ASTRONOMY ----- AN OVERVIEW

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Introduction

Astronomy is the oldest science. Vedic astronomy has a long span starting from antiquity. Astronomical topics are mentioned in vedic literature. An ancient report on conjunction of Jupiter with the star δ cancri is found in Taittireeya samhita and other texts. There are ancient observations of moon recorded in Rigveda. Such records are available in oral traditional literature of vedic times. There was no systematic text compiled prior to 1400 BC Probably Vedanga Jyotisha compiled by Lagadha in 1200BC is one of the earliest texts. Astronomy texts called Siddhantas essentially deal with Planetary motions, their periods of motion, relative sizes of the Earth, the Sun and the Moon and computation of eclipses of the Sun and the Moon. Thus the planetary astronomy had flourished in India starting from Aryabhata I in the 5^{th} century AD to Bhaskara II in the 12^{th} century AD. Aryabhata composed an astronomical text in 476AD containing tables of astronomical constants, sine tables and computation of longitudes of planets. He explained the daily motion of the Earth, duration of day and night and the length of the year. Aryabhata proposed Surya Siddhanta according to which the Sun is at the centre of the cosmos. According to vedic literature, Surya Siddhanta was first revealed by Sun god himself to Mayurasura. Astronomy has been fascinating to the people all over the world since a long time. The Greek astronomer Ptolemy (about 150 AD) compiled a series of 13 volumes in astronomy known as "Almagest". According to Ptolemy, the Earth is supposed to be at the centre of the Universe and the Sun, Moon and the then known planets Mercury, Venus, Mars, Jupiter and Saturn moved around the Earth in circles. This theory called Geo centric theory predominantly prevailed from 1^{st} to 15^{th} century. Arabs extended the work of Ptolemy. They brought Hindu system of numbers to Europe. In the year 1543 Copernicus a great astronomer who laid the foundation for the modern planetary astronomy suggested that Sun is at the centre of the cosmos and planets including the Earth moved around the Sun. This Helio centric theory, originally proposed by Aryabhata was gradually accepted by mid 17^{th} century. After Copernicus, the great observational astronomer Tycho Brahe (1546 – 1601 AD) made accurate observations of planetary positions and his assistant Johannes Kepler (1571 – 1630 AD) studied these observations and formulated the three famous laws of planetary motion. According to these laws, the planets revolve arond the Sun in elliptical orbits with the Sun at one focus; the line joining the Sun sweeps equal areas in equal intervals of time; and the period of revolution of a planet is directly related to Planet's mean distance from the Sun. Later Sir Issac Newton (1642 – 1727 AD) studied the laws of Kepler and discovered the celebrated law of Universal Gravitation. Much earlier to Newton, the Earth's gravity was supposed to be predicted by Bhaskaracharya of 12^{th} century. Newton's law of gravitation along with his 2nd law of motion (mass X acceleration = Force) forms the basis for Celestial Mechanics. The discovery of the planet Neptune is an example for the application of Newton's law of gravitation to Celestial Mechanics. The planets Mercury, Venus, Mars, Jupiter and

Saturn were known from antiquity. Herschel discovered Uranus in 18th century with a telescope. Motion of Uranus could not be explained by taking into account the attraction of all planets known at that time. From perturbation theory of celestial mechanics the mathematicians Laverrier in France and Adams in England independently calculated the position of a new Planet at certain time. They asked the observer Galle in Germany to direct his telescope to the predicted position. Galle accordingly found the new Planet Neptune at the predicted position. This discovery was made in the 19th century.

Relationship with other branches of Science

Astronmy is not only oldest science but it is also closely related to other branches of Science : physics, mathematics, biology and chemistry. Astrophysics dealing with the application of the laws of physics to understand the nature of the planets, stars and galaxies and the universe as a whole is an inseparable part of astronomy. The principles of optics and electronics of physics are the basis for astronomical telescopes. Photometric and Spectroscopic techniques of physics are the basis for the study of structure of stars and galaxies. Principles of statistical mechanics and quantum mechanics are extensively used in theoretical astronomical studies.

As already stated, celestial mechanics which deals with the problems of planetary motion is based on fundamental laws of physics namely Newton's law of gravitation and the 2nd law of motion. Celestial Mechanics is intimately related to space flights. Astronomer – Mathematicians Gauss, Laplace and others developed numerical methods to solve some complicated equations in celestial mechanics.

Thermo nuclear reactions were discovered from the study of Stellar structures, as the stars generate the energy chiefly by conversion of hydrogen to helium through proton-proton and carbon-nitrogen cycles. Recently a number of molecules and radicals are discovered in the atmospheres of stars, planets, comets and in the interstellar space. The element Helium was first found in the Solar spectrum obtained from the observations of the total Solar eclipse of August 18,1868 from the Tobacco fields of Guntur in Andhra pradesh. More recently, Fluorine which is used in our daily tooth paste is found to be produced during certain stages of evolution in some stars. These findings reveal the link between chemistry and astronomy. Recently traces of extra terrestrial life and some organic molecules have been discovered on Mars and elsewhere in outer space. This interesting result has prompted even biologists to work with the astronomers to understand the origin of life. Engineering skills are used in space flights. Thus astronomy is a common ground for scientists from all branches of basic and applied sciences to collaborate.

Scope Of Astronomy

We study astronomy to understand the universe as a whole, in all respects. The universe is very vast and contains enormous quantity of matter. It can be divided into several parts for the purpose of description.

1) The solar system comprising the Sun the Planets and their satellites, asteroids, comets and interplanetary medium.
2) Further out are stars that occur as single, in pairs and multiples.
3) The stars also form groups and clusters and bigger systems called galaxies like our home galaxy, the Milky Way galaxy.
4) The inter stellar space i.e. the space between the stars containing dust and clouds and gas and nebulae
5) Large scale structures such as clusters of galaxies and super clusters of galaxies.

In order to describe the universe, one requires large numbers in terms of physical parameters such as length, mass and time. The average distance between the Sun and the Earth is 150 million kilometres and light takes about 8 1/3 minutes to travel this distance. The distance between the Sun and Pluto in the solar system is 5.5 light hours where a light hour is the distance travelled by light in one hour with the speed of light at 3 lakh kilometres per second. The size of a typical star like our Sun is 700,000 kilometres and the mass is about 2×10^{33} grams. Huge systems like galaxies contain enormous quantity of mass.

Stars

On a clear night sky we can see about 6000 stars of different colours ranging from blue to red with the naked eye. We can see about 10000 stars with a binocular of focal length 3 to 4 inches. The different colors indicate different physical conditions in the stars. Blue stars are much hotter, more massive and much younger while red ones are much cooler and older and also less massive. Our Sun is an yellow type star. The masses range from 0.1 solar mass to about 60 solar masses and sizes range from 1/10 to 20 times that of the sun. The surface temperatures range from 3000 to 40,000 degrees kelvin. The bright stars appear to form groups and suggest to us figures of some animals or mythological heroes. These groups are called Constellations. Most of the Constellations have their origin among Chaldeans and Greek. There are now 88 constellations spread all over the sky Two thousand years ago Greeks recognised 48 constellations. 12 of the 88 constellations lie on the path of the earth (or the apparent path of the Sun) and the moon. These are called Zodiac signs or Rashis. Each rashi is 16 degrees in width and 30 degrees in length.

In India nakshatras are being used from Vedic times. There are 27 nakshatras which are 27 groups of stars lying on or near the paths of Sun and Moon. In Chinese and Arabic systems the counterparts of nakshatras are called Lunar mansions (or Manzils), the house of the Moon. Their number 27 corresponds to the siderealperiod of the moon which is 27.32 days. Thus the moon occupies one mansion each day. As each nakshatra is of 13degrees 22minutes the sun is in each nakshatra for about 13 days since the sun moves at about 1 degree per day. This is the basis for naming the day in India by nakshatra in which the moon is found at Sunrise. Some individual stars have proper names. Some of the prominent stars among them are Sirius (Vyaadha), Canopus (Agastya), Polestar (Dhruva), Altair (Shravana), Aldeberan (Rohini) etc.

We shall now briefly look into the evolution of a star. A star is a luminous ball of gas held together by gravity. Stars are born from clouds of gas and dust by gravitational contraction. During contraction, gravitational potential energy is released and half of this energy is utilised in heating the star and the rest is radiated away. Thus the temperature of the contracting cloud increases and when it reaches about 10 million degrees gravitational contraction stops and nuclear reactions begin to generate the energy. Thus a star is born and begins to radiate. In this process 4 Hydrogen atoms combine to form a Helium atom by fusion and the energy is released. The nuclear fusion continues and more and more heavy elements are formed and the energy is generated until all the nuclear fuel is exhausted. The star undergoes several changes and ends up as a super dense object namely awhite dwarf, a neutron star or a blackhole. The time required for a star to reach the final stage varies from a few million years for a hot blue star to a few billion years for a cool red star. During the final stages of evolution some stars undergo violent explosions and throw away their material into interstellar space. Such stars are called Novae or Supernovae depending on the intensity of the explosion. When such an explosion occurs, the star becomes so bright that it can be seen even at day time. The first known nova was seen in 1054 AD as per the Chinese records. It was so bright that it was seen for 3 weeks during day time. However such explosions are rare.

As already mentioned the stars end up their lives as a super dense object, the less massive stars become white dwarfs with density of the order of 10^5 to 10^6 gm/cc. The mean density of Earth is 5.5gm/cc. and the mean density of Sun is 1.4gm/cc. It means that a white dwarf is so dense that a spoonfull of its matter would weigh a ton on Earth. Chandrasekhar, a renowned astrophysicist showed in 1935 that if the mass of the white dwarf is >1.4 times the solarmass it would become unstable and go on contracting indefinitely. This is called Chandrasekhar's Limit for the mass of a white dwarf. Stars with mass between 8 and 20 solar masses end up as neutron stars while those greater than about 20 solar masses produce black holes. The density in a typical neutron star is around 10^{12} gm/cc. Their maximum mass is 2 to 3 solar masses and radius is 10 kilometers. Black holes have a still higher density. A black hole of one solar mass would have a radius of about 3 kilometers, which means that the entire mass of the sun is squeezed into a sphere of radius of mere 3 kilometers. If the Earth is to become a black hole it has to shrink with all its mass (6×10^{24} kg) to radius as small as 9 mm from the present radius of 6000 kilometers. Chandrasekhar was awarded Nobel prize in 1983 for his outstanding work on white dwarfs and black holes. Some of these super dense stars pair with a normal star to form a binary system. Such pairs emit radiation of very high energy in X-rays and ultrviolet regions. A binary star with a neutron star produces pulsar phenomena. In this, the neutron star rotates very fast on its axis with periods of the order of seconds to milli seconds.

The shortest period pulsar found so far has a period of 1.56×10^{-3} seconds. These objects also emit X-rays. A pair of normal star and black hole is a very powerful X-ray source. Isloted black holes cannot be observed. Centres of galaxies and binary stars are favourable locations for detection of black holes.

GALAXIES

The universe is full of galaxies of different sizes and types. But the night sky is filled with stars belonging to a single galaxy, our home –milky way galaxy. Galaxies are celestial objects having billions of stars as well as gas and dust held together in space by gravity. Our Sun and all the stars in the sky belong to milky way galaxy which appears as a cloudy band of light across the sky as trail of milk spilled in the sky. In Indian literature it is called as Akashganga. Milky way galaxy is a highly disc shaped galaxy. It contains about 600 billion stars like our Sun. It is so huge that the light takes 100,000 years to travel from one edge to the other.

During the 19^{th} and early 20^{th} century the solar system was believed to be at the centre of our galaxy. This concept was found to be wrong in 1920s and it is now establised that the solar system is at a distance of about 27000 light years from the centre. The Sun along with other members of the solar system moves around galactic centre once in about 250 million years. Since the age of the Sun is about 5 billion years it follows that the Sun might have made atleast 20 revolutions about the galactic centre.

There are about three billion galaxies like our milky way in the observable universe. Observable universe is the part of the universe accessible to our best telescope and this distance is about 10,000 million light years. As already mentioned galaxies appear in different shapes and sizes. In 1926 Edwin Hubble classified galaxies into three broad groups depending on their strucutre namely – elliptical, spiral and irregular. Most galaxies that fall into these categories are called Normal galaxies. These emit mostly star light. Our galaxy is a spiral galaxy.

Apart from the three major types, some special types of galaxies having active galactic nuclei have also been discovered. The central region of these galaxies throws out hot gases at large velocity of the order of 1000 km/sec. Some galaxies show the evidence of violent explosions and emit very large amount of energy in radio, infrared, or X-ray wave lengths. These are called active galaxies.

Some other galaxies exhibit morphological features such as tails, bridges, shells, warpsand rings. These features are caused by gravitational encounters between galaxies. Recently the X-ray satellite Chandra photographed pairs of colliding galaxies in disruption and merging processes. It is now believed that elliptical galaxies are merger products of spiral galaxies. Galaxies also occur in groups and clusters. Ours is a dominant member of small collection of galaxies called local group. Our nearest neighbour Andromeda galxy situated at a distance of 2 million light years is another dominant member of this group. Besides these two giants there about 30 other smaller galaxies in this group. The local group occupies a volume of space of about 4 million cubic light years.

Clusters of galaxies usually have a few hundred to a few thousand members held by gravity. Few clusters join together to form still bigger systems called super cluster of galaxies. One such super cluster of galaxies - Hercules at a distance of 720 million light

years from us has a volume of 600 billion cubic light years. It is believed that the universe consists of few hundreds of such large scale structures. It is now established that all galaxies have a massive black hole in the central regions. A black hole of mass of about 3 million solar masses resides in the centre of our own galaxy. The farthest galaxy known is at a distance of 12 billion light years away from us.

Dark Matter

It is found that most of the mass in the galaxies is not in the form of luminous matter that is in the form of stars, gas and dust. Only small fraction of the matter in the galaxies is luminous. The large proportion of non-luminous matter reveals itself only by the influence of its gravity, hence it is called dark matter. The nature of the dark matter is not yet well understood. It appears that in spiral galaxies the dark matter is as high as 95% of the total mass and the remaining 5% is in the form of stars, gas and dust. It is now believed that about 73% of the energy in the universe comes from unknown source, hence it is called Dark Energy. At the moment we do not have the compete knowledge of dark matter in all its different forms.

Origin of the Universe

Most astronomers are of the opinion that the Universe came into existance from a titanic explosion called BigBang that occured 14 billion years ago. The explosion was so powerful that it is equivalent to trillions of trillions of trillions of hydrogen bombs exploding at once. At this point the temparature, density and pressure were infinity and the matter rushing out of the explosion was expanding. The temparature was gradually reducing as expansion continued and a transition from radiation domination to matter domination took place after about 7,00,000 years when the universe cooled to a temparature of about 3,000 degrees and the matter was in the form of atoms. The universe at this stage became transparent to radiation. Simultaneously the universe has swollen to a size of million billion billion kilometers. This distance defines the boundary of observable universe. The universe remained opaque until the temperature reduced to 3000 K as the radiation was blocked by free electrons. The galaxies and stars are born out of the out rushing matter subsequently. The universe continued to cool gradually and at present its temperature is 2.7 degrees kelvin. The universe emits background radiation in microwave region at this temperature.this radiation called cosmic microwave background radiation, which is the relic of Big Bang was discovered in 1964 by Penzias and Robert Wilson. Some scientists now began to think that the big bang has actually created not just a single universe but a large collection of parallel universes. At present there is no satisfactory answer to the question as to what caused the Big Bang explosion and whether there exists other big bang universes seperate from our Universe. It may be noted that Big Bang model is not the only model proposed, but some other alternate models were also proposed and every model has its own strengths and drawbacks.

Some Recent Highlights

We mention some significant recent discoveries made in astronomy. The most significant discovery in the 20^{th} century is the detection of X-ray sources which was initiated in 1962 by Gioeconi. He was awarded Nobel Prize for his pioneering work in X-ray Astronomy. The first Xray satellite was launched in 1970 followed by many incuding Einstein in 1973 and the latest Chandra in 1999, named after renowned Indian astrophysicist S.Chandrasekhar. About 60000 sources with temperatures ranging from 10 to 100 million degrees have been discovered in our own galaxy and in other galaxies. These objects include X-ray binaries formed by a pair of a normal star and a super dense compact object (white dwarf, neutronstar or a blackhole). Recent Chandra observations suggest that there are thousands of smaller black holes of one Solar mass in our milky way galaxy in addition to a central black hole of mass 2 to 3 million solar masses.

Another landmark in closing years of 20^{th} century is the discovery of extra solar planets in our galaxy. The first such object was discovered in 1995. About 190 have been observed so far. These planets are found to move around normal stars in nearly circular orbits. But one extra solar planet discovered in 2000 was found in a binary system consisting of a normal star and a white dwarf and another planet discovered in 2005 was found in a triple star system. These findings reveal the diversity of environments in which extra solar planets can exist in contrast to our solar system planets.

The Gamma ray observatory launched in 1991 made an exciting discovery of source of largest energy (10^{53} ergs) in the universe. These sources called gamma ray bursts release enoromous quantity of energy in a short interval (1 to 1000 seconds) in gamma ray region. These are located outside our galaxy. The first such source was detected in our galaxy also in December 2004. The energy released in this burst is equivalent to the energy generated in the Sun in 50,000 years. One suggestion is that the source for such enoromous energy is from collision of two black holes.

The discovery of exo planets enhances the chances of detection of life on such planets. The question of life on the solar system planet Mars has been a controversial issue since 19^{th} century. Mars Exploration Rovers “Spirit” and “Opportunity” which landed on Mars in january 2004 found evidence for water on Mars. The current thinking among astronomers is that planet Mars, Jupiter’s icy satellite Europa and Saturnian moon Titan appear to have some features favorouble for life to develop.

The challenging task before the astronomers of the 21^{st} century is the question whether there is life elsewhere in the Universe in the light of recent discovery of complex organic molecules in the interstellar clouds. Let us hope that a satisfactory answer would be found soon.