VI. GEOPHYSICS

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RESEARCH OBJECTIVES

This group will be concerned with a variety of problems of geophysical interest, including laboratory investigations of the properties of matter and radiation under extreme conditions. The present program includes three principal projects.

1. Van Allen Radiation Belts

Theoretical and experimental investigations of the properties of low-density plasmas in homogeneous magnetic fields and in the magnetic field of a dipole will continue. Methods for making measurements both in the laboratory and in space, as well as model experiments on the interaction of the solar wind with the earth's magnetosphere, have been started. Results of the past year's work include theoretical and experimental investigations of the interpretation of Langmuir probe measurements under unusual conditions; an experimental investigation of positive column instabilities in a longitudinal magnetic field; and a theoretical investigation of Coulomb scattering matrix elements in the presence of a magnetic field.

F. Bitter, G. Fiocco

2. Ultrahigh Magnetic Fields

The production of magnetic fields in the multimillion gauss range by explosive flux compression have been reported by Fowler, Garn, and Caird from the Los Alamos Scientific Laboratory (J. Appl. Phys. 31, 588 (1960)) and others. The extension of this work to even higher fields and under conditions better suited to experimentation requires the production of more flux for the explosion to compress than has heretofore been available. The technical problems involved in producing up to 1 weber of flux in a metal cylinder of 8-12 inches diameter have been studied, and we hope to test some of resulting proposals experimentally at the National Magnet Laboratory. Of particular geophysical interest is the possibility of using such high magnetic fields to help in the study of matter under the very great pressures that can be achieved only by focused explosions.

F. Bitter

3. Optical Investigation of the Upper Atmosphere

During the past year, studies of the Earth's atmosphere by optical radar have continued. Profiles of the aerosol layers at 20 km and above have been obtained routinely, and have been correlated with other upper atmospheric phenomena. Two optical radar units were taken to Alaska and to Sweden during the summer to observe noctilucent clouds. The research in this area will continue. We aim to improve the data-handling capability of the apparatus and are considering the possibility of installing an optical radar on an airplane for noctilucent cloud investigations. Studies of Raman scattering have been pursued.

We plan to extend our work in some of the following directions: development of a high-resolution spectrograph to resolve, by Doppler techniques, the high-velocity structure of the upper atmospheric winds; laboratory studies of the interaction of a laser beam with gases, including scattering and ionization phenomena; design of satellite instrumentation for the study of interplanetary dust and the counterglow; and studies of the nightglow.

G. Fiocco

A. COULOMB SCATTERING IN A MAGNETIC FIELD – MATRIX ELEMENT CALCULATIONS

The general problem of interest here is the behavior of one charged particle (charge q, mass m) as it moves by another charged particle (the scatterer, of charge Q and mass $M \gg m$ so that it can be assumed to be at rest), both particles being located in a uniform magnetic field B. The problem has been approached quantum mechanically; in particular, scattering has been considered in the limit of the Born approximation. The incoming and outgoing particle states that appear in the computation of the matrix element of the Coulomb potential were represented by the eigenfunctions of a spinless free electron in a uniform magnetic field (Landau states). A first approximation, obtained previously by other authors, has been obtained in a simpler way. In order to assess its validity, we have been able to reduce the complicated radial integral to a much simpler form from which rapidly convergent series expansions can be obtained. Further work, including numerical evaluation of the matrix elements, is in progress.

J. C. Chapman, H. C. Praddaude

B. OPTICAL RADAR RESULTS AND IONOSPHERIC SPORADIC E

Results, obtained by using an optical radar technique, of echoes from atmospheric constituents, presumably dust, at 60-140 km heights, have been reported previously by Fiocco and Smullin.[1] The echoes are often localized between heights below 100 km and between 110 km and 140 km. The upper echoes and the presence of the minimum in the measured crossed section between 100 km and 110 km have been interpreted as being due to meteoric fragmentation.[2] The same data utilized in that discussion have now been correlated with the presence of Ionospheric Sporadic E. Optical radar observations made during thirteen nights in the summer of 1963 at Lexington, Massachusetts, have been compared with results obtained by the ionospheric sounder operated by Lincoln Laboratory at Millstone Hill during the same period. The distance between the two stations is approximately 25 km.

A paper giving an analysis of the results of these observations has been submitted for publication to the Journal of Geophysical Research.

G. Fiocco

References

1. G. Fiocco and L. D. Smullin, Detection of scattering layers in the upper atmosphere (60-140 Km) by optical radar, Nature 199, 1275 (1963).

2. G. Fiocco and G. Colombo, Optical radar results and meteoric fragmentation, J. Geophys. Res. 69, 1795 (1964).

C. OBSERVATIONS OF THE UPPER ATMOSPHERE BY OPTICAL RADAR IN ALASKA AND SWEDEN (PART I)

During the past summer, two optical radar units were taken to Alaska and to Sweden to make observations of the upper atmospjere at latitudes where noctilucent clouds might be visible. The unit in Alaska was installed at the Ester Dome Observatory of the Geophysical Institute of the University of Alaska (geographical coordinates 64°53'N, 148°3'W). (See Fig. VI-1.) It was in operation from 24 July to 31 August 1964. The unit in Sweden, which was mounted in a trailer borrowed from the National Aeronautics and Space Administration, was stationed at Ölands Skogsby (56°38'N, 16°31'E) from 15 July to 31 July 1964 and at Torsta, Ås, Jämtland (63°15'N, 14°33'E) from 5 August to 27 August 1964. The longitudinal coordinates of the two stations differ by 165° so that the stations were almost as far apart as possible at these latitudes.

Because optical radar observations require a dark sky background to obtain a reasonable signal-to-noise ratio, a mobile unit was used in Sweden so that observations could be started at lower latitudes where there are longer periods of darkness.

It was of special interest to make observations during the nights on which rocket experiments were carried out at Kronogård, Sweden (66°N, 17°E). These experiments were designed to measure the temperature and wind velocity at the mesopause and to sample the particular content of the noctilucent clouds. (These rocket experiments were carried out by scientists of the Swedish Space Committee, the National Aeronautics and Space Administration, and the Air Force Cambridge Research Laboratories.)

Throughout the summer, networks of stations were maintained in both Sweden and Alaska to observe noctilucent clouds. These networks were organized by the Geophysical Institute of the University of Alaska, and the Institute of Meteorology of the University of Stockholm.

The apparatus used in Alaska incorporated an RCA Q-switched ruby-laser head that emitted uplses of approximately 1/2 joule with a wavelength of 6843 Å and a duration of 50 nanoseconds at a p.r.f. of 0.1 sec^{-1}. The 3-inch ruby rod and the elliptical cavity were cooled by dry nitrogen which had passed through a coil immersed in liquid nitrogen. We modified the EG & G FX 47A (3-inch arc length) flashtube used in the laser for cooling with distilled water. A refracting telescope with a focal length of 1 meter was used to collimate the outgoing radiation; a synchronized rotating shutter was incorporated into the transmitting unit to prevent the emission of fluorescent light and residual flashlamp light after the pulse had been emitted.

The receiving unit consisted of a Newtonian telescope of 30-cm aperture, an interference filter of 3 Å bandwidth, an EMI 9558A photomultiplier tube cooled by the same nitrogen that cooled the laser cavity, and a synchronized rotating shutter, which was included to prevent exposing the photometer to the intense return obtained from

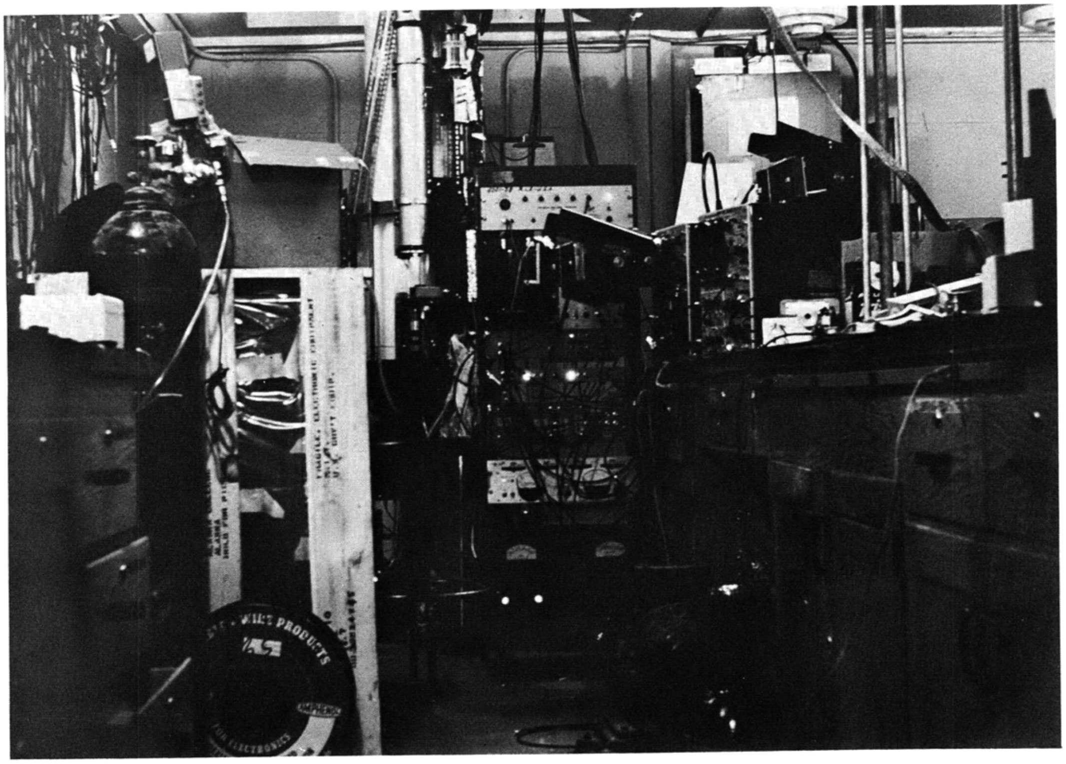

Fig. VI-1. View of the apparatus installed at the Ester Dome Observatory, College, Alaska.

Fig. VI-2. Trailer with optical radar at Torsta, Sweden.

scattering at short distances.

The apparatus taken to Sweden incorporated our 40-cm Cassegrainian receiving telescope and a laser unit built by Applied Laser, Inc. This laser unit was ordinarily used to deliver approximately 1.5 joule pulses of duration shorter than 1 μsec at a p.r.f. of 0.2 sec^{-1}. It had ruby rod of 90° orientation, 6.5 inches long and 3/8 inch in diameter. The ruby flashlamp (EG & G FX 67A) and the elliptical cavity were cooled by closed circulation of distilled water. The Q switching was achieved by a rotating prism, and the output of the laser was collimated by a telescope with a focal length of 1 meter.

The receiver included an interference filter of 6 Å bandwidth, and an EMI 9558QA photomultiplier cooled by methanol and dry ice. Synchronized rotating shutters were part of both the transmitter and the receiver.

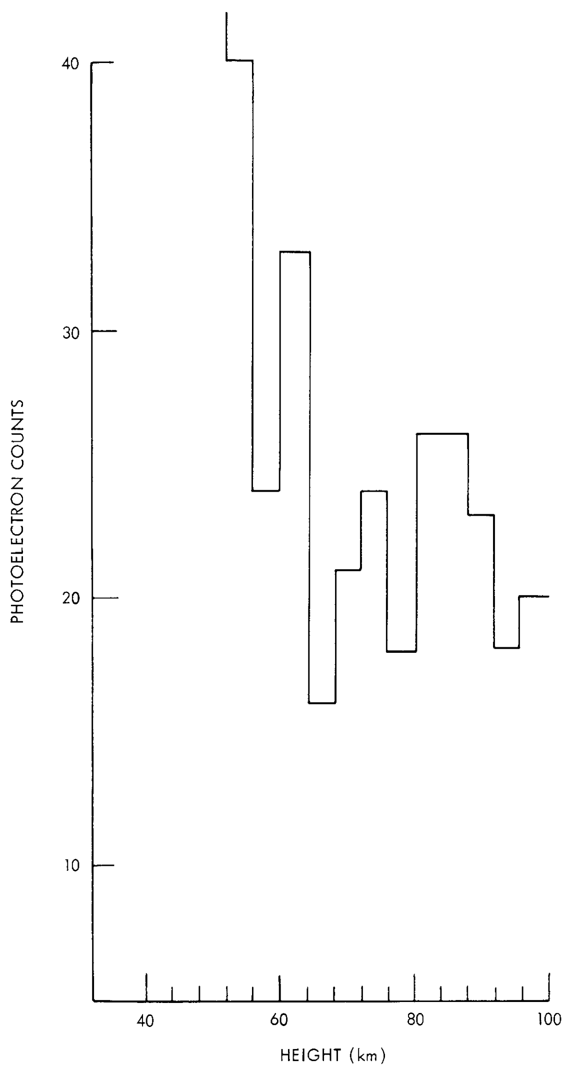

Fig. VI-3. Summary of observations taken at Torsta, Sweden.

The optical radar systems were zenith-oriented during operation. Visibility conditions were less than satisfactory a great deal of the time in Alaska, and also in Sweden. Precipitation was not uncommon, and cirrus or lower clouds were often present. On a few occasions noctilucent clouds were seen low near the horizon, at a distance of several hundred kilometers. On the day of our arrival in Ölands, 15 July 1964, a very strong display was visible overhead and toward the South, but the apparatus was not operational. Thus all of our measurements were made when noctilucent clouds were not visible overhead.

A summary of observations taken at Torsta on 17 August 1964 from 0^h37^m to 1^h47^m U.T. is given in Fig. VI-3. The total photodetection count accumulated during that period of time is shown. Echoes are evident in the region between 80 km and 88 km. During these observations, weak noctilucent clouds were visible on the horizon and a rocket was fired from Kronogård.

From our data we estimate the average optical thickness of the layer overhead to be approximately 4×10^{-5}. Since some of the data taken during the past summer remain to be analyzed, a detailed discussion of the results cannot be presented in this report.

These experiments would not have been possible without the support and encouragement of many agencies and individuals. We thank the Geophysical Institute, the University of Alaska, and the Meteorological Institute of the University of Stockholm for their hospitality and help in planning. The trailer was kindly lent by the Sounding Rocket Branch, Goddard Space Flight Center, National Aeronautics and Space Administration, and the Meteor Physics Group, Geophysics Research Directorate, Air Force Cambridge Research Laboratories, Bedford, Massachusetts, was very helpful in arranging for transportation of the trailer.

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