THE T.I.F.R. SATELLITE EXPERIMENT

The First Indian Scientific Satellite, fabricated by scientists and engineers of the Indian Space Research Organisation at Bangalore, is planned to be launched in a circular orbit by the U.S.S.R. in April this year. The satellite will carry 3 scientific experiments, of which one is due to scientists from the Tata Institute of Fundamental Research (TIFR). The primary objective of this experiment is to discover the impulsive emission of energetic neutrons expected to be produced from intense flare regions on the sun.

Scientific Objective :

It is now well known that the general level of activity on the solar surface goes through a repeating cycle of low and high with a periodicity of 11-years; this is most dramatically revealed by the changing number of sunspots observed over a long period of time. The general increase in the level of solar activity in the 11-year cycle is also accompanied by an increasing frequency of sporadic outbursts known as solar flares. At such times of violent upheavel, electromagnetic radiation in all the spectral regions, beginning from the radio through infrared, visible, ultra-violet, X-ray and gamma-ray, and relativistic charged particles such as electrons, protons and heavier nuclei, are known to be emitted from the flare region; these have now been well studied over the last two decades or so. The acceleration and emission of charged particles in solar flares has convinced scientists that in collisions of these high energy particles with atomic nuclei of the solar atmosphere energetic neutrons should also be produced. Since neutrons, in free space, are unstable with a half life of about 12 minutes, only the energetic ones will have a reasonable chance of reaching distances upto the neighbourhood of the earth and be detected by instruments sent up by man. Such observations, if successfully made, are expected to give important information on particle acceleration, the solar atmosphere and nuclear processes that take place at times of solar flares. However, in spite of a large number of attempts so far made using instruments carried up to great altitudes in balloons and satellites, they have not led to the discovery of the emission of energetic solar flare neutrons. The TIFR experiment is directed towards the solution of this problem. It may be stressed that detecting even one energetic neutron event associated with a solar flare will have immense importance in our understanding of solar phenomena.

The instrument developed by the TIFR for this experiment detects neutrons of energy roughly between 10 and 500 MeV; in addition, it is also capable of detecting gamma-rays in the MeV region emitted at times of solar activity. Further-more, during recent years observations have been made from satellites of sudden bursts of cosmic gamma-rays which have drawn the interest and excitement of scientists all over the world, though more detailed information on such events are needed before their origin can be understood. Our experiment will be able to detect such events when the satellite is in orbit. The instrument will also be able to detect energetic neutrons produced by cosmic ray bombardment of the earth's atmosphere and splashing outwards such observations are expected to give information on the origin of the inner radiation belt of charged particles trapped around the earth. Finally, the detector will also respond to any other rare phenomenon involving sudden increase of gamma-rays from cosmic space such as supernova explosions and give information on the latitude dependence of the production of atmospheric neutrons and gamma rays.

Experimental Method :

The fact that the impulsive emission of energetic solar neutrons has not been observed so far is primarily due to three major considerations. Firstly, since at times of intense solar activity gamma rays are also produced in great profusion, energetic neutrons can be detected only if the instrument is specific enough to identify the low flux of neutrons among the high background of gamma-rays. Unlike almost all experiments so far carried out, we have successfully incorporated in our experiment certain features which enable us to achieve this. Secondly, energetic neutrons are expected to be produced impulsively from the less frequent major flares, and unless the instrument is already above the upper reaches of the earth's atmosphere at such an opportune time the required kind of observations cannot be made. And thirdly, it is likely that the flux of impulsive energetic neutrons is rather low, in which case instruments of high sensitivity and if possible directionality will be needed to detect them. The instrument developed in the present experiment is specific to energetic neutrons with reasonably high sensitivity, corresponding to a minimum detectable solar neutron flux of about 5-10 neutrons per cm^2-sec, while that expected from theoretical considerations during important solar flares is at least an order of magnitude larger than this. This together with the fact that the satellite has a useful life time of about 6 months is in favour of our achieving the major scientific goals of the present experiment.

The Detector System :

The main detector is an inorganic crystal of cesium iodide (doped with thallium) of diameter 5″ and thickness ½″ in which the neutrons or gamma-rays release their energy under favourable conditions making the crystal to "scintillate" emitting optical light which is detected by a photomultiplier tube. This unit is enclosed completely within a plastic scintillator shell looked at by a number of other photomultiplier tubes permitting thereby the rejection of all charged particles entering the main detector. Thus events observed in the main detector without triggering the surrounding plastic scintillator (which acts as an anti-coincidence arrangement for the rejection of charged particles) are identified as due to neutrons or gamma-rays by the simultaneous measurement of the amplitude and shape of the electrical pulse generated by the main detector. The unambiguous separation of these two kinds of events becomes possible because the pulse shape due to neutron induced events is quite different from that due to gamma-rays. The electronic system associated with the detector selects neutral events which release a minimum pre-determined energy (0.2 MeV) in the main detector crystal; it also analyses the energy released and the shape of the pulse resulting from these events. As a means of monitoring the general functioning of the instrument, charged particles traversing the anticoincidence shell are also continuously sampled. All these data are telemetered to the ground receiving station along with those from the other satellite sub-systems. The entire TIFR experiment weighs about 22 kg and consumes about 1.6 watt power.

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REDETERMINATION OF THE HUBBLE CONSTANT AND THE DECELERATION PARAMETER

Astronomers appeal to observational data furnished by distant galaxies to study the structure and evolution of the universe. In the nineteen twenties, Hubble discovered, from the measurements of the spectral features, that the velocity of recession of distant galaxies is proportional to their distances from us. This proportionality constant which has the unit of inverse time is the Hubble constant, H_0. Since the time when Hubble made the measurements, the value of this constant has been successively revised by more refined observatoins. In 1956, the largest redshifts measured were around $z = 0.2$ and on this basis Humason, Mayall and Sandage (*A. J.*, **61,** 97, 1956) gave a value of $H_0 = 180$ km $\text{sec}^{-1}\text{Mpc}^{-1}$. In the nineteen years that have since elapsed, Sandage and his collaborators have systematically revised the measurement of the Hubble constant. In 1968, Sandage (*Observatory*, **88,** 91, 1968) adopted a value of 75 km sec^{-1} Mpc^{-1} for H_0, while in 1974, based on the observations of nearby galaxies, the local value of the Hubble constant was given as 56.9 ± 3.4 km sec^{-1} Mpc^{-1} (cf. Sandage and Tammann, *Ap. J*, **194,** 559, 1974).

Recently, Sandage and Tammann (preprint) have reestimated the value of H_0 by measuring the redshifts of a sample of remote spiral galaxies in the apparent magnitude range $13.5 \lesssim m \lesssim 15.8$. This was done largely to remove any possible disturbances of the local velocity field by " the inhomogeneous clumping of nearby galaxies in the Ursa Major, Virgo, Coma region ". The principal conclusion of this study is that the *global* value of the Hubble constant is 55 ± 5 km sec^{-1} Mpc^{-1}, not altogether different from the corresponding estimate for H_0 obtained by using the local sample of galaxies.

In standard cosmological models, to a sufficient accuracy, H_0^{-1} represents the time since the expansion began; based on the latest estimate of H_0, this time is $17.7 {}^{+1.8}_{-1.5} \times 10^9$ years, which is an order of magnitude larger than the time scale given by Hubble in 1932. But to find the actual age of the universe, T_0, one requires a knowledge of the deceleration parameter, q_0, which essentially embodies the rate of slowing down of the universal expansion, because of the attraction exerted by the total mass-energy present in the universe. In the past, the value of q_0 has been determined by using the observed redshift-magnitude relationship for galaxies with large redshifts. But Sandage and Tammann now adopt a somewhat different approach to determine q_0. Employing the standard formulae in Friedmann models of the universe, they write the following relationship:

$$T_0 = f(q_0)\, H_0^{-1},$$

where $f(q_0)$ is some known decreasing function of the deceleration parameter. In order to solve this equation for q_0, the value of H_0 is inserted from the current estimate of the Hubble constant and the age of the universe is estimated by appealing to various data concerning the age of globular clusters, time-scales for the formation of galaxies and the apparent cut-off in QSO redshifts at $z \simeq 4$. Thus, for globular clusters, taking a lower limit for their age as $14 \pm 1 \times 10^9$ years, the upper limit of the deceleration parameter is found to be:

$$q_0\,(H_0 = 55) = 0.17\,{}^{-0.10}_{+0.26},$$

$$q_0\,(H_0 = 50) = 0.35\,{}^{-0.18}_{+0.40}.$$

However, if the time-scale for galaxy formation, after the birth of the universe, is taken into account and is adopted to be $\simeq 10^9$ years, then $T_0 \simeq 15 \pm 1 \times 10^9$ years gives the more realistic values:

$$q_0\,(H_0 = 55) = 0.10\,{}^{-0.08}_{+0.16},$$

$$q_0\,(H_0 = 50) = 0.20\,{}^{-0.12}_{+0.26}.$$

If the cut-off in quasar redshifts at $z \simeq 4$ is taken to be real and attributed to the epoch of the first galaxy formation, then

$$q_0\,(H_0 = 50) = 0.03\,{}^{-0.03}_{+0.07}.$$

It is clear from the successive values of q_0 obtained over the years that improved observations have led to a steady decrease in the value of q_0. Might one speculate that at a future date more refined observations would produce even negative values of q_0!

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LUNAR OCCULTATION OF X-RAY SOURCE IN CRAB NEBULA

During mid-1974 and early 1975, many attempts were made to establish the size and possible structure of X-ray source in the Crab nebula, during its lunar occultation. First such experiment was conducted by NRL in 1964 during its previous occultation. Later on, modulation collimator technique was used to establish the size of the X-ray source,