

Professor S K Mitra and Ionosphere Research in India

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An attempt is made to trace the growth of ionosphere research in India from its beginnings with Professor S.K. Mitra, at the University of Calcutta, through proliferated activities in the 1950s and 1960s. The early experiments and the topics of investigations taken up by the group with Professor S.K. Mitra, as well as by other groups in India that have grown during this period are discussed. The environment that existed in the laboratory of Professor S.K. Mitra is also described. This brings in some of his students and coworkers, the foresight of Professor S.K. Mitra, in the planning of the book on Upper Atmosphere and his plea for experimental space research in India, that came to fruition in later years.

The Organizing Committee has given me a difficult task. I entered the area of ionosphere research around 1950, with Professor S.K. Mitra, and about the time 'The Book' was being revised for the second edition. That is something like two decades after ionosphere research started in India. However, I am grateful to the Committee for giving me this opportunity to pay my respects to my late Professor and to many of my elder colleagues. I have had the good fortune of meeting later and knowing many of the early associates of Professor S.K. Mitra and also people who had worked elsewhere in India in the 1930s and 1940s.

I shall discuss the early experiments and the topics of investigations taken up by the group with Professor S.K. Mitra and how the activities have developed. I shall attempt also to trace the growth of various other groups in India. I shall be biased, of course regarding the activities of the Calcutta Group, but

trace the proliferated growth of ionospheric research activities in India in the 1950s and shall take you upto the early 1960s, when Professor S.K. Mitra was around us and we could approach him.

Ionospheric work in India is believed to have started around 1930 at Calcutta University with Professor S.K. Mitra. That is probably when reflections of radio waves or echoes from the ionosphere were first obtained by his group. But before this period, there was some activity when the Wireless Laboratory was set up by Professor S.K. Mitra in 1925. There was some experimental arrangement for observation of atmospheric and the first radio broadcasting station in India (with a call sign 2CZ) was set up in this laboratory. One of the early workers during this period with Professor S.K. Mitra was Shri Somesh Chaudhury, who was the technician and was associated with him for a very long time. I remember that even when I

entered this group in 1950, the radio transmitting license was in his name.

displays were on what has been later termed A-scan.

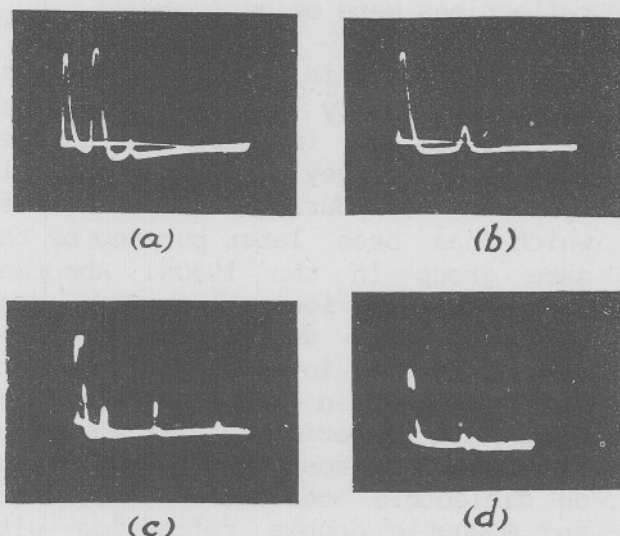


Fig.1 - Echo patterns observed at Calcutta in 1933: (a) first and second hop E-layer echoes, (b) F-layer echo, (c) Es and first and second hop F-layer echoes and (d) F-layer echo with magneto-ionic splitting.

The early ionospheric investigations involved reception of echoes at various frequencies, reflected from the ionosphere, vertically or at short distances away from the transmitter. The heights obtained for the E-layer were rather low, compared to what we know these days. This is perhaps because the oscilloscope time bases were not linear and had to be calibrated. They were generally neon tube or thyatron tube types. The techniques improved naturally with time.

I am not sure, how many of the present generation of young workers in ionospheric physics are exposed to the raw measurements and the excitements that one felt when one observed an echo on the oscilloscope screen or when multiple echoes were observed, with the various echoes waxing and waning with fading. The oscilloscope

The first papers on ionosphere were of S.K.Mitra and H.Rakshit. Then there was J.N.Bhar, who continued with Prof. S.K.Mitra for nearly three decades and took over the reins of the Radio Physics Department from him. Those who have drifted to other places later, include S.S.Banerjee, P.Syam and S.P.Ghosh.

The early ionospheric work involved recording of heights of reflection from the ionosphere. During the International Polar Year of 1932-33, records of heights of reflection at some fixed frequencies were observed regularly. This was the first instance of ionosphere workers in India collaborating in an International way. Their involvements during the International Geophysical Year (IGY) and the International Quiet Sun Year (IQSY) later, were more intense.

Attempts were also made at this stage to get manual P'-f records. One interesting point that comes out, if one goes through the early papers is that the concept of equivalent height (as being different from the actual height) was realised even at that stage. This has later

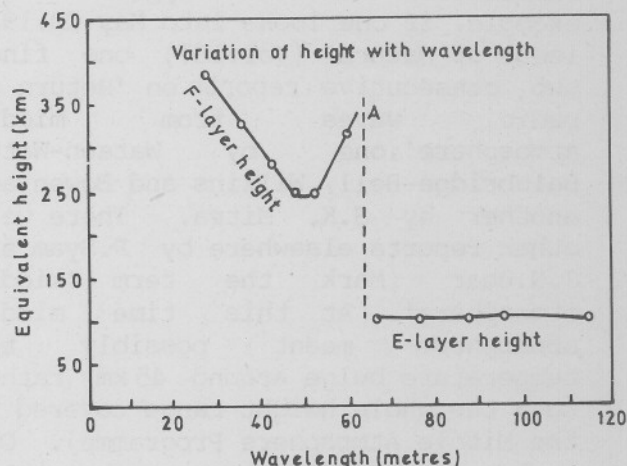


Fig.2 - Manual P'-f record taken at Calcutta in 1933.

been conventionally called virtual height. Changes in electron content (the current term will be peak electron density), measured presumably with the critical frequencies, during an annular solar eclipse in 1933, were reported.

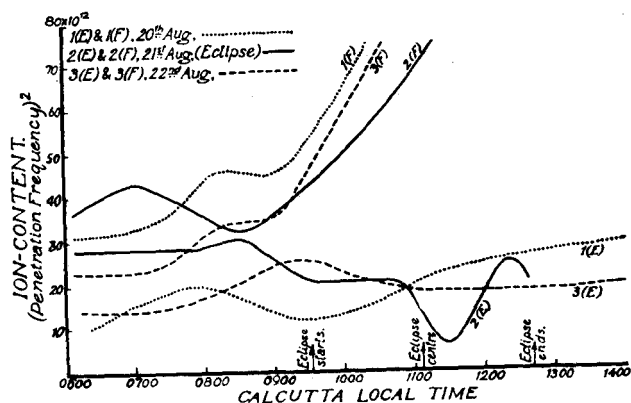


Fig.3 - Observations at Calcutta during solar eclipse of Aug.21,1933 (S.K.Mitra,H.Rakshit,P.Syam and B.N.Ghosh, *Nature*, 132 (1933) 422).

One intriguing aspect has been several reports on reflection from heights much lower than the E-layer and ascribed to D-and C-layers. The nature of these reflection reports is rather difficult to understand from our present knowledge. But this was not the only group which was reporting reflections of this type. For example, if one looks into May 23,1936 issue of *Nature* (Vol.137) one finds two consecutive reports on 'Return of radio waves from middle atmosphere', one by Watson-Watt, Bainbridge-Bell, Wilkins and Bowen and another by S.K. Mitra. There were other reports elsewhere by P.Syam and J.N.Bhar (Mark the term 'middle atmosphere'. At this time middle atmosphere meant possibly the temperature bulge around 45 km rather than the whole height range covered by the Middle Atmosphere Programme). One would be tempted to ascribe these reflections to partial modes, as with MST radar. However, the frequencies were low, so were the powers of the

transmitters. The other possibility is that the antenna used were not directive enough and off-path reflections were being recorded.

About this time, there were also reports by S.K.Mitra,J.N. Bhar and P.Syam on increase in E-layer ionization (they did not call it sporadic E) during thunderstorms, which has been later pursued by the same group in the 1950s. Abnormal increases in ionization were also noted by them during meteor shower days. Another interesting feature to note has been some laboratory simulation experiments carried out by S.K.Mitra,A.C.Ghosh and S.S.Banerjee on dielectric constant of ionized air and magnetic double refraction with varying radio frequency and changing magnetic field.

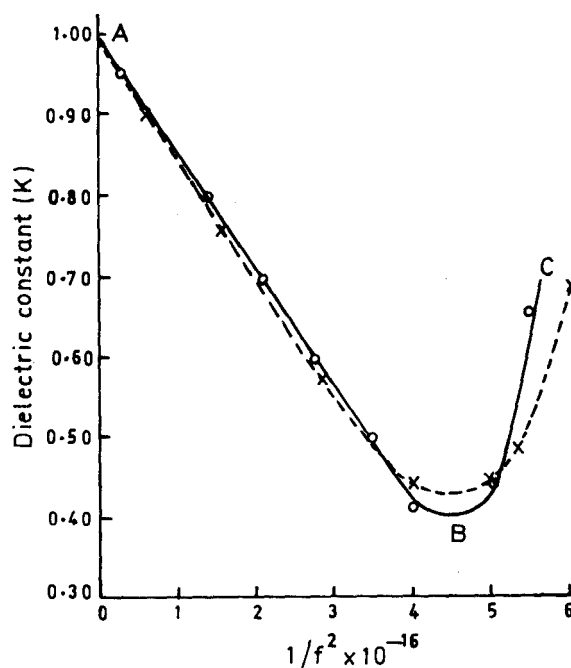


Fig.4 - Variation of dielectric constant of ionized air with inverse of wave frequency (S.K.Mitra and S.S. Banerjee, *Nature*, 136 (1935) 512).

About mid 1930s another group came up at Allahabad with Prof.

M.N.Saha, and the people associated with him were G.R.Toshniwal, R.R.Bajpai, K.B.Mathur and others. One aspect of their activities was measurement of heights of ionospheric reflections and the other being theoretical work on the third and fourth conditions of reflection and the Lorentz term. Some theoretical work on ionospheric layer formation involving temperature gradients was also attempted. The 3rd and 4th conditions of reflection and the Lorentz term have troubled (or fascinated) the Indian workers even later on, into the 1950s. There have been reports of magneto-ionic triple splitting and without a duly recorded ionogram, it was not possible for the early workers to distinguish the 3rd or the 4th echoes observed as what are later on known as satellite traces, being precursors of Spread-F. It is highly unlikely that the z-magneto-ionic trace could be observable in our latitudes. The Lorentz term has also been a problem with many workers abroad and is now discounted on the basis of some rocket measurements in the 1950s and also when the whistler phenomena were being studied by about 1960.

In the late 1930s, two other groups started work on ionospheric height measurement. One was at Banaras where Prof. S.S.Banerjee had moved to, and the other was at Dacca (now in Bangladesh) with Prof. Khastgir, who made use of the All India Radio transmitter set up there. Prof. Banerjee continued at Banaras into the 1960s. Prof. Khastgir later went to Banaras, where his group concentrated mostly on study of atmospheric and thunderstorm electricity. This group later on had the first observations of whistlers at the north Indian latitudes. In the late 1950s Prof. Khastgir shifted to Calcutta and had a fairly active group working on atmospheric and on radio wave absorption.

Two other scientists, who are distinguished in other areas of physics had contributed to ionosphere research in the late 1930s. Prof. R.C.Majumdar had developed some theories giving tensor forms for dispersion, absorption and conductivity and also discussed ionospheric composition and temperature. The other renowned scientist is Prof. S.N.Bose, then at Dacca, who had what is known as the microscopic approach and discussed the equations of Lorentz.

Coming back to Calcutta, and the group with Prof. S.K.Mitra, we find that activities have flourished in, what we now call aeronomy, in addition to the radio exploration experiments. S.K.Mitra and H.Rakshit, and later on J.N.Bhar, had some early attempts at explanation of the production of the various ionospheric layers in terms of the nature of the atmospheric gases and the solar ionizing radiations incident upon them. As we know now, the production and loss processes of electrons in the ionosphere are numerous and complicated and they are much better known these days through additional information from laboratory chemistry and rocket and satellite borne ultraviolet and X-ray measurements. However, one aspect of these attempts still stands out. They had interpreted the E-layer as being formed by ionization of O_2 in the dissociation region of oxygen. Prof. Mitra's interest also extended to the exosphere, known at that time as the fringe region of the atmosphere, and also to auroral and magnetic disturbances.

Another aspect was an early attempt at building a neutral atmosphere model by S.K.Mitra and H.Rakshit. If one compares this model with the current day average neutral atmosphere model, differences appear minor. This model was later modified, in view of data obtained in early rocket explorations abroad, and

included in the second edition of the book 'The Upper Atmosphere'. We were told that when the first Sputnik was launched in 1957, the life time and orbital decelerations were calculated on the basis of this model.

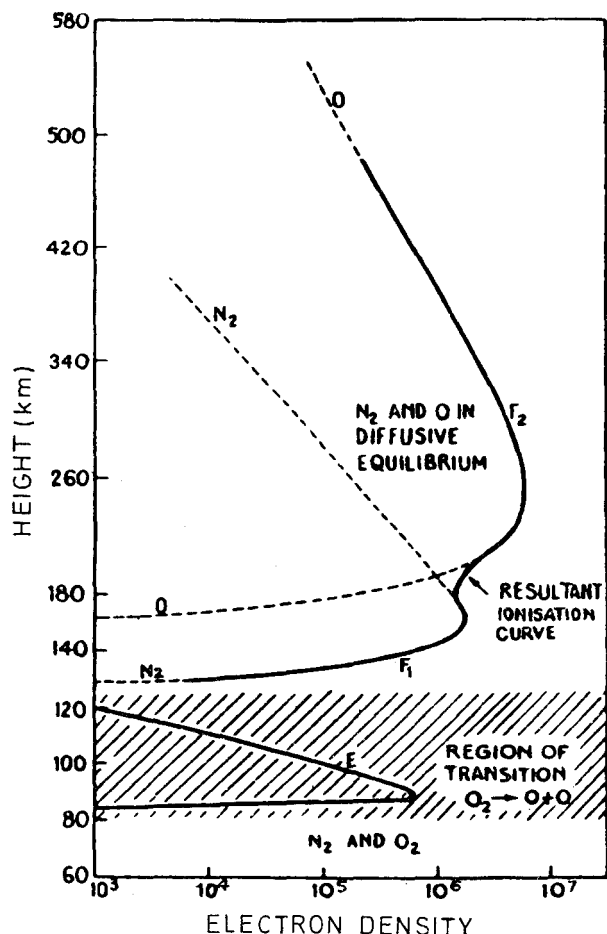


Fig.5 - Origin of E, F1 and F2 layers (J.N.Bhar, Indian J.Phys, 12(1938) 363; S.K.Mitra, Nature, 142 (1938) 914).

In the 1940s the people who came into the group and have distinguished themselves later on, include S.N.Ghosh, S.S.Baral, S.Das Sarma and S.N.Mitra. With the onset of World War II, the radio transmitting license of the group was withdrawn. However, with the war spreading in the far-east with Japan, the data recorded at Calcutta were found to be of importance and the license was restored. Another advantage for observations came in the

form of the blackouts, which permitted recording of night airglow, at that time known generally by the term 'light of the night sky'. Attempts were made to interpret the airglow variations in terms of ionospheric processes. Collision processes in the ionosphere were also investigated involving calculations of cross-sections for elastic collision with electrons in the F-region.

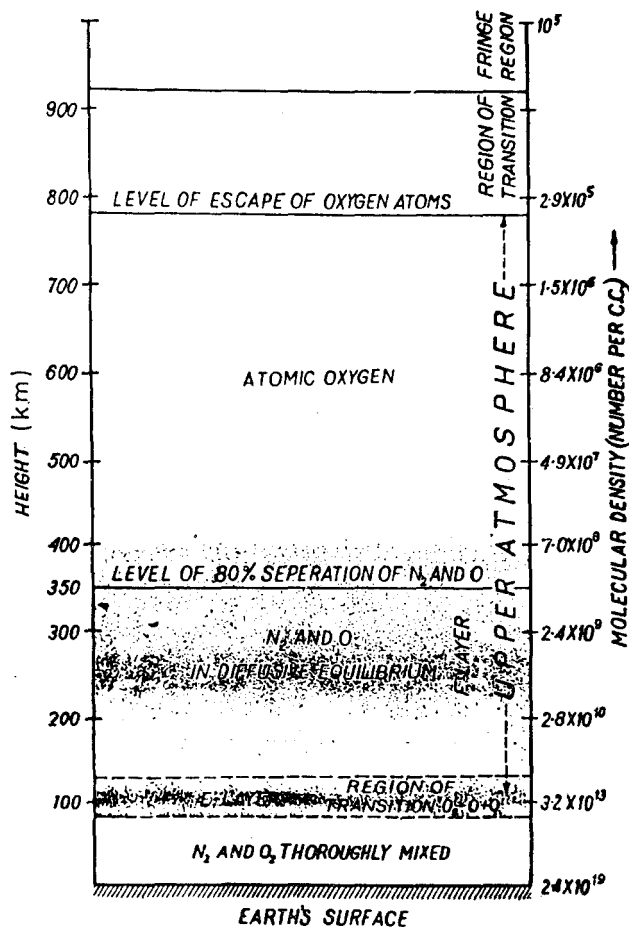


Fig.6 - The neutral atmosphere according to S.K.Mitra and H.Rakshit (Indian J.Phys., 12 (1938) 260).

The most significant work in the 1940s is perhaps the explanation of the geomagnetic anomaly in the F-region by Prof. S.K.Mitra, that came in a letter to Nature in 1946, soon after the recognition of the anomaly by Appleton. The anomalous distribution was interpreted in terms of diffusion of

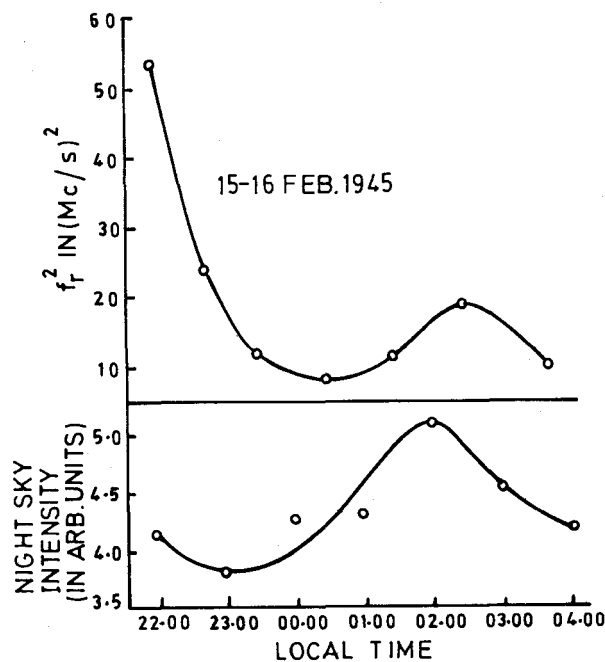


Fig.7 - Variation of night sky intensity (presumably 6300 Å airglow) with f_oF_2 at Calcutta (S.K.Mitra, *Nature*, 155 (1945) 786).

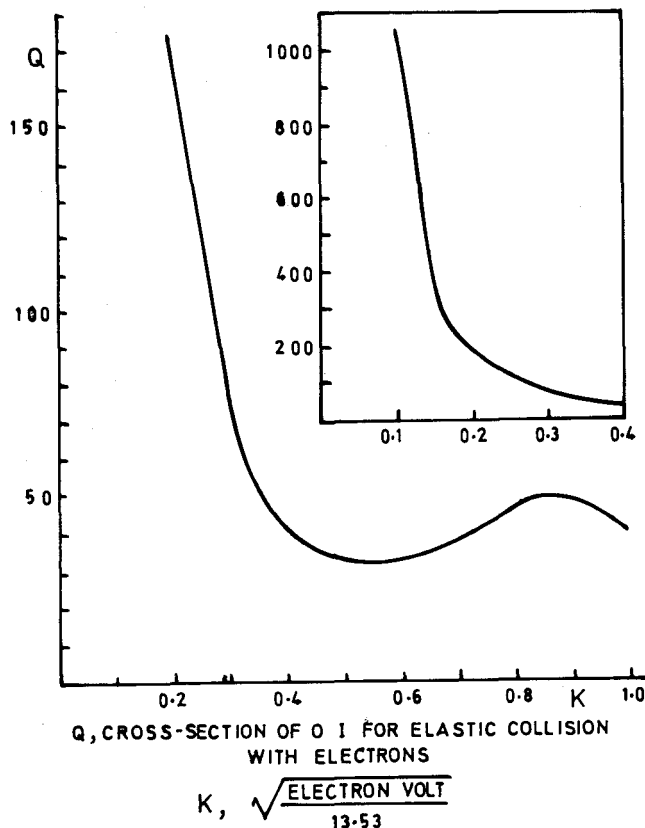


Fig.8 - Cross-section of elastic collisions of OI with electrons as calculated by S.K.Mitra, B.B.Ray and S.P.Ghosh (*Nature*, 145 (1940) 1017).

electrons from the magnetic equator, moving more easily along than across the earth's magnetic lines of force. The concept of electromagnetic drift was brought in later in the 1950s by D.F. Martyn, and subsequent observations and work by various workers following topside ionosonde measurements by the Alouette satellites, have resulted in what is now known as the 'fountain effect'.

Among work coming out from other groups in the 1940s, one particular aspect had been of considerable significance. This had been by M.N.Saha, B.K.Banerjee and U.C.Guha on wave theory of propagation, forming what is perhaps the basic concepts on propagation of low and very low frequency waves in the ionosphere.

The 1950s saw a surge of activities in ionospheric studies at various places in India. Several new groups came up. S.N.Mitra, with his studies on ionospheric drifts at Cambridge, came back and joined All India Radio. They had a set of vertical incidence manual sounding stations and drift and absorption studies centres at various places in India. Prof. K.R. Ramanathan retired from India Meteorological Department, joined the Physical Research Laboratory (PRL) at Ahmedabad and formed a school of ionospheric studies which had activities in various areas. Among the early workers with Prof. Ramanathan were R.G.Rastogi and K.M.Kotadia. An ionospheric magnetic station was set up at Kodaikanal, near the magnetic equator, by the India Meteorological Department with a type C-2 ionosonde, and B.N.Bhargava as the group leader. Some of the best equatorial ionograms are kept at this observatory. I, along with B.N.Bhargava, prepared an 'Atlas of Equatorial Ionograms with Interpretations', based on these records, during my six months' stay there in 1961-62. Prof. B.Ramachandra Rao returned from Pennsylvania State University and established a school at

Andhra University, Waltair. This group had specialized in drifts and absorption measurements and has produced a number of scientific workers who have since spread all over India in various groups. A.P.Mitra on his return from Australia and Penn. State joined the National Physical Laboratory in 1954. With his cosmic noise absorption (or A2) measurements background, the first experimental work at NPL was on this topic. The NPL group also took charge of data collection and dissemination and issue of ionospheric predictions bulletins.

At Calcutta, in the early 1950s, a small group (B.M.Banerjee, R.N.Roy, J.K.D.Verma), with Prof.M.N.Saha, worked for some time on increasing the height resolution of ionospheric echoes with a raster time base and on polarisation measurements of individual magneto-ionic components.

In the Calcutta group with Prof. S.K.Mitra, activities flourished in several areas, possibly as a fall-out of the preparation of the upper atmosphere books. A large number of students with him had helped in the effort, both for the first edition in 1947, as well as for the second revised edition in 1952. When I came into this group in 1950, the first job allotted to me was to prepare a short write-up on the main magnetic field of the earth, which was somehow not directly connected with ionospheric work. The result of this, you will find in Chapter VII of the second edition, printed in a smaller type. The book effort made us work on various topics. For example, although my activities later have been mainly in ionospheric physics and radio sounding, my first publication was on sodium in the upper atmosphere.

Several speakers in this Seminar have talked about the personality of Prof. Mitra and his meticulousness and perfection in speech and writing. I shall not dwell on this.

I remember him as a very affectionate person, looking into the work and personal interests of all of his students. I shall talk, instead, on the environment we had. In addition to the book-related work, we were exposed to various topics that have perhaps helped us later. One such was an article, actually an after-dinner talk by L.V.Berkner that I found in the proceedings of a Symposium at Penn. State on Ionospheric Physics in 1950, which was attended by Prof. Mitra. The topic was evolution of oxygen in the earth's atmosphere. I wondered at that time, how this was relevant to ionospheric physics. But as you know, such topics have become of quite some active interest in the 1970s and later - the growth of the atmosphere, the bio-geo-chemical cycles, and the ecology.

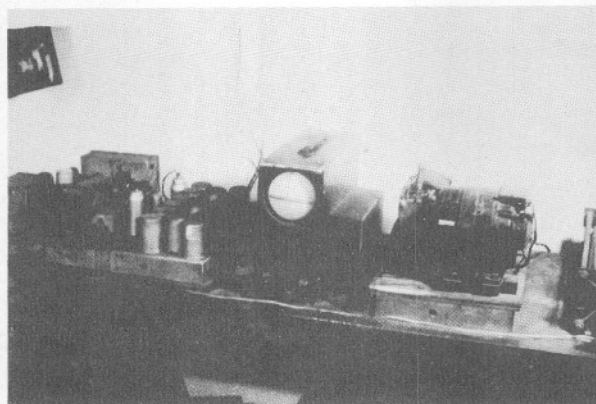


Fig.9 - Receiving system of manual ionosonde at Calcutta in 1950.

In the Ionosphere Laboratory, we had a very well-knit group, the senior member or the group leader being S.S.Baral. Others included A.P.Mitra and R.B. Banerji. R.B.Banerji had brought in some statistical approach, including stochastic processes and time series, in fading analysis. He later spent some time at Penn. State and has shifted to Operations Research and Systems Analysis. Baral and A.P.Mitra had a consolidated analysis report on

the cumulative ionospheric records kept at Calcutta. A.P.Mitra also worked on layer formation theories, F1-F2 bifurcation and D-region.

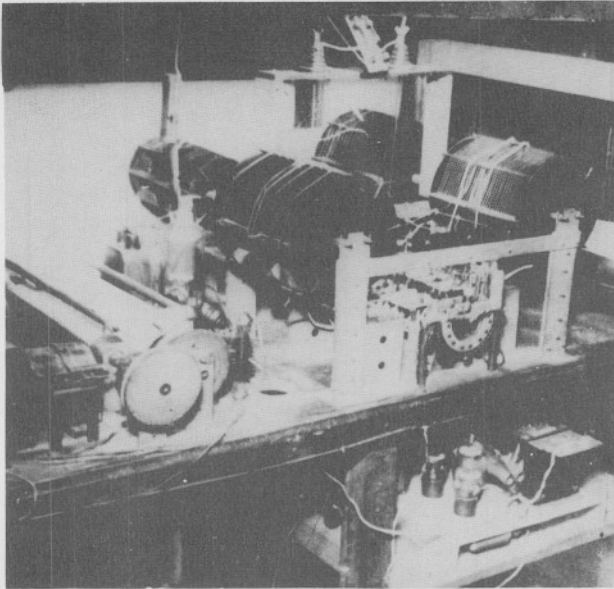


Fig.10- Transmitter coils of manual ionosonde at Calcutta in 1950.

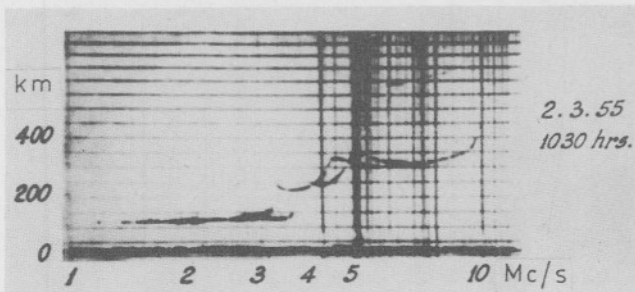


Fig.11- Ionogram recorded at Haringhata with the automatic ionosonde.

Some oblique propagation studies were also made by us, one of them making use of pulse transmissions made by All India Radio at about 22 MHz for the BBC. We got a backward lobe and could distinguish 4 different modes for Delhi-Calcutta transmission, being the ordinary, extraordinary, low angle and high angle rays. Our receiving system was a receiver circuit mounted on a wooden board and an oscilloscope with a thyatron time base. The

transmitter of our manual ionosonde had 4 bands with large coils. The transmitter condenser could be operated (for changing the frequency) from the receiver end through a servo. This was till we moved to the field station at Haringhata, where we set up an Australian type-J ionosonde in 1954. The workers went on changing, with the senior ones moving out and new workers coming in. The fresh batch included B.Chatterjee, M.R.Kundu (the radio astronomer now), (Miss) M.Ghosh, S.Ray (who is now with the Oil and Natural Gas Commission, doing Seismology, a different kind of sounding), S.Datta and P.Bandyopadhyay, one of the conveners of this seminar. The topics covered by them have been in various areas of ionospheric physics. The association of sporadic E with thunderstorms was taken up again. There were some early efforts on reduction of ionograms to true height

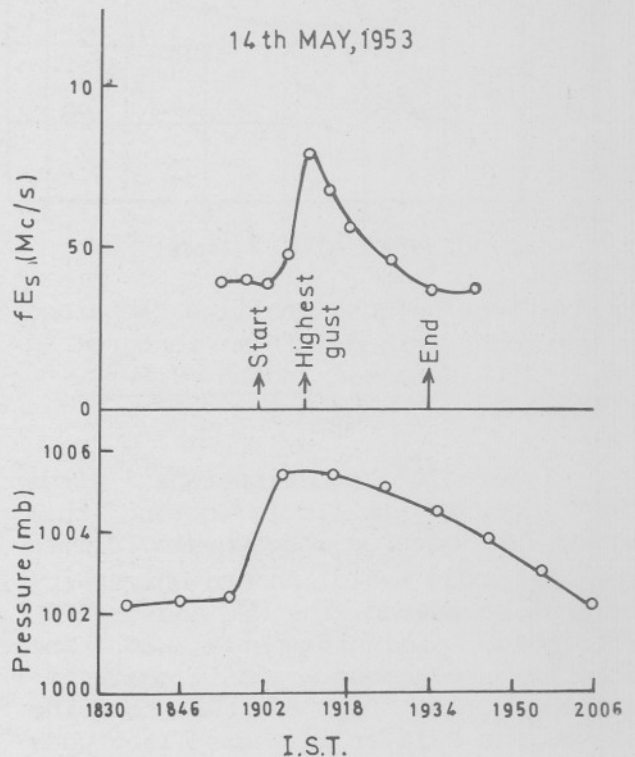


Fig.12- Abnormal increase of Es during a thunderstorm (S.K.Mitra and M.R.Kundu, Nature, 174 (1954) 798).

profiles and studies on certain special phenomena that are noted in ionograms at Haringhata, such as the E2 cusp.

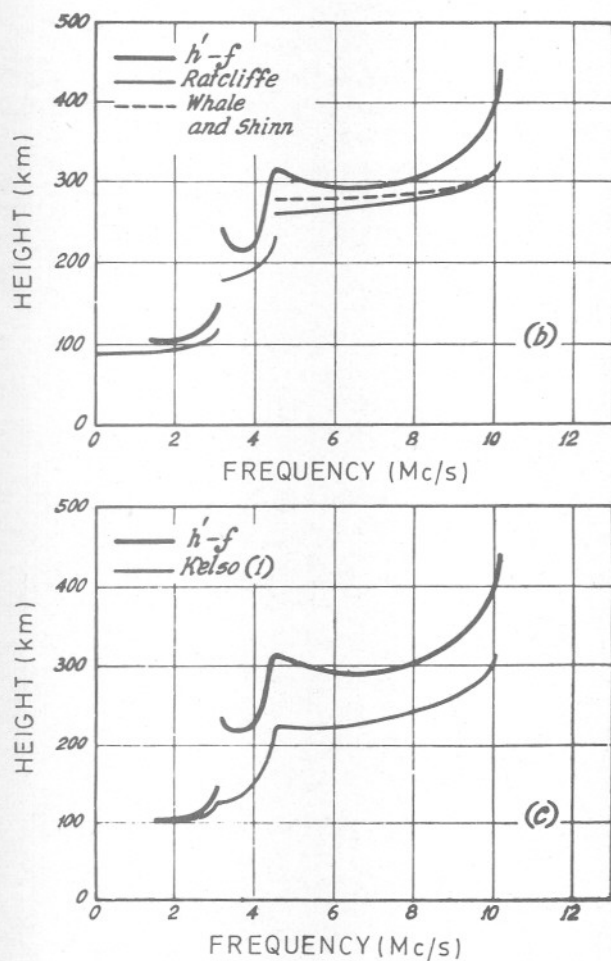


Fig.13- True height profiles obtained by various methods from ionogram in Fig. 11 (A.K.Saha, Indian J.Phys., 30 (1956)464).

Notable contributions from other groups in India during this period had been on ionospheric drifts from All India Radio, Andhra University and PRL, Ahmedabad. The NPL and the PRL contributed significantly to the riometer technique and analyses, carrying them up to the top-side F-layer, the F-layer in these latitudes contributing significantly to the trans-ionospheric ray absorption.

About this time, we entered the space era, spurring incentive perhaps

being the advent of Sputnik and the American satellites. Among the early efforts were construction of ionospheric and neutral density models at NPL, based on radio sounding data, riometer observations, satellite deceleration rates and satellite beacon Faraday rotation measurement results. Routine observation in India of satellite

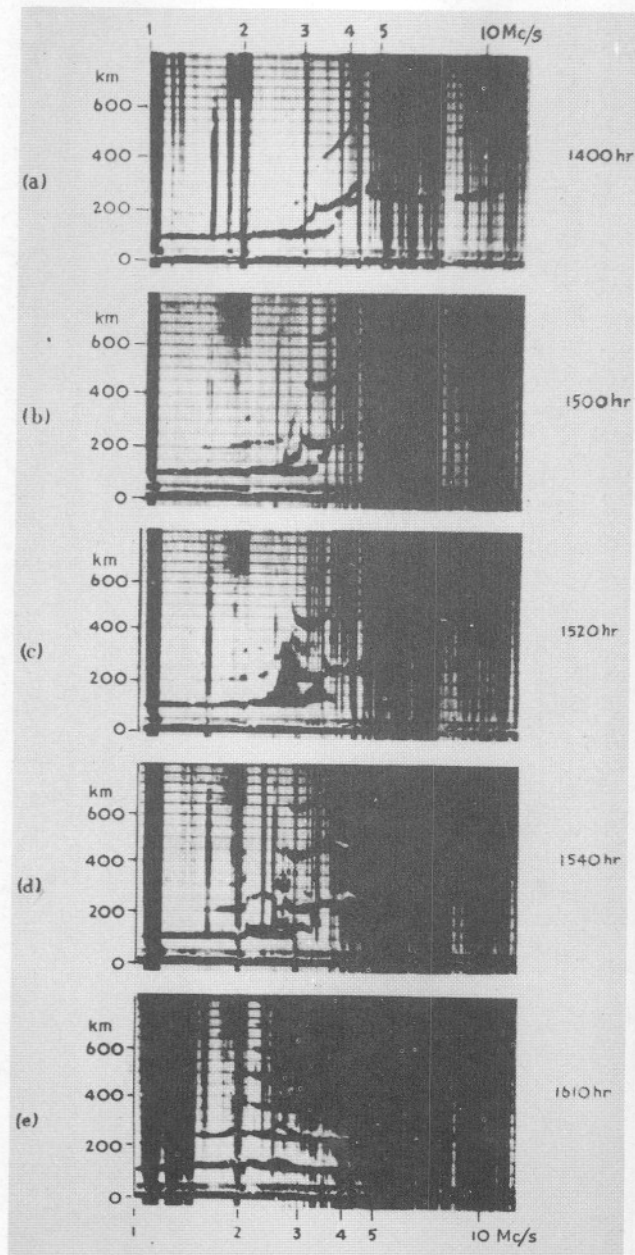


Fig.14- Downward movement of E2 cusp observed at Haringhata (26.1.55) (A.K.Saha and S.Ray, J.Atmos. Terr.Phys., 7 (1955)107).

radio beacons was started by NPL in 1962 with the USSR Cosmos 5 satellite.

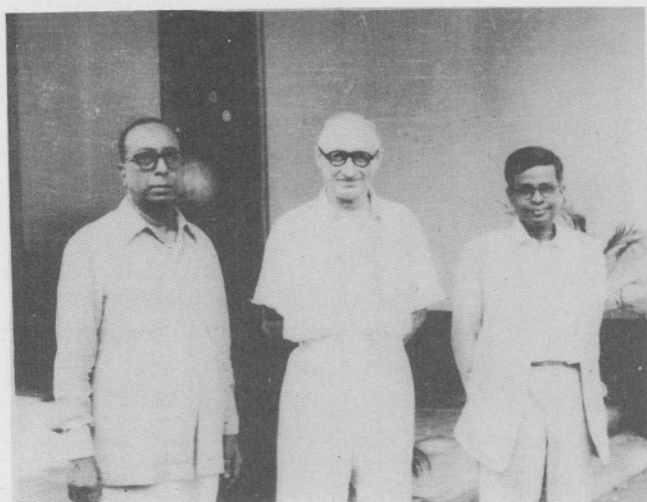


Fig.15 - Professor S.K.Mitra with Sir Harry Massey and Prof. J.N.Bhar (1958).

Prof. S.K.Mitra, in the second edition of his book had added a special chapter on rocket sounding results. He had been an advocate for initiation of Space Research in the country, just as he had been the initiator of Radio and Ionosphere research earlier. In his Presidential address to the National Institute of Science (now the Indian National Science Academy) in 1960, he made a plea for going into experimental space research. Pandit Nehru, our then Prime Minister, who was present, wondered whether we could afford this. However, the realization about the necessity came and the Thumba Rocket Launching Station was set up in 1963, with Prof. Vikram Sarabhai as the first Chairman of the Indian Space Research Committee.

The book on Upper Atmosphere has been discussed by Prof. Gillmor in this seminar. I may only add, what Prof. S.K.Mitra has himself mentioned in the preface to his book, that the

idea of the book originated about 1935. The diverse topics he and his students had covered since his 'Report on the present state of our knowledge of the ionosphere', given to the National Institute of Science in 1935, bear evidence of this. Prof. Mitra had a desire of revising and bringing out a third edition of his book. It is unfortunate that he could not complete this, when he passed away in 1963. Some of his students made an effort at doing this unfinished job after his death. Somehow this has not materialised, perhaps because many of them were spread out.

The book naturally would have had to be modified in view of information that had been gathered in the mean time through measurements with space vehicles. He was aware of this, and one may note that in his lectures and publications, he was discussing more about this aspect. His last published article was entitled 'Physics of Earth's Outer Space' (Science and Culture, July, 1963).

I have based my presentation on my personal memories and on the following listed material.

1. Bibliography of the Ionosphere, L.A. Manning, Stanford Univ. Press (1962).
2. A number of articles by various authors in Science and Culture Vol.29, No.11, Nov. 1963.
3. Biographical Memoirs of Fellows of The Royal Society, J.A. Ratcliffe, Vol.10, p.221, Nov. 1964.
4. Collected papers of S.K.Mitra research work (being under preparation before this seminar, under the supervision of A.P.Mitra).