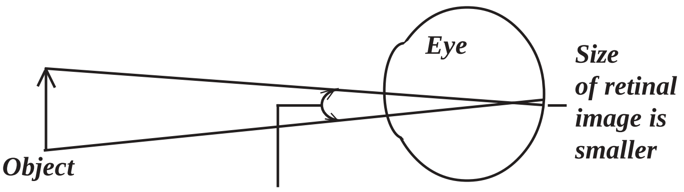
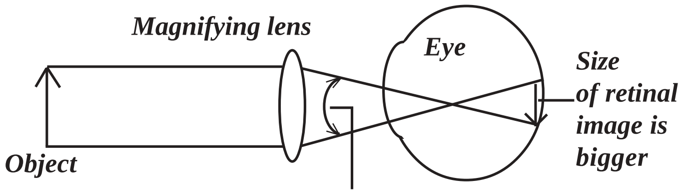
How to see distant objects?

Can we read something, which is written on a small coin kept 150 feet away? We can, but only with the help of a telescope! The amount of light coming from a distant object is so small that it does not take up enough space on our eye's *retina* to form an image of distinguishable shape. The image formed on the retinal screen is so small that the *retinal sensors* of the eyes fail to distinguish the distant object (e.g. the writings on the coin or even the coin itself). If we compare this with an image taken by a digital camera, then we would say that there was not enough *'pixels'* (the smallest discrete component of an image-usually a colored dot) formed to make an image of detectable resolution!



Angle of vision lesser than 1 minute



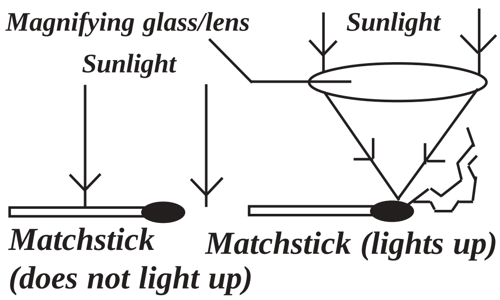
Angle of vision greater than 1 minute

When we look at an object or a part of that object, the *angle of vision* should be wider than one *minute* (a unit of angular distance equal to a 60th of a degree) for the formation of an image of distinguishable shape. If the *angle of vision* is less than one minute, the image of an object appears to be just a *'point'* to our eyes. When we view an object, which is far away (or if the object is too small), the object is observed with an *'angle of vision'* less than one minute.

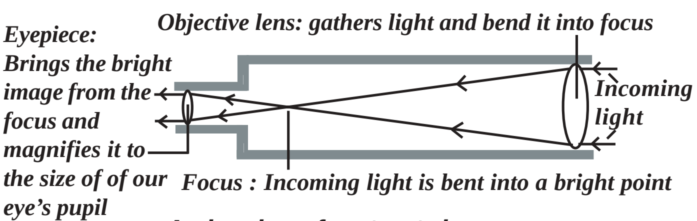
The task of a telescope is to provide a *greater angle of vision*. A telescope accomplishes this either with the help of lenses or with the help of mirrors. With the help of a small 6-inch (15 cm) telescope, we can very well read the writings on a small coin kept 150 feet away!

The telescope makes it possible to look far away objects much closer. The simplest of all the telescopes are the 'refractor' and 'reflector' telescopes. A 'refractor telescope' uses 'glass lenses', whereas a 'reflector telescope' uses mirrors.

In a simple 'refractor telescope', two lenses are used. The bigger *'biconvex lens'* is called the *'objective lens'* and the smaller *'biconvex lens'* is called the *'eyepiece'*. The job of an *objective lens* is to collect lots of light from a distant object and to bring that light, or image, to a point (called *'focus'*). An eyepiece lens takes the bright light from the 'focus' of the objective lens and "spreads that out" (magnify) to take up a large portion of the *retina*. This is also the principle of operation of a simple *magnifying glass* (lens); it takes a small image on the paper and spreads it out over the retina of your eye so that it looks bigger. When we combine the *objective lens* with the *eyepiece*, we get a telescope.



Have you ever tried to light a matchstick with the help of sunlight using a magnifying glass/lens? The sunlight can be made to focus at a point with the help of a magnifying glass. If we keep the matchstick exactly at the focus, it collects enough heat from the sun to light itself! But in a telescope, we not only try to just concentrate enough light at a 'focus', we also try to spread them out so that a brighter image of detectable size forms on our eye's retina. But never look at the sun with an ordinary telescope. The bright sunlight can cause permanent damage to our eyes.



A simple refractor telescope

❑ **Sandeep Baruah**

The Songs of the Distant Earths

"If it is just us….it seems like an awful waste of space."**- Dr. Carl Sagan ('*Contact*')**

"When Earth's sun went nova, the *MAGELLAN* barely escaped in time, with its precious cargo of one million sleepers and gene banks of plants and animals. Five hundred years into the voyage they were going to stop for repairs on the idyllic planet of Thalassa……This was an old dispute, which revived every few decades. One day, most people agreed, Thalassa really should rebuild the big dish on East Island, destroyed when krakan erupted four hundred years ago…."

-Excerpts from the science fiction '***The Songs of Distant Earths***' by **Arthur C. Clarke**

Are we alone in this universe? Or, do we have any fellow advanced civilizations in the universe? If they exist, why have we not been able to communicate with them? Is it possible for us to establish two-way radio communication with them? If so, what would be the probable radio frequencies we need to use? Would such a radio message of extraterrestrial intelligent origin contain information far superior to our present knowledge base, which would be beneficial to the human civilization? Would it enable the mankind to develop a superior system of governance?

For an ordinary ham radio operator, one of the greatest sources of thrills of radio communication lies in its 'uncertainty'. Everyday, ham radio operators talk to unseen and unknown people from different parts of the world. But there are also some ham radio operators who aspire to talk to aliens! They dream about establishing radio contact with scientifically advanced creatures living far beyond the boundary of our solar system, somewhere deep inside the universe. In fact, some of the space explorers, astronomers, radio physicists and ham radio operators have been practically putting serious effort to detect artificial radio waves of extraterrestrial origin.

A Radio Telescope

The 'big dishes' mentioned by Arthur C. Clarke in his science fiction *'The 'Songs of the Distant Earths'*, are the parabolic radio telescope antennas used to probe the universe or these are being employed by the mankind in a bid to communicate with the far away hypothetical extra-terrestrial civilizations. The 'old dispute' mentioned by Clarke is the dispute involving the investment of enormous amount of money for the Search for Extra-terrestrial Intelligence' (SETI was devised by NASA on October 14, 1992 at a cost of $100 million) projects that troubles the astronomy scientists very often.

Astronomy can be considered as a science where the entire universe is a laboratory. It is believed that un-discovering the secrets of the universe can spawn unimagined new benefits to the mankind. Thus the astronomers have always been trying to develop newer techniques and means to enhance their ability to discover those secrets.

Exploration of the universe using optical telescopes is said to have now almost reached its workable limits. An optical astronomer looks for places where she/he is free from 'light pollution' and various other atmospheric hurdles. The Earth's atmosphere blocks out a broad range of the electromagnetic spectrum, allowing only a narrow band of visible light to reach the surface. Due to the varying density and continual motion of atmospheric air, the lights coming through the Earth's atmosphere get blurred and the optical astronomers fail to get clear images of astronomical objects. Thus, putting an optical telescope on the surface of the moon or far deeper in the space outside the Earth's atmosphere may be considered another step ahead in our penetration deeper into the universe for observations with lesser optical aberration. At present, the Hubble Space Telescope (HST) is the largest orbiting public optical telescope in history, which is orbiting outside the Earth's atmosphere.

But mankind has also come to know about forms of energy other than light falling on the earth. Radio frequency energy is one of those. It has been recognized that 'radio frequency' is the most effective medium at present to probe the universe. Utilisation of radio frequency (radio astronomy) can help overcoming many of the limitations of optical exploration.

Radio astronomy is the study of distant objects in the universe by collecting and analyzing the radio waves emitted by those objects. Optical astronomers make images using the light emitted by celestial bodies such as stars and galaxies, whereas radio astronomers can make images using the radio waves emitted by those objects, as well as by gas, dust and very energetic particles in the space between stars. It may be mentioned that about sixty five percent of our current knowledge of the universe has stemmed from radio astronomy alone! Of the ten astronomers who have won the Nobel Prize in Physics, six of them used radio telescopes for the work that won them the Nobel. In fact, the 1993 Nobel laureate in Physics, Dr. H. Taylor, Jr. of New Jersey, USA is an avid ham radio operator (call-sign: K1JT). As a high school student in the mid-1950s, he was conducting experiments in very high frequency ionospheric propagation. In 1958 at the age of 17 years he wrote a paper describing the results of his research that was published in a leading amateur radio periodical. He went on to become a professor of physics in 1974. While conducting radio astronomy research, he discovered ultra-dense stars called 'binary pulsars'.

Dr. Frank Drake was an astronomer with the National Radio Astronomy Observatory in Green Bank, West Virginia. On April 8, 1960, he launched one of the most intriguing space explorations of the millennium pointing his 85 feet radio telescope at two nearby stars - Epsilon Eridani and Tau Ceti. His aim: to 'listen' for signs of communication technology emanating from a civilization beyond Earth.

Dr. Frank Drake

In this series of article, we are trying to throw some light on the use of radio frequency for the exploration of the universe and mainly concentrating on the use of radio frequency in the Search for Extra-Terrestrial Intelligence. According to astronomer Dr. Frank Drake of Cornwell University, *"At this very minute, with almost absolute certainty, radio waves sent forth by other intelligent civilizations are falling on the earth. A telescope can be built that, pointed to the right place and tuned to the right frequency, could discover these waves"*.

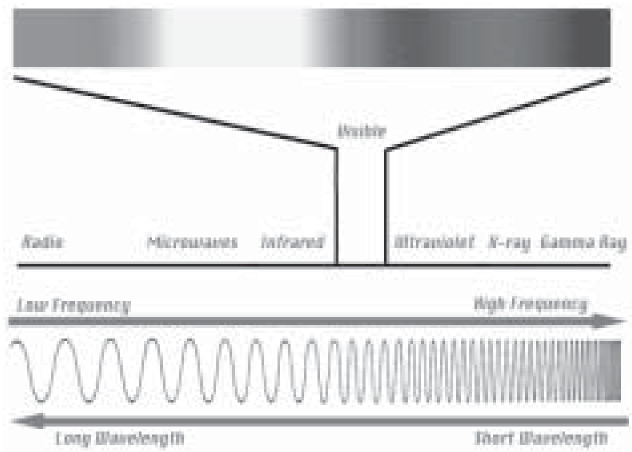
A radio astronomer also has to face various interferences. For example, the radio frequency interference from the man made radio transmitters is one of the greatest hurdles, which can block the universe from her/his view. Radio transmitters in artificial satellites, where the radio astronomers must precisely aim their telescopes to study the universe can also cause interference, because, the radio signals falling on the Earth from astronomical objects are millions of times weaker as compared to radio signals used for communication on Earth. Some of the radio astronomers believe the possibility of the presence of artificially generated radio waves amidst these numerous naturally emanated weak radio waves of cosmic origin.

Light and radio waves are two entities, which are a part of the same spectrum of electromagnetic energy. The electromagnetic spectrum spreads from frequencies of a few hertz (say 30 Hz) to thousands of Giga hertz manifested in different forms. The part of this spectrum, which the human eye can perceive is called the light. In fact, the perception of rainbow through our eyes is possible due to our eye's ability to sense a range of frequencies of the electromagnetic spectrum starting from 4 x 10^{14} hertz (the red colour) to 7 x 10^{14} hertz (the violet colour). Interestingly human eyes cannot sense the frequencies of electromagnetic spectrum just below and above this range! It is said that had our eyes been able to sense the whole spectrum of electromagnetic energy, the rainbow would have been simply become broader with a wider range of colour varieties and we could have very well be able to see the radio waves as well!

The electromagnetic "spectrum" includes all the various forms of electromagnetic energy from extremely low frequency (ELF) energy (e.g. the 50 hertz frequency of domestic electric supply), with very long wavelengths, to X-rays of 0.01^{-10} nanometer wavelength (about the size of an atom) and gamma rays of less than 0.01 nanometer wavelength (about the size of an atomic nucleus), which have very high frequencies and correspondingly shorter wavelengths (1 nanometer, nm = 1/1,000,000,000 m). In between these extremes are radio waves of more than 1mm wavelength, microwaves, infrared radiation (710 nm-1mm), visible light (400-700 nm), and ultraviolet radiation (10-310 nm), in that order.

Arthur C. Clarke

The Radio Frequency (RF) part of the electromagnetic spectrum is generally defined as that part of the spectrum where electromagnetic waves have frequencies in the range of about 3 kilohertz to 300 Giga hertz [One kilohertz (kHz) equals one thousand hertz, one megahertz (MHz) equals one million hertz, and one Giga hertz (GHz) equals one billion hertz] and used for transmission of information in electronic communication. In reality there is no sharp dividing line between the various forms of electromagnetic waves, but one form slowly takes on the identity of the next. Fortunately, the new instrumentation and computer technology has enabled the mankind to see this entire spectrum of electromagnetic energy using devices that are sensitive to the light that our eyes cannot see. The computer image-processing techniques assign arbitrary colour values to different regions



The Electromagnetic Spectrum

of the electromagnetic spectrum, which we can view and analyse!

Electromagnetic energy travels in the form of a wave. Just like the ripples produced in a water pond when we throw a stone. The lowest part of the wave is called a trough. The highest part of the wave is crest. The height of the wave is called amplitude. A wavelength is the distance from two corresponding points on subsequent waves, for example from crest to crest or from trough to trough. The number of waves that pass through a given point in one second is called the 'frequency', measured in units of cycles per second called Hertz. It has been found that the equation that relates wavelength and frequency is: l x n=v, where 'l' is wavelength, 'n' is the frequency and 'v' is the velocity of the wave. For electromagnetic radiation, the speed is equal to the speed of light (3,00,000 km per second).


Carl Sagan

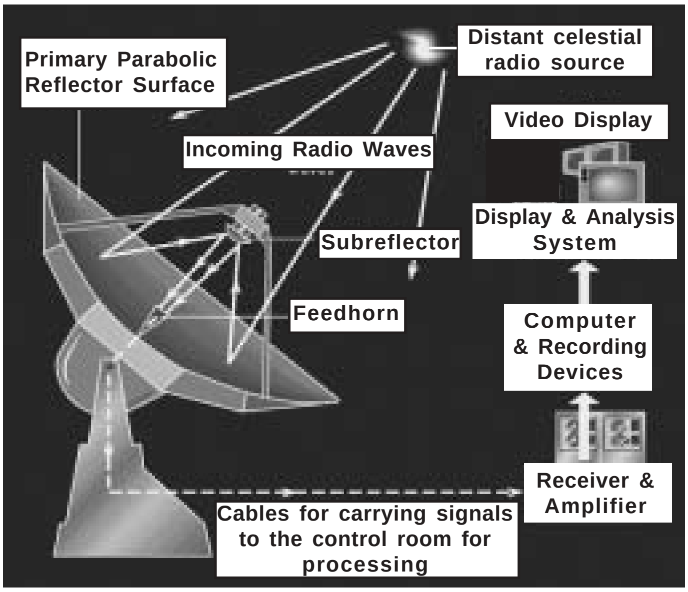
The electronic communication technology employing radio waves (inclusive of microwaves) of the electromagnetic spectrum has advanced tremendously in the recent times. A radio telescope is a device employed by the radio astronomers to transmit or receive radio waves for getting various deductions related to universe. Radio waves remain the fastest medium of exploration of the universe until we are capable of replacing it with a medium, which might even be more advanced than the existing radio communication technology! In fact all forms of electromagnetic energy (which include light & radio waves) travel at the speed of 3,00,000 km per second-the highest speed ever known to us. At present, we can only imagine about a more advanced (faster?) communication system, which can overcome the limitations offered by the vast incomprehensible distances that separate our fellow star systems and of course the time factor involved in traversing of radio waves through such enormous distances.

As Carl Sagan described-"*...Advanced civilizations might very well use some other means of communication with their peers-"zeta rays," say, which we might not discover for centuries. But if they wish to communicate with less advanced civilizations, there are only a few obvious methods, the chief of which is radio.*" But are we in a position to stipulate the existence of some other form of energy, which can be faster than the speed of light? Would such a discovery all together, change the present laws of physics or Albert Einstein's famous theory of relativity? According to this theory, $E=mc^2$ (where E is energy, m is mass and c is the speed of light), where 'c' is a constant, which can never change. This means that nothing can travel faster than light!

Or can we think of traveling to our nearest star and then return back after the exploration? Robert E. Machol (1976) of NASA, Ames Research Center, estimated that if we can build a spaceship, which would accelerate at 1 g for one year, it would reach approximately the speed of light. If it accelerated at 1 g for 4.6 years (according to its own clock) and then decelerated at 1 g for 4.6 years, it would arrive at a point 100 light-years away. Within 100 light-years there are more than 1000 stars sufficiently like our sun (types F, G, and K: more about this later). The spaceship could travel to one of these, explore it, and then return in a total ship time of only 20 years (of course more than 200 years would have passed on Earth before the ship's return!). But can such a spaceship be built? A spaceship, that travels very close to the speed of light? Stephen Hawking, in his book 'A Brief History of Time', put it like this: "*Because of the equivalence of energy and mass, the energy which an object has due to its motion will add to its mass. In other words, it will make it harder to increase its speed. This effect is only really significant for objects moving at speeds close to the speed of light. For example, at 10 percent of the speed of light an object's mass is only 0.5 percent more than normal, while at 90 percent of the speed of light it would be more than twice its normal mass. As the object approaches the speed of light, its mass rises ever more quickly, so it takes more and more energy to speed up further. It can in fact never reach the speed of light, because by then its mass would have become infinite, and by the equivalence of mass and energy, it would have taken an infinite amount of energy to get it there. For this reason, any normal object is forever confined by relativity to move at speeds slower than the speed of light. Only light, or other waves that have no intrinsic mass, can move at the speed of light*."


Stephen Hawking

Would mankind be able to achieve a technology, which can surmount these obstacles of space travel?

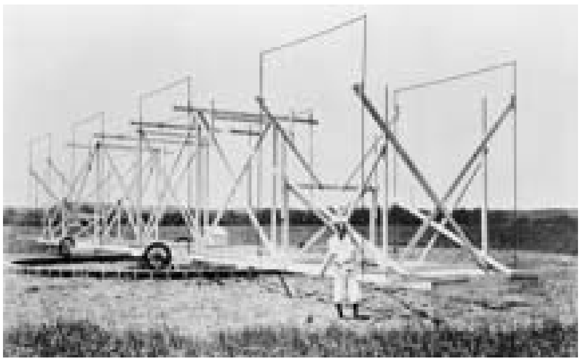


Different stages of a basic radio telescope system

Robert E. Machol has estimated that a 100 percent efficient matter-annihilation engine whose exhaust velocity is equal to the speed of light would consume 34 pounds of fuel (half matter, half antimatter) for each pound of payload. For a 1000-ton spaceship (including crew, living quarters, engines, life-support systems, and whatever else is needed), 34,000 tons of fuel would be required. The total energy expended in the trip would be about 10^{18} kWh-far in excess of all the fossil and nuclear energy expended in human history! According to Mr. Robert, the energy requirements for radio communication are surprisingly modest. It would take of the order of 1kW to power a radio transmitter that could be detected from as far away as 1000 light-years, using transmitting and receiving antennas no larger than the 300 meter dish at Arecibo (more about it later).

There is of course no reason to believe that the other forms of electromagnetic energy cannot be used for communication as well! The X-rays or other forms higher-frequency radiation have however been rejected as possibilities because of their high energy per quantum. Also they have the ionizing effects by virtue of their high energy. It has been estimated that if an ultraviolet radiation at a wavelength of 10^{-7} meters is beamed at the earth from a nearby star for the purpose of making contact with us using a 1 kW laser (Light Amplification by Stimulated Emission of Radiation) with a 10 meter transmitting dish antenna, it could still be detected using a 10 meter receiving dish antenna because the blackbody radiation from the star-with which the ultraviolet signal must compete-is very low at that frequency and such a signal if coming from a distance of 10 light-years-perhaps the maximum range for such a system- can produce 25 photons per second in the 10 meter dish. But unfortunately, even after precise beaming of such a signal at our sun, the beam would still miss the Earth by a wide margin. The use of visible and near-infrared radiation also appear impossible because of the overwhelming background radiation from the nearby stars. On the contrary, the radio frequencies in the microwave region permit signal detection or communication at minimum energy.

Many of the radio frequencies used in radio communication are subject to interference from natural radio sources in outer space, which include radio frequency emissions from speeding electrons caught in galactic magnetic field, the low temperature background noise probably left over from the big bang which created the universe, and possible radio emissions caused by changes in the rotational and vibrational motion of molecules in our own atmosphere. Only the part of the "microwave" spectrum roughly the range between 1000 MHz (1 GHz) to 30,000 MHz (30 GHz)-is only minimally affected by this interference. Even if we listen to our ordinary radio receiver (which covers radio frequencies starting from 500 kHz to say 30 MHz), we can find that the noise level gradually decreases with the increase in frequency. It has been observed that if we go beyond 30 GHz, extending the microwave range to say 60 GHz, the earth's atmosphere itself attenuates this upper range. This necessitates narrowing down of the probable frequency range for the search for radio signals of extra-terrestrial intelligence to 1 to 10 GHz. Considering various other technical difficulties (viz., antenna cost and sensitivity to Doppler frequency shifts), the search window narrows further down to 1 to 2 GHz. Again, there are also the problems of skipping back of weak radio signals of lower side of the microwave spectrum falling on Earth's atmosphere from outer space at lower angles.Karl Jansky (1931), a young engineer working in Bell Telephone Lab was assigned with the job of investigating the problems involved with transoceanic radio interference, lightning discharges, aurora and other unknown reasons due to which radio waves skipped off the ionosphere were facing serious problems in long-range communications. Jansky could detect a strange hissing type of radio noise coming in the 20.5 MHz (during those days this frequency was much above the frequencies used by radio broadcast station). It was theorized by Jansky (1931), that, the strange radio noise originated from a direction towards the center of the Milky Way galaxy. Karl Jansky was using a large steerable antenna with a sensitive radio receiver. The antenna was 100 feet long and could be rotated 360 degrees to act as direction finder. After 1935, Jansky was transferred to another research project not connected with radio noise from space. He did not follow up on radio astronomy as his prime concern was with the radio communication.

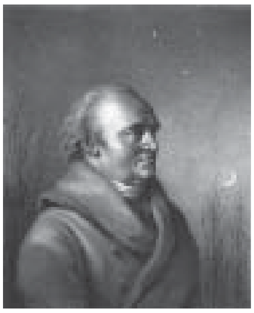

Karl Jansky with his large steerable antenna


Grote Reber

Grote Reber invented radio telescope in 1937. He was an electrical engineer by profession and an avid amateur radio operator (call-sign: W9GFZ) without any formal astronomy training. He was the first to generate a radio map (1944) of the sky using a 10 metre metal dish radio telescope installed in the backyard of his house in Wheaton, Illinois. Grote Reber (W9GFZ) was considered as the world's only radio astronomer from the late 1930s until after World War II.

There are two schools practising radio astronomy for the purpose of exploring the universe, both with the prime objective of knowing the universe but in a different dimension. The first group is the one employing radio telescopes to probe the stars and constellations by listening to the natural radio noises (passive astronomy) or even transmitting radio signal (active astronomy or radar astronomy). They listen to the various natural radio frequencies emanated from distant galaxies or even from within our own solar system (viz., planet Jupiter is a source of natural radio frequency emission). Giant radio telescopes are used by them not only to listen to but also to send radio signals (employing radars) far out in to space. Their experiments are aimed at getting varieties of deductions related to temperature, composition of atmosphere etc. For example, an abundance of hydrogen, in the form of vast gas clouds in inter-stellar space, was, discovered by receiving radio noise with wavelength of about 21 cm (Hydrogen gas has the frequency of about 1.4 Giga Hertz or a wavelength of 21 cm). It is the natural frequency of emission of the neutral hydrogen atoms in space, which was discovered in 1959 by van de Hulst. The Geneva 1963 Extraordinary Administrative Radio Conference thus reserved worldwide the frequency 1420 MHz (i.e. 1.4 GHz) or 21 cm wavelength, for radio astronomy.

In fact all object in the universe emit electromagnetic radiation. The energy of an electromagnetic wave is directly proportional to its frequency, but inversely proportional to its wavelength. Therefore, the amount of radiation at each wavelength determines the temperature of the object. Hot objects emit more light at short wavelengths, and cold objects emit more light at long wavelengths. The radiation temperature of an object is related to the wavelength at which the object gives out most light. An object appears to us of a particular colour, because, it is radiating at its highest intensity in that particular wavelength, which produces the sensation in our eyes of that of a colour. A hot object (say, about 20,000 degrees C) puts out most of its light in the blue region, and a comparatively cooler object (say, about 1,000 degrees C) puts out light in the red region or even a further cooler object (say, about 37 degrees C) puts out light in the infrared region (which we don't see!). By measuring the wavelength of frequency of light coming from objects in the universe, we can learn something about their nature.



Sir William Herschel (1738-1822)

In the 1700s, the British scientist William Herschel discovered that different colors had different temperatures. Sir William Herschel, was also probably the most famous astronomer of the 18th century. In addition to discovering the planet Uranus, many new nebulae, clusters of stars and binary stars. He was the first person to correctly describe the form of our Galaxy, The Milky Way.

It is not possible for the astronomers to collect samples from distant galaxies! So they have to depend on electromagnetic radiation to carry information to them from the distant objects in the universe. Radio astronomy may be conducted using either imaging or non-imaging techniques. Non-imaging radio astronomy includes the observation of radio noises from Jupiter, collection of solar flare data, and meteor in-fall counts. In imaging radio astronomy arbitrary colours are assigned over a large spectrum of electromagnetic radiation for analysis.

In 1991, planetary scientists Duane Muhleman and Bryan Butler from the Jet Propulsion Laboratory (USA), studied Mercury using a radar system consisting of a 70-meter (230-foot) dish antenna at Goldstone, CA, equipped with a half-million-watt transmitter, and the Vary Large Array (VLA) as the receiving system. The beam of 8.5-GHz microwaves sent from Goldstone bounced off Mercury, which was collected at the VLA to produce a radar image of the planet. In this image, red indicates strong reflection of the radar signal and yellow, green, and blue, progressively weaker reflection.

Radar (Radio Detection and Ranging) signals find certain applications where optical astronomy fails. For example, in March 1961, scientists at Deep Space Instrumentation Facility in America, employed a 2,388 MHz radar signal with 12,600 watts of power, which was echoed back from the planet Venus in 6.5 minutes. Venus is hidden by a thick atmospheric cloud, which hampers the visibility of its surface. However, with the use of radar signal, scientists could determine its rotational period along with its surface topography. Similarly, scientists could map out the spiral arms of our own Milky Way galaxy by using radio signals of 21 cm wave length, which otherwise were invisible to the conventional optical telescopes. The discovery of quasers, pulsars, black holes, the 3K background radiation from the 'Big Bang' and the discovery of biochemical hydrogen/carbon molecules are the result of professional radio astronomy. ***(to be continued.....)***

❑ **Sandeep Baruah, VU2MUE**

Contributions of astronomy to the human progress:

1. Calendar and system of timekeeping.
2. Mathematics.
3. Trigonometry (invented by Hipparchus, a Greek astronomer).
4. Adoption of logarithms driven by the needs of astronomical calculation.
5. Calculus (the basis of all modern science and engineering was invented by Sir Issac Newton for astronomical calculations).
6. Navigational techniques (that allowed sailors and aviators to explore our planet).
7. The electronic computers (the need for greater computational power in astronomy)
8. The artificial communication satellites and weather satellites would not have been possible without the fundamental knowledge of gravity and orbit discovered by astronomers.
9. Low-noise radio receivers were developed by radio astronomers that made possible the satellite communication industry.
10. Image-processing techniques developed by astronomers now are a part of the medical imaging systems that allow non-invasive examination of patient's internal organs.

Source : http://www.nrao.edu/whatisra/valueofastro.shtml