, Badr, Uhad, Hizab, Rizwan, Khybar, Fateh, Hunain and Tabuk being representative of our Islamic heritage and culture. Another plus point of this calendar is its suitability for universal calculation; because at the arrival of the Prophet SAW in Qubb’a, the Sun was nearer to the celestial equator i.e. northward spring equinox (in March) which is better for calculations. Addition of an extra day in a leap year to the last month will also not disturb other things. The prayer timings worked out by the Author according to the proposed calendar are simpler with fewer chances of error. The leap year is calculated according to the existing solar calendar. A year divisible by four is a leap year. A year divisible by 100 is not a leap year but the one that could be divided by 400 is considered a leap year.

A computer programme has been designed where conversion of date from solar to solar- Hijri and vice versa is easy.

Solar Hijri is the official calendar in Iran and Afghanistan. It begins on the vernal equinox as determined by astronomical calculations for the Iran Standard Time meridian (52.5°E or GMT+3.5h). This determination of starting moment is more accurate than the Gregorian calendar as far as predicting the date of the vernal equinox is concerned because it uses astronomical calculation rather than mathematical rules, but requires consulting an astronomical almanac.

The Solar Hijri calendar year begins at the start of spring in the northern hemisphere: on the midnight between the two consecutive solar noon which include the instant of the Northern spring equinox, when the sun enters the northern hemisphere. Hence, the first noon is on the last day of one calendar year and the second noon is on the first day (Nowruz) of the next year.

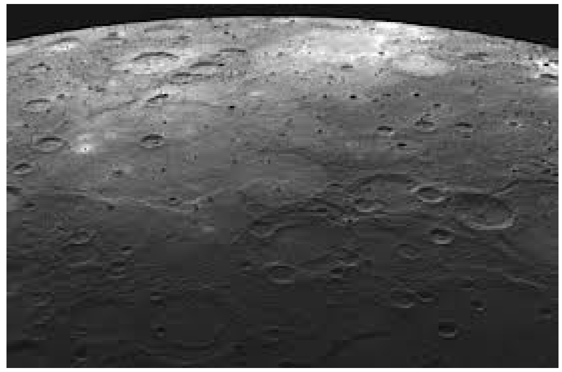
Month names

Order	Days	Iranian Persian (Farsi)		Kurdish		Afghan Persian (Dari)		Afghan Pashto	
		Iranian-English	***Native Script***	***Kurmanji Script***	***Sorani Script***	***Romanized***	***Native Script***	***Romanized***	***Native Script***
1	31	Farvardin	فروردین	Xakelêwe	خاکەلێو	Hamal (Aries)	حمل	Wray (Aries)	ورى
2	31	Ordibehesht	اردیبهشت	Gullan (Banemer)	گوڵان	Sawr (Taurus)	ثور	Ǧwayay (Taurus)	غويى
3	31	Khordad	خرداد	Cozerdan	جۆزردان	Jawzā (Gemini)	جوزا	Ǧbargolay (Gemini)	غبرګولى
4	31	Tir	تیر	Pûşper	پووشپەڕ	Saratān (Cancer)	سرطان	Čungāx̌ (Cancer)	چنګاښ
5	31	Mordad	مرداد	Gelawêj	گەلاوێژ	Asad (Leo)	اسد	Zmaray (Leo)	زمرى
6	31	Shahrivar	شهریور	Xermanan	خەرمانان	Sonbola (Virgo)	سنبله	Waǵay (Virgo)	وږى
7	30	Mehr	مهر	Rezber	ڕزبەر	Mizān (Libra)	ميزان	Təla (Libra)	تله
8	30	Aban	آبان	Xezellwe	گەڵاڕێز	'Aqrab	عقرب	Laṛam (Scorpio)	لړم

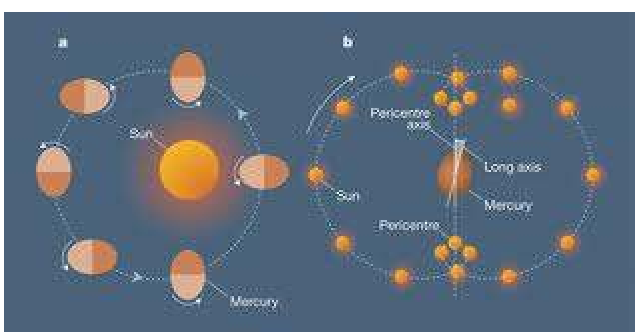
				r (Gelarêzan)	ان	(Scorpio)			
9	30	Azar	آذر	Sermawez	سەرماوەز	Qaws (Sagittarius)	قوس	Līndəi (Sagittarius)	ليندۍ
10	30	Dey	دی	Befranbar	بەفرانبار	Jadi (Capricorn)	جدی	Marğūmay (Capricorn)	مرغومی
11	30	Bahman	بهمن	Rêbendan	ڕێبەندان	Dalvæ (Aquarius)	دلو	Salwāğa (Aquarius)	سلواغه
12	29/30	Esfand	اسفند	Reşeme	ڕەشەمە	Hūt (Pisces)	حوت	Kab (Pisces)	کب

The first day of the calendar year is also the day of the greatest festival of the year in Iran, Afghanistan and surrounding regions, called norooz (two morphemes: no (new) and rooz(day), meaning "new day"). The celebration is filled with many festivities and runs a course of 13 days. The last day of which is called siz-dah bedar (Literal translation-"13 to outdoor")

Planet Mercury

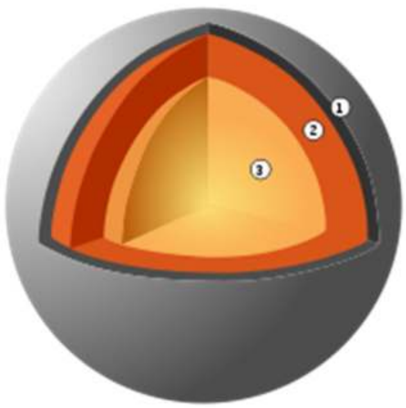


Apparently the Planet Mercury looks like the Moon. It is the innermost of the eight planets in the Solar System thus closet to the Sun with an average distance of 35900000 miles; with a maximum of 43000000 miles and a minimum distance of 29000000 miles. It has an oval rotational pattern. Being close to the Sun, if rises early it is called the morning star or turns into the evening star, rising later than the Sun. It diameter is 3030 miles, a little more than one third of the Earth's diameter. The Planet orbits around the Sun in 88 earth days and its sidereal rotational period is 58.650 days, going around the Sun twice in three sidereal rotations or completing three rotations about its axis for every two orbits. In a single solar day, it orbits around the Sun twice which means that its one day is of one year and night is also a year. There are no seasonal changes because its axis makes a zero angle with the solar axis.



Because of the oval rotational pattern, its days are less hot and nights cooler when away from the Sun. When it is nearer to the Sun, the days are hotter and nights less cool. During the day time, temperatures rise to a maximum of 872 degrees FH and drops to minus 298 degrees FH at night. The surface is without any air and a protective cover lending it exposed to comet strikes. It is also the smallest in size after the planet Pluto with an orbit which has the highest eccentricity of the eight planets. Its surface resembles the moon surface. Mercury has the smallest axial tilt of the Solar System planets.

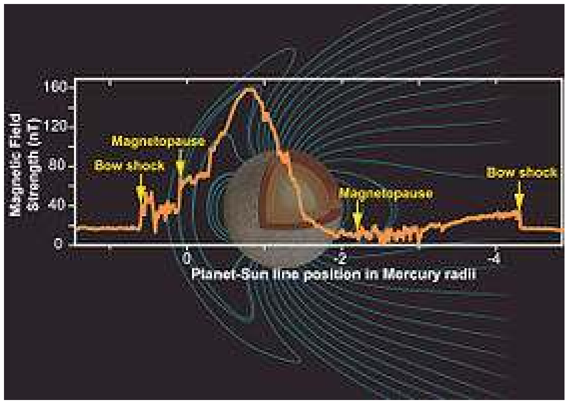
Mercury consists of approximately 70% metallic and 30% silicate material, which is the largest ratio amongst all the planets. Mercury's core has higher iron content than that of any other major planet in the Solar System.



Internal structure of Mercury
1. Crust: 100–300 km thick
2. Mantle: 600 km thick
3. Core: 1,800 km radius

Mercury's density is the second highest in the Solar System at 5.427 g/cm^3, only slightly less than Earth's density of 5.515 g/cm^3 .

Despite its small size and slow 59-day-long rotation, Mercury beside the Earth is the only planet which has a significantly global magnetic field.



Being a planet of the solar system it reflects the Sun light. Like the Moon, planet Mercury changes it shapes.




When between then the Sun and the Earth it is invisible. A little away it appears like a crescent and when the Sun is in between, it appears full. Emits maximum light, when it appears like a Moon of two days, receding in glow when complete being farther away from the Earth. According to Kepler's laws of planetary motion, speed of motion is 24 miles/ second when it is away from the Sun which increases to 37 miles/second when it gets closer. An astronomer reaching the Mercury will ordinarily find the Sun rising in the east and setting in the west but when the Planet is at the maximum distance from the Sun, he will observe a westerly sun rise and setting in the east. The Sun will look stationary for a while. This may not alarm him as the beginning of the end of this world and cession of repentance; this being a usual phenomenon there. Such a happening on the Earth shall be surely be a sign of the Doom's day. According to the conventional understanding planet Mercury has two easts and two wests. It is difficult to comprehend existence of dual directions which are mentioned in the holy Quran.

رَبُّ ٱلۡمَشۡرِقَيۡنِ وَرَبُّ ٱلۡمَغۡرِبَيۡنِ ١٧

(He is Lord of the two easts and Lord of the two wests. Ar Rahman- 17)

Indeed exploration of the universe can unveil many easts and wests.

فَبِأَيِّ آلَاءِ رَبِّكُمَا تُكَذِّبَانِ

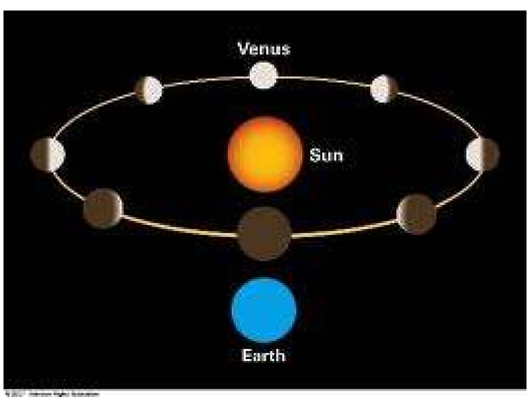
(So, (O mankind and Jinn,) which of the bounties of your Lord will you deny?)

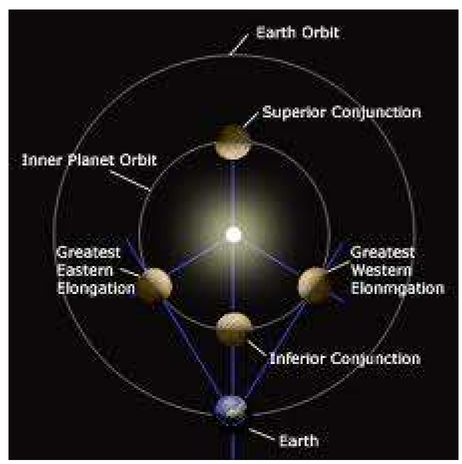
Reflective power of the Mercury is very limited. It only reflects 7% of the light. There are no clouds over the planet. Only half the area of Mercury has been photographed. The rest still remains obscure and unknown. Due to the higher iron content of its core, it shrunk on creation, because of the cold, resulting in large craters and pot holes on its surface.

Planet Venus

The surface is obscured by a thick blanket of clouds.

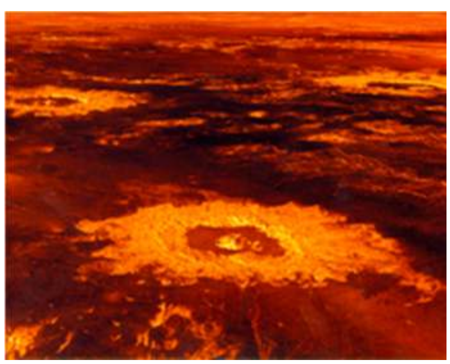




Venus is the second planet from the Sun, orbiting it every 224.7 Earth days. After the Moon, it is the brightest natural object in the night sky, reaching an apparent magnitude of −4.6, bright enough to cast shadows. Some people claim to have seen it during the broad day light. Like Mercury, it never appears to venture far from the Sun: its elongation reaches a maximum of 47.8°. Venus reaches its maximum brightness shortly before sunrise or shortly after sunset, for which reason it has been known since ancient time as the Morning Star or the Evening Star. It also appears like the Moon in many shapes i.e. full to crescent shape. It was not until the Hellenistic era (300-200 BC) astronomers realized that it was one object and gave it the name it has today.

It orbits around the Sun in an almost circular pattern in 225 days; with an axial rotation completed in 243 days. When placed between the Sun and the Earth, it looks like a crescent and with the Sun in between it appears like a full moon from the Earth reflecting maximum light towards the Earth. However because of the distance (160000000 miles) and intensity of the solar light it remains invisible. Thirty six days before its placement between the Sun and the earth it is so bright that shadows of the nearby terrestrial objects can be seen. At this point it is 80000000 miles away from the earth. This phenomenon occurs every eight years. .

Venus is classified as a terrestrial planet and it is sometimes called Earth's "sister planet" owing to their similar size, gravity, and bulk composition (Venus is both the closest planet to Earth and closest in size). It is covered with an opaque layer of highly reflective clouds of sulfuric acid, preventing its surface from being seen from space in visible light. Venus has the densest atmosphere of all the terrestrial planets in the Solar System, consisting of mostly carbon dioxide which enhances its reflective power i.e. reflecting 76% of the Sun light. The atmospheric pressure at the planet's surface is 92 times that of the Earth. Venus has no carbon cycle to lock carbon back into rocks and surface features, nor does it seem to have any organic life to absorb it in biomass. Venus is believed to have previously possessed oceans, but these evaporated as the temperature rose as high as 900 degrees FH, owing to the runaway greenhouse effect (the process used to regulate temperature for growing vegetables under the plastic sheets). The water has most probably photo dissociated, and, because of the lack of a planetary magnetic field, the free hydrogen has been swept into interplanetary space by the solar winds. Venus' surface is a dry desert scrape with many slab-like rocks, periodically refreshed by volcanism. Atmospheric pressure at the Venus is 90 times more than the Earth. A day at the planet is more than its year. Unlike other planets its axial rotation is from east to west, with the Sun appearing to rise from the west and set in the east.



Impact craters on the surface of Venus

Surface of the planet is covered with very large craters and lofty mountains. Two craters found in an area of 1000000 square kilometer are as big as 200 kilometer and more in its diameter. It has a simpler pattern of winds than the earth. These move in a single direction at a speed of 225 miles per hour.

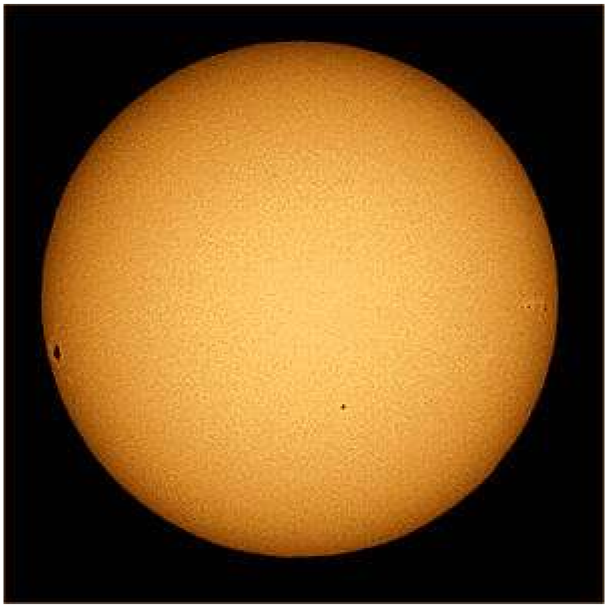
Transits of Venus and Mercury

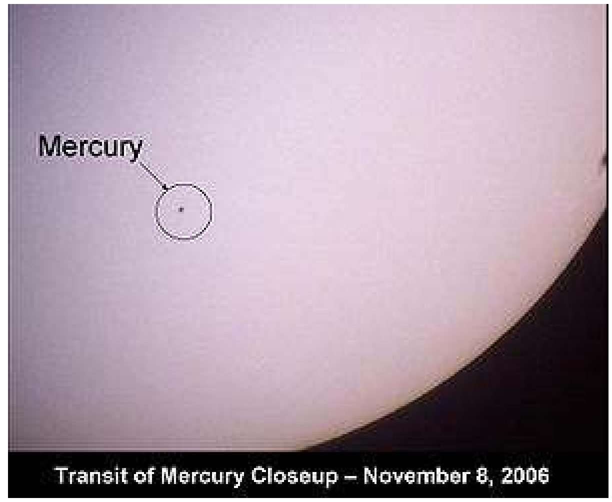
Venus

The Venusians orbit is slightly inclined relative to the Earth's orbit; thus, when the planet passes between the Earth and the Sun, it usually does not cross the face of the Sun. Transits of Venus do occur when the planet's inferior conjunction coincides with its presence in the plane of the Earth's orbit. Transits of Venus occur in cycles of 243 years with the current pattern of transits being pairs of transits separated by eight years, at intervals of about 105.5 years or 121.5 years—a pattern first discovered in 1639 by English astronomer Jeremiah Harrick.

The latest pair was June 8, 2004 and June 5–6, 2012 (shown in the pictures above) appearing like a dot against the bright Sun. If the planet passes at the brim of the Sun it is visible for a short while but passing near the centre it can be seen for approximately eight hours.

Mercury



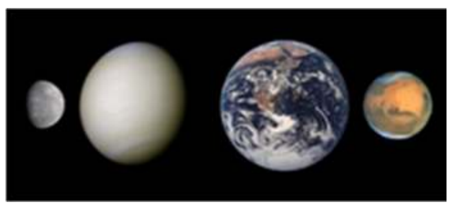


Transits of Mercury with respect to Earth are much more frequent than transits of Venus, with about 13 or 14 per century, in part because Mercury is closer to the Sun and orbits it more rapidly.

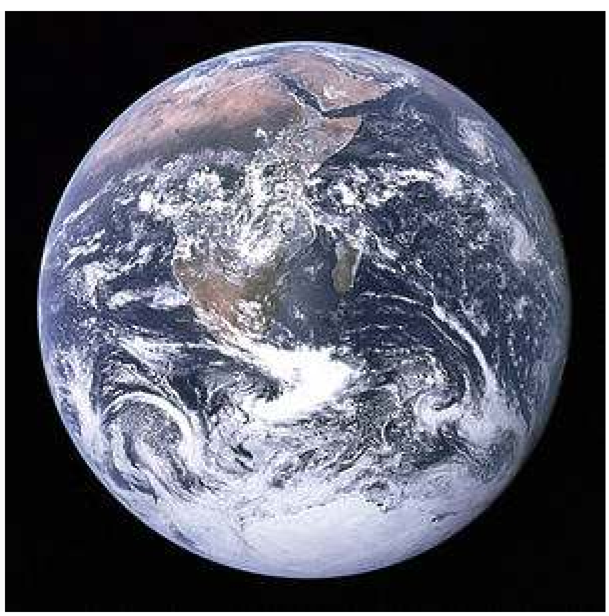
Transits of Mercury occur in May or November. The last three transits occurred in 1999, 2003 and 2006; the next will occur in 2016.

The Earth

The confusing inverted picture is certainly not the Moon but it is the Earth as seen from surface of the Moon. Earth is the third planet from the Sun, and the densest and fifth-largest of the eight planets in the Solar System.



Size comparison of inner planets (left to right): Mercury, Venus, Earth and Mars in true colours.



It is also the largest of the Solar System's four terrestrial planets. It is sometimes referred to as the world, the Blue Planet or by its Latin name, *Terra*.

This chapter will only be restricted to astronomical information. The Earth formed 4.54 billion years ago, and life appeared on its surface within one billion years.

The planet is home to millions of species. Earth's biosphere has significantly altered the atmosphere and other abiotic (characterized by the absence of life) conditions on the planet, enabling the proliferation of aerobic organisms as well as the formation of the ozone layer which, together with Earth's magnetic field, blocks harmful solar radiation, permitting life on land. The physical properties of the Earth, as well as its geological history and orbit, have allowed life to persist during this period. Estimates on how much longer the planet will to be able to continue to support life range from a mere 500 million years, to as long as 2.3 billion years. Physical characteristics of the Earth are appended below:-

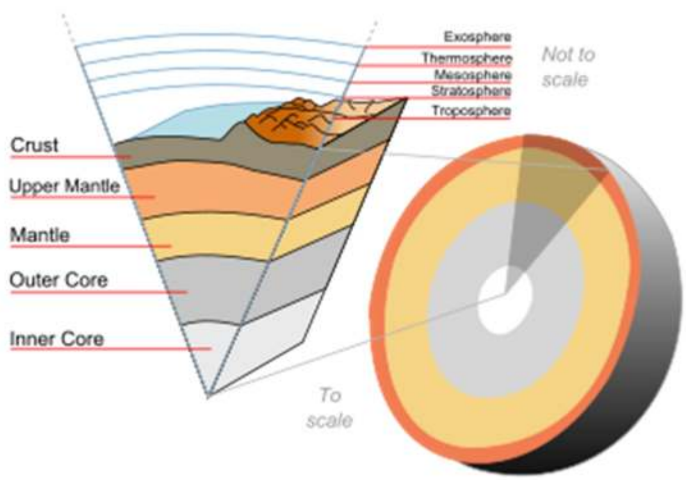
Physical characteristics	
Mean radius	6,371.0 km
Equatorial radius	6,378.1 km
Polar radius	6,356.8 km
Flattening	0.0033528
Circumference	40,075.017 km (equatorial) 40,007.86 km (meridional)
Surface area	510,072,000 km^2 148,940,000 km^2 land (29.2 %) 361,132,000 km^2 water (70.8 %)
Volume	1.08321×10^{12} km^3
Mass	5.9736×10^{24} kg

Mean density	5.515 g/cm^3		
Equatorial surface gravity	9.780327 m/s^2 0.99732 *g*		
Escape velocity	11.186 km/s		
Sidereal rotation period	0.99726968 d 23^h 56^m 4.100^s		
Equatorial rotation velocity	1,674.4 km/h (465.1 m/s)		
Axial tilt	23°26'21".4119		
Albedo	0.367 (geometric) 0.306 (Bond)		
Surface temp.	min	mean	max
Kelvin	184 K	287.2 K[18]	331 K[19]
Celsius	−89.2 °C	14 °C	57.8 °C

The Earth is an oval shaped sphere or an oblate spheroid which is pressed inwards at the poles. Its radius at the equator is 6378 kilometres and 6357 kilometres at the poles with ovality of 1/297.

Structure of the Earth

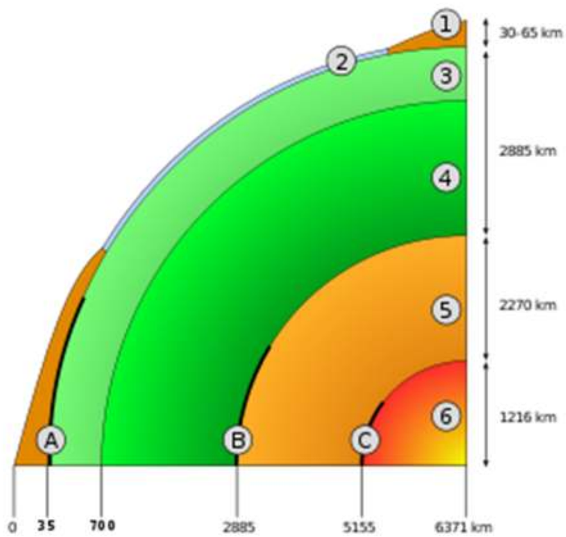
The interior structure of the Earth is layered in spherical shells, like an onion. These layers can be defined by either their chemical or their rheological properties.
The Earth has an outer silicate solid crust, a highly viscous mantle, a liquid outer core that is much less viscous than the mantle, and a solid inner core. Scientific understanding of Earth's internal structure is based on observations of topography and bathymetry, observations of rock , samples brought to the surface from greater depths by volcanic activity, analysis of the seismic waves that pass through the Earth, measurements of the gravity field of the Earth, and experiments with crystalline solids at pressures and temperatures characteristic of the Earth's deep interior.



Depth		Layer
Kilometers	Miles	
0–60	0–37	Lithosphere (locally varies between 5 and 200 km)

0–35	0–22	… Crust (locally varies between 5 and 70 km)
35–60	22–37	… Uppermost part of mantle
35–2,890	22–1,790	Mantle
100–200	62–125	… Astheno sphere
35–660	22–410	… Upper mesosphere (upper mantle)
660–2,890	410–1,790	… Lower mesosphere (lower mantle)
2,890–5,150	1,790–3,160	Outer core
5,150–6,360	3,160–3,954	Inner core

Interior of the Earth (Inner Core)



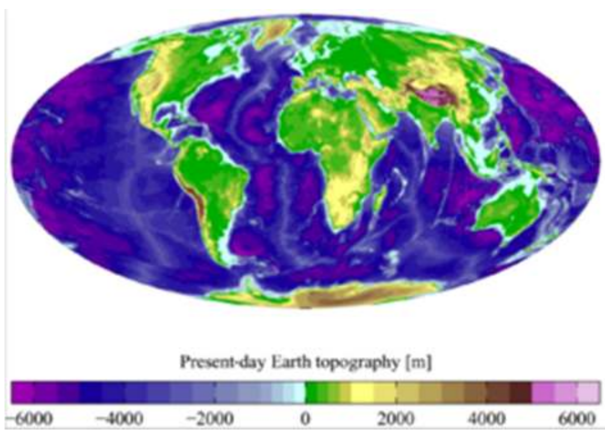
Based on the abundance of chemical elements in the solar system, the inner core is composed primarily of a nickel–iron alloy referred to as Nife: 'Ni' for nickel and 'Fe' for ferrous or iron. Because the inner core is denser than pure iron or nickel, even under heavy pressures, it's believed that the remaining part of the core is composed of gold, platinum and other siderophile elements. The temperature of the inner core is estimated at 5,700 K (5,430 °C; 9,800 °F). The pressure in Earth's inner core is between about 330 to 360 giga pascals (3,300,000 to 3,600,000 atm). Heavy metals are in liquid form because of the intense temperature. Density of the inner most core (1200 kilometres) is 18 times more than the water. The earth is cooling down at a slow rate of one degree after every 10000000 yeas. The Earth separated from the Sun approximately 4 ½ billion years ago, so at this rate the temperature has reduced by 450 centigrade so far.

Mantel

Earth's mantle is a rocky shell about 2,900 km (1,800 miles) thick, which constitutes about 84% of Earth's volume. It is predominantly solid and encloses the iron-rich hot core, which occupies about 15% of Earth's volume. Past episodes of melting and volcanism at the shallower levels of the mantle have produced a thin crust of crystallized melt products near the surface, upon which we live. Two main zones are distinguished in the upper mantle: the inner astheno sphere composed of plastic flowing rock about 200 km thick and the lower most part of the lithosphere composed of rigid rock about 50 to 120 km thick. A thin crust, the upper part of the lithosphere, surrounds the mantle and is about 5 to 75 km thick. In the mantle, temperatures range between 500 to 900 °C (932 to 1,652 °F) at the upper boundary with the crust; to over 4,000 °C (7,230 °F) at the boundary with the core.

Crust

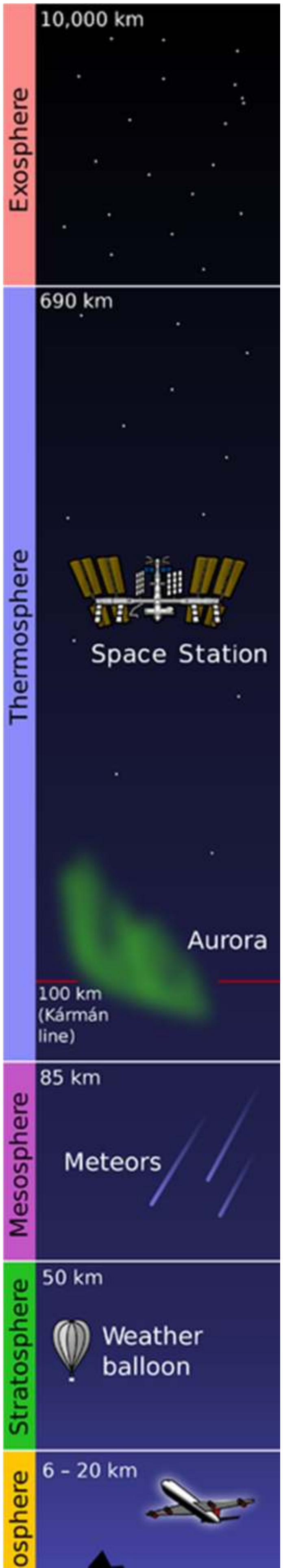
The crust ranges from 5–70 km in depth and is the outermost layer. The thin parts are the oceanic crust, which underlie the ocean basins (5–10 km) and are composed of dense iron magnesium silicate rocks like basalt. The thicker crust is the continental crust, which is less dense and composed of sodium, potassium, aluminium and silicate rocks like granite. 71 % of the crust is submerged in water with only 29% remaining as dry land, out of which 10% is covered with ice.



Atmosphere

The atmosphere of Earth is a layer of gases surrounding the planet Earth that is retained by Earth's gravity. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night . Atmospheric stratification describes the structure of the atmosphere, dividing it into distinct layers, each with specific characteristics such as temperature or composition. The atmosphere has a mass of about 5×10^{18} kg, three quarters of which is within about 11 km (6.8 miles or 36,000 ft) of the surface. The atmosphere becomes thinner and thinner with increasing altitude, with no definite boundary between the atmosphere and outer space. An altitude of 120 km (75 miles) is where atmospheric effects become noticeable during atmospheric reentry of spacecraft. The Kármán line, at 100 km (62 miles), also is often regarded as the boundary between atmosphere and outer space. In general, air pressure and density decrease in the atmosphere as height increases.

Air is the name given to atmosphere used in breathing and photosynthesis. Dry air contains roughly (by volume) 78.09% nitrogen, 20.95% oxygen, 0.93% argon, 0.039% carbon dioxide, and small amounts of other gases. Air also contains a variable amount of water vapor, on average around 1%. While air content and atmospheric pressure vary at different layers, air suitable for the survival of terrestrial plants and terrestrial animals is currently only known to be found in Earth's troposphere and artificial atmospheres.

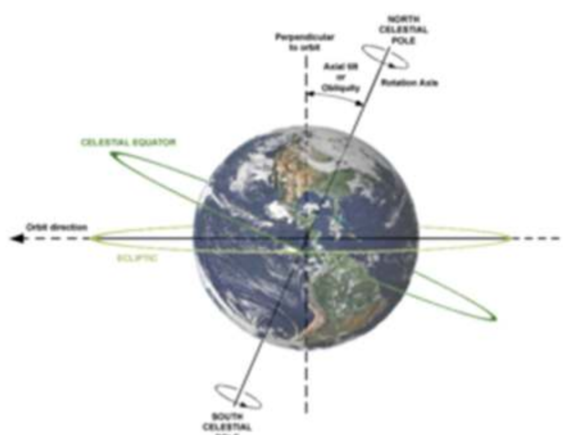


Exosphere
10,000 km
Thermosphere
690 km
Space Station
Aurora
100 km
(Kármán
line)
Mesosphere
85 km
Meteors
Stratosphere
50 km
Weather
balloon
6 – 20 km

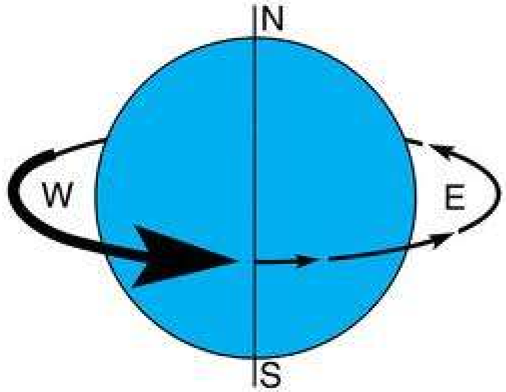
The ozone layer is contained within the stratosphere. In this layer ozone concentrations are about 2 to 8 parts per million, which is much higher than in the lower atmosphere but still very small compared to the main components of the atmosphere. It is mainly located in the lower portion of the stratosphere from about 15–35 km (9.3–22 miles; 49,000–110,000 ft), though the thickness varies seasonally and geographically. About 90% of the ozone in our atmosphere is contained in the stratosphere.

The average atmospheric pressure at sea level is about 1 atmosphere (atm) or 14.7 psi (pounds per square inch) which means that we carry a weight of 400 pounds over our head. Our bodies can biologically with stand this pressure. Total atmospheric mass is 5.1480×10^{18} kg (1.135×10^{19} lb), about 2.5% less than would be inferred from the average sea level pressure and the Earth's area of 51007.2 mega hectares, this portion being displaced by the Earth's mountainous terrain. Atmospheric pressure is the total weight of the air above unit area at the point where the pressure is measured. Thus air pressure varies with location and weather. If the atmosphere had a uniform density, it would terminate abruptly at an altitude of 8.50 km (27,900 ft). It actually decreases exponentially with altitude, dropping by half every 5.6 km (18,000 ft), the average scale height of the atmosphere below 70 km (43 miles; 230,000 ft).

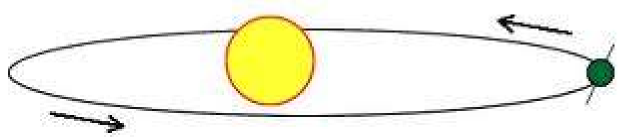
Orbit and Rotation



Earth's rotation is the rotation of the solid Earth around its own axis. The Earth rotates towards the east.



The Earth rotates once in about 24 hours, or currently 23 hours 56 minutes and 4 seconds. Earth's rotation is slowing slightly with time, thus a day was shorter in the past, this is due to the tidal effects the Moon has on Earth's rotation. Atomic clocks show that a modern day is longer by about 17 milliseconds than a century ago, slowly increasing the rate at which UTC is adjusted by leap seconds.



Earth orbits the Sun at an average distance of about 150 million kilometres every 365.2564 mean solar days, or one sidereal year. From Earth, this gives an apparent movement of the Sun eastward with respect to the stars at a rate of about 1°/day, or a Sun or Moon diameter, every 12 hours. Because of this motion, on average it takes 24 hours—a solar day—for Earth to complete a full rotation about its axis so that the Sun returns to the meridian. The orbital speed of the Earth averages about 29.8 km/s (107,000 km/h), which is fast enough to cover the planet's diameter (about 12,600 km) in seven minutes, and the distance to the Moon (384,000 km) in four hours.

The orbital eccentricity of an astronomical object is a parameter that determines the amount by which its orbiting around another body deviates from a perfect circle. A value of 0 is a circular orbit, values between 0 and 1 form an elliptical orbit, and 1 is a parabolic escape orbit. The term derives its name from the parameters of conic sections, as every Kepler orbit is a conic section. It is normally used for the isolated two-body problem, but extensions exist for objects following a rosette orbit through the galaxy.

The eccentricity of the Earth's orbit is currently about 0.0167; thus its orbit is nearly circular. Over hundreds of thousands of years, the eccentricity of the Earth's orbit varies from nearly 0.0034 to almost 0.058 as a result of gravitational attractions among the planets. It returns to its original position after 25800 years. Change in the equator of the Earth is forty times more than at the ecliptic. The equinoxes shift to the west because of these changes which become prominent in thousand of years make a difference in the appearance of the stars. Due to the precession of the equinoxes (as well as the stars' proper motions), the role of North Star passes from one star to another .Therefore no star is a permanent pole star; they take turns to take this position. Polaris is the current northern pole star. In 3000 BC the faint star Thuban in the constellation Draco was the North Star. At magnitude 3.67 (fourth magnitude) it is only one-fifth as bright as Polaris, and today it is invisible in light-polluted urban skies. The precession of the equinoxes takes about 25,770 years to complete a cycle. Polaris' mean position (taking account of precession and proper motion) will reach a maximum declination of +89°32'23", so 1657" or 0.4603° from the celestial North Pole, in February 2102.

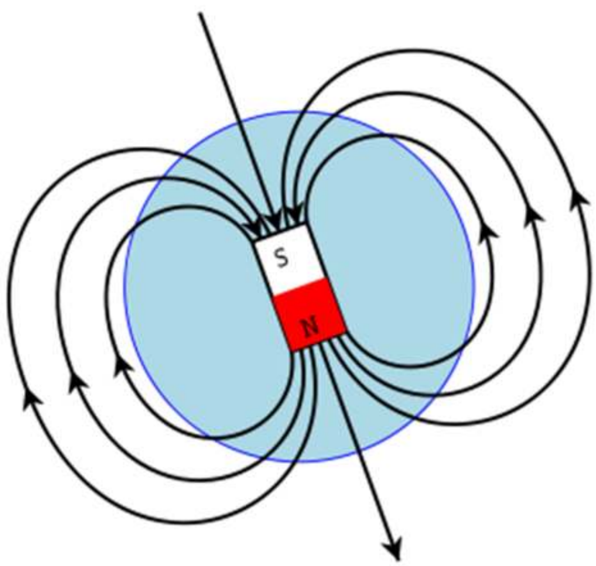
A long exposure photo of Polaris and neighbouring stars (exposure time 45 min), taken in Ehrenbürg (Walberla) in 2001.

Gamma Cephei (also known as Alrai, situated 45 light-years away) will become closer to the northern celestial pole than Polaris around AD 3000. Then Iota Cephei will become the pole star sometime around AD 5200. When Polaris becomes the North Star again around 27800 AD, due to its proper motion it then will be farther away from the pole than it is now, while in 23600 BC it was closer to the pole.

Axial tilt, known to astronomers as obliquity, is the angle between an object's rotational axis, and its orbital axis. The Earth currently has an axial tilt of about 23.4°, This value remains approximately the same relative to a stationary orbital plane throughout the cycles of precession. However, because the ecliptic (i.e. the Earth's orbit) moves due to planetary perturbations, the obliquity of the ecliptic is not a fixed quantity. At present, it is decreasing at a rate of about 47" per century. Schedule of the prayers timings does not remain constant with appreciable difference occurring in a 20-30 year cycle.

Astronomers have devised many calendars for calculating a year but the most popular one is the solar calendar comprising of solar or tropical year, which is the length of time that the Sun takes to return to the same position in the cycle of seasons, as seen from the Earth. A solar year has 365.2422 solar days. However a sidereal year is twenty minutes more than a solar year i.e. 365.25636 days.

The Earth's magnetic field is thought to be produced by convection currents in the outer liquid of Earth's core. The Dynamo theory proposes that these movements produce electric currents which, in turn, produce the magnetic field.

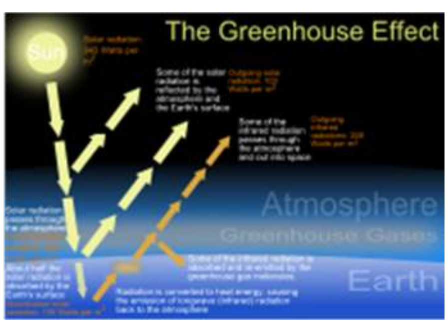


Sketch of the Earth's magnetic field. A magnet is shown as the source. The geographic north pole of Earth is near the top of the diagram, the South Pole near the bottom.

The presence of this field causes a compass, placed anywhere within it, to rotate so that the "north pole" of the magnet in the compass points toward Earth's north magnetic pole. Core of the Earth’s magnet makes a 14.5 degree angle with axis of the Earth. It’s magnitude at the Earth's surface ranges from 0.25 to 0.65 gauss. The region above the ionosphere, and extending several tens of thousands of kilo meters into space, is called the magnetosphere. This region protects the Earth from cosmic rays that would strip away the upper atmosphere, including the ozone layer that protects the earth from harmful ultraviolet radiation.

The age of the Earth is 4.54 ± 0.05 billion years This age is based on evidence from radiometric age dating of meteorite material and is consistent with the ages of the oldest-known terrestrial and lunar samples. Following the scientific revolution and the development of radiometric age dating, measurements of lead in uranium-rich minerals showed that some were in excess of a billion years old. However the real age is only known to Allah Almighty.

The more one ponders about the universe; splendours created by Allah Almighty become ominously visible. The Earth and the Universe call out to the humans that it has been surrendered for their logistical needs. During the day, the Sun rays warm up everything cooling it down at night. The magnitude and their levels are so balanced that these cause no harm to the life. The average temperature could have dropped to minus twenty degrees but that does not happen, it remains at twenty degrees plus. This is the green house effect. A process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases and it is re-radiated in all directions. Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above what it would be in the absence of these gases.



By their percentage contribution to the greenhouse effect on Earth the four major gases are water vapor, 36–70%,carbon dioxide, 9–26%,methane, 4–9% and ozone, 3–7%.The major non-gas contributor to the Earth's greenhouse effect, clouds, also absorb and emit infrared radiation and thus have an effect on radiative properties of the atmosphere. Water vapours and carbon dioxide act as the glass allowing the Sun rays to come in but not escape totally. So the temperature is returned to the earth in the form of infra red thermal radiations thus keeping it warm. Infrared radiation is absorbed by greenhouse gases, which in turn re-radiate much of the energy to the surface and lower atmosphere. In other words, a blanket is perpetually wrapped around the Earth which saves the inhabitants from freezing to death.

Whereas infrared radiations are useful, the ultra violet rays can be very dangerous and harm full to the life. Although ultraviolet radiation is invisible to the human eye, most people are aware of the effects of UV on the skin. A great deal (>97%) of mid-range ultraviolet is blocked by the ozone layer, and would cause much damage to living organisms if it penetrated the atmosphere. The ozone layer is a layer in Earth's atmosphere containing relatively high concentrations of ozone. It absorbs 97–99% of the Sun's medium-frequency ultraviolet light (from about 200 nm to 315 nm wavelength), which potentially damages exposed life forms on Earth. It is unfortunate that such gases are used in air conditioners and refrigerators which damage the ozone layer.

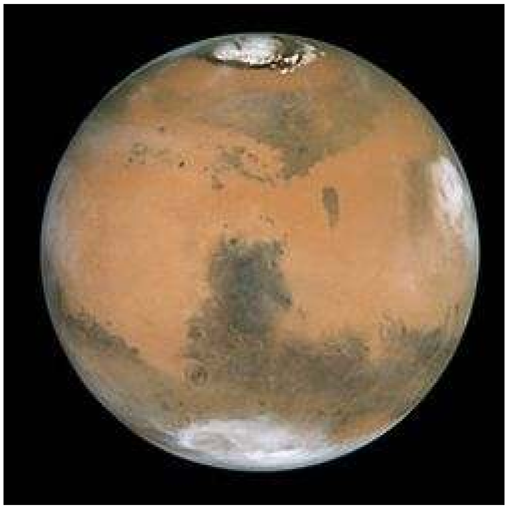
The human beings are damaging very useful natural objects for immediate gains. More mistakes are committed in our quest to control the damage already incurred. It is evident that Allah Almighty knowing well the human needs; created the nature. It is either through ignorance or sheer shortsightedness that our surroundings have been damaged. This has been explicitly described in the holy Quran:-

كلا بل تحبون العا جلتہ وتزرون الاخرتہ

(Undoubtedly you (humans) scum to the immediate gains, ignoring the long term benefits)

It is only Allah Almighty only Who can guide us onto the right path. This is where the difference between a Muslim and non Muslim scientist becomes vivid. May Allah Almighty grant us vision and be pleased. Ameen.

The Mars



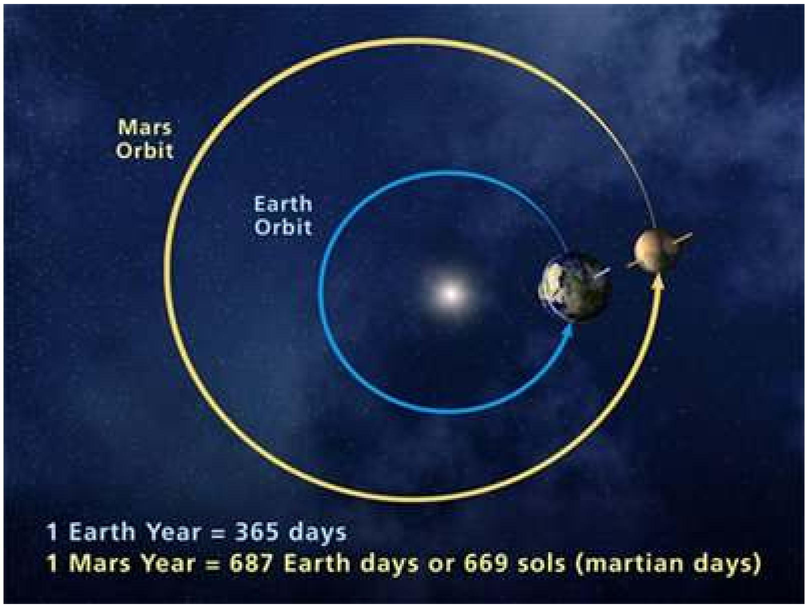
Mars is the fourth planet from the Sun in the Solar System; an outer neighbour of the earth. It is located at an average distance of 141300000 miles from the Sun. It has an orbital eccentricity of 0.093 degrees which vary its distance up to 26000000 miles. Sometimes its distance from the Earth increases to 60000000 miles and at another time it is reduced to 35000000 miles. Its equatorial radius is 3396.2 ± 0.1 kilometres. Orbits around the Sun in 687 days at an orbital average speed of 15 miles per second (24.077 km/s). A day at the Mars is 37 minutes longer than a day at the Earth. A Martian year is equal to 1.8809 Earth years, or 1 year, 320 days and 18.2 hours. The axial tilt is 25.19 degrees with an inclination of 1.850° to ecliptic 5.65° to Sun's equator.

The atmosphere of Mars consists of about 95% carbon dioxide, 3% nitrogen, 1.6% argon and contains traces of oxygen and water. The atmosphere is quite dusty, containing particulates which give the Martian sky a tawny colour when seen from the surface. Of all the planets in the Solar System, the seasons of Mars are the most Earth-like, due to the similar tilts of the two planets' rotational axes. The lengths of the Martian seasons are about twice those of Earth's, as Mars's greater distance from the Sun leads to the Martian year being about two Earth years long. Martian surface temperatures vary from lows of about −143 °C (−225 °F) (at the winter polar caps) to highs of up to 35 °C (95 °F). The wide range in temperatures is due to the thin atmosphere which cannot store much solar heat, the low atmospheric pressure, and the low thermal inertia of Martian soil. Mars also has the largest dust storms in our Solar System. These can vary from a storm over a small area, to gigantic storms that cover the entire planet. They tend to occur when Mars is closest to the Sun. Water content in the atmosphere is far lesser than the earth yet it can cause cloud formation. Signs of waterfalls, lakes and rivers can be found on its surface. Liquid water cannot exist on the surface of Mars due to low atmospheric pressure, except at the lowest elevations for short periods. Named after the Roman god of war, it is often described as the "Red Planet", as the iron oxide prevalent on its surface gives it a reddish appearance. Mars is a terrestrial planet with a thin atmosphere, having surface features reminiscent both of the impact craters of the Moon and the volcanoes, valleys, deserts, and polar ice caps of Earth. The rotational period and seasonal cycles of Mars are like wise similar to those of the Earth, as is the tilt that produces the seasons. Mars is the site of Olympus Mons, the highest known mountain within the Solar System and of Valles Marineris one of the largest canyons.

Top down view of Olympus Mons, the highest known mountain in the solar system.

Mars has two moons, Phobos and Deimos, which are small and irregularly shaped.

Mars is visible in the mid sky for a few months biennially with its visible diameter altering between 2.5 to 3.5 seconds thus fluctuating its distance from the Earth. When closer to the Earth it appears fifty five times brighter than the Pole Star. Except for Venus no other star is comparable in brightness. At the time of its unison with the Sun it is not visible but later starts appearing a few minutes before the Sun rise.



Mars have faster rotation and extreme distance than earth. Mars and Earth are like race cars on an oval track. Earth has the inside lane and moves faster than Mars -- so much faster, in fact, that it makes two laps around the course in about as much time as it takes Mars to go around once. About every 26 months, Earth comes up from behind and overtakes Mars. Despite moving in an easterly direction it appears to move west, then it motions appears to start halting then it regains the westerly movement at a faster pace which is maximised at 180 degrees of . It once again gets stationary at reaching an angle of 137 degrees and then restarts towards the east.

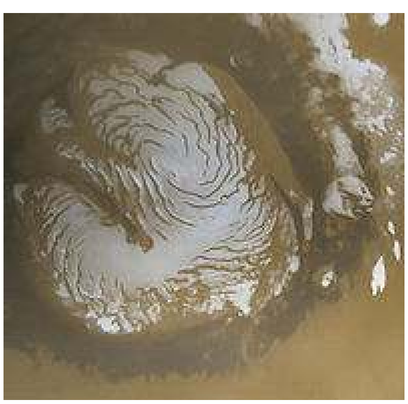
During its orbit around the Sun, the Mars keeps changing it shapes as seen from the Earth. Unlike the Moon it never appears like a crescent because of being the outer orbit from the earth, not coming between the Sun and the Earth.

The dichotomy of Martian topography is striking: northern plains flattened by lava flows contrast with the southern highlands, pitted and cratered by ancient impacts. Mars is scarred by a number of impact craters: a total of 43,000 craters with a diameter of 5 km or greater have been found. The largest confirmed of these is the Hellas impact basin, which is visible from Earth.

Panorama of Gusev crater, where Spirit rover examined volcanic basalts

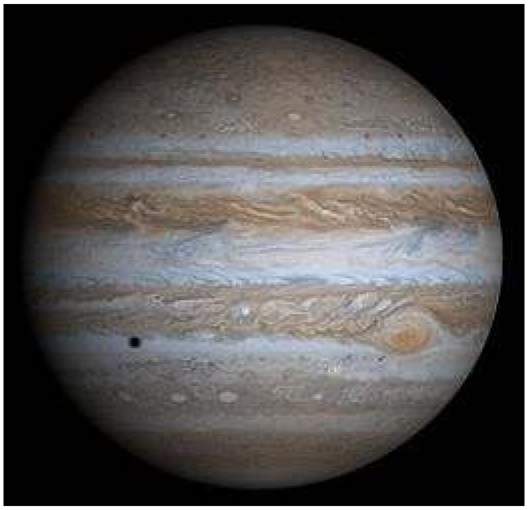
The shield volcano, Olympus Mons (*Mount Olympus*), at 27 km is the highest known mountain in the Solar System. It is an extinct volcano in the vast upland region Tharsis, which contains several other large volcanoes. Olympus Mons is over three times the height of Mount Everest, which in comparison stands at just over 8.8 km.

Mars has two permanent polar ice caps. During a pole's winter, it lies in continuous darkness, chilling the surface and causing the deposition of 25–30% of the atmosphere into slabs of CO_2 ice (dry ice). When the poles are again exposed to sunlight, the frozen carbon dia oxide sublimes, creating enormous winds that sweep off the poles as fast as 400 km/h. These seasonal actions transport large amounts of dust and water vapor, giving rise to Earth-like frost and large clouds. The polar caps at both poles consist primarily of water ice. Frozen carbon dioxide accumulates as a comparatively thin layer about one meter thick on the north cap in the northern winter only, while the south cap has a permanent dry ice cover about eight meters thick. The northern polar cap has a diameter of about 1,000 kilometers during the northern Mars summer and contains about 1.6 million cubic km of ice, which, if spread evenly on the cap, would be 2 km thick.



Northern ice cap of Mars in 1999 *South polar cap in 2000*

The Jupiter



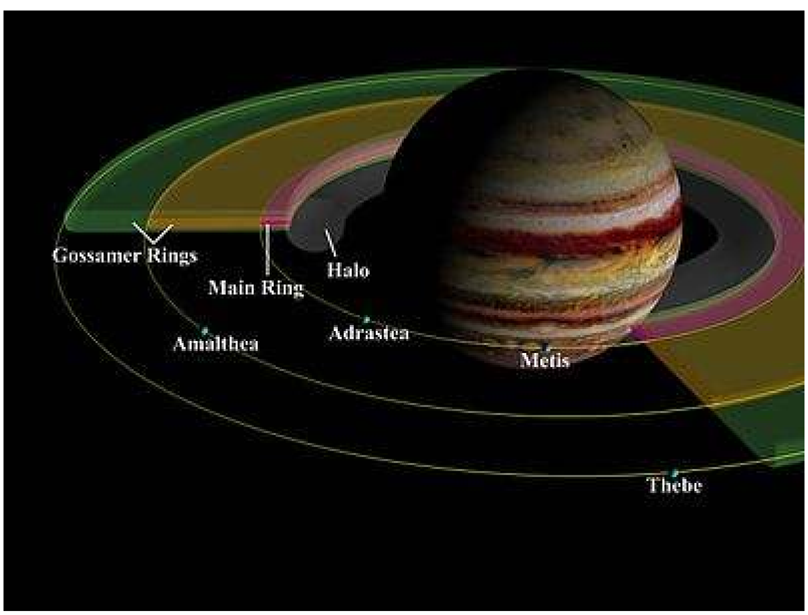
Jupiter is the fifth planet from the Sun and the largest planet within the Solar System. It is a gas giant with mass one-thousandth that of the Sun but is two and a half times the mass of all the other planets in our Solar System combined. It is large enough to accommodate 1321Earths into it with a weight equal to 318 earths. Jupiter is classified as a gas giant along with Saturn, Uranus and Neptune. Together, these four planets are sometimes referred to as the Jovian or the outer planets. Jupiter is primarily composed of hydrogen with a quarter of its mass being helium; it may also have a rocky core of heavier elements. A very large empty space exists between the Jupiter and The Mars, which it is believed was created because of the destruction of a planet. Its remains in the form of small and large particles are scattered in the space; some orbiting around the Sun and other planets. Some of them when entering the outer space of the Earth, in the form of meteors get destroyed. Because of its rapid rotation, Jupiter's shape is that of an oblate spheroid (it possesses a slight but noticeable bulge around the equator). The outer atmosphere is visibly segregated into several bands at different latitudes, resulting in turbulence and storms along their interacting boundaries.

A prominent result is the Great Red Spot, a giant storm that is known to have existed since at least the 17th century when it was first seen by a telescope. Surrounding the planet is a faint planetary ring system and a powerful magnetosphere. There are also at least 66 moons, including the four large moons called the Galilean moons that were first discovered by Galileo Galilee in 1610. Ganymede, the largest of these moons, has a diameter greater than that of the planet Mercury.

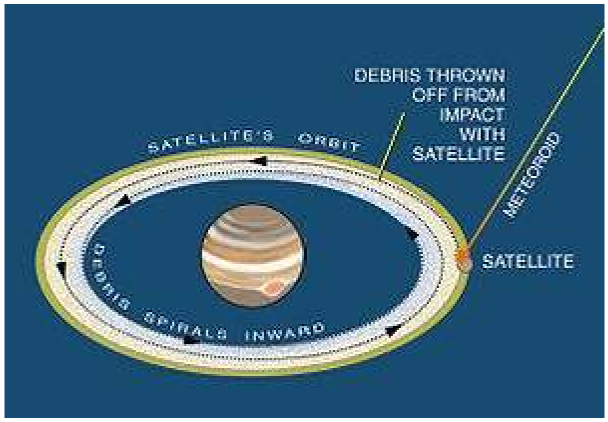
Its mean density is 1.326 g/cm which is only 24% of the Earth’s density. The gravitational pull is 2364 times more than the Earth’s gravity. A rocket propelling at a speed less than 59.5 k/sec cannot disengage itself. On the Earth a speed of 11.19 k/sec is enough for a similar disengagement. Its mean distance from the Sun is 482600000 miles with a temperature of only 90.6 K which is minus 173 degrees centigrade. It completes an orbit every 11.86 years at a speed of eight miles per second.
Jupiter's rotation is the fastest of all the Solar System's planets, completing a rotation on its axis in slightly less than ten hours. The axial tilt of Jupiter is relatively small: only 3.13°. As a result this planet does not experience significant seasonal changes, in contrast to Earth and Mars for example. Its equatorial radius is71, 492 ± 4 km (11.209 earths) and the polar radius being 66,854 ± 10 km (10.517 earths) give it an oblong shape. Jupiter has the largest planetary atmosphere in the Solar System, spanning over 5000 km in altitude. It is mostly made of molecular hydrogen 89% and helium 11%. Other chemical compounds are present only in small amounts and include methane, ammonia, hydrogen sulphide and water. Although water is thought to reside deep in the atmosphere, its directly measured concentration is very low.
The oxygen, nitrogen, sulphur, and noble gas abundances in Jupiter's atmosphere exceed solar values by a factor of about three. Life can not exist on the planet because of existence of the poisonous gases.

Jupiter has the largest planetary atmosphere in the Solar System, spanning over 5000 km in altitude. As Jupiter has no surface, the base of its atmosphere is usually considered to be the point at which atmospheric pressure is equal to 10 bars, or ten times surface pressure on Earth. Prominent lines/ bands can be seen parallel to the equatorial zone. The best known feature of Jupiter is the Great Red Spot, a persistent anti cyclonic storm that is larger than Earth. The storm is large enough to be visible through Earth-based telescopes.

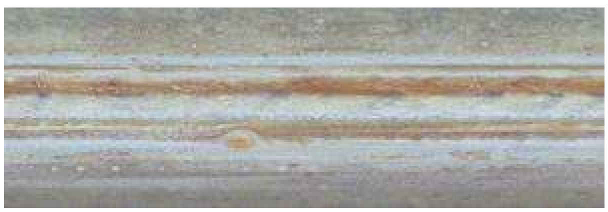
This view of Jupiter's Great Red Spot and its surroundings was obtained by Voyager 1on February 25, 1979, when the spacecraft was 9.2 million km (5.7 million miles) from Jupiter. Cloud details as small as 160 km (100 miles) across can be seen here. To give a sense of Jupiter's scale, the white oval storm directly below the Great Red Spot is approximately the same diameter as Earth.



The planet Jupiter has a system of rings, known as the rings of Jupiter or the Jovian ring system. They comprise of four main components: a thick inner torus of particles known as the "halo ring"; a relatively bright, exceptionally thin "main ring"; and two wide, thick and faint outer "gossamer rings", named after the moons of whose material they are composed.



It was the third ring system to be discovered in the Solar System, after those of Saturn and Uranus. It was first observed in 1979 by the *Voyager 1* space probe and thoroughly investigated in the 1990s by the *Galileo* obiter. It has also been observed by the Hubble Space Telescope and from Earth for the past 23 years.



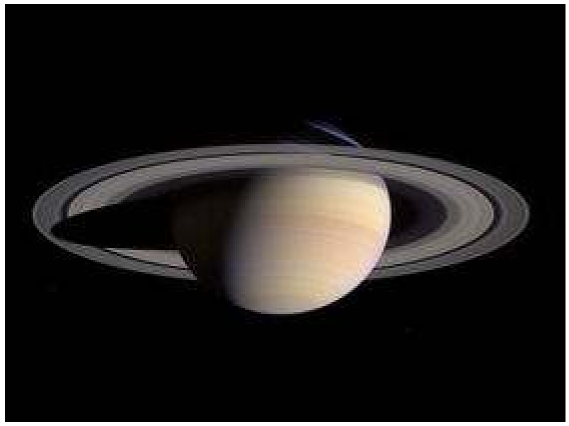
The cloud layer is only about 50 km deep, and consists of at least two decks of clouds: a thick lower deck and a thin clearer region. The orange and brown coloration in the clouds of Jupiter are caused by up welling compounds that change colour when they are exposed to ultraviolet light from the Sun. The exact makeup remains uncertain, but the substances are believed to be phosphorus, sulphur or possibly hydrocarbons.

Montage of Jupiter's four Galilean moons, in a composite image comparing their sizes and the size of Jupiter. From top to bottom: Io, Europa, Ganymede and Callisto.

Out of a total of eighteen moons of the Jupiter, famous are the Galilean four moons which were discovered by Galileo Galilee in January 1610. They are the largest of the many moons of Jupiter and are named as *Io*, *Europa*, *Ganymede*, and *Callisto*. They are among the most massive objects in the Solar System outside the Sun and the eight planets, with radii larger than any of the dwarf planets. Io is the innermost of the four Galilean moons of Jupiter and, with a diameter of 3,642 kilometres, the fourth-largest moon in the System. With over 400 active volcanoes, Io is the most geologically active object in the Solar System. Its surface is dotted with more than 100 mountains, some of which are taller than Earth's Mount Everest.

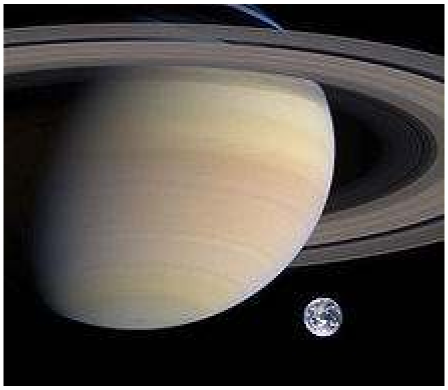
Ganymede is the largest natural satellite in the Solar System at 5262.4 kilometres in diameter, which makes it larger than the planet Mercury - although only at about half of its mass. Europa, the second of the four Galilean moons, is the second closest to Jupiter and the smallest at 3121.6 kilometres in diameter, which is slightly smaller than Earth's Moon. Callisto is the fourth and last Galilean moon, and is the second largest of the four, and at 4820.6 kilometres in diameter, it is the third largest moon in the Solar System.

The Saturn



Saturn is the sixth planet from the Sun and the second largest planet in the Solar System, after Jupiter. It is named after the Roman god Saturn. Saturn is a gas giant with an average radius about nine times that of Earth. While only one-eighth the average density of Earth, with its larger volume Saturn is just over 95 times as massive as Earth. Orange in colour, Saturn has remained famous for its slow motion. Its equatorial diameter is 119980 kilo meters (74552 miles) with a polar diameter of 107982 kilo meters (67097 miles) giving it a oval shape .The average distance between Saturn and the Sun is over 1.4 billion kilometers (9 AU). With an average orbital speed of 9.69 km/s, it takes Saturn 10,759 Earth days (or about 29½ years), to finish one revolution around the Sun. The elliptical orbit of Saturn is inclined 2.48° relative to the orbital plane of the Earth. Because of an eccentricity of 0.056, the distance between Saturn and the Sun varies by approximately 155 million kilometers between perihelion and aphelion, which are the nearest and most distant points of the planet along its orbital path, respectively. It takes 10 hours and 14 minutes to rotate around its axis. However the visible features on Saturn rotate at different rates depending on latitude. Multiple rotation periods have been assigned to various regions e.g. the axial motions other than its equator is relatively faster. The latest estimate of Saturn's rotation based on a compilation of various measurements from the *Cassini*, *Voyager* and *Pioneer* probes reported in September 2007, is 10 hours, 32 minutes, 35 seconds.

Saturn is classified as a gas giant planet because the exterior is predominantly composed of gas and it lacks a definite surface, although it may have a solid core. Saturn is the only planet of the Solar System that is less dense than water; about 30% less. Although Saturn's core is considerably denser than water, the average specific density of the planet is 0.69 g/cm^3 due to the gaseous atmosphere. A piece of any of its part will start floating in water. It is 95 times the mass of the Earth despite being 714 times larger in volume.



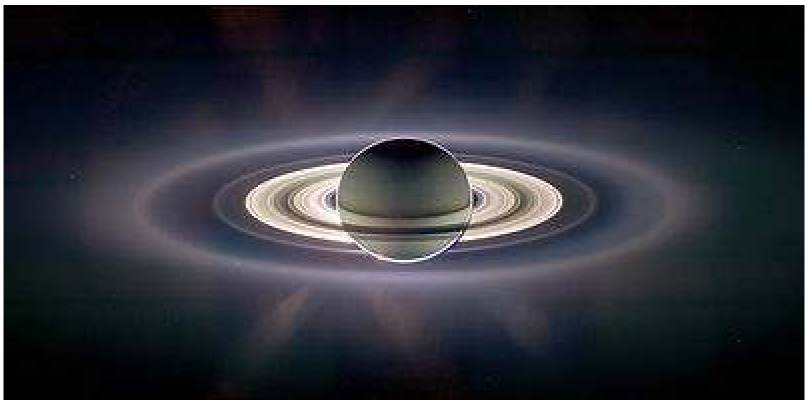
Montage comparing the sizes of Saturn and Earth.

Saturn's interior is probably composed of a core of iron, nickel and rock (silicon and oxygen compounds), surrounded by a deep layer of metallic hydrogen, an intermediate layer of liquid hydrogen and liquid helium and an outer gaseous layer. The planet exhibits a pale yellow hue due to ammonia crystals in its upper atmosphere. Electrical current within the metallic hydrogen layer is thought to give rise to Saturn's planetary magnetic field, which is slightly weaker than Earth's and around one-twentieth the strength of Jupiter's. The outer atmosphere is generally bland and lacking in contrast, although long-lived features can appear. Wind speeds on Saturn can reach 1,800 km/h (1,100 mph), faster than on Jupiter, but not as fast as those on Neptune.

Sixty-two known moons orbit the planet; fifty-three are officially named. This does not include the hundreds of "moonlets" within the rings. Titan, Saturn's largest and the Solar System's second largest moon is larger than the planet Mercury and is the only moon in the Solar System to retain a substantial atmosphere.

A montage of Saturn and its principalmoons (Dione, Tethys, Mimas, Enceladus,Rhea and Titan; Iapetus not shown). This famous image was created from photographs taken in November 1980 by the Voyager 1 spacecraft.

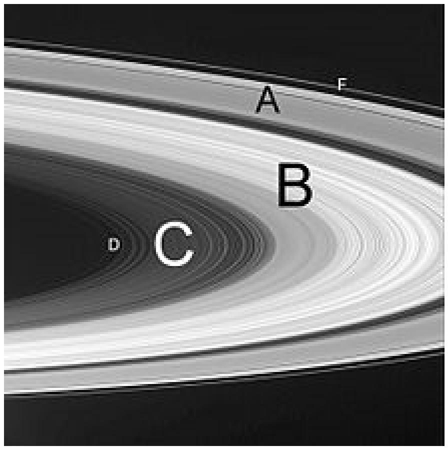
Saturn has a prominent ring system that consists of nine continuous main rings and three discontinuous arcs, composed mostly of ice particles with a smaller amount of rocky debris and dust. It is probably best known for the system of planetary rings that makes it visually unique. The rings extend from 6,630 km to 120,700 km above Saturn's equator, average approximately 20 meters in thickness and are composed of 93% water ice with traces oftholin impurities and 7% amorphous carbon. The particles that make up the rings range in size from specks of dust up to 10 m.



The full set of rings, imaged as Saturn eclipsed the Sun from the vantage of the Cassini spacecraft on 15 September 2006 (brightness is exaggerated). The "pale blue dot" at the 10 o'clock position, outside the main rings and just inside the G Ring, is Earth.

The rings have numerous gaps where particle density drops sharply: two opened by known moons embedded within them, and many others at locations of known destabilizing orbital resonances with Saturn's moons. Other gaps remain unexplained. Stabilizing resonances, on the other hand, are responsible for the longevity of several rings, such as the Titan Ringlet and the G Ring.

Well beyond the main rings is the Phoebe ring, which is tilted at an angle of 27 degrees to the other rings and, like Phoebe, orbits in retrograde fashion.



The rings are named alphabetically in the order they were discovered. The main rings are, working outward from the planet, C, B and A, with the Cassini Division, the largest gap, separating Rings B and A. Several fainter rings were discovered more recently. The D Ring is exceedingly faint and closest to the planet. The narrow F Ring is just outside the A Ring. Beyond that are two far fainter rings named G and E.

The outer atmosphere of Saturn contains 96.3% molecular hydrogen and 3.25% helium. The proportion of helium is significantly deficient compared to the abundance of this element in the Sun. The quantity of elements heavier than helium are not known precisely, but the proportions are assumed to match the primordial abundances from the formation of the Solar System. The total mass of these heavier elements is estimated to be 19–31 times the mass of the Earth, with a significant fraction located in Saturn's core region. The winds on Saturn are by far the fastest among the Solar System's planets. Voyager data indicate peak easterly winds of 500 m/s (1800 km/h).

A global storm girdles the planet in 2011. The head of the storm (bright area) passes the tail circling around the left limb.

Whereas temperatures on Saturn are normally −185 °C, temperatures on the vortex often reach as high as −122 °C, believed to be the warmest spot on Saturn.

Saturn has an intrinsic magnetic field that has a simple, symmetric shape—a magnetic dipole. Its strength at the equator is 0.2 gauss which is slightly weaker than Earth's magnetic field. Most probably, the magnetic field is generated similarly to that of Jupiter—by currents in the metallic-hydrogen layer called a metallic-hydrogen dynamo. This magnetosphere is efficient at deflecting the solar wind particles from the Sun. The moon Titan orbits within the outer part of Saturn's magnetosphere and contributes plasma from the ionized particles in Titan's outer atmosphere. Saturn's magnetosphere, like Earth's, produces auroras.

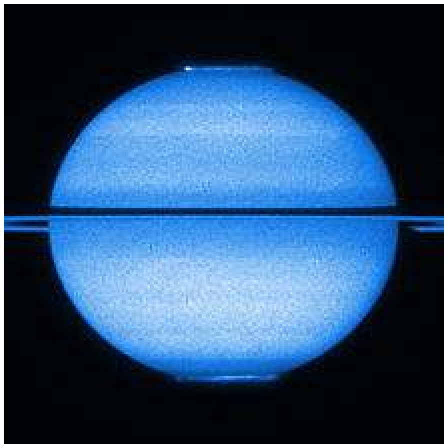


Image of Saturn taken near equinox showing both polar auroras.

The Uranus

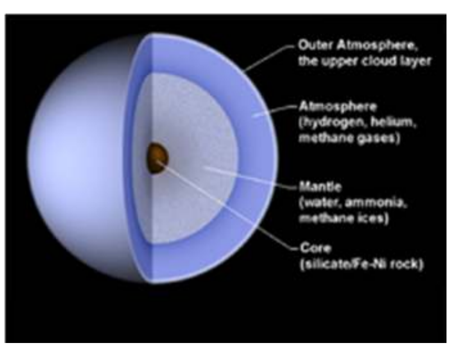
Uranus in 1986 by Voyager 2

Uranus is the seventh planet from the Sun. It has the third-largest planetary radius and fourth-largest planetary mass in the Solar System. It is named after the ancient Greek deity of the sky Uranus . Though it is visible to the naked eye like the five classical planets, it was never recognized as a planet by ancient observers because of its dimness and slow orbit. Ancient astronomers only focused on the five known planets. Sir William Herschel announced its discovery on March 13, 1781, expanding the known boundaries of the Solar System for the first time in modern history. Uranus was also the first planet discovered with a telescope. Sir William Herschel observed the planet on March 13, 1781 while in the garden of his house at 19 New King Street in the town of Bath, Somerset, England (now the Herschel Museum of Astronomy), but initially reported it (on April 26, 1781) as a "comet". Herschel decided to name the object *Georgium Sidus* (George's Star), or the "Georgian Planet" in honour of his patron, King George III. Herschel's proposed name was not popular outside of Britain, and alternatives were soon proposed. Ultimately it was switched from Georgium Sidus to Uranus the Latinized version of the Greek god of the sky, Ouranos, the father of Saturn.

Uranus revolves around the Sun once every 84 Earth years. Its average distance from the Sun is roughly 3 billion km (1783024658 miles). The intensity of sunlight on Uranus is about 1/400 that on Earth. Weight of the Uranus is 14.54 times more than the earth.

Mean density is 1.27 gm/ cm^3 with an equatorial surface gravity of 0.886 gm. Uranus has an axial tilt of 97.77 degrees, so its axis of rotation is approximately parallel with the plane of the Solar System. This gives it seasonal changes completely unlike those of the other major planets.

Although there is no well-defined solid surface within Uranus's interior, the outermost part of Uranus's gaseous envelope that is accessible to remote sensing is called its atmosphere. The composition of the Uranian atmosphere is different from the rest of the planet, consisting as it does mainly of molecular hydrogen and helium. The third most abundant constituent of the Uranian atmosphere is methane. Uranus is similar in composition to Neptune contains more "ices" such as water, ammonia and methane, along with traces of hydrocarbons. It is the coldest planetary atmosphere in the Solar System, with a minimum temperature of 49 K (−224 °C). It has a complex, layered cloud structure, with water thought to make up the lowest clouds, and methane thought to make up the uppermost layer of clouds. In contrast, the interior of Uranus is mainly composed of ices and rock. Uranus's internal heat appears markedly lower than that of the other giant planets; in astronomical terms, it has a low thermal flux.

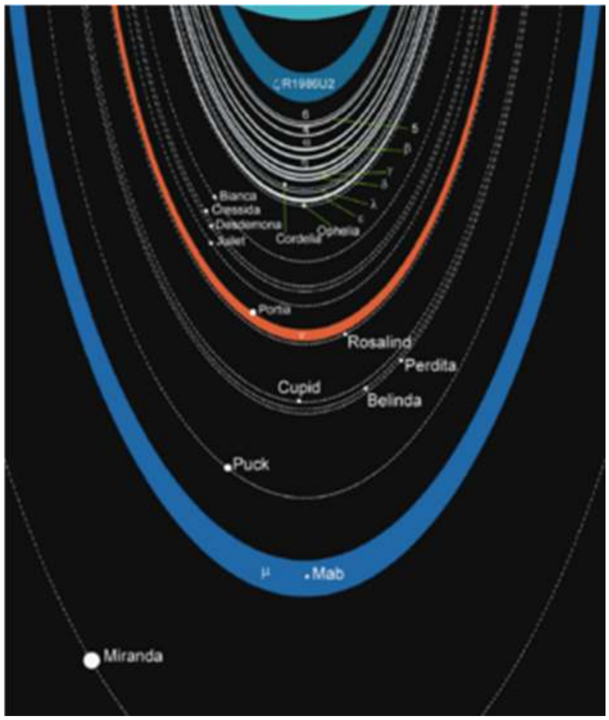


At ultraviolet and visible wavelengths, Uranus's atmosphere is remarkably bland in comparison to the other gas giants, even to Neptune, which it otherwise closely resembles. When *Voyager 2* flew by Uranus in 1986, it observed a total of ten cloud features across the entire planet. One proposed explanation for this dearth of features is that Uranus's internal heat appears markedly lower than that of the other giant planets. The lowest temperature recorded in Uranus's tropo pause is 49 K, making Uranus the coldest planet in the Solar System, colder than Neptune.

Uranus in 2005. Rings, southern collar and a bright cloud in the northern hemisphere are visible (HST ACS image).

Like the other giant planets, Uranus has a ring system, a magnetosphere, and numerous moons. The Uranian system has a unique configuration among the planets because its axis of rotation is tilted sideways, nearly into the plane of its revolution about the Sun. Its north and south poles therefore lie where most other planets have their equators. In 1986, images from *Voyager 2* showed Uranus as a virtually featureless planet in visible light without the cloud bands or storms associated with the other giants. Terrestrial observers have seen signs of seasonal change and increased weather activity in recent years as Uranus approached its equinox. The wind speeds on Uranus can reach 250 meters per second (900 km/h, 560 mph).

Uranus has a complicated planetary ring system, which was the second such system to be discovered in the Solar System after Saturn's. The rings are composed of extremely dark particles, which vary in size from micrometers to a fraction of a meter. Thirteen distinct rings are presently known, the brightest being the ε ring. All except two rings of Uranus are extremely narrow—they are usually a few kilometers wide.



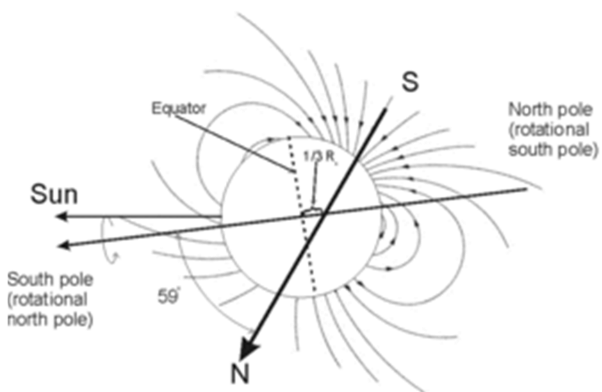
. *Solid lines denote rings; dashed lines denote orbits of moons.*

The rings of Uranus were discovered on March 10, 1977. By 1978, nine distinct rings were identified. Two additional rings were discovered in 1986 in images taken by the *Voyager 2* spacecraft, and two outer rings were found in 2003–2005 in Hubble Space Telescope photos. As currently understood, the ring system of Uranus comprises of thirteen distinct rings. The majority of these rings are opaque and only a few kilometers wide. The ring system contains little dust overall; it consists mostly of large bodies 0.2–20 m in diameter.

Uranus inner rings. The bright outer ring is the epsilon ring; eight other rings are visible.

Before the arrival of *Voyager 2*, no measurements of the Uranian magnetosphere had been taken, so its nature remained a mystery. Before 1986, astronomers had expected the magnetic field of Uranus to be in line with the solar wind, since it would then align with the planet's poles that lie in the ecliptic.

Voyager's observations revealed that the magnetic field is peculiar, both because it does not originate from the planet's geometric center, and because it is tilted at 59° from the axis of rotation. In fact the magnetic dipole is shifted from the center of the planet towards the south rotational pole by as much as one third of the planetary radius. This unusual geometry results in a highly asymmetric magnetosphere, where the magnetic field strength on the surface in the southern hemisphere can be as low as 0.1 gauss (10 μT), whereas in the northern hemisphere it can be as high as 1.1 gauss (110 μT). The average field at the surface is 0.23 gauss (23 μT).



The magnetic field of Uranus as observed by Voyager 2 in 1986. S and N are magnetic south and north poles.

Uranus has 27 known natural satellites or moons. The names for these satellites are chosen from characters from the works of Shakespeare and Alexander Pope. The five main satellites are Miranda, Ariel, Umbriel, Titania and Oberon. The Uranian satellite system is the least massive among the gas giants. The moons are ice-rock conglomerates composed of roughly fifty percent ice and fifty percent rock. The ice may include ammonia and carbon dioxide.

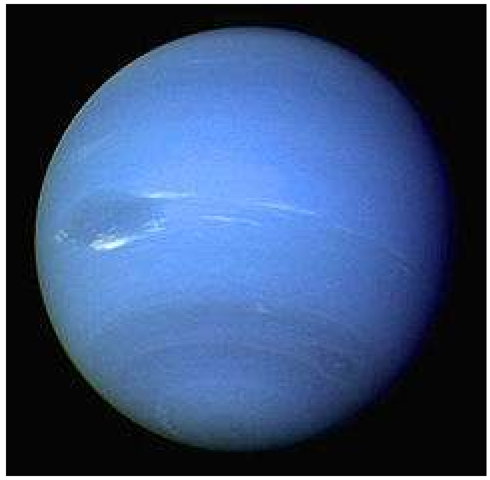
Uranus and its six largest moons compared at their proper relative sizes and relative positions. From left to right: Puck, Miranda, Ariel, Umbriel, Titania, and Oberon.

Among the satellites, Ariel appears to have the youngest surface with the fewest impact craters, while Umbriel's appears oldest. Miranda possesses fault canyons 20 kilometres deep, terraced layers, and a chaotic variation in surface ages and features. Miranda's past geologic activity is believed to have been driven by tidal heating at a time when its orbit was more eccentric than currently.

In 1986, NASA's *Voyager 2* interplanetary probe encountered Uranus. This flyby remains the only investigation of the planet carried out from a short distance, and no other visits are currently planned. Launched in 1977, *Voyager 2* made its closest approach to Uranus on January 24, 1986, coming within 81,500 kilometres of the planet's cloud tops, before continuing its journey to Neptune. *Voyager 2* studied the structure and chemical composition of Uranus's atmosphere, including the planet's unique weather, caused by its axial tilt of 97.77°. It made the first detailed investigations of its five largest moons, and discovered 10 new moons. It examined all nine of the system's known rings and discovered two new ones. It also studied the magnetic field, its irregular structure, its tilt and its unique corkscrew magneto tail caused by Uranus's sideways orientation.

Crescent Uranus as imaged by Voyager 2 while departing for Neptune

The Neptune



Neptune from Voyager 2 with Great Dark Spot at left

Neptune is the eighth and farthest planet from the Sun in the Solar System. It is the fourth-largest planet by diameter and the third largest by mass. Neptune is 17 times the mass of Earth and is somewhat more massive than its near-twin Uranus, which is 15 times the mass of Earth but not as dense. On average, Neptune orbits the Sun at a distance of 30.1 AU, approximately 30 times the Earth–Sun distance. It was named after the Roman god of the sea. Neptune was the first planet found by mathematical prediction rather than by empirical observation. A vivid manifestation of the Quranic verse:-

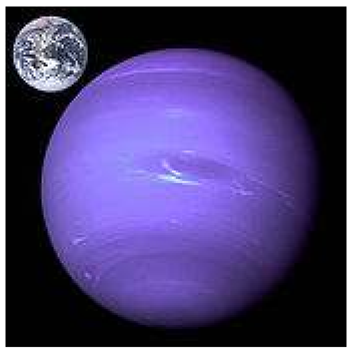
الشَّمْسُ وَالْقَمَرُ بِحُسْبَانٍ

(The sun and the moon are (bound) by a (fixed) calculation. Ar Rahman -5)

Neptune has been visited by only one spacecraft, *Voyager 2*, which flew by the planet on August 25, 1989.

In 1843, John Couch Adams began work on the orbit of Uranus using the data in his possession. He requested extra details from Sir George Airy, the Astronomer Royal, who supplied it in February 1844. Adams continued to work in 1845–46 and produced several different estimates of a new planet. In 1845–46, Urbain Le Verrier, working independently of Adams, developed his own calculations but also experienced difficulties in stimulating any enthusiasm in his compatriots. In June 1846, upon seeing Le Verrier's first published estimate of the planet's longitude and its similarity to Adams's estimate, Airy persuaded Cambridge Observatory director James Challis to search for the planet. Challis vainly scoured the sky throughout August and September.

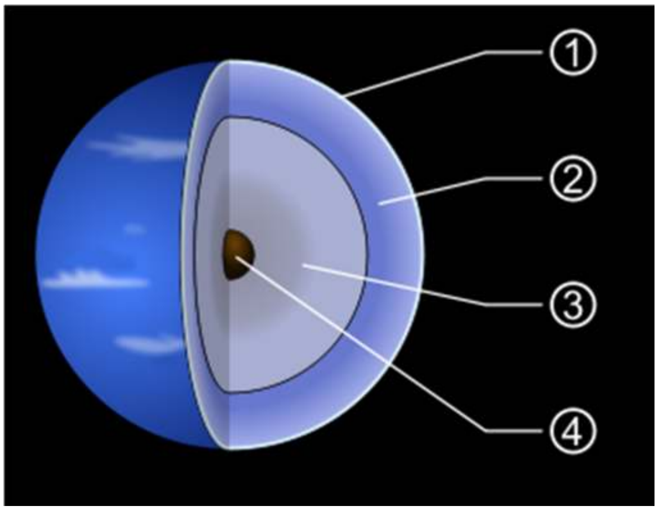
Meantime, Le Verrier by letter urged Berlin Observatory astronomer Johann Gottfried Galle to search with the observatory's refractor. Heinrich d' Arrest, a student at the observatory, suggested to Galle that they could compare a recently drawn chart of the sky in the region of Le Verrier's predicted location with the current sky to seek the displacement characteristic of a planet, as opposed to a fixed star. The very evening of the day of receipt of Le Verrier's letter on September 23, 1846, Neptune was discovered within 1° of where Le Verrier had predicted it to be, and about 12° from Adams' prediction. In the wake of the discovery, there was much nationalistic rivalry between the French and the British over who had priority and deserved credit for the discovery. Eventually an international consensus emerged that both Le Verrier and Adams jointly deserved credit. Shortly after its discovery, Neptune was referred to simply as "the planet exterior to Uranus" or as "Le Verrier's planet". The first suggestion for a name came from Galle, who proposed the name *Janus*. In England, Challis put forward the name *Oceanus*. Claiming the right to name his discovery, Le Verrier quickly proposed the name *Neptune* for this new planet which was accepted and adopted internationally.



A size comparison of Neptune and Earth

Neptune is similar in composition to Uranus, and both have compositions which differ from those of the larger gas giants, Jupiter and Saturn. Neptune's atmosphere, while similar to Jupiter's and Saturn's in that it is composed primarily of hydrogen and helium, along with traces of hydrocarbons and possibly nitrogen, contains a higher proportion of "ices" such as water, ammonia and methane. Astronomers sometimes categorize Uranus and Neptune as "ice giants" in order to emphasize these distinctions. The interior of Neptune, like that of Uranus, is primarily composed of ices and rock. Traces of methane in the outermost regions in part account for the planet's blue appearance. In size it 57.74 times bigger than the Earth but weighing only 17.147 times more because of it low density which is only 0.297 % of earth's density. Equatorial diameter is 24766 kilometers. The average distance between Neptune and the Sun is 4.50 billion km (about 30.1 AU), and it completes an orbit on average every 164.79 years, subject to a variability of around ±0.1 years. The elliptical orbit of Neptune is inclined 1.77° compared to the Earth. Because of an eccentricity of 0.011, the distance between Neptune and the Sun varies by 101 million km between perihelion and aphelion, the nearest and most distant points of the planet from the Sun along the orbital path, respectively. Neptune is never visible to the naked eye, having a brightness between magnitudes +7.7 and +8.0.

The axial tilt of Neptune is 28.32°, which is similar to the tilts of Earth (23°) and Mars (25°). As a result, this planet experiences similar seasonal changes. The long orbital period of Neptune means that the seasons last for forty Earth years. Its sidereal rotation period (day) is roughly 16.11 hours. Since its axial tilt is comparable to the Earth's, the variation in the length of its day over the course of its long year is not any more extreme.

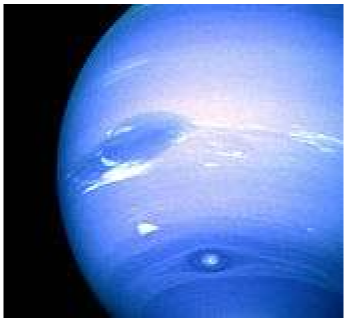


The internal structure of Neptune.

1. Upper atmosphere, top clouds.
2. Atmosphere consisting of hydrogen, helium and methane gas
3. Mantle consisting of water, ammonia and methane ices
4. Core consisting of rock (silicates and nickel-iron)

Neptune's internal structure resembles that of Uranus. Its atmosphere forms about 5% to 10% of its mass and extends perhaps 10% to 20% of the way towards the core, where it reaches pressures of about 10 GPa. Increasing concentrations of methane, ammonia and water are found in the lower regions of the atmosphere. The mantle reaches temperatures of 2,000 K to 5,000 K. It is equivalent to 10 to 15 Earth masses and is rich in water, ammonia and methane. The core of Neptune is composed of iron, nickel and silicates, with an interior model giving a mass about 1.2 times that of the Earth. The pressure at the centre is 7 Mbar (700 GPa), millions of times more than that on the surface of the Earth, and the temperature may be 5,400 K.

At high altitudes, Neptune's atmosphere is 80% hydrogen and 19%helium. Neptune's weather is characterized by extremely dynamic storm systems, with winds reaching speeds of almost 600 m/s—nearly attaining supersonic flow. More typically, by tracking the motion of persistent clouds, wind speeds have been shown to vary from 20 m/s in the easterly direction to 325 m/s westward. At the cloud tops, the prevailing winds range in speed from 400 m/s along the equator to 250 m/s at the poles. Most of the winds on Neptune move in a direction opposite the planet's rotation. In 2007 it was discovered that the upper troposphere of Neptune's South Pole was about 10 °C warmer than the rest of Neptune, which averages approximately −200 °C (70 K). In 1989, the Great Dark Spot, an anti-cyclonic storm system spanning 13000×6600 km, was discovered by NASA's *Voyager 2*spacecraft. The storm resembled the Great Red Spot of Jupiter. Some five years later, on November 2, 1994, the Hubble Space Telescope did not see the Great Dark Spot on the planet. Instead, a new storm similar to the Great Dark Spot was found in the planet's northern hemisphere.



The Great Dark Spot (top), Scooter (middle white cloud) and the Small Dark Spot (bottom), with contrast exaggerated.

Neptune has 13 known moons. The largest by far, comprising more than 99.5% of the mass in orbit around Neptune and the only one massive enough to be a spheroid in shape, is Triton. In 1989, Triton was the coldest object that had yet been measured in the solar system,with estimated temperatures of −235 °C (38 K).

Neptune (top) and Triton (bottom).

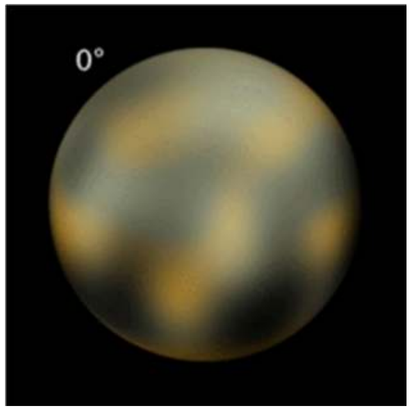
Natural colour view of Neptune with Proteus (top), Larissa (lower right) and Despina (left), from the Hubble Space Telescope

In Voyager 2's last planetary encounter, the spacecraft swooped only 3,000 miles above Neptune's north pole, the closest approach it made to any celestial body since it left Earth. Voyager 2 studied Neptune's atmosphere, Neptune's rings, its magnetosphere, and Neptune's moons. Several discoveries were made, including the discovery of the Great Dark Spot and Triton's geysers. The spacecraft verified the existence of a magnetic field surrounding the planet and discovered that the field was offset from the centre and tilted in a manner similar to the field around Uranus. The question of the planet's rotation period was settled using measurements of radio emissions.

Voyager 2 spacecraft

Voyager 2 also showed that Neptune had a surprisingly active weather system. Six new moons were discovered, and the planet was shown to have more than one ring.

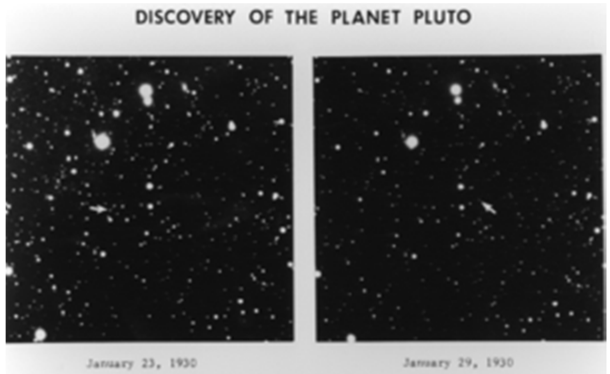
The Pluto



Pluto is considered to be the last known planet of the solar system. Pluto, formal designation 134340 Pluto, is the second-most-massive known dwarf planet in the Solar System (after Eris) and the tenth-most-massive body observed directly orbiting the Sun. Originally classified as the ninth planet from the Sun, Pluto was re categorized as a dwarf planet owing to the discovery that it is only one of several large bodies within the Kuiper belt.

Like other members of the Kuiper belt, Pluto is composed primarily of rock and ice and is relatively small, approximately one-sixth the mass of the Earth's Moon and one-third its volume. It has an eccentric and highly inclined orbit that takes it from 30 to 49 AU (4.4–7.4 billion km) from the Sun. This causes Pluto to periodically come closer to the Sun than Neptune. As of 2011, it is 32.1 AU from the Sun.

Following the discovery of the planet Neptune in 1846, there was considerable speculation that another planet might exist beyond its orbit. The search began in the mid-19th century and culminated at the start of the 20th with Percival Lowell's quest for Planet X. Lowell proposed the Planet X hypothesis to explain apparent discrepancies in the orbits of the gas giants, particularly Uranus and Neptune, speculating that the gravity of a large unseen ninth planet could have perturbed Uranus enough to account for the irregularities.

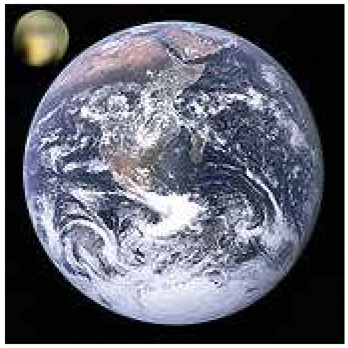


Discovery photographs of Pluto

Clyde Tombaugh's discovery of Pluto in 1930 appeared to validate Lowell's hypothesis. Pluto was officially considered the ninth planet until 2006. In 1978, Pluto was found to be too small for its gravity to affect the gas giants, resulting in a brief search for a tenth planet. The search was largely abandoned in the early 1990s, when a study of measurements made by the *Voyager 2* spacecraft found that the irregularities observed in Uranus's orbit were due to a slight overestimation of Neptune's mass. After 1992, the discovery of numerous small icy objects with similar or even wider orbits than Pluto led to a debate over whether Pluto should remain a planet, or whether it and its neighbours should, like the asteroids, be given their own separate classification. Although a number of the larger members of this group were initially described as planets, in 2006 the International Astronomical Union reclassified Pluto and its largest neighbours as dwarf planets, leaving only eight planets in the Solar System. Today, the astronomical community widely agrees that Planet X, as originally envisioned, does not exist, but the concept of Planet X has been revived by a number of astronomers to explain other anomalies observed in the outer Solar System. In popular culture, and even among some astronomers, *Planet X* has become a stand-in term for any undiscovered planet in the outer Solar System, regardless of its relationship to Lowell's hypothesis. Other trans-Neptunian planets have also been suggested, based on different evidence.

From its discovery in 1930 until 2006, Pluto was classified as a planet. In the late 1970s, following the discovery of minor planet 2060 Chiron in the outer Solar System and the recognition of Pluto's relatively low mass, its status as a major planet began to be questioned. In the late 20th and early 21st centuries, many objects similar to Pluto were discovered in the outer Solar System, notably the scattered disc object Eris in 2005, which is 27% more massive than Pluto. On August 24, 2006, the International Astronomical Union (IAU) defined what it means to be a "planet" within the Solar System. This definition excluded Pluto as a planet and added it as a member of the new category "dwarf planet" along with Eris and Ceres. After the reclassification, Pluto was added to the list of minor planets and given the number 134340. A number of scientists hold that Pluto should continue to be classified as a planet, and that other dwarf planets should be added to the roster of planets along with Pluto.

Pluto's mass is 1.31×10^{22} kg, less than 0.24 percent that of the Earth, while its diameter is 2,306 (± 20) km, or roughly 66% that of the Moon. Pluto's atmosphere complicates determining its true solid size within a certain margin. The Earth weighs four hundred times more than the Pluto.



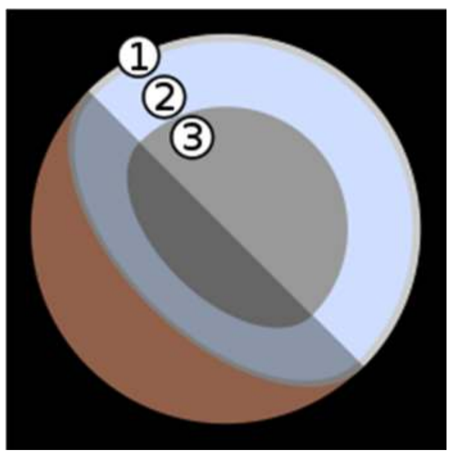
Pluto's atmosphere consists of a thin envelope of nitrogen, methane, and carbon monoxide gases, which are derived from the ices of these substances on its surface. Its surface pressure ranges from 6.5 to 24 μ bar. Pluto's elongated orbit is predicted to have a major effect on its atmosphere: as Pluto moves away from the Sun its atmosphere gradually freezes out.

Artist's vision of Pluto's surface. Image: NASA

When it is closer to the Sun, the temperature increases, causing the ices to sublimate into gas. This creates an anti-greenhouse effect; much as sweat cools the body as it evaporates from the surface of the skin, this sublimation cools the surface of Pluto. Scientists have recently discovered that Pluto's temperature is about 43 K (−230 °C), 10 K colder than would otherwise be expected. The presence of methane, a powerful greenhouse gas, in Pluto's atmosphere creates a temperature inversion, with average temperatures 36 K warmer 10 km above the surface. The lower atmosphere contains a higher concentration of methane than its upper atmosphere.

CRIRES model-based computer-generated impression of the Plutonian surface, with atmospheric haze, and Charon and the Sun in the sky.

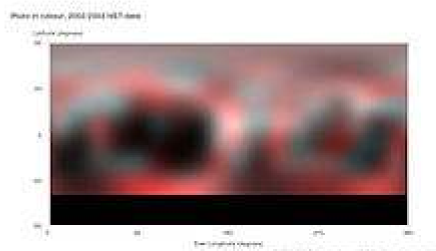
Observations by the Hubble Space Telescope place Pluto's density at between 1.8 and 2.1 g/cm^3, suggesting its internal composition consists of roughly 50–70 percent rock and 30–50 percent ice by mass.



Theoretical structure of Pluto (2006)
1. *Frozen nitrogen*
2. *Water ice*
3. *Rock*

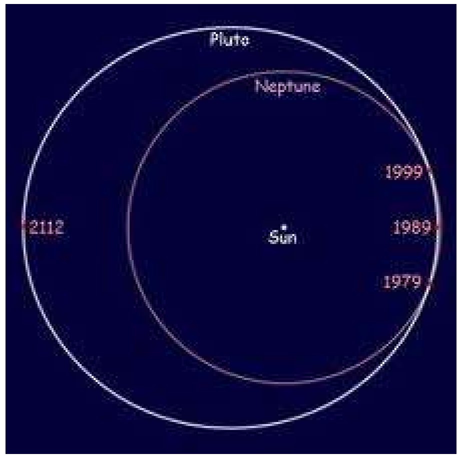
Because decay of radioactive minerals would eventually heat the ices enough for the rock to separate from them, scientists expect that Pluto's internal structure is differentiated, with the rocky material having settled into a dense core surrounded by a mantle of ice. The diameter of the core should be around 1,700 km, 70% of Pluto's diameter. Pluto's distance from Earth makes in-depth investigation difficult. Many details about Pluto will remain unknown until 2015, when the New Horizons spacecraft is expected to arrive there

Pluto's visual apparent magnitude averages 15.1 brightening to 13.65 at perihelion. A telescope is required to see it. It looks star-like and without a visible disk even in large telescopes, because the short angular diameter.



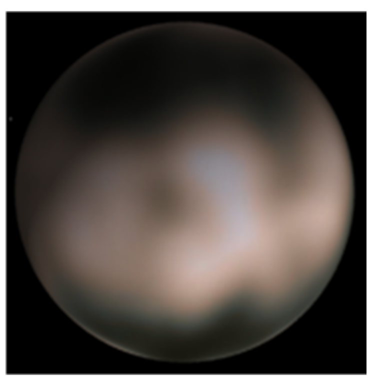
Hubble map of Pluto's surface, showing great variations in colour

Pluto's rotation period, its day, is equal to 6.39 Earth days. Like Uranus, Pluto rotates on its "side" on its orbital plane, with an axial tilt of 120°, and so its seasonal variation is extreme; at its solstices, one-fourth of its surface is in continuous daylight, while another fourth is in continuous darkness. Pluto's orbital period is 248 Earth years. Its orbital characteristics are substantially different from those of the other planets, which follow nearly circular orbits around the Sun close to a flat reference plane called the ecliptic. In contrast, Pluto's orbit is highly inclined relative to the ecliptic (over 17°) and highly eccentric (elliptical). In the long term Pluto's orbit is in fact chaotic. While computer simulations can be used to predict its position for several million years (both forward and backward in time), after longer intervals calculations become speculative: Pluto's tiny size makes it sensitive to measurement of small details of the Solar System.



Despite Pluto's orbit appearing to cross that of Neptune when viewed from directly above, the two objects' orbits are aligned so that they can never collide or even approach closely. The 3:2 resonance between the two bodies is highly stable, and is preserved over millions of years. This prevents their orbits from changing relative to one another; the cycle always repeats in the same way, and so the two bodies can never pass near to each other. Thus, even if Pluto's orbit were not highly inclined the two bodies could never collide. This is how it has been ordained by Allah Almighty.

Neither it is for the sun to overtake the moon, nor can the night outpace the day. Each one is floating in an orbit.   Al Quran, Ya Seen – 40



The surface of Charon

Charon is the largest satellite of the dwarf planet Pluto. It was discovered in 1978 at the United States Naval Observatory Flagstaff Station (NOFS). Following the 2005 discovery of two other natural satellites of Pluto (Nix and Hydra), in 2011, a fourth, S/2011 P 1, and on July 11, 2012, a fifth satellite S/2012 P 1, Charon may also be referred to as Pluto I. The *New Horizons* mission is scheduled to visit Charon and Pluto in July 2015. Charon's diameter is about 1,207 kilometres (750 mi), just over half that of Pluto, with a surface area of 4,580,000 square kilometres (1,770,000 sq miles). Unlike Pluto, the Charonian surface appears to be dominated by less volatile water ice, and also appears to have no atmosphere. Charon and Pluto revolve about each other every 6.387 days. The two objects are gravitationally locked, so each keeps the same face towards the other. The average distance between Charon and Pluto is 19,570 kilometres (12,160 miles).

Artist's concept of Charon seen from the surface of Pluto.

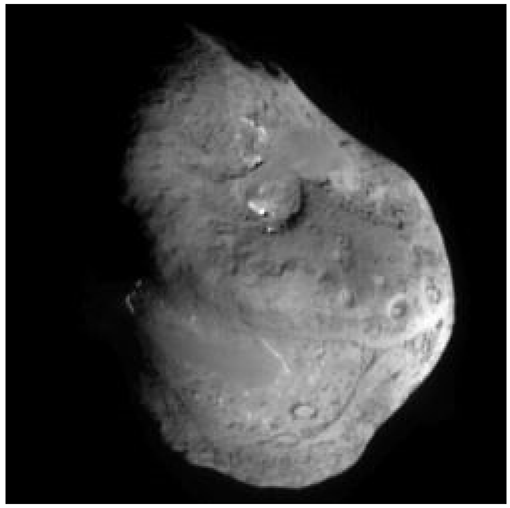
Two additional moons of Pluto were imaged by astronomers working with the Hubble Space Telescope on May 15, 2005, and received provisional designations of S/2005 P 1 and S/2005 P 2. The International Astronomical Union officially named Pluto's newest moons Nix (or Pluto II, the inner of the two moons, formerly P 2) and Hydra (Pluto III, the outer moon, formerly P 1), on June 21, 2006. These small moons orbit Pluto at approximately two and three times the distance of Charon: Nix at 48,700 kilometers and Hydra at 64,800 kilometers.

Comets

A comet is an icy small Solar System body (SSSB) that when close enough to the Sun, displays a visible coma (a thin, fuzzy, temporary atmosphere) and sometimes also a tail. The word *comet* derives from the Latin word cometes. These phenomena are both due to the effects of solar radiation and the solar wind upon the nucleus of the comet. Comet nuclei range from a few hundred meters to tens of kilometers across and are composed of loose collections of ice, dust, and small rocky particles. Comets have been observed since ancient times.

Comets have a wide range of orbital periods, ranging from a few years to hundreds of thousands of years. Short-period comets originate in the Kuiper belt, or its associated scattered disc, which lie beyond the orbit of Neptune. Longer-period comets are thought to originate in the Oort cloud, a hypothesized spherical cloud of icy bodies in the outer Solar System. Long-period comets plunge towards the Sun from the Oort cloud because of gravitational perturbations caused by either the massive outer planets of the Solar System (Jupiter, Saturn, Uranus, and Neptune), or passing stars.

Comets are distinguished from asteroids by the presence of a coma or a tail. However, extinct comets that have passed close to the Sun many times have lost nearly all of their volatile ices and dust and may come to resemble small asteroids. As of January 2011 there are a reported 4,185 known comets of which about 1,500 are Kreutz Sun grazers and about 484 are short-period. This number is steadily increasing. However, this represents only a tiny fraction of the total potential comet population: the reservoir of comet-like bodies in the outer Solar System may number one trillion. The number visible to the naked eye averages roughly one per year, though many of these are faint and unspectacular. Particularly bright or notable examples are called "Great Comets".



The nucleus of Comet Tempel 1.

The nucleus is the solid, central part of a comet, popularly termed a *dirty snowball*. A cometary nucleus is composed of rock, dust, and frozen gases. When heated by the Sun, the gases sublimate and produce an atmosphere surrounding the nucleus known as the coma. The force exerted on the coma by the Sun's radiation pressure and solar wind cause an enormous tail to form, which points away from the Sun. The nucleus of some comets may be fragile. Most cometary nuclei are thought to be no more than about 10 miles (16 kilometers) across.

The comet Ikeya-Zhang exhibiting a bright, condensed coma (March 2002)

In astronomy, a coma is the nebulous envelope around the nucleus of a comet. It is formed when the comet passes close to the Sun on its highly elliptical orbit; as the comet warms, parts of it sublimate. This gives a comet a "fuzzy" appearance when viewed in telescopes and distinguishes it from stars.

The coma is generally made of ice and dust. Water dominates up to 90% of the volatiles that outflow from the nucleus when the comet is within 3-4 AU of the Sun. Larger dust particles are left along the comet's orbital path while smaller particles are pushed away from the Sun into the comet's tail by light pressure. Both the coma and tail are illuminated by the Sun and may become visible from Earth when a comet passes through the inner Solar System, the dust reflecting sunlight directly and the gases glowing from ionization. Most comets are too faint to be visible without the aid of a telescope, but a few each decade become bright enough to be visible to the naked eye. Occasionally a comet may experience a huge and sudden outburst of gas and dust, during which the size of the coma temporarily greatly increases. This happened in 2007 to Comet Holmes. The streams of dust and gas each form their own distinct tail, pointing in slightly different directions. The tail of dust is left behind in the comet's orbit in such a manner that it often forms a curved tail.

While hundreds of tiny comets pass through the inner Solar System every year, very few are noticed by the general public. About every decade or so, a comet becomes bright enough to be noticed by a casual observer—such comets are often designated Great Comets. In times past, bright comets often inspired panic and hysteria in the general population, being thought of as bad omens. More recently, during the passage of Halley's Comet in 1910, the Earth passed through the comet's tail, and erroneous newspaper reports inspired a fear that cyanogen in the tail might poison millions, while the appearance of Comet Hale–Bopp in 1997 triggered the mass suicide of the Heaven's Gate cult.

Predicting whether a comet will become a great comet is notoriously difficult, as many factors may cause a comet's brightness to depart drastically from predictions. Broadly speaking, if a comet has a large and active nucleus, will pass close to the Sun, and is not obscured by the Sun as seen from the Earth when at its brightest, it has a chance of becoming a great comet. However, Comet Kohoutek in 1973 fulfilled all the criteria and was expected to become spectacular, but failed to do so. Comet West, which appeared three years later, had much lower expectations (perhaps because scientists were much warier of glowing predictions after the Kohoutek fiasco), but became an extremely impressive comet.

Great Comets of the past two millennia include the following:

- Caesar's Comet – 44 BC
- Halley's Comet – 1066
- Great Comet of 1106
- Great Comet of 1264
- Great Comet of 1402
- Great Comet of 1556
- Great Comet of 1577
- Great Comet of 1680
- Great Comet of 1744
- Great Comet of 1811

- Great Comet of 1843
- Donati's Comet – 1858
- Great Comet of 1861
- Great Comet of 1882
- Great Daylight Comet of 1910
- Halley's Comet – 1910
- Comet Skjellerup–Maristany – 1927
- Comet Arend–Roland – 1957
- Comet Ikeya–Seki – 1965
- Comet Bennett – 1970
- Comet West – 1976
- Comet Hyakutake – 1996
- Comet Hale–Bopp – 1997
- Comet McNaught – 2007
- Comet Lovejoy – 2011

The late 20th century saw a lengthy gap without the appearance of any great comets, followed by the arrival of two in quick succession—Comet Hyakutake in 1996, followed by Hale–Bopp, which reached maximum brightness in 1997 having been discovered two years earlier. The first great comet of the 21st century was C/2006 P1 (McNaught), which became visible to naked eye observers in January 2007. It was the brightest in over 40 years.

Halley's Comet on March 8, 1986

Halley's Comet officially designated 1P/Halley) is the best-known of the comets. It is visible from Earth every 75–76 years. Halley is the only short-period comet that is clearly visible to the naked eye from Earth, and thus the only naked-eye comet that might appear twice in a human lifetime. Other naked-eye comets may be brighter and more spectacular, but will appear only once in thousands of years. The comet's periodicity was first determined in 1705 by English astronomer Edmond Halley, after whom it is now named. Halley's Comet last appeared in the inner Solar System in 1986 and will next appear in mid-2061.

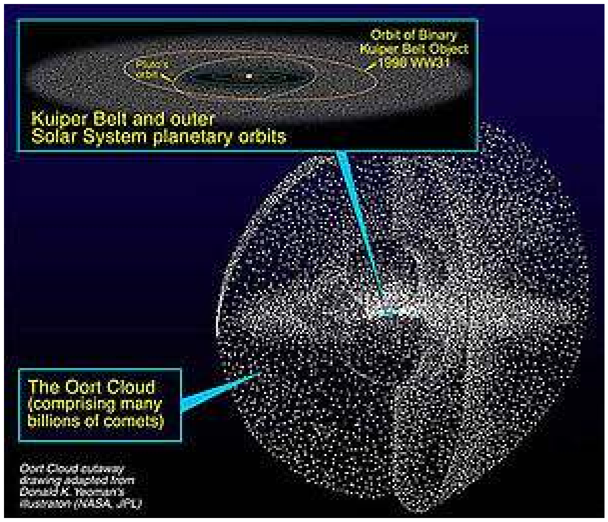
Kreutz Sun grazer with a prominent tail, plunging towards the Sun

A sun grazing comet is a comet that passes extremely close to the Sun at perihelion – sometimes within a few thousand kilometers of the Sun's surface. While small sun grazers can be completely evaporated during such a close approach to the Sun, larger sun grazers can survive many perihelion passages. However, the strong evaporation and tidal forces they experience often lead to their fragmentation. The most famous sun grazers are the Kreutz Sun grazers, which all originate from one giant comet that broke up into many smaller comets during its first passage through the inner Solar System. An extremely bright comet seen by Aristotle and Ephorus in 371 BC is a possible candidate for this parent comet.

The Great Comets of 1843 and 1882, and Comet Ikeya–Seki in 1965 were all fragments of the original comet. Each of these three was briefly bright enough to be visible in the daytime sky, next to the Sun, outshining even the full moon. In 1979, C/1979 Q1 (SOLWIND) was the first sun grazer to be spotted by US satellite P78-1, in corono graphs taken on 30 and 31 Aug 1979.

Since the launch of the SOHO satellite in 1995, hundreds of tiny Kreutz Sun grazers have been discovered, all of which have either plunged into the Sun or been destroyed completely during their perihelion passage, with the exception of C/2011 W3 (Lovejoy). The Kreutz family of comets is apparently much larger than previously suspected.

About 83% of the sun grazers observed with SOHO are members of the Kreutz group. The other 17% contains some sporadic sun grazers, but three other related groups of comets have been identified among them: the Kracht, Marsden and Meyer groups.



An artist's rendering of the Oort cloud and the Kuiper belt (inset). Sizes of individual objects have been exaggerated for visibility.

The Oort cloud is a hypothesized spherical cloud of comets which may lie roughly nearly a light-year, from the Sun. This places the cloud at nearly a quarter of the distance to Proxima Centauri, the nearest star to the Sun. The Kuiper belt and the scattered disc, the other two reservoirs of trans-Neptunian objects, are less than one thousandth of the Oort cloud's distance. The outer limit of the Oort cloud defines the cosmographical boundary of the Solar System and the region of the Sun's gravitational dominance.

The Oort cloud is thought to comprise two separate regions: a spherical outer Oort cloud and a disc-shaped inner Oort cloud, or Hills cloud. Objects in the Oort cloud are largely composed of ices, such as water, ammonia, and methane.

Asteroids & Meteorites

A meteorite is a natural object originating in outer space that survives impact with the Earth's surface. A meteorite's size can range from small to extremely large. Most meteorites derive from small astronomical objects called meteoroids, but they are also sometimes produced by impacts of asteroids. When a meteoroid enters the atmosphere, frictional, pressure, and chemical interactions with the atmospheric gasses cause the body to heat up and emit light, thus forming a fireball, also known as a meteor or shooting/falling star. These are neither planets nor moons of a planet. The bigger ones can have a diameter up to a thousand meters while the other can be as small as a sand particle.

Most of them are destroyed on impact with the Earth's atmosphere. Sometime the un burnt part called a tektites fall to the earth's surface creating havoc.

Willamette Meteorite discovered in the U.S. state of Oregon

Scientists have estimated that a meteorite fell to the Earth about sixty to seventy million years ago causing total extinction of the dinosaurs, petroleum and hydrocarbons. As of February 2010, there are approximately 1,086 witnessed falls having specimens in the world's collections. In contrast, there are over 38,660 well-documented meteorite finds.

Most meteoroids disintegrate when entering Earth's atmosphere. However, an estimated 500 meteorites ranging in size from marbles to basketballs or larger do reach the surface each year only 5 or 6 of these are typically recovered and made known to scientists.

Tektites

Few meteorites are large enough to create large impact craters. Instead, they typically arrive at the surface at their terminal velocity and, at most, create a small pit. Even so, falling meteorites have reportedly caused damage to property and injuries to livestock and people. Large meteoroids may strike the ground with a significant fraction of their cosmic velocity, leaving behind a big impact crater. The kind of crater will depend on the size, composition, degree of fragmentation and angle of the impact. The force of such collisions has the potential to cause widespread destruction.

Meteor Crater, also known as Barringer Crater.

Wolfe Creek Meteor Crater.

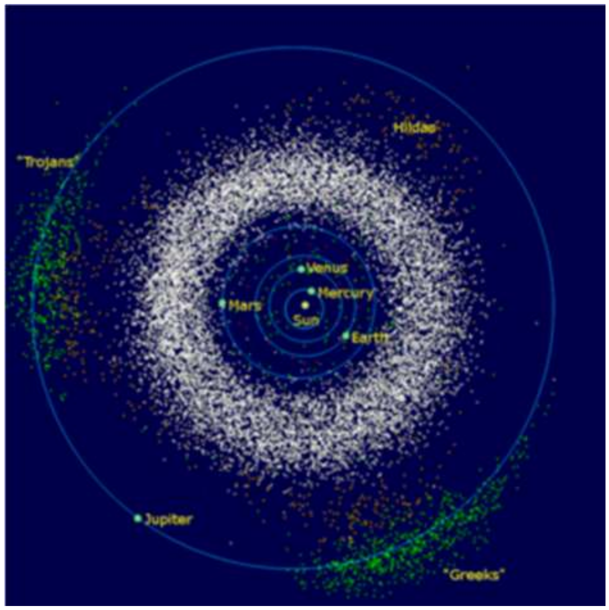
The most frequent hypervelocity cratering events on the Earth are caused by iron meteoroids, which are most easily able to transit the atmosphere intact. The Tunguska event was an enormously powerful explosion that occurred near the

The Southern swamp—the epicentre of the Tunguska explosion.

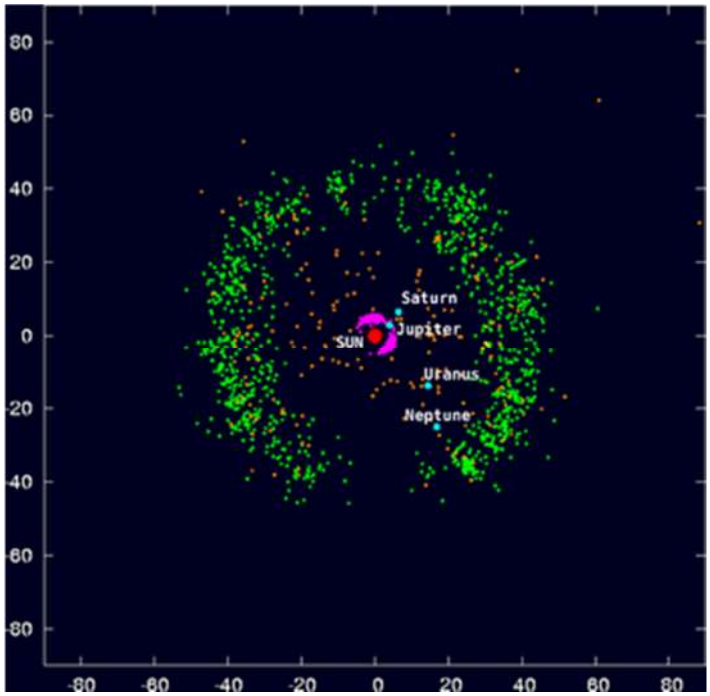
Podkamennaya Tunguska River in what is now Krasnoyarsk Krai, Russia, at about 7:14 a.m. KRAT (0:14 UT) on June 30, 1908. The explosion, having the epicentre (60.886°N, 101.894°E), is believed to have been caused by the air burst of a large meteoroid or comet fragment at an altitude of 5–10 kilometres (3–6 miles) above the Earth's surface. Different studies have yielded widely varying estimates of the object's size, on the order of 100 metres (330 ft). It is the largest impact event on or near Earth in recorded history.

Meteorite find in situ in the desert Rub' al Khali, Saudi Arabia.

The idea that an undiscovered planet could exist between the orbits of Mars and Jupiter was suggested by Johann Elert Bode in 1772. Bode's considerations were based on the Titius–Bode law, observing that there was a regular pattern in the semi-major axes of the known planets marred only by the large gap between Mars and Jupiter. The pattern predicted that the missing planet ought to have a semi-major axis near 2.8 AU. Instead of a star a moving star-like object, this was named Ceres. In the meantime, after the discovery of another asteroid Pallas in 1802 the second asteroid to have been discovered (after Ceres), and one of the largest in the System, it was realized that the zone contained more than one celestial body. So a new quest for more began. By 1986 more than 3450 asteroids were discovered in the same zone



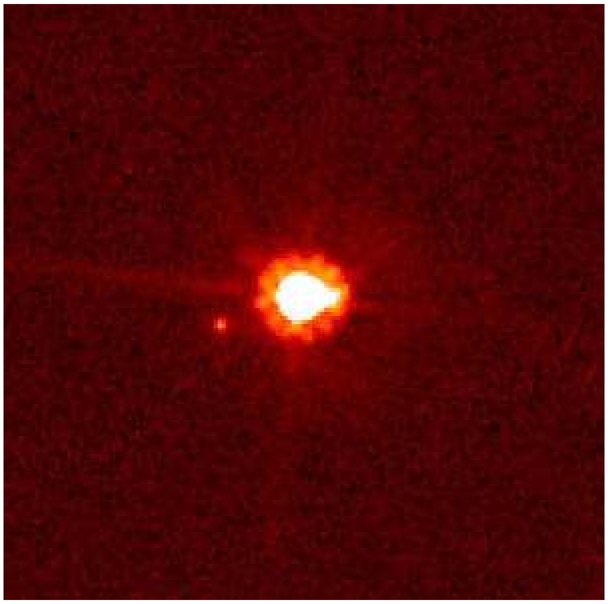
The asteroid belt is the region of the Solar System located roughly between the orbits of the planets Mars and Jupiter. It is occupied by numerous irregularly shaped bodies called asteroids or minor planets. The asteroid belt is also termed the main asteroid belt or main belt because there are other asteroids in the Solar System such as near-Earth asteroids and trojan asteroids. About half the mass of the belt is contained in the four largest asteroids, Ceres, Vesta,Pallas, and Hygiea. These have mean diameters of more than 400 km, while Ceres, the asteroid belt's only dwarf planet, is about 950 km in diameter. The remaining bodies range down to the size of a dust particle.



Positions of known outer Solar System objects. The centaurs are those objects (in orange) that lie generally inwards of the Kuiper belt (in green) and outside the Jupiter Trojans (pink).

Centaurs are an unstable orbital class of minor planets that behave with characteristics of both asteroids and comets.. Centaurs have transient orbits that cross or have crossed the orbits of one or more of the giant planets, and have dynamic lifetimes of a few million years. It has been estimated that there are around 44,000 centaurs in the Solar System with diameters larger than 1 km.

The **Kuiper belt** is a region of the Solar System beyond the planets extending from the orbit of Neptune to approximately 50 AU from the Sun. It is similar to the asteroid belt, although it is far larger—20 times as wide and 20 to 200 times as massive. Like the asteroid belt, it consists mainly of small bodies, or remnants from the Solar System's formation. While most asteroids are composed primarily of rock and metal, Kuiper belt objects are composed largely of frozen volatiles (termed "ices"), such as methane, ammonia and water. The classical (low-eccentricity) belt is home to at least three dwarf planets: Pluto, Haumea, and Make make. Some of the Solar System's moons, such as Neptune's Triton and Saturn's Phoebe, are also believed to have originated in the region. Since the belt was discovered in 1992, the number of known Kuiper belt objects (KBOs) has increased to over a thousand, and more than 100,000 KBOs over 100 km in diameter are believed to exist. The Kuiper belt should not be confused with the hypothesized Oort cloud, which is a thousand times more distant. Pluto is the largest known member of the Kuiper belt.



Eris, the largest known scattered-disc object (center), and its moon Dysnomia (left of object)

The **scattered disc** is a distant region of the Solar System that is sparsely populated by icy minor planets, a subset of the broader family of trans-Neptunian objects. The scattered-disc objects (SDOs) have orbital eccentricities ranging as high as 0.8, inclinations as high as 40°, and perihelia greater than 30 astronomical units($4.5×10^9$ km; $2.8×10^9$ miles). These extreme orbits are believed to be the result of gravitational "scattering" by the gas giants, and the objects continue to be subject to perturbation by the planet Neptune. While the nearest distance to the Sun approached by scattered objects is about 30–35 AU, their orbits can extend well beyond 100 AU. This makes scattered objects "among the most distant and cold objects in the Solar System". The innermost portion of the scattered disc overlaps with a torus-shaped region of orbiting objects traditionally called the Kuiper belt, but its outer limits reach much farther away from the Sun and farther above and below the ecliptic than the belt proper.

Because of its unstable nature, astronomers now consider the scattered disc to be the place of origin for most periodic comets observed in the Solar System.

It is speculated that the Oort cloud is, at least partly, the product of an exchange of materials between the Sun and its sister stars as they formed and drifted apart.

Although no confirmed direct observations of the Oort cloud have been made, astronomers believe that it is the source of all long-period and Halley-type comets entering the inner Solar System and many of the centaurs and Jupiter-family comets as well. The outer Oort cloud is only loosely bound to the Solar System, and thus is easily affected by the gravitational pull both of passing stars and of the Milky Way Galaxy itself.

The **Jupiter Trojans**, commonly called Trojans are a large group of objects that share the orbit of the planet Jupiter around the Sun. Trojan asteroids are distributed in two elongated, curved regions around the Lagrangian points with an average semi-major axis of about 5.2 AU. The first Trojan was spotted in 1906 by the German astronomer Max Wolf. A total of 5,253 Jupiter Trojans have been found as of March 2012. The total number of Jupiter Trojans larger than 1 km in diameter is believed to be about 1 million, approximately equal to the number of asteroids larger than 1 km in the asteroid belt.

The best time to observe a meteorite is the later part of the night. At this hour because of the rotational direction of the earth all the meteorites can be observed frontally moving towards the Earth. In the evening, it is opposite as only those are seen which are catching up with the Earth's rotation.

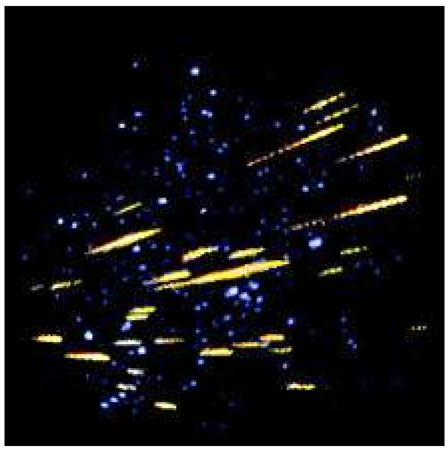


Photo of a part of the sky during a meteor shower over an extended exposure time. The meteors have actually occurred several seconds to several minutes apart.

The most visible meteor shower in most of the years are the Perseids, which peak on 12 August of each year at over one meteor per minute.

A Perseid meteor (light streak somewhat to right of center of photo) and the Milky Way

The Leonid meteor shower peaks around 17 November of each year.

Leonids from space

Approximately every 33 years, the Leonid shower produces a meteor storm, peaking at rates of thousands of meteors per hour. The last Leonid storms were in 1999, 2001 (two), and 2002 (two). Before that, there were storms in 1767, 1799, 1833, 1866, 1867, and 1966. When the Leonid shower is not *storming* it is less active than the Perseids.

The burning process of a meteorite begins when it is sixty miles away from the surface of the Earth. Depending on it size it last till it arrives closer about forty miles away. The smaller ones burn out completely when still fifty two miles away. Meteoroids travel around the Sun in a variety of orbits and at various velocities. The fastest ones move at about 26 miles per second (42 kilometers per second) through space in the vicinity of Earth's orbit. The Earth travels at about 18 miles per second (29 kilometers per second). Thus, when meteoroids meet the Earth's atmosphere head-on (which would only occur if the meteors were in a retrograde orbit), the combined speed may reach about 44 miles per second (71 kilometers per second). Meteoroids moving through the earth's orbital space average about 20 km/s.

The Moon

وَٱلْقَمَرَ قَدَّرْنَٰهُ مَنَازِلَ حَتَّىٰ عَادَ كَٱلْعُرْجُونِ ٱلْقَدِيمِ ٣٩

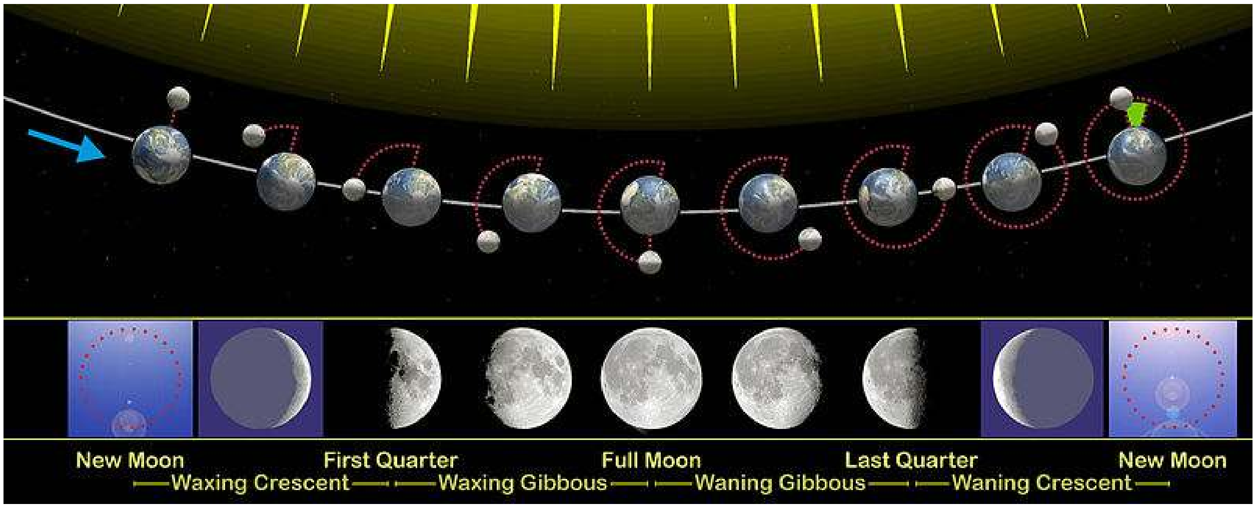
(And for the moon We have appointed measured phases, until it turned (pale, curved and fine) like an old branch of date palm. Yaseen – 39)

The Moon is the fifth largest satellite in the Solar System. It is the largest natural satellite of a planet in the Solar System relative to the size of its primary, having 27% the diameter and 60% the density of Earth, resulting in $\frac{1}{81}$ th of its mass. The Moon is the second densest satellite after Io, a satellite of Jupiter. The Moon is the brightest object in the sky after the Sun, although its surface is actually very dark. Since ancient times, the Moon had an important cultural influence on language, calendars, art and mythology. The Moon's gravitational influence produces the ocean tides and the minute lengthening of the day. The Moon's current orbital distance, about thirty times the diameter of the Earth, causes it to appear almost the same size in the sky as the Sun, allowing it to cover the Sun nearly precisely in total solar eclipses.

The Moon is thought to have formed nearly 4.5 billion years ago, not long after Earth's formation. Its maximum distance from the earth is 252710 miles and a minimum distance of 221463 miles averaging to 237058 miles. With a diameter of 2160 miles, volume of the Moon is 1/49 of the Earth's volume and a mass 1/89. Equatorial surface gravity is one sixth of the earth (1.622 m/s^2 (0.165 4 g).

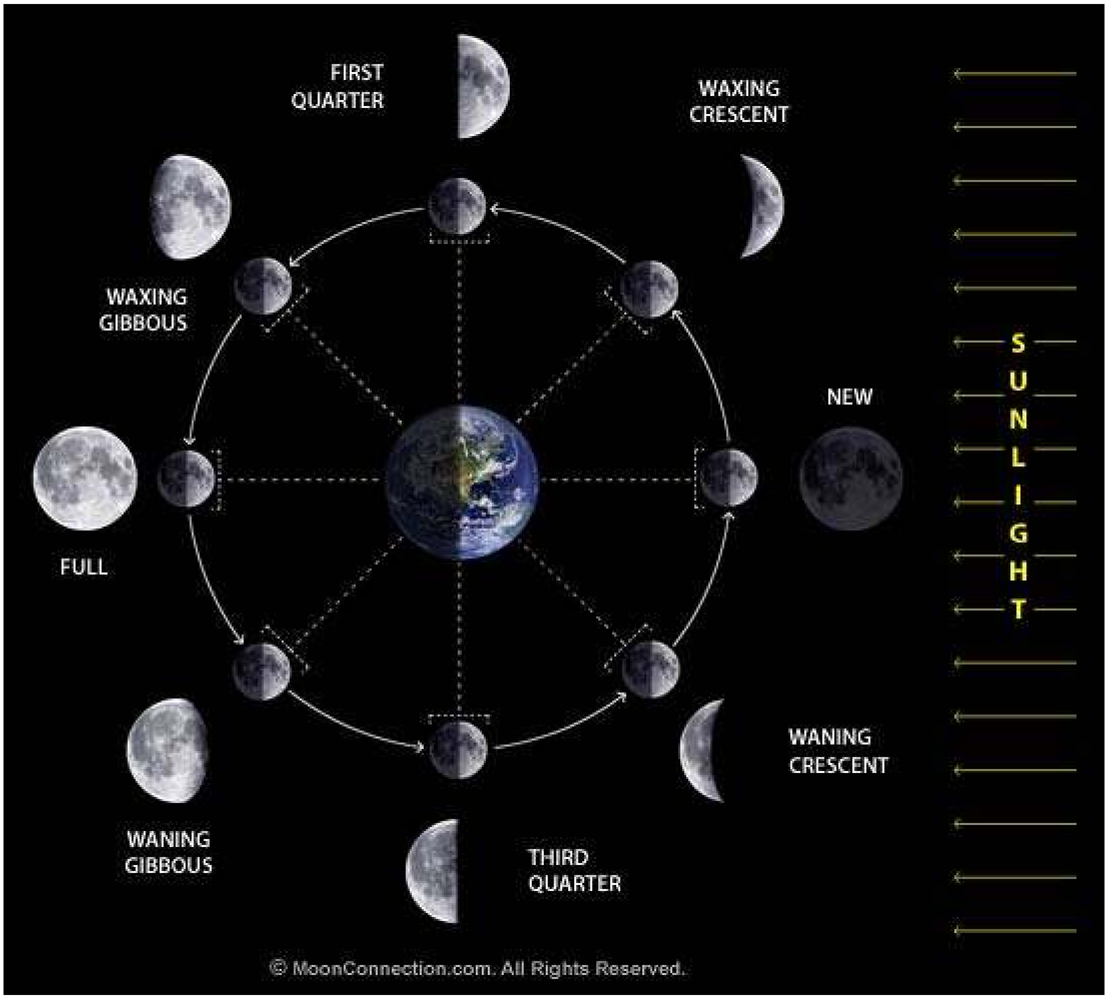
The Moon makes a complete orbit around the Earth with respect to the fixed stars about once every 27.3 days (its sidereal period). However, since the Earth is moving in its orbit about the Sun at the same time, it takes slightly longer for the Moon to show the same phase to Earth, which is about 29.5 days (its synodic period or lunar period). The same have been mentioned in books of the Hadith. Unlike most satellites of other planets, the Moon orbits nearer the ecliptic plane than to the planet's equatorial plane.

Process of the Sun rise at the Moon takes about an hour or so. Only 41% of the Earth is visible from the surface of the Moon.



The monthly changes of angle between the direction of illumination by the Sun and viewing from Earth, and the phases of the Moon that result

A lunar phase or phase of the moon is the appearance of the illuminated (sunlit) portion of the Moon as seen by an observer on the Earth. The lunar phases change cyclically as the Moon orbits the Earth, according to the changing relative positions of the Earth, Moon, and Sun. The half of the lunar surface facing the Sun is always sunlit, but the portion of this illuminated hemisphere that is visible to an observer on Earth can vary from about 100% (full moon) to 0% (new moon). The lunar terminator is the boundary between the illuminated and un illuminated hemispheres. Aside from some craters near the lunar poles such as Shoemaker, all parts of the Moon see around 14.77 days of sunlight followed by 14.77 days of "night”.



It's probably easiest to understand the moon cycle in this order: new moon and full moon, first quarter and third quarter, and the phases in between.

As shown in the above diagram, the new moon occurs when the moon is positioned *between* the earth and sun. The three objects are in approximate alignment The entire illuminated portion of the moon is on the back side of the moon, the half that we cannot see.

At a full moon, the earth, moon, and sun are in approximate alignment, just as the new moon, but the moon is on the opposite side of the earth, so the entire sunlit part of the moon is facing us. The shadowed portion is entirely hidden from view.

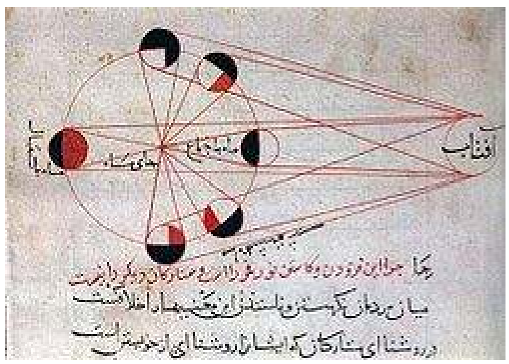
The first quarter and third quarter moons (both often called a "half moon"), happen when the moon is at a 90 degree angle with respect to the earth and sun. So we are seeing exactly half of the moon illuminated and half in shadow.

An easy way to remember and understand those "between" lunar phase names is by breaking out and defining 4 words: crescent, gibbous, waxing, and waning. The word crescent refers to the phases where the moon is less than half illuminated. The word gibbous refers to phases where the moon is more than half illuminated. Waxing means "growing" or expanding in illumination and waning means "shrinking" or decreasing in illumination.

After the new moon, the sunlit portion is increasing, but less than half, so it is a waxing crescent. After the first quarter, the sunlit portion is still increasing, but now it is *more* than half, so it is a waxing gibbous. After the full moon (maximum illumination), the light continually decreases. So the waning gibbous phase occurs next. Following the third quarter is the waning crescent, which wanes until the light is completely gone -- a new moon.

Phase	Northern Hemisphere	Southern Hemisphere	Visibility	Standard time of culmination (mid-phase)
New moon	Not visible, traditionally Moon's first visible crescent		after sunset	12 noon
Waxing crescent moon	Right 1–49% visible	Left 1–49% visible	afternoon and post-dusk	3 pm
First quarter moon	Right 50% visible	Left 50% visible	afternoon and early night	6 pm
Waxing gibbous moon	Right 51–99% visible	Left 51–99% visible	late afternoon and most of night	9 pm
Full moon	Fully visible	Fully visible	sunset to sunrise (all night)	12 midnight
Waning gibbous moon	Left 51–99% visible	Right 51–99% visible	most of night and early morning	3 am

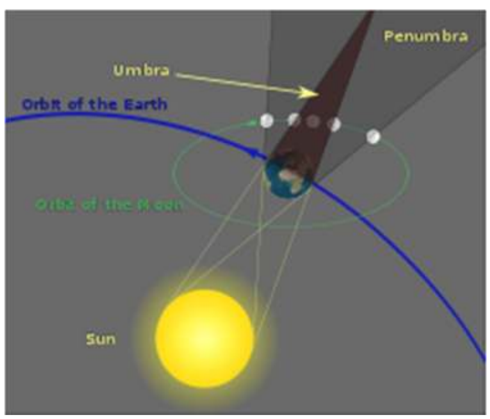
Third (last) quarter moon	Left 50% visible	Right 50% visible	late night and morning	6 am
Waning crescent moon	Left 1–49% visible	Right 1–49% visible	pre-dawn and morning	9 am
Dark moon	Not visible, traditionally Moon's last visible crescent		before sunrise	12 noon



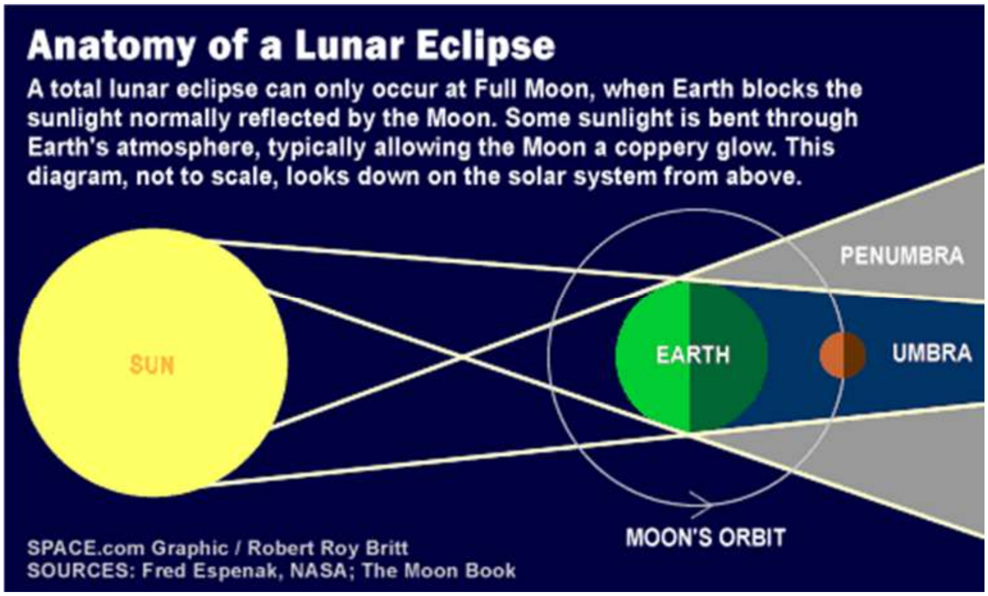
An illustration from al-Biruni's astronomical works, explains the different phases of the moon.

The June 2011 total eclipse

A lunar eclipse occurs when the Moon passes directly behind the Earth into its umbra (shadow). This can occur only when the Sun, Earth, and Moon are aligned exactly, or very closely so, with the Earth in the middle. Hence, a lunar eclipse can only occur the night of a full moon.

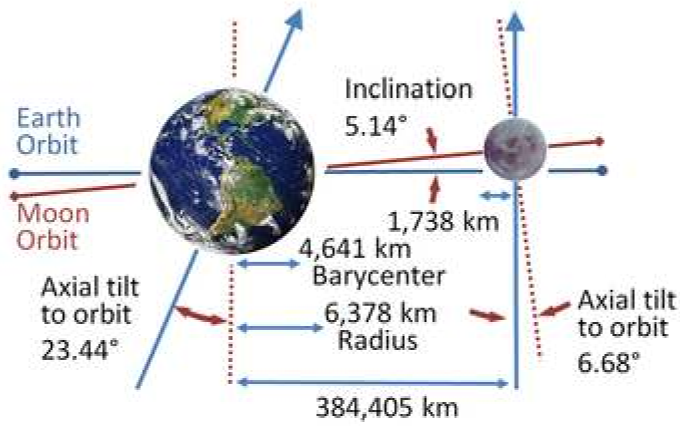


Schematic diagram of the shadow cast by the Earth. Within the central umbra shadow, the Moon is totally shielded from direct illumination by the Sun. In contrast, within the penumbra shadow, only a portion of sunlight is blocked.



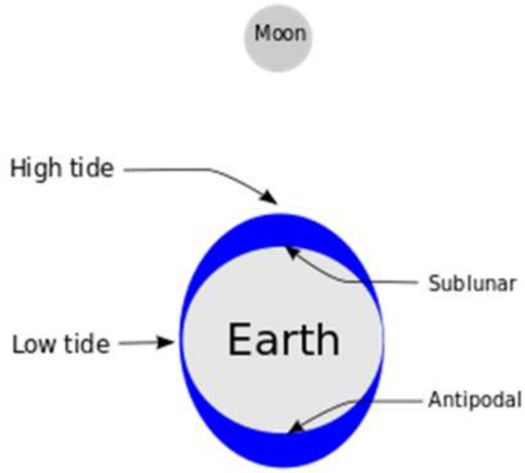
The type and length of an eclipse depend upon the Moon's location relative to its orbital nodes. Unlike a solar eclipse, which can only be viewed from a certain relatively small area of the world, a lunar eclipse may be viewed from anywhere on the night side of the Earth. A lunar eclipse lasts for a few hours, whereas a total solar eclipse lasts for only a few minutes at any given place, due to the smaller size of the moon's shadow. The Moon’s speed through the shadow is about one kilometre per second (2,300 mph), and totality may last up to nearly 107 minutes. Nevertheless, the total time between the Moon’s first and last contact with the shadow is much longer, and could last up to 4 hours. Exact location, time and duration of a lunar eclipse can be determined these days. Ceros method (the oldest way) specifies that a lunar eclipse will reoccur at a place after 18 years, 11days and 8 hours. It may not, however, be visible at that spot. To find the time there one shall to wait for 36 years and 34 days.

A selenelion or selenehelion occurs when both the Sun and the eclipsed Moon can be observed at the same time. This can only happen just before sunset or just after sunrise, and both bodies will appear just above the horizon at nearly opposite points in the sky.



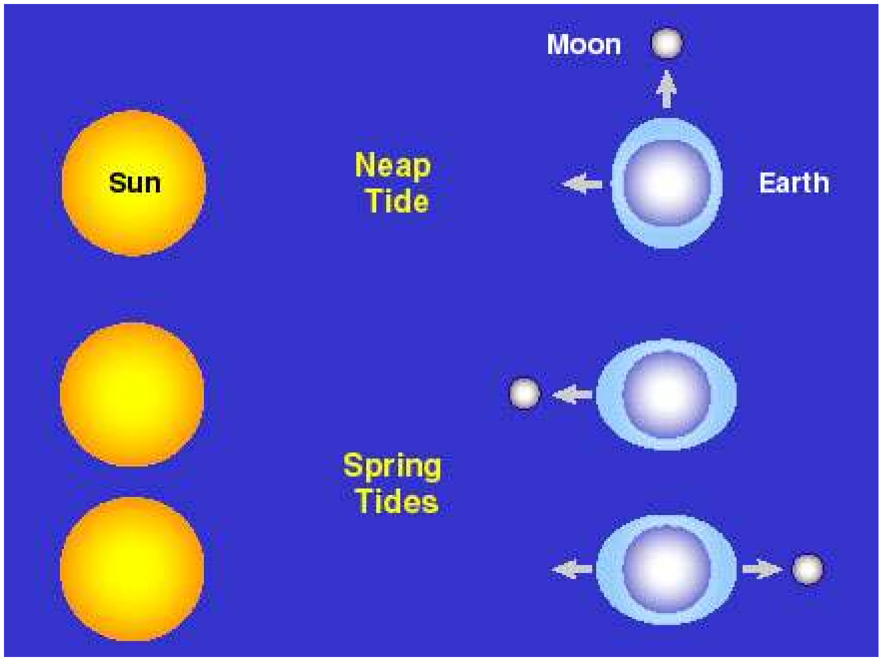
There are many irregularities (or perturbations) in the Moon's motion, and many attempts have been made over a long history to account for them. The sidereal period of the Moon is 29.5 days that are taken to move along its orbit of 360 degrees which means that the Moon commences its journey 12.5 degrees behind the previous day’s beginning. Moving at a speed of one degree in four minutes, the moon should be late by 51 minutes daily. Actually this keeps alternating but this average is maintained in a month. As popularly believed, fourteenth day may not necessarily be a full moon. To complete the Moon may take sixteen days. The visible thickness also keeps altering. This is probably the reason that in the books of Hadith, actual sighting has been laid than guessing the thickness

The Moon orbits nearer the ecliptic plane than to the planet's equatorial plane. The Moon's orbit is subtly perturbed by the Sun and Earth in many small, complex and interacting ways. For example, the plane of the Moon's orbital motion gradually rotates, which affects other aspects of lunar motion. The Moon is in synchronous rotation: it rotates about its axis in about the same time it takes to orbit the Earth. This result in it nearly always keeping the same face turned towards the Earth. The highest altitude of the Moon in the sky varies: while it has nearly the same limit as the Sun, it alters with the lunar phase and with the season of the year, with the full moon highest during winter. The 18.6-year nodes cycle also has an influence: when the ascending node of the lunar orbit is in the vernal equinox, the lunar declination can go as far as 28° each month. This means the Moon can go overhead at latitudes up to 28° from the equator, instead of only 18°. The orientation of the Moon's crescent also depends on the latitude of the observation site: close to the equator, an observer can see a smile-shaped crescent Moon.



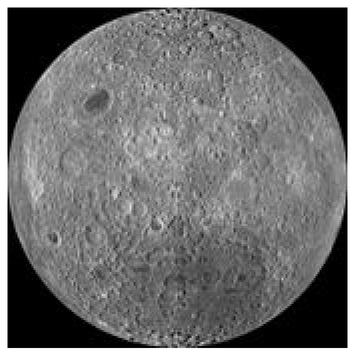
The tides on the Earth are mostly generated by the gradient in intensity of the Moon's gravitational pull from one side of the Earth to the other, the tidal forces. This forms two tidal bulges on the Earth, which are most clearly seen in elevated sea level as ocean tides. Since the Earth spins about 27 times faster than the Moon moves around it, the bulges are dragged along with the Earth's surface faster than the Moon moves, rotating around the Earth once a day as it spins on its axis. The ocean tides are magnified by other effects: frictional coupling of water to Earth's rotation through the ocean floors, the inertia of water's movement, ocean basins that get shallower near land and oscillations between different ocean basins. Each day, there are two high tides and two low tides. The ocean is constantly moving from high tide to low tide, and then back to high tide. There is about 12 hours and 25 minutes between the two high tides.

The gravitational attraction of the Sun on the Earth's oceans is almost half that of the Moon and their gravitational interplay is responsible for spring and neap tides.



Not only the Moon, but other objects in the Solar System also influence the Earth's tides. For most their tidal forces are negligible on Earth, but the differential gravitational force of the Sun does influence our tides to some degree (the effect of the Sun on Earth tides is less than half that of the Moon). For example, particularly large tides are experienced in the Earth's oceans when the Sun and the Moon are lined up with the Earth at new and full phases of the Moon. These are called spring tides (the name is not associated with the season of spring). The amount of enhancement in Earth's tides is about the same whether the Sun and Moon are lined up on opposite sides of the Earth (full Lunar phase) or on the same side (new Lunar phase). Conversely, when the Moon is at first quarter or last quarter phase, the Sun and Moon interfere with each other in producing tidal bulges and tides are generally weaker; these are called neap tides. The figure shown above illustrates spring and neap tides.

Having a mean density of 3,346.4 kg/m³, the Moon is a differentiated body, being composed of a geochemically distinct crust, mantle, and core. This structure is believed to have resulted from the fractional crystallization of a magma ocean shortly after its formation about 4.5 billion years ago. The energy required to melt the outer portion of the Moon is commonly attributed to a giant impact event that is postulated to have formed the Earth-Moon system and the subsequent reaccretion of material in Earth orbit. Lunar crust is composed primarily of oxygen, silicon, magnesium, iron, calcium, and aluminum, but important minor and trace elements such as titanium, uranium, thorium, potassium, and hydrogen are present as well. Based on geophysical techniques, the crust is estimated to be on average about 50 km thick. Several lines of evidence imply that the lunar core is small, with a radius of about 350 km or less. The size of the lunar core is only about 20% the size of the Moon, in contrast to about 50% as is the case for most other terrestrial bodies. The composition of the lunar core is not well constrained, but most believe that it is composed of metallic iron alloyed with a small amount of sulfur and nickel.



Near side *Far Side*

The dark and relatively featureless lunar plains which can clearly be seen with the naked eye are called Maria (Latin for "seas"), since they were believed by ancient astronomers to be filled with water. They are now known to be vast solidified pools of ancient basaltic lava. While similar to terrestrial basalts, the mare basalts have much higher abundances of iron and are completely lacking in minerals altered by water. The majority of these lavas erupted or flowed into the depressions associated with impact basins. Several geologic provinces containing shield volcanoes and volcanic domes are found within the near side Maria. The other major geologic process that has affected the Moon's surface is impact cratering, with craters formed when asteroids and comets collide with the lunar surface. There are estimated to be roughly 300,000 craters wider than 1 km on the Moon's near side alone.

Liquid water cannot persist on the lunar surface. When exposed to solar radiation, water quickly decomposes through a process known as photo dissociation and is lost to space. However since the 1960s, scientists have hypothesized that water ice may be deposited by impacting comets or possibly produced by the reaction of oxygen-rich lunar rocks, and hydrogen from solar wind, leaving traces of water which could possibly survive in cold, permanently shadowed craters at either pole on the Moon.

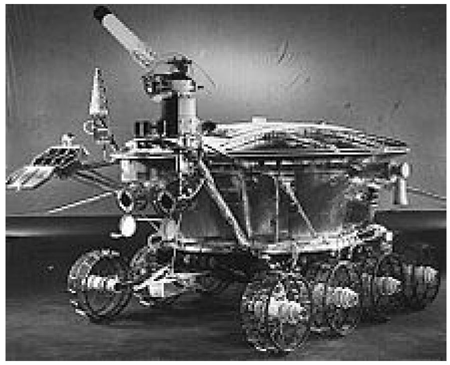
The gravitational field of the Moon has been measured through tracking the Doppler shift of radio signals emitted by orbiting spacecraft. The main lunar gravity features are mascons, large positive gravitational anomalies associated with some of the giant impact basins, partly caused by the dense mare basaltic lava flows that fill these basins. These anomalies greatly influence the orbit of spacecraft about the Moon. There are some puzzles: lava flows by themselves cannot explain the entire gravitational signature. The Moon has an external magnetic field of the order of one to a hundred nanoteslas, less than one-hundredth that of the Earth.

For most practical purposes, the Moon is considered to be surrounded by vacuum. The elevated presence of atomic and molecular particles in its vicinity is negligible in comparison with the gaseous envelope surrounding Earth and most planets of the Solar system. It is less than one hundred trillionth of Earth's atmospheric density at sea level.

One source of the lunar atmosphere is the release of gases such as radon and helium resulting from radioactive decay within the crust and mantle. Another important source is the bombardment of the lunar surface by micrometeorites, the solar wind, and sunlight, in a process known as sputtering. The Moon's axial tilt with respect to the Ecliptic is only 1.54°, much less than the 23.44° of the Earth. Because of this, the Moon's solar illumination varies much less with season, and topographical details play a crucial role in seasonal effects.

The Moon is thought to have formed nearly 4.5 billion years ago, not long after Earth's formation. Although there have been several hypotheses for its origin in the past, the current most and widely accepted explanation is that the Moon formed from the debris left over after a giant impact between Earth and a Mars-sized body.

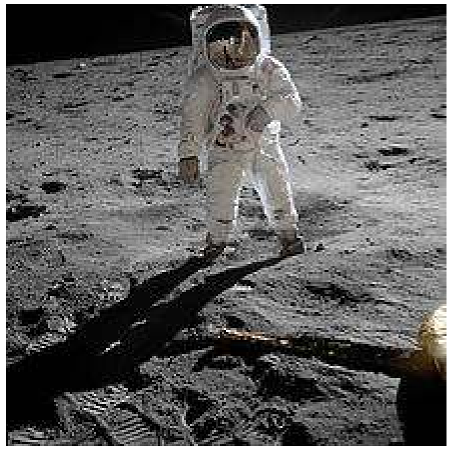
Understanding of the Moon's cycles was an early development of astronomy: by the 5th century BC, Babylonian astronomers had recorded the 18-year Saros cycle of lunar eclipses. Later, the physical form of the Moon and the cause of moonlight became understood. In Aristotle's (384–322 BC) description of the universe, the Moon marked the boundary between the spheres of the mutable elements (earth, water, air and fire), and the imperishable stars of the ether, an influential philosophy that would dominate for centuries. During the middle Ages, before the invention of the telescope, the Moon was increasingly recognized as a sphere, though many believed that it was "perfectly smooth". In 1609, Galileo Galilei drew one of the first telescopic drawings of the Moon in his book *Sidereus Nuncius* and noted that it was not smooth but had mountains and craters.



Lunokhod 1 (lit. moonwalker), the first successful space rover.

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

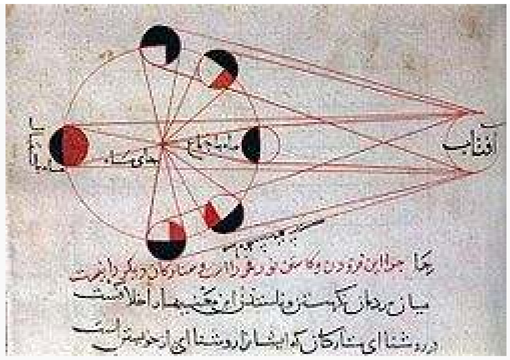
The first spacecraft to perform a successful lunar soft landing was *Luna 9* and the first unmanned vehicle to orbit the Moon was *Luna 10*, both in 1966. Rock and soil samples were brought back to Earth by three *Luna* sample return missions (*Luna 16* in 1970, *Luna 20* in 1972, and *Luna 24* in 1976),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



American lunar exploration began with robotic missions aimed at developing understanding of the lunar surface for an eventual manned landing. NASA's manned Apollo program was developed in parallel; after a series of unmanned and manned tests of the Apollo spacecraft in Earth orbit, and spurred on by a potential Soviet lunar flight. Apollo 8 made the first crewed mission to lunar orbit in 1968 . The subsequent landing of the first humans on the Moon in 1969 is seen by many as the culmination of the Space Race.

Farouk El-Baz (born January 2, 1938) is an Egyptian American scientist who worked with NASA to assist in the planning of scientific exploration of the Moon, including the selection of landing sites for the Apollo missions and the training of astronauts in lunar observations and photography.

Post-Apollo and *Luna*, many more countries have become involved in direct exploration of the Moon. In 1990, Japan became the third country to place a spacecraft into lunar orbit with its *Hiten* spacecraft. The European spacecraft *SMART-1*, the second ion-propelled spacecraft, was in lunar orbit from 15 November 2004 until its lunar impact on 3 September 2006, and made the first detailed survey of chemical elements on the lunar surface. China has expressed ambitious plans for exploring the Moon, and successfully orbited its first spacecraft, *Chang'e-1*; from 5 November 2007 until it's controlled lunar impact on 1 March 2008.



An illustration from al-Biruni's astronomical works, explains the different phases of the moon.

The period from 1025 to 1450 is the one when a distinctive Islamic system of astronomy flourished. The period began as the Muslim astronomers began questioning the framework of the Ptolemaic system of astronomy by bringing it into line with its own principles.

Between 1025 and 1028, Ibn al-Haytham wrote his Al-Shuku ala Batlamyus (meaning "Doubts on Ptolemy"). While maintaining the physical reality of the geocentric model, he criticized elements of the Ptolemic models. Many astronomers took up the challenge posed in this work, namely to develop alternate models that resolved these difficulties. In 1070, Abu Ubayd al-Juzjani published the Tarik al-Aflak. In Al-Andalus, the anonymous work al-Istidrak ala Batlamyus (meaning "Recapitulation regarding Ptolemy"), included a list of objections to the Ptolemic astronomy.

Other critical astronomers include: Mu'ayyad al-Din al-'Urdi (c. 1266), Nasir al-Din al-Tusi (1201–74), Qutb al-Din al Shirazi (c. 1311), Sadr al-Sharia al-Bukhari (c. 1347), Ibn al-Shatir (c. 1375), and Ali al-Qushji (c. 1474).

Calculation of Prayer Timings.

The daily prayers are an integral part of a Muslim's life. In order to fulfill this very important religious obligation, it is necessary to know the timings of the daily prayers. *Zuhr* and *Maghrib* prayers are not a problem; but to know the timing of *Morning Prayer* has not been easy. Beside relying on the *mu'azzin* of the neighbourhood mosques, it is essential to know the working out of the prayer timings. Whereas it easy to find the times of "noon" and "sunset, the difficulty arises in determining the time for *fajr* (dawn) prayer. How do you define *fajr.* How do you explain the difference between the "false" dawn and the "true" dawn? It has been attempted to impart this essential knowledge in the succeeding paragraphs.

A hadîth-i sherîf quoted in the books Muqaddimet-us-salât, at-Tefsîr-al-Mazharî and al-Halabî al-kebîr states: “Jabrâîl ‘alaihissalâm’ (and I performed [the prayer termed] namâz [or salât] together, and Jabrâîl ‘alaihis-salâm’ conducted the prayer as the imâm for two of us, by the side of the door of Ka’ba, for two days running. We two performed the morning prayer as the fajr (morning twilight) dawned; the early afternoon prayer as the Sun departed from meridian; the late afternoon prayer when the shadow of an object equaled its midday shadow increased by the length of the object; the evening prayer as the Sun set [it supper limb disappeared]; and the night prayer when the evening twilight darkened. The second day, we performed the morning prayer when the morning twilight matured; the early afternoon prayer when the shadow of an object increased again by the length of the object; the late afternoon prayer immediately thereafter; the evening prayer at the prescribed time of breaking fast; and the night prayer at the end of the first third of the night. Then he said ‘O Muhammad, these are the times of prayers for you and the prophets before you. Let your Ummat perform each of these five prayers between the two times at which we performed each’.” This event took place on the fourteenth of July, one day after the Mi’râj, and two years before the Hegira. Ka’ba was 12.24 metres tall, the solar declination was 21 degrees and 36 minutes, and Ka’ba’s latitudinal location was twenty-one degrees and twenty-six minutes. Hence its midday (shortest) shadow (fayi zawâl) was 3.56 cm. Thereby performing prayers (salât) five times a day became a commandment. This hadîth-i sherîf clarifies that the number of (daily) prayers is five.

There is absolutely no disagreement among the Muslims on the fact that *al-fajr as-sadiq* (the true dawn) is the time for the Morning Prayer. At the true dawn, first blush of the light appears from the east in form of a semi circle. It’s more horizontally spread unlike the false dawn which has a vertical aurora. The true dawn lasts for a longer period with light gradually increasing in the semi circle. At times it spreads beyond its usual confinements giving a wrong impression of being the false dawn. Actually the line separating day and night as laid down in the Quran appears at this time.

TRUE FAJR

FALSE FAJR

Some of the reasons causing this impression are:-

a. It is normally presumed that appearance of the false dawn is a must at every place, which may not be true. Actually this is the zodiac light ascending on the horizon because of its reflection from very minute dust particles bordering the sun. The light spreads all along the zodiac belt. Since the belt appears perpendicular to the horizon in the tropical regions so its visibility is more pronounced. As we keep moving away from the equator the belt starts slanting and its visibility is reduced. Experiments show that the zodiac stars at the time of false dawn appear above the horizon whereas the light at the true is dawn evenly spread along the horizon.
b. Those not accustomed to persistent observation fail to identify the limits of the semi circle of light and tend to mistake the false zodiac light with true dawn.

Appearance of the zodiac light in the premises of Madinah Munawara conforms to what has been described in the books of the Hadiths. This light if visible in the northern areas of Pakistan will be slanting with the horizon.

From the scientific point of view, the light which appears before sunrise and remains after sunset is known as "twilight". Twilight literally means "the light between the two," i.e., between night and day or between day and night. In Arabic, "twilight" is known as "*ash-shafaq*."

It is obvious that the light of morning twilight gradually increases in brightness; to distinguish the various stages of twilight, the scientists have divided it into three types of twilights:

1. The Astronomical Twilight: this begins when the Sun's center is 18 degrees below the horizon.
2. The Nautical Twilight: this occurs when the Sun's center is at 12 degrees below the horizon.
3. The Civil Twilight: this occurs when the Sun's center is at 6 degrees below the horizon.

The third twilight known as the Civil Twilight is of no use for us as it is mostly used by civil authorities to decide when the street lights and car head-lights are no longer needed. Some scientists have given it the name of "head-lights twilight."

A board of religious scholars from Karachi, headed by Hazrat Mufti Shafi (RA) and Hazrat Maulana Yousaf Banori (RA) after experimentation determined the twilight angle to be 18 Degrees. Hazrat Mufti Rashid Ahmed Ludhanvi (RA) has indicated it to be 15 degrees with a reference to “Fatwa e Alamgiri”.

The author after an extensive research and observations feels this angle to be 18 degrees. Justifications are appended below:-

The author observed the true dawn for a month. It became evident after a week or ten days that the twilight angle of 18 degrees is correct for working out the time of the Morning Prayer (faj’r). The 15 degree angle was based on a technical error. The author observed diminishing of the red twilight for almost six months. The conclusion was that at this stage the angle under the horizon is not 12 degrees but it fluctuates between 12 ½ to 16 ½ degrees. The day, red twilight disappears at more than 15 ½ degrees it means it disappeared after 15 degrees of the white twilight. Since disappearance of white twilight before the red twilight is impossible, so this proves that it was an error to lay down 15 degrees below horizon as a rule for faj’r prayer. The true dawn and white twilight follow the same principle.

To elucidate this technical error, it is stated that with the first appearance of true dawn a large semicircular arc appears in north south direction. Experience is needed to observe this happening else it can be missed. The author could only observe it after many days. Initially the light in the arc is too less increasing in intensity with passage of time till it spills over the arc. At this precise moment the sun is 15 degrees below the horizon radiating ample light. This is generally mistaken as the true dawn, which actually occurs when the sun is 18 degrees below with lesser light.

Although Hazrat Mufti Rashid Ahmed has offered very cogent reasons in volume II of his book 'Ahsan ul Fatawa' when discussing the true dawn. The author however has strong arguments to contest it:-

a. The jurists and interpreters of the Hadiths unanimously agree that height of the false dawn is more than its spread on the horizon. The author, however, during his experimentation observed that it was the other way around. At the angle of 18 degrees the light appearing is spread more along the horizon than its vertical extent. It can be said that it is a large wheel of light which looks to be half buried into the earth. At the false dawn light is more vertically spread and it can in no way be described as a semi circle. Amongst the Muslim scholars the rising of *fajr* is known by the appearance on the horizon of a light which ascends towards the sky and resembles tail of a fox--this is known as *al-fajr al-kazib* (the false dawn). Then the light spreads on the horizon (and becomes like a white cotton and like the river of Sura') in such a way that whenever you look towards it, it will convince you of its increasing beauty. Some have described it as a light which appears vertically on the horizon, ascending towards the sky like a pillar, and it decreases and weakens till it disappears. Verdict of Alama Alusi in his book ' Roh ul Ma'ani' explicitly describes it,
   Xxxxxxxxxxxxxx
   Xxxxxxxxxxxxxx (Arabic Text – page 124).

b. The second argument is related to the experimental observations. The author at least twice saw the red dawn disappearing after 15 degrees. Since the red twilight can not disappear after the white twilight so 15 degree rule cannot be true. 18 degree rule is therefore considered to be the correct yardstick. Anyone differing with it can try it himself requiring observations for months. He may not be able to observe the 15 degree twilight (not often visible) but can certainly discover that the red twilight never vanishes at 12 degrees as proclaimed by Mufti Rashid Ahmed. An extract from the famous compilation ' Fatwa e Alamgiri' reads::-

   xxxxxxxxxx (Arabic text – page 124).

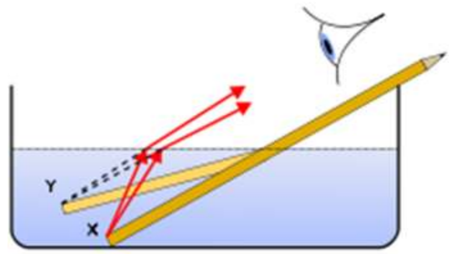
   It suggests that the first rule should be followed for observance of the night prayer (isha) and breaking the fast and reference is made to the second quote for the Morning Prayer (fajr). The indication for the true dawn corresponds to the 18 degree rule. Another thing proven here is that Hazrat Mufti Rashid Ahmed is not the only one who had erred on this issue. However his other research may not be ignored because of this one error. The third fact enunciated in the text is that the

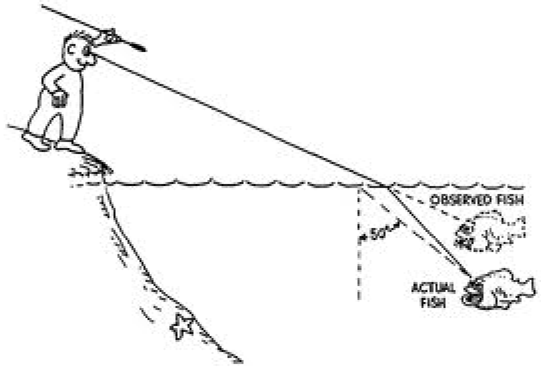
> later dawn is of two kinds. Firstly when the light spread on the horizon appears for the first time. Secondly the light intensifies and begins to spread.

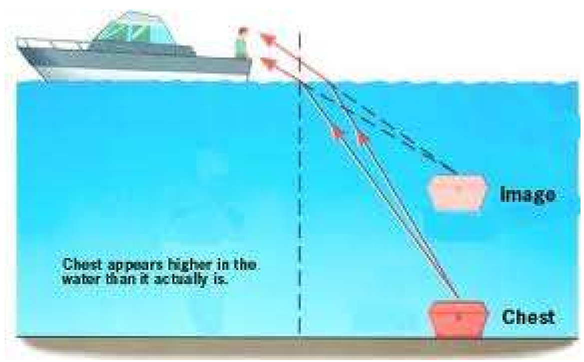
Limits of the light spread on horizon are familiar to an experienced person; which is seen in the form of a very large sunken half circle. This is more akin to the Quranic description of dividing white and black line. With further spread of light it can be identified even by a novice. There are two groups of the researchers; those with scanty observations of few days and those who deduced better conclusions with elaborate study. It is therefore prudent to accept the results of the second group who are closer to the reality without belittling the first ones. There is another segment of cautious people who profess to offer the fajr prayers towards the later time (15 degrees) but observe the earlier timings for the night prayers and breaking the fast i.e. conforming to the 18 degrees verdict. It’s like the Hinaf who recommend offering the noon prayers (zahur) in the early timings and the afternoon prayers (as’r) later. The same advice has been rendered in the ‘Fatwa e Alamgiri’. The author apprised Hazrat Mufti Rashid Ahmad about his research in 1984. He was kind enough not to insist on his contention. He rather accept the verdict from ‘Fatwa e Alamgiri’ advised to adhere to 18 degrees rule for the isha prayers and breaking the fast while conforming to 15 degrees rule for the morning prayers (fajr). May Allah Almighty bless him that he considered the author’s research of some value. Ameen.

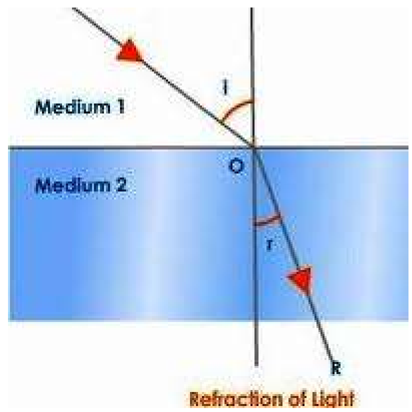
Rule for Sun Rise and Sun Set

In mathematical calculations, the sun is considered as a single dot. So to work out time of its rise and set, we adopt the zero degree below the horizon as the datum point. This is the moment when centre of the sun is exactly at the horizon. At this point it cannot be called to be rising or setting because half of it has still to rise or set. Completion of the process will indicate actual sun rise or sun set. Since diameter of the sun is 32 minutes so 16 minute below the horizon rule has to be adopted. This cannot be totally true because of the visibility of the sun from it actual position due to the process of refraction. Light refracts when entering a denser medium and bends thus making the things below it also visible.



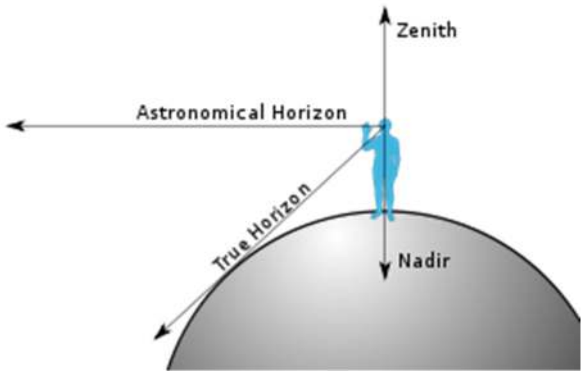






The figures above amply exhibit the phenomena. The denser atmosphere at the horizon act like water thus the sun is visible 34 minutes higher than its actual position. Addition of 34 +16 = 50. So when centre of the sun is 50 minutes below the horizon, this is the sun rise/set time. At this stage centre of the sun is making an angle of 90° and 50 minutes with which will 90.833°. When this angle is to the east then it is the sun rise. This will indicate the sun set when in the west.

Zenith or الراءس is an imaginary point directly "above" a particular location, on the imaginary celestial sphere. "Above", means in the vertical direction opposite to the apparent gravitational force at that location. The opposite direction, i.e. the direction in which gravity pulls, is toward the nadir.



The Noon (zahur) Prayer

Soon after the zawa'l time i.e. when last end of the solar disc goes past the equator, the time for the noon prayer (zahur) begins. In Pakistan, when shadow of an object from the north tilts to the east the zawa'l time will start (details will be covered in explanation of the disapproved مکروہ timings). When shadow of a vertical object after reduction begins to expand, this indicates the time of decline (zawa'l).

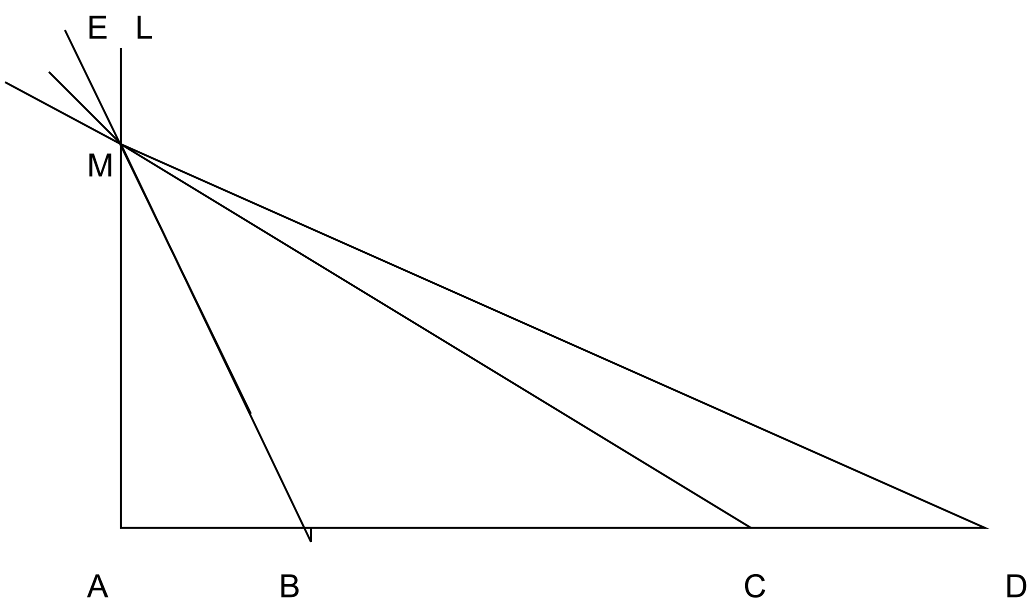
Picture shows shadows of trees, when the sun is directly overhead (at the zenith). This happens at solar noon provided the tree's latitude equals the sun's declination at that moment.

To determine the time of decline Dayra Hindia' can be consulted. These timings are also listed day wise in the Astronomical Almanac. Work it out as under:-

a. Divide the local time difference of Greenwich Time (GMT) with 24 hours. Multiply the dividend with difference in seconds of the decline time (zawa'l) from the previous day. Subtract the result from the GMT zawa'l time.
b. Add one minute and eight seconds to it. This is the duration that half the solar disc passes over the decline line (khat e zawal).
c. Add to the value of the spread of the locality. Addition of two minutes is sufficient for a city.

The Afternoon (as'r) Prayer

Shadow at the decline (zawa'l) time is the real shadow of an object.



In the figure above real shadow of AM is AB. If height of the vertical body AM is added to the real shadow AB then it will become equal to shadow cast by the object i.e. AC. This is called shadow of the first replica (SFR). If twice the height of the body is added to the real shadow it will be equal to A, which is called the shadow of the second replica (SSR). At the time of SSR the sun makes < LMN which is equal to < DMA. Similarly at SFR the sun makes an < LMO which is equivalent to < CMA. If the sun corresponds to the desired location then the sun will be at exactly at zenith at the time of decline(zawa'l) , but in case of any variance it will make an angle LME equal to < BMA and line AB will the length of its shadow at the time of decline (zawa'l). Therefore

$AB \div AM = \tan BMA$

Real shadow = $\tan B\text{-}D$

If the sun angle with the zenith is denoted as 'A' then,

$SFR = \tan^{-1} (1 + \tan (B - D))$

$SSR = \tan^{-1} (2 + \tan (B - D))$

The Night Prayer (Ish'a)

18 ° below the horizon rule is followed. Research by the learned elders has established that after the disappearance of the red twilight, the white one also vanishes by this time. However because of the presence of one colour below the horizon this rule is not applied. If someone has to call for prayer (aza'n) by the red twilight then it must be carefully observed as it cannot be calculated. Only white twilight is calculable because its angle below the horizon has been determined.

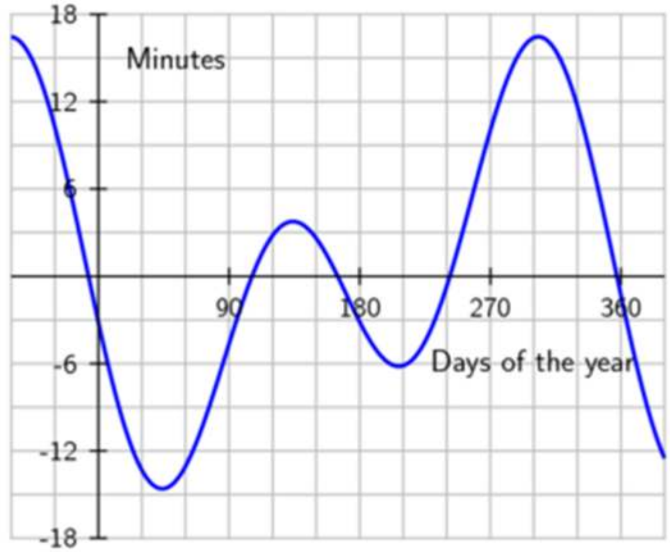
Working of Disapproved Timings (Makroh)

At the sun rise when it is 1.4 degrees above the horizon its fadedness is gone and it cannot be observed with the naked eye. Similarly at the sun set when it is 2.3 degrees above the horizon its light gets defused and it can be observed with the naked eye. This research was conducted by Hazrat Mufti Rashid Ahmad and the author subscribes to its correctness.

Method of working out the prayer timings

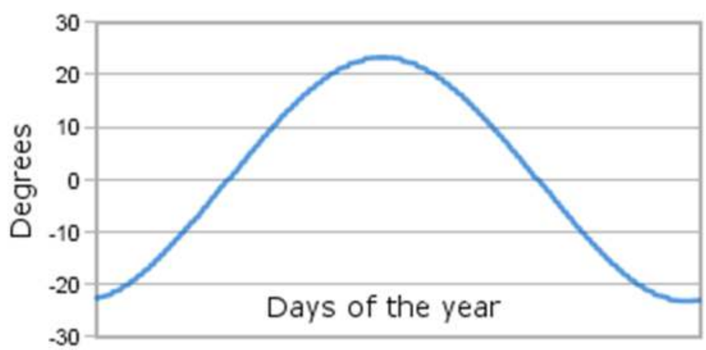
There are two astronomical measures that are essential for computing prayer times. These two measures are the equation of time and the declination of the Sun.

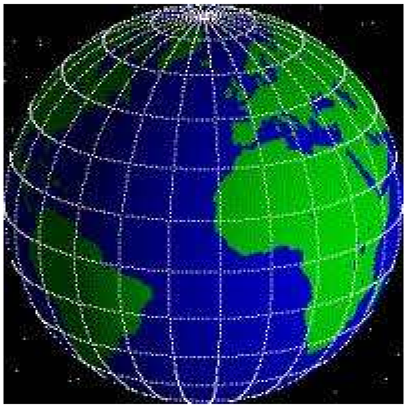
The equation of time is the difference between time as read from a sundial and a clock. It results from an apparent irregular movement of the Sun caused by a combination of the obliquity of the Earth's rotation axis and the eccentricity of its orbit. The sundial can be ahead (fast) by as much as 16 min 33 s (around November 3) or fall behind by as much as 14 min 6 s (around February 12), as shown in the following graph:

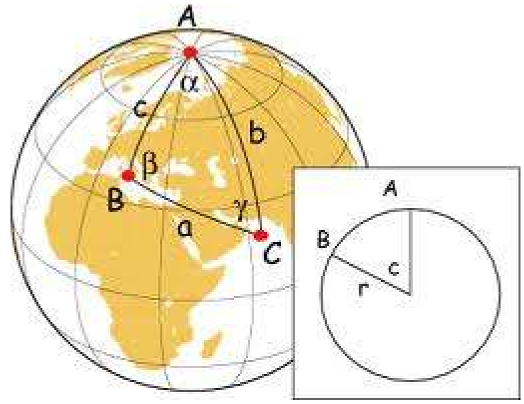


The Equation of Time (Ref)

The declination of the Sun is the angle between the rays of the sun and the plane of the earth equator. The declination of the Sun changes continuously throughout the year. This is a consequence of the Earth's tilt, i.e. the difference in its rotational and revolutionary axes.





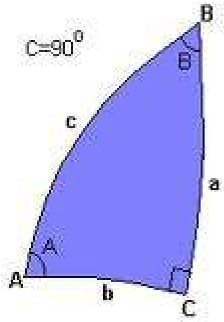


Prayer timings are calculated with the help of a spherical triangle in conjunction with longitudes and latitudes. To calculate the prayer times for a given location, we need to know the latitude and the longitude of the location, along with the local Time Zone for that location. We also obtain the equation of time (EqT) and the declination of the Sun (D) for a given date. Following parameters are essentially needed:-

a. Longitude and Latitude of the place.
b. Local time zone. Standard time longitude of the desired place.
c. Latitude of the sun of the desired date.
d. Decline time (zawa'l) or noon time of the desired date.
e. Under the horizon degree of the sun at the desired time angle of altitude of the sun i.e. declination of the sun for a given date.

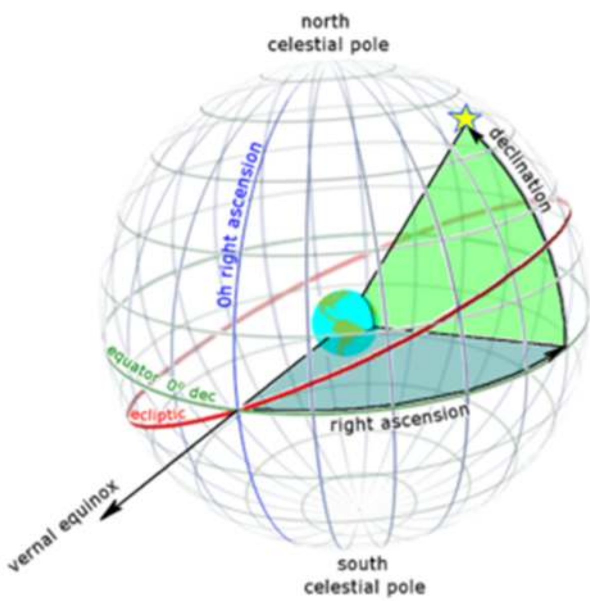
Practical Method

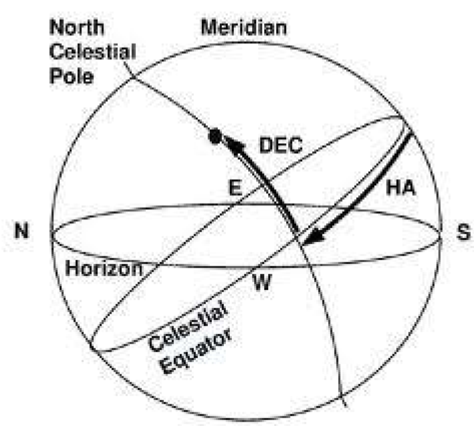
With the help of longitude and latitude the location pin pointed on the globe. In the figure below it is indicated by point 'A'.

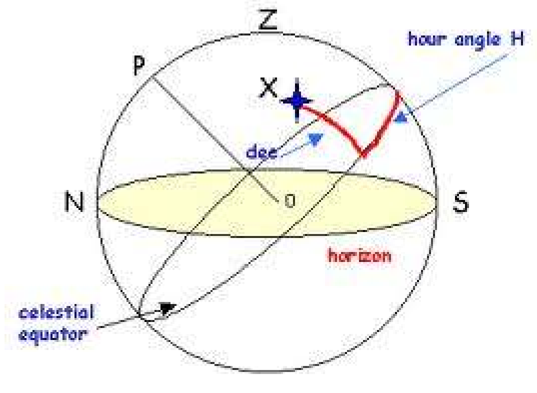


By rotating latitude of the sun, along the latitude which the sun is making at the desired spot and its angle with the zenith at the desired time? If the time for Maghrib (evening prayer) is desired to be found, then if 'A' is the latitude of the desired place and 'C' which is the declination angle of the sun then rotate 'C' on the sphere in such a way that while latitude stays as 'C' but the arc AC make an angle of 90.83°. Determine the longitude at which this takes place. Work out the difference between this latitude and latitude of the desired location. This is called a horary angle. Multiply the angle with four, to find the difference between the desired time and decline time (zawa'l) in minutes.

Declination (abbreviated dec; symbol δ) is one of the two direction coordinates of a point on the celestial sphere in the equatorial coordinate system, the other being either right ascension or hour angle. Declination's angular distance is measured north or south of the celestial equator, along the hour circle passing through the point in question

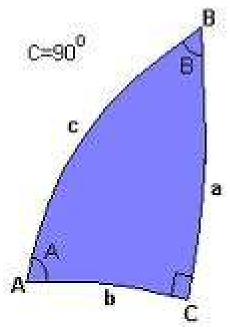






Mathematical Method

In this method a spherical triangle is used.



Following sides are taken from the figure above.

- The side joining a point at the latitude of the desired location and the North Pole is AB which is equal to 90 – Latitude or 90 – A.
- The side joining the latitude receiving the sun rays perpendicularly and the North Pole is CB which is equal to 90 – declination angle of the sun or 90 – C.
- Angle of the sun with the zenith at the desired time of prayer e.g. for the Faj'r is 108° and represented by side AC.
- Angle B is the differential between the latitudes at points A and C.

$H = \cos^{-1} (\cos A - \sin B \times \sin D \div \cos B \times \cos D$

This is Equation # 1 where A is angle B, B is the latitude, D is declination angle of the sun and H is the horary angle. This equation has three parts

Sin (B) x sin (D)

And

Sin (B) x sin (D)

And

Cos (A)

It is easier to solve the problems if these are worked out before hand. Daily values of B and D for a city remain the same. To find out the prayer timings of a location for a specific day the first and the second parts remain constant, only A has to be changed to find value of H for every prayer. Value of A for the Morning Prayer (faj'r) is108°. Accrued value of H will be subtracted from the noon time (zawa'l) of that day. To find the time for the Maghrib Prayer it will have to be added to the noon time. In the Sunni's point of view, the time for Maghrib prayer begins once the Sun has completely set beneath the horizon, that is, Maghrib = Sunset (some calculators suggest 1 to 3 minutes after Sunset for precaution).

Angle 'A' changes daily for calculation of As'r prayers. There are two main opinions on how to calculate Asr time. The majority of schools (including Hanafi, Shafi'i, Maliki, and Hanbali) say it is at the time when the length of any object's shadow equals the length of the object itself plus the length of that object's shadow at noon. The dominant opinion in the Hanafi school says that Asr begins when the length of any object's shadow is twice the length of the object plus the length of that object's shadow at noon.

Ishraq Prayer

According to the research of Hazrat Mufti Rashid Ahmed if declination angle of the sun is 1.4 degrees of < A is 88.6 then Ishraq time can be mathematically calculated. The author does not differ with it.

Beginning of the Forbidden time before As'r (Afternoon Prayer)

Hazrat Mufti Rashid Ahmed states that if declination angle of the sun is 2.3 degrees i.e. < A is 87.7° then the forbidden time before As'r can be calculated. The author agrees with the research.

The Decline (zawa'l) Time of Noon

The **time of true- zawâl** is when the centre of the Sun rises to the location's celestial meridian circle, i.e. when it has traversed the mid day arc peculiar to that location or, in other words, when it culminates with respect to the true horizon. Thereafter, when its following limb descends to the point of culmination with respect to the western arc of the surface horizon of the location, the **time of apparent zawâl** ends, the shadow is observed to begin gaining length. The motion of the Sun and that of the tip of the shadow are imperceptibly slow as the Sun ascends from the apparent zawâl time to true zawâl time, and as it descends thence to the end of the apparent zawâl time, because the distance and the time involved are negligibly short. When the following limb descends to the point of culmination with respect to the shar'î horizon on the western arc of the line of surface horizon of the location, the **time of apparent zawâl** ends and the **time of shar'î zuhr** begins. This time is later than the time of true zawâl, because the difference of time between the true and the shar'î zawâls is equal to the difference of time between the true and the shar'î horizons, which in turn is equal to the period of time. The zâhirî (apparent) times are determined with the shadow of the rod. The shar'î times are not found with the shadow of the rod.

The true time of zawâl is found by calculation, (length of) time is added, hence the (mathematical) shar’î time of zuhr. The result is recorded in calendars. The shar’î time of zuhr continues until the ’asr awwal, which is the time when the shadow of a vertical rod on a level place becomes longer than its shadow at the time of true zawâl by as much as its height, or until ’asr thânî, which is the time when its shadow’s length increases by twice its height.

Many misgivings and doubts exist amongst the masses about the time of decline. Actually some authors in their prayer tables have included the time from the Shar’i noon to the time of decline. One is not sure as to how this misunderstanding commenced but now it’s too widespread in spite of vivid elucidations in the Hadith that it is the time of when the sun is over the Celestial Equator. In the Book of Sunan Nisai it has been narrated:-

XXXXXXXXXXX (Arabic Text - Page 133)

Although mid day time has been mentioned in some of the books, but to associate it with Shar’i mid day is incorrect because it has no link with استواء الشمس. However if the true noon is taken then the anomalies get corrected. True Noon is once the sun has crossed the celestial meridian (true noon), exactly halfway between sunrise and sunset. This is when the sun is at the highest point in the sky and a little after that. . Those associating it with the shari midday commit two mistakes:-

a. To associate it with the shari noon whereas in the Hadith true noon is implied when the sun has reached its peak. Importance of shari noon is linked with fasting before which intention to fast may be declared.
b. To consider the culmination as the central time of zawa’l. Limits of the zawa’l time are dependent on the sun’s exit of it total sphere/disc and not its centre point. Otherwise time not prescribed is also added to the zawa’l time.

The prohibitive time of zawa’l for the As’r prayer begins when the sun has paled to a limit that it can be seen with the naked eye i.e. until the Sun turns yellow, an event that takes place when the distance between the Sun’s lower [preceding] limb and the line of apparent horizon is a spear’s length, which is five angular degrees. Hazrat Mufti Rashid Ahmed has discussed it well in “Ahsan e Fatawa, Volume II”.

Local and Standard Time

Normally the local time for prayers is known. To workout the prayers timings in accordance with the Pakistan Standard Time (PST):-

Difference of local and standard time = (standard latitude – local latitude) x 4

To find prayer timings in Peshawar, (latitude of 71degrees and 30 minutes) and Pakistan with latitude of 75°, the difference is 75:00 – 73:30= 3.30.
A difference of four minutes occurs for every degree so there is a difference of fourteen minutes with PST which has to be added being positive.

Table of Decline Time (Zawa'l)

The tables are printed in the Astronomical Almanac every year can be consulted to find out the daily decline time or else it can be worked out. A specimen table for the year 2022 included here.

Time Equation
In the presence of a Table of Decline Time it is not needed. To understand it is technically useful because the tables have been based on this. Working of the Deviation of the daily time of decline with the true noon is based on this equation.

Example

Find out the prayers timings of Islamabad for 18 December?

Latitude of Islamabad = 33 degrees, 43 minutes or 33.71667

Declination Angle of the sun = - 23.71667

Time of Decline (zawa'l) = 11. 94238

Therefore:-

B = 33.71667
D = - 23.389

First Part

Sin (B) X Sin (D) = Sin (33.71667) X Sin (- 23.389) = -0.396984 X 0.555086 = - 0.22036

Second Part

Cos (B) X Cos (D) =Cos (33. 71667) X Cos (- 23.389) = 0.763441

Third Part

Cos (A)

For true dawn A = 108°

Cos (90.30902) = - 0.30902

< A for the sun rise and set = 90.833°

Cos (90.833) = 0.0145381

< A for Isra'q = 88.6°

Cos (88.6) = 0.02443

< A for the prohibitive time of As'r = 87.7°

Cos (87.7) = 0.04015

Now subtract the first part from the third part and divide the outcome with second part to find to find its horary angle (Cos^{-1}) its horary angle. Then multiply it with 4 to find the difference in minutes from the noon (zawa'l) e.g. for the true dawn and white twilight this difference is 386.67574 minutes, for the sun rise and set 297.43920 minutes and for the prohibited time As'r it is 280.19863 minutes. Subtract the difference of the true dawn from the decline time for Islamabad. Use تقریبی کلیہ for calculating the zawa'l time of Islamabad. It is known that the earth 360° everyday. So the difference from the time of zawa'l (true noon) and time taken by the longitude of Islamabad to rotate be found. According to the Table, Greenwich Noon time is 11.94238. Longitude of Islamabad is 73:05 (73.08333). To find the noon time in Islamabad, work out the difference of the noon at both the places and divide it by 360. Multiply the out come with the longitude of Islamabad and add it to Greenwich Noon Time.

18 December Noon from the Table = 11.94238

17 December Noon from the Table = 11.93420

11.94238 – 11.93420 = 0.00818

0.00818 X (– 73.08333) = - 0.59782

- 0.59782 ÷ 360 = - 0.00166

- 0.00166 + 11. 94238 = 11. 94072 (Noon time of Islamabad)

To find the local time

Latitude of Pakistan – Islamabad Latitude

75 – 73.08333 = 1.9127

1.9127 X 4 = 7. 6508 minutes (0. 127778 hours)

Islamabad Local Noon time = 11.94072 + 0.127778 = 12.0685

Difference for the true dawn and white twilight was found to be 386.67574 minutes

386.67574 ÷ 60 = 6.4446 hours

True dawn = 12.0685+ = 6.4446 = 18. 5131

0.5131 X 60 = 30.786 or 31 minutes

So the white twilight on 18th December in Islamabad is 6:31 minutes. Now subtracting 6.4446 from the noon and repeating the same process will result in 5:37 as the time of true dawn.

With application of the same process following timings are indicated:-

Sun set = 17:02 or 5. 02 PM

Sun Rise = 7. 7 AM

Ishraq = 7.19 AM

The difference of beginning of the prohibitive time of As'r is 280.19863, the time commencing at 4.44 PM. The formula for the 'misle awal' is:-

$\tan^{-1}(1+\tan(D-B))$

And the 'misle thani' is:-

$\tan^{-1}(2+\tan(D-B))$

D- B = 33.71667 – (-23.38976) = 57.10643

Tan (B-D) = 1.54615

With addition of 1 and finding $\tan^{-1}$ it is < A which is = 68.55755. Using this value in equation 1, < H = 159.48510. By applying the above process the early time is 2.44PM. After adding 2 and $\tan^{-1}$, value of < A = 74.25174. Through Equation 1, value of < H works out to be 199.59205. value of ' misl e awal' is 3.24 PM.

Higher Latitudes

In locations at higher latitude, twilight may persist throughout the night during some months of the year. In these abnormal periods, the determination of Fajr and Isha is not possible using the usual formulas. To overcome this problem, several solutions have been proposed, three of which are described below.

Middle of the Night

In this method, the period from sunset to sunrise is divided into two halves. The first half is considered to be the "night" and the other half as "day break". Fajr and Isha in this method are assumed to be at mid-night during the abnormal periods.

One-Seventh of the Night

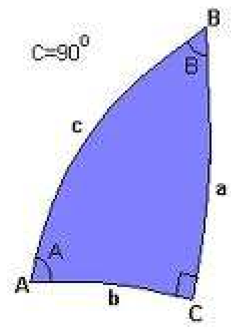
In this method, the period between sunset and sunrise is divided into seven parts. Isha begins after the first one-seventh part, and Fajr is at the beginning of the seventh part.

Angle-Based Method

This is an intermediate solution, used by some recent prayer time calculators. Let α be the twilight angle for Isha, and let t = α/60. The period between sunset and sunrise is divided into t parts. Isha begins after the first part. For example, if the twilight angle for Isha is 15, then Isha begins at the end of the first quarter (15/60) of the night. Time for Fajr is calculated similarly.

In case Maghrib is not equal to Sunset, we can apply the above rules to Maghrib as well to make sure that Maghrib always falls between Sunset and Isha during the abnormal periods.

Desired place is located pin pointed on the globe with the help of its longitude and



latitude. In the figure above it is indicated by ‘A’.

Sighting of the Moon

Sighting of the Moon for lunar months and the religious festivals has become controversial in the Islamic World. Emotionality in such matters aggravates the matter further. All endeavours should be directed to seek the Divine truth and submission to the will of our Lord, Almighty Allah. Winning or losing, thus becomes inconsequential. Notwithstanding our emotional preferences, a correctly researched solution to the problem is an important need of the time. Therefore salient aspects of the arguments and opinions offered by dissenting parties have been elicited here. It is up to the reader to form his/her own opinion. Arguments furnished by the two schools of thought i.e. Conservatives and the Modernist are compiled in the succeeding paragraphs.

One party proclaiming to follow in the footsteps of their ancestors declare that calculations in such matters are unnecessary. According to their contention; a witness to sighting of the Moon should be produced before a court and his testimony accepted irrespective of being illogical or contradictory to the ground realities. They think that a judge is like a 'jeefa' in the hands of a witness. So he has to base his decision on what the witness says; and not to question the logic of his testimony.

The other group thinks that living in the modern times; its dictates cannot be ignored arbitrarily. Acceptance of an illogical or a contradictory testimony (shahadat) can be dangerous for the newly converted Muslims, those with a weak faith or those non Muslims with leanings towards Islam who have been attracted to it, considering it a religion closest to the nature. Controversial religious decisions as such can irrevocably damage their confidence and faith. These people welcome scrutiny of erroneous and groundless testimony.

The Conservatives offer the logic of being the followers of an illiterate (ummi) Prophet (SAW), therefore not obliged to calculations and written work. They insist on retaining a simplistic approach and only follow basic dictates of the Sharia. Whereas the other party contends that Islamic virtue of its being a natural religion is as important as its simplicity. So long as both the virtues could be blended together; its fine but where it is not possible then a logically researched solution should be accepted and adapted. Avoiding logic is not simplicity but it is being irrational.

Another logic offered by the first group is; that it is laid down in the Hadith; to begin fasting after the Moon is sighted and break it on sighting of the Moon. If something intervenes then complete thirty days of the month of Shaban. Therefore depend only on testimony and avoid intricate calculations. The Modernists abiding by the same Hadith contend that scrutiny is essential to determine whether the Moon was actually sighted or not. This approach obviates unnecessary trouble to the majority who are likely to suffer because of a whimsical witness. It is explicitly mentioned in the holy Quran:-

(The sun and the moon are (bound) by a (fixed) calculation.   Ar Rahman – 5)

The Conservatives respond that how can a witness be doubted and disbelieved who truly practises Sharia and is also a just person, especially when he has also sworn to have sighted the Moon. A true Muslim (Momin) cannot be disbelieved but trusted. The others view it differently; arguing that it is not a matter of mistrust or disbelief but to shun errors and mistakes. It is better to correct a mistake and eradicate it leading on to benevolence. Amongst the followers of the Prophet (SAW), Hazrat Anis (RH) was mistaken to have observed the Moon. A young man removed an eye lash from his eyes and inquired if he could still see the Moon. He readily accepted his mistake. This proves that an error should be always corrected whenever possible.

Another logic offered by the first group is that renowned books of Islamic jurisprudence advocate mathematicians and fortune tellers should not be believed. So how can testimony of a witness be rejected on the basis of calculations? In reply, the other group agreeing with this contention; admit that if the Moon is not actually sighted for any reason like cloud cover etc verdict of the scientists will not be accepted. On the other hand, if it is ascertained that a witness testifying to sighting of the Moon has erred, then recourse to scientific tools is in order. Science should be made subservient to the religion. There is nothing extra ordinary in ascertaining the facts. Great religious scholars of the past always questioned a witness to reach the logical truth. These questions were mostly based on the prevalent scientific knowledge. In the same vein, modern day scientific advancements should not be shunned. Use of computers adheres to the same logic proffered by our elders.

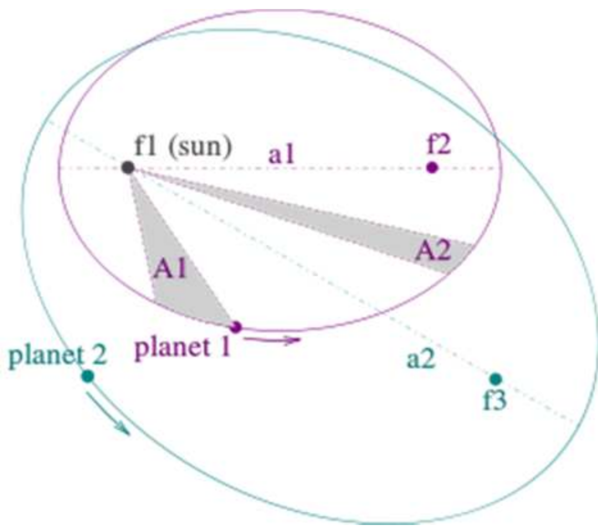
Controversies amongst the mathematicians are made the basis for rejection of scientific tools by the Conservatives. They contend that experts are seldom unanimous on a single date for sighting of the Moon. How can their advice be made the ground for rejection of a testimony. In response, the Modernists argue; that in the prevalent two types of calculations, difference of opinion can only arise in one set but there can be no differing views in the second set of calculations. The first relate to height of the Moon from the horizon or its age etc because these are based on human observations and estimations. Experience and knowledge play an important role in these estimations. The other type of calculations relate to the lunar birth; which is a process beyond human observation. This occurs at a precise moment and there cannot be two opinions; it being a constant fact. All the scientific rules applied to verify testimony of lunar sighting are similar constants. For example a scientist rules that the Moon will not be sighted on a particular day; some people, however, claim to have sighted the Moon will not be ignored. If the time of sighting is after the birth time of the Moon, the witnesses shall have to be heard and if their testimony does not contradict the constant scientific parameters it shall have be accepted. Verdict of a scientist irrespective of his status or stature cannot override the bonafide testimony of a witness. This is a manifestation of the fact that word of fortune tellers and prognosticator is not to be entertained.

It is further argued by the first group that books of jurisprudence especially those of Hanaf contend that a testimony of any veracity has to be accepted. Their contention categorically negates the role of astronomical calculations. The other group, however, cite the notions of ancient scholars like Al Subki, Alama Kausri and others who profess thorough investigation of a witness is only intended to ascertain the reality. Al Subki had ruled that a witness testifying falsely should be condemned for ever, especially when testimony is based on negation of the constant factors. The Conservatives feel that since Al Subki was from the Shaffi School of Islamic jurisprudence, his thoughts cannot be a guiding rule for the Hanaf. Even more, his work was rejected by some of the Shaffi scholars. The second group conceding to the objection, point out that Al Subki focused on the subject at a time, when because of the lack of communication infra structure no substantial harm could have been caused to the masses. So rather than condemning him, his foresight should be appreciated. To revisit problems suitable enough to modern time; shall need a reference to basic laws of the Quran and Hadith. Old verdicts and interpretations being transitionary in nature shall become null and void thus necessitating a reference to the Quran and the Hadith; which are the only permanent sources of guidance. Concurrence of some past visionary jurists if available should be taken as a Divine blessing and accepted rather than discarding it on flimsy grounds. Take for example the issue of praying and fasting in the intemperate regions, where logic of all Schools of Jurisprudence was suitably adapted. Or the issue of a missing husband where the verdict of Hazrat Imam Malik was accepted by the Hanaf scholars.

Another argument tendered by the first group is that whereas a Hadith is an absolute verdict, recourse to calculations is an abstract mean. How can an absolute rule, be rejected on the basis of thing which is abstract in nature. The second group's rebuttal emphasises that the issue is not of acceptance of the Hadith or otherwise but to determine the truthfulness of a witness. Being an act of observation, difference of opinion can occur here but astronomical calculations are an absolute constant which shall remain unchanged. To pitch a whimsical act of observations against absolute calculations is not fair, especially if the observation is based on misperception. This can surely be labelled as a zetetic or a doubter "durayat".

The first group contends that to consider astronomical calculations at par with the tradition is not an established act of our ancestors. The second group negating the contention declare it a proven practice of the elders. To support their argument they cite the case of Alama Badr ud Din Ainee (RA) who conducted an extensive debate based on astronomical laws, on a Hadith of Imam Bukhari about the Prophet's (SAW) ascension to the Heavens (Merajj). This was also ratified by Alama Kausri (RA). So if questioning the author of Bukhari Sharif is in order, why cannot a witness be questioned now? To counter this argument, the first group contend that the cited incident was part of research on the Hadith. No where it has been indicated that problems of the lunar sighting be resolved through astronomical calculations or accepted as a standard. Defying the logic, the second group proffer that it is explicitly laid in the Hadith that actual sighting of the Moon by a witness and actual hearing of something has to be established because both are based on sensory perceptions. Calculations of the prayer timing were not based on astronomical calculations. However the authenticity of calculated timings was established over the observations in spite of clear illustrations given in the books of jurisprudence that a call for prayers can not be made unless the correctness of the time has been physically observed. These days, charts are used to both make a call for the prayers and also offering them. So if the time of the Moon setting is similarly compared; it will correctly correspond to the calculations. There is no reason to accept the absolute correctness of the calculations. Based on this logic, when these charts establish setting of the Moon before the Sun set on a certain day; testimony of a witness shall have to be rejected.

The first group continuing with their argument add that whenever they accepted the verdict of the second group, they were disappointed to find the Moon next day into a bigger crescent and higher in altitude. It looked to be the second or third day crescent leading to grumbling amongst the masses. In their reply, the second group expresses their shock at the ignorance of those scholars. It is clearly laid down in the Hadith that size of the Moon is inconsequential in determining its appearance. Appearance is the only final criterion in sighting of the Moon.



The technical reply in the matter is as follows. Orbit of the Moon is distinctly elliptical with an average eccentricity of 0.0549. The non-circular form of the lunar orbit causes variations in the Moon's angular speed and apparent size as it moves towards and away from an observer on Earth. The mean angular daily movement relative to an imaginary observer at the barycentre is 13.176° to the east; which means that it appears close and away from the earth. So according to Kepler's laws of planetary motion; when the Moon is near the Earth, it moves faster and grows rapidly but slows down when it is farther away.

The first group goes further and argues that in keeping with the tradition of the conservative elders it is better to stay away from calculation and scientific tools. Sighting of the Moon is basically for worship and not for a festival. Variations make no significant difference when it relates to worshiping. The second group responding to this; contend that it is easier to satisfy people about a factual happening than an abstract assumption. What is needed is awareness and education; which is now prevailing in the Muslim world. Ours are no ordinary times; it is an era of mischief and wickedness. Everything is noted and spread through the media. Anti Islamic lobbies are all out to fabricate false testimonies and mislead the Muslims in order to cause disunity and frustration. Buying out a few Muslims to further their nefarious goals is no big deal. So there is an urgent need to be cognisant of the situation and apply latitudes provided in the Sharia to harmonize and attune our practises.

Another point put forward by the first group furnishes that all sorts of calculations be done away with; as they no room exist for them in Islam. The other group feels that a judge has been allowed latitude to base his judgement on popular sentiment and not be restricted by a couple of witnesses. This is primarily to obviate fallacy and distortions. All methods to eradicate falsehood should be adapted.

Now that reasoning of both schools of thought has been narrated, it is up to the reader to fathom the truth. The material offered here is certainly not exhaustive and complete. A reader may like to elicit further arguments and counter arguments by referring to scholars from both the schools. Author’s book ‘kasf e Hilal’ may also be consulted.

Latest Scientific Research on Sighting of the Moon.

Sighting of the Moon is a serious contemporary issue of our times. The lunar months are dependent on it, as warranted in the Sharia. Many of the worships are regulated with sighting of the Moon. It is thus obligatory for a Muslim to keep a track of it; lest all of us get condemned as sinners. Gist of a Hadith, lays down that fasting should be commenced with sighting of the Moon and also ended with it. In case of an obstruction like clouds etc thirty days of Shaban should be completed and then begin the fast. This amply proves that sighting of the Moon is not mathematical as commonly misperceived by some but only dependent on physical sighting of the Moon. So it is important to keep track of the Shaban moon. The question arising here is that whether scientific research and tools could be used to facilitate sighting of the Moon?

Answer to this query depends on whether the sighting is to be solely based on the traditional methods or a zetetic or a doubter “durayat” is being allowed. The traditionalists restrict their decision to physical lunar sighting only. They may therefore be scientifically aided by indicating the probable site of the lunar appearance on the horizon and nothing more. Those who also subscribe to possibility or otherwise of appearance of the Moon at desirable time based on astronomical calculations can be helped with the latest scientific research. Beside its location on the horizon, the duration and its probability of appearance at the specific sites can be indicated. The testimony of a witness is only accepted when the lunar birth has already taken place. A witness is sufficiently questioned to ascertain that his testimony is not mistakenly based on a misperception. In accordance with the latest research available, changes in the horizon or the places of appearance and possibility of the common lunar sighting in different countries can be indicated. Configurations of the Moon can be shown to a witness to ascertain the truth. The author has practically experienced that a witness shown the lunar images only points to the real picture. A few more questions can be asked to further verify the actual sighting.

Lunar Sighting – Questions & Answers

Some of the questions posed to the experts about sighting of the Moon are answered below.

As mentioned in theHadith, we being an ilitrate Umma, how can the decisions be based on calculations?

This is a resonable questions. Our decisions should not be based solely on calcultions. This applies also to the prayers timings indicated in the charts and tables which are primarrily based on solar calcultions. The books of jurisprudence categorically lay down that unless one is not sure of the time, call for a prayer should neither be recited nor the prayer offered. The charts are still used to subsantiate our physical judgement of the timings. These aids reinforce the confidence to determine the correct time for praying and fasting. Similarly lunar rise/ set charts can be prepared to reinforce our physical observations. When these match the observations and are proven correct then there is no harm in using them to reinforce the decision making process.

Its high time that the concept of being an ilitrate Umma is reanalysed, in order to obviate contradictions in decision making. If our understanding of the concept is based on the Prophet's (SAW) teachings to adopt easier courses; then the present day calculations are very easy and useful. The only submission here is that; when the astronomical calculations indicate setting of the Moon before the Sun set on a certain day; no witnesses claiming to have sighted the Moon should be entertained. Secondly if the lunar images do not match with the explanation of a witness; his testimony be all together ignored. Nonetheless the decision should be based on physical observation but a witness is questioned to verify the plausibility of his testimony. All the calculation should remain subservient to the Hadith and acceptance of the following Quranic injunction should also be demonstrated.

(The sun and the moon are (bound) by a (fixed) calculation. Ar Rahman – 5)

Basically the decision is not based very elaborate scientific facts which include intricate details of the Moon and its appearance i.e. presence of the Moon on the horizon, its altitude and exact location of its setting etc. The decision is always based on its actual and logical sighting. True testimony is therefore awaited. The testimonies which are contradictory to zetetic or "durayat" rule are ignored. Author's book 'Kasf e Hilal' will be useful to consult, Insha Allah.

How can the verisaty of lunar images be justified to verify the testmony of a witness?

Lunar images are primarilly used to verify the pattern of lunar appreances. A person claiming to have sighted the Moon, bases his observation on his perception. It is proven through incidents of the revered Companions of the holy Prophet (SAW) that an error is possible in sighting of the Moon. Possibly a person not having actually sighted the Moon may perceive to have seen it. Incident of Hazrat Annas (RH) is prominently described in annals of the Muslim history. When repeated observations synchronize with the astronomical calculations, then confidence level is raised to trust their authenticity and correctness. So when this authentic data is compared to the perecived tradition; then correctness of the calculations has to be accepted. This is what is called ‘ duriat’. Hazrat Ashraf Ali Thanvi (RA) has eloborately dwelled on it in his book , “Al Nabtahat ul Mufida fil Mashadat ul Hadisa (pages 42-43)”.

It is professed that when age of the Moon is less than sixteen hours or its inclination angle is less than eight degrees then testimony of a witness is not to be accepted. Please comment?

Some scholars like Maulana Tamiz ud Din Qasmi and Maulana Burhan ud Din Sunbhali have formulated such rules. In reckoning of the author, it is incorrect to do so because these rules are based on perception; which could be wrong. Appreance of the Moon is also dependent on its actual sighting by a person. Different people of varying background cannot be governed by a set of rules to regulate their perceptions. Use of the real lunar images to verify testimony is an established fact and can be used as a rule to aid the judges. In such a case, no voilation of the Sharia is involved rather these pictures serve as symetrical context to verify a testimony and obviate chances of misleading fallacy.

At times evidence is rejected being unplausable. Bigger size of the Moon next day conravenes the decision. Does it not prove fallibility of the rule?

It has been expilictly forbidden to in the Haddith to depend on size for sighting of the Moon . Some legends cite it as an a Doom’s day indicator. Scientifically the Moon has an oval orbit, so it keeps getting near the Earth and then gets away. When it is near, it moves faster but keeps slowing down as its gets farther away. So if the sighting coincides with a day of higher speed; because of its proximity to the Sun, it remains invisible. Any claim of sighting of the Moon is therefore rejected. The next day due to its speed, the Moon has drifted so far away from the Sun that its appearance becomes very prominent which is often mistaken as a late Moon.

The other reason for the Moon to be sighted; is that its age should be sixteen hours otherwise it cannot be seen even fifteen minutes before. Next day it has grown to approximately forty hours in age and thus becomes pominent enough to be mistaken as the third day moon.

You have written that if the Moon is visible in the morning then it cannot be seen in the evening. Whereas it is mentioned in ‘Shami’ that it can be seen the same day in the evening. Please clarify the contradiction?

In no way, Alama Shami (RA) is being contradicted. Actually it is that expert who had posed a wrong question to Maulana Shami (RA). If it was the opinion of Maulana Shami (RA) then he had based it on the scientific knowledge available then. Today the modern sciences are by far more advanced, so their verdicts have to be accepted. Author’s book may be consulted for detailed scientific arguments. There cannot be any two opinions on rules from the Quran and Hadith adopted by Maulana Shami (RA). However matters of jurisprudence can be debated. An argument based on the modern sciences gets preference the one which is derieved from older knowledge of science.

It has been accepted that the modern sciences are still in a state of flux and inconsistency. So how can they serve as a tool in the system of lunar sighting?

Our rules have been based and tested on detailed daily observations. These can be verified through the daily obsevtions of the Moon, the Sun and Stars and their rise and set in timings with respect to their locations. Our results can also be verified with a comparison of lunar and solar eclipse data with their normal observations. We can be held responsible for our computer programme which forms the basis of our decisions. Any future changes shall absolve us of our responsibility. Alama Badr ud Din Ainni (RA) had based his critique of Bukhari on the then prevalent rules of astronomy. Prayer timings are also similarly calculated. Futuristic changes are a distinct possibility. Anyone not accepting our workings may be advised to refrain from praying in accordance with the tables and charts in vogue but may do so on definite physical observations.

How do you justify the contradictions in your sighting methodology (Ikhtalaf e Mataleh) with research of the scholars from the past?

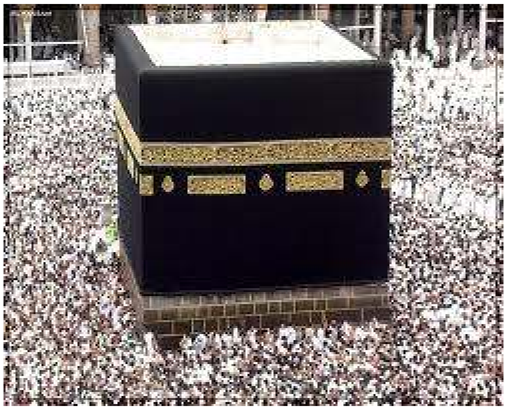
May Allah Almighty give me the acumen to answer this reasonable question. By no means it is my intention to challenge the findings of the elders. As you are aware,Islamic jurisprudence has an inbuilt system of corrections to keep abreast with the changing times and conditions. A verdict isaltered, if any change in its conditions occurs. In the times of our elder jurists, geography of the world was confined only upto Moroco. Lack of communication infra structure confined new research and discoveries to the respective areas. West was not bound by any thing practised in the East. This hardly created any functional problems for anyone. Now with advanced communcications available, application of verdicts of the old jurists can create irraprable loss and damage. Let me explain it further. Lets say that the Moon was not sighted here after the Sun set. Since one is bound to the local sighting, so a decision is accordinly made and everyone is relaxed. Conversely if the rule of Ikhtalaf e Mataleh (difference in sighting) is not accepted then one will to wait for the Moon to be sighted in other countries like Iran and Afghanistan. Hoping that lunar appearance will be reported from Saudi Arabia, Egypt, Moroco or even USA. The whole night is spent in waiting and ultimately it is reported to have been seen in the USA. The Sun sets after a lapse of twelve hours in the USA. By then it the dawn has appeared here. Anyone who has not eaten during the night can fast but others can neither fast nor can they eat. This is inspite of the fact that it just took five minutes for the news to reach here; but imagine the magnitude of misery that it has caused. A real big loss.

So basically it was to surmount such problems that the later jurist of the Hanaf accepted the doctrine of ‘ Ikhtalaf e Mataleh’ or differnces in sighting. We are now adhering to the decisions of our elders. To corroborate it further, acceptance of the verdict of Hazrat Imam Malik (RA) in the case of a missing person by Hazrat Thanvi (RA) can be cited as a fine example. Majority of the religious scholars have accepted this concurrence and have not classified it as any thing out of their school of jurisprudence. So the doctrine of ‘Difference in Sighting” is based on the quotes of the Companions of the Prophet (SAW) and renowned jurists. A recourse to their opinion is a logical option. Especially in a situation when adoption of any other opinion becomes practically impossible to address our needs.

Is sighting of the Moon with help of a binocular acceptable as evidence?

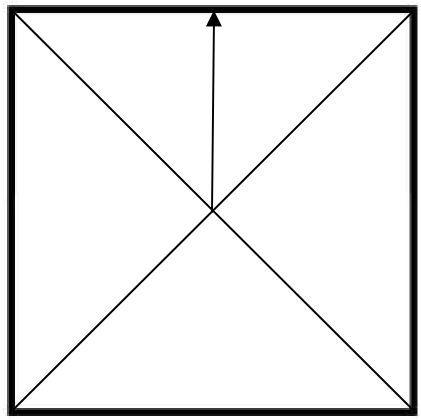
Religious scholars have accepted it as a correct evidence. If sighting of the Moon with the help of an aid was unacceptable then use of spectacles would have been forbidden. Binocular is an extended form of the glasses.

Determination of the Qibla Direction



Prayers (salah) is a pillar of Islam and Qiblah, Kiblah or Kibla, is the obligatory direction that should be faced when a Muslim prays. As soon as a person realizes that he is facing in the wrong direction, it must be immediately corrected even during the course of the worship. Similarly a person facing the wrong direction during prayers has to be corrected. In an unknown and strange place, direction of the Qibla must be ascertained (tehari). The best is to ask a local resident or else it should be determined with help of a grave yard, direction of the Sun, stars or any other plausible means. In case of failing to do so, judgement may be exercised. Later finding out that the prayers were offered in the wrong direction; there is no need to repeat them. Even during course of the worship, if another direction transpires to be the right Qibla then the direction should be changed. Anyone differing with direction of the Imam has to then individually pray in the perceived direction otherwise his/her worship will remain faulty. When travelling in a train or an aircraft it becomes obligatory to shift to the changing Qibla direction unless one is all alone and theft of assets is feared. A person failing in perceiving the correct Qibla direction; has to pray in every direction once. Inside Kabba, any direction is allowed except inside the hateem where Kabba has to be faced.

In books of Islamic jurisprudence, Qibla is defined as the direction that a Muslim has to face during the course of praying (salah). This is called ‘Istaqbal e Qibla’. It is mandatory for a worshiper to face the Qibla direction. The Islamic Qibla is in the direction of the Holy Kabba. Some scholars concede a mistake of 45 degrees astride a line drawn between the worshiper and the Kabba.



A person making an angle of 30 degrees during prayers is considered right being within 45 degrees margin. It is laid down that inside the Holy Haram exact direction of the Kabba has to be faced. In the city of Makkah, residents have to face the Holy Mosque and outside Makkah, it is obligatory (farz) to face the Kabba.

The general direction of the Kabba, in the Indo Pak Subcontinent is towards the West. In winters, the Sun sets in South West and in summers it does so in North West. So a place in between is considered to be the right Qibla direction.

During construction of a mosque, ideally the exact Kabba direction should be determined to obviate any mischief in future. Any deviation from the true Kabba direction falling within 45 degrees already existing in the old mosques may be ignored.

Determination of True Qibla Direction

First Method – Use of the North.

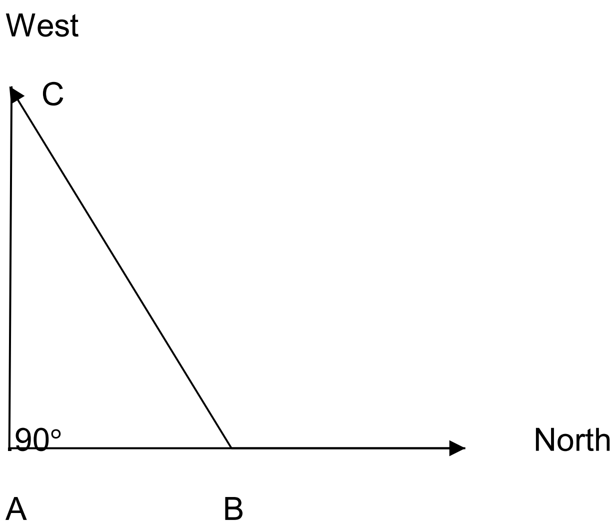
Having determined direction of the North and angle of the Kabba direction true direction of the Qibla can be found. To do so find the true north and with help of a protector draw the Kabba angle which shall indicate the true direction of the Qibla.

Figure 30

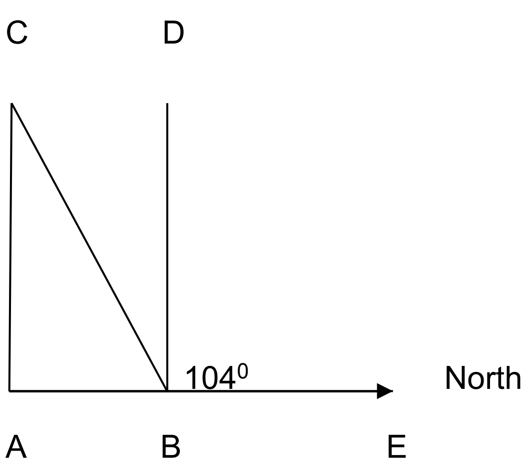
In Islamabad, Qibla direction makes an angle of 104 degrees with the North. As indicated in the figure, true direction of the Kabba can be thus pointed.

Second Method- Angle.

In the figure below, line AB indicates direction of the North. A one meter line AC drawn perpendicular to it; along with length of line AB will give us triangle ABC which should indicate the Qibla direction at point B making the requisite angle at that point.



It is known that Qibla direction in Islamabad makes a 104^0 angle with the true North. To find the Qibla direction line AB is drawn towards the North and another line AC towards the West. Suppose the length is AC is 100 cm. Which is the length at line AB at which line BC will exactly point to the Kabba.



Draw perpendicular BC on line AB. Angle ACE should be equal to the angle which Qibla direction in Islamabad makes with the North i.e. 104^0 .

< CBE = < DBE + < DBC = < 90 + < DBC

< ACB = < CBD (being complimentary angles)

Therefore if < ACB is known then it is easy to find < CBD

Tan ACB = Line AB / Line AC

< ACB = < CBD = < DBD – 90 = 104 – 90 = 14

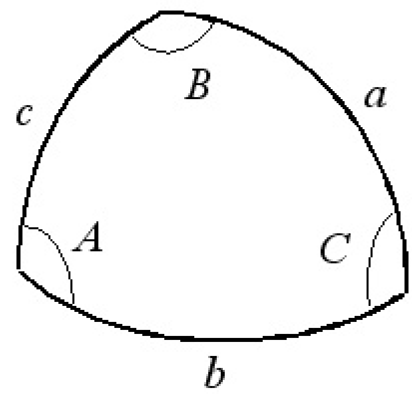
Tan 14 = 0.249328002832 or approx 25 cm.

So as shown in the figure 32 above a Line approx 25 cm is drawn from point A towards the North (AB) and another line of one meter length drawn towards the West (AC). Line joining BC will point in direction of the Qibla.

This is an easy method for the architects and builders to use during construction of mosques. It cumbersome for the majority to make such detailed calculations, therefore the Author has listed line AB for 5000 places in Pakistan, in his book ‘Al Mouazan’. Since Line AC is always taken as one meter so it has not been repeated.

How to find the Qibla Angle?

If the longitude and latitude of a place is known then the angle of Qibla direction can be easily indicated. Exact longitude and latitude of Makkah will be needed which are Longitude 39.75^0 East and its latitude is 21.4499986^0 North.



As shown in the figure above the place selected for finding its Qibla direction is donated by B which is the intersection of its longitude and latitude. There are 90^0 from the equator to the North Pole so line BC should be 90- C. Similarly AC is the intersection of the longitude and latitude of Makkah. Therefore line AB should be 90- AC. Point B represents the difference between the longitude of Makkah and the desired location. Actually it is the angle that is made with the North Pole.

If longitude is donated by LONG and latitude by LAT then Makkah can be represented by LONGM and LATM.

DF= LONG – LONGM

Therefore Q i.e. the Qibla angle can be found with the following formula :-

F = SIN (DF)

G1 = COS (LAT) X TAN (LATM)

G2 = SIN (LAT) X COS (DF)

G = G1 – G2

Q = COS^{-1} (F / G)

If G has a negative sign then add 180^0 to the Qibla angle and if both G and F both have negative values then subtract 180^0 from the angle.

Example

To find the Qibla angle for Islamabad:

Islamabad has Longitude = 73.05 East, Latitude = 33.43 North and Makkah is Longitude = 39.45 East and Latitude = 21.4499986

Therefore:-

LAT = 33:43 = 33.716676

LONG = 73:05 = 73.08333

LONGM = 39:45 = 39.75

LATM= 21.4499986

DF = 73.08333 – 39.75 = 33. 33333

G 1 = COS (33.71667) X TAN (21.4499986) = 0.32681

G 2 = SIN (33.71667) X COS (33.33333) = 0.463768

G = G 1 – G 2 = 0.32681- 0.463768 = 0.13696

F = SIN (DF) = SIN (33.33333) = 0.54951

Q = TAN (F / G) = (- 13696 / 0.54951) = TAN (- 0.24924) = - 76.0047

Since G has a negative value so 180 should be added to Q.

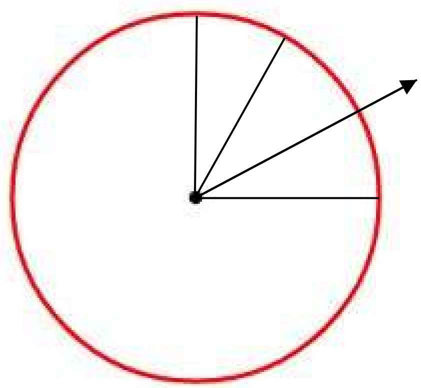
Therefore Q = 180 + -76.0047 = 104^0 .

How to find the North?

First Method – Use of Compass

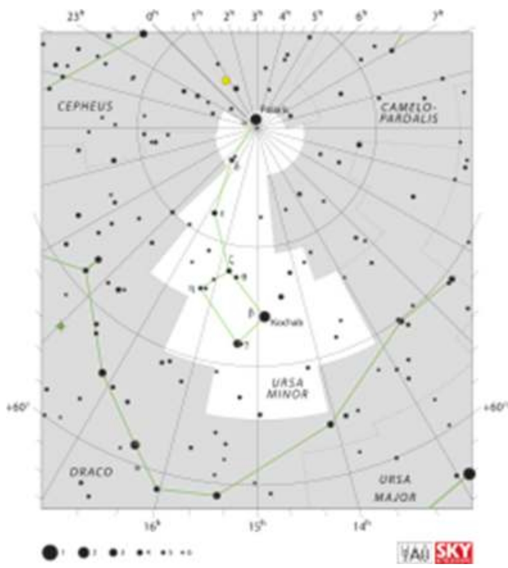
Compass needle always rests in North South direction. North can be found when the needle is stationary. There is a minor difference in the true and magnetic north but being very insignificant it can be ignored. While determining the direction, it is advisable to keep away from metallic (iron) objects

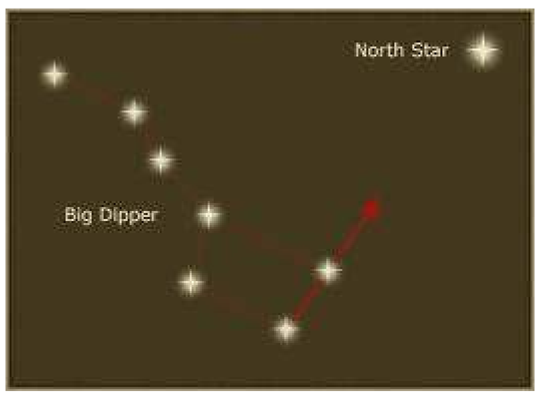
Second Method- Use of Indian Circle



The process takes two days. Select a plain piece of land and put a shaft at point M as shown in the figure. Now at about 11 AM mark the end of the shadow at point A. keeping line AM as the radius, draw a circle around the shaft. After reduction the shadow will start growing again. As soon as it touches the circle, mark it as point B. Now bisect angle AMB, which will cut the circle at point C. Line MC will point to the North.

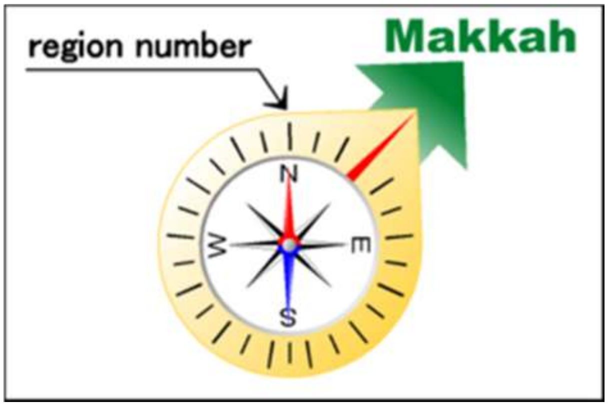
Third Method – Use of the Pole Star





In practice, the term Pole Star usually refers to Polaris, which is the current northern pole star, also known as the North Star. Pole star is a prominently visible star that is approximately aligned with the Earth's axis of rotation. A line drawn towards it will indicate direction of North.

Fourth Method – Use of Qibla Indicator



A Qibla indicator is basically a compass, but its dial has thirty six, forty or 400 graduations. The user's manual shows an index or region number for every place. When the region number is aligned with needle pointing to the North, Direction of Qibla (Makkah) is indicated. The index or region numbers given in these booklets are mostly faulty. Use of Author's Book 'Al Mouazan' may be used as a help to find the correct index/region number in Pakistan.

Fifth Method – Use of the Solar Shadow

This is the easiest and the most correct method. Twice a year the Sun is exactly atop the holy city of Makkah. These timings are often published in the newspapers. At that precise moment, shadow of a vertical object will point in exact opposite direction of the Qibla. Where ever the Sun is visible, this method can be used to find the direction of Kabba. Inclination angle of the Sun then equals the latitude of Makkah. The noon time in Makkah can be used to determine the Qibla direction. In Pakistan, two hours will have to be added to compensate for the time differential.

Beside these two days Qibla direction can be found as under:-

a. During the day if at any time the Sun comes in between a place and the Kabaa, the above situation arises.
b. Alternatively the desired place can come between the Kabba and the Sun. At that moment shadow of a vertical object shall point in exact direction of the Qibla.
c. Else the right angle (90^0) method can be used with help of the solar shadow which it makes with the Kabba.

These simple methods are better than the instruments being devoid of errors. Direction of the Qibla is determined directly rather than using the North. The difference between the magnetic and true North is obviated. Secondly the methodology is simple. To pick shadow of a vertical body, a weight has to be tied to a rope which forms the vertical shadow. The only problem is the precise calculation of a place at these specific moments which are difficult and tedious.

World of the Stars

Astronomy is one of the oldest sciences. Right from beginning of the civilization, only two things prominently visible were the sky and the earth. So the human mind started wondering and pondering about them. Initially the religions disclosed as much as was possible to digest and understand; the rest was left for posterior evolution and growth. Those with a cleansed heart (Qalb e Saleem) and guidance through the Divine revelations remained constrained to disclose what ever was revealed to them. On the other hand, those with crooked hearts portrayed their self fabricated ideas and projected them as religious gospels, even rejecting the Divine revelations. Alama Albairooni, in his Book ‘Kitab ta'rikh al-Hind’ writes,

“Hindus believe, that all stars are spherical bodies, aqua’s in temperament and totally dark. It is only the Sun that is bright with a fiery temperament which provides light to all the stars when they pass by it. Some of the visible stars are actually the blessed persons who congregate in the sky sitting over their crystal and quartz chairs.”

Some misguided souls impressed with their grandeur, mistook the celestial bodies to manifest Divinity and started worshiping them. Different clans and tribes worshiped stars and the Moon. Most of them bowed before the Sun because it provided light and heat. Gigantic temples of The Sun God and the Moon God abound the world. Even in the civilized world of today, worshipers of the Mercury, Venus and other stars and other planets exist in large numbers. Worship of the celestial bodies has ever since been a popular form of worship.

Hazrat Ibraheem AS (Abraham) who was deputed to the peoples of Euphrates and Tigris found them to be worshiping stars. He chose a unique way to deter them from their established practises. One by one he selected a star, the Moon and the Sun as his Benefactors and rejected them; to exhibit that all these objects were meaningless and mortal. He beseeched his people to worship only one God, Allah Almighty who is the Most powerful and Immortal. This has been narrated in the holy Quran:-

فَلَمَّا جَنَّ عَلَيْهِ اللَّيْلُ رَأَى كَوْكَبًا قَالَ هَـذَا رَبِّي فَلَمَّا أَفَلَ قَالَ لا أُحِبُّ الأفِلِينَ، فَلَمَّا رَأَى الْقَمَرَ بَازِغًا قَالَ هَـذَا رَبِّي فَلَمَّا أَفَلَ قَالَ لَئِن لَّمْ يَهْدِنِي رَبِّي لأكُونَنَّ مِنَ الْقَوْمِ الضَّالِّينَ، فَلَمَّا رَأَى الشَّمْسَ بَازِغَةً قَالَ هَـذَا رَبِّي هَـذَا أَكْبَرُ فَلَمَّا أَفَلَتْ قَالَ يَا قَوْمِ إِنِّي بَرِيءٌ مِّمَّا تُشْرِكُونَ

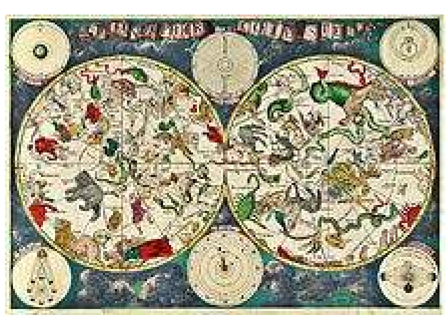
(So, when the night enveloped him, he saw a star. He said, "This is my Lord." But, when it vanished, he said, "I do not like those who vanish." Later, when he saw the moon rising, he said, "This is my Lord." But, when it vanished, he said, "Had my Lord not guided me, I would have been among those gone astray." Thereafter, when he saw the sun rising, he said, "This is my Lord. This is greater." Again, when it vanished, he said, "O my people, I disown whatever you associate with Allah. I have, indeed, turned my face straight towards the One who created the heavens and the earth, and I am not one of those who associate partners with Allah." Al Anaam 76-78)

After seeing these great symbols; rather than recognizing the supremacy of Allah Almighty, they chose to burn him (AS) alive. Allah Almighty save his prophet and friend with one single pronouncement of:-

قُلْنَا يَا نَارُ كُونِي بَرْدًا وَسَلَامًا عَلَى إِبْرَاهِيمَ

(We said, "O fire, be cold and safe for Ibrahim." Sura Al Anbiya - 69)

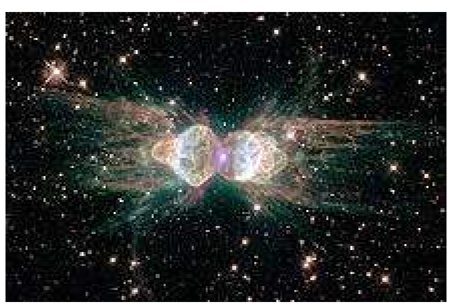
Prehistoric cultures left behind astronomical artefacts such as the Egyptian and Nubian monuments. The Babylonians, Greeks, Chinese, Indians, Iranians and Maya civilizations performed methodical observations of the night sky. However, the invention of the telescope was required before astronomy was able to develop into a modern science. Historically, astronomy has included disciplines as diverse as astrometry, celestial navigation, observational astronomy, and the making of calendars.



(A celestial map from the 17th century, by the Dutch cartographer Frederik de Wit.)

Astronomy is nowadays often considered to be synonymous with astrophysics. Astronomy is a natural science that deals with the study of celestial objects (such as moons, planets, stars, nebulae and galaxies); the physics, chemistry, and evolution of such objects; and phenomena that originate outside the atmosphere of Earth (such as supernovae, gamma ray bursts, and cosmic background radiation). A related but distinct subject, cosmology, is concerned with studying the universe as a whole.

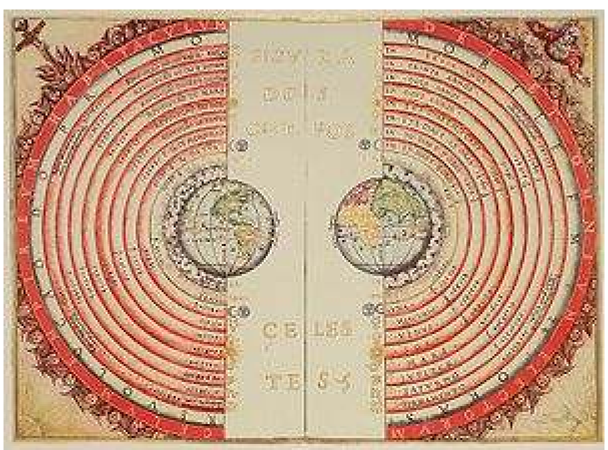
In the vast celestial world of stars, planets exist in a very short number. The nebulae are millions of times more than them. So far the planets that have been be discovered do not exceed even a dozen in number. Against this our galaxy alone has over a trillion stars and yet there are many worlds beyond it. The universe has very many galaxies which contain billion and trillions of stars. It is impossible to count the number of stars in the universe. This fact clearly shows that a human being is humble and a subservient creation of Allah Almighty.

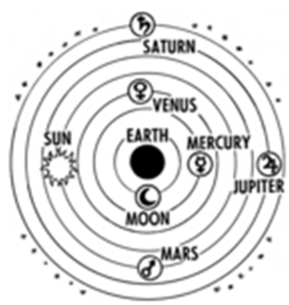


Notwithstanding the theories propounded by the early civilizations about the fixed stars/nebulae, now these are unanimously recognized as giant balls of gases and fire; with hydrogen bombs exploding every now and then. The gaseous material gathered at different points and formed creates the fixed stars/nebulae. Accumulation of gases in a restricted space agitated these, resulting in fire and heat. Nebulae/ fixed stars are these big and small fire balls. Some stars have more gases than others causing the difference in their temperatures, colour and brightness. The hotter stars are bluish white in colour and least hot are red. The remaining stars exhibit white, mild orange, orange, golden and yellow colours.

Till the advent of the modern concept of our solar system, all stars were considered to be at the same distance. Although no one knew that distance. The astronomers and the masses all considered fixed stars to be father away than the Sun, the Moon and the planets of the solar system.

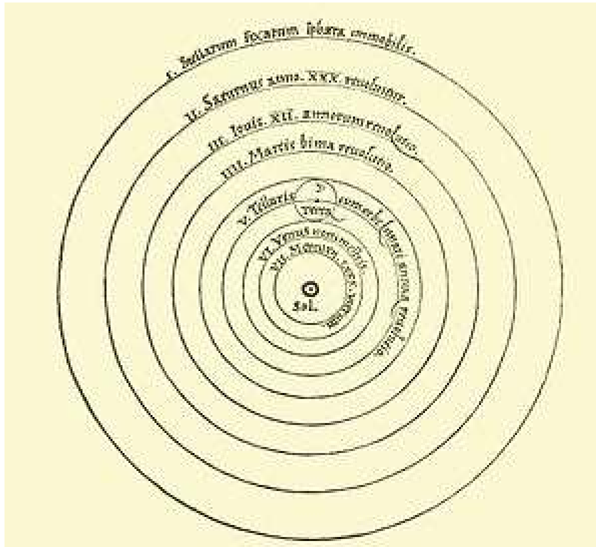
Ptolemaic system, a mathematical model of the universe formulated by the Alexandrian astronomer and mathematician Ptolemy about AD 150 was recorded in his book *Almagest* and *Planetary Hypotheses*. The Ptolemaic system was a geocentric cosmology which assumed that the Earth was stationary and located at the centre of the universe.





An illustration of the Ptolemaic geocentric system by Portuguese cosmographer and cartographer Bartolomeu Velho, 1568

According to the Ptolemaic system the universe comprised of eight spheres or skies. These namely were Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, Fixed Stars and sphere of the fixed stars or nebulae.



Heliocentric model from Nicolaus Copernicus

Nicolaus Copernicus rejected the Ptolemaic notion of the Earth being at centre of the world, but failed to challenge the location of the fixed stars. Giordano Bruno altogether rejected the concept of the sphere of the fixed stars. His cosmological theories went beyond the Copernican model in proposing that the Sun was essentially a star, and that the universe contained an infinite number of inhabited worlds populated by other intelligent beings. He theorized that every star is a sun. In the vast expanse of the universe there are many solar systems. Their light gets diffused because of very large distances. After the Roman Inquisition found him guilty of heresy for his pantheism, he was burned at the stake. After his death he gained considerable fame, particularly among 19th and early 20th century commentators who, focusing on his astronomical beliefs, regarded him as a martyr for free thought and modern scientific ideas. Later times proved him right. He succeeded in establishing that all stars were not in one plane, but existed in their respective spheres and varying distances from the earth.

During the Middle Ages, astronomy was mostly stagnant in medieval Europe, at least until the 13th century. However, it flourished in the Islamic world and other parts of the world. This led to the emergence of the first astronomical observatories in the Muslim world by the early 9th century. In 964, the Andromeda Galaxy, the largest galaxy in the Local Group, containing the Milky Way, was discovered by the Persian astronomer Azophi and first described in his *Book of Fixed Stars*. The SN 1006 supernova, the brightest apparent magnitude stellar event in recorded history, was observed by the Egyptian Arabic astronomer Ali ibn Ridwan and the Chinese astronomers in 1006. Some of the prominent Islamic (mostly Persian and Arab) astronomers who made significant contributions to the science include Al-Battani, Thebit, Azophi,Albumasar, Biruni, Arzachel, Al-Birjandi, and the astronomers of the Maragheh and Samarkand observatories. Astronomers during that time introduced many Arabic names now used for individual stars. It is also believed that the ruins at Great Zimbabwe and Timbuktu may have housed an astronomical observatory.

It was Galileo Galilei who ushered in the era of new discoveries. Galileo has been called the "father of modern observational astronomy" for his achievements which include improvements to the telescope and consequent astronomical observations. With improvements in the telescope its enhanced field of vision, astronomers like William Hershel and John Hershel spent their life times in studying the universe. Many more scientists with the permission and blessings of Allah Almighty discovered many new galaxies, nebulae and quasi stellar bodies. They realized that the visible universe was only a part of it. It was beyond human capacity to observe further.

Alas amongst them, the non Muslims were also men of understanding and wisdom (**اولوالباب**) as described in the holy Quran.

Verily in the creation of the heavens and the earth and in the alternation of the night and the day are signs unto the men of understanding. *Al e Imran - 190.*

Kepler was the first to devise a system that described correctly details of the motion of the planets with the Sun at the centre. However, Kepler did not succeed in formulating a theory to support the laws formulated by him. It was left to Newton's invention of celestial dynamics and his law of gravitation to finally explain motions of the planets. Newton also developed the reflecting telescope.

Further discoveries paralleled improvements in the size and quality of a telescope. More extensive star catalogues were produced by Lacaille. The astronomer William Herschel made a detailed catalog of nebulosity and clusters and in 1781 discovered the planet Uranus, the first new planet found. The distance to a star was first announced in 1838 when the parallax of 61 Cygni was measured by Friedrich Bessel.

During the 18–19th centuries, attention to the three body problem by Euler, Clairaut, and D'Alembert led to more accurate predictions about the motions of the Moon and planets. This work was further refined by Lagrange and Laplace, allowing the masses of the planets and moons to be estimated from their perturbations.

Significant advances in astronomy came about with the introduction of new technology, including the spectroscope and photography. Fraunhofer discovered about 600 bands in the spectrum of the Sun in 1814–15, which, in 1859, Kirchhoff ascribed to the presence of different elements. Stars were proven to be similar to the Earth's own Sun, but with a wide range of temperatures, masses, and sizes.

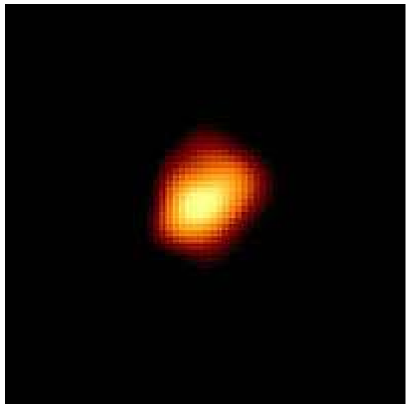
The existence of the Earth's galaxy, the Milky Way, as a separate group of stars, was only proved in the 20th century along with the existence of "external" galaxies. Modern astronomy has also discovered many exotic objects such as quasars, pulsars, blazers, and radio galaxies, and has used these observations to develop physical theories which describe some of these objects in terms of equally exotic objects such as black holes and neutron stars. Physical cosmology made huge advances during the 20th century, with the model of the Big Bang heavily supported by the evidence provided by astronomy and physics, such as the cosmic microwave background radiation, Hubble's law, and cosmological abundances of elements. Space telescopes have enabled measurements in parts of the electromagnetic spectrum normally blocked or blurred by the atmosphere.

The effort to list, tabulate and catalogue astronomical objects has gone on since the ancient times. The oldest amongst them is the Ptolemaic's 'Almagest' which list 1022 celestial objects. An earlier list was compiled three hundred years by a Greek Astronomer but it did not survive. The catalogues prepared in the Middle Ages by the Muslim astronomers were later improved. The most famous was prepared by Abdul Rahman Sufi 'Kaqab e Sabta'. The Timorese Prince Alkh Beg, who was the grandson of Timor the lame (historically known as Tamerlane) prepared many compilations and also created a big observatory at Samarqand. The last list prepared without the aid of instruments was made by Ticobrahi which listed one thousand stars.

After invention of the telescope, the first list was prepared by John Flemend which included 2866 stars. Two German scientists, Fredric William August and Sun Field compiled a list of the Northern Hemisphere which list 324198 stars.

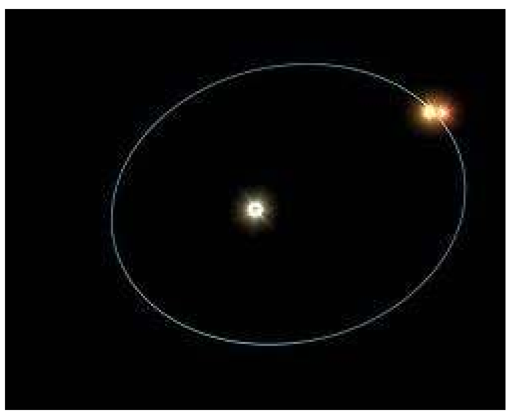
Three lists have been complied for reference sake; with French Astronomer Myser's being the most popular. Galaxies and star clusters have been allotted reference numbers. New General Catalogue of Nebulae and Clusters of Stars (abbreviated as NGC) is the other reference work used to locate the celestial bodies. The NGC contains 7,840 objects, known as the NGC objects. It is one of the largest comprehensive catalogues, as it includes all types of deep space objects and is not confined to, for example, galaxies. Dreyer published two supplements to the NGC, known as the Index Catalogues (abbreviated as IC). The first was published in 1895 and contained 1,520 objects, while the second was published in 1908 and contained 3,866 objects, for a total of 5,386 IC objects. John Herschel's Catalogue of Nebulae and Clusters of Stars is the oldest reference work which is seldom used these days.

Since the number of stars is numerous so these list proved to be impractical. Total population of the known celestial bodies has been categorized into 89 clusters. A Greek alphabet is added along with name of the cluster for identification. When the alphabets end, then a number is added to it.



The asymmetrical appearance of Mira, an oscillating variable star.

Variable stars have periodic or random changes in luminosity because of intrinsic or extrinsic properties. Binary star is a star system consisting of two stars orbiting around their common centre of mass. Star systems with more than two stars, is called a multiple star systems. These stars which orbit each other are bound by gravitational attraction.



Artist's impression of the orbits of HD 188753, a triple star system

Multiple star systems or physical multiple stars are systems of more than two stars. Multiple star systems are called triple, trinary or ternary if they contain three stars; quadruple or quaternary if they contain four stars; quintuple with five stars; sextuple with six stars; septuplets with seven stars; and so on. These systems are smaller than open star clusters, which have more complex dynamics and typically have from 100 to 1,000 stars.

Star clusters or star clouds are groups of stars. Two types of star clusters can be distinguished: globular clusters are tight groups of hundreds of thousands of very old stars which are gravitationally bound, while open clusters, more loosely clustered groups of stars, generally contain fewer than a few hundred members, and are often very young. Open clusters become disrupted over time by the gravitational influence of giant molecular clouds as they move through the galaxy, but cluster members will continue to move in broadly the same direction through space even though they are no longer gravitationally bound; they are then known as a stellar association

There are many galaxies which appear like hazy white spots but actually have billions of stars. The Andromeda Galaxy has a total of 15 satellite galaxies. It has a white spot in the centre known as M 31.

M31, the Great Galaxy in Andromeda

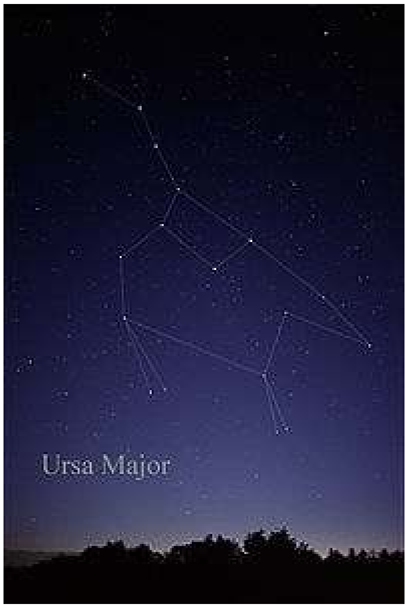
There are many more such like giant galaxies with trillions of stars. It is certainly beyond human capacity to fathom true dimension of the universe.

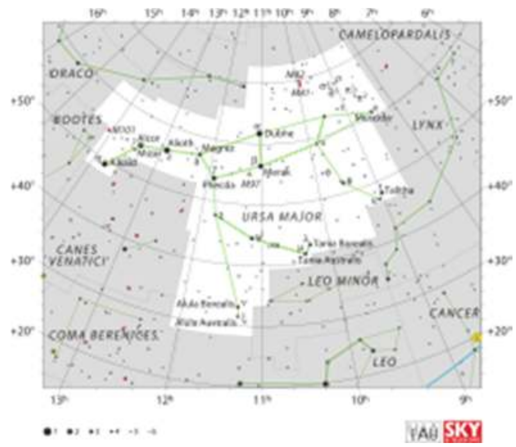
Introduction To Famous Constellations

There are a total of eighty nine constellations. Some of them are very famous. Those located in the Northern Hemisphere can be easily seen by us. The ideal place in Pakistan to study them is the city of Multan and the best time is 10 PM.

Ursa Major

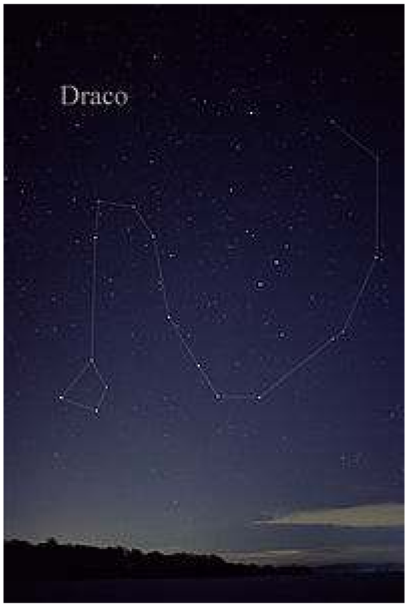
Ursa Major also known as the Great Bear is a constellation visible throughout the year in most of the northern hemisphere. It can best be seen in April. It is dominated by the widely recognized asterism known as the Big Dipper or Plough, which is a useful pointer toward north. The seven brightest stars of Ursa Major form the asterism known as the Big Dipper or the Plough. The constellation of Ursa Major has been seen as a bear by many distinct civilizations.

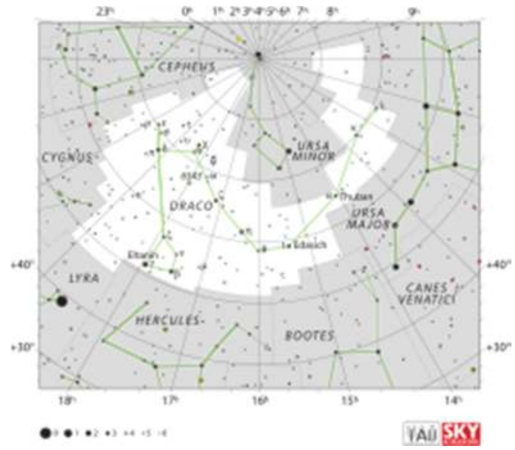




Draco

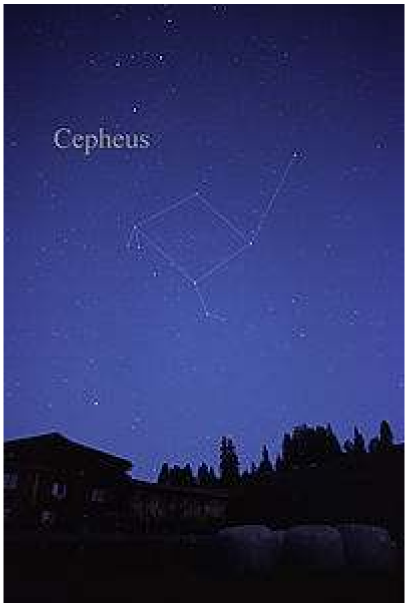
Draco is a constellation in the far northern sky. Its name is Latin for dragon. Draco is circumpolar (that is, never setting) for many observers in the northern hemisphere. It was one of the 48 constellations listed by the 2nd century astronomer Ptolemy, and remains one of the 89 modern constellations today. The north pole of the ecliptic is in Draco. The star Thuban was the northern pole star around 3000 BCE, during the time of the ancient Egyptians. The Egyptian Pyramids were designed to have one side facing north, with an entrance passage designed so that Thuban would be visible at night. There are two other stars above magnitude 3 in Draco. The brighter of the two—and the brightest star in Draco—is Gamma Draconis, traditionally called Etamin or Eltanin. Draco is home to several double stars and binary stars.

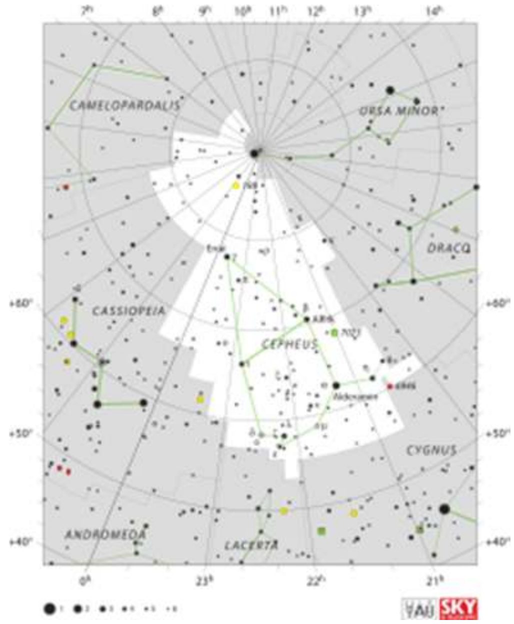




Cepheus

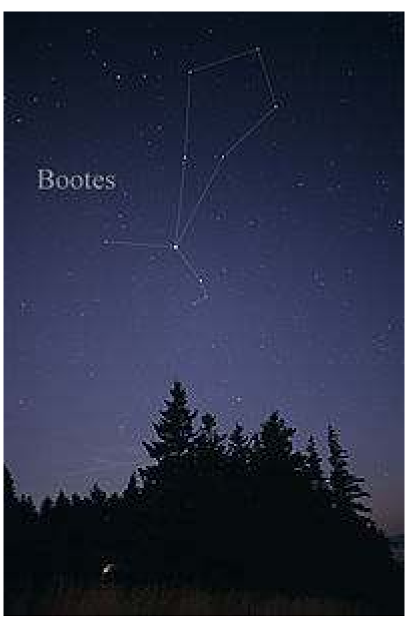
Cepheus is a constellation in the northern sky. It is named after Cepheus, King of Aethiopia in the Greek mythology. It was one of the 48 constellations listed by the 2nd century astronomer Ptolemy, and remains one of the 88 modern constellations. Alpha Cephei, traditionally called "Alderamin", is white hued star 49 light-years from Earth. Beta Cephei, traditionally called "Alfirk", is a double star with a blue-hued giant. The primary is a variable star considered to be the prototype of its subclass of pulsating variable stars.

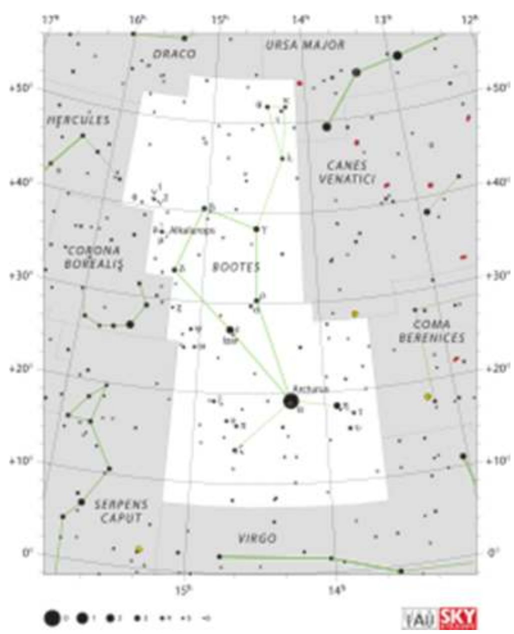




Bootes

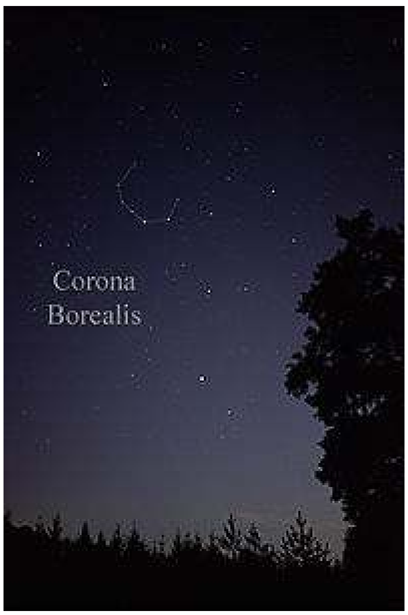
Boötes is a constellation in the northern sky. It was one of the 48 constellations described by the 2nd century astronomer Ptolemy and is now included in the modern constellations. It contains the fourth brightest star in the night sky, Arcturus. It is home to many other bright stars, making a total of 29 stars easily visible to the naked eye.

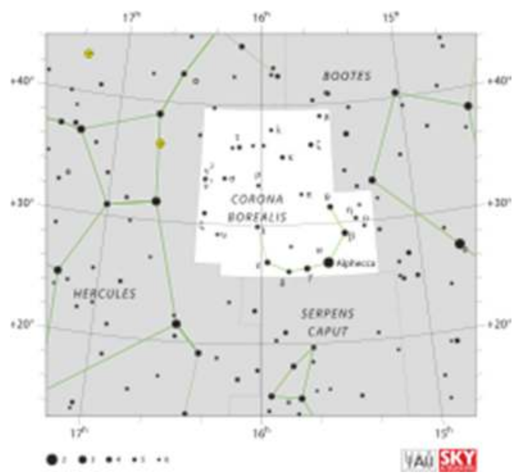




Corona Borealis

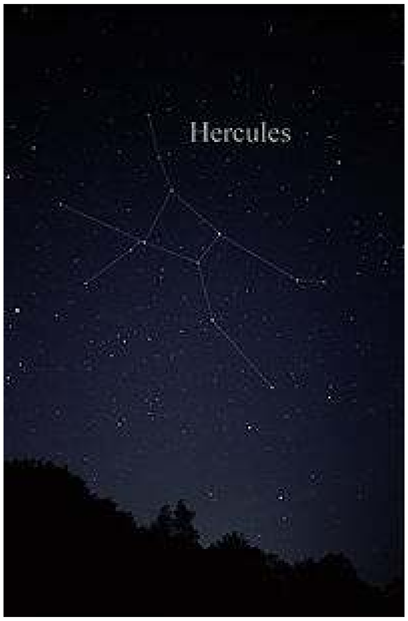
Corona Borealis is a small constellation in the northern sky. Its name is Latin for "northern crown", a name inspired by its shape; its main stars form a semicircular arc. It was one of the 48 constellations listed by the 2nd century astronomer Ptolemy and remains one of the modern constellations. Seven stars make up the constellation's figure with the brightest star, Alpha Coronae Borealisre. The other six stars are Theta, Beta, Gamma, Delta, Epsilon, and Iota Coronae Borealis.

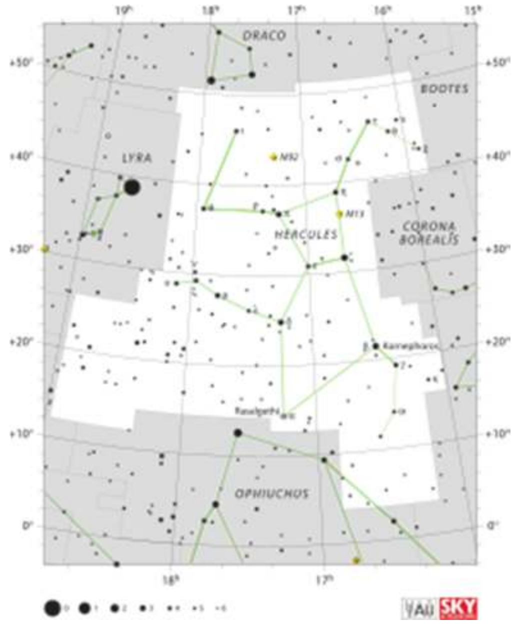




Hercules

It is the fifth largest of the modern constellations, named after Hercules, the Roman mythological hero.

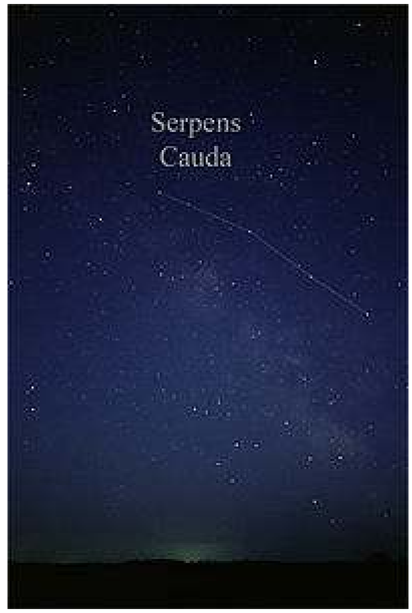


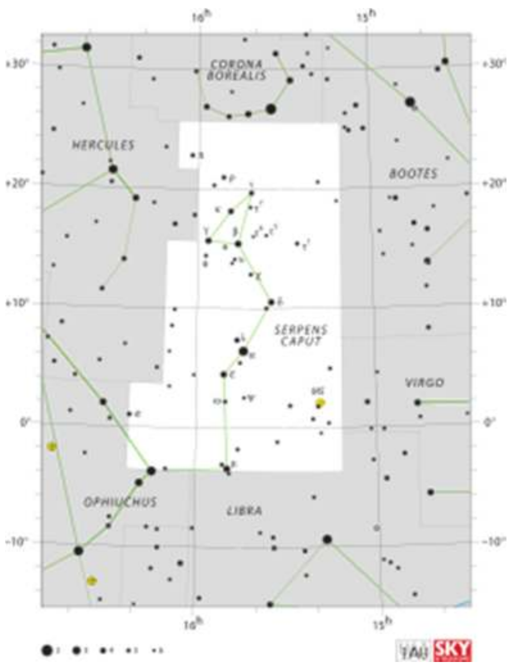


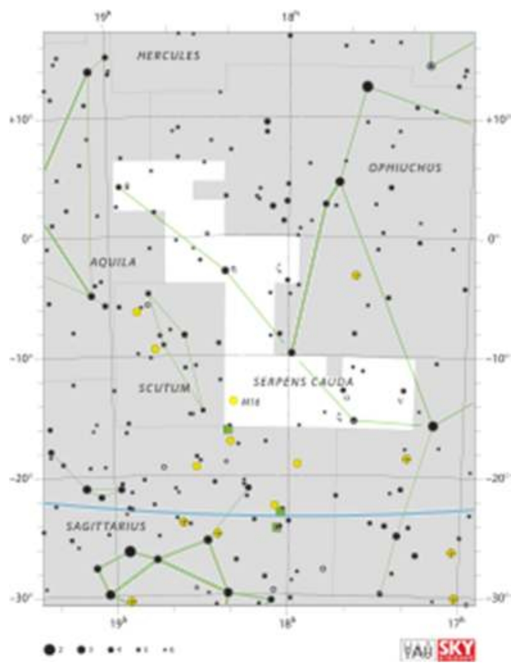
Hercules has no first magnitude stars. However, it does have several stars above magnitude 4. Alpha Herculis, traditionally called Rasalgethi, is a binary star. There are several dimmer variable stars in Hercules. It is also home to many double stars and binary stars.

Serpens

It is unique among the modern constellations in being split into two non-contiguous parts, Serpens Caput (Serpent's Head) to the west and Serpens Cauda (Serpent's Tail) to the east. Between these two halves lies the constellation of Ophiuchus, the "Serpent-Bearer". Only one of the stars in Serpens is brighter than third magnitude, so the constellation is not easy to perceive.

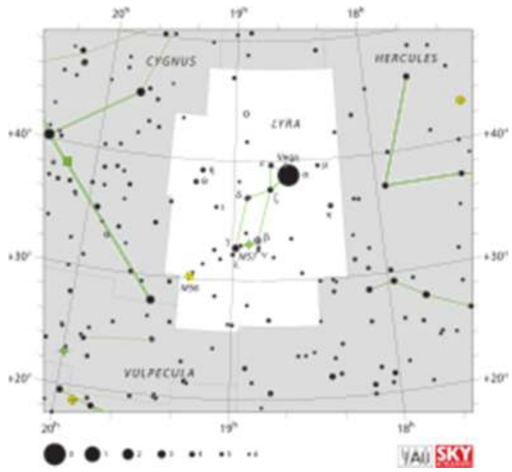




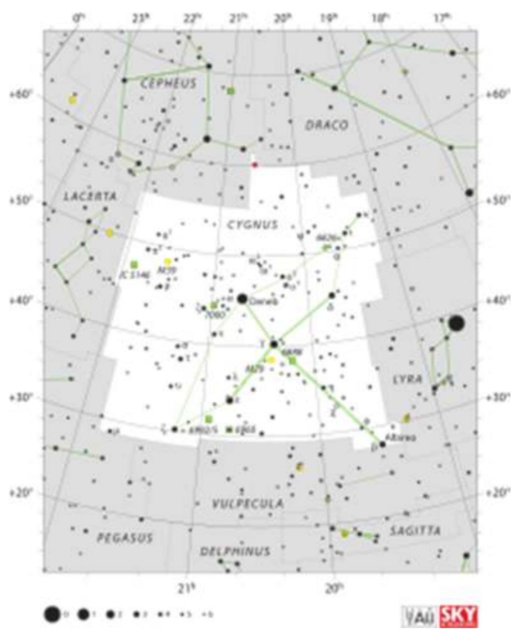


Lyra

Lyra is a small constellation which is visible from the northern hemisphere from spring through autumn, and nearly overhead, in temperate latitudes, during the summer months. From the southern hemisphere, it is visible low in the northern sky during the winter months. Sulafat is the main star of this multiple star system Vega is the second brightest star of the northern hemisphere after Arcturus.



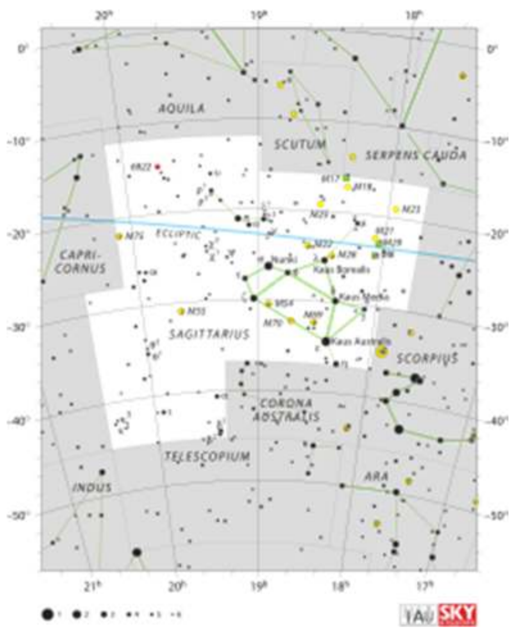
Cygnus



It is a northern constellation lying on the plane of the Milky Way. One of the most recognizable constellations of the northern summer and autumn, it features a prominent asterism known as the Northern Cross (in contrast to the Southern Cross). There are several bright stars in Cygnus. Alpha Cygni, called Deneb, is the brightest star in Cygnus. Beta Cygni, is a celebrated binary star among amateur astronomers for its contrasting hues.

Sagittarius

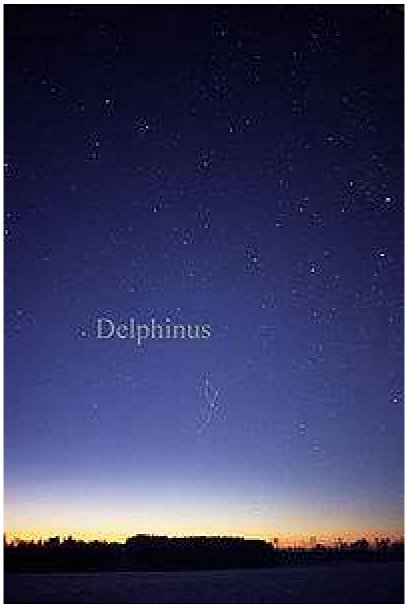
Sagittarius is a constellation of the zodiac, the one containing the galactic center. Its name is Latin for the archer.

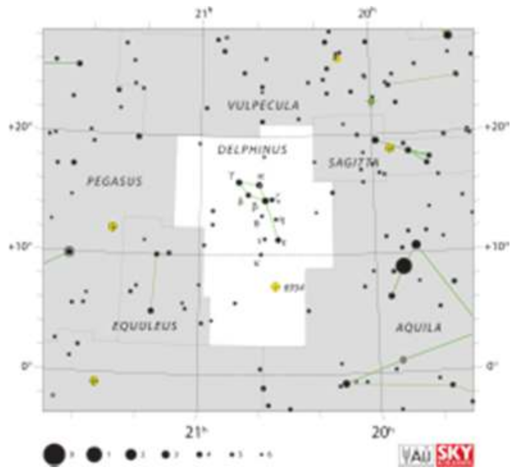


The constellation's brighter stars form an easily recognizable asterism known as 'the Teapot'. The constellation as a whole is often depicted as having the rough appearance of a stick-figure archer drawing its bow, with the fainter stars providing its horse body.

Delphinus

Delphinus is a constellation in the northern sky, close to the celestial equator. Its name is Latin for dolphin. It is one of the smaller constellations, ranked 69th in size.



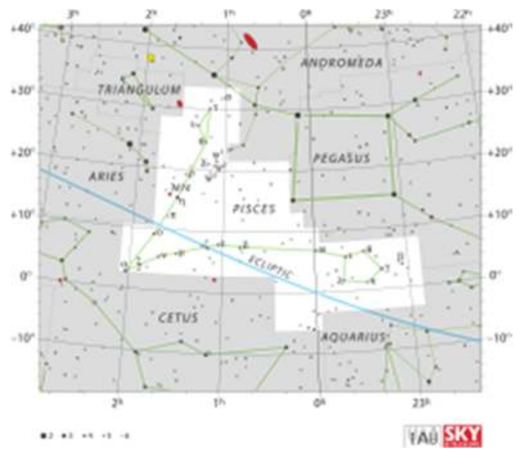


Delphinus's brightest stars form a distinctive asterism that can easily be recognized. It is bordered (clockwise from north) by Vulpecula the fox, Sagitta the arrow, Aquila the eagle, Aquarius the water-carrier, Equuleus the foal and Pegasus the flying horse.

Aquariu

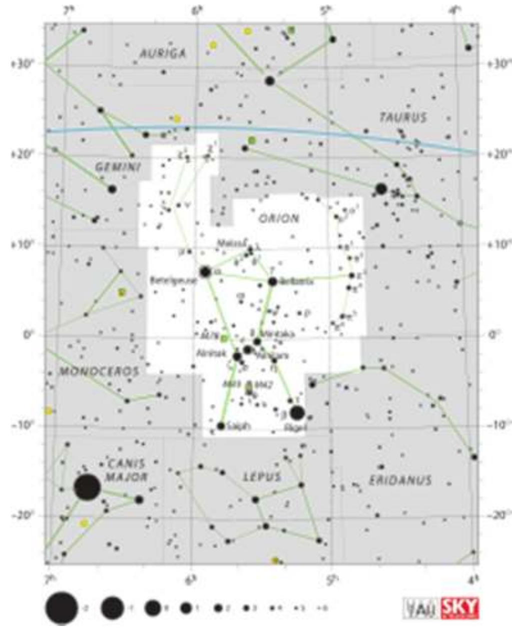
Aquarius is a constellation of the zodiac, situated between Capricornus and Pisces. Its name is Latin for "water-carrier" or "cup-carrier"a representation of water. It is one of the oldest of the recognized constellations. It is found in a region often called the Sea due to its profusion of constellations with watery associations. Despite its prominent position on the zodiac and the large size, Aquarius has no particularly bright stars.

Pisces



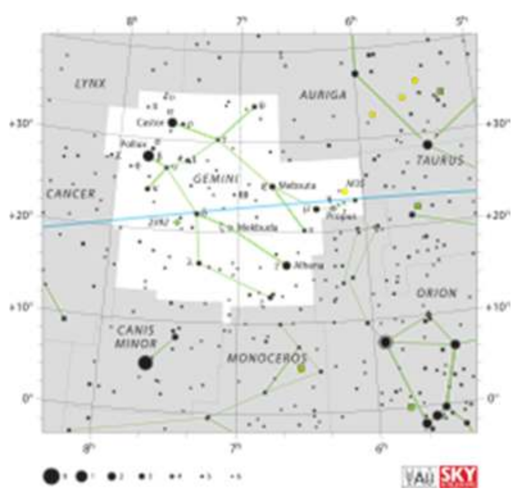
Its name is the Latin plural for fish. It lies between Aquarius to the west and Aries to the east. The ecliptic and the celestial equator intersect within this constellation and in Virgo. Van Maanen's Star, is located in this constellation. The Vernal equinox is currently located in Pisces.

Orion



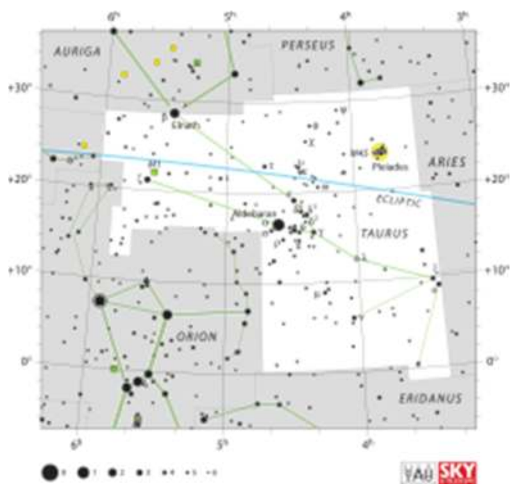
Orion sometimes subtitled The Hunter, is a prominent constellation located on the celestial equator and visible throughout the world. It is one of the most conspicuous and recognizable constellations in the night sky. Orion includes the prominent asterism known as the Belt of Orion: three bright stars in a row. Rigel is a pulsating star which is the brightest star of the constellation and the sixth brightest star in the sky. The star as seen from earth is actually a triple star system around 117,000 times as luminous as our Sun.

Gemini



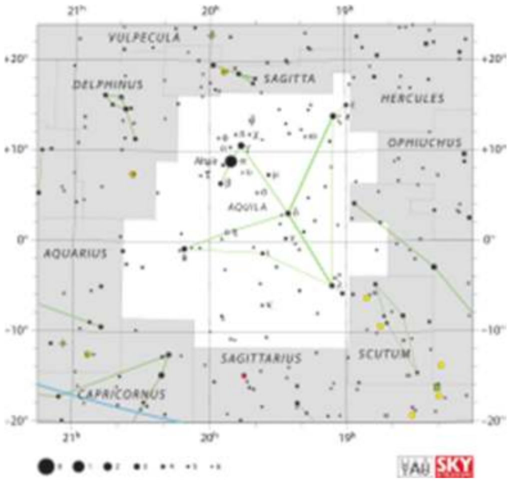
Gemini is one of the constellations of the zodiac. Its name is Latin for "twins. The brightest stars in Gemini are Castor and Pollux. There are several other bright stars, including multiple stars.

Taurus



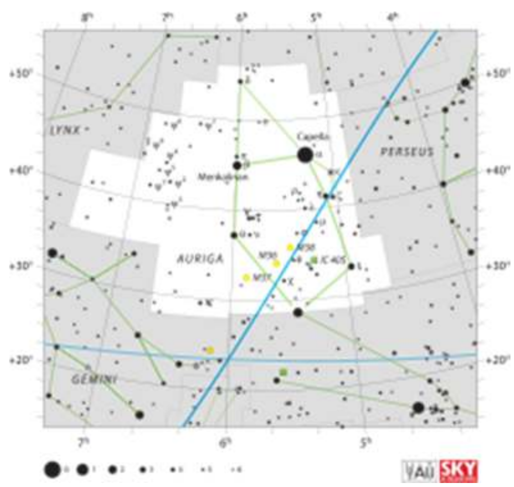
Taurus is a large and prominent constellation in the northern hemisphere's winter sky. It is one of the oldest constellations, dating back to at least the Early Bronze Age when it marked the location of the Sun during the spring equinox. Taurus hosts two of the nearest open clusters to Earth, the Pleiades and the Hyades, both of which are visible to the naked eye.

Aquila



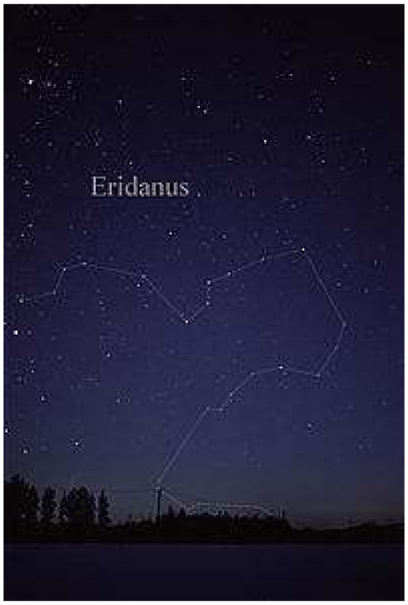
Aquila is a constellation in the northern sky. Its name is Latin for 'eagle'. Aquila lies just a few degrees North of the celestial equator. The constellation is best seen in the summer as it is located along the Milky Way.

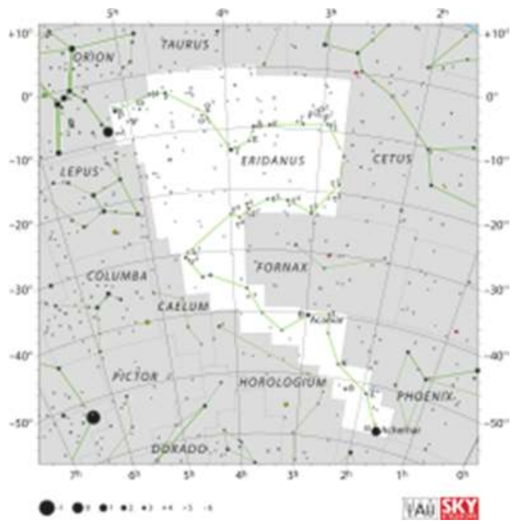
Auriga



Located north of the celestial equator, its name is the Latin word for "charioteer". Auriga is most prominent during winter evenings in the Northern Hemisphere, along with the five other constellations. Its brightest star, Capella, is an unusual multiple star system among the brightest stars in the night sky.

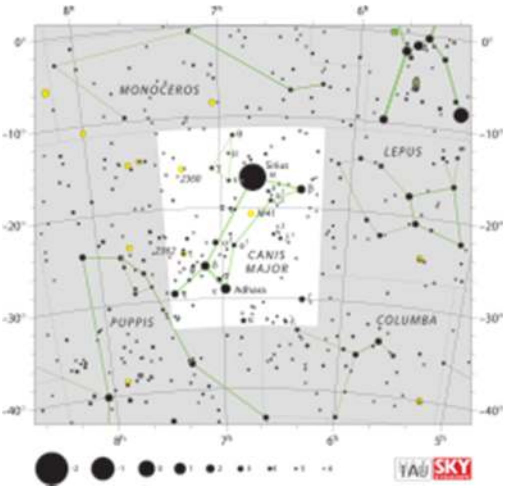
Eridanus

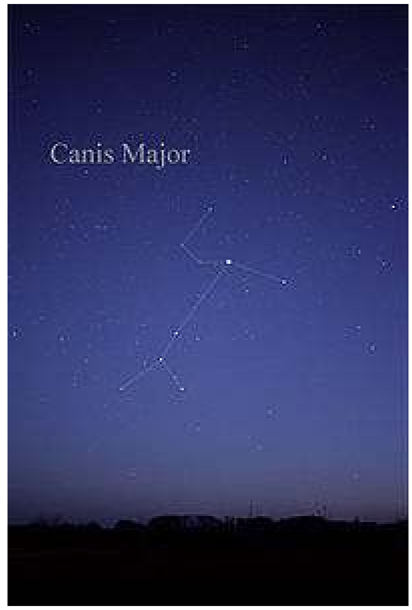




It is represented as a river; its name is the Ancient Greek name for the Po River. At its southern end is the star Achernar, 144 light-years from Earth, it is a blue-white hued main sequence star whose traditional name means "the river's end". Achernar is a very peculiar star because it is one of the flattest stars known. There are several other noteworthy stars in Eridanus, including some double stars.

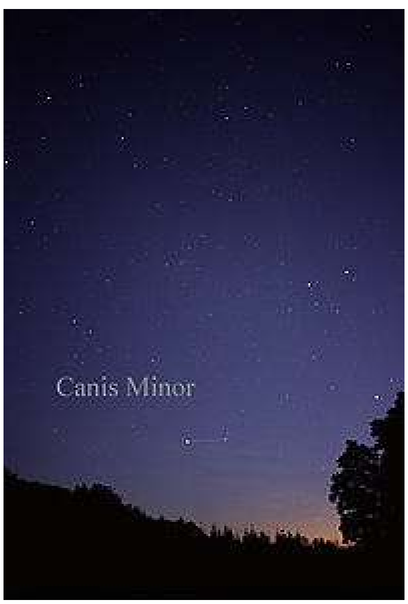
Canis Major

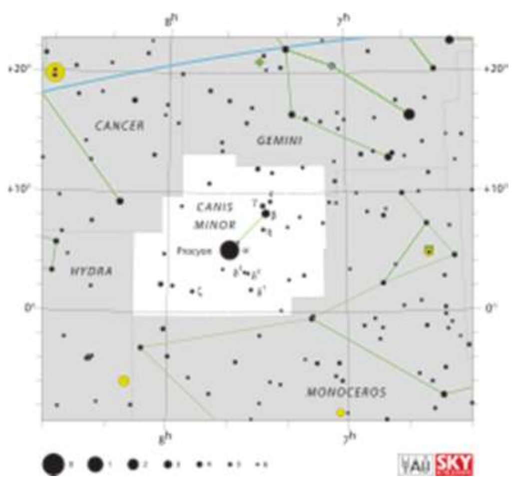




Canis Major contains Sirius, the brightest star in the night sky. This star has been mentioned in the holy Quran also.

Canis Minor



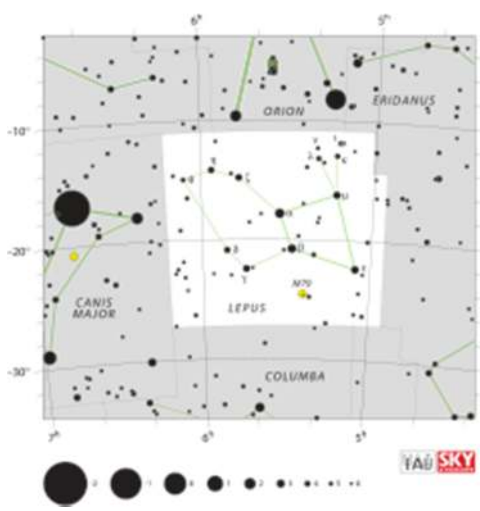


Canis Minor is a small constellation in the celestial northern hemisphere. It contains only two bright stars Procyon and Gomeisa.

Cancer

Cancer is relatively small among the constellations with an area of only 505 square degrees and its stars are rather faint.

Lepus



A constellation, which is south of the celestial equator, immediately south of Orion. There are a fair number of bright stars, both single and double, in Lepus. Alpha Leporis, the brightest star of Lepus, is a white super giant.

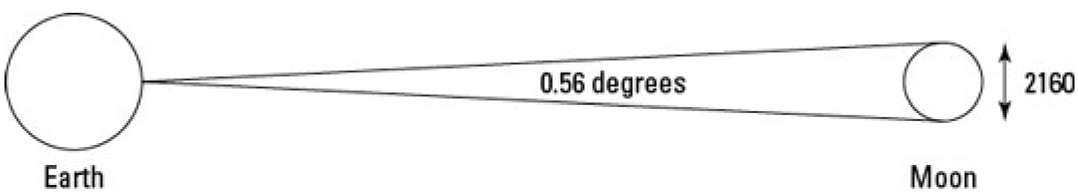
Stellar Distances

The Ptolemaic system was espoused by the Hellenistic astronomer Claudius Ptolemaeus in the 2nd century AD. Ptolemy argued that the Earth was in the centre of the universe. He professed that by simple observation half the stars were above the horizon and half were below the horizon at any time (stars on rotating stellar sphere), and the assumption that the stars were all at some modest distance from the centre of the universe. If the Earth was substantially displaced from the centre, this division into visible and invisible stars would not be equal. He placed all the stars in a single plain at the eighth sky. Accordingly the eighth sky was named the sky of the stars. The Muslims subscribed to the notion along with Ptolemaic theory of the Solar system. Nicolaus Copernicus rejected the Ptolemaic notion of the Earth being centre of the world, but failed to challenge the location of the fixed stars. Giordano Bruno (1548- 1600) altogether rejected the concept of the sphere of the fixed stars. His cosmological theories went beyond the Copernican model in proposing that the Sun was essentially a star, and moreover, that the universe contained an infinite number of inhabited worlds populated by other intelligent beings. He theorized that every star is a sun. In the vast expanse of the universe there are many solar systems. Their light gets diffused because of very large distances.

Parallax Method

After the universal acceptance of the notion, a quest to measure celestial distances began. The lunar distance was measured quite early using the parallax method. Prior to the 20th century, the best way to determine the distance to the Moon was to use parallax. The Moon's coordinates in the sky are slightly different from different places on Earth. The Moon forms a skinny triangle with the two locations on Earth. The small angle is the angular distance between the two measured lunar positions. Its opposite side is the physical distance between the two places on Earth. Using trigonometry, you can thus find the distance to the Moon.

One of the earliest applications of trigonometry was in measuring distances that you couldn’t reach, such as distances to planets or the moon or to places on the other side of the world. Here’s an example:



A person on the earth sights the two sides of the moon.

The diameter of the moon is about 2160 miles. When the moon is full, a person sighting the moon from the earth measures an angle of 0.56 degrees from one side of the moon to the other (see the preceding figure).

To figure out, how far away the moon is from the earth, consider a circle with the earth at the center and the circumference running right through the center of the moon, along one of the moon's diameters. The moon is so far away that the straight diameter and slight curve of this big circle's circumference are essentially the same measure. The arc that runs through the moon's diameter has an angle of 0.56 degrees and an arc length of 2160 miles (the diameter). Using the arc-length formula, solve for the radius of the large circle, because the radius is the distance to the moon. Follow these steps:

1. First, change 0.56 degrees to radians. Round to five decimal places.

   $$\frac{0.56}{180} = \frac{\theta^R}{\pi}, \theta^R = \frac{0.56\pi}{180} \approx 0.00977$$

2. Input the numbers into the arc-length formula.

   Given the arc-length formula,

   $s = \theta^R \bullet r,$

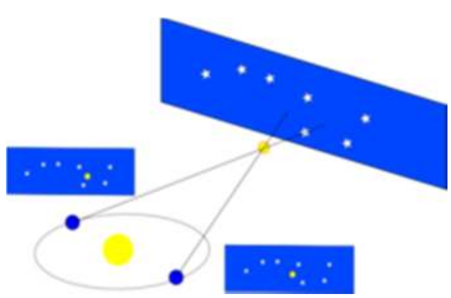
   Enter 0.00977 radians for the approximate radian measure and 2160 for the arc length:

   $2160 = 0.00977 \bullet r.$

3. Divide each side by 0.00977.

   The distance to the moon is $r = \frac{2160}{0.00977} \approx 221{,}085$ miles.

Stellar parallax is the effect of parallax on distant stars in astronomy.



It is parallax on an interstellar scale, and it can be used to determine the distance of Earth to another star directly with accurate astrometry. It was the subject of much debate in astronomy for hundreds of years, but was so difficult it was only achieved for a few of the nearest stars in the early 19th century. Even in the 21st century, stars with parallax measurements are relatively close on a galactic scale, as most distance measurements are calculated by red-shift or other methods.

The parallax is usually created by the different orbital positions of the Earth, which causes nearby stars to appear to move relative to more distant stars. By observing parallax, measuring angles and using geometry, one can determine the distance to various objects in space, typically stars, although other objects in space could be used.

In case of the Moon, if the parallax is measured from two different spot with an intervening distance of 8000 miles and algebraically calculated then the lunar distance can be measured. This parallax works out to be 57^0 and 2.7 minutes or 0.95075^0 .The distance to the Moon, therefore works out to be 238857 miles.

This method has been in use for centuries to measure distance to the Moon. It is in vogue even now; with use of improved measuring instruments. This method was once considered redundant for measuring stellar distance when the Earth was considered to be static and all the stars were considered to exist in one plain. Abū al-Rayhān Muhammad ibn Ahmad al-Bīrūnī went to extent of saying;-

' It is not possible to measure stellar distances with the parallax method except that of the Moon'.

He was right for his times because the Earth was considered to be static. The longest straight line that could be drawn was eight thousand miles. Comparing it with the colossal stellar distances it was negligible i.e. like a zero compared with infinity.

However with the change perception about the Earth of being rotational, it became possible to measure stellar distances by using parallax method. Even in the 21st century, stars with parallax measurements are relatively close on a galactic scale, as most distance measurements are calculated by red-shift or other methods.

With the invention of RADAR, more precise determinations of the lunar distance became possible. Also, thanks to the Apollo astronauts, there is a large reflector on the Moon's surface, off of which laser light can be bounced from Earth. By measuring the time the laser light takes to make the round trip to the moon and back, its instantaneous distance can be measured to within one inch.

The Light Year

A student of science knows that the light travels at a speed of 186000 miles per second. A year has 3,15,56,880 second. So in a year, light can a travel a distance of sixty billion miles (six trillion). A stellar object sixty billion miles away will be reached in one year.

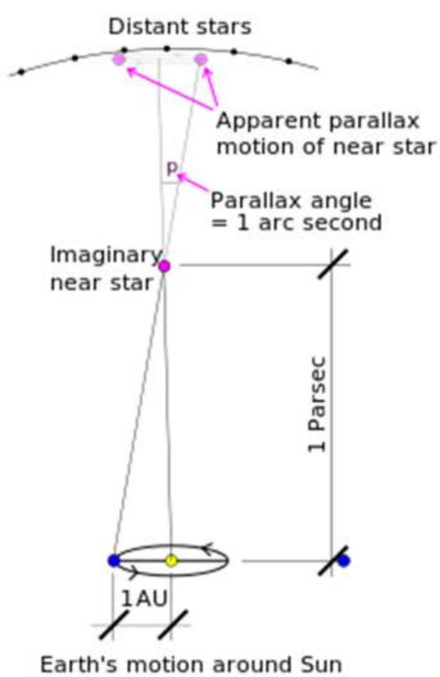
This is called a light year. A light-year therefore is a unit of length equal to just under 10 trillion kilometers (or about 6 trillion miles). As defined by the International Astronomical Union (IAU), a light-year is the distance that light travels in a vacuum in one Julian year (365.25 days). There is not a single star that is one light year away. Rigil Kentaurus, a star of the Centaurus which is the nearest constellation from the Earth is 4.4 light-years away. Imagine measuring those objects which are billion and trillions of light years away. Human mind is simply baffled and perplexed.

The Sun is considered to be the biggest and most luminous body being the primary source of light and heat. Actually the Pole Star is 1585 times more luminous but looks diffused because of its colossal distance from the Earth i.e. 466 light years away. The other important star is Sirius, the brightest of the fixed stars. It is 27 times brighter than the Sun. This is 8.6 light years away.

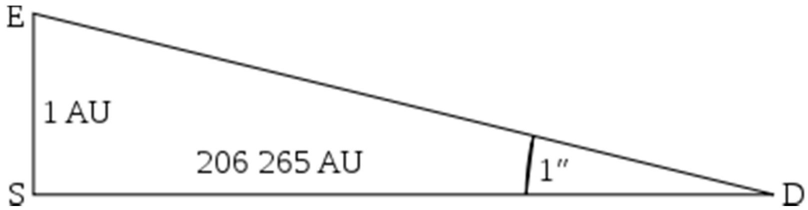
Parsec

A unit of length used in astronomy. It is about 3.26 light-years, which is about 30.9 trillion (3.09×10^{13}) kilometers or about 19.2 trillion (1.92×10^{13}) miles.

The name *parsec* is "an abbreviated form of 'a distance corresponding to a parallax of one second'." It was coined in 1913 at the suggestion of British astronomer Herbert Hall Turner.



Calculating the value of a parsec



In the diagram above *(not to scale)*, S represents the Sun, and E the Earth at one point in its orbit. Thus the distance ES is one astronomical unit (AU). The angle SDE is one arc second (1/3600 of a degree) so by definition D is a point in space at a distance of one parsec from the Sun. By trigonometry, the distance SD is

$$SD = \frac{\mathrm{ES}}{\tan 1''}$$

Using small-angle approximation,

$$SD \approx \frac{\mathrm{ES}}{1''} = \frac{1\ \mathrm{AU}}{\left(\frac{1}{60\times 60} \times \frac{\pi}{180}\right)} = \frac{648\,000}{\pi}\,\mathrm{AU} \approx 206\,264.81\ \mathrm{AU}.$$

One AU ≈ 149597870700 meters, so 1 parsec ≈ 3.085678×10^{16} m ≈ 3.261564 ly.

A corollary is that 1 parsec is also the distance from which a disc with a diameter of 1 AU must be viewed for it to have an angular diameter of 1 arc second (by placing the observer at D and a diameter of the disc on ES).

Structure and Shape of Stars

Visibly most of the planets and stars look like a spread of shiny twinkling dots spread across the sky. Therefore it is difficult for an ordinary observer to differentiate them. The Sun and the Moon are like two luminous plates, whose light reaches the Earth. One is the source of heat and energy; while the other is cool and comforting. Beyond this, when an attempt is made to find their truth, one is amazed to learn that there are vast difference between them. Mainly the planets and the stars that we see are part of the solar system and those associated with it. The Earth that we live on, being a planet of the solar system has distinct physical characteristics. Now that human feet have touched the Moon, we also know the conditions there – a sphere without air and water. Similarly all the other stars, planets and dwarfs are solid celestial bodies which shine with the solar light. The Sun being an averaged sized star is different in structure from the Moon and other planets, being a voluminous mass of gases and fire. Agitation of these gases constantly produces light and heat, which makes these bodies a permanent source of light and heat.

Primarily sciences are based on experience and observation. In most of the branches of science, it is possible for a scientist to discover an object through experimentation in a laboratory. However no such facility is available to an astronomer. He has to mainly rely on hypotheses and observations. Indirect methods are used towards this end e.g. use of spectroscope to determine spectrum of the stars. The object of study is the spectrum of electromagnetic radiation, including visible light, which radiates from stars and other hot celestial objects. Spectroscopy can be used to derive many properties of distant stars and galaxies, such as their chemical composition, temperature, density, mass, distance, luminosity, and relative motion using Doppler shift measurements.

In astronomy, stellar classification is a classification of stars based on their spectral characteristics. The spectral class of a star describes the ionization of its photosphere giving an objective measure of the photosphere's temperature. Most stars are currently classified using the letters O, B, A, F, G, K, and M. Where O stars are the hottest and the letter sequence indicates successively cooler stars up to the coolest M class. After a comparison of stellar classifications, scientists have concluded that generally all the stars have similar chemical composition. The only element which creates a difference is their individual temperature.

The Harvard classification system is a one-dimensional classification scheme. Stars vary in surface temperature from about 2,000 to 40,000 Kelvin. Physically, the classes indicate the temperature of the star's atmosphere and are normally listed from hottest to coldest, as is done in the following table:

Class	Surface temperature (kelvin)	Conventional colour	Apparent colour	Mass (solar masses)	Radius (solar radii)	Luminosity (bolometric)	Hydrogen lines	Fraction of all main-sequence stars
O	≥ 33,000 K	blue	blue	≥ 16 $M_\odot$	≥ 6.6 $R_\odot$	≥ 30,000 $L_\odot$	Weak	~0.00003%
B	10,000–33,000 K	white to blue white	blue white	2.1–16 $M_\odot$	1.8–6.6 $R_\odot$	25–30,000 $L_\odot$	Medium	0.13%

A	7,500–10,000 K	white	white to blue white	1.4–2.1 $M_\odot$	1.4–1.8 $R_\odot$	5–25 $L_\odot$	Strong	0.6%
F	6,000–7,500 K	yellowish white	white	1.04–1.4 $M_\odot$	1.15–1.4 $R_\odot$	1.5–5 $L_\odot$	Medium	3%
G	5,200–6,000 K	yellow	yellowish white	0.8–1.04 $M_\odot$	0.96–1.15 $R_\odot$	0.6–1.5 $L_\odot$	Weak	7.6%
K	3,700–5,200 K	orange	yellow orange	0.45–0.8 $M_\odot$	0.7–0.96 $R_\odot$	0.08–0.6 $L_\odot$	Very weak	12.1%
M	2,000–3,700 K	red	orange red	≤ 0.45 $M_\odot$	≤ 0.7 $R_\odot$	≤ 0.08 $L_\odot$	Very weak	76.45%
L	1,300–2,000 K	purple-red	red	Unknown	Unknown	Unknown	Extremely weak	≥ 100.00%
T	700-1,300 K	brown	purple-red	Unknown	Unknown	Unknown	Extremely weak	≥ 100.00%
Y	≤ 700 K	dark brown	brown	Unknown	Unknown	Unknown	Extremely weak	≥ 100.00%

In the light of logical conjecturing and some arguments, it can be said that creation of stars began with clouds of dust and gases. Their energy was result of the conversion of hydrogen to helium gas. In the large stars the process ends in a billion year but in the small stars/dwarfs it continues for trillions of years. Amount of hydrogen in a newly formed star despite its abundance has to end at some stage. In the core of a star, hydrogen is gradually reduced due to very high temperatures and pressure resulting in lowering of energy. Reduction of nuclear energy shrinks the core and the adjoining parts get closer; enhancing the gravitation pressure. At this stage environments are suited for the conversion of hydrogen into helium. The process begins when 12% of the hydrogen gets converted. The inner core shrinks while the outer crust faces a reduced external pressure due to increasing energy. The outer crusts start increasing and brighten up gradually. The outer surface of a star is increased substantially which reduces the per square foot level of energy. The bigger and brighter a star gets, its surface is cooler and turns red in colour.

When the nuclear energy of a star diminishes and it cannot sustain it pressure and fuel, it shrinks into a dwarf. A white dwarf, also called a degenerate dwarf, is a stellar remnant composed mostly of electron-degenerate matter. They are very dense; a white dwarf's mass is comparable to that of the Sun and its volume is comparable to that of the Earth.

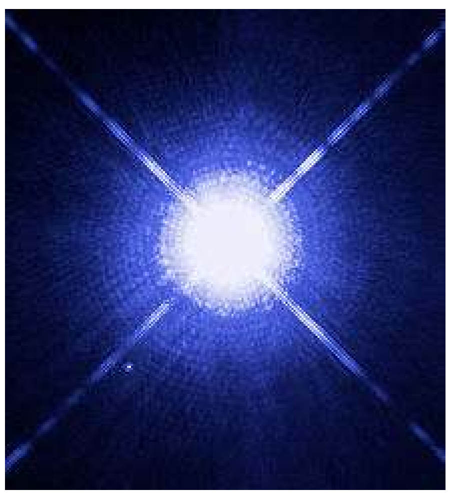


Image of Sirius A and Sirius B taken by the Hubble Space Telescope. Sirius B, which is a white dwarf, can be seen as a faint pinprick of light to the lower left of the much brighter Sirius A.

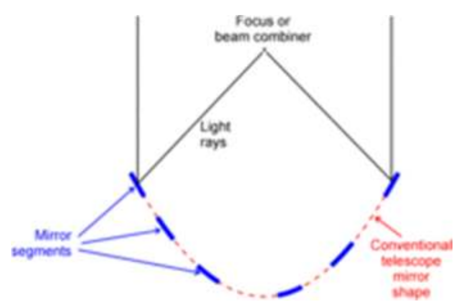
In the picture above, Sirius B is shown. It is a white dwarf which has reduced to 1/50 of the Sun’s diameter and 1/500 in luminosity.

White dwarfs are thought to be the final evolutionary state of all stars, whose mass is not high enough to become a neutron star—over 97% of the stars in our galaxy. If a red giant has insufficient mass to generate the core temperatures required to fuse carbon, around 1 billion K, an inert mass of carbon and oxygen will build up at its center. After shedding its outer layers to form a planetary nebula, it will leave behind this core, which forms the remnant white dwarf. Usually, therefore, white dwarfs are composed of carbon and oxygen

The material in a white dwarf no longer undergoes fusion reactions, so the star has no source of energy, nor is it supported by the heat generated by fusion against gravitational collapse. It is supported only by electron degeneracy pressure, causing it to be extremely dense. A carbon-oxygen white dwarf that approaches this mass limit, typically by mass transfer from a companion star, may explode as a Type Ia supernova via a process known as carbon detonation.

Stellar mass is usually enumerated in terms of the Sun's mass as a proportion of a solar mass. Hence, the bright star Sirius has around 2.02 solar masses. A star's mass will vary over its lifetime as additional mass becomes accreted, such as from a companion star, or mass is ejected with the stellar wind or pulsational behavior. There are few fixed stars whose diameter can be measured directly:-

a. Diameter of Red super giants can be measured with the help of an interferometer which is an array of telescopes or mirror segments acting together to probe structures with higher resolution.



b. Diameter of some stars is measured because of occulation. An occultation occurs when an apparently larger body passes in front of an apparently smaller one. The term occultation is most frequently used to describe those relatively frequent occasions when the Moon passes in front of a star during the course of its orbital motion around the Earth.
c. There are approximately fifty stars whose diameters have been determined with the help of their associated stars.

Due to their great distance from the Earth, all stars except the Sun appear to the human eye as shining points in the night sky that twinkle because of the effect of the Earth's atmosphere. The Sun is also a star, but it is close enough to the Earth to appear as a disk instead. Other than the Sun, the star with the largest apparent size is R Doradus, with an angular diameter of only 0.057 arc seconds. The disks of most stars are too small in angular size to be observed with current ground-based optical telescopes. So interferometer telescopes are required to produce images of these objects. The method commonly used to measure the mass of a star is with the help of a spectroscope. The table below shows a comparison of the mass of some stars in comparison with the Sun:-

Star	**Comparison of Diameter with the Sun.**	**Comparison of Mass with the Sun.**
Sirius A	2.1	9.261
Capella	9.9	970
Rigel	84	592704
Procyon	2.07	8.87
Betelguese	430	79507000
Aldebran	26	17576
Altair	1.8	5.83
Arctures	16	4096
Regulaus	3.63	48
Sirius B	0.028	0.000021952
Mira	0.04	0.000064
Vega	3	27

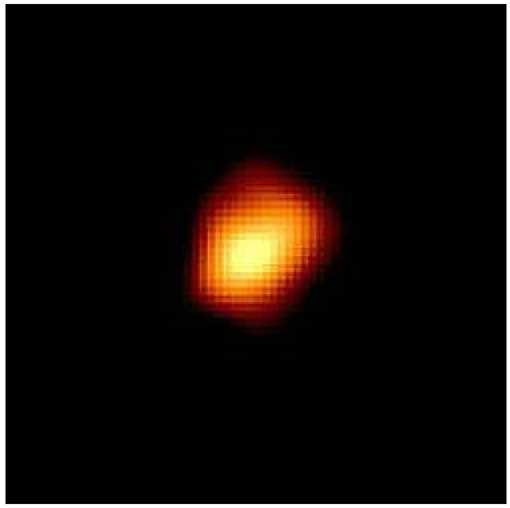
A glean into the table clearly indicates that nothing is big enough. The Sun is considered to be very big as it occupies 99.96 of the volume of the solar system. There are yet stars like Betelgeuse, a red supergiant big enough to accommodate 79500000 suns into it. One is overawed to exclaim:-

سبحان ربی الاعلی

Allah Almighty can create anything bigger than those already created.

Now let's look at the white dwarfs. Sirius B has a diameter which is only 0.028 of the Sun's diameter and its mass is only 0.000021952 of the Sun's mass.

Mira is a binary star, which consists of the red giant Mira A and the Mira B. Mira A is also an oscillating variable star and was the first non-supernova variable star discovered, with the possible exception of Algol. Apart from the unusual Eta Carinae, Mira is the brightest periodic variable in the sky that is not visible to the naked eye for part of its cycle.



Mira A is 400 times bigger than our Sun. Whereas Mira B is a dwarf star which is only 0.00007 times of the Sun's mass and its diameter is 0.04 of the Sun's diameter. This comparison vividly indicates that there is a huge difference in the mass and diameters of the stars, red giants and white dwarfs. However their matter content and density are virtually similar. The red giants are very light in their weight whereas the white dwarfs are extremely heavy. A survey of the stellar population shows that only 20% comprises of red giants and white dwarfs, with the remaining 80% is that of the ordinary stars.

Stars are not spread uniformly across the universe, but are normally grouped into galaxies along with interstellar gas and dust. A typical galaxy contains hundreds of billions of stars, and there are more than 100 billion (10^{11}) galaxies in the observable universe. A 2010 star count estimated three hundred sextillion (3×10^{23}) stars in the observable universe. While it is often believed that stars only exist within galaxies, intergalactic stars have been discovered. Due to the relatively vast distances between stars outside the galactic nucleus, collisions between stars are thought to be rare. In denser regions such as the core of globular clusters or the galactic center, collisions can be more common. Such collisions can produce what are known as blue stragglers. These abnormal stars have a higher surface temperature than the other main sequence stars with the same luminosity in the cluster.

فَتَبَارَكَ اللَّهُ أَحْسَنُ الْخَالِقِينَ

Temperatures of the Stars

The surface temperature of a main sequence star is determined by the rate of energy produced at the core and radius of the star. It is often estimated from the star's color index. Normally it is given as the effective temperature, which is the temperature of an idealized black body that radiates its energy at the same luminosity per surface area as the star.

In astronomy, the colour index is a simple numerical expression that determines the colour of a star and gives its temperature. To measure the index, one observes the magnitude of an object successively through two different filters, such as U and B, or B and V, where U is sensitive to ultraviolet rays, B is sensitive to blue light, and V is sensitive to visible (green-yellow) light. The set of pass bands or filters is called a photometric system. The difference in magnitudes found with these filters is called the U-B or B–V color index, respectively. The smaller the color index, the bluer (or hotter) the object is. Conversely, the larger the color index, the more red (or cooler) the object is. This is a consequence of the logarithmic magnitude scale, in which brighter objects have smaller (more negative) magnitudes than dimmer ones. For comparison, the yellowish Sun has a B–V index of 0.656 ± 0.005, while the bluish Rigel has a B–V of –0. Colour indices of distant objects are usually affected by interstellar extinction i.e. they are redder than those of closer stars.

Sample calibration colours

Class	B–V	U–B	V–R	R–I	T_{eff} (K)
O5V	–0.33	–1.19	–0.15	–0.32	42,000

B0V	–0.30	–1.08	–0.13	–0.29	30,000
A0V	–0.02	–0.02	0.02	–0.02	9,790
F0V	0.30	0.03	0.30	0.17	7,300
G0V	0.58	0.06	0.50	0.31	5,940
K0V	0.81	0.45	0.64	0.42	5,150
M0V	1.40	1.22	1.28	0.91	3,840

The temperature variation of stars is not very big as compared to their luminosity. Barring a few exceptions. These range between 2000 to 30000 centigrade. Our Sun is a star of a low average category in its mass and volume. According to its temperature zone, it is considered yellowish with a B–V index of 0.656 ± 0.005(a G0 star of temperature range beginning at 5900 K).

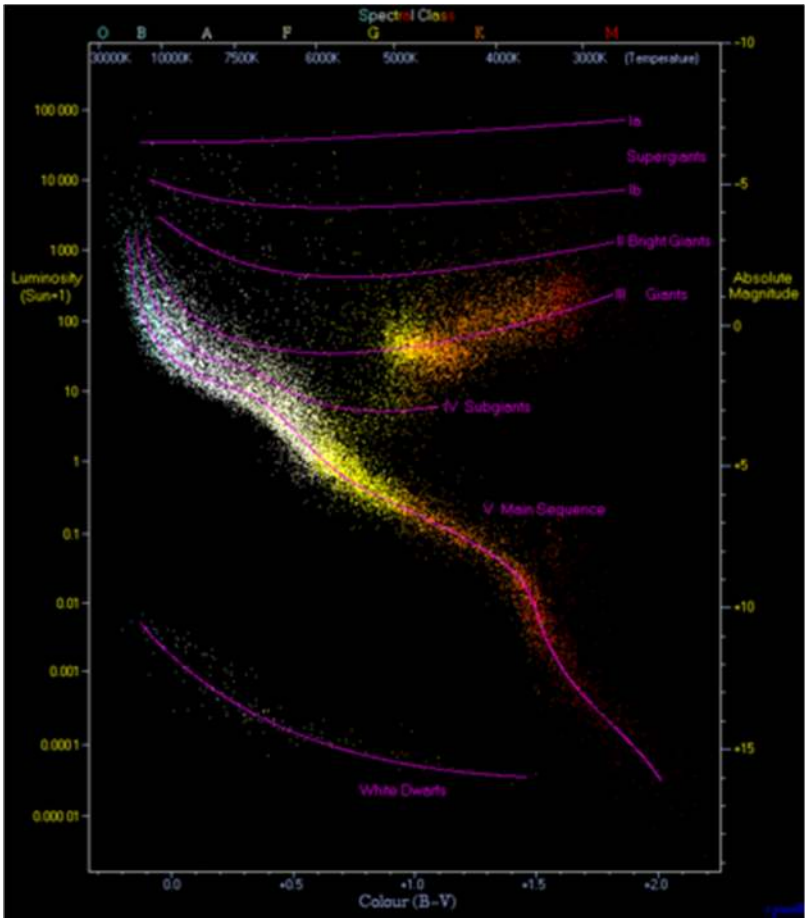
Apparently there is a link in the temperature and luminosity of a star. Hotter stars are brighter. However role of the distance in the visible and absolute magnitude cannot be ignored. The Sun, although a smaller star, looks very bright from the Earth than many brighter ones which are silhouetted because of their distance and the lunar light.

Absolute Magnitude is an important index. Absolute magnitude (also known as absolute visual magnitude when measured in the standard V photometric band) is the measure of a celestial object's intrinsic brightness. Absolute magnitude of the Sun is 4.83 and Sirius A is 1.4 which shows that it is 24 times brighter than the Sun.

The apparent magnitude of a celestial body is a measure of its brightness as seen by an observer on the Earth, adjusted to the value it would have in the absence of the atmosphere. The brighter the object appears, the lower the value of its magnitude.

The absolute magnitude uses the same convention as the visual magnitude. The Hertzsprung–Russell diagram (HR Diagram) is a scatter graph of stars showing the relationship between the stars' absolute magnitudes or luminosities versus their spectral types or classifications and effective temperatures. Hertzsprung–Russell diagrams are *not* pictures or maps of the locations of the stars. Rather, they plot each star on a graph measuring the star's absolute magnitude or brightness against its temperature and color.

Hertzsprung–Russell diagrams are also referred to by the abbreviation H–R diagram or HRD. The diagram was created in 1910 by Ejnar Hertzsprung and Henry Norris Russell. It represents a major step towards an understanding of stellar evolution or "the lives of stars".



Hertzsprung–Russell diagram with 22,000 stars plotted from the Hipparcos catalog and 1,000 from the Gliese catalog of nearby stars. Stars tend to fall only into certain regions of the diagram. The most predominant is the diagonal, going from the upper-left (hot and bright) to the lower-right (cooler and less bright), called the main sequence. In the lower-left is where white dwarfs are found, and above the main sequence are the sub giants, giants and super giants. The Sun is found on the main sequence at luminosity 1 (absolute magnitude 4.8) and B-V color index 0.66 (temperature 5780K, spectral type G2V).

In the above picture, relationship of temperature and luminosity are plotted graphically. Some emerging patterns are:-

a. The main sequence includes most of the stars. Their luminosity increases proportionately with their temperatures. Stars like Sirius and Vega are included here. Temperature of all these stars equals that of the Sun ranging from 20000000 to 30000000 centigrade. Another characteristic is the similarity in their densities. Average density of the Sun is 1.4 which means that matter

b. The ‘Giants’, whose luminosity is greater than their temperature. Weighing 1.4 tons can be accommodated in a space of one cubic meter.
c. The ‘Super Giants’ whose temperatures are proportionately lesser the similar stars. Cygnus and Betelgeuse Fall in this category.
d. The ‘Dwarfs’ whose temperatures are much more than the luminosity.

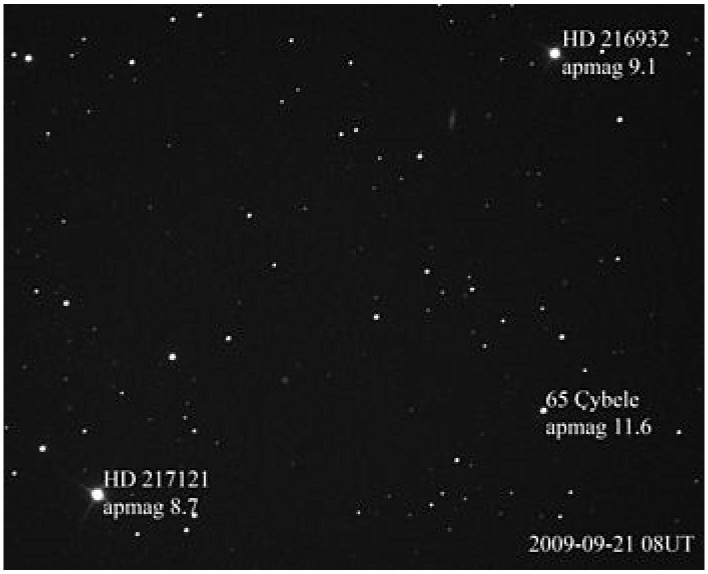
If the surface temperature of a star is less than 2000 centigrade, it will not be luminous. Star Auriga C which is the biggest cold star in the Auriga constellation has a diameter 3000 times bigger than the Sun and a mass 12700000000 times more has temperature of only 1700^0 centigrade. It mostly radiates infra red rays.

Colour of some of the prominent stars is tabulated below:-

Star	**Colour**
Altair	White
Betelgeuse	Red
Aldebran	Orange
Spica	Bluish White
Antares	Red
Famalhaut	White
Denb	White
The Sun	Yellow
Sirius	White
Canopus	Yellowish White
Vega	White
Capella	Yellow
Arcturus	Orange
Rigel	Bluish White
Procyon	Yellowish White

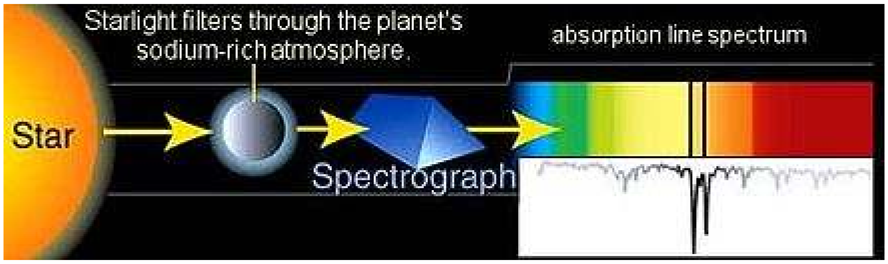
Absolute & Apparent Magnitude of Stars

The apparent brightness of a star is measured by its apparent magnitude, which is the brightness of a star with respect to the star's luminosity, distance from Earth, and the altering of the star's light as it passes through Earth's atmosphere. Intrinsic or absolute magnitude is directly related to a star's luminosity and is what the apparent magnitude a star would be if the distance between the Earth and the star were 10 parsecs (32.6 light-years). Both the apparent and absolute magnitude scales are logarithmic units: one whole number difference in magnitude is equal to a brightness variation of about 2.5 times. This means that a first magnitude (+1.00) star is about 2.5 times brighter than a second magnitude (+2.00) star, and approximately 100 times brighter than a sixth magnitude (+6.00) star. The faintest stars visible to the naked eye under good seeing conditions are about magnitude +6.



Asteroid 65 Cybele and 2 stars with their magnitudes labelled.

The best method to determine the magnitudes of a star is through the spectrum method. These help in establishing standards which can be applied to work out formulae for determination of the absolute magnitude.



Magnitude of stars vary substantially. Absolute magnitude of the super giants is 100000 times more than the Sun. Nova and super Nova type of stars even surpass the super giants in magnitude especially when agitated. On the other end of the spectrum are the dim stars from the main sequence whose magnitudes are only 0.0001 of the Sun. This figure descends further to absolute darkness when the stars become invisible. A comparison of the bright stars is shown in the figure below:-

Star	Comparable Brightness with the Sun (X times)
Sirius	23
Canopus	1446
Rigel Kentaurus	1.446
Vega	52.5
Capella	158.52
Arcturus	110
Rigel	43674
Procyon	7.58
Achernar	209
Hadar	3632
Altair	11
Betelgeuse	13188
Acrux	5250
Aldebran	100
Spica	2291
Polaris	1630
Antares	5250
Famalhaut	14.45
Denb	47888

The above table shows that no star listed there is less in luminosity than the Sun. Rigel Kentaurus is the only one nearly equalling the Sun with a margin of 0.3. The star is only

4 light years away from the Earth. Actually it owes this brightness to its shorter distance. Rigel Kentaurus will become invisible if replaced with Canopus.

These were the natural properties of the stars. Another facet is that how are they seen by the human beings. The apparent magnitude and visibility are not sufficient to portray their physical conditions, yet lot of information can be gained by their sight. Stars have been classified according to their apparent magnitude depending on distance from the Sun and their absolute magnitude.

It is important to understand absolute magnitude at this stage. Absolute magnitude is directly related to a star's luminosity and is what the apparent magnitude a star would be if the distance between the Earth and the star were 10 parsecs (32.6 light-years) represented by M. Stars being at varying distances. Different formulae are applied in their computations.

One can compute the absolute magnitude M of an object given its apparent magnitude m and luminosity distance D_L:

$$M = m - 5((\log_{10} D_L) - 1)$$

where D_L is the star's luminosity distance in parsecs, wherein 1 parsec is approximately 3.2616 light-years. For very large distances, cosmological redshift complicates the relation between absolute and apparent magnitude, and an additional k correction might be required.

For nearby astronomical objects (such as stars in our galaxy) luminosity distance D_L is almost identical to the real distance to the object, because space time within our galaxy is almost Euclidean. For much more distant objects the Euclidean approximation is not valid, and General Relativity must be taken into account when calculating the luminosity distance of an object.

In the Euclidean approximation for nearby objects, the absolute magnitude M of a star can be calculated from its apparent magnitude and parallax:

$$M = m + 5(1 + \log_{10} p)$$

where p is the star's parallax in arc seconds.

You can also compute the absolute magnitude M of an object given its apparent magnitude m and distance modulus μ:

$$M = m - \mu.$$

Examples

Rigel has a visual magnitude of $m_V = 0.12$ and a distance of about 860 light-years

$$M_V = 0.12 - 5 \cdot (\log_{10} \frac{860}{3.2616} - 1) = -7.02.$$

Vega has a parallax of 0.129", and an apparent magnitude of +0.03

$$M_V = 0.03 + 5 \cdot (1 + \log_{10} 0.129) = +0.6.$$

Alpha Centauri A has a parallax of 0.742" and an apparent magnitude of −0.01

$$M_V = -0.01 + 5 \cdot (1 + \log_{10} 0.742) = +4.3.$$

The Black Eye Galaxy has a visual magnitude of m_V=+9.36 and a distance modulus of 31.06.

$$M_V = 9.36 - 31.06 = -21.7.$$

Given the absolute magnitude M, for objects within our galaxy you can also calculate the apparent magnitude m from any distance d (in parsecs):

$$m = M - 5(1 - \log_{10} d).$$

For objects at very great distances (outside our galaxy) the luminosity distance D_L must be used instead of *d* (in parsecs).

Given the absolute magnitude M, you can also compute apparent magnitude m from its parallax p:

$$m = M - 5(1 + \log_{10} p).$$

Also calculating absolute magnitude M from distance modulus μ:

$$m = M + \mu.$$

The table below shows the difference of their magnitude.

Visible to typical human eye	Apparent magnitude	Brightness relative to Vega	Number of stars brighter than apparent magnitude
Yes	−1	250%	2
	0	100%	4
	1	40%	15
	2	16%	48
	3	6.3%	171
	4	2.5%	513
	5	1.0%	1 602
	6	0.40%	4 800
No	7	0.16%	14 000
	8	0.063%	42 000
	9	0.025%	121 000

	10	0.010%	340 000

A comparison of absolute and apparent magnitudes of different stars is given in the table.

S.No	Star	Apparent Magnitude	Absolute Magnitude
1	Sirius	-1.47	1.4
2	Canopus	-0.72	-3.1
3	Arcturus	-0.06	-0.3
4	Rigel Kentauurus	-0.01	4.4
5	Vega	0.04	0.5
6	Capella	0.05	-0.7
7	Rigel	0.14	-6.8
8	Procyon	0.37	2.6
9	Betelgeuse	0.41	-5.5
10	Archernar	0.51	-1
11	Hadar	0.63	-4.1
12	Altair	0.77	2.2
13	Aldebran	0.86	-0.2
14	Arocus	0.9	-4.5
15	Spica	0.91	-3.6
16	Antares	0.92	-4.5
17	Famalhaut	1.15	1.9
18	Moakhar Toaimin	1.16	0.8
19	Denb	1.26	6.9

Stellar Rotation

The word rotation sounds a bit strange to be associated with the fixed stars and celestial bodies. Fixed stars are normally perceived to be stationary objects. Nonetheless who can deny the Quranic injunctions:-

(لا الشمس ينبغي لها أن تدرك القمر ولا الليل سابق النهار وكل في فلك يسبحون)

(Neither it is for the sun to overtake the moon, nor can the night outpace the day. Each one is floating in an orbit. Ya Seen - 40)

(وهو الذي خلق الليل والنهار والشمس والقمر كل في فلك يسبحون)

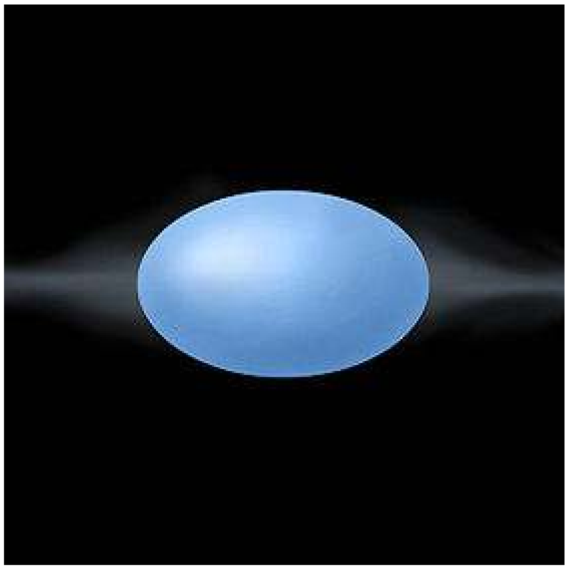
(He is the One who has created the night and the day, and the Sun and the Moon, each floating in an orbit.   Al Anbiya – 33)

In these verses word كل has been used which is a plural and includes all the celestial bodies i.e. stars like the Sun and planets like the Moon. Hazrat Maulana Muhammad Musa (RA) has also contended that it means all the celestial bodies despite apparently referring to the Sun and the Moon. The latest research also points towards this reality.

Some may object that how are the fixed stars in motion like the planets. In case both types are in rotation, then why have they been named differently? Secondly if the stars are also moving, why do they appear to be static since many centuries? Shape of the constellations has remained unchanged since thousands of years. A brief answer is that fixed stars are so far away that because of the distance their motion (even faster than the planets) cannot be noticed with a naked eye. Views observed from an aircraft changed slowly as compared to a car, only because of their distance. A star of the constellation Centaurus is moving at a speed of hundred miles per second traversing a distance of 360000 miles in one hour. This star, despite its tremendous speed appears to move only thirty degrees in two hundred years. The Moon moves only at a speed of less than a mile per second, the Mercury moves at 30 miles/second, the Earth’s speed is 18 miles/second and the Pluto moves at 1.5 miles/second. It is because of their proximity that these planets appear to move faster.

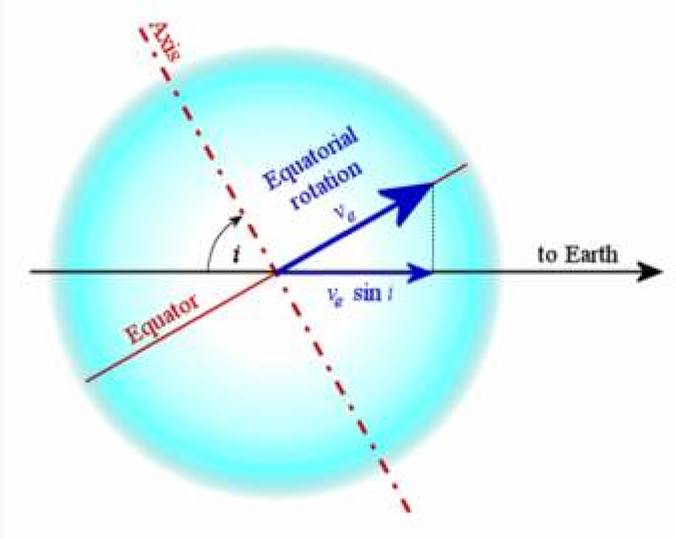
Stellar rotation is the angular motion of a star about its axis. The rate of rotation can be measured from the spectrum of the star, or by timing the movements of active features on the surface.

The rotation of a star produces an equatorial bulge due to centrifugal force. As stars are not solid bodies, they can also undergo differential rotation. Thus the equator of the star can rotate at a different angular velocity than the higher latitudes.



This illustration shows the oblate appearance of the star Achernar caused by rapid rotation.

Unless a star is being observed from the direction of its pole, sections of the surface have some amount of movement toward or away from the observer. The component of movement that is in the direction of the observer is called the radial velocity. For the portion of the surface with a radial velocity component toward the observer, the radiation is shifted to a higher frequency because of Doppler shift. Likewise the region that has a component moving away from the observer is shifted to a lower frequency. When the absorption lines of a star are observed, this shift at each end of the spectrum causes the line to broaden. However, this broadening must be carefully separated from other effects that can increase the line width.



This star has inclination *i* to the line-of-sight of an observer on the Earth and rotational velocity v_e at the equator.

The component of the radial velocity observed through line broadening depends on the inclination of the star's pole to the line of sight. The derived value is given as $v_e \cdot \sin i$, where v_e is the rotational velocity at the equator and *i* is the inclination. However, *i* is not always known, so the result gives a minimum value for the star's rotational velocity. That is, if *i* is not a right angle, then the actual velocity is greater than $v_e \cdot \sin i$. This is sometimes referred to as the projected rotational velocity.

For giant stars, the atmospheric micro turbulence can result in line broadening that is much larger than effects of rotational, effectively drowning out the signal. However, an alternate approach can be employed that makes use of gravitational micro lensing events. These occur when a massive object passes in front of the more distant star and functions like a lens, briefly magnifying the image. The more detailed information gathered by this means allows the effects of micro turbulence to be distinguished from rotation.

If a star displays magnetic surface activity such as star spots, then these features can be tracked to estimate the rotation rate. However, such features can form at locations other than equator and can migrate across latitudes over the course of their life span, so differential rotation of a star can produce varying measurements. Stellar magnetic activity is often associated with rapid rotation, so this technique can be used for measurement of such stars. Observation of star spots has shown that these features can actually vary the rotation rate of a star, as the magnetic fields modify the flow of gases in the star.

The radial velocity of a star or other luminous distant objects can be measured accurately by taking a high-resolution spectrum and comparing the measured wavelengths of known spectral lines to wavelengths from laboratory measurements. A positive radial velocity indicates the distance between the objects is or was increasing; a negative radial velocity indicates the distance between the source and observer is or was decreasing. It is, however, difficult to obtain a spectrum of every star. Therefore radical velocity of fifteen thousand stars has been determined so far. 32% have a velocity less than 20km/sec, 20% are between 10-20 km/sec and the remaining are above 20km/sec. Those above 60km/sec are not more than 6%. The maximum radial velocity of a star known so far is +338km/sec; which means that it is drifting away from the observer at that velocity. The other star seems to be approaching an observer is moving at – 383km/sec.

It takes a very long time to observe these movements. The fastest moving star Barnard takes 175 years to cover half a degree (30 minutes). The Muslim astronomer Abdul Rahman Sufi wrote,' Sirius was once on other side of the galaxy. It has moved through the entire galaxy to reach its present location.' Modern astronomers have verified it and feel that it took at least 50000 years for this to happen. The Sirius moving at a velocity of 11 miles/sec or 29500 miles/hour took such a long time to move only a few degrees.

Radial velocity is expressed in terms of seconds (per year, per century or per a thousand year). If distance to a star is known, then to find its velocity, distance is multiplied with the angle. To work out the velocity in a year, the distance to the star is measured in light years. Before that its arc angle has to be changed to Radian. The multiple has to be divided by 206265. If the answer is desired in sec/mile, result of division or the quotient has to be multiplied with 186000 and for an answer in km/sec multiply it with 299793. The star Barnard moves 10.24 seconds from its location every year. It distance from the solar system is 10.8 light years. So

$10.24 \times 10.8 \div 206265 \times 186000 = 99.97$ or 99.97 miles / sec.

Magnitude of radial velocity is very small. There are only about 100 stars with a radial velocity which is 0.1 seconds per year (considered to be the fastest). In other words, a star will take twenty thousand years to traverse the diameter of the Moon. Despite all the difficulties radial velocity of approximately 330000 stars has been determined.

The Sun, which is a star itself, has a distinct motion associated with its neighboring stars. The Sun is moving towards the Constellation Hercules, along with the entire solar system with a radial velocity of 19.5 km/sec. The solar apex (Apex of the Sun's Way) is the direction that the Sun travels with respect to the Local Standard of Rest. In lay terms, it's the "target" within the Milky Way that the Sun appears to be "chasing" as it orbits the galaxy. In this journey, the stars moving towards the Sun have a negative velocity while those moving away have positive velocity.

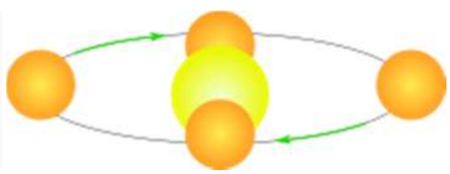
Radial velocity and directional speed of some prominent stars is tabulated below.

Star	Directional Velocity	Radial Velocity

The Binary, Triple and Multiple Stars

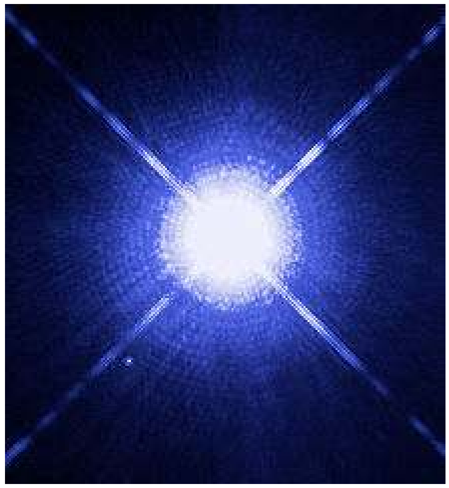
All the Stars seen with the naked eye appear to be singletons. When any two are aligned in line of sight, these appear as twins. Research has proven that there is hardly an interconnection within these stars being hundreds or thousands of light years away from each other. Nonetheless there are twin, triple and multiple stars in the universe. It is not possible to observe them with the naked eye, when all appear to be one. When seen with a telescope these start separating into multiple stars.

Sir Frederick William Herschel, *German: Friedrich Wilhelm Herschel* (1738 –1822) became famous for his discovery of the planet Uranus, along with two of its major moons (Titania and Oberon), and also discovered two moons of Saturn. Herschel's early observational work soon focused on the search for pairs of stars that were very close together visually. In 1803 he confirmed the hypothesis that the two stars might be "binary sidereal systems" orbiting under mutual gravitational attraction. In all, Herschel discovered over 800 confirmed double or multiple star systems, almost all of them physical rather than virtual pairs.



A system with two stars

The term double star may be used synonymously with a binary star. Generally, a double star may be either a binary star or an optical double star consisting of two stars without a physical connection; but these appear together in the sky as seen from the Earth. Binary stars are often detected optically, in which case they are called visual binaries. Many visual binaries have long orbital periods of several centuries or millennia and therefore have orbits which are uncertain or poorly known. They may also be detected by indirect techniques, such as spectroscopy (spectroscopic binaries) or astrometry (astrometric binaries).



Hubble image of the Sirius binary system, in which Sirius B can be, clearly distinguished (lower left)

If a binary star happens to orbit in a plane along our line of sight, its components will eclipse and transit each other; these pairs are called eclipsing binaries, or, as they are detected by their changes in brightness during eclipses and transits.

Astronomers classify a binary star as the one which appears single to the naked eye but when seen with a telescope a system of binary or double stars is observed. If components in binary star systems are close enough they can gravitationally distort their mutual outer stellar atmospheres. In some cases, these close binary systems can exchange mass, which may bring their evolution to stages that single stars cannot attain. Examples of binaries are Sirius and Cygnus X-1.

Binary stars are classified into four types according to the way in which they are observed: visually, by observation; spectroscopically, by periodic changes in spectral lines; photometrically, by changes in brightness caused by an eclipse; or astrometrically, by measuring a deviation in a star's position caused by an unseen companion. Any binary star can belong to several of these classes; for example, several spectroscopic binaries are also eclipsing binaries.

Visual binaries

A visual binary star is a binary star for which the angular separation between the two components is great enough to permit them to be observed as a double star in a telescope, or even high-powered binoculars. The angular resolution of the telescope is an important factor in the detection of visual binaries, and as better angular resolutions are applied to binary star observations increasing number of visual binaries will be detected. The brightness of the two stars is also an important factor, as brighter stars are harder to separate, due to their glare, than the dimmer ones.

The brighter star of a visual binary is the primary star, and the dimmer is considered the secondary.

Spectroscopic binaries

Sometimes, the only evidence of a binary star comes from the Doppler Effect on its emitted light. In these cases, the binary consists of a pair of stars where the spectral lines in the light emitted from each star shifts first toward the blue, then toward the red, as each moves first toward us, and then away from us, during its motion .In these systems, the separation between the stars is usually very small, and the orbital velocity very high. Since radial velocity can be measured with a spectrometer by observing the Doppler shift of the stars' spectral lines, the binaries detected in this manner are known as spectroscopic binaries. Most of these cannot be resolved as a visual binary, even with telescopes of the highest existing resolving power.

Eclipsing binary

An eclipsing binary star is a binary star in which the orbit plane of the two stars lies so nearly in the line of sight of the observer that the components undergo mutual eclipses. The Algol is the best-known example of an eclipsing binary. Eclipsing binaries are variable stars, not because the light of the individual components vary but because of the eclipses.

Astrometric binaries

Astronomers have discovered some stars that seemingly orbit around an empty space. Astrometric binaries are relatively nearby stars which can be seen to wobble around a point in space, with no visible companion. The same mathematics used for ordinary binaries can be applied to infer the mass of the missing companion. The companion could be very dim, so that it is currently undetectable or masked by the glare of its primary, or it could be an object that emits little or no electromagnetic radiation, for example a neutron star.

Example

- Sirius, a binary consisting of a main-sequence type A star and a white dwarf.
- Procyon, which is similar to Sirius.
- Mira, a variable.
- Delta Cephei, a Cepheid variable.
- Epsilon Aurigae, an eclipsing binary.

Hot and cold

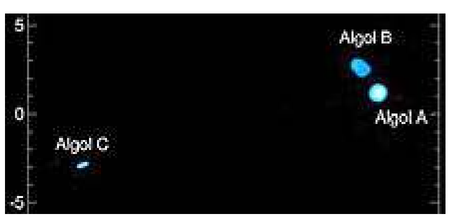
The components of a binary star system may be designated by their relative temperatures as the hot companion and cool companion.

Examples:

- Antares (Alpha Scorpii) is a red super giant star in a binary system with a hotter blue main sequence star Antares B. Antares B can therefore be termed a hot companion of the cool super giant.
- The luminous blue variable Eta Carinae has recently been determined to be a binary star system. The secondary appears to have a higher temperature than the primary and has therefore been described as being the "hot companion" star.
- R Aquarii shows a spectrum which simultaneously displays both a cool and hot signature. This combination is the result of a cool red super giant accompanied by a smaller, hotter companion. Matter flows from the super giant to the smaller, denser companion.
- NASA's Kepler mission has discovered examples of eclipsing binary stars where the secondary is the hotter component. KOI-74b is a 12,000 K white dwarf companion of KOI-74 (KIC 6889235), a 9,400 K early A-type main sequence star. KOI-81b is a 13,000 K white dwarf companion of KOI-81 (KIC 8823868), a 10,000 K late B-type main sequence star.

Multiple Star Systems

Multiple star systems or physical multiple stars are systems of more than two stars. Multiple star systems are called triple, trinary or ternary if they contain three stars; quadruple or quaternary if they contain four stars; quintuple with five stars; sextuple with six stars; septuple with seven stars; and so on. These systems are smaller than open star clusters, which have more complex dynamics and typically have from 100 to 1,000 stars.



The Algol system as it appeared on 12 August 2009. This is not an artistic representation, but rather is a true two-dimensional image. The elongated appearance of Algol B and the round appearance of Algol A are real. The form of Algol C, however, is an artifact.

The examples are listed below:-

Triple

- Polaris, the North Star, is a triple star system in which the closer companion star is extremely close to the main star—so close that it was only known from its gravitational tug on Polaris A until it was photographed by the Hubble Space Telescope in 2006.
- Gliese 667, which houses the "super-Earth" Gliese 667Cc is a triple star system.
- Alpha Centauri is a triple star composed of a main binary yellow dwarf pair (Alpha Centauri A and Alpha Centauri B), and an outlying red dwarf, Proxima Centauri. A and B are a physical binary star, with an eccentric orbit in which A and B can be as close as 11 AU or as far away as 36 AU.
- HD 188753 is a triple star system located approximately 149 light-years away from Earth in the constellation Cygnus. The system is composed of HD 188753A, a yellow dwarf; HD 188753B, an orange dwarf; and HD 188753C, a red dwarf. B and C orbit each other every 156 days, and, as a group, orbit A every 25.7 years.
- Xi Tauri is a triple star system in the constellation Taurus. Xi Tauri a spectroscopic and eclipsing triple star. It consists of three blue-white B-type main sequence dwarfs. Two of the stars are in a close orbit and revolve around each other once every 7.15 days. These in turn orbit the third star once every 145 days. Xi Tauri is approximately 222 light years from Earth.

Quadruple

- 4 Centauri.
- Mizar is often said to have been the first binary star discovered when it was observed in 1650 by Giovanni Battista Riccioli . Spectroscopy of its components Mizar A and B revealed that they are both binary stars themselves.
- HD 98800

Quintuple

- 91 Aquarii.
- Delta Orionis.

Sextuple

- Castor
- HD 139691
- If Alcor is considered part of the Mizar system, the system can be considered a sextuple.

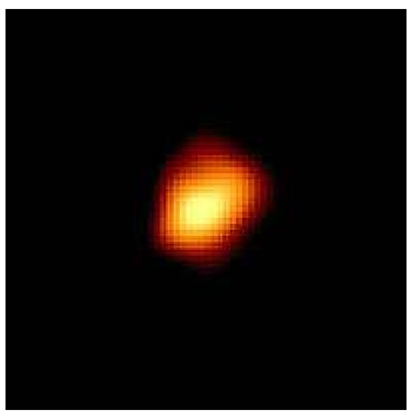
Septuple

- Nu Scorpii.
- AR Cassiopeiae.

Variable Stars

A variable star is a star whose brightness as seen from Earth (its apparent magnitude) fluctuates. This variation may be caused by a change in emitted light or by something partly blocking the light, so variable stars are classified as either:

- Intrinsic variables, whose luminosity actually changes; for example, because the star periodically swells and shrinks.
- Extrinsic variables, whose apparent changes in brightness are due to changes in the amount of their light that can reach Earth; for example, because the star has an orbiting companion that sometimes eclipses it.



Asymmetrical appearance of Mira, which is an oscillating variable star.

Mira variables are very cool red super giants, which are undergoing very large pulsations. Since hydrogen is the most abundant element almost everywhere in Universe and in stars, the pulsations generally have great amplitude. Over periods of usually many months, they may brighten by between 2.5 and up to 11 magnitudes (six fold to 30 thousand fold changes in luminosity) before fading again. Mira itself varies in brightness from almost 2nd magnitude to as faint as 10th magnitude within a period of roughly 332 days.

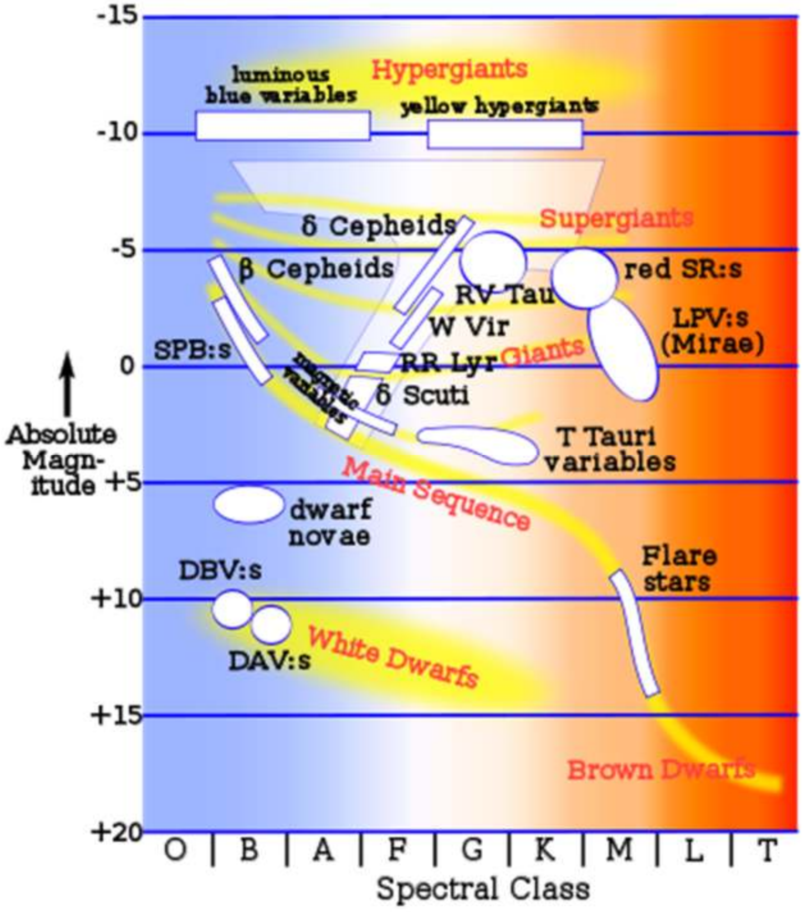
Pulsating variable stars

The pulsating stars swell and shrink regularly by stellar radius, magnitude and spectrum, most often with a defined period. The two most important types are:

- Cepheids and cepheid-like stars. They have short periods (days to months) and their luminosity cycle is very regular.
- Long period variables. Their period is longer, on the order of a year, and much less regular.

Cepheids and cepheid-like variables

This group consists of several kinds of pulsating stars that swell and shrink very regularly by the star's own mass resonance.



Intrinsic variable types in the Hertz sprung–Russell diagram

Blue white variables with early spectra (O and B)

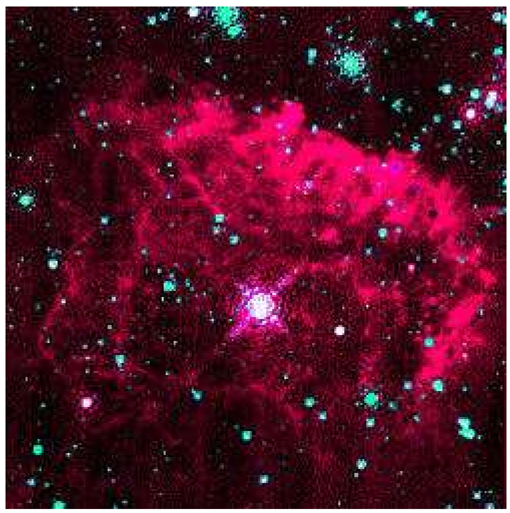
Blue white stars, often giants, with small brightness variations and short periods.

Giants and Super Giants

Large stars lose their matter relatively easily. For this reason, eruptivity is fairly common among giants and super giants.

Luminous blue variables

Also known as the S Doradus variables, the most luminous stars known belong to this class. Examples include the hypergiants Carinae and P Cygni.



The Pistol Star

Gamma Cassiopeiae variables

Gamma Cassiopeiae variables (shell stars) are BIII-IVe type stars that fluctuate irregularly by up to 1.5 magnitudes (fourfold change in luminosity) due to the ejection of matter at their equatorial regions caused by a fast rotational speed.

Achernar, the brightest shell star as seen from Earth

R Coronae Borealis variables

While classed as eruptive variables, these stars do not undergo periodic increases in brightness; instead, they spend most of their time at maximum brightness. At irregular intervals, however, they suddenly fade by 1 – 9 magnitudes (2.5 to 4000 times dimmer), slowly recovering to their maximum brightness over months to years. This variation is thought to be caused by episodes of dust formation in the atmosphere of the star. As dust is formed and moves away from the star, it eventually cools to below the dust condensation temperature, at which point a cloud becomes opaque, causing the star's observed brightness to drop. The dissipating dust results in a gradual increase of brightness.

R Coronae Borealis (R CrB) is the prototype star. Other examples include Z Ursae Minoris (Z UMi) and SU Tauri (SU Tau). DY Persei variables are a subclass of R CrB variables that have a periodic variability in addition to their eruptions.

Long period and semi regular variables

There are various groups of red giant stars that pulsate with periods in the range of weeks to several years. The period is not always constant but changes from cycle to cycle.

Cataclysmic or explosive variable stars

Supernovae

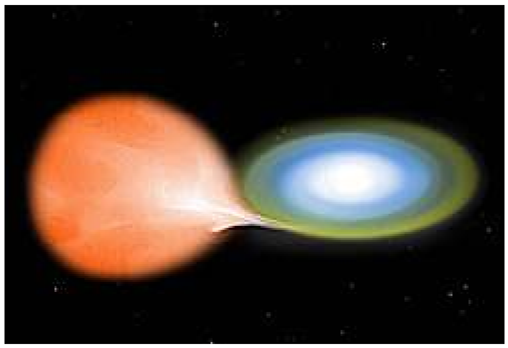
SN 1994D, a type Ia supernova in theNGC 4526 galaxy (bright spot on the lower left)

A supernova can briefly emit as much energy as an entire galaxy, brightening by more than 20 magnitudes (over one hundred million times brighter). The supernova explosion is caused by a white dwarf or a star core reaching a certain mass/density limit, the Chandrasekhar limit, causing the object to collapse in a fraction of a second. This collapse "bounces" and causes the star to explode and emit this enormous energy quantity. The outer layers of these stars are blown away at speeds of many thousands of kilometers an hour. The expelled matter may form nebulae called supernova remnants. A well known example of such a nebula is the Crab Nebula, left over from a supernova that was observed in China and North America in 1054. The core of the star or the white dwarf may either become a neutron star (generally a pulsar) or disintegrate completely in the explosion.

Supernovae can result from the death of an extremely massive star, many times heavier than the Sun. At the end of the life of this massive star, a non-fusible iron core is formed from fusion ashes. This iron core is pushed towards the Chandrasekhar limit till it surpasses it and therefore collapses.

A supernova may also result from mass transfer onto a white dwarf from a star companion in a double star system. The Chandrasekhar limit is surpassed from the in falling matter. The absolute luminosity of this latter type is related to properties of its light curve, so that these supernovae can be used to establish the distance to other galaxies. One of the most studied supernovae is SN 1987A in the Large Magellanic Cloud.

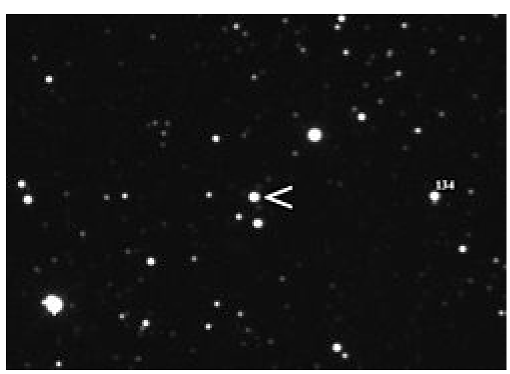
Novae



Artist's conception of a white dwarf star accreting hydrogen from a larger companion

Novae are also the result of dramatic explosions, but unlike supernovae do not result in the destruction of the progenitor star. Also unlike supernovae, novae ignite from the sudden onset of thermonuclear fusion, which under certain high pressure conditions (degenerate matter) accelerate explosively. They form in close binary systems, one component being a white dwarf accreting matter from the other ordinary star component, and may recur over periods of decades to centuries or millennia. Novae are categorized as fast, slow or very slow, depending on the behaviour of their light curve. Several naked eye novae have been recorded, Nova Cygni 1975 being the brightest in the recent history, reaching 2nd magnitude.

Dwarf Novae



Dwarf nova HT Cas seen in outburst on 2010 November 2.

Dwarf novae are double stars involving a white dwarf star in which matter transfer between the component gives rise to regular outbursts. There are three types of dwarf nova:

- U Geminorum stars, which have outbursts lasting roughly 5–20 days followed by quiet periods of typically a few hundred days. During an outburst they brighten typically by 2 – 6 magnitudes. These stars are also known as SS Cygni variables after the variable in Cygnus which produces among the brightest and most frequent displays of this variable type.
- Z Camelopardalis stars, in which occasional plateaux of brightness called standstills are seen, part way between maximum and minimum brightness.
- SU Ursae Majoris stars, which undergo both frequent small outbursts, and rarer but larger superoutbursts. These binary systems usually have orbital periods of under 2.5 hours.

Z Andromedae variables

These symbiotic binary systems are composed of a red giant and a hot blue star enveloped in a cloud of gas and dust. They undergo nova-like outbursts with amplitudes of some 4 magnitudes.

Extrinsic Variable Stars

There are two main groups of extrinsic variables: rotating stars and eclipsing stars.

Rotating variable stars

Stars with sizable sunspots may show significant variations in brightness as they rotate, and brighter areas of the surface are brought into view. Bright spots also occur at the magnetic poles of magnetic stars. Stars with ellipsoidal shapes may also show changes in brightness as they present varying areas of their surfaces to the observer.

Optically variable pulsars

Few pulsars have been detected in visible light. These neutron stars change in brightness as they rotate. Because of the rapid rotation, brightness variations are extremely fast, from milliseconds to a few seconds. The first and the best known example is the Crab Pulsar.

Eclipsing binaries

Extrinsic variables have variations in their brightness, as seen by terrestrial observers, due to some external source. One of the most common reasons for this is the presence of a binary companion star, so that the two together form a binary star. When seen from certain angles, one star may eclipse the other, causing a reduction in brightness. One of the most famous eclipsing binaries is Algol, or Beta Persei

Algol variables

Algol variables undergo eclipses with one or two minima separated by periods of nearly constant light. The prototype of this class is Algol in the constellation Perseus.

W Ursae Majoris variables

The stars in this group show periods of less than a day. The stars are so closely situated to each other that their surfaces are almost in contact with each other.

Creation and End of the Universe

It will not be an exaggeration to say that very few people are aware of the reality of our universe. One can say with total confidence that its creation and dimensions remain inexplicable even in these modern times. A universal consensus does exit as far as the definitions, terminology and explanations are concerned but the logic offered to explain substantial aspects still remain controversial. Most of the views are hypothetical and based on visual experiments. A variable array of theories has emerged to offer solutions for a single problem.

It is generally believed that universe is that part of the space where matter exists in any form. Beyond it any part that is devoid of the matter is not included in it. Some thinkers believe it to exist within certain boundaries and limits. Strangely enough, despite terming it to be limited, its vastness has not been determined or measured. Marvel or enigmatic character of a thing in no way qualifies it to be ignored or refuted. With a little change of perception and adoption of Islamic outlook starts solving the riddles and things begin fitting into their slots. Everything that exists in the universe is a creation of Allah Almighty, coming into being because He had willed it to happen (Kun). Possibly Allah Almighty has permitted a part of it to be visible and the remaining has been denied. Arrangements were provided by Him to witness what He has desired to be seen and the rest is oblivion because He has desired it not to be seen.

It is essential for us to define the shape of the universe. Till recently it was considered to be three dimensional and all the laws of geometry were applicable. Distances were considered to be measurable inconformity with the short distances on the earth. This methodology and hypothesis, however, failed to resolve certain intricate issues and a rethinking became necessary. Albert Einstein is the pioneer of the changed thought. Refuting the old theory of tri dimensional universe, he added another dimension to it i.e. time. Elucidating his theory, he professed that changes keep occurring in the universe. Any incident that takes place has to be judged in relation to time and space which otherwise make it impossible to explain.

Comprehension of the concept of time and space is arbitrarily difficult because in our lives we do not come across many things of this nature. It can, however, be explained with an example from our surroundings. Volume of a solid object is measures in cubical units. A cubical unit has three dimensions i.e. length, width and thickness. Volume of a certain quantity of water in fluid form can be only calculated when it is static. But when the same water is flowing in a drain or a canal then to measure the flow of water at a certain point, time dimension has to be added to it i.e. amount of flow/ discharge of water at a point in a certain time unit. The fourth dimension of time in this situation is added to quantify it. The term cubic feet per second (cusecs) is used by engineers. This example in the context of the universe may not be very apt, yet it can help to understand the concept of four dimensions. The universe comprising of matter is in motion. Einstein had concluded in his research work that because of the simultaneous application of gravitational laws and laws of repulsion, the universe is expanding and shrinking. It can be termed as limitless because of the process of expansion and limited because of it shrinking. So it can be said that it is in perpetual motion, expanding sometime and then shrinking. Edwin Powel Hubble, the American astronomer using the Doppler’s Law and Hooker telescope changed the prevailing view of the cosmos that the galaxies are moving at rapid speed. This led to the theory of the metric expansion of space. Hubble's Laws lays down that all objects observed in deep space (interstellar space) are found to have a Doppler shift observable relative velocity to Earth, *and* to each other; and secondly that this Doppler-shift-measured velocity, of various galaxies receding from the Earth, is proportional to their distance from the Earth and all other interstellar bodies. In effect, the space-time volume of the observable universe is expanding and Hubble's law is the direct physical observation of this process. It is considered the first observational basis for the expanding space paradigm. According to the expanding space paradigm, the speed in km/s of a galaxy is 1 mega parsec (3.09×10^{19} km) away i.e. other galaxies are moving away at a speed of 50 to 100 kilo meter mega parsec. If the distance of our galaxy i.e. Milky Way is one mega parsec from the earth then its speed is 50 to 100 kilo meters. Drift of the other cosmos should be looked at like an expanding balloon when every point in relation to the other seems to be running away when air is being blown into it.

With the acceptance of the reality of a four dimensional space/ universe, laws of geometry are no longer applicable there. Its limits cannot be measured with straight lines but crooked curves have to be used to delineate its limits. To illustrate it, let's consider the example of a three dimensional sphere with a lean curved surface. This sphere is actually a finite body with its limits yet its ends are not discernable. It will therefore be considered limitless. Any terrestrial body in the universe is considered to be spherical with the addition of time dimension. This vividly shows how complex is our universe. It is therefore not wrong to say that the universe despite being finite has no limits. Spread of the universe is difficult to determine notwithstanding it being finite. Use of huge modern telescopes has broadened the field of vision yet the maximum distance attained so far is two billion light years. The scientists believe that ultimately a limit shall be reached beyond which even a very powerful telescope may not be able to observe and man would never be able to know the end. Based on this conclusion the space has been divided into two parts; one that can be observed with powerful instruments (Hoyle thinks this too may not be possible) called the Observable Universe and the second part is beyond it that cannot be observed. The famous astronomer Fred Hoyle writes at page 108 of his book 'Dimensions of the Universe',*" Presently we are only able to see up to half the distance of the expected limits. Even a telescope million times powerful than the Mount Plummer Telescope will not be to double our depth of vision…………………....This part will be called the Observable Universe."*

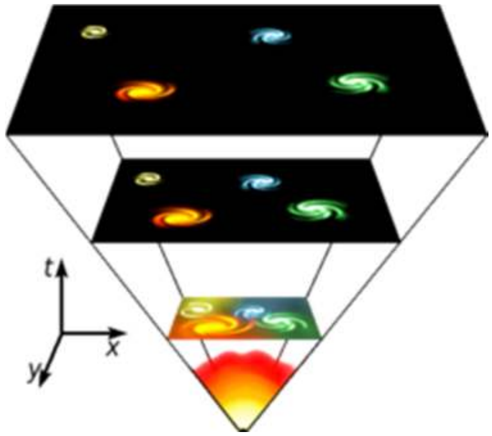
It is beyond human imagination to gauge/understand the complexities of our existence and intricate happenings of the universe. In the vast spread of time and space there exist millions of galaxies and cosmos with a multitude of nebulas, planets and stars. Many amorphous nebula of matter are afloat in its vastness. These celestial bodies are interfiled with interstellar dust, gases, frozen ice particles and what not. Capacity of the human mind is too restrictive to fathom the perplexing puzzle of the nature. Our solar system a like a speck of dust floating in this amazing universal expanse. Human mind is dumbfound to gauge the enigmatic labyrinthine created by Allah Almighty.

Understanding of creation of the universe is far more complex and variegated than to comprehend its limits and spread. Human mind has ever since been struggling to decipher the time of its beginning and the various stages of evolution that it took to reach the present stage. Scholars, thinkers and scientists have strived to find suitable answers to the multitude of these questions. Depending on their research and comprehension a number of theories mostly hypothetical based have been formulated. Nonetheless no one is yet sure about reality and a certain answer. A probable sequence of events has though been charted but it does not provide an authenticated final answer. The underlying base of these theories is that all the physical events of the past were similar to those occurring today. In the absence of this hypothetical basis the whole discussion will become a mere guess work and an imaginary fabrication totally detaching it from the realm of prudent knowledge.

Modern research indicates that the earth formed approximately 4.54 billion years ago by accretion from the solar nebula. The sun is approximately eight billion years old. Difference between the near and distant parts of the universe has an estimated beginning of some 12- 18 billion years . Some of the stars have been emitting light for the last ten billion years and some began to do so just a ten million years ago. The spiral parts of some of the galaxies were born between ten million to hundred million years ago. These are not the final figures and are being contested by the experts. However no figures go beyond twenty billion years which may be the time frame of the beginning of the universe. The huge planets and spiral galaxies are relatively new.

Many theories have been propounded about creation of the universe. Basically only two of them are significant, while the rest are their variants. The first theory is named as ‘Universal Atom or the Big Bang Theory’ and the other is called ‘Constant Matter or Stellar Nucleosynthesis Theory’.

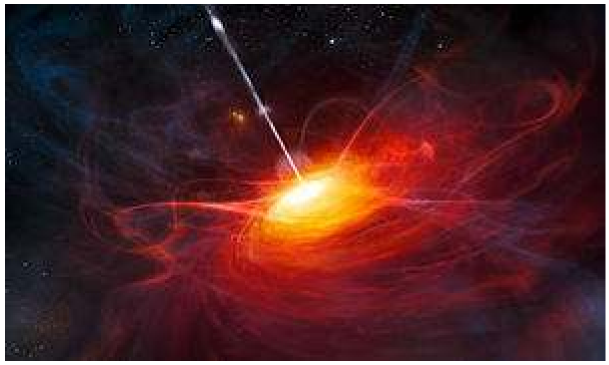
The German scientist assuming the universe to be vacant applied Albert Einstein's general theory of relativity. The Russian scientist Fredmaan adding the role of density proffered that with the increase in density the universe shrinks and expands with its reduction. Belgian scientist A B Le Meyer presented the idea of a universal atom where the matter was stored. In it electrons, neutrons and protons were all present in a jumbled form in one of its parts where the temperature, pressure and density were amazingly high. A time came that that the matter started expanding with a bang and spread into the space.



According to the Big Bang model, the Universe expanded from an extremely dense and hot state and continues to expand today. A common analogy explains that space itself is expanding, carrying galaxies with it, like spots on an inflating balloon. The graphic scheme above is an artist's concept illustrating the expansion of a portion of a flat universe.

During the process of expansion the temperature dropped so low that the electrons, neutrons and protons got arranged and emerged as atoms. With the advent of matter formation of elements commenced. It is probable that the ratio of lighter elements was more than the heavier ones. Then galaxies started forming and started drifting away. Expansion and spread of the matter shall continue for an indefinite period and the galaxies will be disconnected from each other. This will ultimately usher in end of the universe. In this concept, the most difficult question is from where the universal atom came? Was it created at a specified moment or did it exist before hand.

The other theory rejecting the 'Big Bang Theory' was conceived by the Sir Fred Hoyle an English astronomer along with Bendy and Gold. This theory is called the Theory of Stellar Nucleo synthesis. The concept of nucleosynthesis in stars was first established by Hoyle in 1946. This provided a way to explain the existence of elements heavier than helium in the universe, basically by showing that critical elements such as carbon could be generated in stars and then incorporated in other stars and planets when that star "dies". The new stars formed now start off with these heavier elements and even heavier elements are formed from them. Hoyle theorized that other rarer elements could be explained by supernovas, the giant explosions which occasionally occur throughout the universe, whose temperatures and pressures would be required to create such elements. Simply put it theorises that matter is being created continuously in a gradual form from ever. This logic has however been criticized by the proponents of big bang theory. They feel that the discovery of 'Quasers' (quasi-stellar radio source), has proved that the universe was never static but kept on changing.



Artist's rendering of ULAS J1120+0641, a very distant quasar powered by a black hole with a mass two billion times that of the Sun.

Light from the quasers that reached the earth after twelve billion years, show an old picture of the universe. Being totally different it points to the change, which negates the Theory of Stellar Nucleosynthesis. The other factor negating it is the discovery of certain areas where the temperature is in conformity with the Big Bang Theory. (Encyclopaedia Encarta)

Many scientists find it is easier to reconcile to the idea of a continuous and gradual growth of the universe than to believe in the sudden big bang.

Fred Hoyle responding to his critics writes,” *The most important question being asked about the continuous creation is where from the matter is coming? It comes from no where but it is being created. Some critics argue that concept of perpetual creation has added an astonishing hypothesis to the realm of sciences. I do not agree with this contention of it being an absurd hypothesis. Notwithstanding it being a fresh concept it has only substituted another theory which contends the all the matter was produced by a big bang in the distant past. Rationale scientific reasoning supporting the big bang theory looks less logical being an irrational process that can not be explained in scientific terms.” (Dimensions of the Universe Pages 112-113)*

Though it is difficult to offer a sure shot reason for all the happenings in our stellar universe but either of the above two theories conclusively indicate that the matter gave birth to large interstellar gas and dust nebulas which exist even today. Later the stars were created through condensation at extremely low temperature.

After the end of this prolonged discussion, the question arises that is the whole process of conversion of matter into nebulas, stars and galaxies self generated or is it being created and regulated by someone? In the holy Quran Allah Almighty says:-

Do not the Unbelievers see that the heavens and the earth were joined together (as one unit of Creation), before We clove them asunder? We made from water every living thing. Will they not then believe?   Al Anbia – 30

This clearly indicates that the universe was all one entity and then Allah Almighty chose to create seven earths and heavens from it. Did it all happen simultaneously or was it a gradual process? Our religion shuns any explanation but aptly confirms the all the creation were master minded by a Creator. Apparently religious belief may seem to be in discord with the scientific logic. However rising above prejudices, rationale of a Creator is more reasonable and logical.

When scientific concepts are based on assumptions then to suppose existence of a Creator is fairly logical. One who created the matter and the universe? The One being, who is wisest, beyond any limits and bounds and the most powerful. He has been there ever since and shall remain for ever.

Looking at the issues in hand; two questions logically emerge. Is the matter an accidental creation or an endless process which is unceasing? A little contemplation shows that basically these two are just one question. If the matter is considered to be a creation then it has a basis for occurrence. So one has to subscribe to either existence of the universe from ever to ever or linked to the will and desire of the Creator. The 'Ever option' if adopted ceases at one stage to answer, how did the matter come into being? Law of Entropy defines that everything seeks disorder and scatter until and unless controlled and regulated by an outside force. How has the order been brought in? Definitely there is someone exercising the power to regulate the whole process. Who else can it can it be except the Creator himself. Creation is more difficult then its subsequent maintenance and continuity. To understand this phenomenon is beyond the capacity of the human mind. Man being a creation can never gauge how the Creator functions. Allah Almighty is a non matter like energy. Any other assumption will involve us into an imprudent discussion about Allah Almighty taking us to same ambiguity as being resolved about the universe.

Ice melting in a warm room is a common example of increasing entropy described in 1862 by Rudolf Clausius as an increase in the disgregation of the water molecules in ice.

One can be led to believe that energy being a non matter formed the basis for creation of the matter. Here a question arises as to how it could have happened on its own because energy lacked consciousness and ability to act. Secondly why did it choose to convert into matter only twenty billion years ago despite being there ever since? These anomalies surface when we accept energy to have existed form ever. Any deviation will take us astray to the same unending debate about its creation. All issues start to resolve the moment it is accepted that the Wisest of all and the most Powerful created it all, at His will and desire. Energy was created with the capability to convert into matter. This phenomenon will continue till He desires it and shall then end at His will. To obviate any doubts about His creations, one will have to accept that He has been there since ever and that no one created Him. In nut shell, acceptance of a powerful, wise, limitless and perpetual being as the creator of our universe provides answers to all doubts and anomalies. As far as the mystery of the universe is concerned, the holy Quran aptly states:-

Surely, in the creation of the heavens and the earth, and in the alternation of night and day, there are signs for the people of wisdom, Who remember Allah standing and sitting, and (lying) on their sides, and ponder on the creation of the heavens and the earth (and say) "Our Lord, You have not created all this in vain. We proclaim Your purity. So, save us from the punishment of Fire.   Ale Imran 190-191.

A Muslim with a firm and unflinching belief in Allah Almighty requires no theories like ‘Big Bang’ etc to learn as to how the universe was created. These become secondary to his conviction that everything was created at His will and desire and that nothing can happen on its own. That being so, we have to accept that He has the capability to create matter in one go or gradually or any other arrangement that He chooses. This is beyond the capacity of the human mind to fathom. In this complete discourse there is only one salient aspect that the Devil attempts to obscure from us by indulging us into trivial non issues which is the presence of our Lord and Creator Allah Almighty. The above quoted verses were revealed to set right such misgivings.

The last issue being debated about the universe is that whether it is static or dynamic. Observations have proven that the concept of a static universe is absurd. A glean into the galaxies show that they are not stationary but dynamic and are drifting apart at a tremendous speed. Our universe is like an inflating balloon being filled with air. Fred Hoyle has stated that every passing moment fresh matter is being created which converts into nebulas and pushes outward the earlier galaxies and nebulas to create space for itself. The motion is so rapid that it is incomparable with any speed that we experience or comprehend except that of light. The fastest moving nebula observed sofar is drifting at an amazing speed of 140000 kilometres per second (88000 miles/second) thus attaining 46% of speed of light. This is not the ultimate because the universe is spread far and beyond. It can be assumed that the nebulas in the deep space are moving at a much greater speed along with other elements moving at the speed of the light. Those nebulas that are moving at the speed of light can be observed with telescopes stronger than the Mount Plummer Telescope but those faster than this remain invisible. Rays from a body moving at a speed higher than light will never reach us and it will never be seen. To explain this phenomenon, Fred Hoyle writes,

“Those nebulas at twice the distance from the farthest galaxies can be seen with Mount Plummer Telescope because they are moving away at the speed of light. Those beyond and moving faster than light will remain unseen. Some of the people get irritated who see the phenomenon in the light of Albert Einstein’s theory of relativity, which states that a body comprising of matter can not attain a speed higher than light. This is only true when applied in its ordinary context to objects belonging to a simple system of time and space. Our universe is a complex place and explanations have to be based in terms of the common theory. To explain it further, it can be said that that farther a galaxy from us, its distance is constantly increasing disallowing its light from reaching the earth. Now light from a galaxy too far will never reach us because it is traversing its opposite path simultaneously with an increasing speed than the speed of light. No one from our galaxy will ever be able to see them irrespective of the strength of the viewing devices.”
Dimensions of the Universe - Page 107

After observing speed of nebulas scientists are in doubt as to what is being seen is real or there are other elements in the atmosphere which are only creating illusions. They think that a beam of light which reaches us after billions of light years has to traverse through many mediums and matters enroute. So it is not certain that it reaches us in the original form. This ambiguity is keeping the scientists perplexed. No one denies the fact that nebulas are dynamic and are moving away rapidly resulting in continuous expansion of the universe. Another doubt that is still lingering in minds relates to the speed of expansion of the space. Is it more or less than what is seen or presumed? It is quite possible that soon it would become possible to grow out of hypotheses into the realm of reality. Some scientists believe that it will be possible to get real observations from surface of the moon which is totally devoid of gravity and atmosphere.

Having discussed creation of the universe one is tempted to ponder whether it will persist or end? Scientists keep on guessing about it. Being a matter of the future no clue can be found. Ancient Greek thinkers like Aristotle disbelieved in the Dooms day. They thought that the universe was permanent and would stay for eternity. Now the new astronomical research states that the universe being prone to accidents in not permanent and it shall end some day. They, however, cannot predict the end time and a scientific explanation to support their contentions. Destruction of the solar system and earth has particularly remained under discussion. The experts have outlined various eventualities of a partial end (Dooms day):-

a. Solar system will be glaciated, freezing every living being to death. Our solar system is moving in one direction at a speed of eleven miles per second. It has to pass through hot and cold regions in the space. Mr. Maxwell writes that so far it has successfully passed four times through severely cold regions which caused extreme winters on the earth. Global experts think that the earth has so far covered one fourth of its journey of the last cold spell. This is why the areas of South Pole and Greenland are still covered in snow. It is plausible that the coming spell the journey may be severer in cold resulting in end of the life.
b. The earth may collide with another planet or terrestrial body and the resulting havoc may end the life on the earth.
c. Collusion of the sun with any other planet can bring about the destruction of whole of the solar system.
d. The sun is rapidly expanding its hydrogen element being consumed as fuel. Burnt hydrogen is converted to helium. According to George Gimo, with burning of this fuel a stage will arrive when the sun will become very bright and extremely hot. After ten billion years sun will become hundred times brighter. Temperatures on the earth shall cross the boiling point thus causing the oceans to evaporate. Life on the earth shall become extint. The

temperature of the sun shall start receding and its size will reduce. Reduction in its force of attraction will let the other planets loose and they shall drift away from the orbit of the sun.

Islamic View Point. Above were sited the views and conjecturing by the eminent scientists, who are solely focused on the causes; totally oblivious to the revealed words of Allah Almighty. All their postulations shall only end in an utter surprise and dismay. There are only a few fortunate ones who remain within the permissible limits ordained through the revelation. They always take a lead from the words of Allah Almighty.

When the earth will be trembled with its quake, and the earth will bring forth its burdens And man will say, "What has happened to it? Zalzala 1-3

When the sun will be folded up, and when the stars will swoop down and when the ten-month pregnant she-camels will be abandoned, and when the seas will be flared up. Al Takwir 1-6

When the sky will split apart, and will listen to (the command of) its Lord, and it ought to, and when the earth will be stretched, and it will throw up whatever it contains, and will become empty.

Al Inshiqaq 1-4

When the sky will be cleft asunder, and when the stars will disperse, and when the seas will be burst forth. Al Infitar 1-3

So, when the stars will be extinguished, and when the sky will be split, and when the mountains will be blown away as dust, And when the messengers will be assembled at the appointed time, (then all matters will be decided. Do you know) for which day has all this been delayed? For the Day of Decision! And what may let you know what the Day of Decision is? Woe that Day to the deniers!

Al Mursilat 8-14

All the above verse from the holy Quran vividly spell out that the end (Dooms Day) shall not be partial but will be final end of our universe. The sky will asunder into pieces. The sun shall be wound up terminating its own glow and that of the moon. Oceans shall turn into the seas of fire as if converted into the Hell. All the stellar bodies like the sun, the earth and the moon shall be destroyed. Our science can not say a word about the end of the sky because it is far beyond the limits of our observation.

Application of Astronomy in Sharia

بلسان عربي مبين

(In plain Arabic language. Al Shuara – 195)

The holy Quran was revealed in the Arabic language prevalent at that time. Similarly the Hadiths are written in the contemporary Arabic. It is therefore important to be familiar with the Arabic of those times. Secondly the Quran is not a text book but these are words Allah Almighty, which contains guidance for all times to come. Anyone seeking guidance can be blessed by the Quran provided he/she is pious. In the beginning of this Book, it was explained that astronomy can serve as a tool to interpret and explain the holy verses and the Hadith. It is essential that one must be well versed with sciences to be able to comprehend the revelations from the Quran. These sciences include mathematics and astronomy. Precisely for this reason, Hazrat Ibn e Abbas (RH) had desired to learn it. Hazrat Ali (RH) was also an admirer of these two sciences.

In the succeeding paragraphs, authentic commentaries/treatise of selected Quranic verses by eminent scholars, have been enumerated. Relevant astronomical explanations are being added to the commentaries, as a service. May Almighty accept the effort and guide us. Ameen.

الشمس والقمر بحسبان.

(And the sun and moon for the reckoning (of time   Ar Rahman - 5)

Author of ‘ Maaruf ul Quran’ , Hazrat Mufti Muhammad Shafee (RA) in volume seven of the Book writes,” حسبان is a verb form that functions as a noun expressing the plural of حساب like ‘Ghufran, Subhan and Quran’. Meaning of the verse are that rotation of the Sun and the Moon (on which are dependent many of the human activities like seasonal changes, night and day, determination of months and years) follow a laid down and balanced pattern. ‘Husban’ being a plural of ‘Hisab’ indicate that each has an independent rotational system. These parameters control the solar system so efficiently that despite a lapse of millions of years, difference of not single second has accrued”.

Those experts, who believe in astronomical calculation for sighting of the Moon, refer to this verse as an authority to indicate that the systems functions very rigidly and no deviations occur in it. Lunar and Solar eclipses are a good example of the phenomenon. Many days before the event, exact eclipse timings are published and telecast. Then the event is witnessed by millions; unfolding precisely as forecast right down to a second. So if the same very scientists forecast that on a specific day the Moon has set before the Sun, how can those testifying to have witnessed the Moon on that day, be believed? Nevertheless decision on lunar sighting cannot be solely based on calculations.

Abu Huraira (Allah be pleased with him) narrated that the Messenger of Allah (May peace he upon him) made a mention of the new moon and (in this connection) said:

Observe fast when you see it (the new moon) and breakfast when you see it (the new moon of Shawwal), but when (the actual position of the month is) concealed from you (on account of cloudy sky), then count thirty days.

Book 006, Number 2381, Muslim.

Astronomical calculations are only a useful tool but cannot substitute the physical act of sighting of the Moon.

والسماء رفعها و وضع الميزان

‘Rafa’ and ‘Waza’ are antonyms, totally opposite in their meaning. ‘Rafa’ is to elevate and raise while ‘Waza’ means to lower and descend. In this verse, the sky has been mentioned to have been raised and spread. It includes both the literal meaning and the spiritual meaning i.e. higher stature of the sky and its elevation over the Earth. These two have been similarly compared throughout in the Quran. In this verse, after elevation of the sky, lowering of the balance is mentioned; which is not comparable to the sky. With a little more thought, one can gauge that actually the sky and the Earth have been compared here which has been clarified in a later verse.

وَٱلْأَرْضَ وَضَعَهَا لِلْأَنَامِ ﴿١٠﴾

A question arises here, as to why the balance has been mentioned here? Actually it is a Divine Command and injunction to ensure that justice and equity are practiced to eliminate repression and that no rights are usurped. There is a vivid indication here that the sky and the earth have been created for the maintenance of equity and justice; which lead to peace and tranquility otherwise there will be total chaos and anarchy.

Another interpretation leads to the supreme balance that has been ensured in the universe. When balance is related to the mass, it naturally points to the gravity amongst the stellar objects. Here ‘miazan’ is indicative of the universal balance. This meaning is more plausible. Progress made in the Astronomical sciences has confirmed that our universe is structured on a meticulously precise system of balance. Scientists have always ventured to discover balance in the celestial bodies. The Neptune and Pluto are a result of this quest. This balance, in essence, is the main reason for continuation of the universal order. Similarly absence of justice in a society shall lead to destruction of law and order. Probably it is for this reason that next verse exhorts, “*That you not transgress within the balance.*

Or

“So establish weight with justice and fall not short in the balance”. *Ar Rahman – 8.*

رَبُّ ٱلْمَشْرِقَيْنِ وَرَبُّ ٱلْمَغْرِبَيْنِ ﴿١٧﴾

[He is] Lord of the two sunrises and Lord of the two sunsets.

The conventional meanings ascribed to the verse are that He is the Lord of east and west of the winters and summers. Another meaning points to an astronomical reality. The Sun rises from the West of the planet Mercury and sets it its East and then rises from the East and set in the West.

يَٰمَعۡشَرَ ٱلۡجِنِّ وَٱلۡإِنسِ إِنِ ٱسۡتَطَعۡتُمۡ أَن تَنفُذُواْ مِنۡ أَقۡطَارِ ٱلسَّمَٰوَٰتِ
وَٱلۡأَرۡضِ فَٱنفُذُواْۚ لَا تَنفُذُونَ إِلَّا بِسُلۡطَٰنٖ ٣٣

O company of jinn and mankind, if you are able to pass beyond the regions of the heavens and the earth, then pass. You will not pass except by authority [from Allah].

A person conversant with the vastness of the solar system can appreciate the spread of our universe. The discovered universe is spread over vast distances of billions of light years. No one is aware of the stretch of the undiscovered universe except Allah Almighty. One is baffled to think about these dimensions. Only Allah Almighty can allow someone to pass over and go beyond the universe. He called our Prophet SAW during the 'Meraj' or raised Hazrat Essa (AS) to the skies. And if the verse is referring to day of the judgment then no comments can be offered as on that day humans shall have ceased their resources and will.

والشمس تجری لمستقرها ذالک تقدیر العزیز العلیم

(And the Sun runs his course for a period determined for him: that is the decree of (Him) the Exalted in Might, the All-Knowing. Ya Seen – 38)

The abode mentioned here can both refer to a place in time and space. Time dimension of the Sun means that it shall cease to exist at a specified time. The spatial reference indicates that it moves on a set course towards a specified destination. We daily observe it rising and setting.

Narrated Abu Dhar (RH):

The Prophet, SAW asked me at sunset, "Do you know where the sun goes (at the time of sunset)?" I replied, "Allah and His Apostle know better." He said, "It goes (i.e. travels) till it prostrates itself underneath the Throne and takes the permission to rise again, and it is permitted and then (a time will come when) it will be about to prostrate itself but its prostration will not be accepted, and it will then ask permission to go on its course but it will not be permitted, but it will be ordered to return whence it has come and so it will rise in the west. And that is the interpretation of the Statement of Allah: "And the sun runs its fixed course for a term (decreed). That is The Decree of (Allah) The Exalted in Might, The All-Knowing." (36.38)

(Bukhari, *Volume 4, Book 54, Number 421.)*

It has been observed for centuries that the Sun moves on a set course daily. It rises at a chosen place and then sets at another point. Apparently there is no chance of its prostration. Then the heaven has surrounded and immersed all the creations in the universe. Another doubt that can arise here is, that points of the Sun rise and Sun set vary from place to place. So what is then implied here and how can the Sun prostrate? A logical answer is that every object has its own way of bowing before Almighty Allah. Prostration of the celestial bodies is in their total submission to the Divine will and His commands. Human prostration represents humility and meekness before their Lord Allah Almighty. Similarly the Sun exhibits its humility in submission and obedience. So all along during its orbit, the Sun perpetually prostrates before Allah Almighty. When the Sun shall be told to return; it will then be the end of the world. There is no room for a doubt in the Hadith referred to above.

The sun located below the heavens is constantly in a position of adoration to Allah Almighty. It is sufficient for the masses to know that the Sun rises and sets daily. Actually it also is moving towards the Constellation Hercules at a speed of eleven miles per second along with all the planets of the Solar System.

وَٱلْقَمَرَ قَدَّرْنَٰهُ مَنَازِلَ حَتَّىٰ عَادَ كَٱلْعُرْجُونِ ٱلْقَدِيمِ ﴿٣٩﴾

(And the moon - We have determined for it phases, until it returns [appearing] like the old date stalk. Ya seen - 39)

Rotation of the Moon is recognized by observing its changing shapes that are seen from the Earth. This verse, points towards those stages of the lunar journey. The Moon takes about twenty seven and half days to revolve around the Earth. Since the Earth has already advanced around its orbit by two days; the Moon has to catch up and it therefore rises after twenty nine and half days.

لَا ٱلشَّمْسُ يَنۢبَغِى لَهَآ أَن تُدْرِكَ ٱلْقَمَرَ وَلَا ٱلَّيْلُ سَابِقُ ٱلنَّهَارِ ۚ وَكُلٌّ فِى
فَلَكٍ يَسْبَحُونَ ﴿٤٠﴾

(It is not allowable for the sun to reach the moon, nor does the night overtake the day, but each, in an orbit, is floating. Ya Seen – 40)

Astronomical interpretation of the verse is simple. Each of the celestial objects like the Sun and the Moon have a defined orbit to move and a collision does not occur. The day and the night are a result of the Earth's rotation; so they are not accumulated but come one after another. Debate of some scholars' bases on Ptolemaic system / Theories is no longer valid because of its redundancy.

Narrated Abu Sa'id (RH):

That Allah's Apostle, SAW said, "Pray Zahur prayer when it becomes (a bit) cooler as the severity of heat is from the raging of the Hell-fire."

Volume 1, Book 10, Number 513, Bukhari.

The solar heat is like the hell fire with a surface temperature of 8000^0 centigrade and the core temperature of 25000000^0 centigrade. This indicates that heat of the Sun is comparable to the Hell (though less in intensity). It has therefore been permitted to offer the Zahur prayer at a cooler time (within permissible limits).

Narrated Abu Huraira (RH):

The Prophet (SAW) said, "In very hot weather delay the Zuhr prayer till it becomes (a bit) cooler because the severity of heat is from the raging of Hell-fire. The Hell-fire of Hell complained to its Lord saying: O Lord! My parts are eating (destroying) one another. So Allah allowed it to take two breaths, one in the winter and the other in the summer. The breath in the summer is at the time when you feel the severest heat and the breath in the winter is at the time when you feel the severest cold."

Volume 1, Book 10, Number 512, Bukhari.

The two breaths of the Hell indicated in this Hadith refer to the simultaneity of temperatures on the Earth. When it is cold in the Northern hemisphere, summers rule in the South and vice versa. Though the literal meanings of the Hadith cannot be explained but our observations definitely confirm the narration. Either way it is a Divine command which can never be contradictory. It is the limitation of human mind that cannot fathom these intricacies. There is therefore a need to build up our capacity through knowledge and research. As some scholars of Hadith had taken the metaphorical mundane meanings of the previous hadith, so here too,the same approach is prudent. The summers are the worst because of their scorching heat. The winters bring in relief overcoming the heat. These two conditions have as such been depicted as breaths of the Hell. This is possibly a plausible interpretation of the prophetic message; which was pronounced when our modern sciences did not exist. One cardinal point to remember is that our religion Islam is above philosophical explanations being straight and simple. Rather than finding scientific reasons, it is better to gauge the essence of a message i.e. will and desires of Almighty Allah. A mission statement should not be mixed up with the executional modalities. Otherwise mischief can be caused. The essence of this hadith is simply that in summers, the Zahur prayers may be delayed (within permissible limits) to avoid the summer heat.