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AURORAL SPECTROGRAPH DATA

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CONTENTS

Page

PREFACE vii

I. INTRODUCTION ix

Patrol Spectrograph ix
General Description ix
Technical Specifications ix
Film Processing x

Data Reduction xi
Procedures xi
Sources of Error xi

Presentation of Data xii
Film, Punched Cards, and Tabulations xii

Acknowledgements xii

References xii

Figures
1. Patrol Spectrograph xiii
2. Optical System of the Patrol Spectrograph xiv
3. Photometer xiv
4. Recording of a Full Data Cycle xv
5. The Auroral Spectrum xvi
6. Punched Card for the Auroral Spectrogram xvi
7. Drift of Ice Floe A xvii
8. Map: IGY Auroral Spectrograph Stations xxi

Tables
I. Codes Used on Punched Cards and in Tabulations xviii/xix
II. List of Patrol Spectrograph Stations xxii

II. DATA TABULATIONS FOR UNITED STATES - NEW ZEALAND STATIONS

C222 Alamogordo 1
A092 Alaska (College) 7
Andover 37
A997 Byrd 39
A990 Ellsworth 97
B300 Fritz Peak 119
A998 Hallett 121
A019 Ice Floe A 149
B268 Ithaca 157
A995 Little America 169
A999 Pole (Amundsen-Scott) 197
B245 Rapid City 229
B207 Shingleton 233
A025 Thule 253
A977 Wilkes 273
B266 Williams Bay 297
B994 Invercargill 317

Page

III. DATA TABULATIONS FOR CANADIAN STATIONS

A099 Baker Lake 321
A145 Churchill 323
A154 Meanook 335
A030 Resolute Bay 341
A157 Saskatoon 345

IV. REPORT ON OBSERVATIONS IN THE UNITED KINGDOM AT ST. ANDREWS. . 353

V. REPORT ON AURORAL OBSERVATIONS IN THE USSR 357

C071 Abastumani 358
C050 Alma-Ata 359
A055 Loparskaya 360
A143 Roshchino 366
A124 Yakutsk 369
B356 Zvenigorod 371

PREFACE

The plans for publication of data from the auroral patrol spectrograph program were outlined at the V CSAGI Assembly in 1958 in Moscow. The specific proposal to publish tabulations of eye-estimated intensities was reported to the Comité International Géophysique (CIG); all stations which had participated in the IGY patrol spectrograph program were urged to include their data in this volume of the IGY Annals. Data from twenty-nine stations which operated as part of the IGY programs of Canada, New Zealand, the Soviet Union, the United Kingdom, and the United States are included in this volume. The patrol spectrograph instruments were distributed at various sites in the northern and southern hemispheres. A large number of spectrograms were obtained and provided an almost continuous record of the night sky activity.

The five Canadian spectrographs were operated by the National Research Council of Canada, the Defence Research Board, the Dominion Observatory and the University of Saskatchewan. The United States Program was undertaken jointly by the Air Force Cambridge Research Laboratories, Arctic Institute of North America, Cornell University, Geophysical Institute of the University of Alaska, National Bureau of Standards, and Yerkes Observatory. Data from the Canadian stations were reduced at the University of Saskatchewan; data from the US-New Zealand program were reduced at Boston College (with the support of the National Science Foundation) as part of the US-IGY program.

The manuscript for this volume of the IGY Annals was assembled in the Coordination Office of World Data Center A. The editors are responsible for the introductory section and for the tabulations of data from the Canadian and US-New Zealand stations. The reports on observations in the Soviet Union and United Kingdom have been added as separate chapters; these reports were transmitted for inclusion in this volume by World Data Center B and by the British Royal Society, respectively.

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I. INTRODUCTION*

Patrol Spectrograph

General Description

The patrol spectrograph built by the Perkin-Elmer Corporation for the Aurora and Airglow Program of the IGY was a high-speed, low-dispersion, automatic instrument. It was designed to photograph spectra of aurora occurring along a given magnetic meridian of the sky. The major components were: (1) an all-sky (180° field) lens assembly, (2) collimator and grating, (3) Schmidt camera, (4) photometer, (5) calibration cell, (6) data box, and (7) control circuits. All components were contained in a metal cabinet of dimensions 142 cm x 33 cm x 41 cm (56" x 13" x 16") illustrated in Figure 1. The optical system is illustrated in Figure 2.

Radiation from the aurora passed through a slotted metal dome at the top of the instrument and through an all-sky lens which focused the radiation on a narrow slit. The all-sky lens had the unique capacity to focus light emanating from any point of the sky onto the slit which limits the field to approximately 2° x 165°. The light was collimated and then dispersed into a spectrum by a 600 line-per-millimeter grating. The dispersion of the spectrograph was almost linear so that linear interpolations may be used to identify unknown lines. The dispersion was: 269Å/mm in the wave-length range 3900Å to 4500Å; 251Å/mm in the range 5500Å to 6600Å.

The spectrum was brought to a focus by an optically high-speed Schmidt camera and was recorded on 16 mm spectrographic film. It was possible to adjust the position of the camera to photograph spectral regions of approximately 3500 - 6800 Å, or 4400 - 8800 Å, although all instruments were operated in the first-named range.

The length of exposure was determined by a photometer with axicon (Figure 3) which integrated the amount of radiation falling on the sky lens. When the integrated light reached a pre-determined level (as registered by a solenoid-actuated counter) a data recording cycle was initiated, which advanced the film through four frames in the following order:

(1) Sky exposure
(2) Data panel exposure
(3) Calibration wedge spectrum exposure
(4) Blank frame

The data panel identified each spectrum photographed with (1) the time it was recorded, (2) the film exposure number, (3) the photon count accumulated during the sky exposure, and (4) related data such as the geographical location of the instrument (Figure 4). The calibration spectrum was produced by an exposure of a tungsten lamp through a calibrated neutral step wedge and provided an index to film characteristics.

Technical Specifications

Physical Characteristics

Weight	102 kg (225 lb)
Dimensions	142 cm x 33 cm x 41 cm (56 in. x 13 in. x 16 in.)
Power Requirements	110 V. 60 cps
	120 Watts (220 during data cycle)

* The information in the introduction, especially the description of the patrol spectrograph and the method of data reduction, applies only to the Canadian and U.S. - New Zealand programs.

Optical-Mechanical Characteristics

Sky Lens Assembly	
Field	180° (field limited to approximately 165° x 2° by the slit)
Focal Length	10.3 mm
Aperture	f/8
Slit Dimensions	0.3 x 30 mm
Collimator	
Type	Petzval, consisting of 2 separated doublets
Focal Length	24 in. (61 cm)
Working Aperture	f/8
Transmission Grating	600 lines/mm blazed for first order radiation at 5100Å
Camera	
Type	Semi-solid Schmidt
Aperture	3 in. (76 mm) f/0.625
Photometer	
Axicon	Internal total reflecting cone with vertex angle of 90°.
Lens	
Focal Length	4.5 in. (11.5 cm)
Relative Aperture	f/3
Filter	Transmission, interference, peaked at 5577Å
Calibration Cell	
Source	25-watt tungsten lamp
Condensing System	Two plano-convex lenses and reflecting prism.
Step Filter Constants	Nine steps showing diffuse density of steps increasing in increments of 0.3
Data Box	
Illumination	6-watt tungsten lamp
Optics	Projection lens and two-plane mirrors

Film Processing

The patrol spectrograph used Kodak spectroscopic 103a-F film in 16 mm x 50 ft. (30 m.) rolls. It was usually developed in D19 for 5 - 7 minutes at 68°F, except at Invercargill, New Zealand, where Ilford phenidone developer was used. All film was rewashed before the data were reduced at Boston College, since clean water was not always available at the stations.

Data Reduction

Procedures

Because of the large number of spectra that were produced by the patrol spectrographs, it was decided to estimate visually the density of the individual lines and bands.

Densities of the lines of a number of randomly selected spectrograms were measured by a microphotometer. Four operators then estimated the densities of the same lines without referring to the microphotometer measurements. The final reduction of the data was begun only when the four operators achieved the ability to estimate the densities with a reasonable precision. Periodically a set of frames were reduced by a second operator and the results compared with those of the first. This was done in order to achieve uniformity in the visual density estimates of the four operators.

The lines and bands selected for reduction are shown in Figure 5. The wavelength identifications are based on the work of Chamberlain and Oliver (1), Chamberlain and Meinel (2), and A. Vallance Jones (3). Two general classes of spectra were rejected -- those which showed only a few weak lines, and those in which the lines had a strong overlay of continuum. The first class was rejected because they were considered unreliable; the second class was rejected because densities could not be visually estimated.

Sources of Error

A major source of error in the study was the inability to produce accurate calibration curves. The following factors contributed to this problem.

(1) The spectrographs produced calibration spectra which were affected to different degrees by scattered light.

(2) The tungsten filament lamp, used as the source for the calibration spectra, required the techniques of heterochromatic microphotometry.

(3) The nine-step filter, used to attenuate the source light along the length of the slit may not have remained neutral over the full visible range.

Other sources of error resulted from the varied film processing procedures followed by the field observers. Of particular concern was the failure to maintain uniform temperatures of the processing solutions.

In addition, there was a reciprocity error due to the necessarily marked difference in the exposure times of the calibration spectrum and the sky spectrum. Variations in the exposure times of the sky spectra must also be considered as a source of error.

It was possible to reduce most of the above errors to within tolerable limits. Nevertheless, the limitations of the study are recognized; it is not recommended that the eye-estimated densities as recorded in the tables presented in this volume be used for statistical studies for which precision in spectral resolution and densities is required.

Presentation of Data

Film, Punched Cards, and Tabulations

Data from each spectral frame were recorded on an IBM punched card (Figure 6). The data thus recorded on the cards were printed onto the tabulations in this volume. In accordance with the CSAGI Guide to World Data Centers, these tabulations will be available in the World Data Centers for auroral (instrumental) observations in College, Alaska, Moscow, and Stockholm in the form of this printed volume of the IGY Annals. In addition, one complete set of the punched cards from which the tabulations were obtained and one complete copy of the spectrograph film will be sent to each of the three WDC's. The original film will be kept permanently in WDC-A. Copies of the film can be made for the purpose of verifying the presence or absence of spectral lines and bands: because the normal copying process necessarily introduces uncertainties in spectral resolution and densities, copies of the original film are not regarded as suitable for studies for which these details are essential, e.g., microphotometry.

Acknowledgments

The editors wish to express their gratitude to Dr. A. Vallance Jones of the University of Saskatchewan and Dr. Joseph W. Chamberlain of Kitt Peak National Observatory for the many fruitful discussions and helpful suggestions.

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In addition, the authors would like to acknowledge the assistance from personnel of the IGY World Data Center A, National Weather Records Center, Asheville, North Carolina, who kindly provided the weather data for many of the stations.

Data from the Canadian stations were reduced at the University of Saskatchewan under the direction of Dr. A. Vallance Jones.

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(1) Chamberlain, Joseph W. and Norman J. Oliver, Atomic and Molecular Transitions in Auroral Spectra. Journal of Geophysical Research, Vol. 58, p. 457, 1953.

(2) Chamberlain, Joseph W. and A. B. Meinel, Emission Spectra of Twilight, Night Sky, and Aurora. Chapter 11 in: The Earth as a Planet (Solar System, Part II), Gerard P. Kuiper, ed., University of Chicago Press, 1954.

(3) Jones, A. Vallance, An Atlas of the Auroral Spectrum. Scientific Report No. AR-20, University of Saskatchewan, 1955.

(4) Perkin Elmer Corporation, Instruction Manual for the Model 173 IGY Auroral Spectrograph Norwalk, Connecticut, 1956.

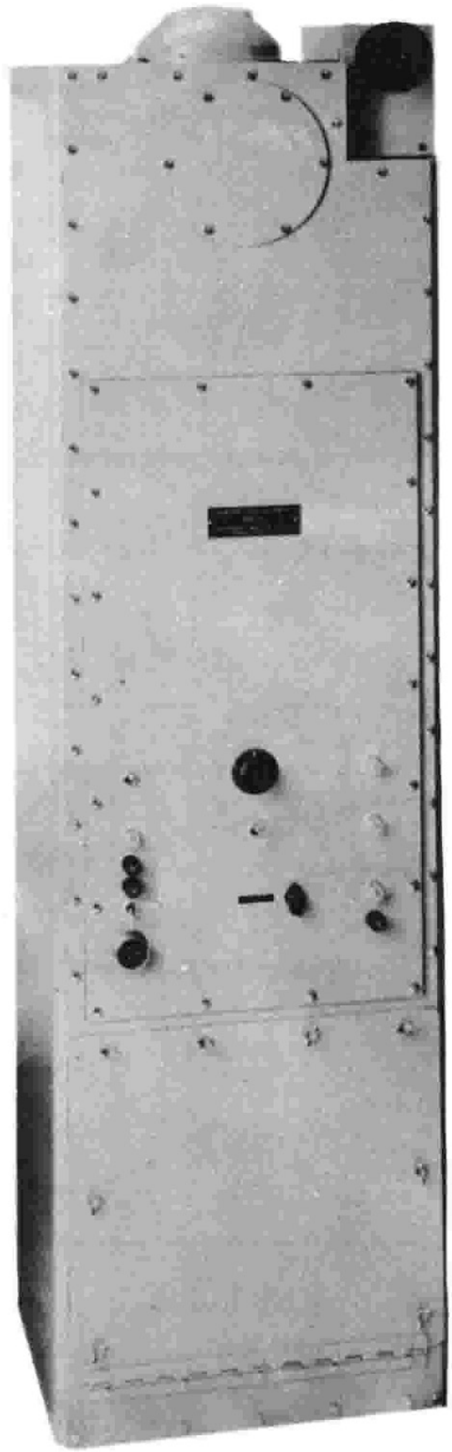

Fig. 1 Patrol Spectrograph.

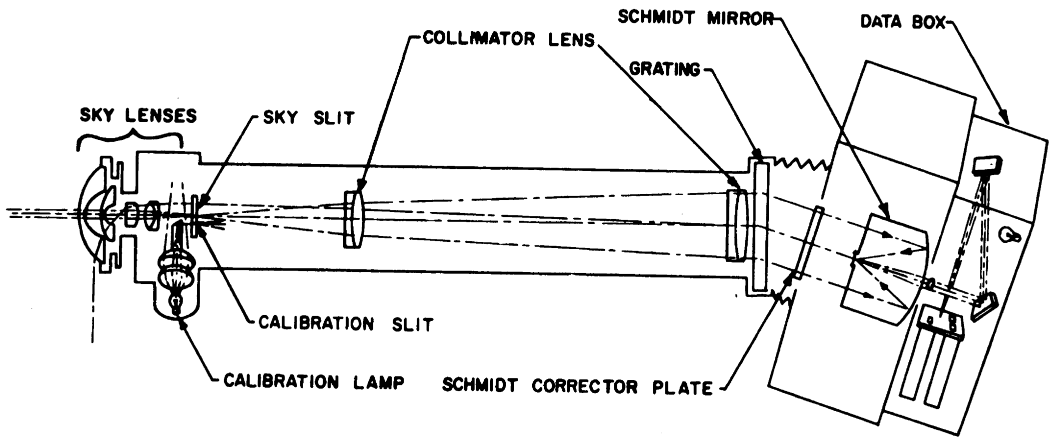

Fig. 2 Optical System of the Patrol Spectrograph.

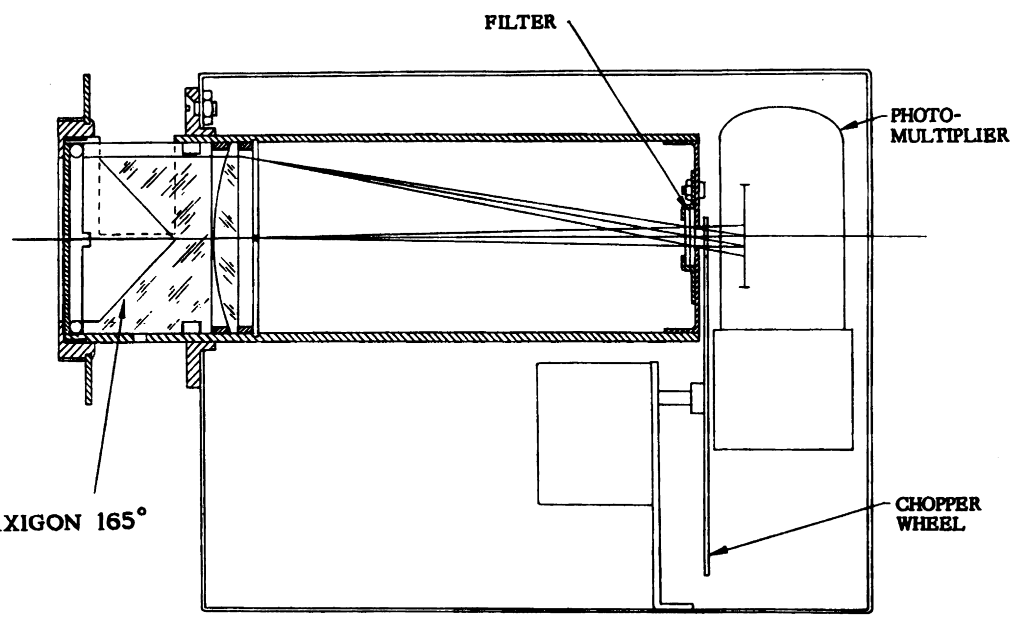

Fig. 3 Photometer.

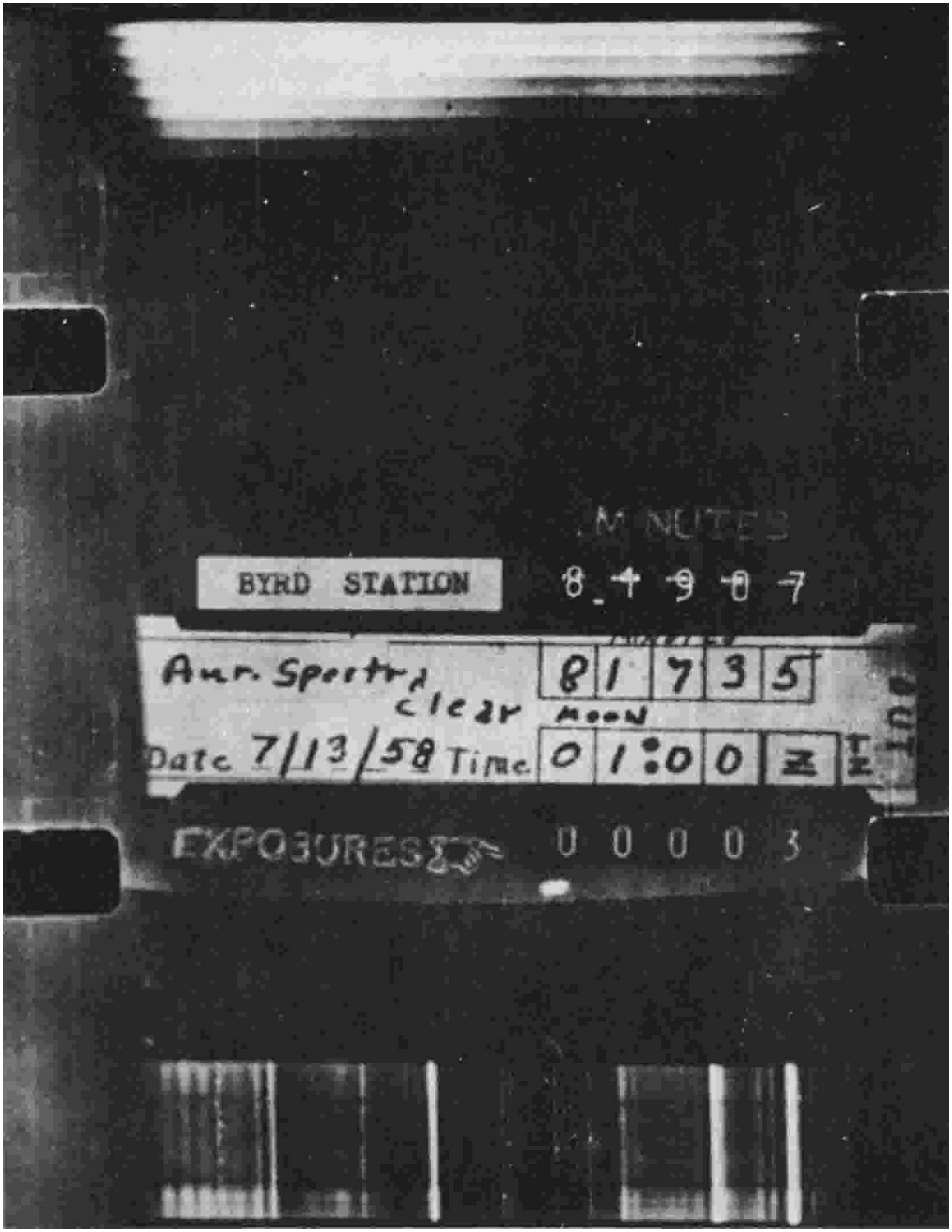

Fig. 4 Recording of a Full Data Cycle.

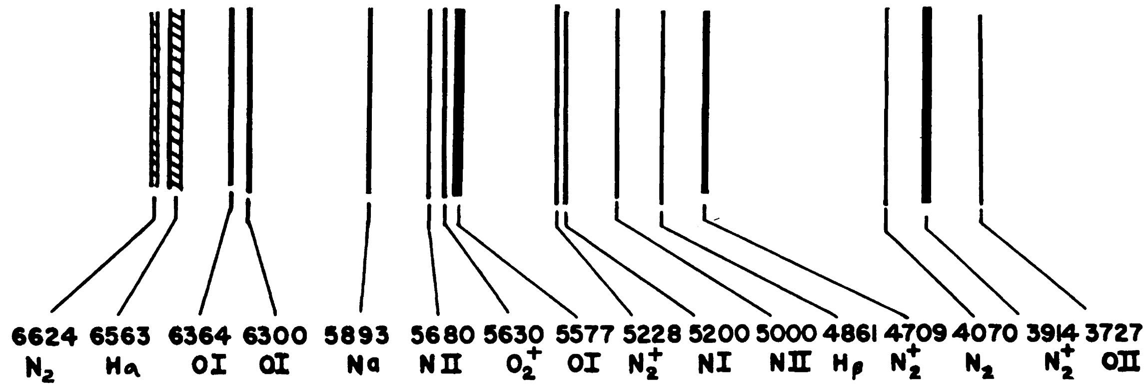

Fig. 5 The Auroral Spectrum.

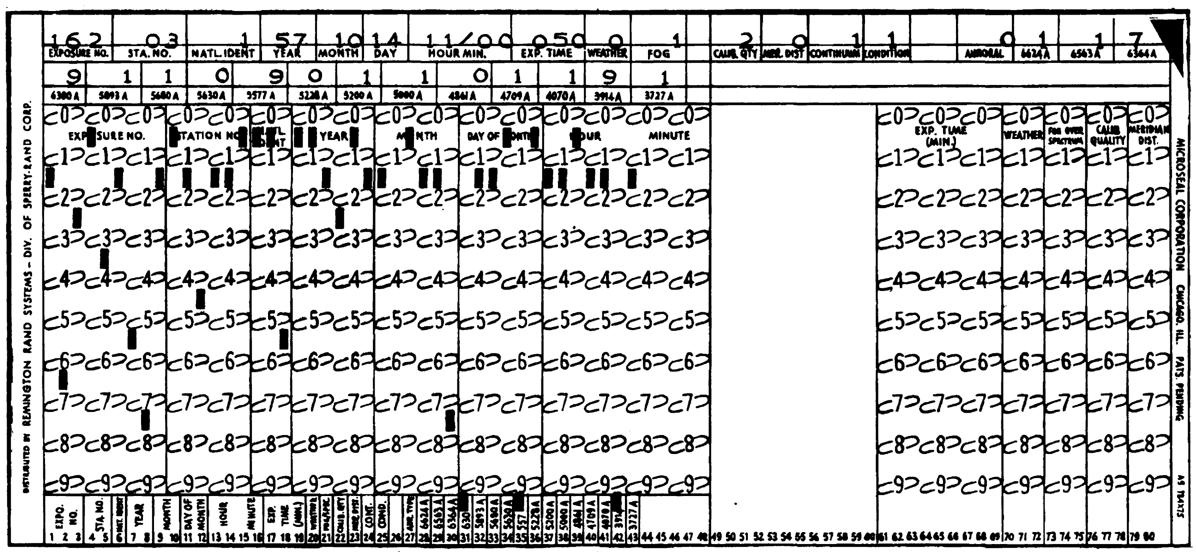

Fig. 6 Punched Card for the Auroral Spectrogram.

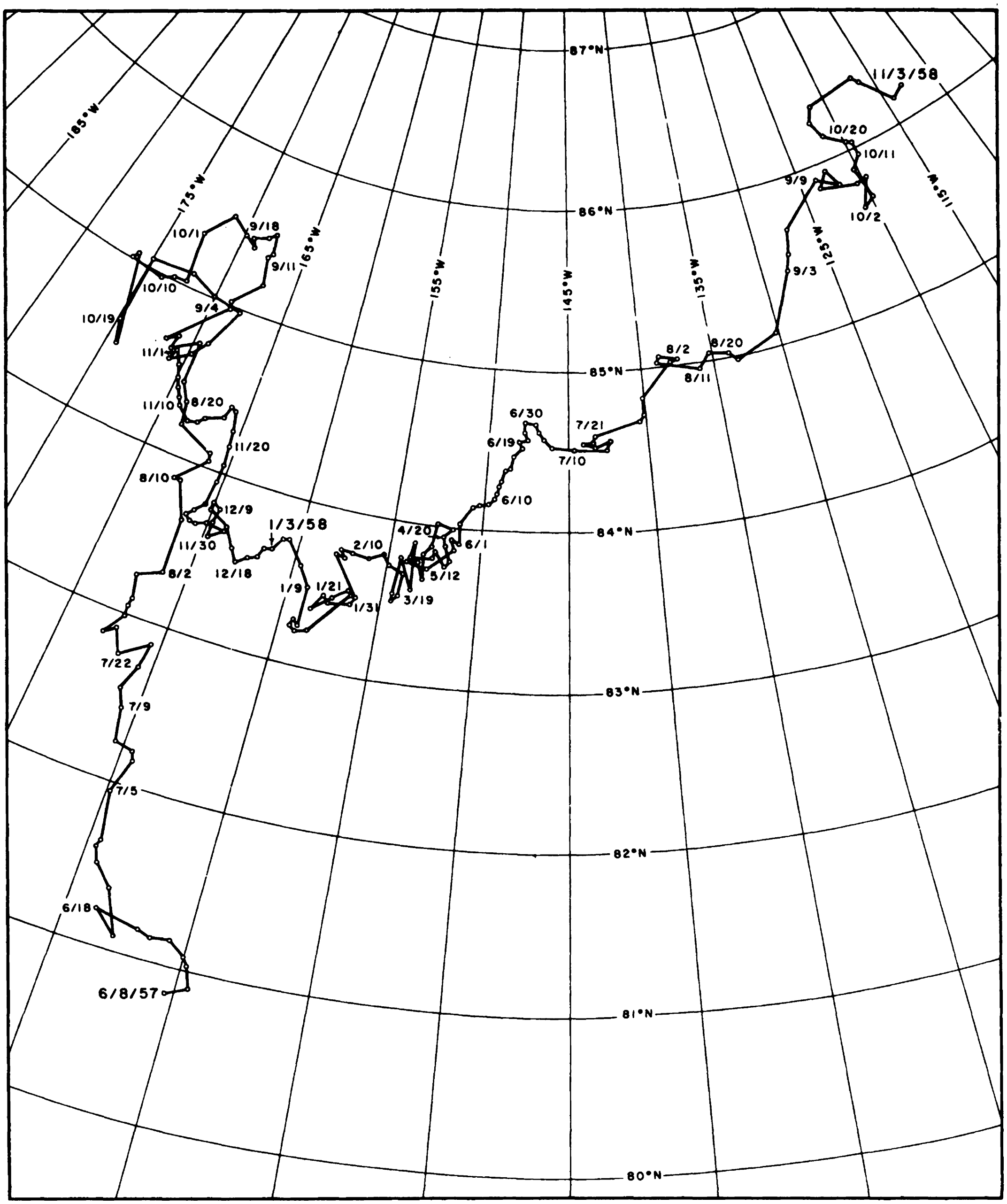

Fig. 7 Drift track of Ice Floe A (Station Alpha) from 8 June 1957 (6/8/57) to 3 November 1958.

TABLE I. CODES USED ON PUNCHED CARDS AND IN TABULATIONS

Column Numbers		Abbreviation in Tabulations	Explanation	Notes (see next page)
Cards	Tables			
1-3	1-3	EXPNO	Exposure number from exposure counter photographed on the film.	4,5
4-5			Station number. (see Table II)	3
6	4	NATID	Code number identifying nation operating instrument: 1 - US-New Zealand 2 - Canadian	
7-8	5-6	YEAR	Final two digits of the year.	
9-10	7-8	MONTH	Number of month, e.g., 09 = September	
11-12	9-10	DAY	Day of the month 08 = 8th (Greenwich date).	
13-16	11-14	HOUR-MIN	Greenwich Mean Time of termination of exposure. This is taken from frame following the termination of each exposure.	4,5
17-19	15-17	EXPTM	Duration of exposure in minutes, e.g., 063 = 63 minutes.	
20	18	WEATH	Weather index: 0 - clear 1 - partly clear 2 - cloudy 9 - lightning	
21	19	FOG	Index giving amount of fogging superimposed on the spectrum by scattered light from the moon, from the sun at twilight, or from other causes: 0 - no fog 1 - some fog 2 - badly fogged	
22	20	CALIB	Quality of calibration exposure: 0 - very good (suitable for microphotometry) 1 - intermediate 2 - poor	

TABLE I (Continued)

23	21	MERID	Distribution of intensity along meridian: 0 - uniform or substantially uniform 1 - marked intensity maximum in north below 45° 2 - marked intensity maximum in south below 45° 3 - other cases.	8
24	22	CONTM	Interference by continuum: 0 - free from continuum 1 - partially affected by continuum 2 - badly affected by continuum	
25	23	COND	Condition of film: 0 - perfect 1 - scratched but mostly usable 2 - badly scratched	
26			(This column used for Saskatoon only; see note 9)	9
27	24	TYPE	Significant information as to type of aurora: 0 - no information available 1 - indefinite or mixed forms	6
28-43	25-40		Eye estimated densities of lines and bands *	1,7
28	25	6624	6624Å N_2 First positive band (6-3)	
29	26	6563	6563Å H_α	
30	27	6364	6364Å [OI]	
31	28	6300	6300Å [OI]	
32	29	5893	5893Å NaI	
33	30	5680	5680Å NII	
34	31	5603	5603Å O_2^+	
35	32	5577	5577Å [OI]	
36	33	5228	5228Å N_2^+ First negative band (0-3)	
37	34	5200	5200Å [NI]	
38	35	5000	5000Å NII	
39	36	4861	4861Å H_β	
40	37	4709	4709Å N_2^+ First negative band (0-2)	
41	38	4070	4070Å N_2 VK band (2-13)	
42	39	3914	3914Å N_2^+ First negative band (0-0)	
43	40	3727	3727Å** OII	2

* See note 1 ** see note 2