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on

"A RESEARCH IN SUPPORT OF NASA'S SPACE SCIENCE"

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Principal Investigator



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INTRODUCTION

The guiding philosophy behind the work on this grant is twofold:

(1) maintenance of competence for participation in future space flight opportunities including preparation for Space Shuttle and (2) contributions to U. S. leadership in space sciences through productive research efforts. The former of these requires a continuing base of operation in experimental activities involving space technology and instrument development, while the latter requires some continuity of effort to remain at the forefront of several areas of space research. The two are somewhat interwoven, as the design of new space experiments is dependent upon an appreciation of recent accomplishments in space research and of the problems that can be resolved by measurements in space.

There are four general tasks that can be identified as supportive of the above philosophy:

- (1) Instrument development for projected or potential future space missions, especially preparing for the changed modes of operation to be expected with the Space Shuttle.
- (2) Maintenance of nuclei of engineering support groups. The availability of a key man or two in the engineering and technical areas, familiar with research instrumentation, space technology requirements and NASA procedures, is a prerequisite for the generation of realistic proposals to prepare instrumentation

for space projects. Fortunately, this task meshes well with the first, as the development of new instruments requires these same talents and provides tasks that can keep key team members working together.

- (3) Analysis of past measurements to improve the design of new experiments. In several cases, space measurements have been made that require study and interpretation before the logical next step in observation can be defined. Thus, such analysis is frequently a prerequisite to the design of new instrumentation for future space flight opportunities.
- (4) Analysis of past measurements to obtain new space sciences results. This task represents an end in itself, as it deals with analyses that lead to new conclusions that will contribute to U. S. leadership in space science so measured by significant advances in understanding.

Support from this grant has made it possible to maintain an active and productive space science group at The University of Texas at Dallas with continuity of effort in many areas. This group has developed new instrumentation and improved older tested instruments for flight in future NASA missions. In addition, they have pursued analysis of data previously collected beyond the first phase and into the more rewarding correlative phase where a broader synthesis of related phenomena can be achieved.

This report highlights some of the progress that has been made in the last six months on projects directly supported by this grant. Detailed discussion of these projects follows.

ION DRIFT METER - W. B. Hanson

The ion Drift Meter is an instrument that has been developed with funds from this grant. An opportunity to flight test the instrument arose in the Atmospheric Explorer program, for which we provided an ion Retarding Potential Analyzer (RPA). The project permitted the inclusion of the ion Drift Meter as an add-on without cost impact to the RPA. This flight test of the ion Drift Meter on Atmosphere Explorer has made available for the first time satellite measurements of the total ion drift velocity in the 150 km to 1500 km altitude range.

The operating principles of the ion Drift Meter and the ion Retarding Potential Analyzer, from which the three mutually perpendicular components of ion drift velocity are obtained, are well established. However, the very low perigees reached by Atmospheric Explorer resulted in a number of unforeseen practical difficulties in interpreting the data. A full description of the determination of the ion drift velocity from a satellite and a discussion of the difficulties at low altitudes, primarily due to neutral particle impact on the instrument collectors, is given by Hanson and Heelis (1976).

The Atmospheric Explorer satellites were principally designed for the study of the aeronomical properties of the earth's ionosphere. However, the vector ion drift velocity was measured in the high latitude F-region where the effects of a magnetospheric convection electric field are dominant. The

study of the gross nature and fine structure of the large ion velocities produced by the electric field has to date been the main thrust of the science output from the drift meter.

The nature of the ion convection reversals in the dayside cusp has been a topic of interest for some time. If the reversal involves a component of flow across the boundary associated with the magnetopause, the boundary may not be an equipotential and there may be a strong merging process between the interplanetary magnetic field and the earth's geomagnetic field.

There are regions where the reversal is indicative of this merging region, but a study of a number of orbits shows that this region may be restricted to a very small region of local time on the dayside and that substantial portions of the dayside magnetopause are very nearly electric equipotentials (Heelis et al., 1975). The familiar two-cell convection pattern is preserved but the symmetry of the pattern is controlled by the extent and location of the small merging region which in turn depends upon the direction of the interplanetary magnetic field.

The region of reversal in the ion convection velocity from sunward to antisunward is also of interest since it appears to coincide with the occurrence of energetic electron precipitation regions. Detailed study of the velocity structure at these reversals and the energetic electron precipitation has been possible from the simultaneous measurements of these parameters made on Atmosphere Explorer.

Both weak and strong acceleration regions (or inverted V's) have been identified in different regions of the convection. The acceleration regions are described well by Maxwellian beams which have increased temperatures as a result of being accelerated through a field-aligned electrostatic potential (Burch et al. , 1975).

The weak acceleration regions appear to be confined to the cusp region and to the dusk side precipitation zone where the convection velocity direction changes from antisunward to sunward. The strong acceleration regions typically overlap well into the sunward convection region, at times lying completely within it. A weakening in the observed ion velocity is associated with the occurrence of the strong acceleration regions.

Examination of the fine structure in the ion velocity within the region of weakly accelerated particle precipitation has revealed spike-like velocity signatures which can be associated with electric fields along the spacecraft orbit which are directed toward the region of the inverted V (Burch et al. , 1975). Such a signature is consistent with an upward flowing field-aligned current. Ion velocity signatures consistent with downward flowing field-aligned currents have been observed and these have been coincident with the absence of energetic electron fluxes.

EXTREME ULTRAVIOLET LABORATORY
AND SPECTROMETER - A. B. Christensen

During the reporting period covered by this report, the EUV Laboratory activities have been directed toward the absolute calibration of two extreme ultraviolet spectrometers and the development of an extreme ultraviolet grating photometer. The EUV laboratory has been established and is maintained under this grant to support space research projects and space instrumentation development.

The first of the ultraviolet spectrometers has been successfully operated on a sounding rocket payload for the measurement of the dayglow spectrum in the 550-1250A wavelength range. The payload was launched on a Nike-Tomahawk vehicle, NT18.163, and attained an altitude of 279 km. The solar zenith angle at the time of launch was 73.4° . The payload was despun to a rate less than intended, which led to a large coning angle. The rocket long axis swept slowly through an arc almost perpendicular to the earth-sun line during flight.

The second spectrometer is presently being calibrated. The detector response functions have been measured and the complete instrument will be under test in the near future. It will be launched February 1976, from Poker Flat, Alaska to obtain EUV spectra of the aurora.

An ultraviolet grating photometer has been constructed and calibrated and will be part of an auroral sounding rocket payload. The instrument will monitor the OII 834 emission and it is planned that an altitude profile for the emission will be obtained.

The extreme ultraviolet spectrometer (EUVS) is a normal incidence 0.4m concave grating instrument using open spiral electron multipliers as detectors. It viewed along the rocket long axis and scanned the wavelength range 550-1250A with a resolution of 20A. The instrument is equipped with a single entrance slit and two exit slits arranged so that the extremes of the spectral range are scanned by one slit but the spectral range 830-1000A is scanned across both slits. The scan is accomplished by a simple rotation of the grating with a 200 step/revolution stepper motor, which on the first flight was set to dwell 0.25 sec at each wavelength position throughout the wavelength range. On the return portion of the cam, the rate is much faster, resulting in a total scan time of 30 sec.

The instrument began its first scan at 170 km altitude at a zenith angle of approximately 37° and completed 11 scans above 110 km at zenith angles as great as 145° . Figures 1 and 2 show flight spectra obtained by summing together 5 scans for each exit slit. The background counting rate is very low. In the spectral region near 770A, the rate was about 1.2 counts/dwell position or 4.8 counts/sec. Note also that the scattered light in the vicinity of Lyman α is at a fairly low level, consistent with the initial design criteria.

The absolute intensity scale is based in part on the observed Lyman α signal. The procedure followed was to use the laboratory calibration data to determine the relative wavelength response of the system and to use the Lyman α signal observed in flight as a reference point on the relative

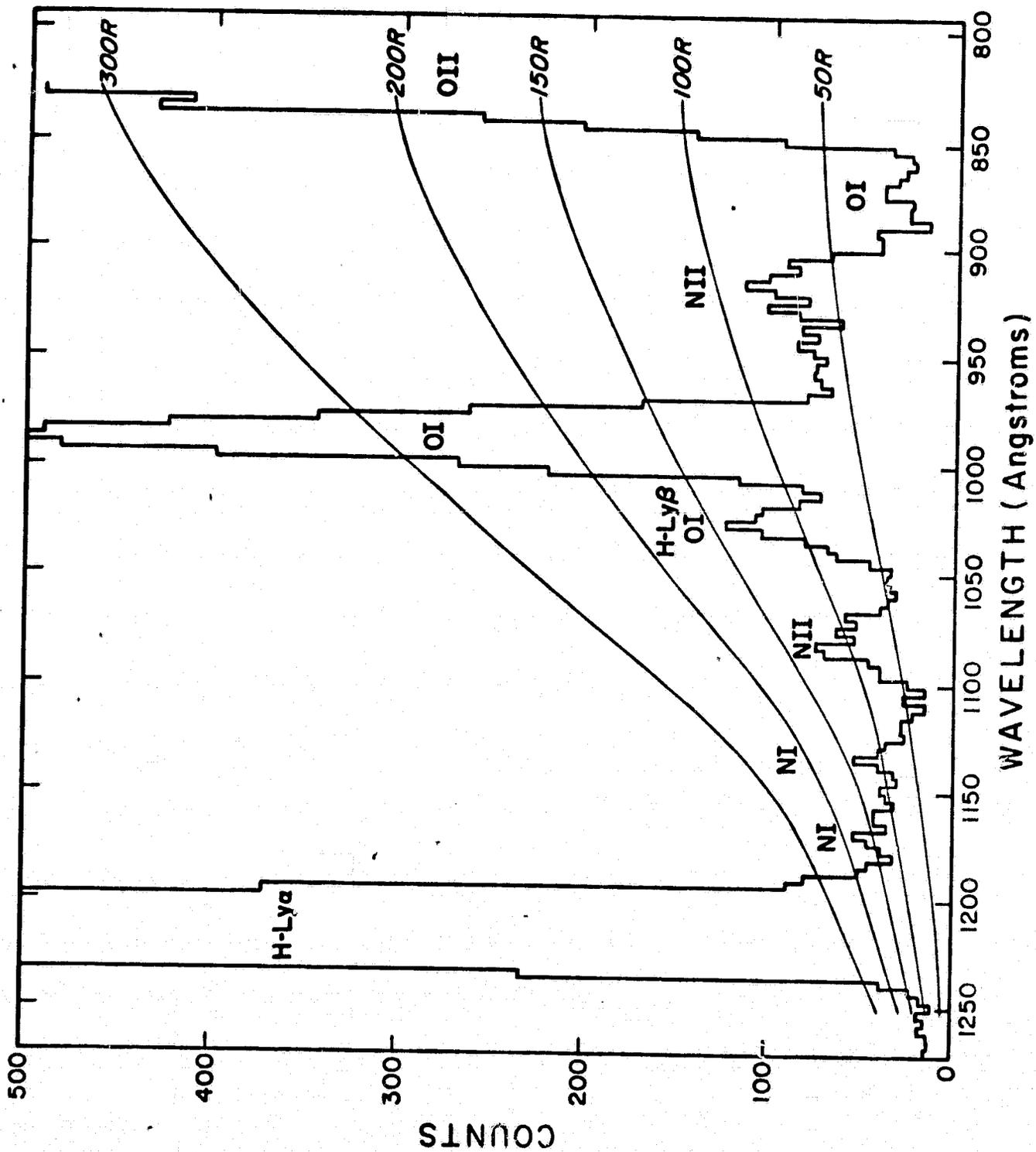


FIGURE 1

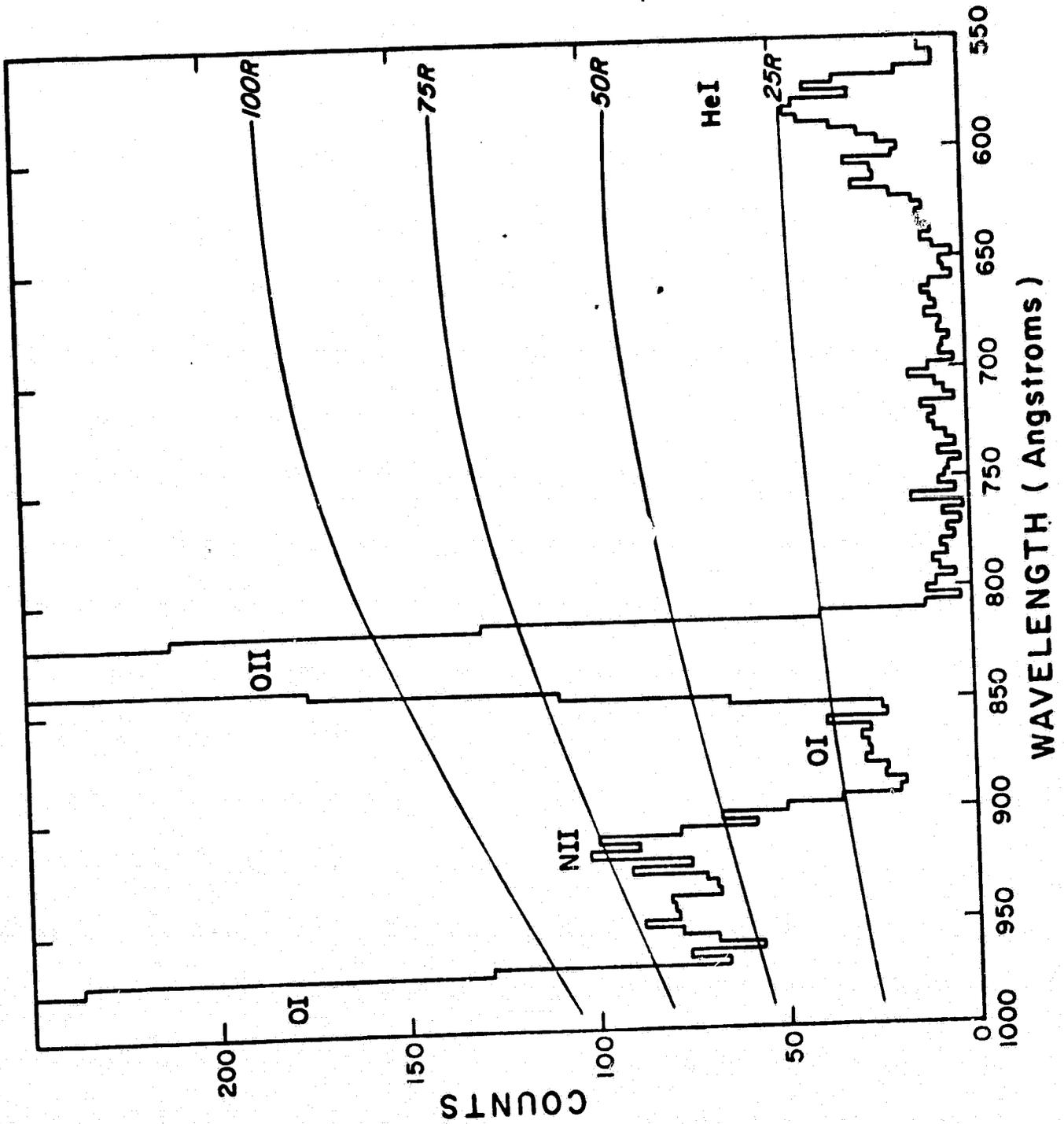


FIGURE 2

TABLE I

WAVE LENGTH	IDENTIFICATION	SCAN #2		PEAK		AVG. 5 SCANS	
		INTENSITY*	INTENSITY**	INTENSITY**	INTENSITY	INTENSITY	INTENSITY
584	HeI(584)	25R	37R†	25R	25R		
612	OII(617) ?	13R	29R	16R	16R		
834	OII(834)	225R	426R††	260R	260R		
874	OI(878)	27R	44R	23R	23R		
918	NII(916)	57R	170R	82R	82R		
950 unres.	OI(950)	1.7R/A	8.2R/A	3.4R/A	3.4R/A		
990	[OI(989)] [OI(999)]	580R	670R	520R	520R		
1027	[LyB(1027)] [OI(1027)]	95R	320R	135R	135R		
1080	NII(1085)	35R	435R	130R	130R		
1136	NI(1135)	90R	230R	135R	135R		
1170 unres.	[NI(1168)] [OI(1152)]	6.0R/A	19.1R/A	8.7R/A	8.7R/A		
1215	NI(1164) NI(1177) Lyα(1215.7)	(120R)	(380R)	(174R)	(174R)		
		10.8KR	12.6KR	10.0KR	10.0KR		

*Scan #2: Altitude 210-240km; zenith angle 44-50°

**Scan #7: Altitude 276-263km; zenith angle 100-110°

†Scan #5: Altitude 276-279km; zenith angle 83-90°

††Scan #6: Altitude 279-276km; zenith angle 90-100°

response curve. The Lyman α intensity was set at 10 kR for the composite spectra and the lines on the figures represent the resultant absolute response. Using the laboratory calibration data only, the Lyman α intensity turns out to be 15 kR.

A Lyman α intensity of 10 kR is consistent with the present model of the hydrogen distribution and the solar cycle variation of the solar flux. However, detailed computations for the expected intensity in our view direction and for the atmospheric and solar conditions on the launch date have not yet been carried out. There remain some uncertainties in the laboratory calibration data that are presently under study. Because of these remaining questions, it was decided to normalize the results to a 10 kR Lyman α intensity and adjust the scales upon completion of further investigations. Nevertheless, we are confident that the reported intensities are accurate to better than a factor of two.

There are several interesting aspects of the spectra shown in Figure 1 and 2. The spectra are dominated by atomic multiplets. The features that have been identified are listed in Table I. The strongest after Lyman α are the features at 990A, which we assign to atomic oxygen, and OII(834). There is then a group of weaker multiplets in the 850 to 1200A region.

The most striking aspect of the spectra is the apparent absence of any molecular bands of N_2 , which is quite surprising in view of laboratory

experiments. According to the laboratory work on the electron impact excitation of the Rydberg states in N_2 , there are many narrow bands that have significant electron impact cross sections that should be excited in the dayglow in the wavelength region of 900-1000A. There is a strong N_2 band at 958A that is observed in laboratory work, for which no evidence is found in the present spectra. In fact, the cross sections for NII(916) excitation by dissociative excitation is the order of 30 times smaller than the N_2 (958) cross section. In addition, there are a multitude of other narrow ($<2A$) N_2 bands in the same wavelength region with smaller cross sections that because of their numbers should provide a large continuum at the coarse resolution used in the rocket experiment. There are some unresolved features in this wavelength band, but they are weaker on the average than the NII(916) emission.

It could be that the main excitation of the NII(916) is electron impact on atomic nitrogen. This would probably require substantial N densities, but the quantitative evaluation of these various possibilities is yet to be done.

The essence of the dilemma is what happens to the radiation from these states. The laboratory cross sections have been substantiated by several experimenters so that the confidence level is high. This means that the states must be strongly excited in the dayglow by photoelectron impact. The absence of the radiation may be due to self absorption in

which the energy eventually shows up in the dissociation product of N_2 . If this were the case, the bands might be detectable at sufficiently high altitude where the optical depth is small. However, the excitation rate is also proportional to the N_2 concentration, so that the intensity diminishes with altitude.

Originally we conjectured on the possibility of nonlocal ionization of O_2 and O by intense N_2 EUV emission bands. The absence of the N_2 lines in the spectrum now precludes this possibility, however, the absorption by O_2 may be important for some of the N_2 emissions.

The ratio of the intensities of the NII(916) and NII(1085) lines may also depart significantly from what is expected. Again, if excitation is by electrons on N_2 , the 1085A line should be the order of 3 times brighter than 916A, but the rocket data yield a ratio about one-half that expected. In addition, there is a fairly strong solar NII(1085) line that should add some resonance scattered radiation and would tend to increase the apparent discrepancy. A good altitude profile for these two emissions would be of value.

At short wavelength end of the spectrum there are two lines. The first is HeI(584) and its intensity is in good agreement with the computational models. Meier (private communication) calculates that at 250 km the vertical intensity is 26R for a symmetric helium model and $1000^\circ K$ exosphere temperature. The second line has a wavelength of $612_{+3}A$ and

its identity is not clear. The most obvious candidate is HeII(304) in second order. However, the instrument response to 304A radiation is expected to be considerably smaller than for 584A, although it has not been measured (mainly because the reflectance of the grating in our laboratory monochromator is small for HeI(304) radiation and insufficient flux is available for calibration). Nevertheless, assuming only a small decrease in sensitivity, the intensity would be in excess of 20R, which is several times greater than previous HeII304 photometric measurements, and not in agreement with model computations.

If the line is not HeI(304), then we are not sure of its identity. But its intensity ranks it as one of the brightest features in the 500-800A portion of the spectrum and casts some doubt on the interpretation of photometric experiments designed to study the HeI(584) emission.

SOFT-PARTICLE SPECTROMETER AND
DIGITAL LANGMUIR PROBE - W. J. Heikkila

Activity under this grant for the current reporting period has included continuing analysis of past measurements with Soft-Particle Spectrometers and consideration of their implications with regard to magnetospheric physics. Instrument development and computer simulation of instrument design has also been pursued under this grant. Analysis of data from several recent rocket flights carrying the new Soft-Particle Spectrometer developed through support from this grant is also continuing. Two additional flight

opportunities for this instrumentation into the dayside cleft were achieved in January, 1976. These flights are part of a continuing program of shaped charge barium releases being conducted by the AEC. Flight experience gained from these launchings provide a unique opportunity to make a complete evaluation of the instrument's operation under true flight conditions. For example, recent flights have shown that the current version of the Soft-Particle Spectrometer is completely insensitive to sunlight. This had been a problem in earlier versions of the instrument, and is apparently a problem with other similar instruments now in use.

Further developments in the Soft-Particle Spectrometer instrumentation are currently being studied. One highly desirable goal is to develop an instrument which has the capability of adjusting its energy resolution and/or sensitivity in flight in response to varying conditions in the particle environment or in response to ground control. To this end computer programs have been developed and are being made operational which simulate the instrument's operating characteristics. With these programs it is possible to alter various parameters of the instrument design and to analyze the effects of such changes on resolution and sensitivity of the instrument. Once these effects have been adequately established it will be possible to design an instrument using clustered or continuous surface detection devices which, through electronic switching, will have the capability of varying its energy resolution and sensitivity in flight.

The Soft-Particle Spectrometers on the ISIS-1 and -2 satellites provided a vast quantity of new data on auroral particle fluxes. Attempts to explain their characteristics in terms of their origin and of magnetospheric processes in general have led to some important new work on magnetospheric theories. A number of interesting questions have been raised, in view of apparent discrepancies between observations and the predictions of current magnetospheric theories.

Perhaps the most obvious of these discrepancies concerns energy flow or conversion at the dayside magnetopause (Heikkila, 1975a). The usual reconnection model of the magnetosphere involves an electrostatic field, the so-called reconnection electric field, along the dayside magnetopause; the potential difference involved is the same as that across the magnetosphere, some 5×10^5 volts. If this were correct, then the dayside magnetopause current of about 10^7 amperes would dissipate 5×10^{11} watts, and this energy would have to be carried away by particles. This is a large amount of energy, and it should be easily detectable; nevertheless, this has not been identified by any spacecraft measurements. On the contrary, the plasma in the magnetopause boundary layer and mantle plasmas is cooler, not hotter, than that in the adjacent magnetosheath. Unless this energy can be accounted for we must conclude that the dayside magnetopause is at least approximately an equipotential surface, and thus that the steady state reconnection rate is zero.

This warning sign led to the listing of a number of questions that pose difficulties for the reconnection theory, (Heikkila, 1975b, c) having to do with the location of various plasma boundaries relative to the boundary of closed field lines, and thus of the X-line. On the dayside the new observations provided by the Heos-2 satellite of an entry layer of magnetosheath-like plasma on closed field lines just inside the dayside magnetopause (Haerendel and Paschmann, 1975) is one such puzzle. The entry mechanism may be some kind of diffusion, not yet identified or understood. There may well be some question on the morphology of the electric field, as the mode of entry clearly works in spite of a dawn-to-dusk electric field, which would tend to convect the plasma back out.

There are similar questions to be raised on the nightside. Energetic particles sometimes show a trapped pitch angle distribution poleward of the discrete auroral arcs on the nightside; this suggests that there may be closed field lines beyond the source region of auroral particles, which is presumably the plasma sheet. This finding, if substantiated, would imply that the X-line at the boundary of closed field lines is not in the plasma sheet, but is instead at the magnetopause on the nightside. If so, then the role of reconnection in steady state auroral processes is again called into question.

We have also considered the possible mechanisms for the conversion of magnetic energy into particle kinetic energy during magnetospheric substorms.

Poynting's theorem may be used to show that such conversion necessarily involves an explicit time dependence of the magnetic field, and therefore an induced electric field. All of the mathematical theory of reconnection is based on $\text{curl } \underline{E} = 0$, and is not capable of dealing with the problem. It is necessary to focus on the electric field; when this is done it is immediately apparent that the induced electric field can be much stronger than the dawn-dusk electrostatic field. Furthermore, it cannot be eliminated by the plasma because of the different topologies of irrotational and solenoidal fields (Heikkila and Pellinen, 1975).

VISITING SCIENTISTS - W. B. Hanson

As part of the visiting scientist program supported by this grant, A. -C. Levasseur, a French scientist, was at UTD from mid-September through mid-October 1975. She is the project scientist for an optical experiment designed to measure hydrogen Balmer α radiation from the geocorona on a French satellite D2A. Her visit provided an opportunity for Dr. Brian Tinsley and others at UTD to compare satellite and ground-based data related to the Balmer α problem. A paper entitled "Resolution of the Discrepancy Between Balmer α Emission Rates, the Solar Lyman β Flux and Models of Geocoronal Hydrogen Concentration" has been prepared by A. -C. Levasseur, R. R. Meier of the Naval Research Laboratory, and B. A. Tinsley for publication in the Journal of Geophysical Research.

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