the Corfu Advanced Study Institute on

RADIO-ASTRONOMICAL *and* SATELLITE STUDIES *of the* ATMOSPHERE

By Jules Aarons

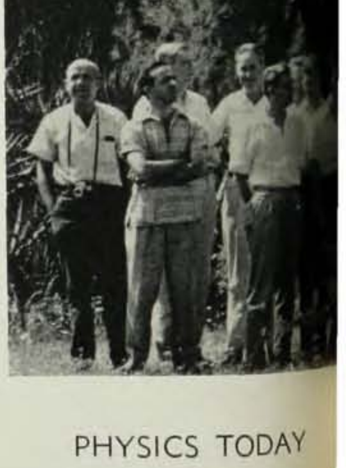
SHORTLY after the study of astronomy by radio techniques began in earnest, a basic problem arose. Three "sources" of radio flux had been delineated: the sun, the cosmic-noise background, and the discrete sources (radio stars). Were the discrete sources variable, as the sun showed evidence of being, or was the atmosphere modulating fixed-flux sources? The first answer was that the radio-star sources exhibited intrinsic fluctuations in intensity, but studies in Australia and England utilizing spaced receivers indicated that the earth's ionosphere and troposphere produced effects similar to the "twinkling" of visible stars. The study of "twinkling" or scintillation was the first of the upper-atmospheric effects to be investigated in detail.

No fluctuating discrete sources (other than the sun and the planets) have been found by radio astronomers. The very absence of variable sources allowed the field of radio-astronomical studies of the atmosphere to flourish.

In addition to radio-frequency energy from the discrete sources such as Cygnus A and Cassiopeia, the cosmic-noise background radiation, the broad pattern of the sky, also provides a high-level signal in the radio spectrum to 100 Mc. Using cosmic noise as the transmitter, we can study the fluctuations of the overhead terrestrial atmosphere. To examine the discrete sources, the radio observatory needs highly directive antennas and sensitive stable receivers. In the case of the broadband cosmic noise, the simple device of attaching an antenna to a good receiver produces a signal level greater than that created by receiver noise. The only requirement for studying the absorbing medium between earth and sky is stability of the equipment. Several modern radio techniques achieve this, and a means for studying absorption in the D, E, and F layers of the ionosphere is open.

In time sequence, the next development after the scintillation experiments was the study of lunar reflections. Again, as in the earlier discrete-source measurements, the variations in the returned signals were an enigma. Two separate reasons were found for the fading of the lunar echo. Kerr and Shain of the CSIRO, Australia, showed that the cause of one type of fluctuation was the apparent rocking or libration of the moon as observed from the transmitting and receiving station. A major contribution to the studies of the ionosphere was the isolation (by scientists at Jodrell Bank in England) of the rotation of the plane of polarization of the signal as the second cause of lunar-echo fading. As the signal traverses the ionosphere the plane of polarization is rotated because of the electron-density structure within the earth's magnetic field. The rotation resulting from the Faraday effect allows a means of studying the integrated electron density beyond the limit of 400 kilometers which had previously been imposed by conventional ionosounding techniques.

With the advent of transmissions from satellites, distinct capabilities were added to ionospheric studies. Satellite signals were coherent narrow-band signals; from radio stars wide-band noise is observed. Narrow-band signals, when shifted in frequency by the motion of the satellite relative to the ground observer, as well as by electron-density variations, can be measured by



Weekend excursions, organized by Prof. and Mrs. Anastassiades, offered the members of the Institute an opportunity to visit some of the more exotic points of interest on the Grecian island of Corfu. Jules Aarons, the author of this report, is chief of the Radio Astronomy Branch of the Air Force Cambridge Research Laboratories in Bedford, Mass.

M. Anastassiades of the University of Athens served as director of the Corfu Advanced Study Institute, which was held under the sponsorship of the Scientific Affairs Division of NATO.

simple techniques. Once the motion of the source, the true Doppler effect, is calculated, the remainder of the frequency shift can be attributed to the intervening ionosphere. Doppler techniques are thus readily available for studying total electron density and gradients of the electron concentration.

It was basically these capabilities and results that led to the Advanced Study Institute concentration on the subject of radio-astronomical and satellite studies of the atmosphere. The stress was to be on the contribution to space physics of these transatmospheric transmissions, rather than on the techniques used to probe the ionosphere from ground-based transmissions. The Institute, which had concentrated on ionospheric subjects in its two previous sessions, was directed by M. Anastassiades of the University of Athens. The sponsor was the Scientific Affairs Division of the North Atlantic Treaty Organization.

The scene for the Institute was the Castello Mibelli on the island of Corfu, Greece. I served as program director, orienting the program toward a combination of review of available material in each of the specialties followed by original contributions. The time given for each review paper varied from one to two hours, depending on the amount of ground to be covered; the contributions were one-half hour. The Institute took two weeks with a relatively leisurely pace dictated as a reaction to two pressures. The first was associated with the type of conference run during recent years which requires 7.5-minute papers followed by 2.5-minute discussions, simultaneous sessions, luncheon talks, and evening invited lectures—rumor even has it that formal technical breakfast discussions are being contemplated. Many of the members of the group attending the Advanced Study Institute had been present at the recent spring meeting of the United States URSI group, which was run almost simultaneously with the International Committee for Space Research, which in turn, was run almost at the same time as the annual meeting of the American Geophysical Union. In addition to the larger technical sessions (each including simultaneous scientific sessions), there were working group meetings. All of this was coupled with the meeting of Glenn and Titov. The need at Corfu for review papers followed by longer contributions with time to discuss them was expressed by all of the invited participants.

The second pressure was to give ample time for discussing technical ideas outside of the confines of the formal discussion periods. Within atmospheric studies, there has been an increased number of papers combining many disciplines. Balloon and ground experiments, cosmic-ray and solar measurements, comparison of results at various latitudes and longitudes, review papers

Log periodic antenna (for studying refraction and scintillation of radio stars) and 84-foot and 28-foot parabolas of Air Force Cambridge Research Laboratories, Sagamore Hill Radio Observatory, Mass.

Photo by Berenice Abbott

incorporating solar radio astronomy, cosmic-noise absorption, micropulsations, and a myriad of other types of observations are part of the literature. The need for informal technical conversations among the members of an international group of scientists representing various disciplines was thus felt to be important.

The program started at 8 a.m. and ended at 1 p.m. A few sessions from 6 to 8 p.m. were held with several 6 to 8 p.m. meetings of smaller groups both within the NATO sphere and having common interests. Professor Anastassiades opened the conference with remarks on the general aims of the institute, i.e., to look at problems of transatmospheric studies in depth. In particular, the electron density structure by various amplitude and frequency techniques would be stressed, both the normal structure and the irregularities would be considered, and we would then look at the needs which would have to be satisfied by future instrumentation of both satellites and ground stations.

In opening the technical sessions, H. Kallman-Bijl summarized the contributions made with rockets, satellites, and deep-space probes in understanding the structure of the atmosphere. The density, pressure, and temperature variations show seasonal and latitude effects only below 100 km. From 200 to 800 km, a 24-hour variation of density has been observed with increased variation with altitude. The density around 650 km at night (during solar minimum) may decrease by a factor of 200 when compared to daytime density (during solar maximum). The composition of the major constituents changes at 100 km and above. For the identification of atoms and molecules, observations are needed of diurnal variations, seasonal and latitude changes, and ion ratios.

C. G. Little outlined in his review paper on radio-star scintillations the types of studies made, i.e., amplitude and phase scintillations of the discrete-source signals. The phase scintillations led to refraction variations both in the vertical plane for rising and setting of sources and in the horizontal plane by means of interferometers. The so-called point sources have angular diameters of finite amounts $2.5 \times .7$ minutes for Cygnus A, and 4 minutes for Cassiopeia. In turn, these might be readily distinguished from a true point source, such as a satellite, in amplitude of scintillations. Little pointed out the broad-band, nonpolarized nature of the point sources. He gave some results of his work in Alaska, particularly the absence of an elevation-angle dependence of scintillations.

In reviewing the theoretical aspects of radio-star scintillations, Harrower first outlined the scintillation observations the theory would have to satisfy—that is, the height of the region (300–400 km), the size of the irregularities (1–4 km), and the wind measurements. He gave in detail the technique for studying the ionospheric irregularity sizes and the winds by measuring the elliptical shadow pattern of the irregularities as one observed radio-star scintillation from several spaced receivers.

In observing the rise and set of Cygnus A with a large parabola and a multifrequency feed, Aarons reported, the group at Sagamore Hill Radio Observatory was able to separate ionospheric and tropospheric scintillations. The latter were characterized by one-minute periods and the former by shorter fluctuations. Observations of single and multiple scattering were made at low angles of elevation with single scattering shown by correlation at many ionospheric frequencies and multiple scattering characteristic of periods of high magnetic activity. Separation of scintillation types into normal, low-angle, and cloud scintillation was made. A basic difficulty is that of separating the subionospheric geomagnetic latitude of the radio star from the elevation of the source. Radio stars observed from a middle latitude site (40–50° geomagnetic north) have high elevation angles at middle geomagnetic latitudes and low elevation angles over auroral disturbed regions.

Noci showed the 3-cm sunrise observations at Arcetri, with tropospheric scintillations noted in the first few degrees of elevation.

Tuominen, in his studies in Finland, measured fading rates showing a small wind-velocity component in addition to the earth's rotation. A second effect observed was the cancellation of the interferometric fringe pattern. In the discussions, many possibilities were pointed out which could produce this loss during the period around midnight local time in the winter. One hypothesis was that, during this local time period, small-scale irregularities are present. A discussion of single scattering versus multiple scattering ensued. Single scattering by ionospheric irregularities, as Hewish had shown, occurs when the mean-square phase deviation produced by the irregularities is less than one radian.

If the layer producing the scintillation is thin and single scattering occurs, the shadow pattern on the ground is a projection of the irregularity structure in the ionosphere. However, if the phase deviations are greater than one radian the correlation distance on the ground is small, the bandwidth decreases, and correlation at various frequencies is lost. Only recently have examples been observed of this type of scattering from radio stars.

In equatorial regions, Wright showed records of the loss of fringe patterns for an interferometer. In a paper co-authored by Koster, Wright gave for the scintillation region, rather than the irregularity size, the equatorial axial ratio of 7 with the east-west measurements as 442 km and the thickness less than 120 km. At sunspot maximum on quiet days, scintillation is a normal nighttime occurrence. The absence of scintillation is an almost certain indication of severe magnetic disturbance. At middle latitudes, scintillation amplitudes and rates increase with magnetic index.

Radar Astronomical Techniques

Taylor reviewed studies of the earth's ionosphere by lunar radar techniques, stressing recent observations of total electron density by moon bounce. The 1954 work at Jodrell Bank, attributing the slow fading to Faraday rotation, led to the immediate identification of one component of the Sputnik fading as having the same cause. The total number of electrons in the bottom of the ionosphere (from 60 km to the height of the maximum number of electrons in the *F2* layer—approximately 300–400 km) as compared to the top of the ionosphere (from the 300–400 km height to several thousand kilometers) varies from 1:3 to 1:5. The Faraday rotation of phase is inversely proportional to f^2 and directly proportional to the product of the secant of the angle of elevation, to the angle between the earth's magnetic field and the line from the observer to the moon, and, most importantly, to the total number of electrons in the column illuminated by the transmissions. New results reveal a drastic decrease in total electron content at the Jodrell Bank geomagnetic latitude during the severe magnetic storm of November 12–13, 1960.

Using large antennas and high-power transmitters designed for radar reflections from rockets, Millman reported on reflections from Echo I done at the low-latitude station of Port of Spain, Trinidad. He obtained results by estimating angular polarization rotation. In this case the estimates are bolstered by ionospheric sweep-frequency sounder data for the lower ionosphere. At 400 Mc it was found simple to eliminate ambiguities in the equation, since experimental data moved some hypothetical Faraday rotational angles too far out of the realm of possibility.

Both in the review and in subsequent discussions, the problem of ambiguities in Faraday rotation came up. The solution used by Evans for determining the exact number of rotations (since every 180° phase shift gives a null) was to use two closely related frequencies (differing by the order of 1%). An ionospheric satellite, S 66, is being planned with transmission at two frequencies, 40 and 41 Mc, again in order to be able to count the total number of rotations.

Satellite Studies

Mass spoke on effects of the atmosphere on satellite signals, providing an extensive review of Doppler methods for determining electron density (including the work that he and Vassy had done), the Faraday rotation of polarization, and scintillation observations. In addition, he introduced concepts on measuring electron density at satellite altitudes. For Faraday rotation, the methods of calculation (1) assume no horizontal gradient factors; (2) utilize the point where θ, the angle between the propagation path and the earth's magnetic field, is 90°, and therefore the rotation is zero; (3) assume a model ionosphere, the lower part of which is deduced from ionospheric soundings; (4) employ geometrical techniques. Mass also pointed out that, for horizontal gradients, once the total electron content under one point of the trajectory is known from other measurements, then gradients can be determined along the whole trajectory.

Since the Doppler shift is slightly altered from its free-space value because of dispersion in the medium, the frequency beat between two coherent frequencies is proportional to total electron content, as de Mendonca pointed out, if motion is along the stratification. If motion is perpendicular to the layer, beat-frequency data yield information on local electron density. De Mendonca illustrated his technique of eliminating ambiguities by integrating the differential Doppler frequency rather than using the difference in slopes. He uses the time of closest approach to obtain his constant of integration.

Burgess, who had proposed in the past the technique of combining Faraday fading and Doppler data, compared electron density obtained from Faraday measurements alone and the combination of Faraday fading and differential Doppler frequency. Each technique showed internal consistencies but differences between the methods. He emphasized the need to find a method of using Faraday fading alone since this is the simplest type of measurement.

Golton, extending Burgess' method, has computer-programmed his data and the necessary equations. His results show a decrease in mean summer midday electron content as the sunspot number descends towards minimum.

One new parameter in ionospheric physics for measuring changes in total electron content is that of equivalent slab thickness (y):

$$y = \frac{n_t}{N_{\max}},$$

where n_t is the total number of electrons in a column and $N_{\max}$ is the maximum electron density in the *F2*

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All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin. U.S. citizenship required layer. Roger, utilizing several spaced ionosoundings, compared satellite data with the moon reflection results of Taylor. He found for the most part excellent agreement. The equivalent slab thickness shows a relative constancy by day and during part of the night with y ranging from 200 to 300 km. E. Vassy discussed electron density measurements by use of Doppler data obtained simultaneously at several stations, a technique worked out by Mass.

Satellite signals scintillate at times so that the clean Faraday peaks are disturbed by modulation. Auroral observations of scintillation were reported by two contributors. Frihagen, reporting on 20 Mc and 108 Mc spaced-receiver experiments near Oslo and Tromso in Norway, found scintillation regions at altitudes between 300 and 500 km with elongation along the lines of force of the earth's magnetic field. Liszka, observing at Kiruna, Sweden, in the auroral zone, found good correlation of his scintillation data with auroral sporadic *E*, a lower-altitude phenomenon. Liszka reviewed several experiments in auroral-zone reception of satellite signals, stressing the general prevalence of irregularities in reception compared to the normal recording of Faraday rotations at lower geomagnetic latitudes. The height of the region producing the irregularities was to be investigated further. Both Liszka and Frihagen plan on operating a joint program of spaced-receiver and correlation studies at several sites in Norway and Sweden. Both data and interpretation would be compared.

In reviewing instrumentation for radio-astronomy techniques, Whitney outlined the stringent stability needs. Techniques of switched radiometry maintain stability to 1 part in 1000 for atmospheric studies. Basically a known stable signal is compared with antenna temperature, and the difference is measured. Dieter, describing a complex differential Doppler system for satellite signals, approaches recording of the raw data with the analysis system and computer as integral parts of the experiment. The basic potential is for synoptic results in a field where satellite passes have been analyzed intensively but sparsely.

Cosmic Noise Absorption

Hultqvist reviewed nondeviative absorption measurements by observing the apparent changes in cosmic noise. The refractive index for the primary frequency used in auroral zones, 27 Mc, is nearly unity. The dissipation of energy results from collisions of electrons with other particles. The *D* layer and the *F2* layer are the altitude regions where most of the normal absorption takes place in middle latitudes; absorption at *E*-layer heights is also observed in auroral regions. The most dramatic event observed is the polar-cap absorption, the proton-produced signal decrease after some large flares. The time of flight of protons from the flare eruption on the sun to the start of the slowly increasing absorption in the auroral polar cap (one-half hour to several hours) has been measured. Daytime absorption is four to six times greater than night for these events. The results obtained recently in Kiruna on sunrise and sunset absorption were discussed in detail by Hultqvist. Holt and Landmark presented a paper disagreeing with aspects of the theory of Hultqvist, in particular on the role of photodetachment and recombination in the *D* layer. Holt and Landmark found auroral day-to-night ratios of 2.2, concluding that photodetachment was of importance for auroral absorption.

In Canada a group of riometers (Relative Ionospheric Opacity Meters) was set up along a line of geomagnetic latitudes from 56.4° to 82.5° N. For auroral absorption, Hartz reported a peak from 60° to 65° Geomagnetic North with a fall in absorption both north and south of this region. Norwegian results from a chain of riometers had maximum absorption of cosmic noise at about 67° G.N., indicating that the auroral belt takes an elliptical form in the Northern Hemisphere, dipping down in the Hudson Bay region.

In middle-latitude observations by riometer techniques, Anastassiades showed the important contributions of the *F2* regions. At Athens, peak absorption occurs in the summer around noon. Comparisons have been made with other middle latitude stations, notably at Stanford and New Delhi. The close correlation between sudden cosmic-noise absorption and flares has been looked at statistically. Optical maxima precede absorption maxima by approximately two minutes.

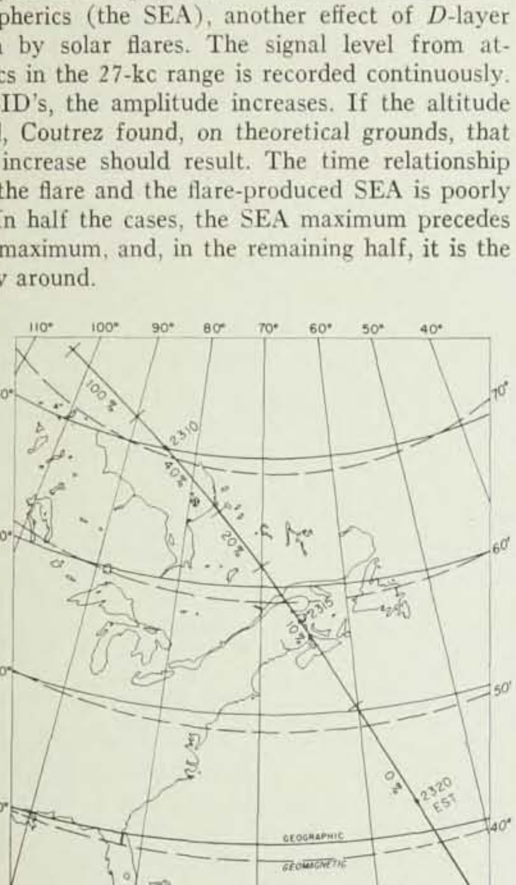
Incoherent Scatter

Within the field of atmospheric studies, a new technique has been evolved, that of incoherent scattering from free electrons. First postulated by Gordon and verified experimentally by Bowles, this method has been used to determine the detailed electron-density profile to an altitude of several thousand kilometers. Millman, reviewing theory and observations, compared results obtained by several high-powered radar installations. For the future, measurement of ionic constituents (by Doppler studies of returned pulses), magnetic-field variations, and electron to ion temperatures, remain to be done. Millman's technique of Faraday-rotation recordings of the incoherent scatter signal allows for absolute measurements. The probing wave suffers zero rotation below the *D* and *E* layers; all subsequent rotations can be counted from this point, thus eliminating ambiguities present in single-frequency satellite and lunar studies.

The Solar-Terrestrial Relationship

Details of the solar-terrestrial relationship have become more sharply defined with the advent of the IGY and with rocket and satellite observations. As Boischot pointed out in the sessions on solar effects, decimetric and centimetric measurements of flare bursts and slowly varying activity (the latter linked with sunspot regions) are readily available data sources. Other contributors described the solar x-ray and UV radiation, high-velocity protons from flares, and the somewhat slower solar plasma streams. C. Warwick discussed the sudden ionospheric disturbance (SID), the solar-flare-produced increase in absorption in the *D* layer. Mogel, in 1930, compared transmissions over intercontinental paths and found for sunlit circuits a fadeout of signals. New observations show a close relationship in the time of occurrence of SID's with centimeter-wavelength bursts associated with the flash phase of the flare. She discussed models of the mechanism for ionization in the *D* layer, including the x-ray contribution (hard and soft) and Lyman alpha and Lyman beta.

Coutrez and a group from the Royal Observatory of Belgium presented a paper on the sudden enhancement of atmospherics (the SEA), another effect of *D*-layer ionization by solar flares. The signal level from atmospherics in the 27-kc range is recorded continuously. During SID's, the amplitude increases. If the altitude decreased, Coutrez found, on theoretical grounds, that a power increase should result. The time relationship between the flare and the flare-produced SEA is poorly defined. In half the cases, the SEA maximum precedes the flare maximum, and, in the remaining half, it is the other way around.



In addition to producing short-wave fadeout and sudden enhancement of atmospherics, the SID has other manifestations. At high altitudes (*E* and *F* layers), the phase, frequency, and angle of arrival of 15–20-Mc ionospherically reflected signals varied, Kanellakos reported. About 83% of Class 3 flares produced these fluctuations in signals.

In searching for the mechanism for the production of sudden cosmic-noise absorption, another effect produced by solar flares and another manifestation of the SID, Holt compared the variation in absorption with solar zenith distance. He concluded that x-ray intensities during solar flares produced the SCNA, the hard x rays below 1.5 Å contributing considerably to the ionization.

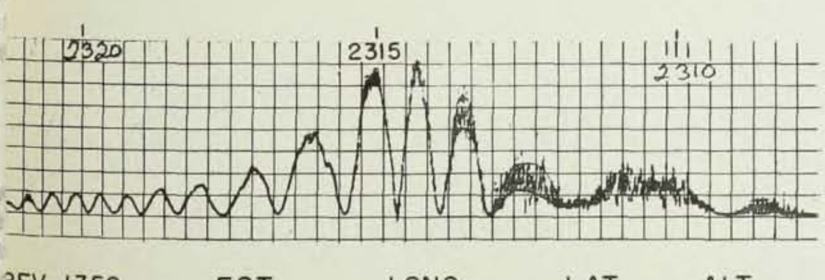
Planetary Radiation

Sampling radiation from the planets across the radio spectrum has produced exciting observations, with interpretation still being in its infancy. J. Warwick, in reviewing black-body, nonthermal, and burst-like radiation observed in planetary studies, gave as coherent a picture of planetary atmospheres as the present accumulation of data would permit. The radio astronomer has been observing planets by reflection techniques (Venus) and by passive methods, and the result has been the expansion of planetary atmospheric studies and a knowledge of the astronomical unit. Planetary atmospheres, ionized and neutral, and magnetic fields are undoubtedly the next areas to which radio astronomy will contribute.

Summary and The Future

It is customary for any study group to conclude the formal program of a discussion session with a review of the direction of present research, as well as to speculate on the nature of future work. The Advanced Study Institute, therefore, held informal discussions on needed research, as well as the possibilities of different avenues of approach to transatmospheric studies. A summary of the directions indicated by the participants follows.

In reviewing the work to date on radio-astronomical and satellite techniques for atmospheric study, one is struck by the advantage gained when one technique or



REV 1359	E.S.T.	LONG.	LAT.	ALT.
OCT. 4, 1961	2320	55.36	32.5	942
1961 OMICRON I	2315	65.15	47.3	965
54 MC	2310	84.39	60	986

Passage of Transit IV A (54 Mc) into auroral regions on October 4, 1961. Nulls are Faraday rotations; heavy black fluctuations are scintillations. Both geographic and geomagnetic latitudes are given.

type of measurement is supplemented by a second. The frozen picture of the ionosphere provided by a satellite passing from horizon to horizon in a few minutes can be contrasted to the slow atmospheric changes recorded by radio-star and moon-reflection techniques. The instrumental complexity and vastness of the incoherent-scatter station is in sharp contrast to the simplicity of satellite-ground receiving equipment. The minimum data for any ionospheric study are supplementary solar and magnetic observations; the needs for the total picture include many simultaneous measurements of the same phenomena.

Many suggestions for future satellite instrumentation for ionospheric studies were put forth. Most scientists in the field anxiously await the ionosphere-beacon units with their closely spaced frequency transmissions, coherent oscillations, and multifrequency output. Using this instrument, many of the problems brought to the fore in the chapters on electron-density measurements will be eliminated and the data analysis will be relatively simple and unambiguous.

In addition to the currently planned satellites, C. G. Little suggested measuring differential absorption of the ordinary and extraordinary modes at frequencies not too far from the critical frequency of the *F2* layers. The technique would be a comparison of depth of Faraday fading nulls to determine the ratio of *O* to *E* modes. J. Warwick emphasized the need for a 1–2-Mc radiometer placed in a polar-orbit satellite, whose purpose would be to attempt to detect emission at the gyro frequency of electrons in the earth's magnetic field. The importance of the inclination of the satellite was stressed since observations of cosmic noise in the 1–10-Mc portion of the radio spectrum are being planned. T. Hartz pointed out, for example, that the Canadian topside sounder will monitor cosmic noise in this range at the 1000-kilometer-height level.

In reviewing the transatmospheric studies at middle and equatorial latitudes, there appeared to be many avenues of research to which relatively small efforts have been attached. The small number of observatories working in these geographical regions, many of them inadequately equipped in comparison with auroral-zone geophysical institutes, could well be better instrumented during the International Year of the Quiet Sun. M. Anastassiades outlined the sparsity of riometer sites, particularly of the multifrequency variety, at middle latitudes. Since the work of International Geophysical Year on solar activity stressed auroral research, the IQSY could well put its resources behind middle-latitude and equatorial-region research. E. Golton described future work in Singapore, designed to emphasize the variation of upper-*F*-layer profiles in equatorial regions.

At the present time there are only a few observatories working in low-latitude regions, and they are performing measurements over a very limited range. Closely spaced riometer studies, differential mode-absorption experiments, and ELF-VLF observations all hold possibilities for future middle- and low-latitude work.

On the subject of interrelationships in multidisciplinary research, the increased needs for "relating" were apparent to all. Fitting a total picture to an individual observation requires consistent long-term solar measurements. Satellite observations are needed to go beyond the present measurements of density variations, a very significant and needed addition to atmospheric physics. H. Kallmann-Bijl outlined ideas of needed measurements on ion and neutral-particle densities as a function of height, diurnal variation, and solar-ionospheric conditions. Future space programs should include rocket measurements in addition to satellite observations for low-altitude data, as well as information on fluctuations in the 200-km region and beyond.

On the subject of absorption, B. Landmark and B. Hultqvist both agreed on the need for additional observations using both balloon and rocket techniques to supplement ground measurements. Within the sphere of ground measurements, comparison of data is needed from the cross modulation and the riometer techniques. The expansion of absorption measurements at low latitudes is certainly of importance in understanding the mechanism of absorption in detail.

The radar-reflection technique, with both man-made targets and natural satellites, is not outmoded by satellite transmissions. G. Millman advocated the use of high frequencies (400 Mc) for Faraday-rotation studies, emphasizing the ease in eliminating ambiguities from single-frequency measurements by use of this band. He stressed the need for data on the total refraction through the earth's atmosphere. The possible future of incoherent scatter was outlined. Valuable contributions from this field would yield a better understanding of geomagnetism, the constitution of the atmosphere, and of electron and ion physics.

N. Taylor suggested the extension of the Faraday technique in studying other planets. The possibilities of exploring planetary atmospheres by Faraday-rotation observations are quite exciting. This research would lead to an increased understanding of the magnetic field of the planets, the ionized atmosphere, and solar control data.

Conclusion

Coming away from an intensive session of this type, two divergent ideas seem to be present: one, that everything is done and done well, and, conversely, the nagging thought that only a rough beginning has been made. Even if atmospheric physicists look backward, they must explore the available data more fully. As C. Dieter pointed out, the systematic exploration of a known technique to obtain synoptic information calls for observations made with automatic data-analysis equipment and a computer program.

Certainly, once an end is in sight, tedious data analysis is archaic. However, even in space physics, where the enormous capability of the computer is so important a factor, there is need for individual creativity and ingenuity.